Hornsea Project Four

Clarification Note on Peak Herring Spawning Period and Seasonal Piling Restriction (Tracked)

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Revision Summary

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Revision Change Log

Rev	Page	Section	Description
01	N/A	N/A	Document prepared and presented to Natural England and the MMO in response to Relevant Representation and submitted to ExA at Deadline 1.
02	N/A	N/A	Updated throughout in response to comments received from the MMO (REP1-076) and submitted to ExA at Deadline 2.

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Glossary

Term	Definition
Commitment	A term used interchangeably with mitigation and enhancement measures. The purpose of Commitments is to reduce and/or eliminate Likely Significant Effects (LSEs), in EIA terms. Primary (Design) or Tertiary (Inherent) are both embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, Preliminary Environmental Information Report (PEIR) or ES). Secondary commitments are incorporated to reduce LSE to environmentally acceptable levels following initial assessment i.e. so that residual effects are acceptable.
Cumulative effects	The combined effect of Hornsea Four in combination with the effects from a number of different projects, on the same single receptor/resource. Cumulative impacts are those that result from changes caused by other past, present, or reasonably foreseeable actions together with Hornsea Four.
Demersal	Relating to the seabed and area close to it. Demersal spawning species are those which deposit eggs onto the seabed.
Development Consent Order (DCO)	An order made under the Planning Act 2008 granting development consent for one or more Nationally Significant Infrastructure Projects (NSIP).
Effect	Term used to express the consequence of an impact. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity, of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	A statutory process by which certain planned projects must be assessed before a formal decision to proceed can be made. It involves the collection and consideration of environmental information, which fulfils the assessment requirements of the EIA Directive and EIA Regulations, including the publication of an Environmental Impact Assessment (EIA) Report.
EIA Regulations	The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Export cable corridor (ECC)	The specific corridor of seabed (seaward of Mean High Water Springs (MHWS)) and land (landward of MHWS) from the Hornsea Four array area to the Creyke Beck National Grid substation, within which the export cables will be located.
Fish larvae	The developmental stage of fish which have hatched from the egg and receive nutrients from the yolk sac until the yolk is completely absorbed.
High Voltage Alternating Current (HVAC)	High voltage alternating current is the bulk transmission of electricity by alternating current (AC), whereby the flow of electric charge periodically reverses direction.
Hornsea Project Four Offshore Wind Farm	The term covers all elements of the project (i.e. both the offshore and onshore). Hornsea Four infrastructure will include offshore generating stations (wind turbines), electrical export cables to landfall, and

	connection to the electricity transmission network. Hereafter referred to as Hornsea Four.
Maximum Design Scenario (MDS)	The maximum design parameters of each Hornsea Four asset (both on and offshore) considered to be a worst case for any given assessment.
Mitigation	A term used interchangeably with Commitment(s) by Hornsea Four. Mitigation measures (Commitments) are embedded within the assessment at the relevant point in the EIA (e.g. at Scoping, PEIR, or ES).
Order Limits	The limits within which Hornsea Four (the 'authorised' project) may be carried out.
Orsted Hornsea Project Four Ltd.	The Applicant for the proposed Hornsea Project Four Offshore Wind Farm Development Consent Order (DCO).
Planning Inspectorate (PINS)	The agency responsible for operating the planning process for Nationally Significant Infrastructure Projects (NSIPs).
Spawning	The release or deposition of eggs and sperm, usually into water, by aquatic animals.

Acronyms

Term	Definition
AfL	Agreement for Lease
DCO	Development Consent Order
dML	Deemed Marine Licence
ECC	Export Cable Corridor
EIA	Environmental Impact Assessment
ES	Environmental Statement
HVAC	High Voltage Alternating Current
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
MDS	Maximum Design Scenario
MHWS	Mean High Water Springs
MMO	Marine Management Organisation
PINS	Planning Inspectorate
PSA	Particle Size Analysis
SSC	Suspended Sediment Concentration

1 Background

1.1.1.1 Orsted Hornsea Project Four Limited (hereafter the Applicant) has submitted a Development Consent Order (DCO) application to the Planning Inspectorate (PINS), supported by a range of plans and documents including an Environmental Statement (ES) which set out the results of the Environmental Impact Assessment (EIA) on the Hornsea Project Four Offshore Wind Farm (hereafter Hornsea Four) and its associated infrastructure.

1.1.1.2 Within the fish and shellfish ecology assessment within the ES, herring (*Clupea harengus*) was identified as a key receptor, with this species being recognised to have important spawning grounds in the vicinity of Hornsea Four (**Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**). The nearest herring spawning ground to Hornsea Four is the Banks (Central North Sea) spawning ground (**Figure 1**).

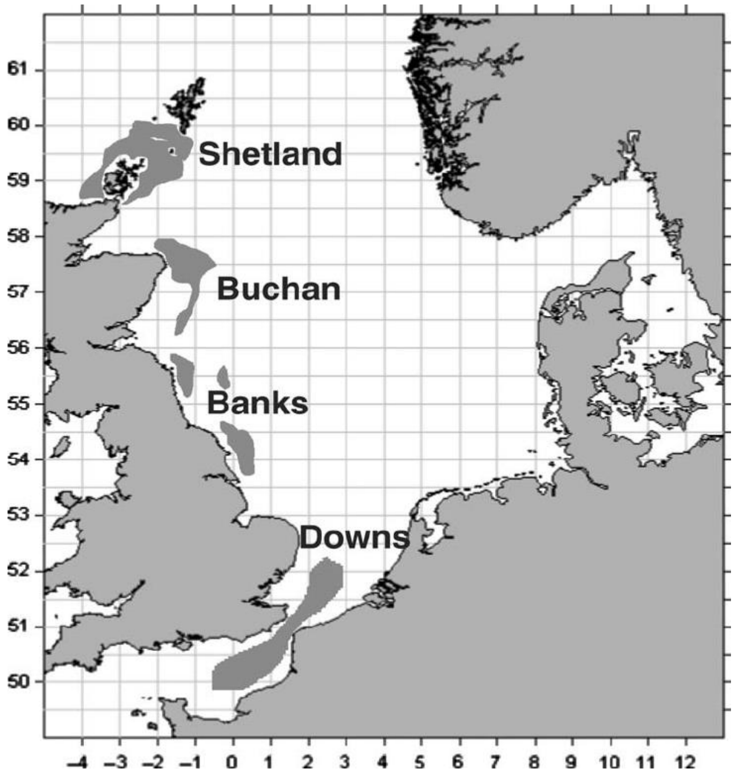

Figure 1: Herring spawning grounds within the North Sea (Beirman *et al.*, 2010).

1.1.1.3 As defined in Section 4.5.1 of **Volume A5, Annex 3.1: Fish and Shellfish Ecology Technical Report**, herring are demersal spawners, exhibiting a preference for spawning habitats comprising coarser sediments such as sandy gravels to gravel, upon which eggs are deposited. Herring go through various developmental stages, which are key to the context of this note. Kendall *et al.* (1984) defined the early developmental stages of teleosts (bony fishes, including herring) into three key stages (**Figure 2**):

- Egg (from spawning to hatching);
- Larva (from hatching to juvenile); and
- Juvenile.

1.1.1.4 Kendall *et al.* (1984) further divided the larval stage into the following sub–stages (**Figure 2**):

- Yolk–sac larva (from hatching to the absorption of yolk reserves);
- Pre-flexion larva; and
- Flexion larva.

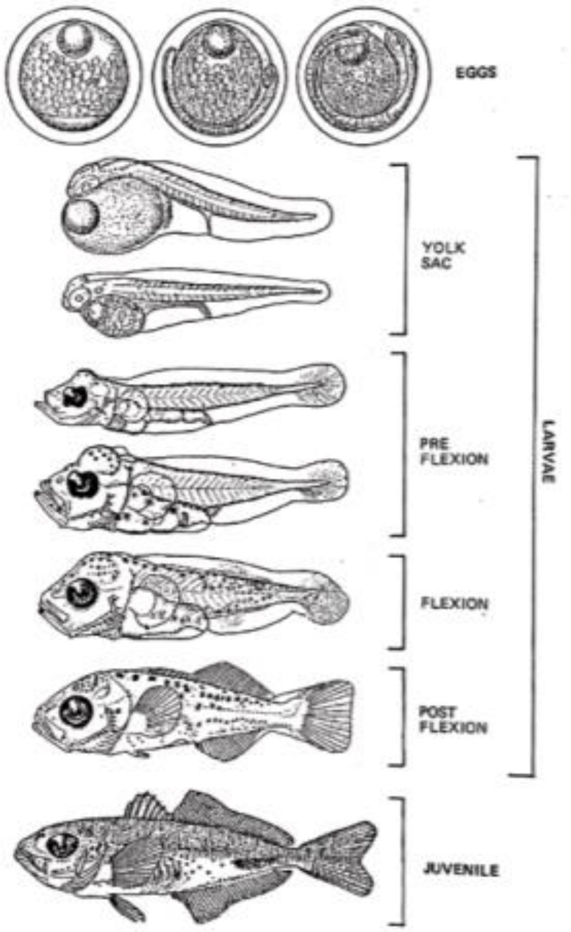

Figure 2: Bony fish developmental stages (adapted from Ahlstrom and Ball (1954)).

1.1.1.5 The key stages in relation to this note are the egg and yolk sac larval stages of herring development.

1.1.1.6 The primary source of information for the current status of herring spawning is the International Herring Larval Survey (IHLS) data, which is collected under the auspices of International Council for the Exploration of the Sea (ICES). Previous analyses (Boyle & New, 2018) have demonstrated the suitability of the IHLS data to be used to aid in informing the location and extent of active herring spawning grounds as an update to the historical spawning grounds as defined by Coull *et al.* (1998). This method has been broadly accepted for use in EIAs, including for Hornsea Four.

1.1.1.7 To mitigate impacts from underwater noise to herring, specifically within the Banks spawning ground, the Applicant have made a commitment (Commitment 190 in **Volume A4, Annex 5.2: Commitments Register**) to avoid percussive piling at the High Voltage Alternating Current (HVAC) Booster Station within the Export Cable Corridor (ECC) during the "peak" spawning season for herring at the Banks spawning ground, specifically between

1st September to 16th October each year. This commitment is secured by DCO Schedule 12, Part 2 - Condition 23 (**C1.1 Draft DCO including Draft DML**).

1.1.1.8 Following pre-application consultation on this proposed seasonal restriction, further evidence to support the appropriateness of the "peak" spawning season (and therefore the associated piling restriction dates) has been requested by the Marine Management Organisation (MMO) and Natural England within their respective Relevant Representations (RR-020 (paragraphs 3.7.25 - 3.7.36) and RR-029 (paragraph 5.65 and Appendix G), respectively). This note has been produced to provide further analysis and justification of the "peak" spawning period for herring in the vicinity of Hornsea Four in order to support the proposed timing of the seasonal restriction, using the methodology proposed by Cefas as part of the Hornsea Four Evidence Plan process. This note is being submitted to the MMO and Natural England with an aim to agreeing the timing of this "peak" spawning period and the associated piling restriction timing for Hornsea Four.

2 Seasonal Restriction Timing

2.1 Introduction

2.1.1.1 To determine the commencement of the "peak" spawning period for herring in the Banks grounds, the IHLS data has been interrogated and a back-calculation has been performed to identify the most likely date for when spawning commenced for the majority of the larvae captured within the IHLS data.

2.1.1.2 For the purposes of the spawning timing analysis, IHLS data for 2007 – 2020 for the Banks stock was interrogated to ensure the suggested peak spawning timing was applicable year to year.

2.1.1.3 The parameters required for the back-calculation for spawning timings are as follows, with each subsequently described in the following sections:

- IHLS survey timings;
- Larval length in survey sample data;
- Larval length at hatching;
- Egg development duration;
- Yolk absorption duration; and
- Growth rate.

2.2 IHLS Survey Timings

2.2.1.1 Whilst the survey start dates for the IHLS are broadly similar year to year, there are small interannual variations in the timings of the survey dates within each region. Based on the survey start dates for the main section of the Banks stock (**Table 1**) (excluding where small numbers (<5) of sampling locations had been sampled on the same day as the adjacent Buchan region), the average start date for the IHLS trawls between 2007 – 2020 has been calculated to be 24th September. As shown in **Table 1**, the variation in survey start dates between years is generally small, and by using the average survey start date rather than an average survey date to inform the back calculation, a precautionary approach has been utilised.

