FIVE ESTUARIES OFFSHORE WIND FARM

ENVIRONMENTAL STATEMENT

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

Application Reference	EN010115
Application Document Number	6.5.6.4
Revision	B
Pursuant to	Deadline 1
Ecodoc Number	005076725-02
Date	October 2024

In preparation of this document Five Estuaries Wind Farm Ltd has made reasonable efforts to ensure that the content is accurate, up to date and complete for purpose.

Revision	Date	Status/Reason for Issue	Originator	Checked	Approved
B	Oct-2024	Deadline 1	GoBe	GoBe	VE OWFL

CONTENTS

TABLES

FIGURES

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. This note was submitted as part of the DCO Application, in March 2024. The note has subsequently been updated and submitted to the Planning Inspectorate, at Deadline 1, following a request made by the MMO in their Relevant Representations. In addition to updates to the note, Appendix D (Section 8) has also been -added. This was primarily in response to comments from the MMO within their relevant representations which requested updates to a number of the Herring and Sandeel habitat suitability figures.

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 (Figure 1-1). 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.

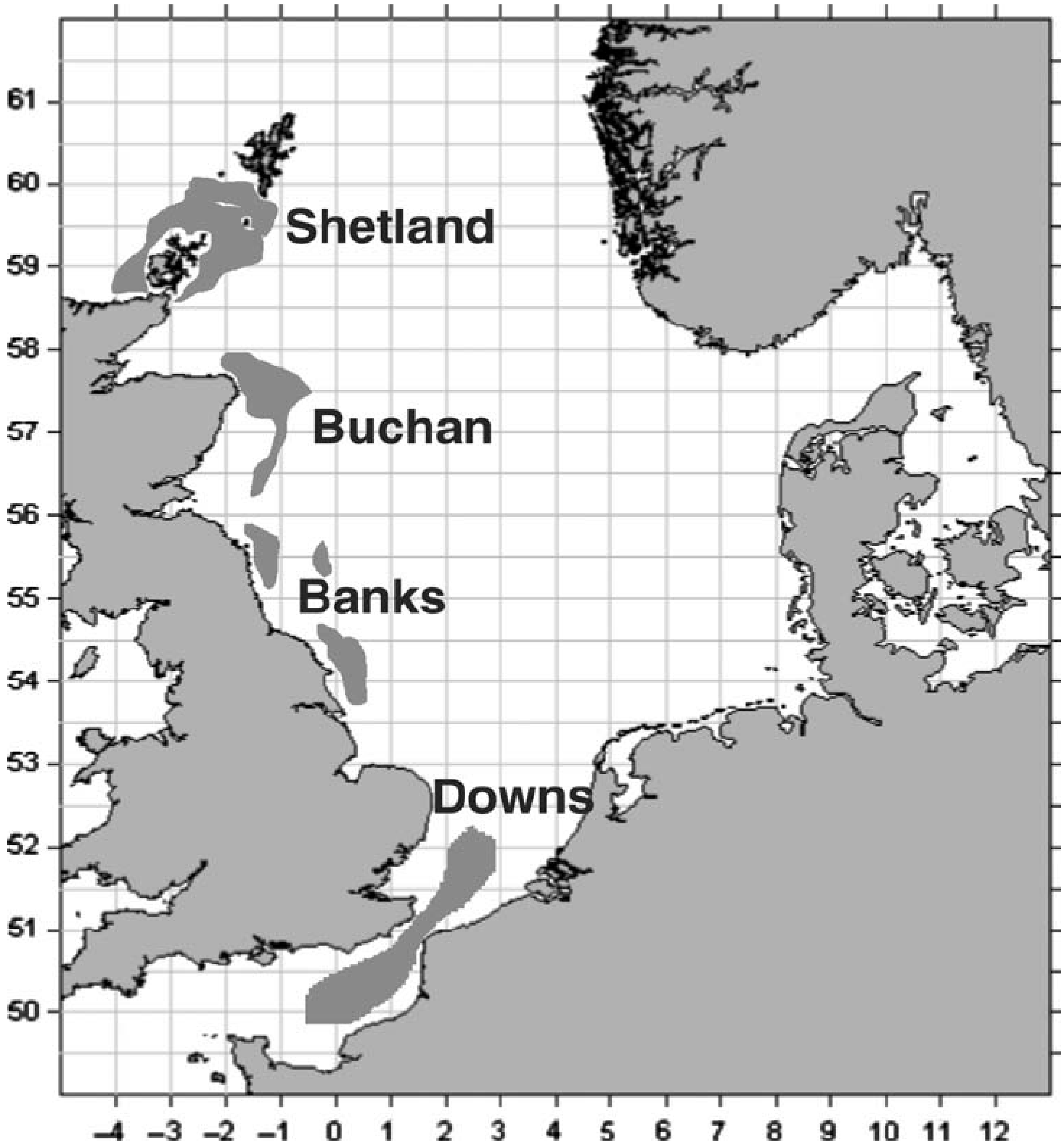

Figure 1-1: Herring spawning grounds within the North Sea (Beirman *et al*., 2010).

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.

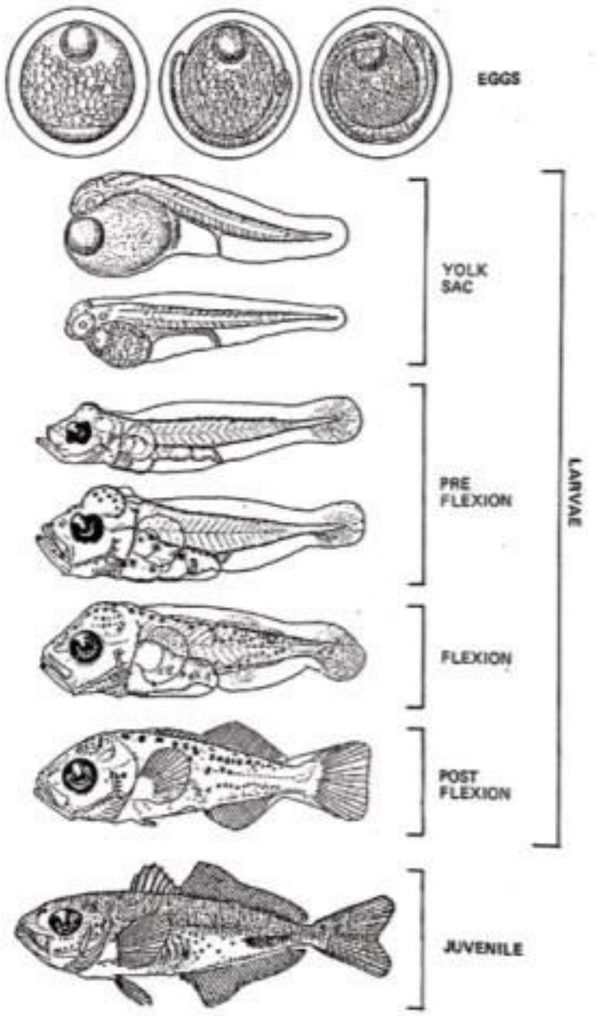

Figure 1-2-2: Bony fish developmental stages (from Kendall *et al.*, 1984).

