FIVE ESTUARIES OFFSHORE WIND FARM

ENVIRONMENTAL STATEMENT

VOLUME 6, PART 5, ANNEX 6.4: HERRING SEASONAL RESTRICTION NOTE

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DEFINITION OF ACRONYMS

Term	Definition
DCO	Development Consent Order
EIA	Environmental Impact Assessment
ES	Environmental Statement
ICES	International Council for the Exploration of the Sea
IHLS	International Herring Larvae Survey
LSE	Likely Significant Effects
MHWS	Mean High Water Springs
NSIP	Nationally Significant Infrastructure Projects
PEIR	Preliminary Environmental Information Report
VE	Five Estuaries

GLOSSARY OF TERMS

Term	Definition
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.
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.
Mitigation	Mitigation measures, or commitments, are commitments made by VE to reduce and/or eliminate the potential for significant effects to arise as a result of the project.
Spawning	The release or deposition of eggs and sperm, usually into water, by aquatic animals.

1 BACKGROUND

1.1.1 Five Estuaries Offshore Wind Farm (hereafter referred to as VE) has prepared this technical note to define the peak spawning period for the Downs herring stock, to inform a seasonal piling restriction for the mitigation of impacts to spawning herring from underwater noise in relation to VE.

1.1.2 Within both Volume 6, Part 5, Annex 6.1: Fish and Shellfish Ecology Technical Baseline Report and Volume 6, Part 2, Chapter 6: Fish and Shellfish Ecology, herring (*Clupea harengus*) has been identified as a key receptor, with this species being recognised to have important spawning grounds in the vicinity of VE. The nearest herring spawning ground to piling operations in the VE array areas is the Downs spawning ground (). A comprehensive assessment on the potential for impacts on spawning herring has been undertaken in Volume 6, Part 2, Chapter 6: Fish and Shellfish Ecology, and significant effects have been concluded on Downs stock spawning herring in relation to underwater noise from piling activities in the array areas.

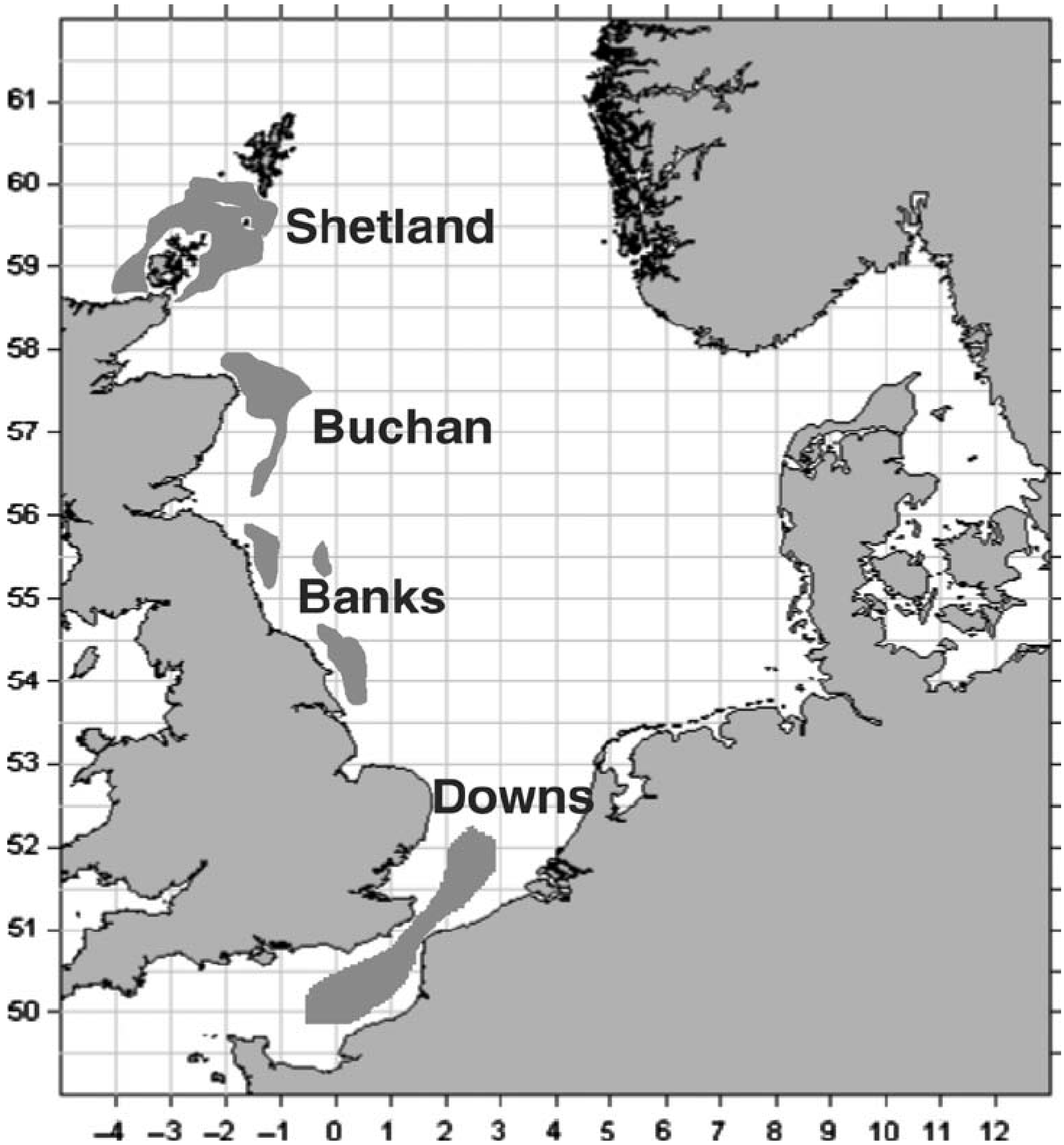


Figure 1.1: Herring spawning grounds within the North Sea (Beirman *et al*., 2010).

1.1.3 As defined in Volume 6, Part 5, Annex 6.1: Fish and Shellfish Ecology Technical Baseline 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 undergo 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 1.2):

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

1.1.4 Kendall *et al*. (1984) further divided the larval stage into the following sub–stages (Figure 1.2):

> Yolk–sac larvae (from hatching to the absorption of yolk reserves);

> Pre-flexion larvae;

> Flexion larvae; and

> Post-flexion larvae.

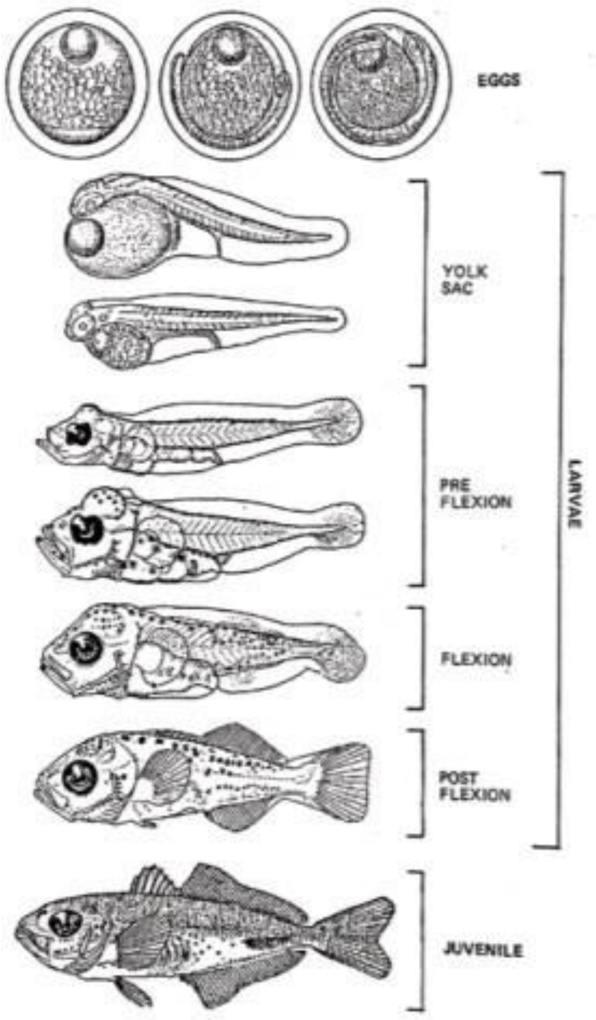


Figure 1.2: Bony fish developmental stages (from Kendall *et al.*, 1984).

1.1.5 The key stages in relation to defining the peak spawning period are the egg development duration and yolk absorption duration stages of herring development.

1.1.6 The primary source of information for the current status of herring spawning is the International Herring Larvae Survey (IHLS) data, which is collected under the auspices of International Council for the Exploration of the Sea (ICES) (IHLS survey data stations presented in Figure 5.1 of Appendix A). 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 Environmental Impact Assessments (EIAs), including for VE.

1.1.7 Following the conclusion of significant effects on spawning herring in relation to underwater noise from piling activities in the array areas (Section 6.11, Impact 1, Volume 6, Part 2, Chapter 6: Fish and Shellfish Ecology), this note has been produced to provide the analysis and justification of this “peak” spawning period for Downs stock herring in the vicinity of VE in order to support the proposed timing of the seasonal restriction.

2 SEASONAL RESTRICTION TIMING

2.1 INTRODUCTION

2.1.1 To determine the start and end of the "peak" spawning period for herring in the Downs stock spawning ground (as defined by Coull et al., 1998), the IHLS data has been interrogated and back-calculations have been performed to identify the most likely dates for when spawning commenced and ceased for the majority of the larvae captured within the IHLS data.

2.1.2 For the purposes of the spawning timing analysis, IHLS data for 2007 – 2022 for the Downs herring stock were interrogated to ensure the suggested peak spawning timing was applicable year to year.

2.1.3 It should be noted that for much of the 2020-2022 data, there are missing data relating to the distances travelled by the survey vessels, and it has therefore not been possible to convert these data entries into larval densities for use in the heatmaps[1] (Figure 6.12 to Figure 6.14). Nonetheless, this does not impact the parameters used to inform the back calculations, which have been based on the full dataset (2007 – 2022).

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

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

2.1.5 In the simplest terms, these parameters are used in relation to the following back-calculation to determine the start of the peak spawning period:

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

2.1.6 Similarly, the following calculation is used to determine the end of the peak spawning period:

End of peak spawning period = latest survey end date – numbers of days from hatch length to catch length – yolk absorption duration – egg development duration.

2.1.7 Additionally, consideration of herring migratory patterns has also been provided in Section 2.9 of this technical note.

[1] These data have been requested from ICES and will be incorporated to an updated version of this note if received. The Applicant has queried this with ICES and if a resolution is possible, these data will be added into the analysis. These data have therefore been omitted from the specific analyses informed by the heatmapping.

2.2 IHLS SURVEY TIMINGS

2.2.1 Whilst the survey start dates for the annual IHLS are broadly similar year to year, there are small interannual variations in the timings of the survey dates within each region. As shown in Table 2.1 below, the variation in survey start dates between 2007 and 2022 is generally small, and by using the earliest start date and latest survey end dates rather than average survey dates to inform the back calculations, a precautionary approach has been used. For the Downs herring spawning stock IHLS trawl surveys, the earliest survey start date is the 15 December[2], and the latest end date is the 22 January[3].

2.2.2 It should be noted that in 2018, surveys were undertaken for the Shetland stock only (Table 2.1), therefore the IHLS data for 2018 are therefore not applicable for use within the back-calculations for the Downs stock (the herring stock of relevance for VE). These years have therefore been omitted from Table 2.1.

Table 2.1: Range of survey dates.