2.2.1.2 It should be noted that there were no IHLS surveys undertaken in 2017. In 2018, the survey was undertaken for the Shetland stock only (**Figure 1**) and is therefore not applicable for use within the back-calculations for the Banks stock (the stock of relevance for Hornsea Four). These years have therefore been omitted from **Table 1**.

Table 1: Range of survey start dates.

Survey Year	IHLS Survey Start Date Range
2007	24th - 25th Sept
2008	22nd - 23rd Sept
2009	28th - 30th Sept
2010	27th – 29th Sept
2011	26th – 28th Sept
2012	26th - 27th Sept
2013	24th - 25th Sept
2014	23rd - 24th Sept
2015	18th – 23rd Sept
2016	23rd – 28th Sept
2019	23rd – 26th Sept
2020	17th – 22nd Sept
Average Survey Start Date: 24th September	

~~2.2.1.1~~2.2.1.3 For the purposes of this assessment therefore, it has been assumed that the 24th September can be considered to represent the mean start of the peak occurrence of herring larvae for the Banks stock as recorded from the IHLS larval survey sampling and is therefore considered to be a reasonable mean date to use for the back-calculations of spawning.

2.3 Larval length in survey sample data (catch length)

~~2.3.1.1~~ The IHLS data provides records of the number of larvae of each length recorded within each survey sample. Overall, 97% of all larvae recorded within the IHLS surveys from 2007 – 2020 were equal to or less than 10 mm in length; ranging from >68% in the 2020 survey to 99.9% in the 2008 and 2013 surveys. It is notable that the frequency of larger larvae is more common in the lower density areas of the spawning ground, with the larvae at the sampling locations which overlap with the primary hotspots (stations 78 and 80, **Figure 5**) all being 10 mm or less over all the survey years (**Figure 3**). ~~80% of all larvae recorded within the IHLS surveys from 2007 – 2020 were equal to or less than 10 mm in length; ranging from >56% in the 2007 and 2020 surveys up to 99.9% in the 2013 survey.~~

2.3.1.1 As such, the use of a 10 mm larval length in the back-calculation represents, over the considered survey period, the majority of all larvae recorded in all years, and all larvae in the key hotspots. On the basis that the majority of all larvae are consequently smaller than this selected size, 10 mm is considered an appropriate larval length upon which to base the calculation of a conservative estimate of the start of peak spawning as most of the larvae within the survey will have been spawned later than the calculated start date. Furthermore, ICES classify newly hatched larvae as those <10 mm in length, and therefore the use of a catch length of 10 mm ensures that all newly hatched larvae would be captured within this value.

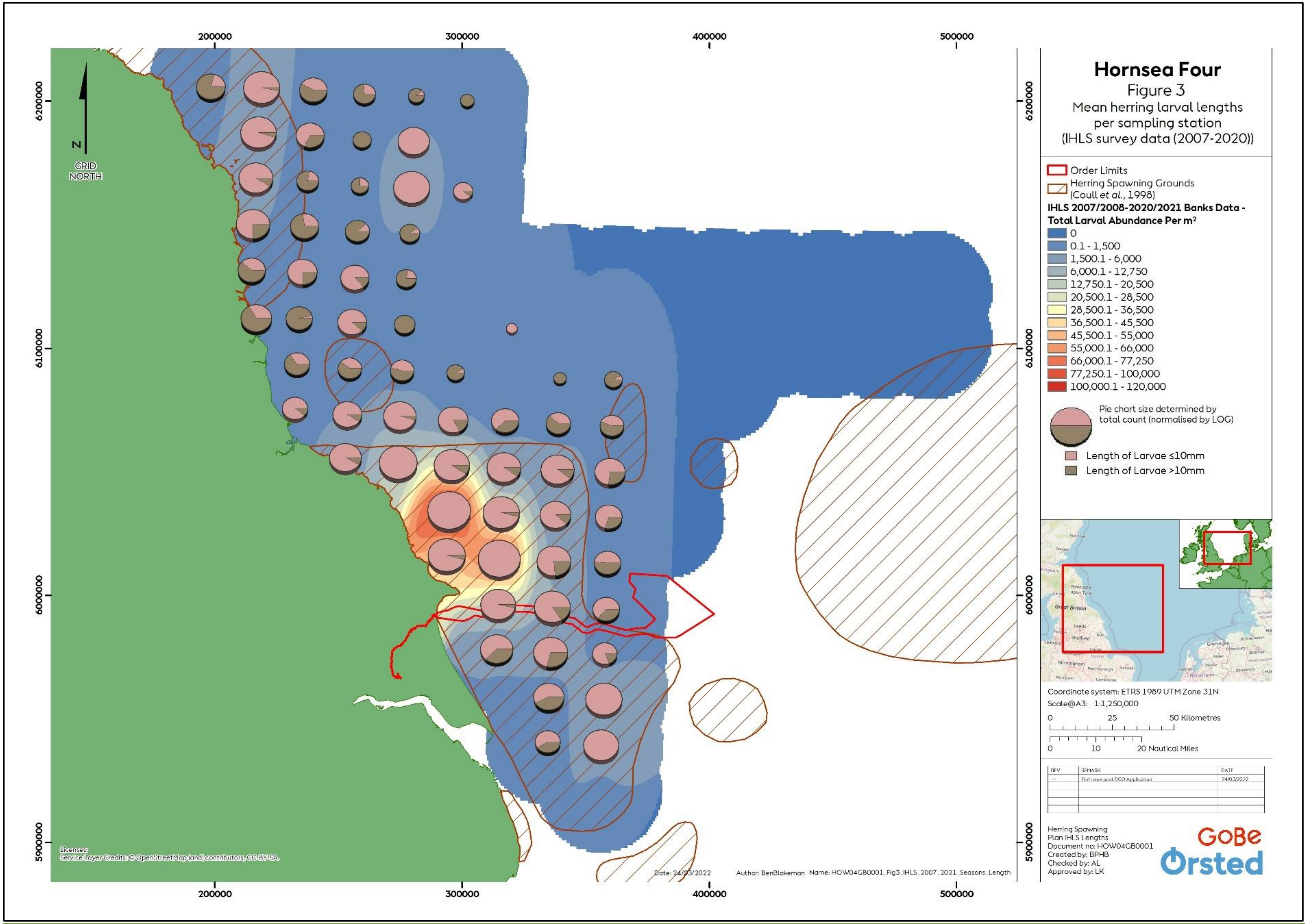

Figure 3: Mean herring larval lengths per sampling station (IHLS survey data (2007 - 2020)).

2.4 Larval length at hatching

~~2.4.1.1~~ There is relatively large variation in the published average larval lengths at hatching within the scientific literature for the Banks stock, with estimates of average hatch length given as 8 mm (Blaxter and Hempel, 1963) or 6.5 mm (Heath, 1993).

2.4.1.1

~~2.4.1.2~~ Larval sizes within the IHLS data are occasionally recorded as being as low as 5 mm, however this is rare (there were nine records of larvae at 5 mm from 2007 to 2020, which equates to 0.5% of the recorded larvae), with most years recording the smallest larval size as being 6 mm~~.~~, and even then, only in relatively low numbers (65 records of larvae at 6 mm, equates to 3.7% of all recorded larvae from 2007 to 2020). Due to the limitations of the IHLS sampling and the expectation that newly hatched larvae would not be routinely collected (Cefas, pers. comms.), it is considered that the larval sizes (at hatching) in the available literature are the most reliable source, rather than attempting to undertake an estimation of larval sizes (at hatching) from the IHLS data. ~~However, based on the available IHLS data, the 6.5 mm average larval size (at hatching) from Heath (1993) appears to be somewhat conservative.~~

2.4.1.2

~~2.4.1.3~~ For the purposes of this back-calculation, both 6.5 mm (Heath, 1993) and 8 mm (Blaxter and Hempel, 1963) larval sizes (at hatching) have been used as the basis for~~to~~ the back-calculation analysis. ~~, providing a potential range of peak spawning timings based on varying hatch size assumptions.~~

2.4.1.3

2.4.1.4 While the values identified above are those presented within the literature, the IHLS data recorded larvae captured at lengths of 5 mm and 6 mm, therefore, to implement further conservatism into the assessment, hatch sizes of 5 mm (most conservative length) and 6 mm (minimum length identified in meaningful numbers within the IHLS data) have also been included as a scenario for the back-calculation. In addition to this, as noted above larvae within the Banks stock are known to hatch up to 10 mm in length, therefore, to provide back-calculation dates for a full range of potential hatch sizes, 10 mm has also been included as a scenario for the back-calculation.

2.4.1.5 The application of a various larval hatching lengths as the basis of the back-calculations provides a range of peak spawning timings based on varying hatch size assumptions, within which the true start date will likely fit.

2.5 Egg development duration

2.5.1.1 A temperature dependent egg development duration has been used for this calculation, based on the durations from Russell (1976). Data for the temperature at the maximum sampling depth for each trawl is recorded as part of the IHLS data. This data has been used to determine the average temperature at the maximum sampling depth to represent the average seafloor temperature for egg development duration.

2.5.1.2 For the 2007 – 2020 dataset, the temperature during sampling (at maximum sampling depth), has ranged from 8.0°C – 15.8°C. Pre-2016, all survey data show strong agreement with a more limited temperature range (approximately 11°C – 15°C) (see **Figure 6** to **Figure 14**). Increased variation in the spread of temperature values (higher and lower values) is recorded in the 2016 (**Figure 15**), 2019 (**Figure 16**) and 2020 (**Figure 17**) survey data; however, note that all temperatures <12°C in the 2016 – 2020 surveys were found to the north of Hornsea Four and the lowest temperatures (<10°C) were all recorded to the north of the primary larval hotspot within each years data (and outwith the Coull *et al.* (1998) historical spawning grounds). See **Figure 4** below for average temperatures recorded at maximum sampling depths across the site within IHLS survey data. The average temperature from the full dataset does not reach below 12.2°C for any of the sampling locations within the Coull *et al.* (1998) spawning ground, with the average temperature at the key hotspots, being slightly higher than the average. This suggests that the average temperature used herein in is conservative for the purposes of considering the environmental conditions experienced by the majority of the larvae within the Banks stock.

2.5.1.3 Based on all sample locations for the full dataset considered, the mean temperature at the maximum sampling depth is calculated as 12.23°C. The mode and median values were 12.6°C and 12.6°C respectively.

2.5.1.4 Therefore, for the purposes of the temperature dependent values within the back-calculation, the water temperature has been considered to be 12.2°C.

2.5.1.5 Based on the expected development period for eggs from Russell (1976), the egg development time within the calculations herein has been assumed as a precautionary nine days (based on the upper duration for the range of seven to nine days for an average temperature of 12°C – 13°C).