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. 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.

2.1.3 Since the submission of this note in the ES, the Applicant has been made aware of a suitable way to extrapolate and interpret these data without this information, and the heatmaps have been updated accordingly, see 10.15 Revised International Herring Larval Survey Heat Map Figures[1]. Further, the Applicant has also incorporated the most recent publicly available IHLS data into the back calculations and heatmaps (up to the 2023/2024 Downs stock spawning season).

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.

[1] Note, the IHLS heatmaps submitted within 6.2.6 Fish and Shellfish Ecology [APP-075], 6.5.6.1 Fish and Shellfish Ecology Technical Baseline Report [APP-121] and 6.5.6.3 Spawning Herring Heatmaps - International Herring Larval Survey Data [APP-124] have subsequently ~~also~~ been updated and submitted to the Planning Inspectorate at Deadline 1 – see 10.15 Revised International Herring Larval Survey Heat Map Figures.

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

2.2 IHLS SURVEY TIMINGS

2.2.1 The Southern North Sea Downs stock IHLS surveys were conducted as three different sampling events. These consisted of the following surveys:

> Surveys undertaken by the Netherlands in the 4th quarter of each year (2012-2024);

> Surveys undertaken by Germany in the 1st quarter of each year (2012-2024); and

> Surveys undertaken by the Netherlands in the 1st quarter of each year ((2012-2018) (from 2018 onwards, these surveys were discontinued)).

2.2.2 The survey start and end dates of each of these separate sampling events are provided in Table 2-1 below. It should be noted that in 2018, IHLS surveys were undertaken for the Shetland stock only~~)~~, therefore the IHLS data for 2018 are not applicable for use within the back-calculations for the Downs herring stock. These years have therefore been omitted from Table 2-1.

2.2.3 On recommendation of the MMO, to take into account the discrete nature of the sampling events undertaken in the different survey periods, these data have been considered separately within this note, to allow for better interrogation of the data. The survey start and end dates are therefore presented relative to the individual survey events in Table 2-1 below.

2.2.4 Whilst the individual survey start dates for the annual IHLS across the separate sampling events are broadly similar year to year, there are small interannual variations in the timings of the sampling events in the survey periods~~surveys within the region~~. Therefore, by using the earliest survey start dates, and latest survey end dates within each survey period, ~~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 (from the December sampling events undertaken by the Netherlands) and latest survey end dates (from the January sampling events, undertaken by the Netherlands)~~ 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~~surveys, the earliest survey start date and latest survey end dates for the different survey periods are as follows:

> Surveys undertaken by the Netherlands in the 4th quarter of each year (11th December – 23rd December);

> Surveys undertaken by Germany in the 1st quarter of each year (3rd January – 16th January); and

— Surveys undertaken by the Netherlands in the 1st quarter of each year (14th January – 24th January).

> ~~is the 14 December, and the latest end date is the 24 January.~~

Table 2-1~~2.1~~: Range of survey dates.

Survey Year	Survey Country	IHLS Survey Start Date	IHLS Survey Start Date
2012/2013	Netherlands	17th December 2012	20th December 2012
	Netherlands	14th January 2013	18th January 2013
	Germany	3rd January 2013	6th January 2013
2013/2014	Netherlands	16th December 2013	19th December 2013
	Netherlands	20th January 2014	24th January 2014
	Germany	8th January 2014	11th January 2014
2014/2015	Netherlands	19th January 2015	23rd January 2015
2015/2016	Netherlands	14th December 2015	17th December 2015
	Netherlands	18th January 2016	22nd January 2016
	Germany	11th January 2016	16th January 2016
2016/2017	Netherlands	19th December 2016	22nd December 2016
	Netherlands	16th January 2017	20th January 2017
	Germany	8th January 2017	15th January 2017
2019/2020	Netherlands	16th December 2019	20th December 2019
2020/2021	Netherlands	14th December 2020	17th December 2020
	Germany	6th January 2021	9th January 2021
2021/2022	Netherlands	20th December 2021	23rd December 2021
	Germany	8th January 2022	11th January 2022
2022/2023	Netherlands	19th December 2022	23rd December 2022
	Germany	9th January 2023	11th January 2023
2023/2024	Netherlands	18th December 2023	21st December 2023

2.2.5 The larval densities of their respective survey periods have been plotted relative to the Proposed Development in Figure 2.1 to Figure 2.3 below. As evident, although of low intensity (relative to the broadscale spawning of the Downs stock), herring spawning of the Downs stock herring appears to occur later in the season, with larval densities of up to 3,500 larvae per m^2 recorded in the January surveys alone. As apparent in Figure 2.1, any Downs stock larvae recorded in the December surveys, are present within the English Channel and Dover Strait. Taking this into consideration, the data collected as part of the December surveys are therefore not considered further in this note and are discounted from the back calculations.

2.2.6 Considering the discrete nature of the January surveys, separate back calculation scenarios will be undertaken using the earliest start and latest end dates from the respective surveys. As stated above these are the following:

- Surveys undertaken by Germany (3rd January – 16th January); and
- Surveys undertaken by the Netherlands (14th January – 24th January).

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 January survey sample from 2012 to 202407-2022. 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

2.3.2 95.68% of larvae recorded in surveys undertaken by Germany in the 1st quarter of each year in the Southern North Sea, from 2012 to 2024 were equal to or less than 11 mm in length, ranging from 88.38% in the 2020/2021 season, to 97.42% in the 2012/2013 season, with an average larval size of 10.34 mm (2012/2013-2023/2024). The larval sizes from 2012/2013 to 2023/2024 are presented relative to their densities in Figure 2.2.