Survey Year	IHLS Start Date	IHLS End Date
2007/2008	17th December 2007	22nd January 2008
2008/2009	16th December 2008	21st January 2009
2009/2010	15th December 2009	20th January 2010
2010/2011	21st December 2010	19th January 2011
2011/2012	20th December 2011	20th January 2012
2012/2013	18th December 2012	17th January 2013
2013/2014	17th December 2013	22nd January 2014
2015	20th January 2015	22nd January 2015
2015/2016	15th December 2015	21st January 2016
2016/2017	20th December 2016	19th January 2017
2019	18th December 2019	19th December 2019
2020	15th December 2020	17th December 2020
2021	22nd December 2021	23rd December 2021
2022	21st December 2022	22nd December 2022

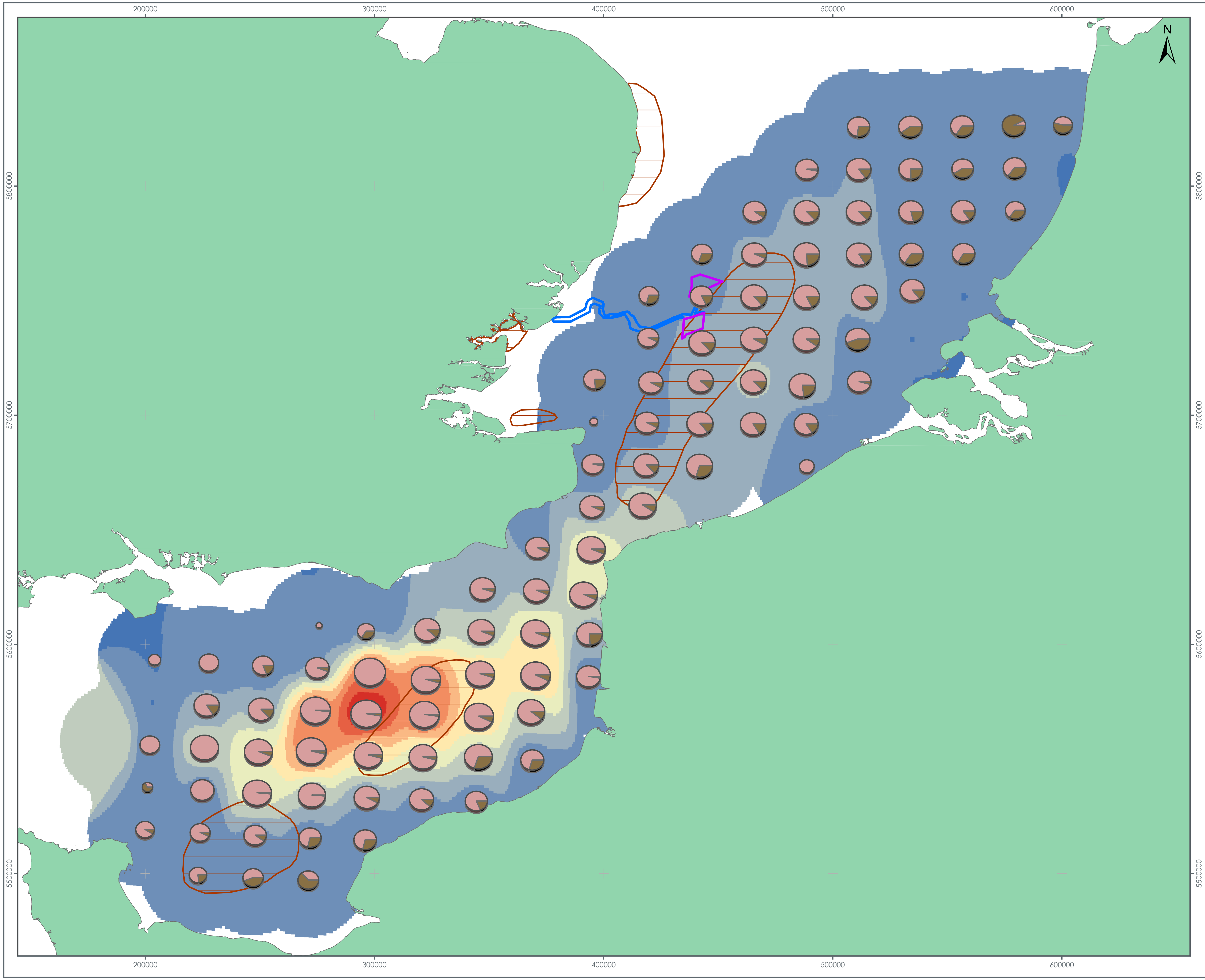
[2] The survey start date does not include consideration of the 2014 surveys, as sampling was only conducted in January for this year.
[3] The 2019-2022 surveys only occurred through December, while the data from these surveys has been used to inform the back-calculations, they cannot be used to inform the overall end date for IHLS surveys, due to ending one month earlier than the 2007-2017 surveys.

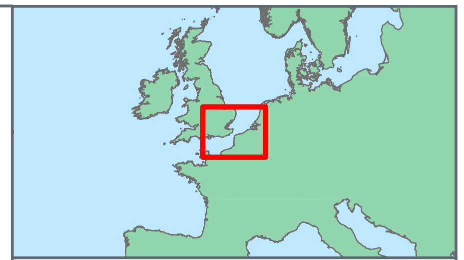
2.3 LARVAL LENGTH IN SURVEY SAMPLE DATA (CATCH LENGTH)

2.3.1 As explained in paragraph 2.1.5, larval length (catch length) is an important parameter in the back-calculation. This parameter represents a larval length threshold at which it can be considered the majority of the larvae at the Downs spawning hotspots are captured within the trawl surveys. The IHLS data provide records of the number of larvae of each length recorded within each survey sample from 2007-2022. Overall, 89.9% of all larvae recorded within the IHLS surveys from 2007-2022 were equal to or less than 11 mm in length; ranging from 58% in the 2017 survey to 99.2% in the 2019 survey, with a mode and mean larval size of 10 mm (2007-2022).

2.3.2 It is notable that the frequency of larger larvae (>11 mm) 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 all being ≤11 mm over all the survey years (Figure 2.1). As such, the use of a ≤11mm 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.

2.3.3 On the basis that the majority of all larvae are consequently smaller than this selected size, 11 mm is considered an appropriate larval length upon which to base the calculation of a conservative estimate of the start and end 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 Downs stock larvae as those <11 mm in length, and therefore the use of a catch length of 11 mm ensures that all newly hatched larvae would be captured within this value.





LEGEND

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Mean Herring Larval Lengths per Sampling Station (IHLS Survey Data (2007-2022))

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 2.1

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

2.4 LARVAL LENGTH AT HATCHING

2.4.1 Once the catch length has been identified (Section 2.3), it is necessary to establish the length of Downs stock larvae immediately after hatching to determine the duration larvae take to go from hatch length to catch length. In the published literature, there are relatively large variations in the average larval lengths at hatching, with estimates of average hatch length given from 5 mm to 6 mm (Heath, 1993) and 7.5 mm (Blaxter and Hempel, 1963).

2.4.2 Larval sizes within the IHLS data for the Downs stock 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 2019, 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 (2.3% of all recorded larvae from 2007 to 2019). 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 Channel IHLS data.

2.4.3 For the purposes of these back-calculations, 5 mm and 6 mm (Heath, 1993) and 7.5 mm (Blaxter and Hempel, 1963) larval sizes (at hatching) have been used as the basis for the back-calculation analysis. The use for these larvae sizes are further supported by IHLS data, where hatch sizes of 5 mm (most conservative length) and 6 mm (minimum length) have been identified in significant quantities.

2.4.4 In addition to this, and as noted above, larvae within the Downs stock are known to hatch up to 11 mm in length, therefore, to provide back-calculation dates for a full range of potential hatch sizes, an 11 mm larval length at hatching has also been included as a scenario.

2.4.5 The application of various larval hatch 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 and end date will likely fit.

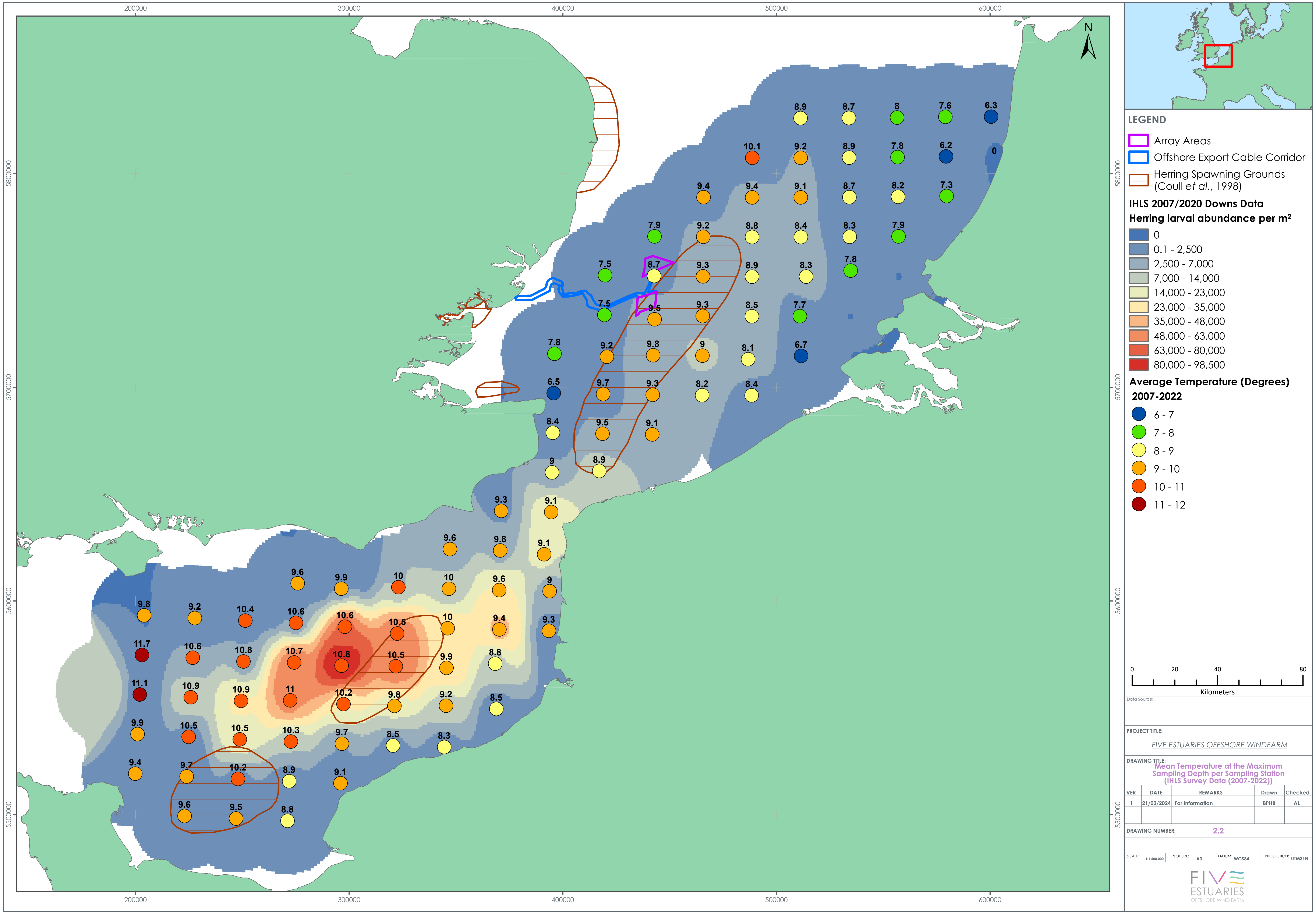
2.5 EGG DEVELOPMENT DURATION

2.5.1 As explained in paragraph 2.1.5, egg development duration is an important parameter in the back-calculation and this duration is affected by water temperature. Lower water temperatures relate to a longer egg development duration and higher temperatures relate to a shorter egg development duration. As such, a temperature dependent egg development duration has been used for this calculation, based on the egg development durations from Russell (1976). Data for the temperature at the maximum sampling depth for each trawl is recorded as part of the IHLS data (2007-2022). These data have been used to determine the average temperature at the maximum sampling depth to represent the average seafloor temperature for egg development duration.

2.5.2 Between 2007 and 2022 for the IHLS dataset covering the full extent of the English Channel, the temperature during sampling (at maximum sampling depth) across the Downs stock spawning grounds ranged from 5.9°C in 2009, to 13.8°C in 2023, with an average temperature of 9.9°C. See Figure 2.2 below for average temperatures recorded at maximum sampling depths in the IHLS survey data (2007 – 2022) for the Downs stock (see Figure 6.1 to Figure 6.14 in Appendix B for the individual survey years).

2.5.3 Nonetheless, for the IHLS dataset covering just the northeastern extent of the English Channel over the same time period, the average temperature (at maximum sampling depth) ranged between 6.3°C to 10.1°C, with an average of 8.5°C, which is 1.4°C less than the entire English Channel. As such, for the purposes of the temperature dependent values within the back calculation, the average water temperature (at maximum sampling depth) of 8.5°C from the northeastern extent of the Channel has been chosen because it represents an extended growth rate for herring larvae and therefore a precautionary approach when determining the start date and end dates for peak herring spawning. The average temperate (at maximum sampling depth) from 2007 – 2022 within the Coull *et al.* (1998) spawning area is 9.3°C, further highlighting the precautionary nature of the use of 8.5°C as the average temperature (Figure 2.2).

2.5.4 To ensure conservatism is built into the back calculations, a 14 day egg development period has been used to inform the start date and end date for peak spawning of the Downs herring stock, as informed by Russell (1976), at a temperature of 8.5°C.



200000
300000
400000
500000
600000
5800000
5700000
5600000
5500000
N
LEGEND
Array Areas
Offshore Export Cable Corridor
Herring Spawning Grounds (Coull et al., 1998)
IHLS 2007/2020 Downs Data
Herring larval abundance per m²
0
0.1 - 2,500
2,500 - 7,000
7,000 - 14,000
14,000 - 23,000
23,000 - 35,000
35,000 - 48,000
48,000 - 63,000
63,000 - 80,000
80,000 - 98,500
Average Temperature (Degrees) 2007-2022
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
0 20 40 80
Kilometers
Data Source:
PROJECT TITLE:
FIVE ESTUARIES OFFSHORE WINDFARM
DRAWING TITLE:
Mean Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data (2007-2022))
VER | DATE | REMARKS | Drawn | Checked
1 | 21/02/2024 | For Information | BPHB | AL
DRAWING NUMBER: 2.2
SCALE: 1:1,500,000 PLOT SIZE: A3 DATUM: WGS84 PROJECTION: UTM31N
FIVE ESTUARIES
OFFSHORE WIND FARM

2.6 YOLK ABSORPTION DURATION

2.6.1 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.

2.6.2 During this yolk absorption period, larvae are initially 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).

2.6.3 Information from a range of studies has been used to inform yolk absorption sites to inform back calculations. Russell (1976) identified that the yolk sac absorption phase lasted between 5 to 14 days at 12.0°C and decreased to 3 to 9 days at 12.8°C.

2.6.4 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). Furthermore, Kiorboe *et al*. (1985) found no yolk was present at the start of feeding for the autumn larvae. Geffen (2002) also noted that the yolk absorption phase for larvae raised at 7°C was 9 – 11 days. Furthermore, additional studies suggest a yolk absorption period at lower temperatures, from 3 to 6.5 days at 8°C, and 9 to 11 days at 7°C (Kiorboe *et al*., 1985; Geffen, 2002).