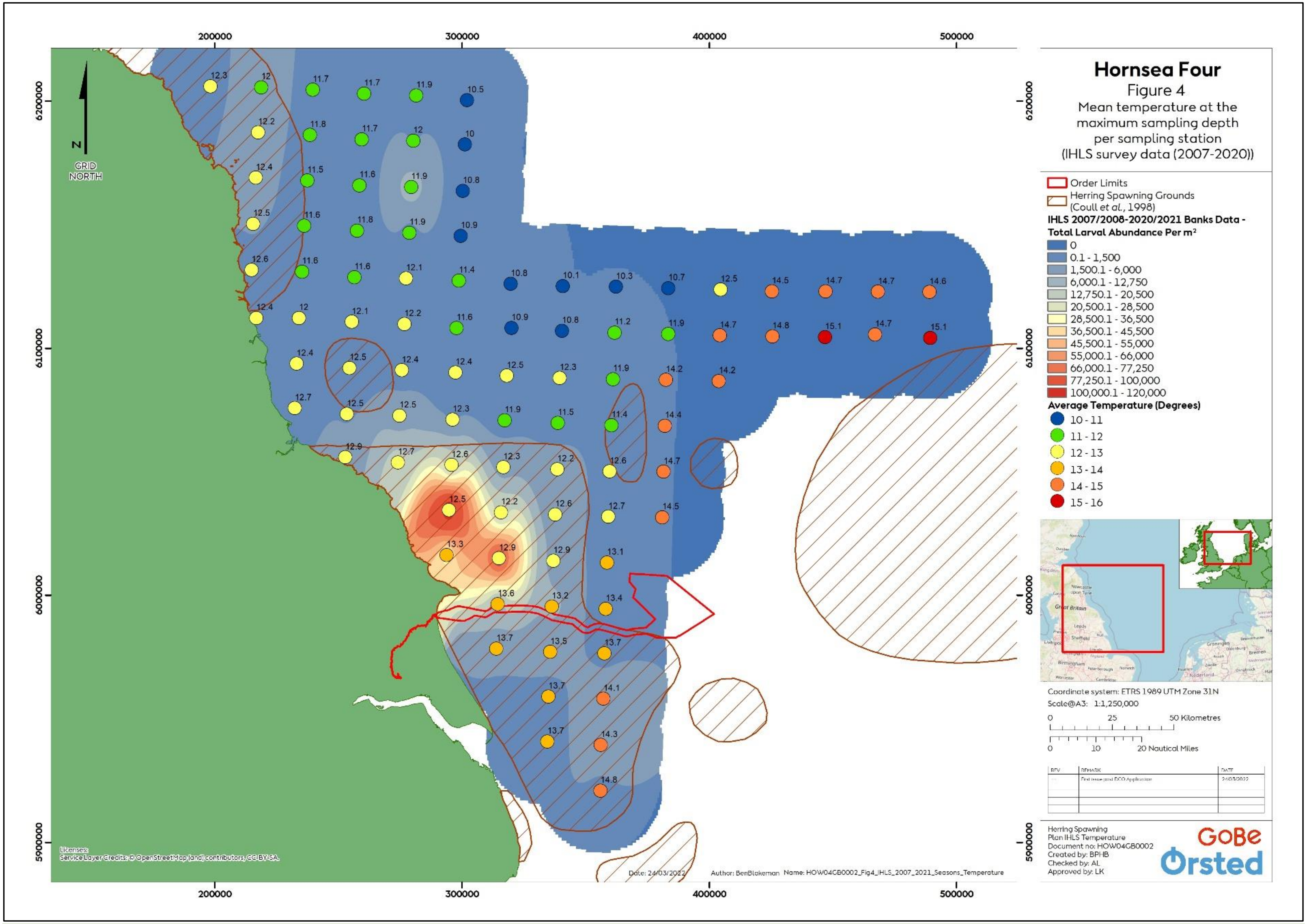

Figure 4: Mean temperature at the maximum sampling depth per sampling station (IHLS survey data (2007 – 2020))

2.6 Yolk absorption duration

2.6.1.1 Yolk absorption periods are also temperature dependent (Russell, 1976), with higher ambient temperatures equating to faster yolk absorption. During the yolk absorption stage, larvae are negatively buoyant and tend to remain close to the seabed, and as such are much less likely to be captured within the IHLS trawls, which target sampling higher in the water column.

2.6.1.2 During this yolk absorption period, larvae are non-feeding, with limited energy involved in swimming activity. As the larvae start to reach the start of active feeding, swimming activity increases, with larvae consequently rising within the water column (Kiorboe *et al.*, 1985).

2.6.1.3 Russell (1976) identified that the yolk sac absorption phase lasted for 5 and 14 days at 12.0°C or 3 and 9 days at 12.8°C. Kiorboe *et al.* (1985) identified that autumn spawning herring larvae, reared at 8°C started actively feeding after 4.5 days at high prey densities and after 6.5 days at low prey densities (based on a 50% increase in feeding incidence for the days after hatching; feeding was noted from 3 days at high prey densities). No yolk was present at the start of feeding for the autumn larvae in Kiorboe *et al.* (1985). Geffen (2002) also noted that the yolk absorption phase for larvae raised at 7°C was 9 – 11 days.

2.6.1.4 These studies (Kiorboe *et al.*, 1985; Geffen, 2002) suggest, based on active feeding being noted after 3 – 6.5 days and 9 – 11 days at much lower temperatures (8°C and 7°C respectively) than recorded for the Banks stock (12.2°C), that the most appropriate yolk absorption period from Russell (1976) to use for this study is 5 days. For the purposes of this calculation, it is assumed that this represents the point at which the larvae commence feeding, consequently rising up higher into the water column and therefore become available to the survey equipment used for the IHLS.

2.7 Growth rate

2.7.1.1 Various studies have identified a wide range of growth rates for herring larvae; however, all studies have used temperatures below the average recorded for the Banks stock during the IHLS dataset examined for Hornsea Four (12.2°C), with only one study undertaken at 12°C (Folkvord *et al.*, 2004) and other studies using lower temperatures (1°C – 11.5°C) (e.g. Das, 1972; Fox *et al.*, 2003; Geffen, 1986 and ~~;~~Heath, 1993~~; Hufgnal & Peck, 2011~~).

2.7.1.2 Importantly, the primary determinant of larval growth rates has been identified as temperature, with prey density a further factor (Folkvord *et al.*, 2004; Heath, 1993~~7~~; Houde, 1997; Oeberst *et al.*, 2009). Specifically, temperature has been identified as potentially explaining more than 50% of the variability in growth rate between studies (Houde, 1997; Oeberst *et al.*, 2009).

2.7.1.3 Oeberst *et al.* (2009) have developed an equation to calculate temperature dependent growth rates, using data from extensive survey campaigns within the Baltic, and based on changes in growth rates of 5 – 20 mm larvae during the growing season, where natural water temperatures vary from 5°C to 20°C over the season. Using the equation from Oeberst *et al.* (2009), for the average temperature recorded in the IHLS data (12.2°C), a growth rate of 0.47~~6~~ mm d^{-1} is calculated. In the literature, growth rates of 0.4 mm d^{-1} have been recorded for larvae reared at temperatures ranging from 8°C (Gamble *et al.*, 1985) to 10.5°C (Fox *et al.*, 2003) to 12°C (Folkvord *et al.*, 2004). Oeberst *et al.* (2009) also identified that the equation had strong agreement with values in the literature at the lower temperatures, although the regression lines for the equation based on survey data and literature values diverge at higher values (where values in the literature are unavailable), suggesting that extrapolating from values in the literature would tend to give an artificially low estimate of growth rates.

~~2.7.1.3~~2.7.1.4 As noted above, the temperatures experienced by the majority of the larvae within the Banks stock will be above this average temperature, with the key hotspots based on the IHLS data suggesting that the average temperature over all years at these locations is higher than the average used herein and in the growth rate calculation (and thus would equate to a slightly higher growth rate).

~~2.7.1.4~~2.7.1.5 Consequently, the growth rate used within the back-calculation to determine the start of the peak spawning period is 0.4~~6~~7 mm d^{-1}.

Table 2: Literature Sources of Daily Growth Rates

Data Source	Growth Rate	Reared. Field Observation, Mesocosm	Temperature	Stock Origin	Spawner Type	Prey Density
Folkvord et al., 2004	0.15, 0.4 mm d^{-1}	Reared	12 °C	Norwegian Sea	Spring	N/A
Das, 1972;	0.14–0.29 mm d^{-1}	Field Observation	1 –11.2 °C	Bay of Fundy	–	N/A
Fox et al., 2003;	0.4 mm d^{-1}	Reared	10.1 – 10.5 °C	North Sea (Buchan)	Autumn	High (1025± 290 prey items $^{-1}$)
Fox et al., 2003;	0.3 mm d^{-1}	Reared	10.1 – 10.5 °C	North Sea (Buchan)	Autumn	Low (64 ± 14 prey items $^{-1}$)).
Geffen, 1986;	0.33 mm d^{-1}	Field Observation	8 - 10 °C	Clyde	Spring	N/A
Heath, 1993;	0.2–0.3 mm d–1	Field	N/A	North Sea	Spring/ Autumn	N/A
Oeberst et al., 2009	0.2–0.65 mm d^{-1}	Field observation	5-20 °C	Rügen,	Spring	N/A
Gamble et al., 1985	0.35–0.40 mm d^{-1}	Mesocosm	7 - 8 °C	Clyde	Spring/ Autumn	N/A

2.8 Back-calculation

2.8.1.1 The factors for consideration within the back-calculation based on the above evaluation are summarised in **Table 3** below, with the five~~two~~ scenarios for the five different ~~two~~ hatch lengths presented:

Table 3: Factors considered within the back-calculations.

Factor	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Mean survey start date	24th September	24th September	24th September	24th September	24th September
Larval length at catch	109 mm	109 mm	10 mm	10 mm	10 mm
Indicative hatch length	6.5 mm	8 mm	5 mm	6 mm	10 mm
Period of egg development	9 days	9 days	9 days	9 days	9 days
Yolk absorption period	5 days	5 days	5 days	5 days	5 days
Assumed growth rate	0.476 mm d^{-1}	0.476 mm d^{-1}	0.47 mm d^{-1}	0.47 mm d^{-1}	0.47 mm d^{-1}

2.8.1.2 For scenario A, based on a growth rate of 0.476 mm d^{-1}, it would take a 6.5 mm larvae approximately 7.55 days to grow to the 109 mm catch size. For scenario B, it would take an 8 mm lLarvae approximately 4.32 days to grow to the 910 mm hatch size. For Scenario C, it would take a 5 mm larvae 10.6 days to grow to the 10 mm hatch size. For Scenario D, it would take a 5 mm larvae 8.5 days to grow to the 10 mm hatch size. For Scenario E, it would take a 10 mm larvae 0 days to grow to the 10 mm hatch size.

2.8.1.22.8.1.3 It should be noted that the inclusion of the yolk absorption period separately to the duration required for larvae to grow to size on catching is likely to result in a degree of double counting and is therefore considered precautionary – i.e. larvae commence growth during the yolk absorption period and e.g. where a 5 day period is required for growth to catch size, this is likely to run at least partially simultaneously with the yolk absorption period rather than sequentially as assumed in the calculations, adding further conservatism to the calculation.

2.8.1.32.8.1.4 For the purposes of the back-calculations, the following calculation has been used to determine the start of the peak spawning period:

Start of peak spawning period = Survey start date – numbers of days from hatch size to catch size – yolk absorption duration – egg development duration

2.8.1.42.8.1.5 For Scenario A, the start of the peak spawning season is calculated as:

24th September – (7.55 days+5 days+ 9 days) = **2nd5th September**

2.8.1.52.8.1.6 For Scenario B, the start of the peak spawning season is calculated as:

24th September – (24.3 days+5 days+9 days) = **58th September**

2.8.1.7 For Scenario C, the start of the peak spawning season is calculated as:

24th September – (10.6 days+5 days+9 days) = **30th August**

2.8.1.8 For Scenario D, the start of the peak spawning season is calculated as:

24th September – (8.5 days+5 days+9 days) = **1st September**

2.8.1.9 For Scenario E, the start of the peak spawning season is calculated as:

24th September – (0 days+5 days+9 days) = **10th September**

3 Conclusion

3.1.1.1 The Applicant committed to the implementation of a seasonal restriction on piling at the HVAC Booster Station location, to cover the "peak" period for the herring spawning within the Banks spawning grounds to the north of the ECC. It is therefore proposed that this seasonal restriction runs from 1st September – 16th October.

3.1.1.2 Following an interrogation of the IHLS data and the available literature to identify the key timings and durations for herring larval development, a back-calculation based on the IHLS survey dates and larval lengths at survey has been undertaken to estimate the start of the "peak" spawning season.

3.1.1.3 Based on the variable information in the literature and the IHLS survey data regarding larval hatch sizes, the back-calculation (as presented in **Section 2**) indicates, with suitably precautionary assumptions, that the ~~mean~~ start of the "peak" spawning season is between approximately the 30th August and the ~~5th and 8th~~ 10th of September, with this considered to be a conservative estimate ~~(as discussed throughout **Section 2**)~~.

3.1.1.4 It should be noted that significant conservatisms have been applied to the back-calculations. These include the consideration of a 5 mm hatch size (the most conservative hatch size) despite the low abundances of larvae caught at 5 mm within the IHLS survey data. Further conservatism was applied to the back-calculation through the inclusion of the yolk absorption period separately to the duration required for larvae to grow to size on catching which will likely result in double-counting (larvae commence growth during the yolk absorption period). As such, it is considered that the multiple conservatisms built into the calculation, result in dates which are likely to be much earlier in time than the true start of the peak spawning period. Therefore, the Applicant considered that that a peak spawning period of 1st September – 16th October remains appropriate to avoid population impacts on herring.