2.3.3 80.52% of larvae recorded in surveys undertaken by the Netherlands in the 1st quarter of each year in the Southern North Sea, from 2012 to 2017 were equal to or less than 11 mm in length, ranging from 70.84% in the 2015/2016 season, to 91.36% in the 2014/2015 season, with an average larval size of 11.18 mm (2012/2013-2017/2018). The larval sizes from 2012/2013-2017/2018 are presented relative to their densities in Figure 2.3.

2.3.1 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~~2.3.4 As highlighted above, the majority of larvae caught in the January surveys undertaken by Germany and the Netherlands are less than or equal to 11 mm in length. It is on this basis, that a catch length of 11 mm is considered ~~On the basis that the majority of all larvae are consequently smaller than this selected size, 11 mm is considered~~ an appropriate larval catch 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.

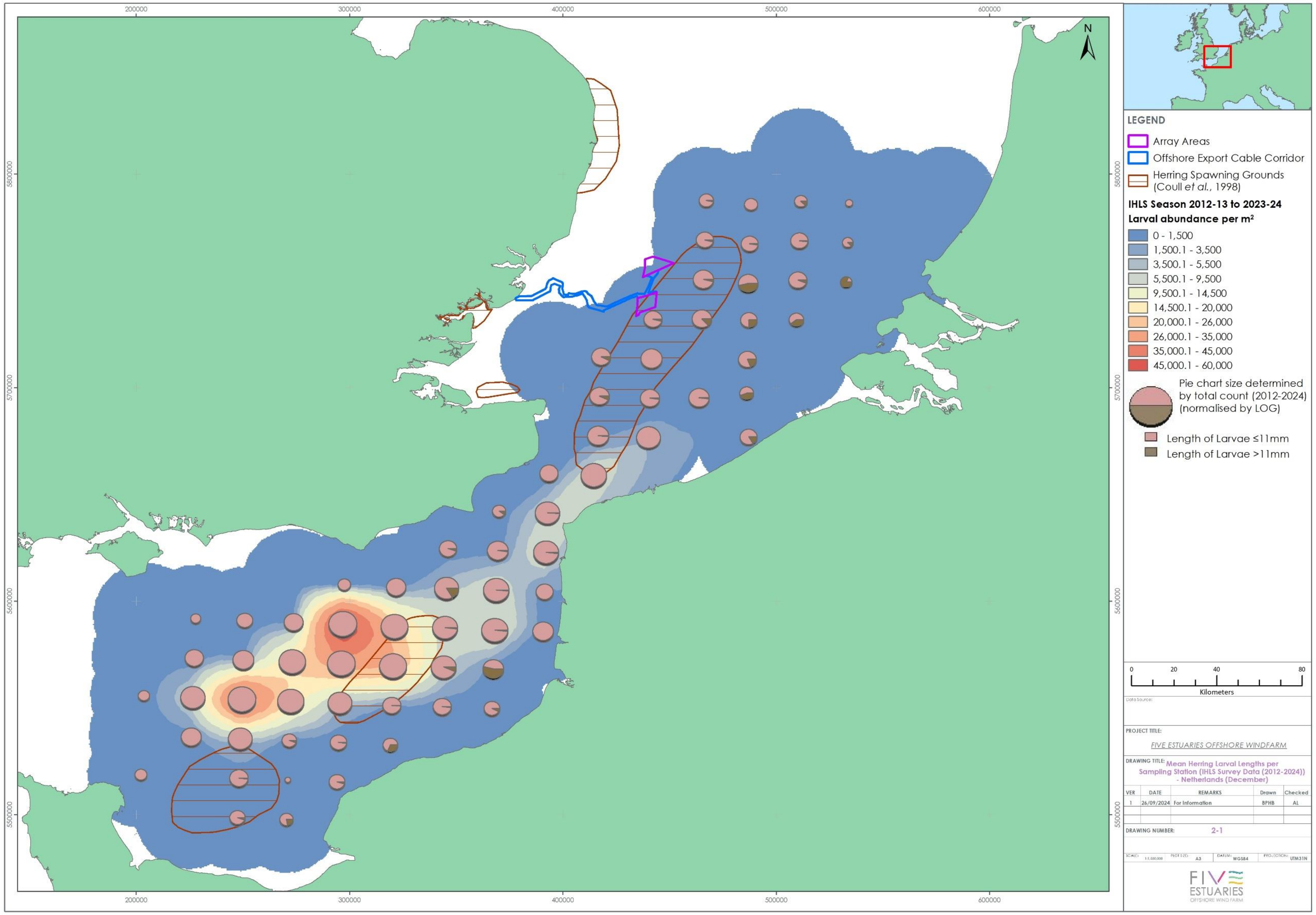

Figure 2.1: Mean herring larval lengths per sampling station (IHLS survey data (2012 – 2024) – Netherlands (December)