2.6.5 Taking this range of temperatures into account, the most appropriate yolk absorption period to use for the start date and end date back calculations is 7 days, as informed by the consistency in results from Kiorboe *et al*., (1985) and Geffen (2002). It should be noted however, that the proposition of a 7 day period for yolk absorption is a conservative assumption, because the durations for yolk absorption (proposed by Kiorboe *et al*.,1985 and Geffen,2002), are respectively lower (7°C & 8°C) than temperatures recorded for the Downs stock (8.5°C), meaning that realistically Downs stock larvae could have a shorter yolk absorption duration and faster development. 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 becoming available to the survey equipment used for the IHLS.

2.7 GROWTH RATE

2.7.1 Various studies have identified a wide range of growth rates for herring larvae; based on temperatures ranging from 1°C – 12°C (see Table 2.2).

2.7.2 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; 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).

2.7.3 Oeberst *et al*. (2009) 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.

2.7.4 Using the equation from Oeberst et al. (2009), for the average temperature recorded in the Northeastern Channel IHLS data (8.5°C), a growth rate of 0.34 mm d-1 has been calculated. This is supported by the literature, where growth rates of 0.4 mm d-1 have been recorded for larvae reared at temperatures from 8°C (Gamble et al., 1985; Geffen, 1986). 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.

2.7.5 Consequently, based off an average temperature of 8.5°C, the growth rate used within the back-calculation to determine the duration of the peak spawning period is 0.34 mm d-1.

Table 2.2: 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 The factors for consideration within the back-calculation based on the above parameters are summarised in Table 2.3 below, with the four scenarios for both the start and end dates of peak spawning based on the four different hatch lengths presented.

Table 2.3 Factors considered within the back-calculations.

Factor	Scenario A	Scenario B	Scenario C	Scenario D
Earliest survey start date	15th December	15th December	15th December	15th December
Latest survey end date	22nd January	22nd January	22nd January	22nd January
Larval length (catch length)	11mm	11mm	11mm	11mm
Larval length at hatching (hatch length)	5 mm	6mm	7.5mm	11mm
Egg development duration	14 days	14 days	14 days	14 days
Yolk absorption duration	7 days	7 days	7 days	7 days
Growth rate	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}

2.8.2 To determine the start and end dates of peak spawning, the number of days from hatch length to catch length for the different scenarios are as follows (difference between the catch length and the hatch length, divided by the growth rate):

- Scenario A - based on a growth rate of 0.34 mm d-1, it would take 5 mm larvae 17.7 days to grow to the 11 mm catch length,
- Scenario B - it would take 6 mm larvae 14.7 days to grow to the 11 mm catch length,
- Scenario C - it would take 7.5 mm larvae 10.3 days to grow to the 11 mm catch length,
- Scenario D - it would take 11 mm larvae 0 days to grow to the 11 mm catch length.

2.8.3 It should be noted that the inclusion of the yolk absorption period separately to the duration required for larvae to grow to catch length is likely to result in a degree of double counting and is therefore considered precautionary. This is due to the fact that larvae will be growing during the yolk absorption phase rather than growing and yolk absorption being sequential processes.

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

Start of peak spawning period = Earliest survey start date – numbers of days from hatch length to catch length – yolk absorption duration – egg development duration.

End of spawning period = Latest survey end date – numbers of days from hatch length to catch length – yolk absorption duration – egg development duration.

Table 2.4: Peak Spawning Start and End Dates

Scenario	Start Date	End Date
A (5 mm)	6th November (15th December – 39 days (17.7 days + 7 days + 14 days))	14th December (22nd January – 39 days (17.7days + 7 days + 14 days))
B (6 mm)	9th November	17th December
C (7.5mm)	14th November	22nd December
D (11 mm)	24th November	1st January

2.8.5 The peak spawning periods are defined in Table 2.4 above for all scenarios. In addition to the precautionary nature of the chosen values for the individual parameters set out in Sections 2.2 to 2.7, the Applicant has committed to a seasonal piling restriction that corresponds to the earliest start date from the scenarios above (6 November – Scenario A) and the latest end date from the scenarios above (1 January – Scenario D). This represents a pilling restriction period of 56 days.

2.9 HERRING MIGRATORY PATTERNS

2.9.1 The Downs herring stock migrates in a clockwise circuit in the North Sea, migrating from the northeast to the Downs spawning ground to the southeast, and then continuing in a northerly direction (Cushing, 2001). The migration circuit has been mapped alongside the herring larval hotspots (the closest piling activities to the herring larval hotspot) in Figure 7.1 of Appendix C.

2.9.2 VE lies within the migration pathway for herring, however, is positioned on the northeastern return leg of the herring migration pathway. Therefore, it is not considered that piling would have any impacts on herring migration to the spawning grounds. Notwithstanding this, the Applicant is confident it has implemented a sufficiently precautionary approach in defining the Downs stock herring spawning period to accommodate the migration of herring from the spawning grounds.

3 CONCLUSION

3.1.1 The Applicant is committed to the implementation of a seasonal restriction on piling at VE, to cover the “peak” period for the herring spawning within the Downs stock spawning ground. Following an interrogation of the IHLS data and the available literature to identify the key timings and durations for herring larval development, the back-calculations based on the IHLS survey dates and larval lengths at survey has been undertaken to provide a suitably precautionary definition of the “peak” spawning season which has been defined as the 6 November until 1 January.

3.1.2 It should be noted that significant conservatism has been applied to each of the factors used to determine the back- calculations for both the start and end dates for peak spawning. These include;

- The consideration of a four hatch sizes, from 5mm (the most conservative hatch size to determine the start date) to 11mm (the most conservative hatch size to determine the end date) as informed IHLS survey data;
- Additional conservatism was also applied through the inclusion of a 14 day egg development duration, a 7 day yolk absorption period and slower growth rate (0.34 mm d-1);
- Further conservatism was applied to the back-calculation through the use of the earliest survey start date and latest survey end dates across all four hatch sizes as a precautionary measure, extending the seasonal restriction period from 38 days to 56 days.

3.1.3 As such, with the implementation of conservatism to both the start and end dates it is considered that a the proposed dates encompass the greatest possible extent of the Downs spawning period.

3.1.4 The Applicant therefore concludes that the proposed seasonal pilling restriction will 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 on herring spawning. The Applicant considers that that a pilling restriction implemented from the 6th November until 1st January is an appropriate mitigation measure to avoid population impacts on herring.

4 REFERENCES

Ahlstrom, E.H. and O.P. Ball, 1954. Description of Eggs and Larvae of Jack Mackeral (Trachurus symmetricus) and Distribution and Abundance of Larvae in 1950 and 1951. U.S. Government Printing Office, USA., Pages: 3

Blaxter, J.H.S. & Hempel, G. 1963. The influence of egg size on herring larvae, Clupea harengus L. Journal du Conseil, 28, 211-240.

Bierman, S. M., Dickey-Collas, M., van Damme, C. J. G., van Overzee, H. M. J., Pennock-Vos, M. G., Tribuhl, S. V., and Clausen, L. A. W. 2010.Between-year variability in the mixing of North Sea herring spawning components leads to pronounced variation in the composition of the catch. – ICES Journal of Marine Science, 67: 885 –896

Boyle, G. & New, P. 2018. ORJIP Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options. Final report – June 2018. The Carbon Trust. United Kingdom. 247 pp.

Coull, K.A., Johnstone, R., & Rogers, S.I. 1998. Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

Cushing, D.H. 2001, in Encyclopaedia of Ocean Sciences (Second Edition). Herring: A Case Study of a Pelagic Fish

Das, N. 1972. Growth of larval herring (Clupea harengus L.) in the Bay of Fundy and Gulf of Maine area. Journal of the Fisheries Research Board of Canada, 29: 573-575.

Dickey-Collas, M. 2004. The current state of knowledge on the ecology and interactions of North Sea Herring within the North Sea ecosystem. WOT kennisbasis project 325122921.

Folkvord, A., Johannessen, A., & Moksness, E. 2004. Temperature-dependent otolith growth in Norwegian spring spawning herring (Clupea harengus L.) larvae. Sarsia, 89: 297-310.

Fox, C.J., Folkvord, A., & Geffen, A.J. 2003. Otolith micro-increment formation in herring Clupea harengus larvae in relation to growth rate. Marine Ecology Progress Series, 264: 83-94.

Gamble, J.C., MacLachlan, P., & Seaton, D.D. 1985. Comparative growth and development of autumn and spring spawned Atlantic herring larvae reared in large enclosed ecosystems. Marine Ecology Progress Series, 26: 19-33.

Geffen, A.J. 2002. Length of herring larvae in relation to age and time of hatching. Journal of Fish Biology, 60: 479-485.

Heath, M. 1993. An evaluation and review of the ICES herring larval surveys in the North Sea and adjacent waters. Bulletin of Marine Science, 52: 795-817.

Houde, E.D. 1997. Patterns and consequences of selective processes in teleost early life histories. In Early Life History and Recruitment in Fish Populations, pp. 173-196. Ed. by R. C. Chambers, and E. A. Trippel. Chapman and Hall, London. 596 pp.

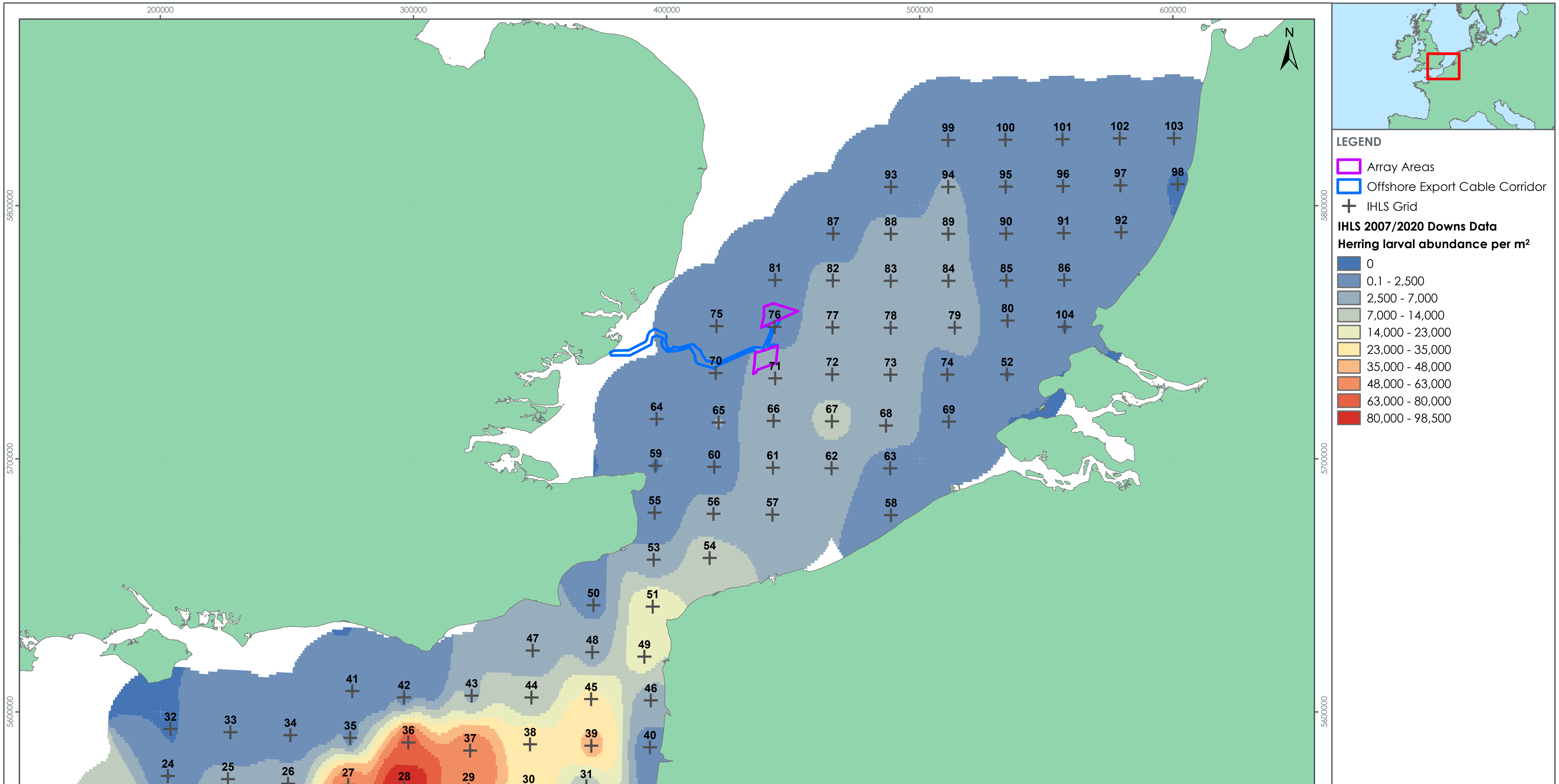
Hufnagl, M. & Peck, M.A. 2011. Physiological individual-based modelling of larval Atlantic herring (Clupea harengus) foraging and growth: insights on climate-driven life-history scheduling. ICES Journal of Marine Science, 68: 1170-1188.

Kiorboe, T., Munk, P., & Stottrup, J.G. 1985. First feeding by larval herring Clupea harengus L.. Dana, 5: 95-107.