~~3.1.1.3~~

~~3.1.1.4~~3.1.1.5 ~~Therefore, it~~ It is therefore ~~can be~~ concluded that the proposed seasonal restriction for Hornsea Four acts to effectively cover the "peak" of the spawning season for herring, with additional conservatism incorporated into the proposed dates beyond that required based on the back-calculations as informed by available literature, and as a result provides a robust mitigation of the potential effects of piling of the HVAC booster station on herring spawning.

4 References

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Appendix A

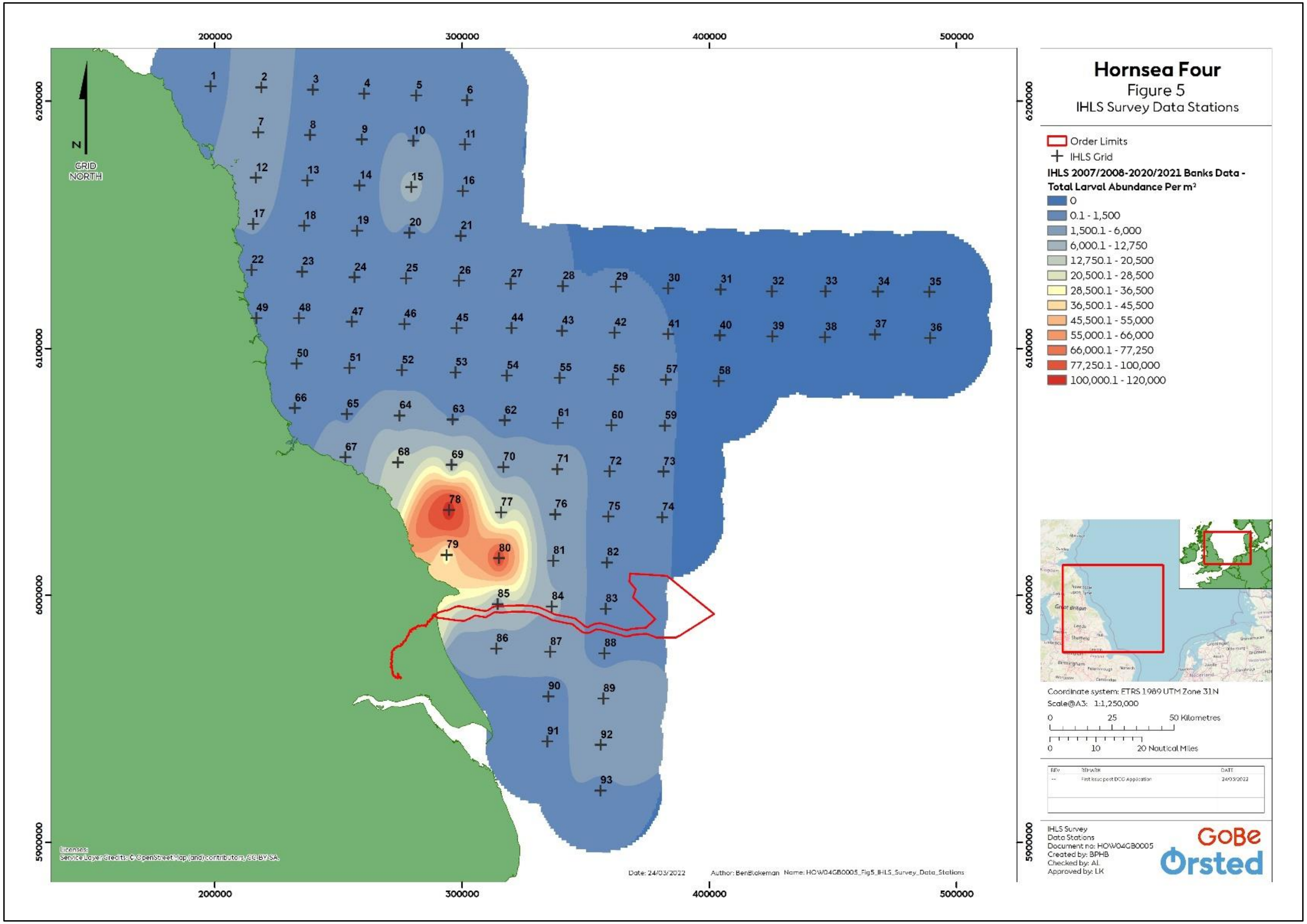


Figure 5: IHLS Survey Data Stations

Appendix B

Table 4: Mean larval catch sizes per year per station (IHLS survey data, 2007-2020).

	Year											
Station	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2019**	**2020**
1		12.5 mm	13.7 mm		10.0 mm				10.5 mm	13.1 mm		
2		12.0 mm	10.0 mm						11.5 mm	13.0 mm		
3			12.7 mm						12.2 mm	12.4 mm		
4			14.0 mm						11.0 mm			
5								12.0 mm			7.0 mm	
6									14.0 mm	14.0 mm		
7			9.0 mm	10.5 mm	10.0 mm				11.0 mm	11.5 mm		
8			13.8 mm						12.0 mm	14.0 mm		
9			16.0 mm	12.0 mm			12.0 mm					
10										7.5 mm	7.8 mm	
12		8.0 mm	10.1 mm	9.7 mm	11.0 mm				9.0 mm	11.9 mm		
13			14.9 mm	10.0 mm	10.0 mm				11.0 mm	14.5 mm		
14			15.0 mm		10.5 mm					15.0 mm		
15	8.0 mm				10.0 mm				12.0 mm	7.0 mm		
16										9.3 mm		
17		8.0 mm	10.0 mm	9.0 mm	6.5 mm				8.0 mm	14.0 mm		
18			17.3 mm	11.5 mm					11.0 mm	15.0 mm		
19		9.5 mm							13.0 mm	13.5 mm		
20									11.0 mm	15.0 mm		
22		9.5 mm			6.5 mm				9.5 mm	15.0 mm		
23		9.5 mm	14.4 mm			8.0 mm			10.5 mm	13.5 mm		
24		8.5 mm	21.0 mm						12.0 mm	14.5 mm		
25									11.5 mm			
27											8.0 mm	
30												8.0 mm
44											8.0 mm	

	Year											
Station	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2019	2020
46				16.0 mm				11.0 mm	12.0 mm	14.0 mm		
47		9.5 mm	13.4 mm						12.5 mm	13.0 mm		
48		10.8 mm	9.0 mm						11.5 mm	14.0 mm		
49		10.0 mm	9.5 mm							15.0 mm		
50			16.0 mm	13.5 mm		11.5 mm			8.5 mm	15.0 mm		
51		10.6 mm	15.0 mm					9.0 mm		14.0 mm		10.5 mm
52								11.0 mm		15.7 mm	8.3 mm	11.3 mm
53				9.0 mm						16.5 mm		11.5 mm
54					16.0 mm							
55						20.0 mm	12.0 mm			11.0 mm		
56										12.3 mm	8.0 mm	13.5 mm
60										12.0 mm	10.0 mm	10.5 mm
61						11.0 mm				13.1 mm		
62			11.0 mm	11.5 mm	9.0 mm		7.5 mm	10.5 mm		11.5 mm	7.0 mm	12.3 mm
63					8.0 mm			8.0 mm	10.5 mm	13.0 mm	9.0 mm	9.5 mm
64					9.0 mm		8.0 mm	10.0 mm	9.0 mm	10.5 mm	8.8 mm	11.5 mm
65		13.0 mm	12.0 mm		9.5 mm	9.8 mm	9.0 mm	9.0 mm	9.0 mm	16.5 mm	9.0 mm	10.0 mm
66			11.5 mm			9.5 mm			8.5 mm	13.5 mm	12.0 mm	
67					8.5 mm		7.5 mm	9.5 mm	8.5 mm			8.9 mm
68	9.5 mm	10.0 mm	9.5 mm	8.5 mm	8.3 mm		7.5 mm	8.0 mm		10.3 mm	8.5 mm	9.5 mm
69	9.2 mm		8.8 mm	9.5 mm	9.0 mm		8.0 mm	9.0 mm	10.0 mm	12.5 mm	8.0 mm	9.0 mm
70			9.5 mm	9.5 mm	9.0 mm			9.2 mm	10.0 mm	10.1 mm	9.0 mm	9.0 mm
71				9.5 mm	8.0 mm			9.0 mm		10.3 mm	8.5 mm	11.2 mm
72				10.5 mm				9.0 mm		10.7 mm	10.5 mm	8.5 mm
75				11.5 mm				10.5 mm		9.5 mm	9.5 mm	
76	12.0 mm		10.0 mm	10.5 mm	10.5 mm			8.0 mm	13.0 mm	8.5 mm	8.0 mm	9.8 mm
77	11.0 mm	7.0 mm	9.0 mm	9.0 mm	9.0 mm		7.5 mm	8.0 mm	9.0 mm	10.0 mm	8.5 mm	9.4 mm
78	9.6 mm	7.0 mm	8.5 mm	10.0 mm	8.5 mm		7.0 mm	8.5 mm	8.9 mm	10.2 mm	7.3 mm	9.4 mm
79	9.5 mm	8.0 mm	10.0 mm	9.5 mm	8.5 mm	6.8 mm	8.0 mm	8.5 mm	9.3 mm	10.0 mm	8.5 mm	8.9 mm

	Year											
Station	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2019	2020
80	10.0 mm	7.0 mm	8.5 mm	8.0 mm	7.1 mm	7.5 mm	7.0 mm	9.0 mm	9.0 mm	8.5 mm	9.0 mm	9.5 mm
81	11.0 mm		9.5 mm	10.0 mm	9.5 mm	10.0 mm		8.0 mm	11.0 mm	10.5 mm	8.0 mm	9.7 mm
82				12.0 mm		9.0 mm		11.0 mm		9.0 mm		
83				10.5 mm		8.4 mm		10.0 mm	12.0 mm	10.5 mm		
84	10.0 mm	9.5 mm	9.0 mm	8.9 mm	9.0 mm	9.7 mm		10.0 mm	10.0 mm	11.0 mm	7.5 mm	11.7 mm
85	9.5 mm	7.0 mm	9.5 mm	7.5 mm	9.5 mm	11.0 mm	8.8 mm	9.0 mm	9.5 mm	10.0 mm	9.0 mm	10.0 mm
86	11.0 mm	6.0 mm	9.5 mm	8.5 mm	11.0 mm	11.0 mm	7.5 mm	9.5 mm	8.5 mm	11.5 mm		9.5 mm
87	11.5 mm		9.5 mm	8.0 mm	10.6 mm	10.0 mm		10.0 mm	12.5 mm	11.5 mm	8.5 mm	13.5 mm
88				10.0 mm			16.0 mm	12.0 mm		10.0 mm	6.0 mm	
89				12.0 mm	7.0 mm					10.2 mm	7.5 mm	
90			9.7 mm	8.0 mm	12.0 mm			9.0 mm		12.0 mm	9.0 mm	13.0 mm
91				9.5 mm						13.3 mm	7.5 mm	8.0 mm
92					7.4 mm					9.5 mm	7.8 mm	