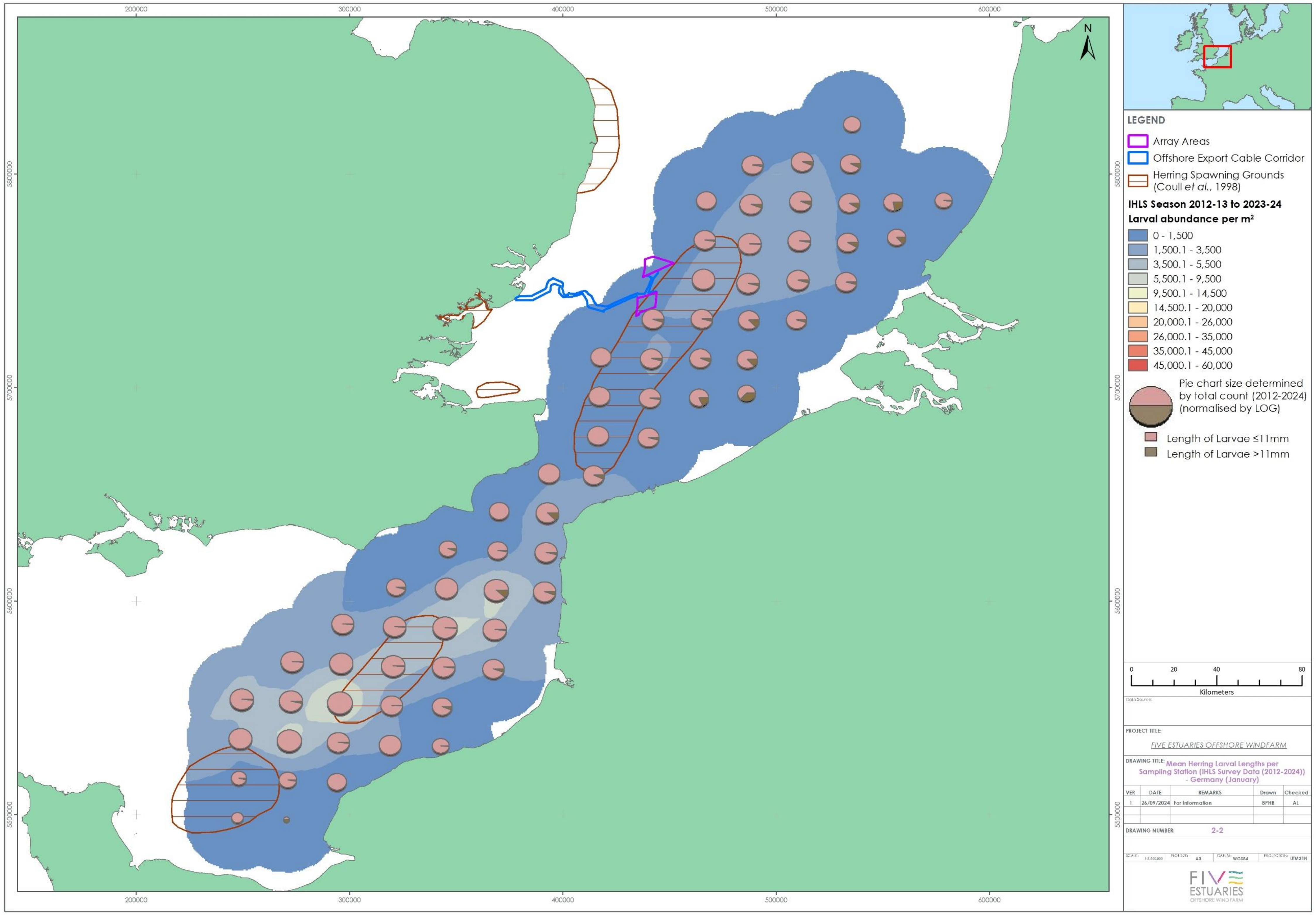

Figure 2.2: Mean herring larval lengths per sampling station (IHLS survey data (2012 – 2024) – Germany (January)

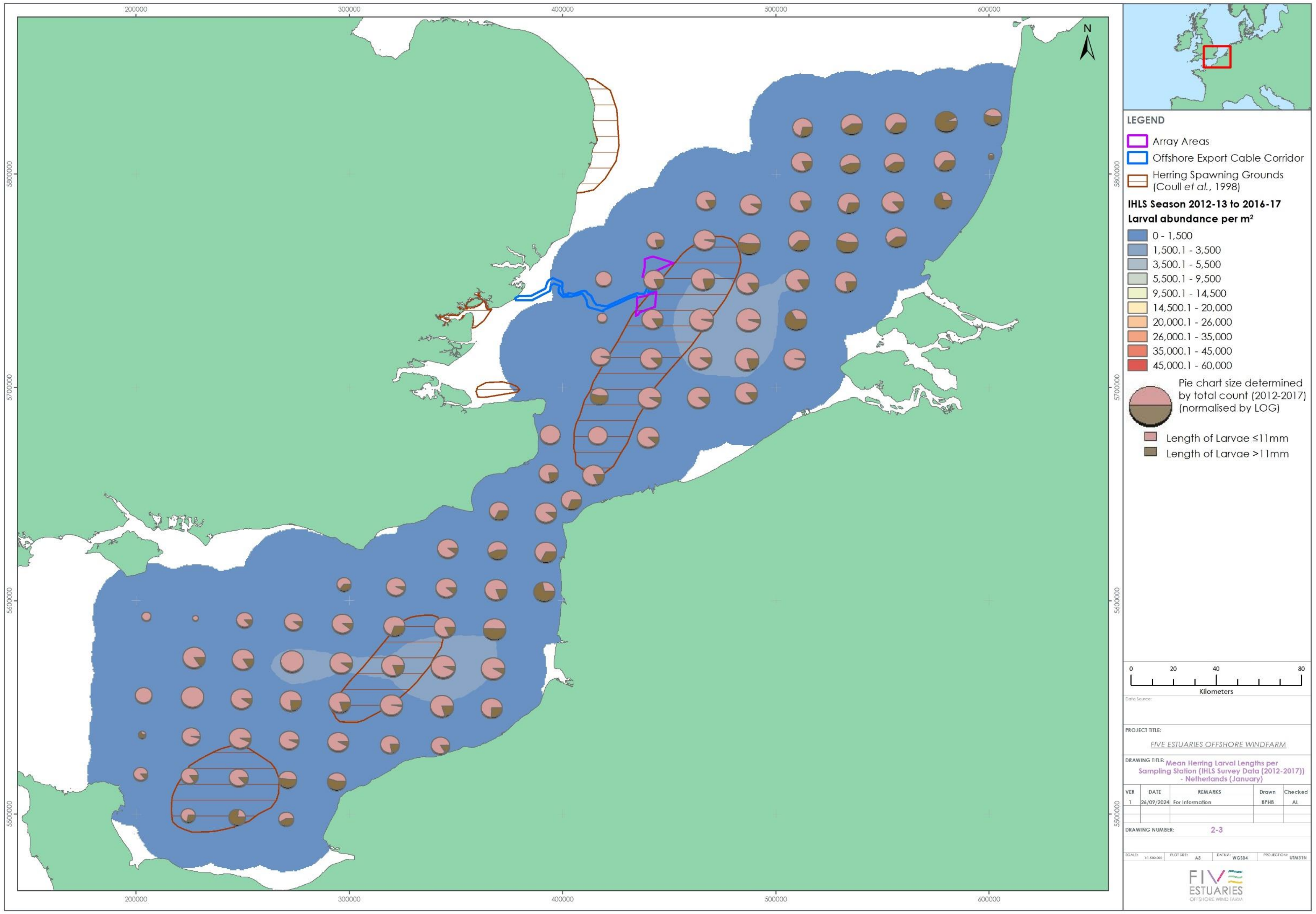

Figure 2.3 Mean herring larval lengths per sampling station (IHLS survey data (2012 to 2017) – Netherlands (January)