Oeberst, R., Dickey-Collas, M., & Nash, R.D.M. 2009. Mean daily growth rate of herring larvae in relation to temperature over a range of 5 - 20°C, based on weekly repeated cruises in the Greifswalder Bodden. ICES Journal of Marine Science, 66: 1696-1701.

Russell, F.S. 1976. The eggs and planktonic stages of British marine fishes. Academic Press, London. 482pp.

5 APPENDIX A: IHLS SURVEY DATA STATIONS



Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

IHLS Survey Data Stations (2007-2020)

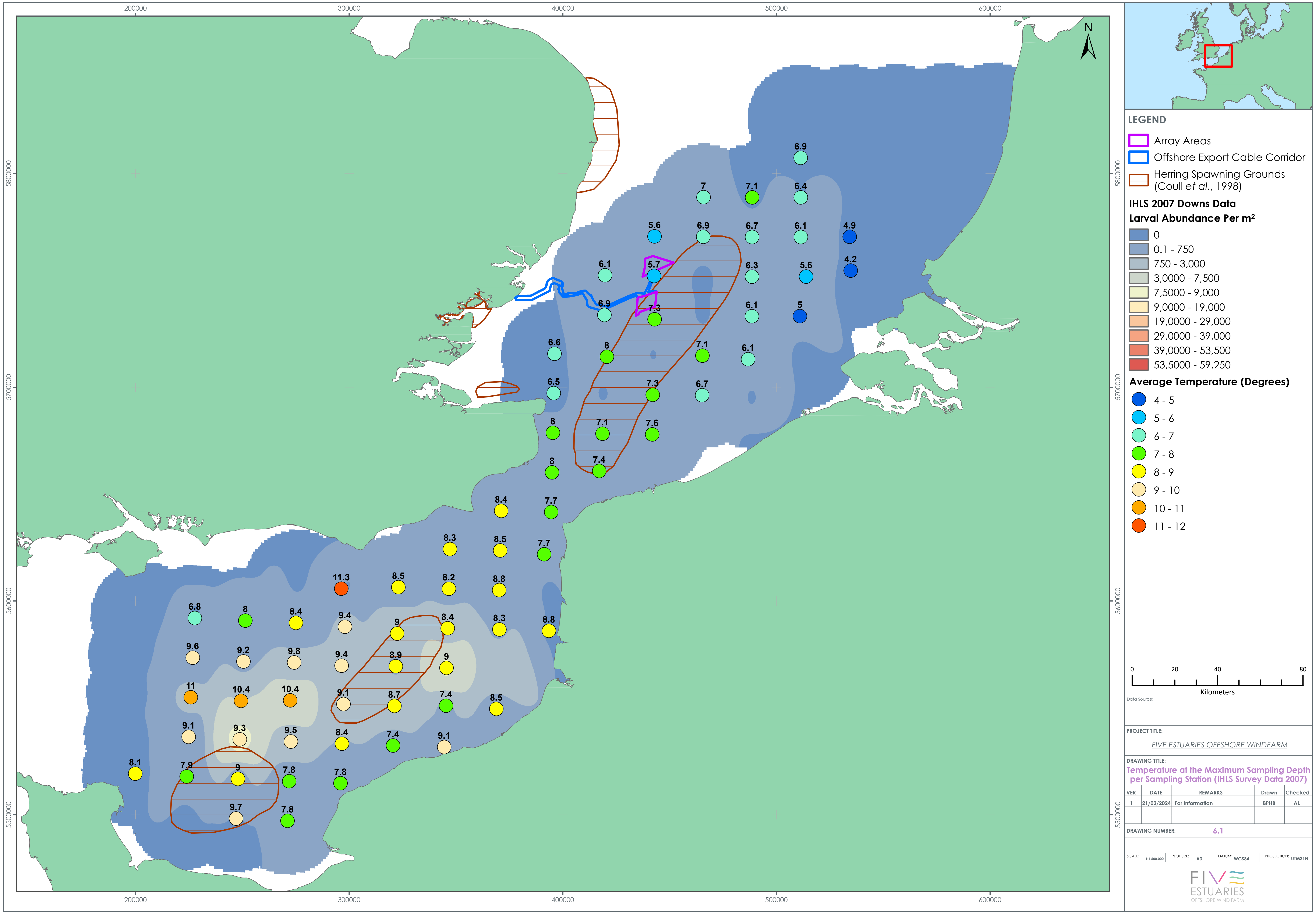
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

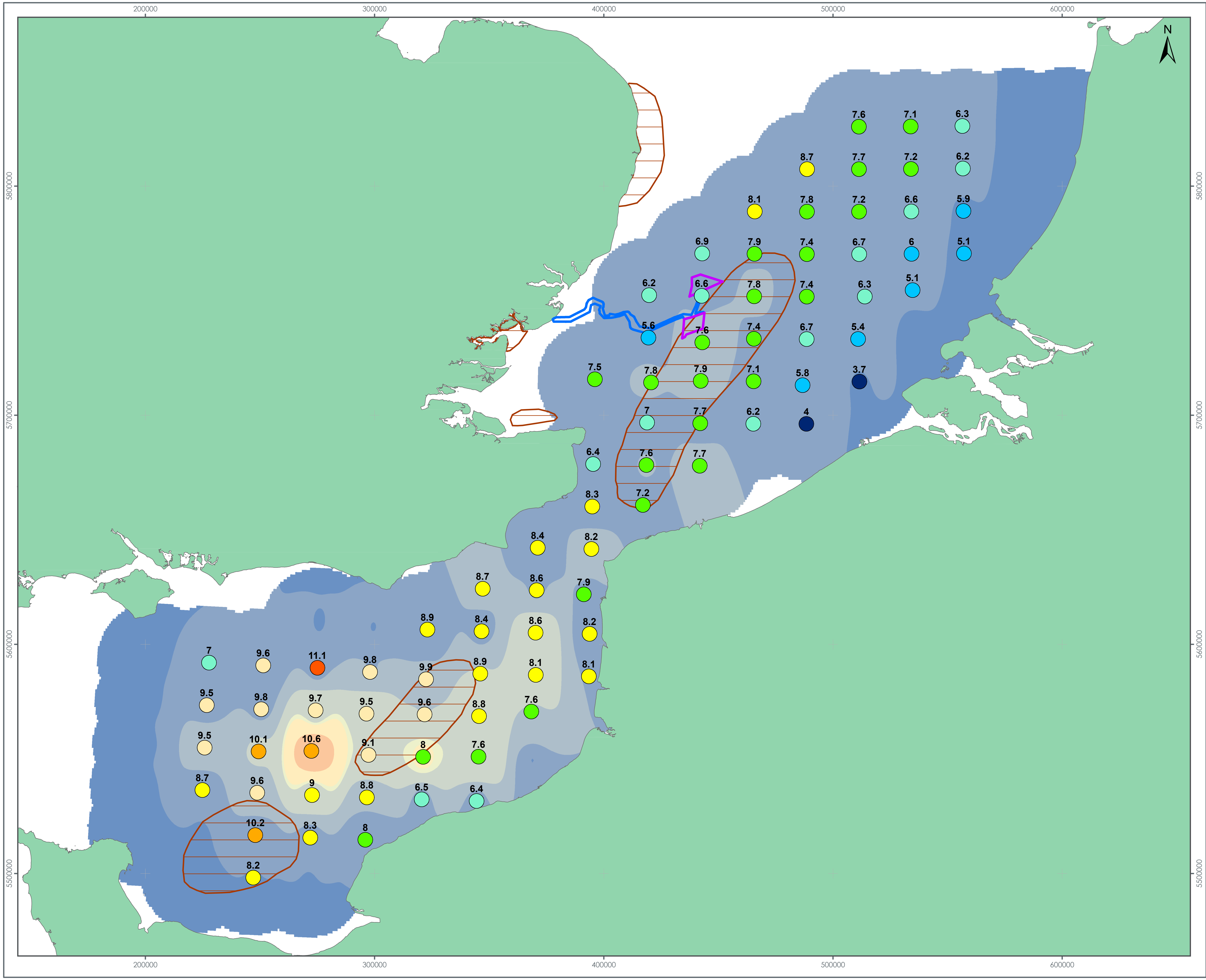
DRAWING NUMBER: 5.1

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

6 APPENDIX B: MAXIMUM SAMPLING DEPTH TEMPERATURE


LEGEND
Array Areas
Offshore Export Cable Corridor
Herring Spawning Grounds (Coull et al., 1998)
IHLS 2007 Downs Data
Larval Abundance Per m²
0
0.1 - 750
750 - 3,000
3,0000 - 7,500
7,5000 - 9,000
9,0000 - 19,000
19,0000 - 29,000
29,0000 - 39,000
39,0000 - 53,500
53,5000 - 59,250
Average Temperature (Degrees)
4 - 5
5 - 6
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
N
0 20 40 80
Kilometers
Data Source:
PROJECT TITLE:
FIVE ESTUARIES OFFSHORE WINDFARM
DRAWING TITLE:
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2007)
VER DATE REMARKS Drawn Checked
1 21/02/2024 For Information BPHB AL
DRAWING NUMBER: 6.1
SCALE: 1:1,500,000
PLOT SIZE: A3
DATUM: WGS84
PROJECTION: UTM31N
FIVE ESTUARIES
OFFSHORE WIND FARM



LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2008 Downs Data

Larval Abundance Per m²

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 3 - 4
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12

0 20 40 80
Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

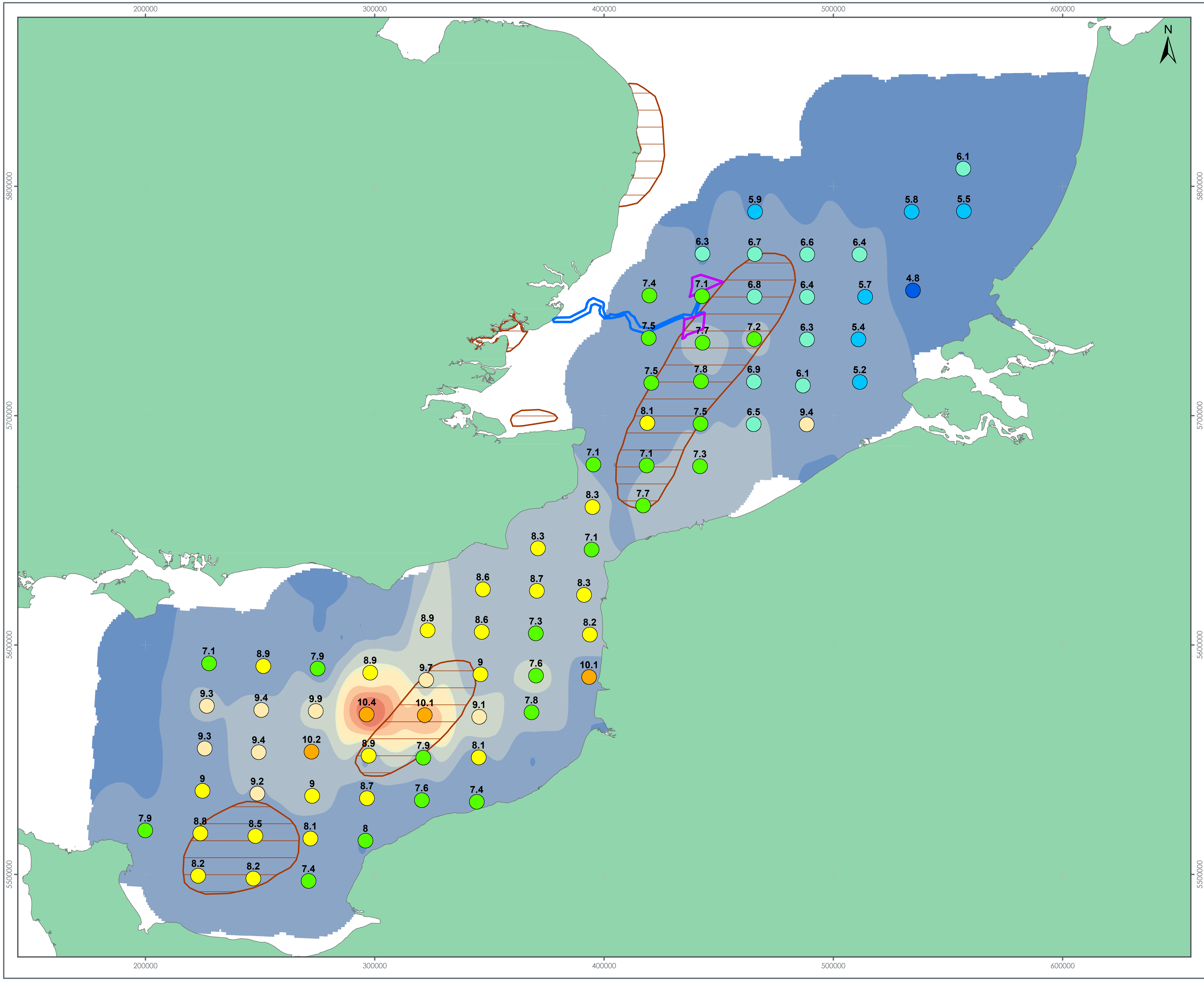
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2008)

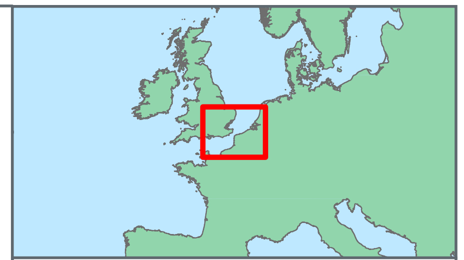
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.2