Appendix C

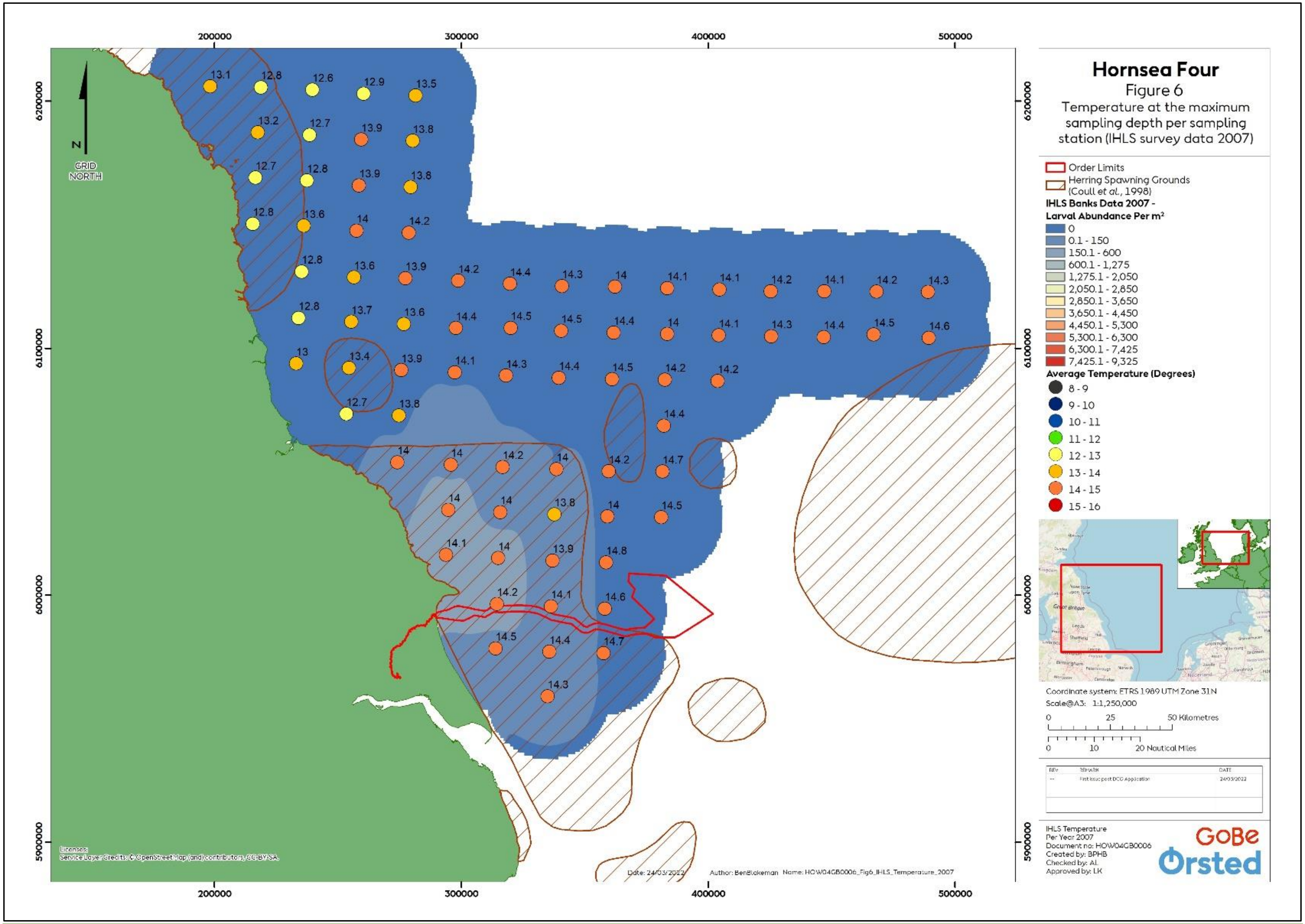


Figure 6: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2007)).

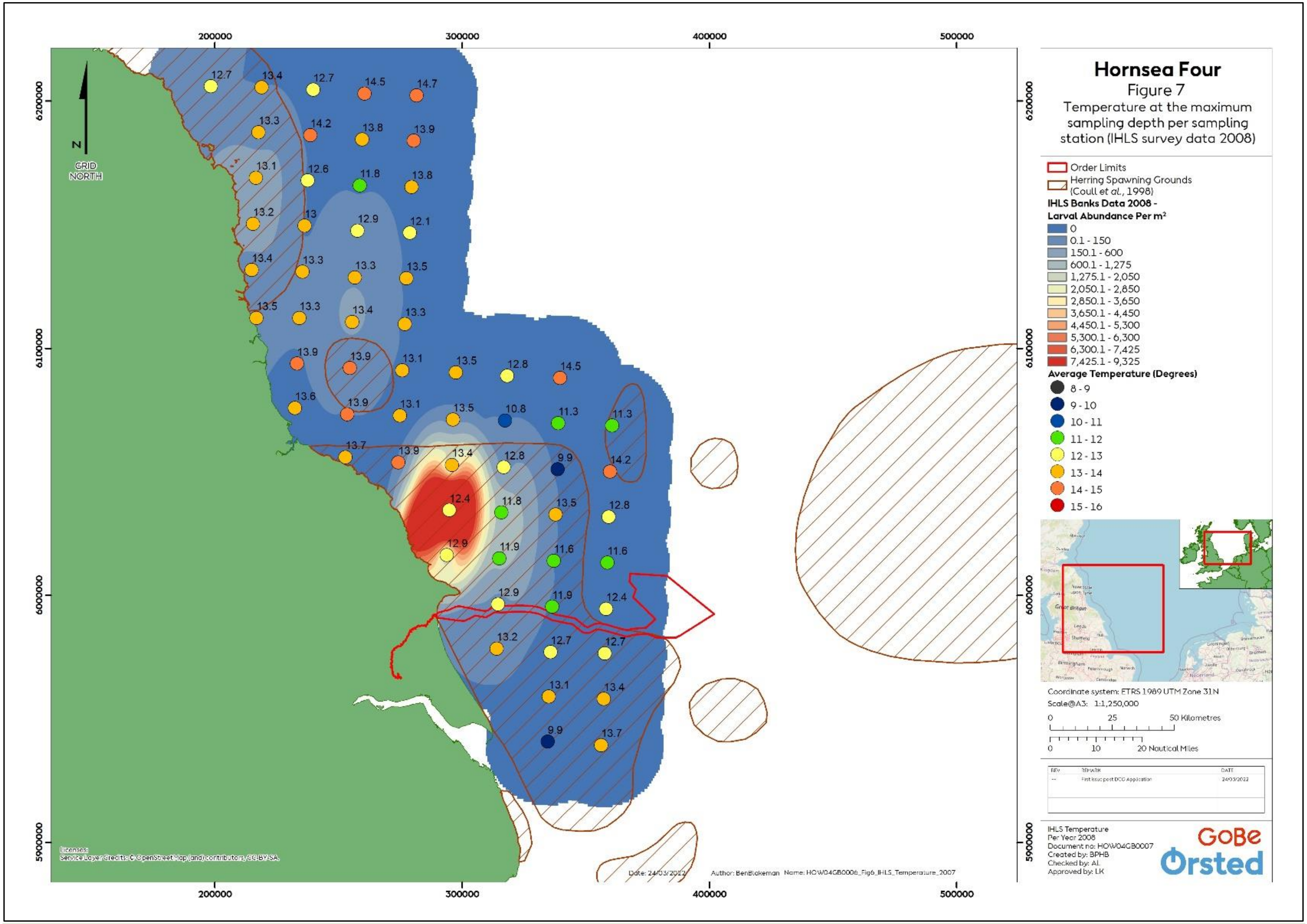


Figure 7: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2008)).

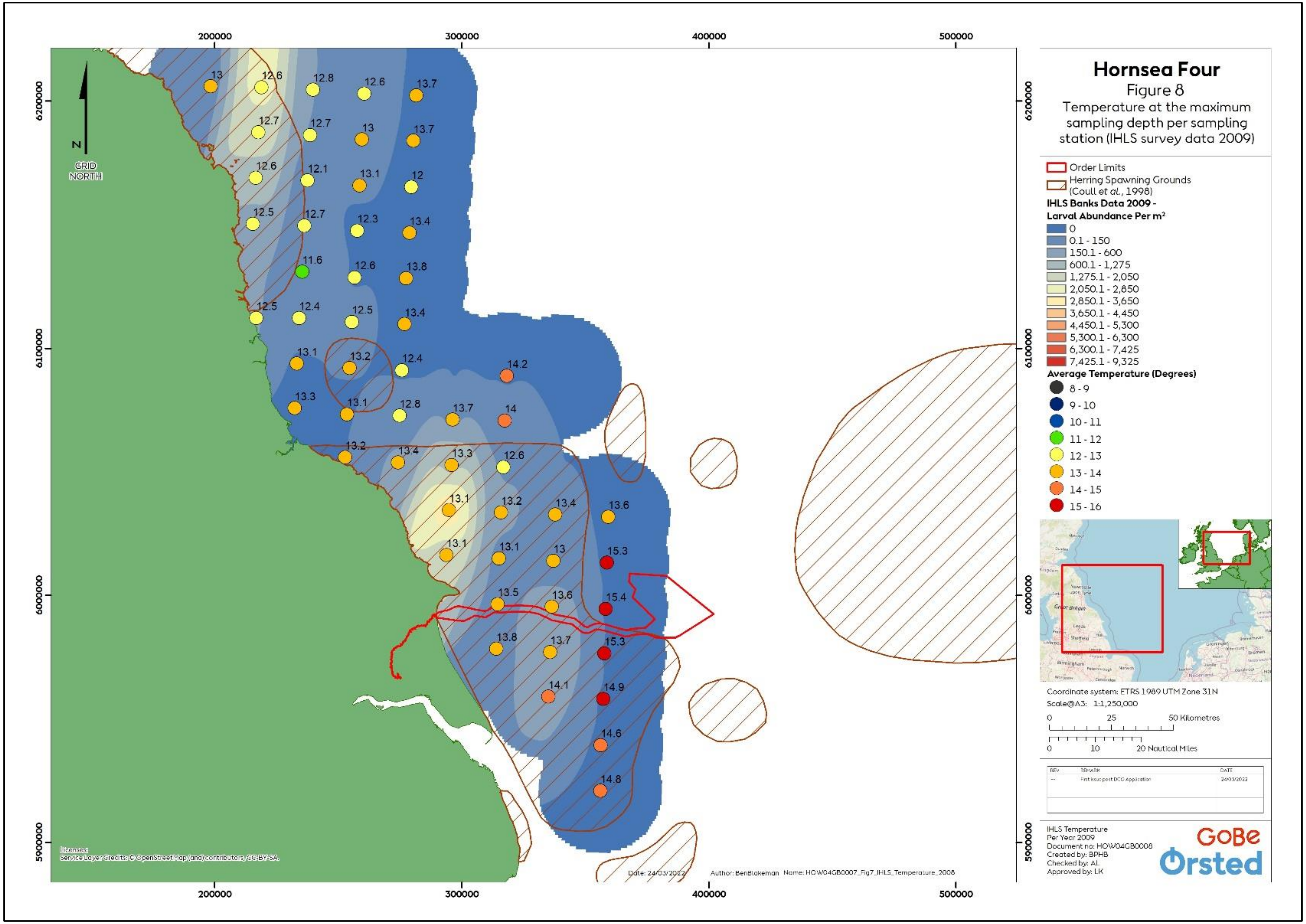


Figure 8: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2009)).