2.4 LARVAL LENGTH AT HATCHING

2.4.1 Once the catch length has been identified (Section 2.2.5), 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 in the Southern North Sea~~-~~, 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~~ 0.2~~5~~% of the recorded larvae from 2012/2013 to 2023/2024 in the January surveys undertaken by Germany, and 0% of the recorded larvae from 2012/2013 to 2016/2017 in the January surveys undertaken by the Netherlands), with higher abundances of 9 mm larvae recorded as the smallest ~~most years recording the smallest larval size as being 6 mm,~~ and even then, only in relatively low numbers (13~~2.3~~% of all recorded larvae from 2012/2013 to 2023/2024 in the January surveys undertaken by Germany, and 0% of the recorded larvae from 2012/2013 to 2016/2017 in the January surveys undertaken by the Netherlands~~)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 S~~s~~outhern North Sea 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 (2012/2013-2023/2024~~07-2022~~). 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 2012 and 2024, as recorded in the IHLS January surveys in the S~~s~~outhern North Sea, the temperatures during sampling (at maximum sampling depth)~~ across the Downs stock spawning grounds ~~, ranged from 5.5°C in January 2017~~5.9°C in 2009, ~~ to 11.6~~13.8~~°C in January 2016~~ 2023~~, with an average temperature of 8.3~~9.9~~°C (2012/2013-2023/2024). See Figure 2-4 below for average temperatures recorded at maximum sampling depths in the IHLS survey data (2012/2013~~07~~ – 2023/2024~~2022~~) for the Downs stock ~~(s~~see Figure 6-1 to Figure 6-10 ~~-~~in Appendix B for the individual survey years~~)~~.

~~2.5.1 Nonetheless, ~~S~~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).~~

~~2.5.2~~2.5.3 To ensure further 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 8.3~~5~~°C.

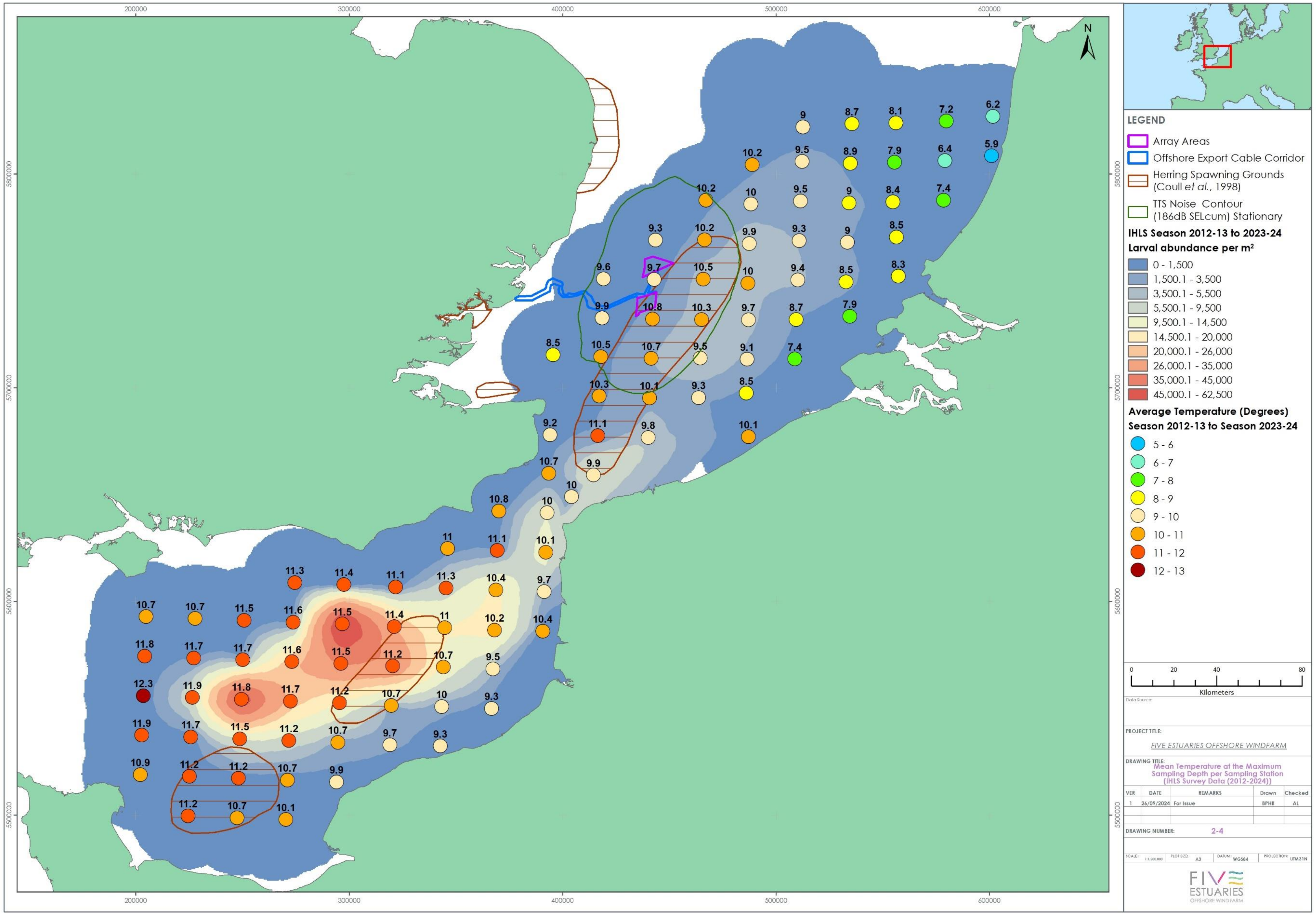

Figure 2-4: Mean temperature at the maximum sampling depth per sampling station (IHLS survey data (2012 – 2024)

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 Southern North Sea ~~Northeastern Channel~~ IHLS data (8.3~~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 8.3~~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 2-22.2: 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 eight scenarios for both the start and end dates of the peak spawning based on the four different hatch lengths presented, and the earliest start and latest end dates for the Germany and Netherlands surveys, undertaken in from the 3rd to the 16th January, and the 14th to the 24th January respectively.

Table 2-32.3 Factors considered within the back-calculations.