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2009 Downs Data

Larval Abundance Per m²

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11

0 20 40 80

Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

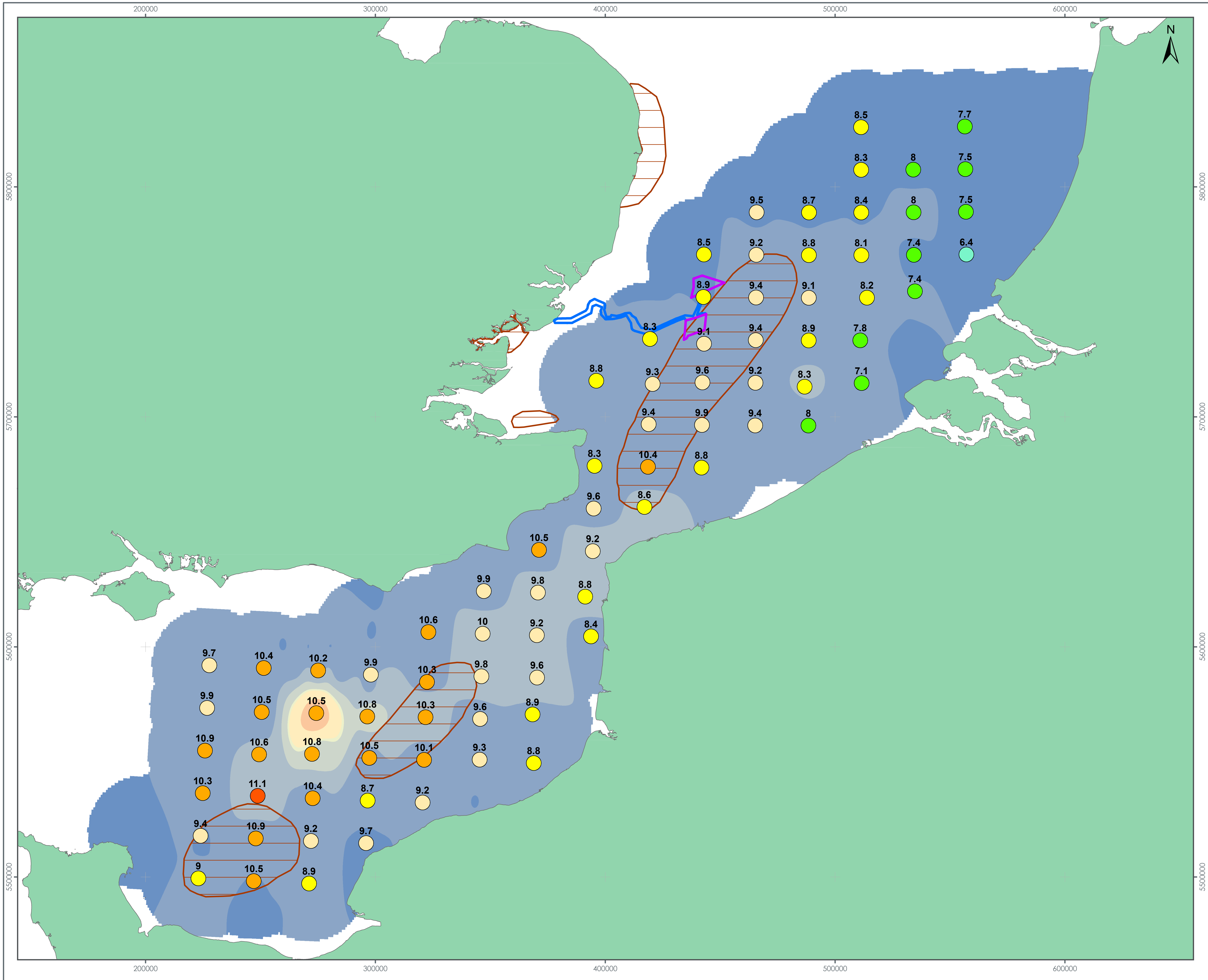
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2009)

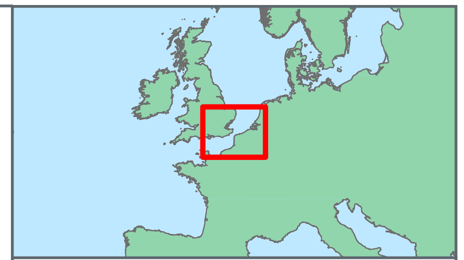
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.3

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2010 Downs Data

Larval Abundance Per m²

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12

0 20 40 80

Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

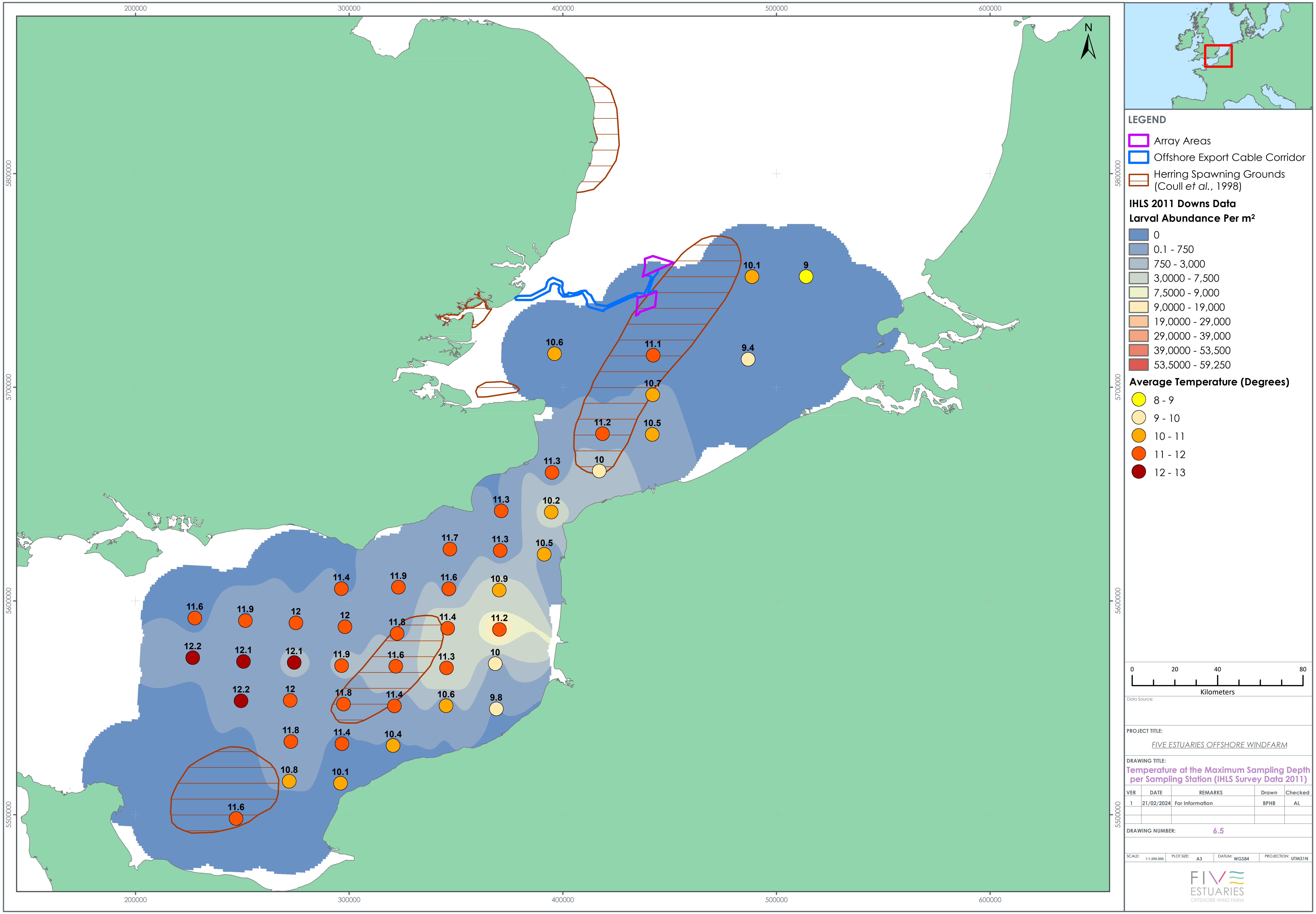
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2010)

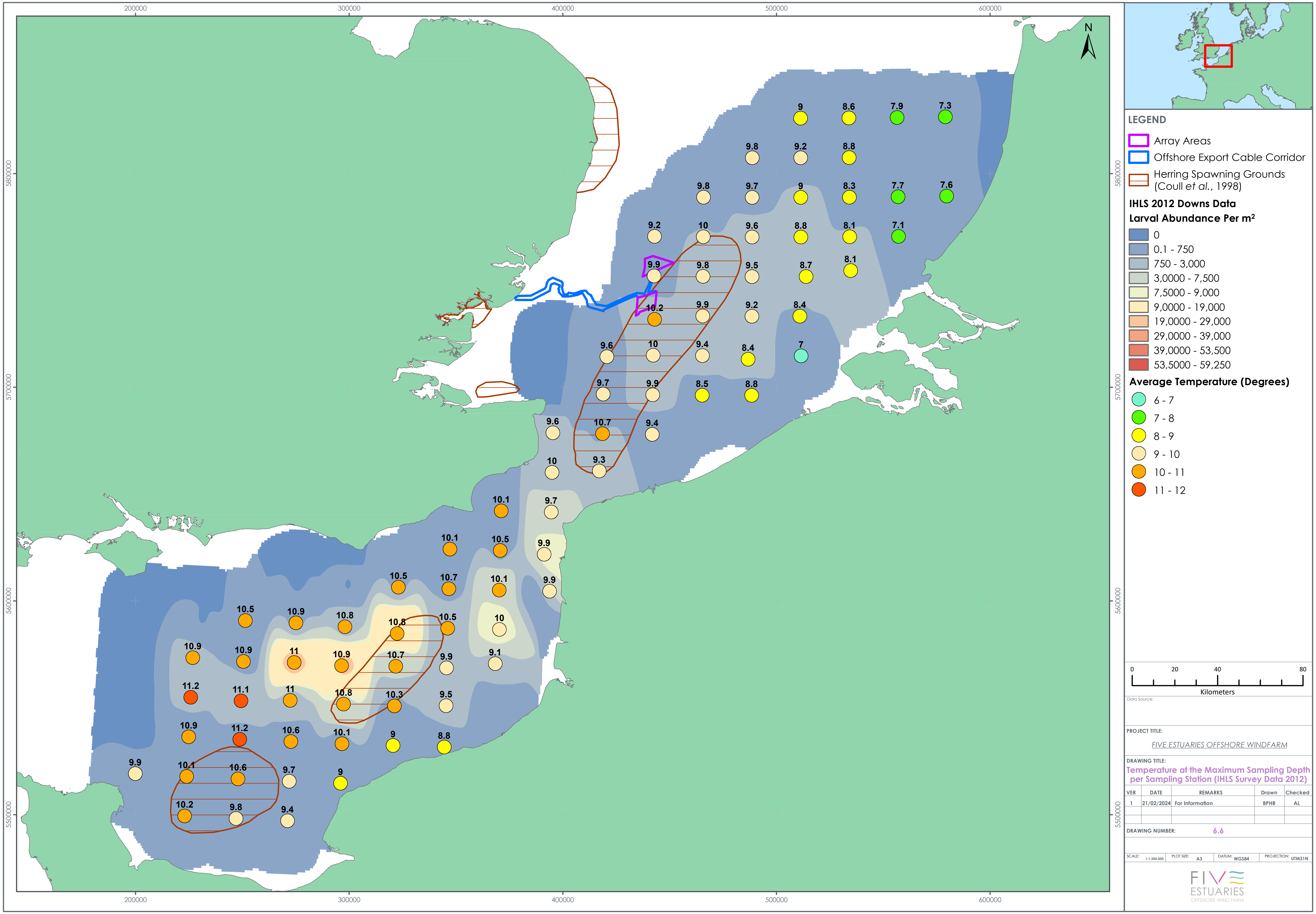
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.4