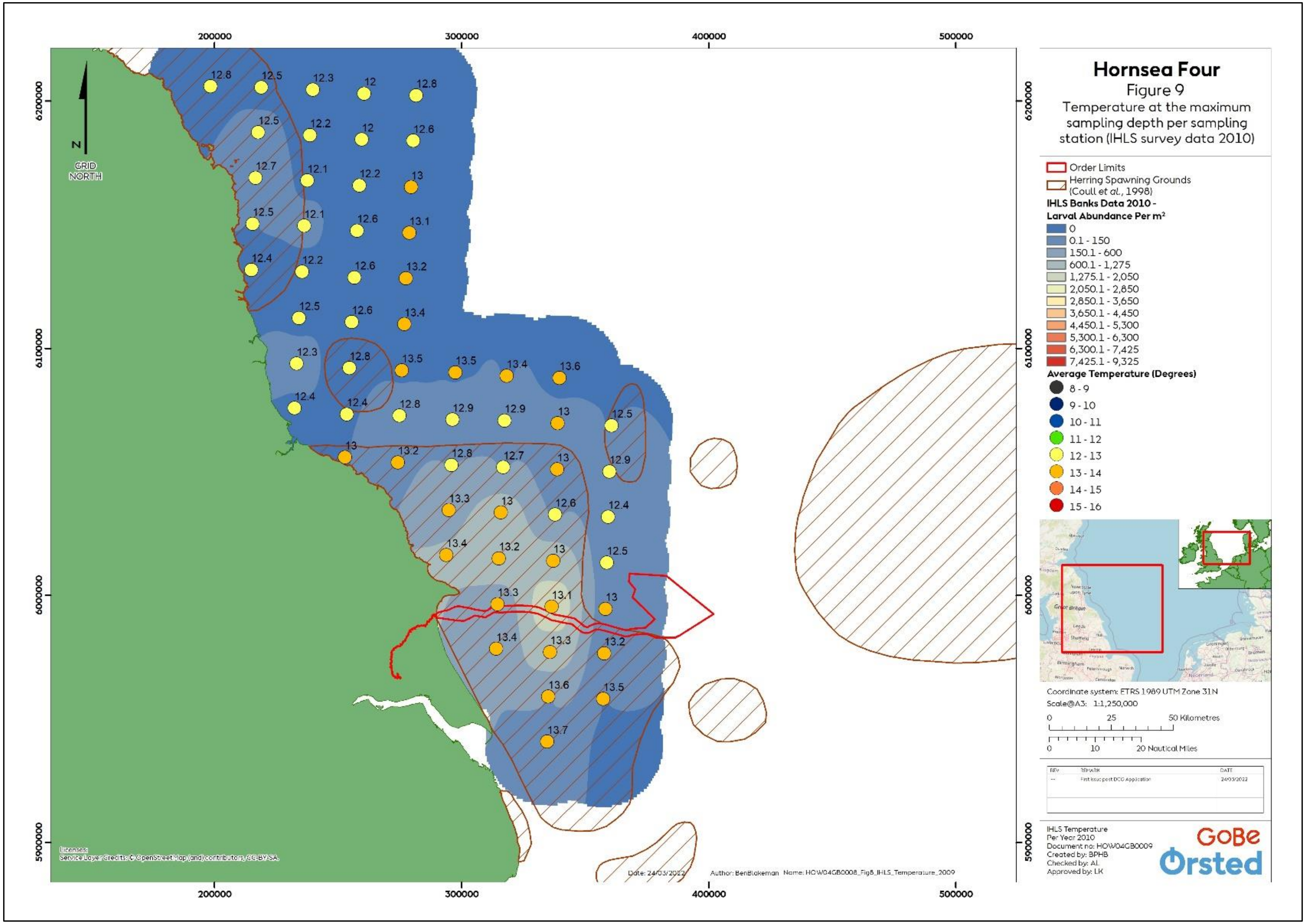
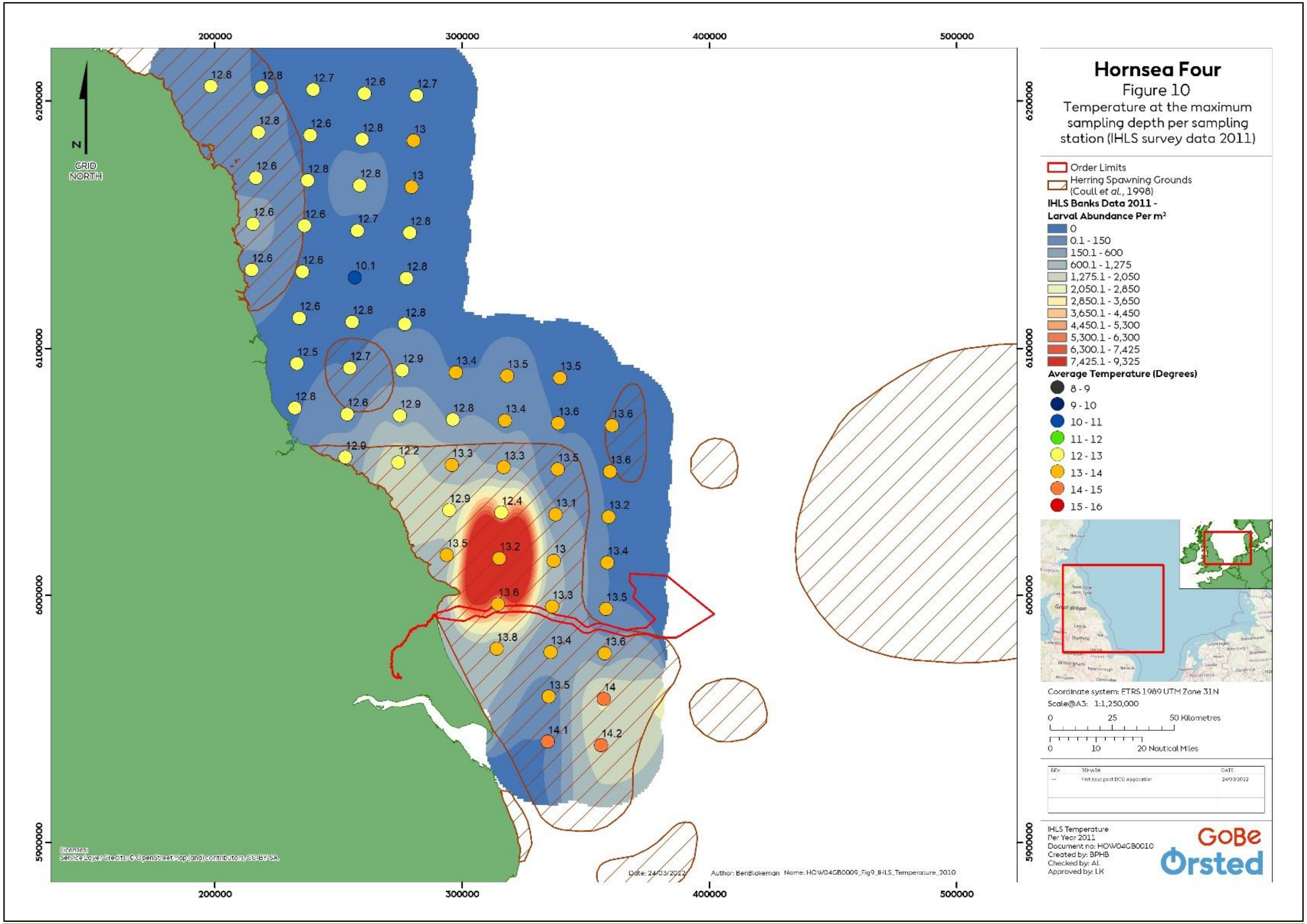


Figure 9: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2010)).


Hornsea Four
Figure 10
Temperature at the maximum sampling depth per sampling station (IHLS survey data 2011)
Order Limits
Herring Spawning Grounds (Coull et al., 1998)
IHLS Banks Data 2011 - Larval Abundance Per m²
0
0.1 - 150
150.1 - 600
600.1 - 1,275
1,275.1 - 2,050
2,050.1 - 2,850
2,850.1 - 3,650
3,650.1 - 4,450
4,450.1 - 5,300
5,300.1 - 6,300
6,300.1 - 7,425
7,425.1 - 9,325
Average Temperature (Degrees)
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:1,250,000
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0 10 20 Nautical Miles
REV REMARK DATE
-- First issue post DCO Application 24/03/2022
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Per Year 2011
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Created by: BPHB
Checked by: AL
Approved by: LK
GoBe
Ørsted
N
GRID NORTH
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300000
400000
500000
6200000
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6000000
5900000
Date: 24/03/2022
Author: BenBlakeman
Name: HOW04GB0009_Fig9_IHLS_Temperature_2010
Licenses: Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA

Figure 10: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2011)).

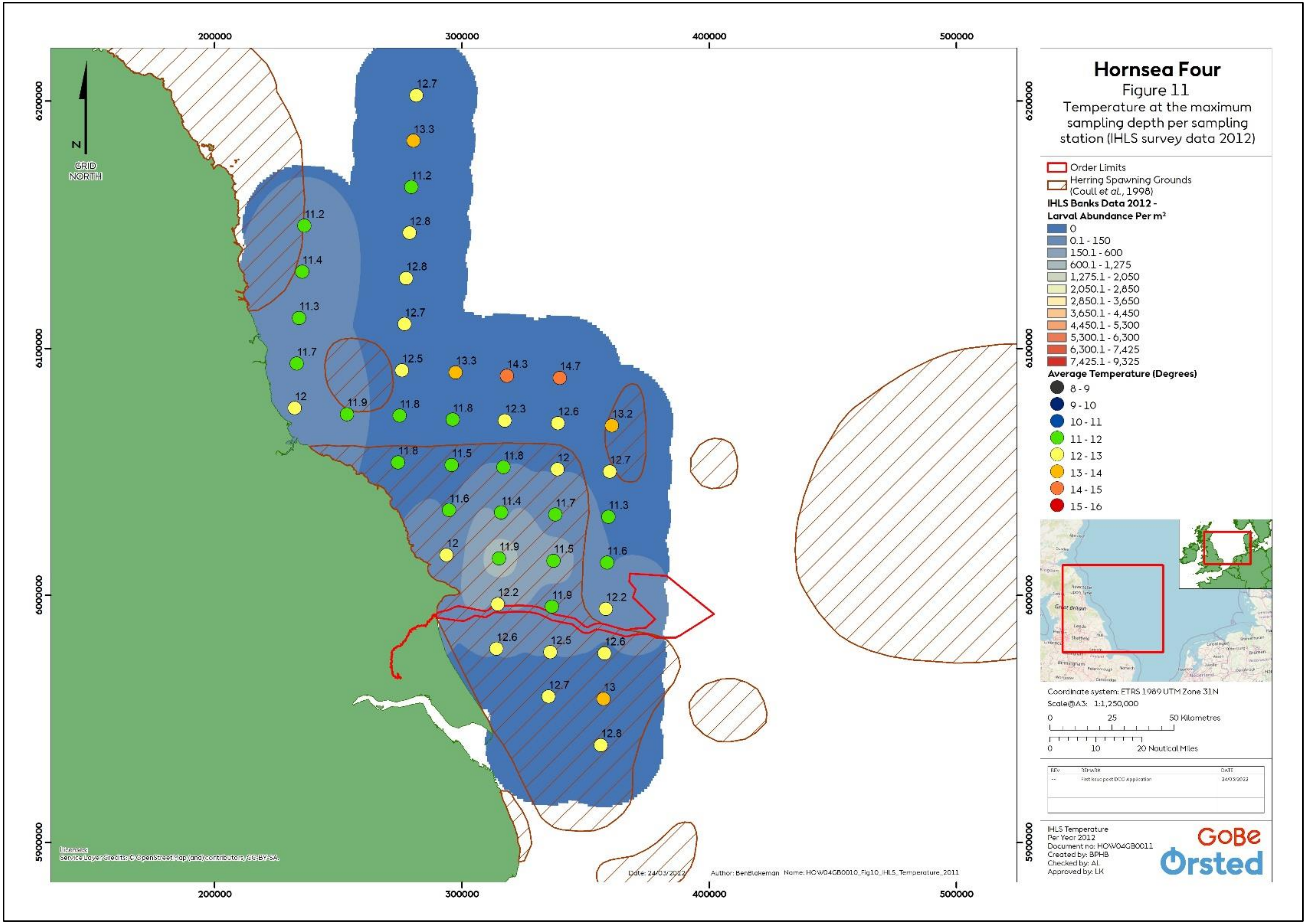


Figure 11: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2012)).