Factor	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F	Scenario G	Scenario H
Earliest survey start date	3rd January15th December	14th January 15th December	3rd January15th December	14th January 15th December	3rd January	14th January	3rd January	14th January
Latest survey end date	16th January22nd January	24th January 22nd January	16th January22nd January	24th January 22nd January	16th January	24th January	16th January	24th January
Larval length (catch length)	11mm	11mm	11mm	11mm	11mm	11mm	11mm	11mm
Larval length at hatching (hatch length)	5 mm	5 mm 6mm	7.5mm6 mm	11mm6 mm	7.5 mm	7.5 mm	11 mm	11 mm
Egg development duration	14 days	14 days	14 days	14 days	14 days	14 days	14 days	14 days
Yolk absorption duration	7 days	7 days	7 days	7 days	7 days	7 days	7 days	7 days

Factor	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F	Scenario G	Scenario H
Growth rate	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}	0.34 mm d^{-1}

2.8.12.8.2 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):

- Scenarios A and B - based on a growth rate of 0.34 mm d-1, it would take 5 mm larvae 17.67 days to grow to the 11 mm catch length,.
- Scenarios C and DB - based on a growth rate of 0.34 mm d-1, it would take 6 mm larvae 14.7 days to grow to the 11 mm catch length. it would take 6 mm larvae 14.7 days to grow to the 11 mm catch length,
-
- Scenarios E and FC - based on a growth rate of 0.34 mm d-1, it would take 7.5 mm larvae 10.3 days to grow to the 11 mm catch length.it would take 7.5 mm larvae 10.3 days to grow to the 11 mm catch length,
- Scenarios GF and HG D - based on a growth rate of 0.34 mm d-it1, it would take 11 mm larvae 0 days to grow to the 11 mm catch length.

2.8.22.8.3 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.

2.8.32.8.4 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 2-42.4: Peak Spawning Start and End Dates

Scenario	Start Date	End Date
A (5 mm)	25th November (3rd January –6th November (15th December – 39 days (17.76 days + 7 days + 14 days))	8th December (14th December (22nd16th January – 39 days (17.67 days + 7 days + 14 days))
BB (6 mm)	6th December (14th January - 39 days (17.6 days + 7 days + 14 days))9th November	116th December (24th January - 39 days (17.6 days + 7 days + 14 days))7th December
CC (7.5mm)	28th November 14th November (3rd January – 36 days (14.7 days + 7 days + 14 days))	11th December22nd December (16th January – 36 days (14.7 days + 7 days + 14 days))

Scenario	Start Date	End Date
DD (11 mm)	9th December24th November (14th January - 36 days (14.7 days + 7 days + 14 days))	19th December1st January (24th December - 36 days (14.7 days + 7 days + 14 days))
E	2nd December (3rd January - 31 days (10.3 days + 7 days + 14 days))	15th December (16th January - 31 days (10.3 days + 7 days + 14 days))
F	13th December (14th January - 31 days (10.3 days + 7 days + 14 days))	23rd December (24th January - 31 days (10.3 days + 7 days + 14 days))
G	13th December (3rd January - 21 days (0 days + 7 days + 14 days))	26th December (16th January - 21 days (0 days + 7 days + 14 days))
H	24th December (14th January - 21 days (0 days + 7 days + 14 days))	3rd January (24th January - 21 days (0 days + 7 days + 14 days))

2.8.42.8.5 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 (25th th6 November – Scenario A) and the latest end date from the scenarios above (3rd rd January 1 January – Scenario DH). This represents a pilling restriction period of 3956 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 impact 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 625th th November until 3rd rd1 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 for both the Germany and Netherlands January surveys, across all four hatch sizes as a precautionary measure, extending the seasonal restriction period from 38 10 days (Scenarios C and D) to 5639 days.

3.1.3 As such, with the implementation of conservatism to both the start and end dates it is considered that 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 625th th November until 3rdrd1st January is an appropriate mitigation measure to avoid population impacts on the Downs stock herring.

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5 APPENDIX A: IHLS SURVEY DATA STATIONS

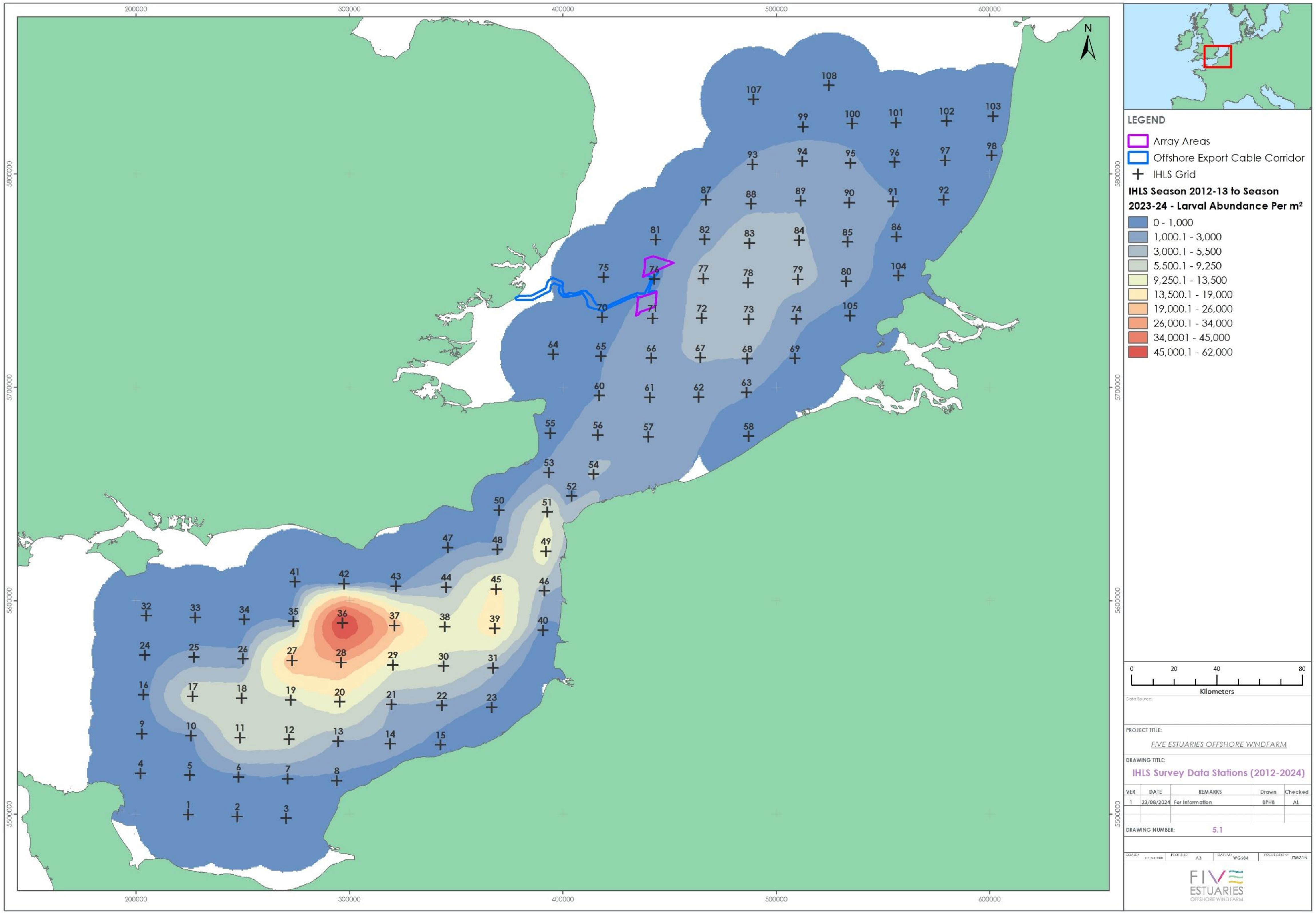


Figure 5-1: IHLS Survey Data Stations (2012-2024)