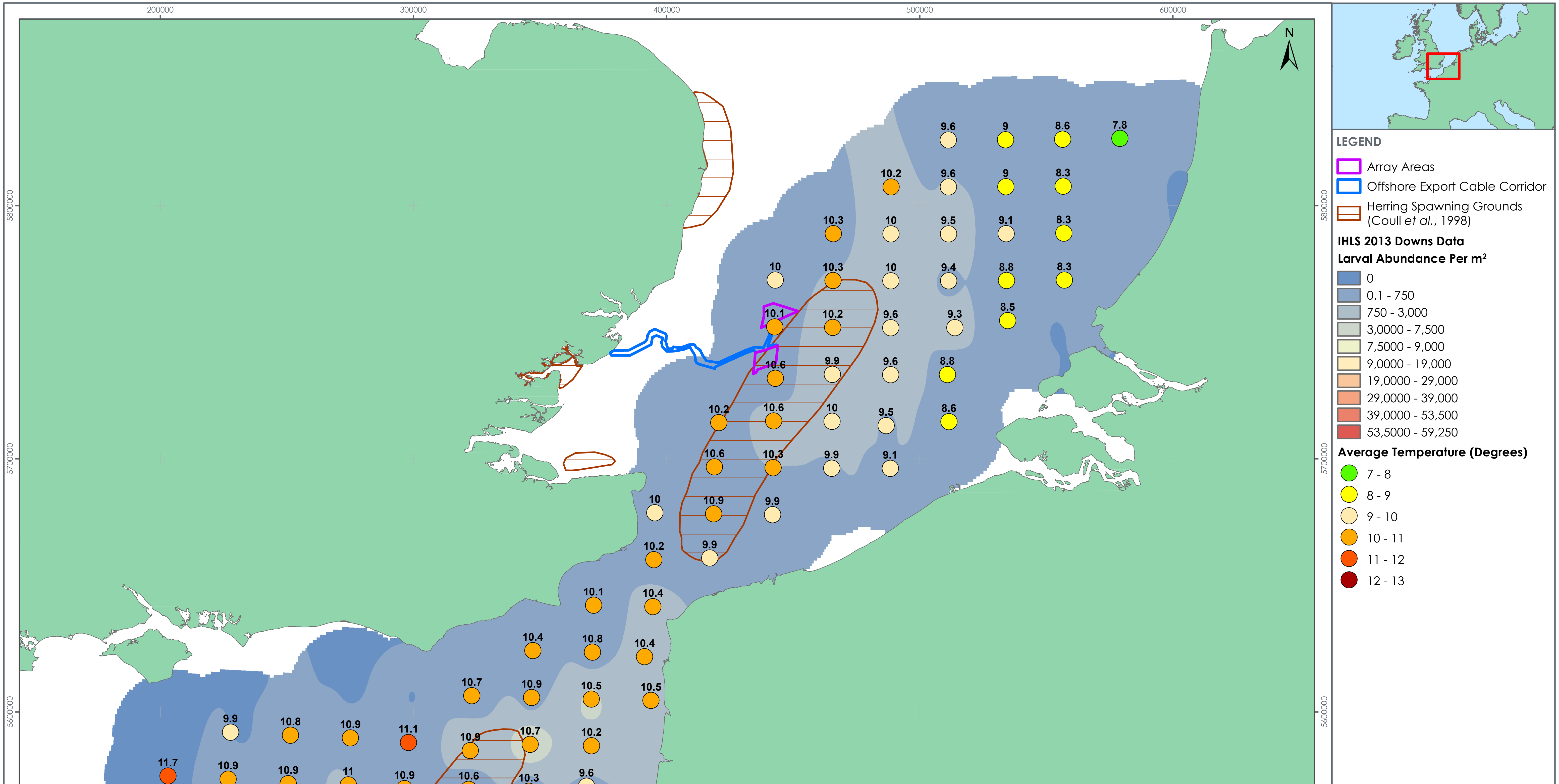
SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM


LEGEND
Array Areas
Offshore Export Cable Corridor
Herring Spawning Grounds (Coull et al., 1998)
IHLS 2011 Downs Data
Larval Abundance Per m²
0
0.1 - 750
750 - 3,000
3,0000 - 7,500
7,5000 - 9,000
9,0000 - 19,000
19,0000 - 29,000
29,0000 - 39,000
39,0000 - 53,500
53,5000 - 59,250
Average Temperature (Degrees)
8 - 9
9 - 10
10 - 11
11 - 12
12 - 13
N
10.1
9
10.6
11.1
9.4
10.7
11.2
10.5
11.3
10
11.3
10.2
11.7
11.3
10.5
11.4
11.9
11.6
10.9
11.6
11.9
12
12
11.8
11.4
11.2
12.2
12.1
12.1
11.9
11.6
11.3
10
12.2
12
11.8
11.4
10.6
9.8
11.8
11.4
10.4
10.8
10.1
11.6
200000
300000
400000
500000
600000
5800000
5700000
5600000
5500000
0
20
40
80
Kilometers
Data Source:
PROJECT TITLE:
FIVE ESTUARIES OFFSHORE WINDFARM
DRAWING TITLE:
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2011)
VER | DATE | REMARKS | Drawn | Checked
1 | 21/02/2024 | For Information | BPHB | AL
DRAWING NUMBER: 6.5
SCALE: 1:1,500,000
PLOT SIZE: A3
DATUM: WGS84
PROJECTION: UTM31N



LEGEND
Array Areas
Offshore Export Cable Corridor
Herring Spawning Grounds (Coull et al., 1998)
IHLS 2012 Downs Data
Larval Abundance Per m²
0
0.1 - 750
750 - 3,000
3,0000 - 7,500
7,5000 - 9,000
9,0000 - 19,000
19,0000 - 29,000
29,0000 - 39,000
39,0000 - 53,500
53,5000 - 59,250
Average Temperature (Degrees)
6 - 7
7 - 8
8 - 9
9 - 10
10 - 11
11 - 12
0 20 40 80
Kilometers
Data Source:
PROJECT TITLE:
FIVE ESTUARIES OFFSHORE WINDFARM
DRAWING TITLE:
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2012)
VER DATE REMARKS Drawn Checked
1 21/02/2024 For Information BPHB AL
DRAWING NUMBER: 6.6
SCALE: 1:1,500,000 PLOT SIZE: A3 DATUM: WGS84 PROJECTION: UTM31N
FIVE ESTUARIES OFFSHORE WIND FARM



Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

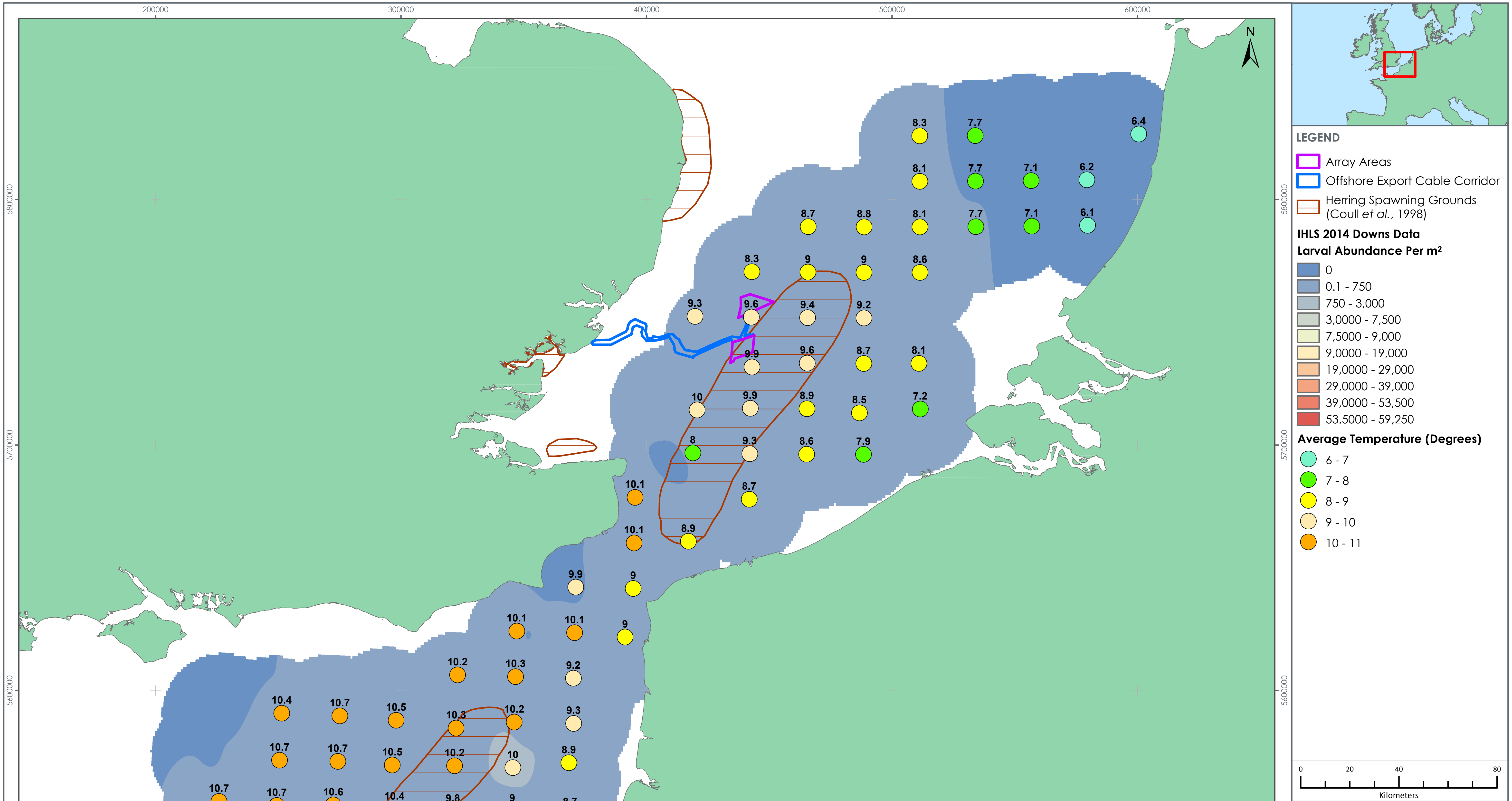
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2013)

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.7

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM



Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

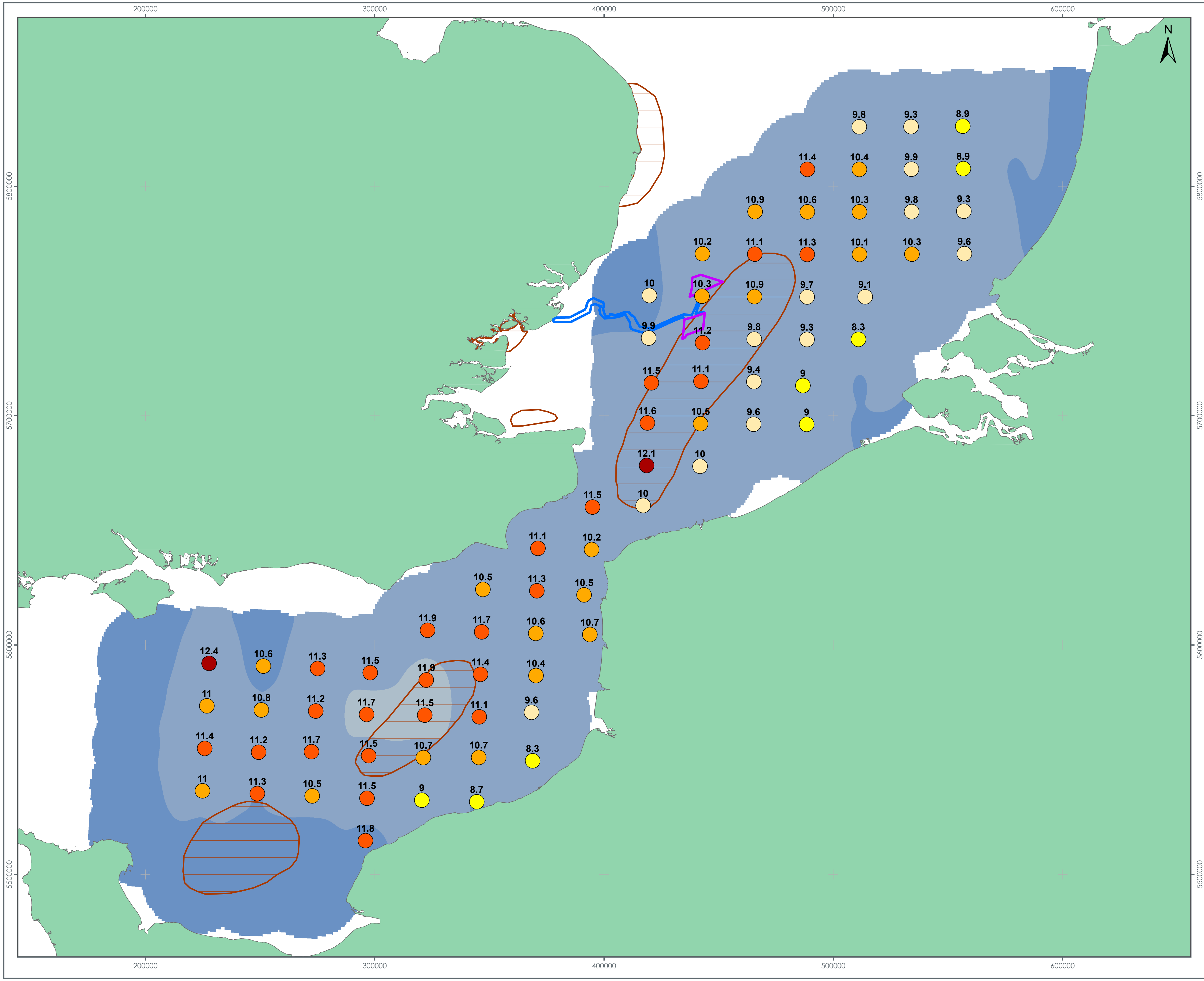
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2014)

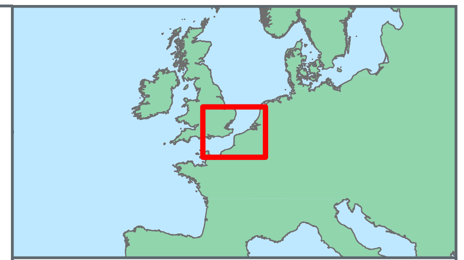
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.8

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2015 Downs Data
Larval Abundance Per m²

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12
- 12 - 13

0 20 40 80
Kilometers

Data Source:

PROJECT TITLE:
FIVE ESTUARIES OFFSHORE WINDFARM

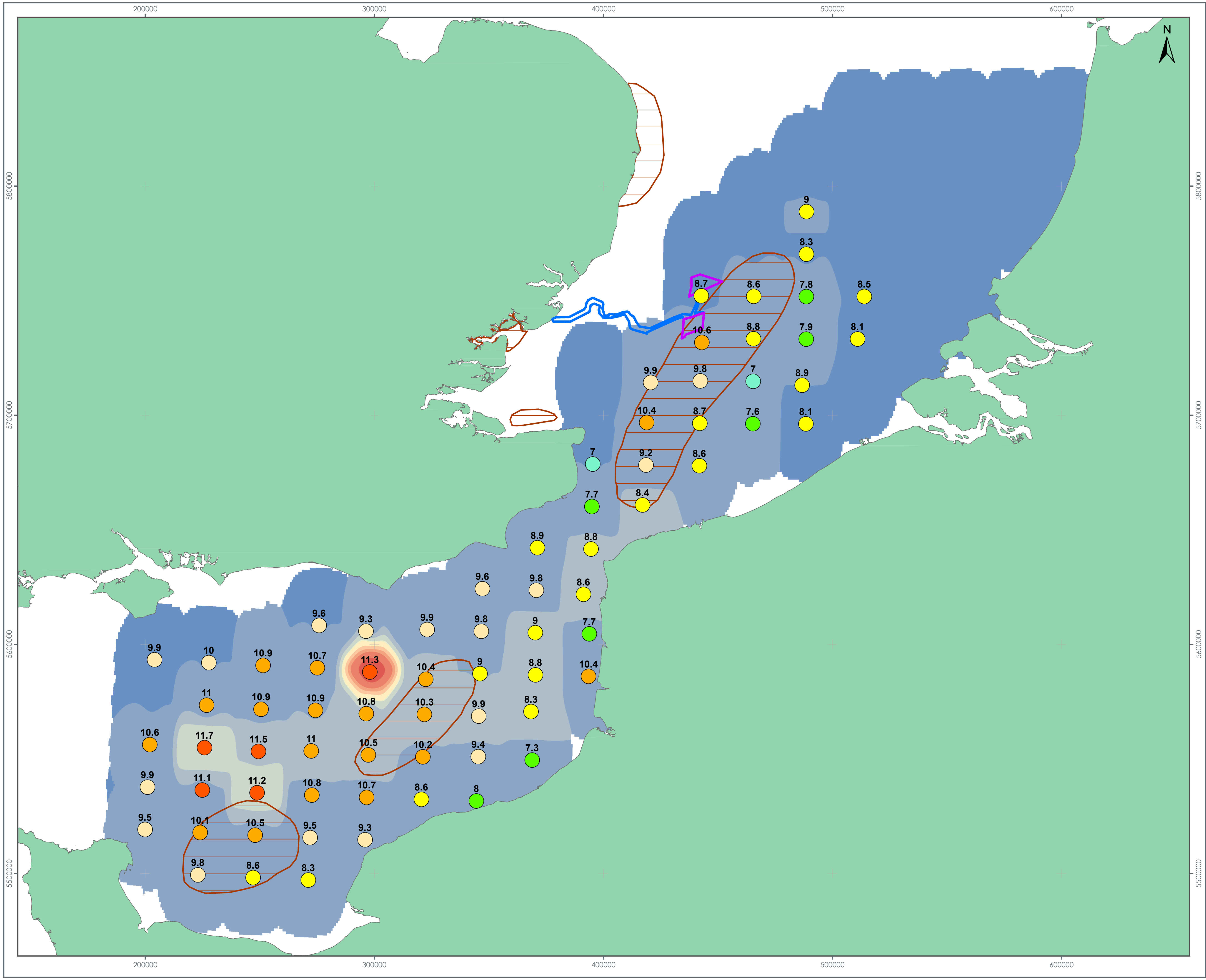
DRAWING TITLE:
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2015)

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.9

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM



LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2016 Downs Data

Larval Abundance Per m^2

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12

0 20 40 80

Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

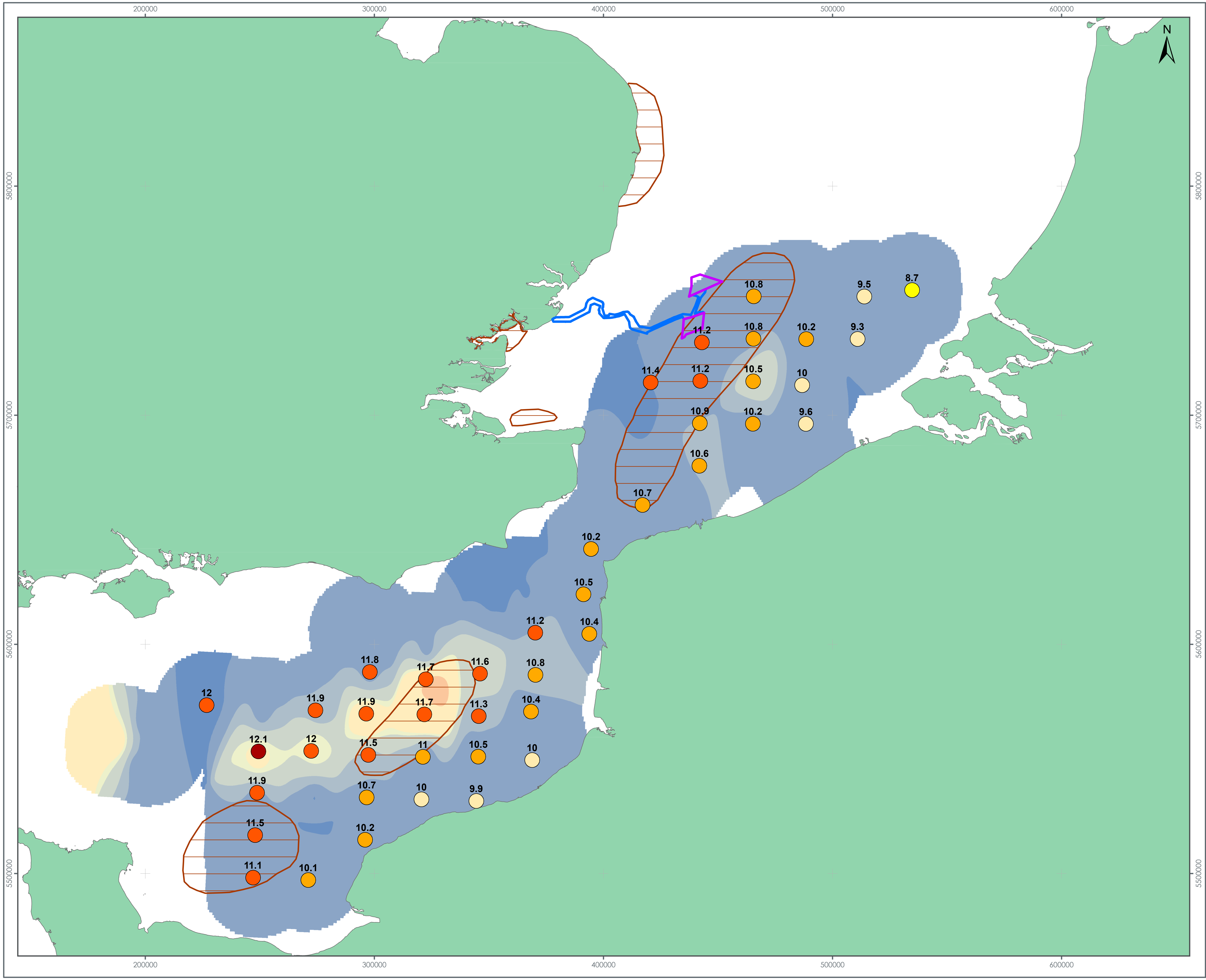
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2016)

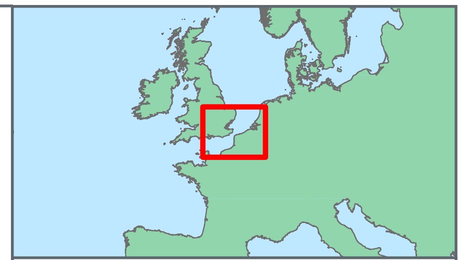
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.10

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2019 Downs Data

Larval Abundance Per m²

- 0
- 0.1 - 750
- 750 - 3,000
- 3,0000 - 7,500
- 7,5000 - 9,000
- 9,0000 - 19,000
- 19,0000 - 29,000
- 29,0000 - 39,000
- 39,0000 - 53,500
- 53,5000 - 59,250

Average Temperature (Degrees)

- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12
- 12 - 13

0 20 40 80

Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

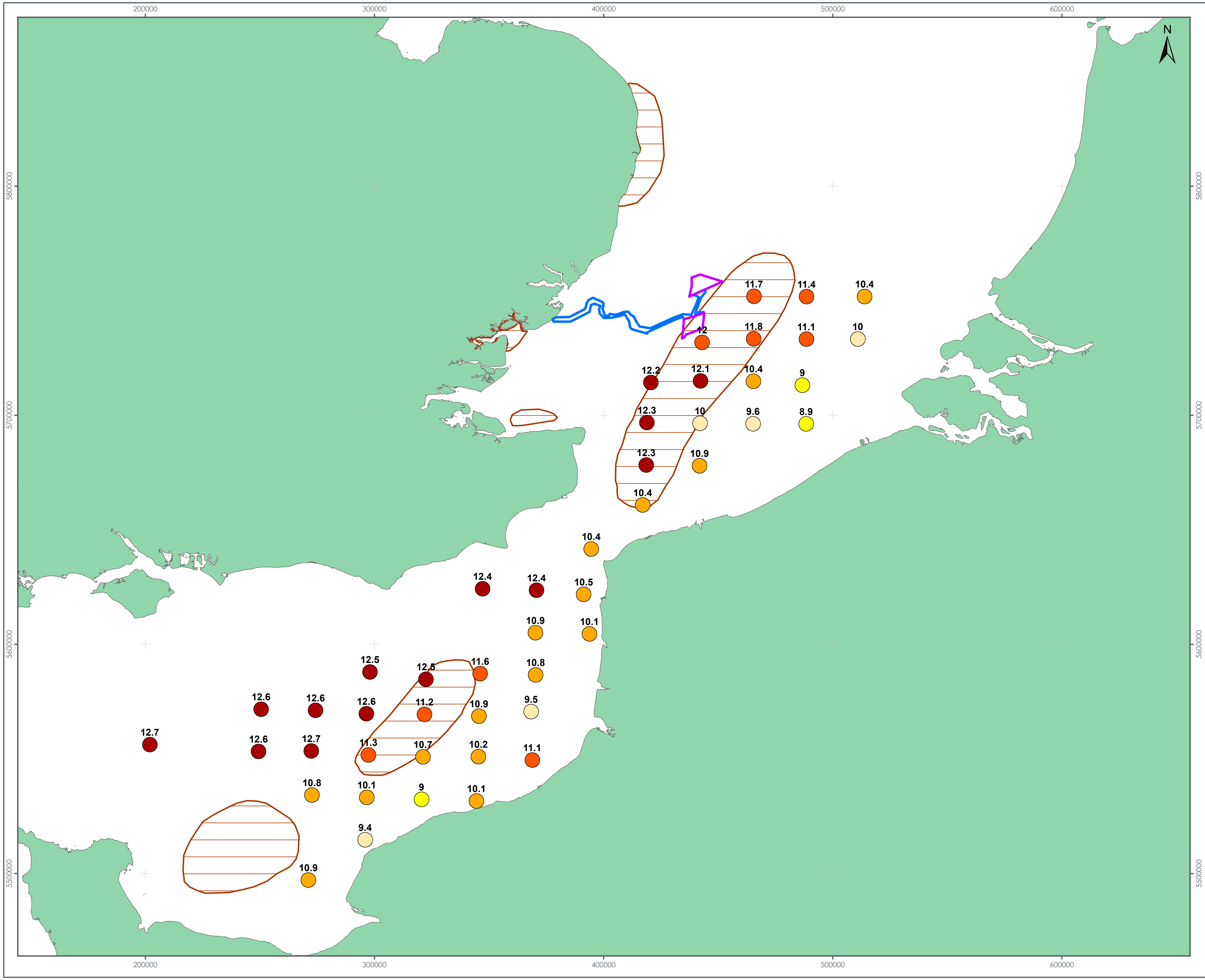
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2019)

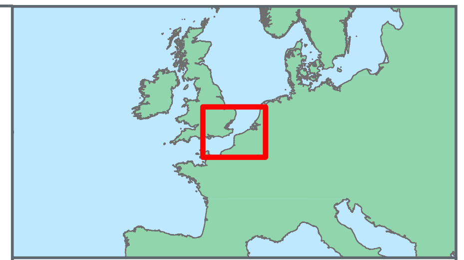
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.11

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

Average Temperature (Degrees)

- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12
- 12 - 13

0 20 40 80
Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

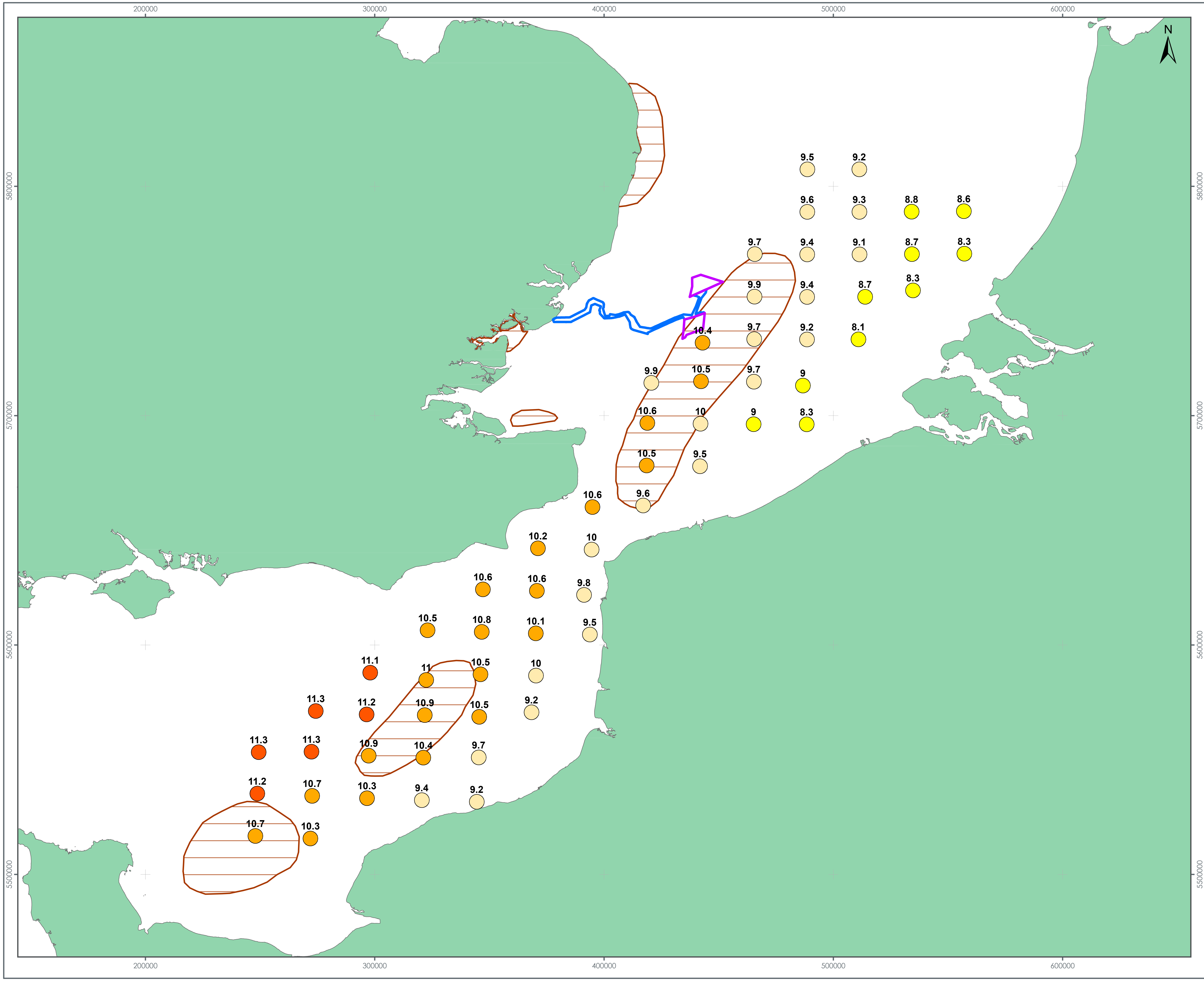
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2020)

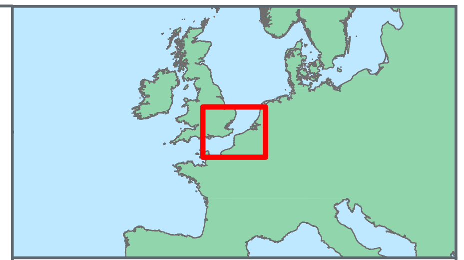
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.12

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM





LEGEND

- Array Areas
- Offshore Export Cable Corridor
- Herring Spawning Grounds (Coull *et al.*, 1998)

Average Temperature (Degrees)

- 8 - 9
- 9 - 10
- 10 - 11
- 11 - 12

0 20 40 80
Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

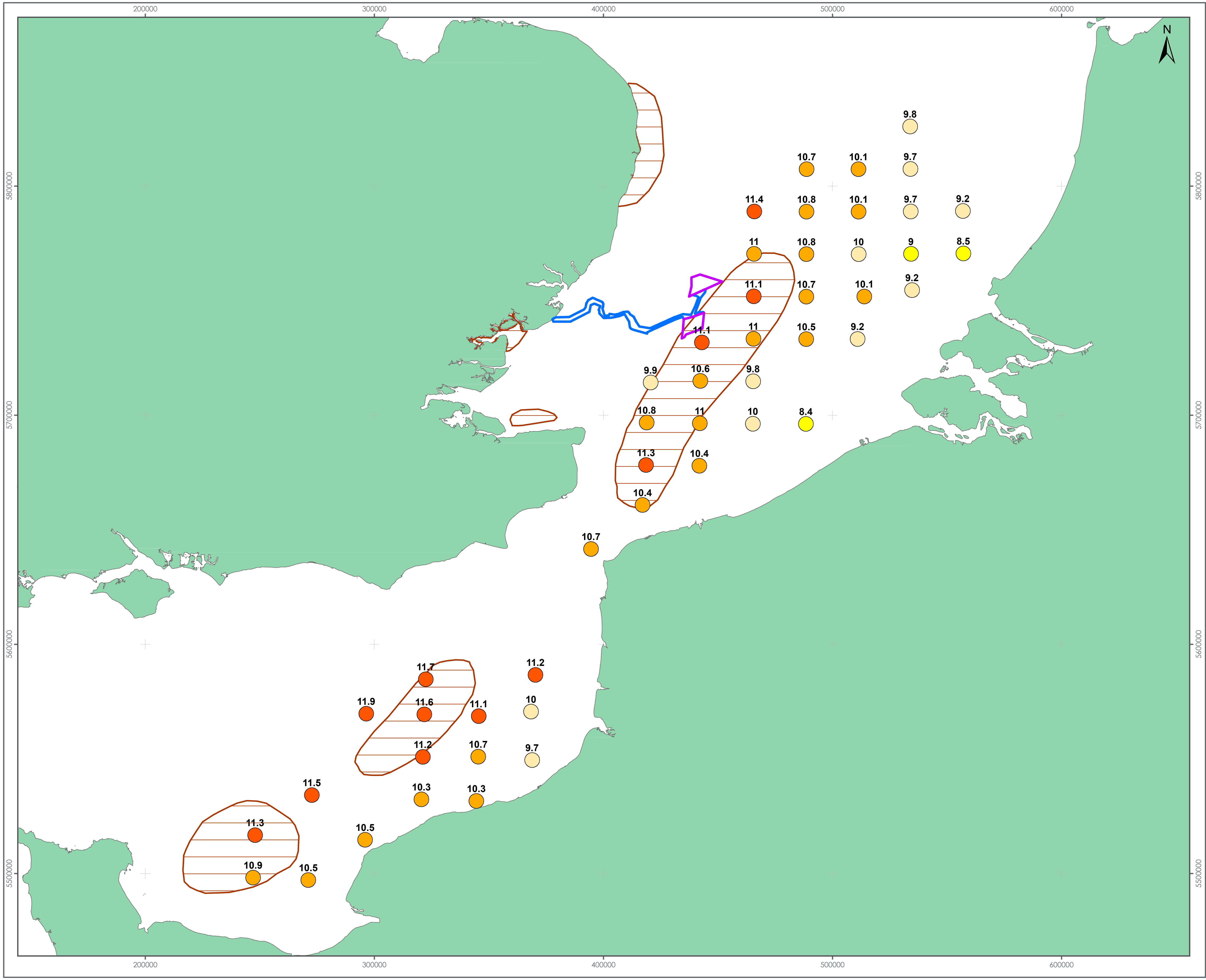
Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2021)

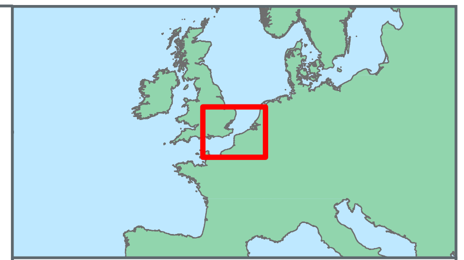
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.13

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM





Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Temperature at the Maximum Sampling Depth per Sampling Station (IHLS Survey Data 2022)

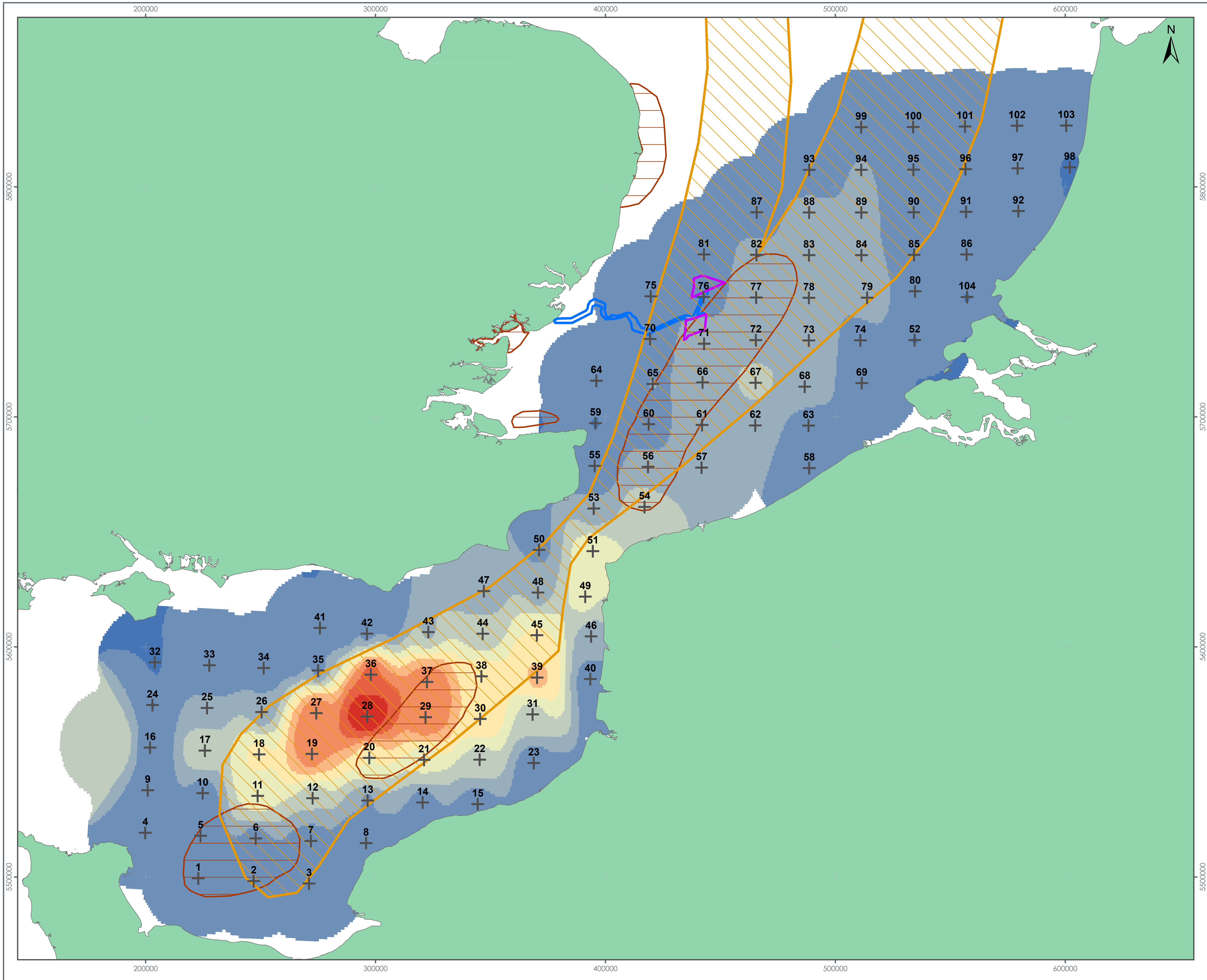
VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 6.14

SCALE: 1:1,500,000 | PLOT SIZE: A3 | DATUM: WGS84 | PROJECTION: UTM31N

FIVE ESTUARIES OFFSHORE WIND FARM

7 APPENDIX C: MIGRATION CIRCUIT OF THE DOWNS HERRING STOCK IN THE NORTH SEA



LEGEND

- Array Areas
- Offshore Export Cable Corridor
- IHLS Grid
- Downs Herring Migration Circuit (Cushing, 2001)
- Herring Spawning Grounds (Coull *et al.*, 1998)

IHLS 2007/2020 Downs Data
Herring larval abundance per m²

- 0
- 0.1 - 2,500
- 2,500 - 7,000
- 7,000 - 14,000
- 14,000 - 23,000
- 23,000 - 35,000
- 35,000 - 48,000
- 48,000 - 63,000
- 63,000 - 80,000
- 80,000 - 98,500

0 20 40 80
Kilometers

Data Source:

PROJECT TITLE:

FIVE ESTUARIES OFFSHORE WINDFARM

DRAWING TITLE:

Migration Circuit of the Downs Herring Stock in the North Sea

VER	DATE	REMARKS	Drawn	Checked
1	21/02/2024	For Information	BPHB	AL

DRAWING NUMBER: 7.1

SCALE: 1:1,500,000	PLOT SIZE: A3	DATUM: WGS84	PROJECTION: UTM31N

FIVE ESTUARIES
OFFSHORE WIND FARM