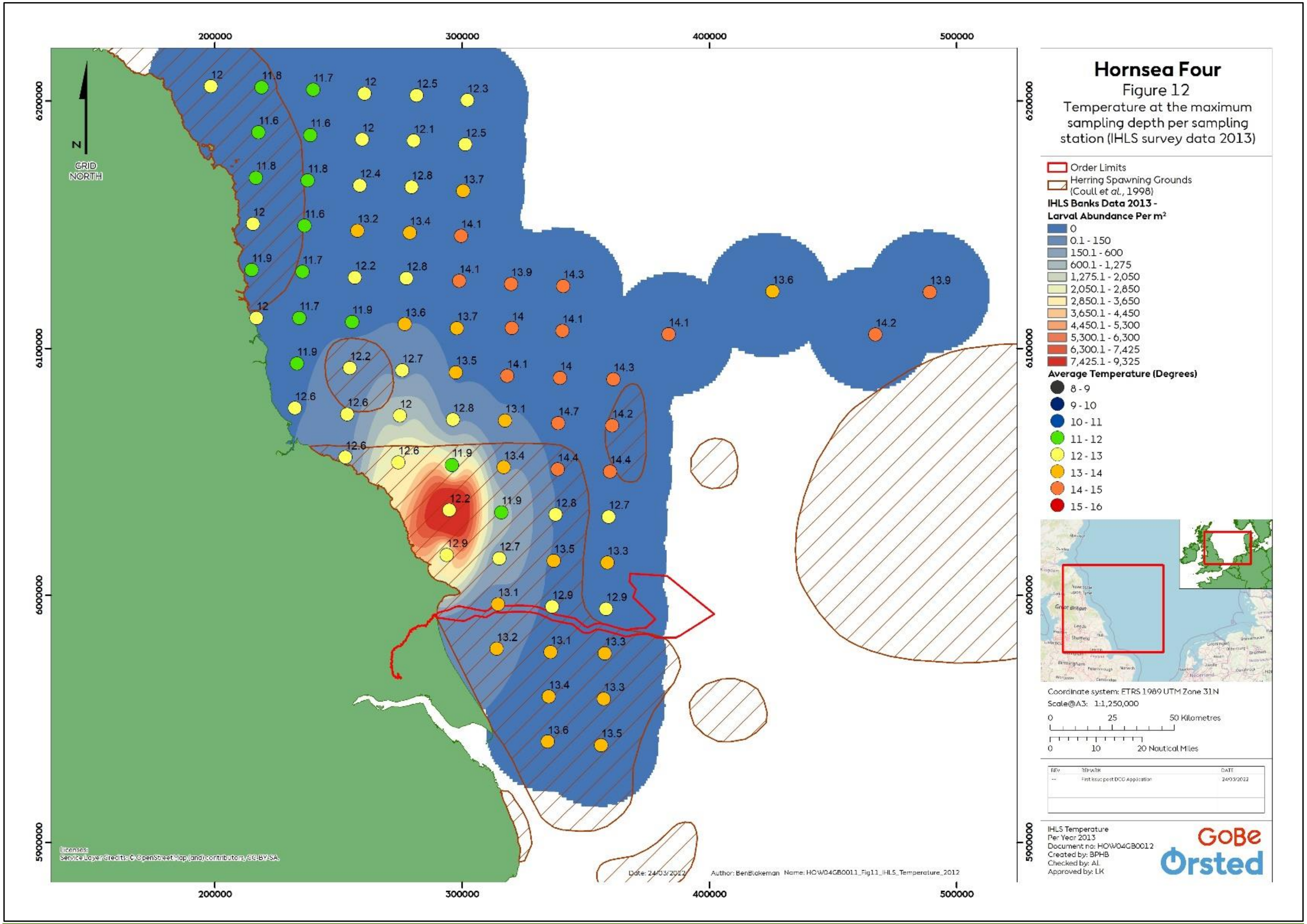
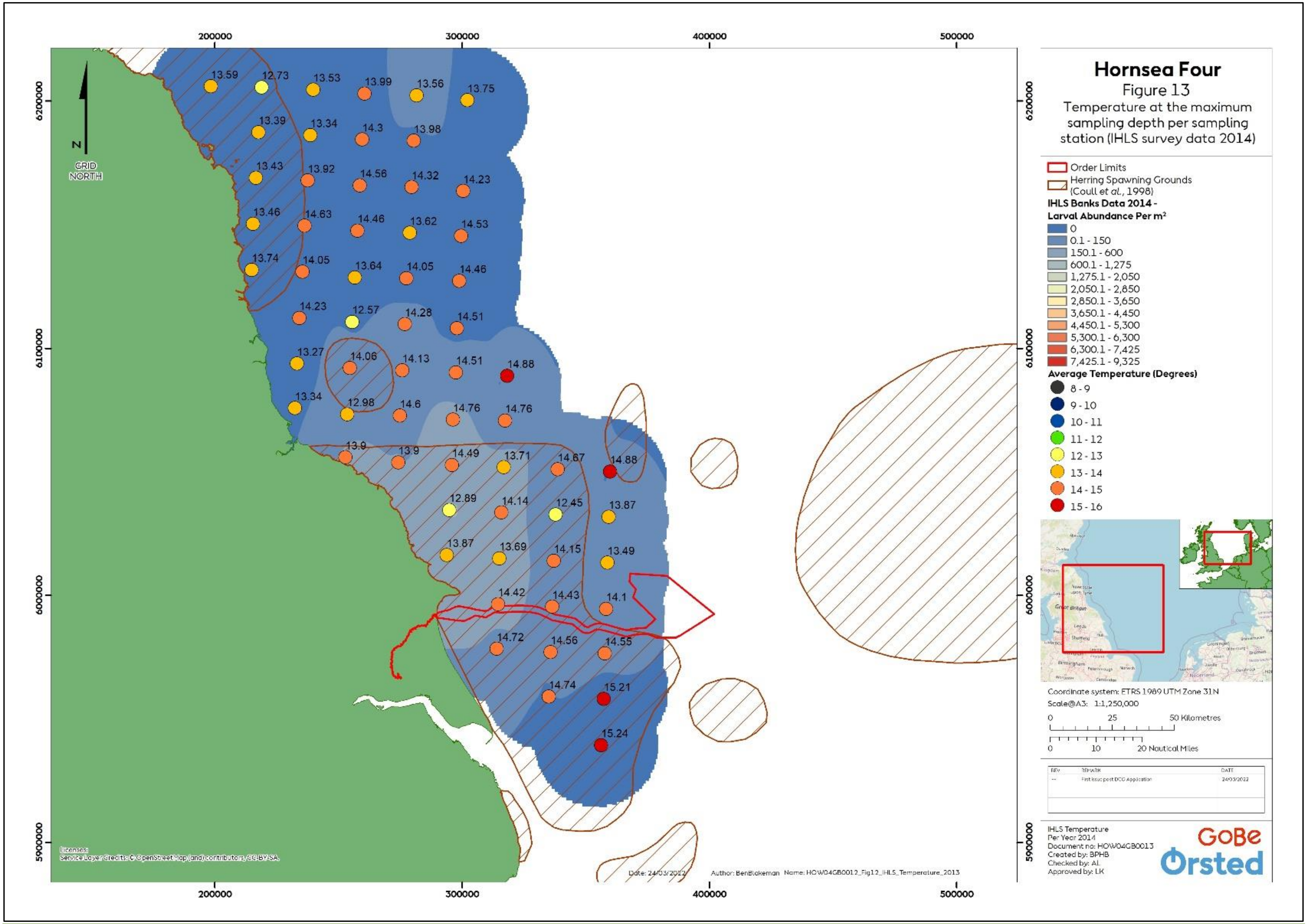


Figure 12: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2013)).



Hornsea Four
Figure 13
Temperature at the maximum sampling depth per sampling station (IHLS survey data 2014)
Order Limits
Herring Spawning Grounds (Coull et al., 1998)
IHLS Banks Data 2014 - Larval Abundance Per m²
0
0.1 - 150
150.1 - 600
600.1 - 1,275
1,275.1 - 2,050
2,050.1 - 2,850
2,850.1 - 3,650
3,650.1 - 4,450
4,450.1 - 5,300
5,300.1 - 6,300
6,300.1 - 7,425
7,425.1 - 9,325
Average Temperature (Degrees)
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:1,250,000
0 25 50 Kilometres
0 10 20 Nautical Miles
IHLS Temperature Per Year 2014
Document no: HOW04GB0013
Created by: BPHB
Checked by: AL
Approved by: LK
GoBe
Ørsted
GRID NORTH
N
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300000
400000
500000
6200000
6100000
6000000
5900000
13.59 12.73 13.53 13.99 13.56 13.75
13.39 13.34 14.3 13.98
13.43 13.92 14.56 14.32 14.23
13.46 14.63 14.46 13.62 14.53
13.74 14.05 13.64 14.05 14.46
14.23 12.57 14.28 14.51
13.27 14.06 14.13 14.51 14.88
13.34 12.98 14.6 14.76 14.76
13.9 13.9 14.49 13.71 14.67 14.88
12.89 14.14 12.45 13.87
13.87 13.69 14.15 13.49
14.42 14.43 14.1
14.72 14.56 14.55
14.74 15.21
15.24
Licenses:
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Author: BenBlakeman
Name: HOW04GB0012_Fig12_IHLS_Temperature_2013

Figure 13: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2014)).

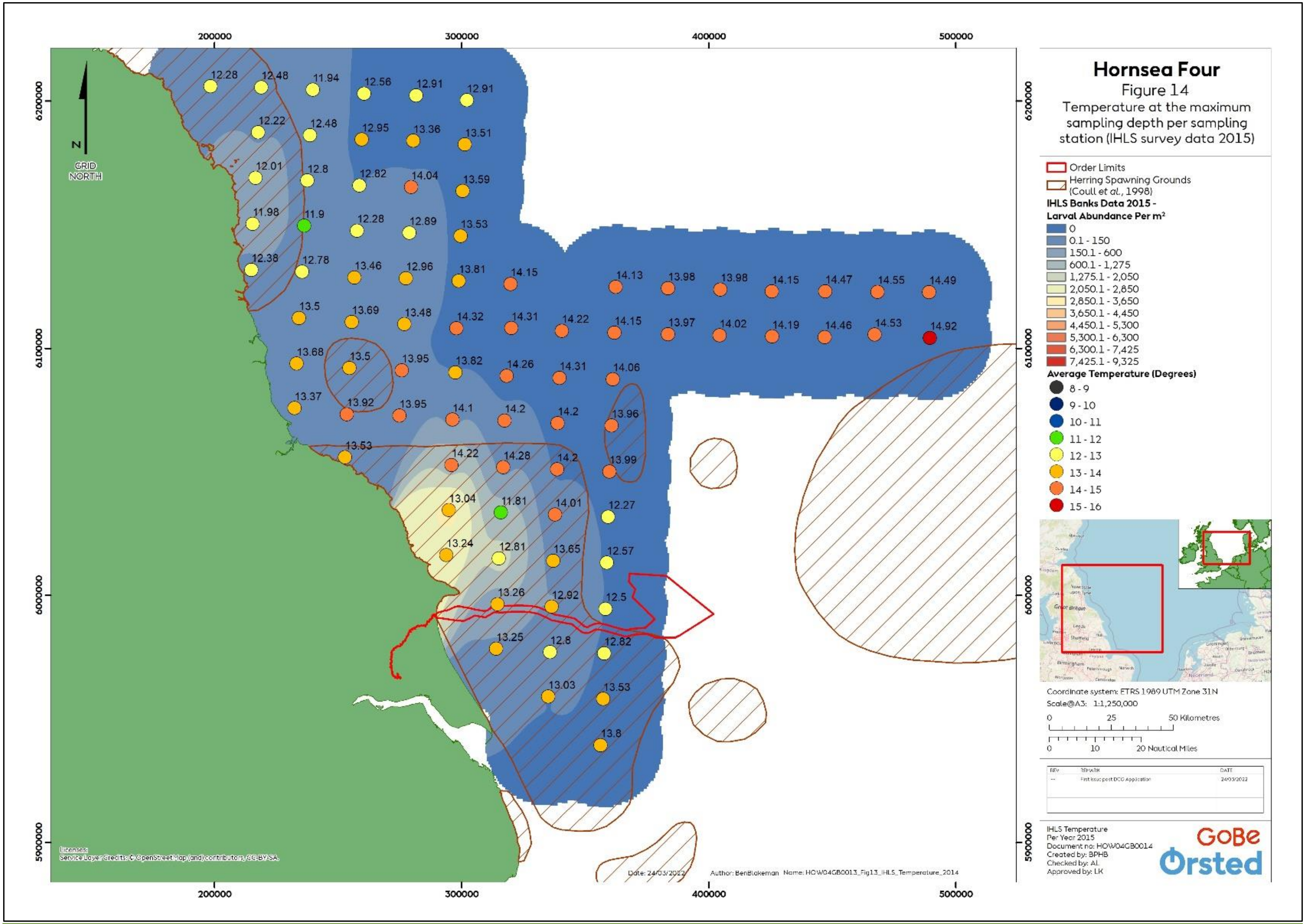
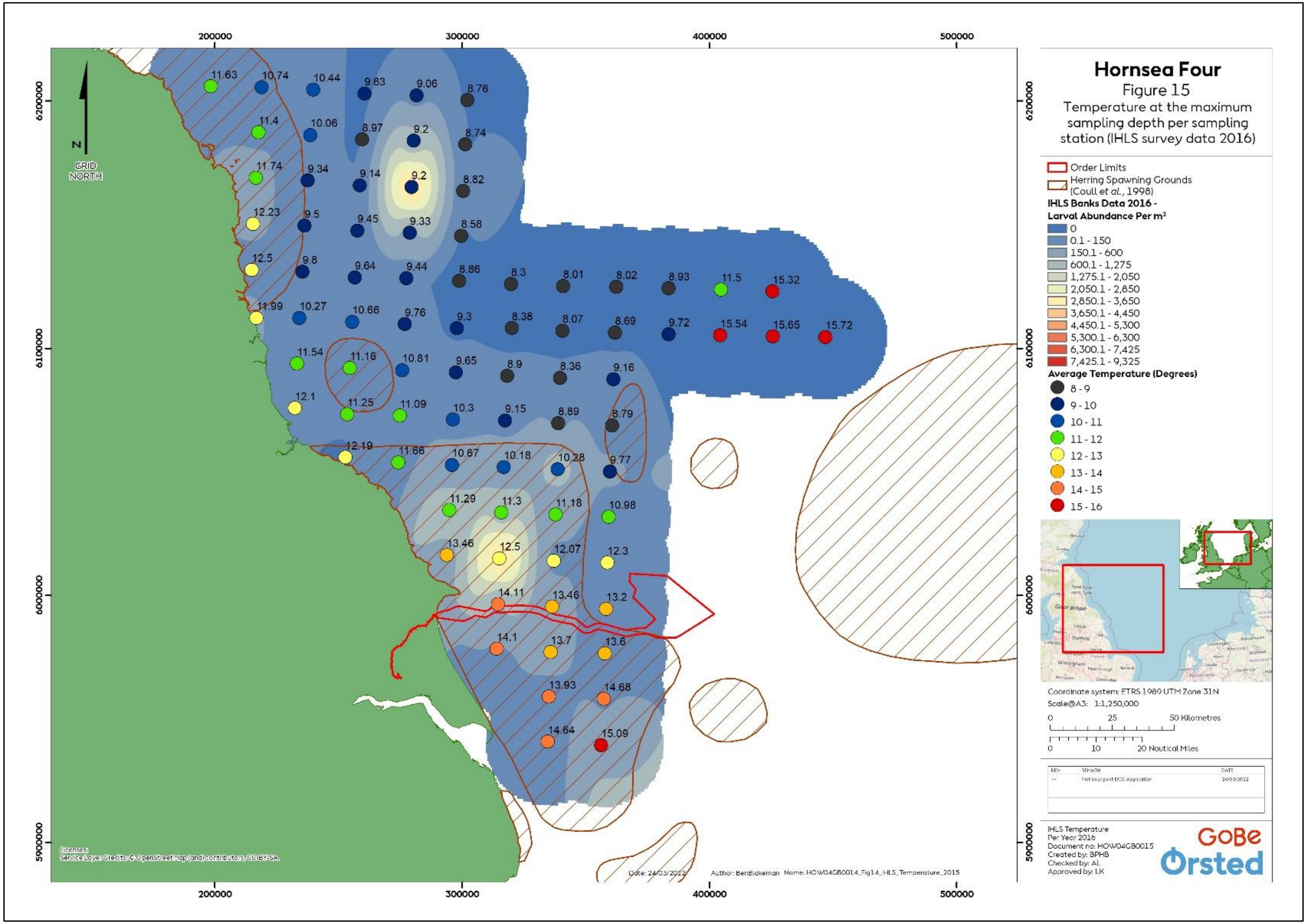