6 APPENDIX B: MAXIMUM SAMPLING DEPTH TEMPERATURE

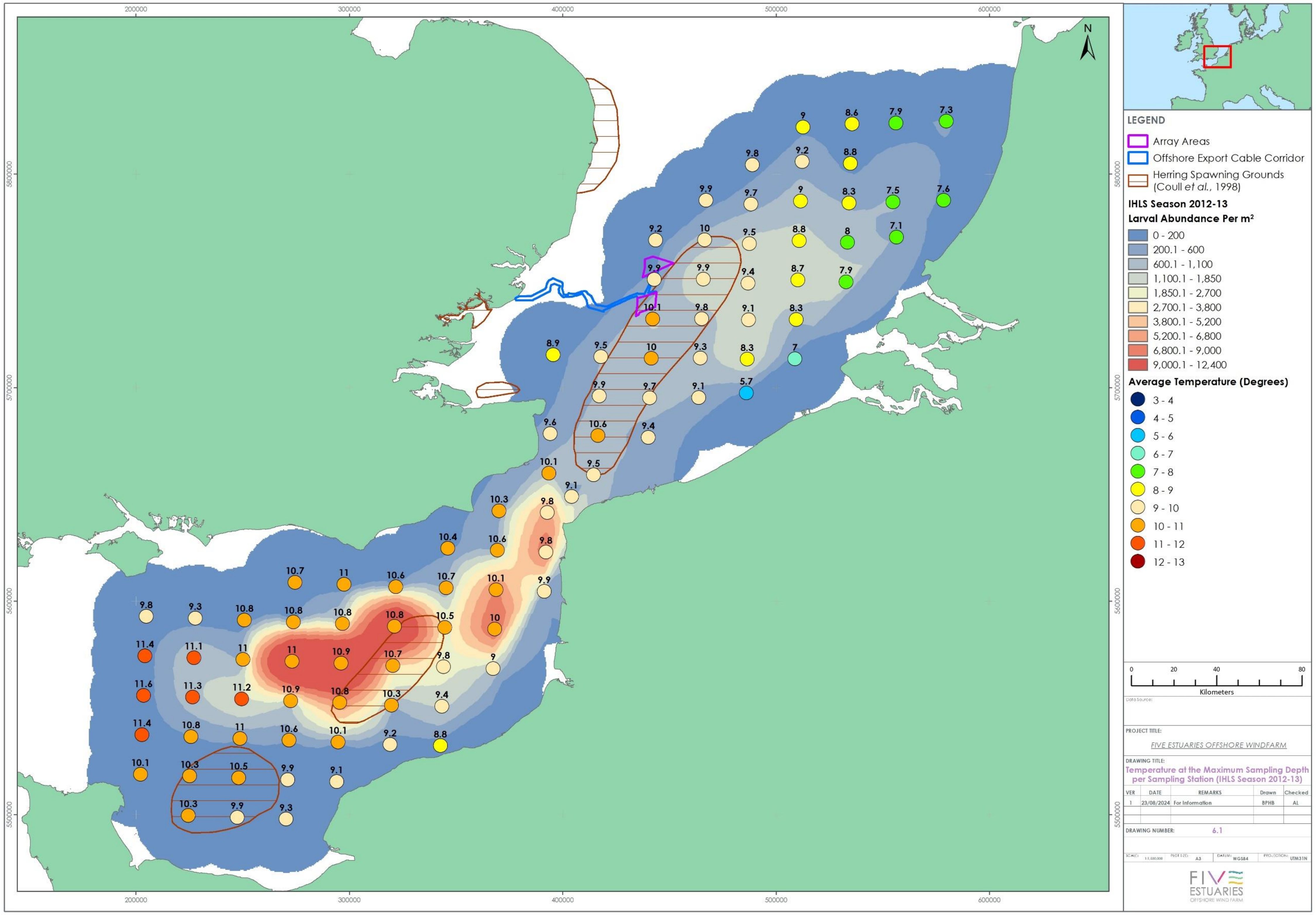


Figure 6-1: Temperature at the maximum sampling depth per sampling station (IHLS season 2012-13)