Figure 14: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2015)).


Hornsea Four
Figure 15
Temperature at the maximum sampling depth per sampling station (IHLS survey data 2016)
Order Limits
Herring Spawning Grounds (Coull et al., 1998)
IHLS Banks Data 2016 - Larval Abundance Per m²
0
0.1 - 150
150.1 - 600
600.1 - 1,275
1,275.1 - 2,050
2,050.1 - 2,850
2,850.1 - 3,650
3,650.1 - 4,450
4,450.1 - 5,300
5,300.1 - 6,300
6,300.1 - 7,425
7,425.1 - 9,325
Average Temperature (Degrees)
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
Coordinate system: ETRS 1989 UTM Zone 31N
Scale@A3: 1:1,250,000
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0 10 20 Nautical Miles
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Author: BenBlakeman Name: HOW04GB0014_Fig14_IHLS_Temperature_2015

Figure 15: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2016)).

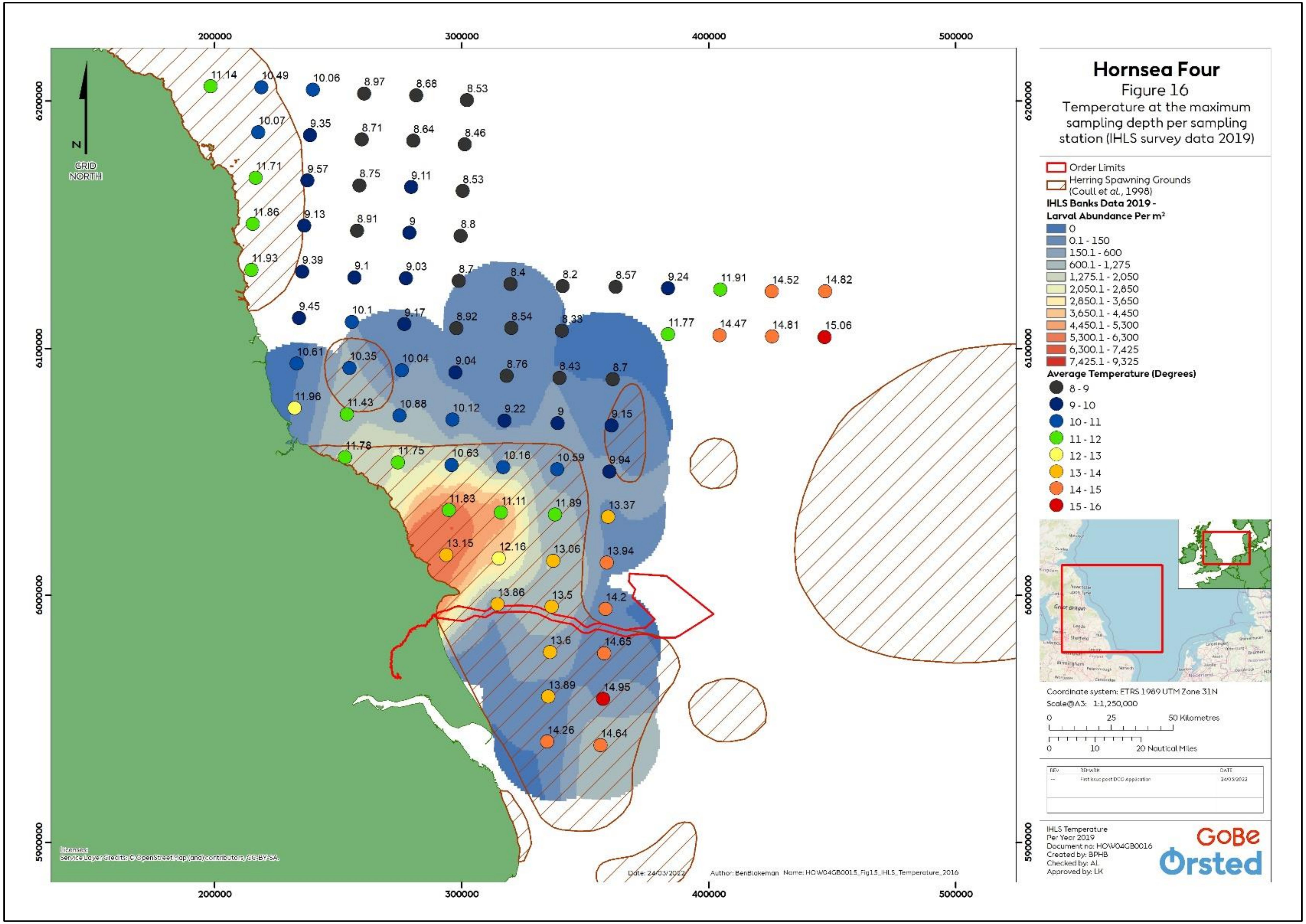
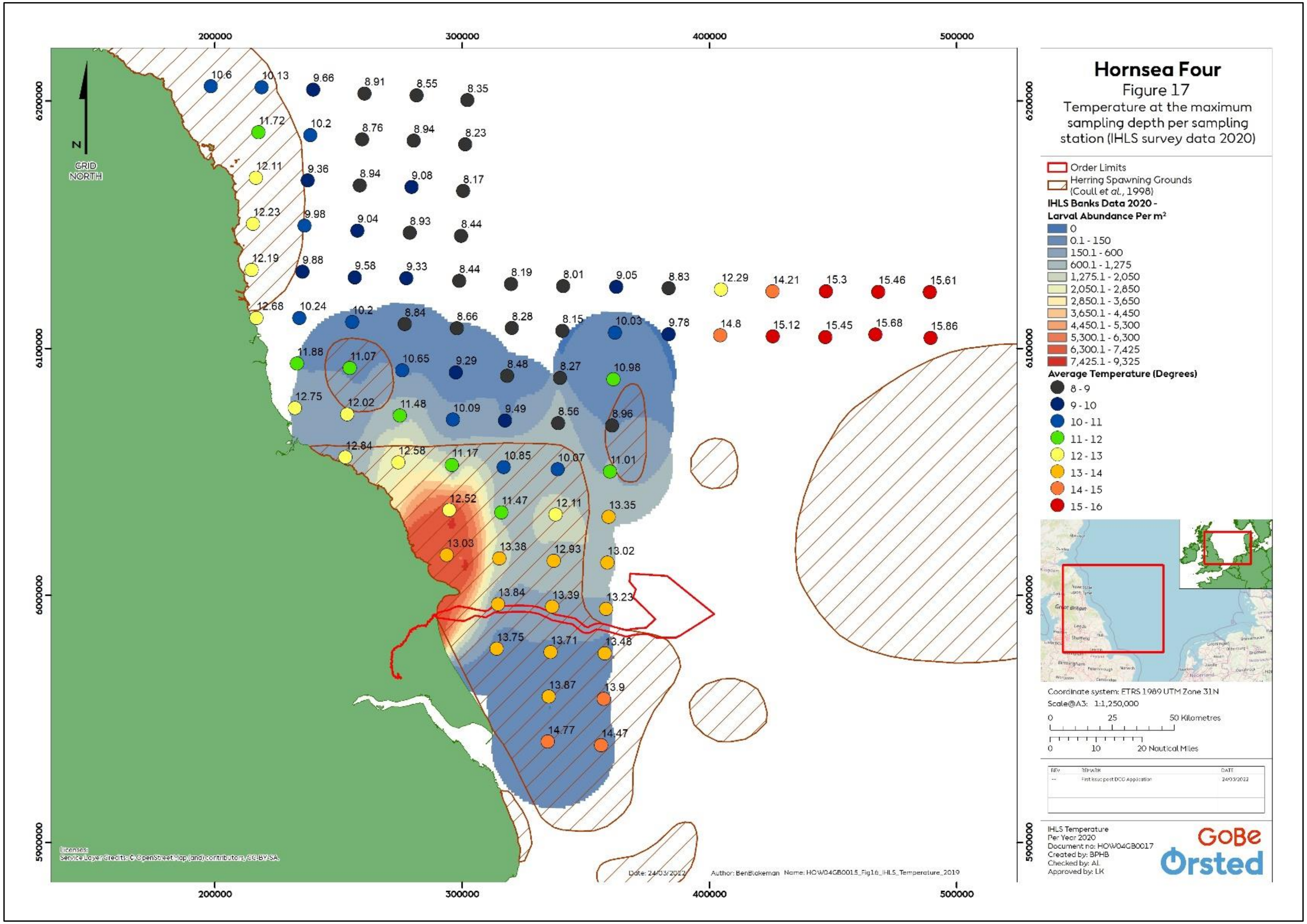


Figure 16: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2019)).


Hornsea Four
Figure 17
Temperature at the maximum sampling depth per sampling station (IHLS survey data 2020)
Order Limits
Herring Spawning Grounds (Coull et al., 1998)
IHLS Banks Data 2020 - Larval Abundance Per m²
0
0.1 - 150
150.1 - 600
600.1 - 1,275
1,275.1 - 2,050
2,050.1 - 2,850
2,850.1 - 3,650
3,650.1 - 4,450
4,450.1 - 5,300
5,300.1 - 6,300
6,300.1 - 7,425
7,425.1 - 9,325
Average Temperature (Degrees)
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
13 - 14
14 - 15
15 - 16
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Date: 24/03/2022
Author: BenBlakeman
Name: HOW04GB0015_Fig16_IHLS_Temperature_2019
Licenses: Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA

Figure 17: Temperature at the maximum sampling depths per sampling station (IHLS survey data (2020)).