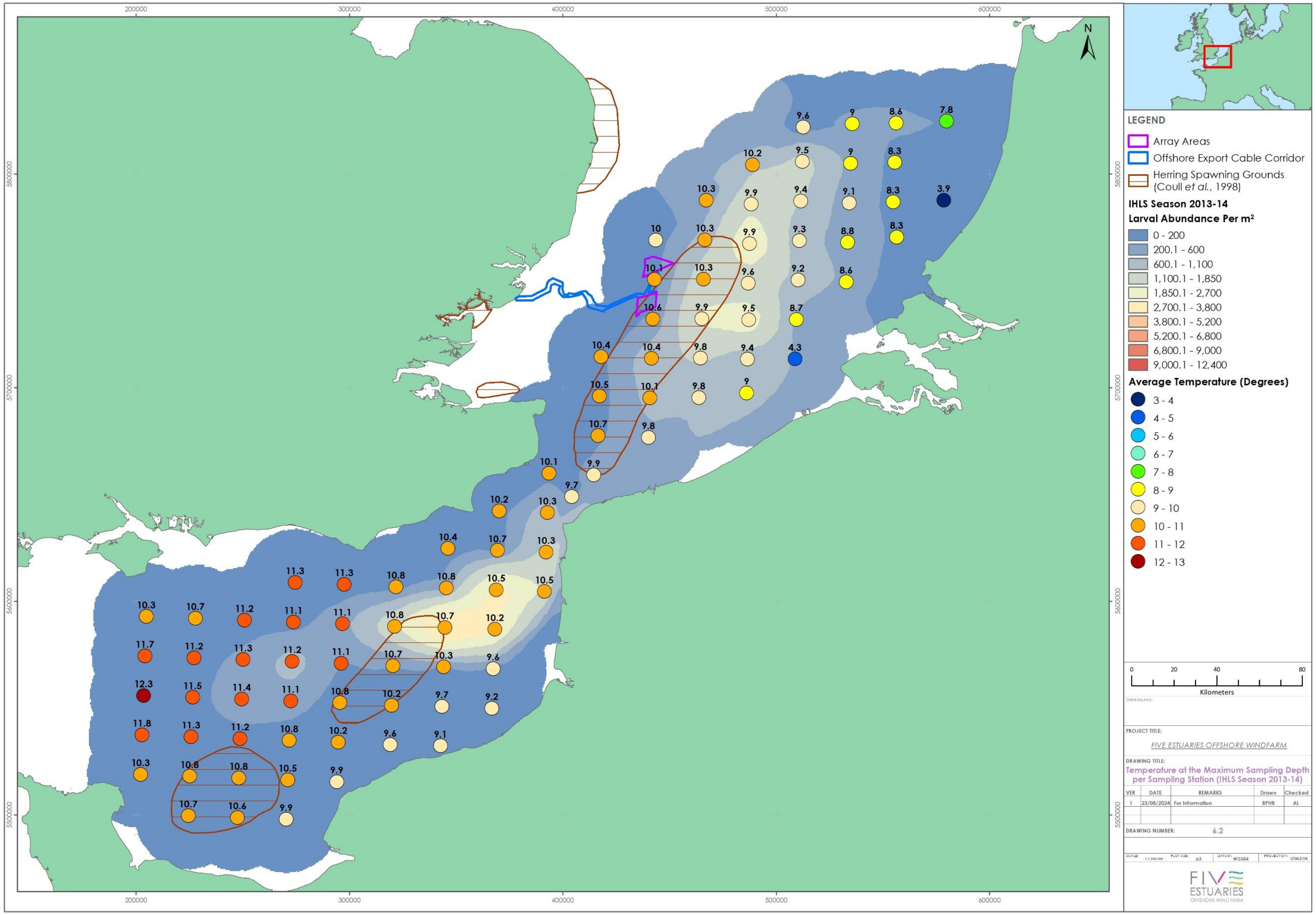


Figure 6-2: Temperature at the maximum sampling depth per sampling station (IHLS season 2013-14)

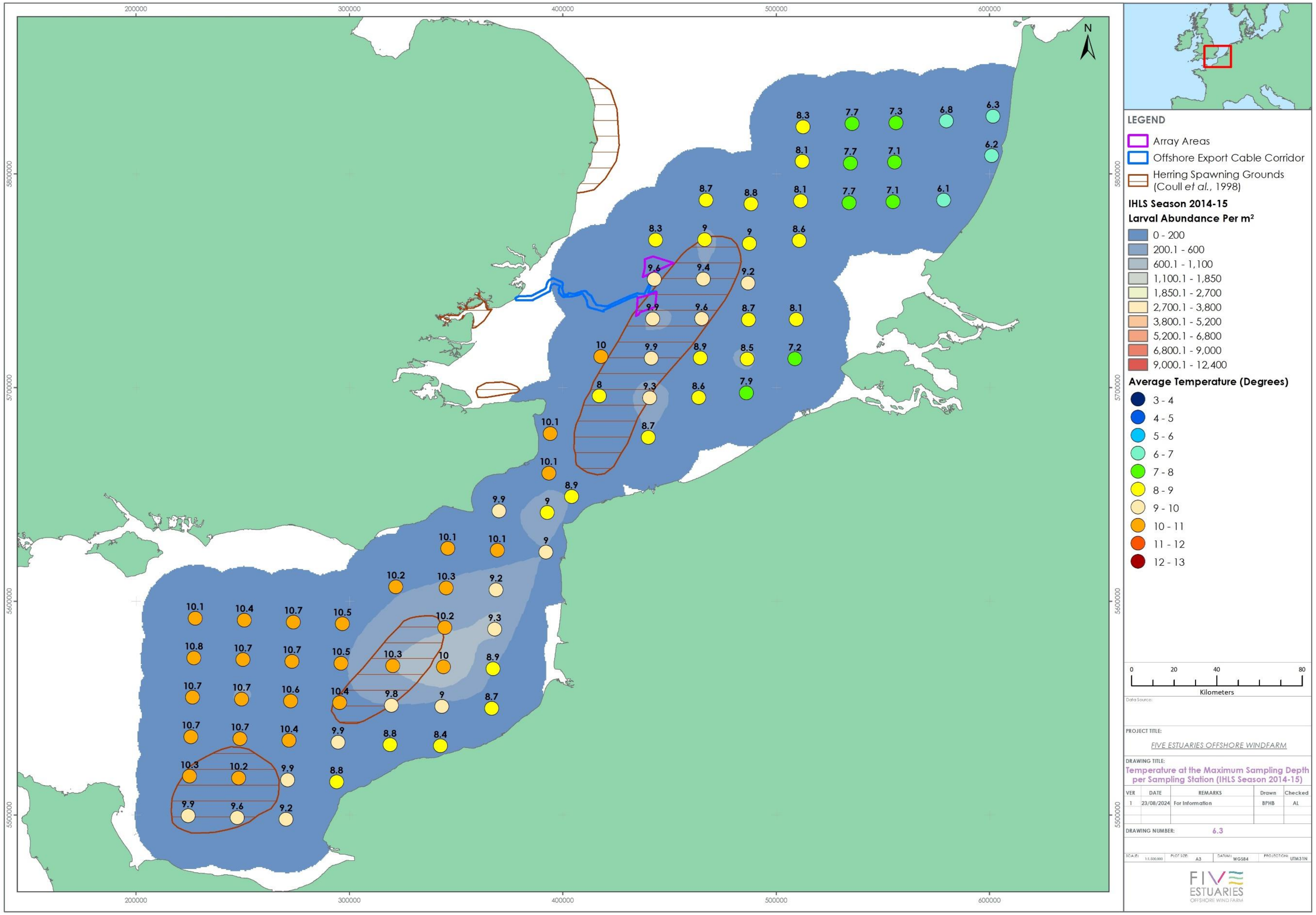


Figure 6-3: Temperature at the maximum sampling depth per sampling station (IHLS season 2014-15)

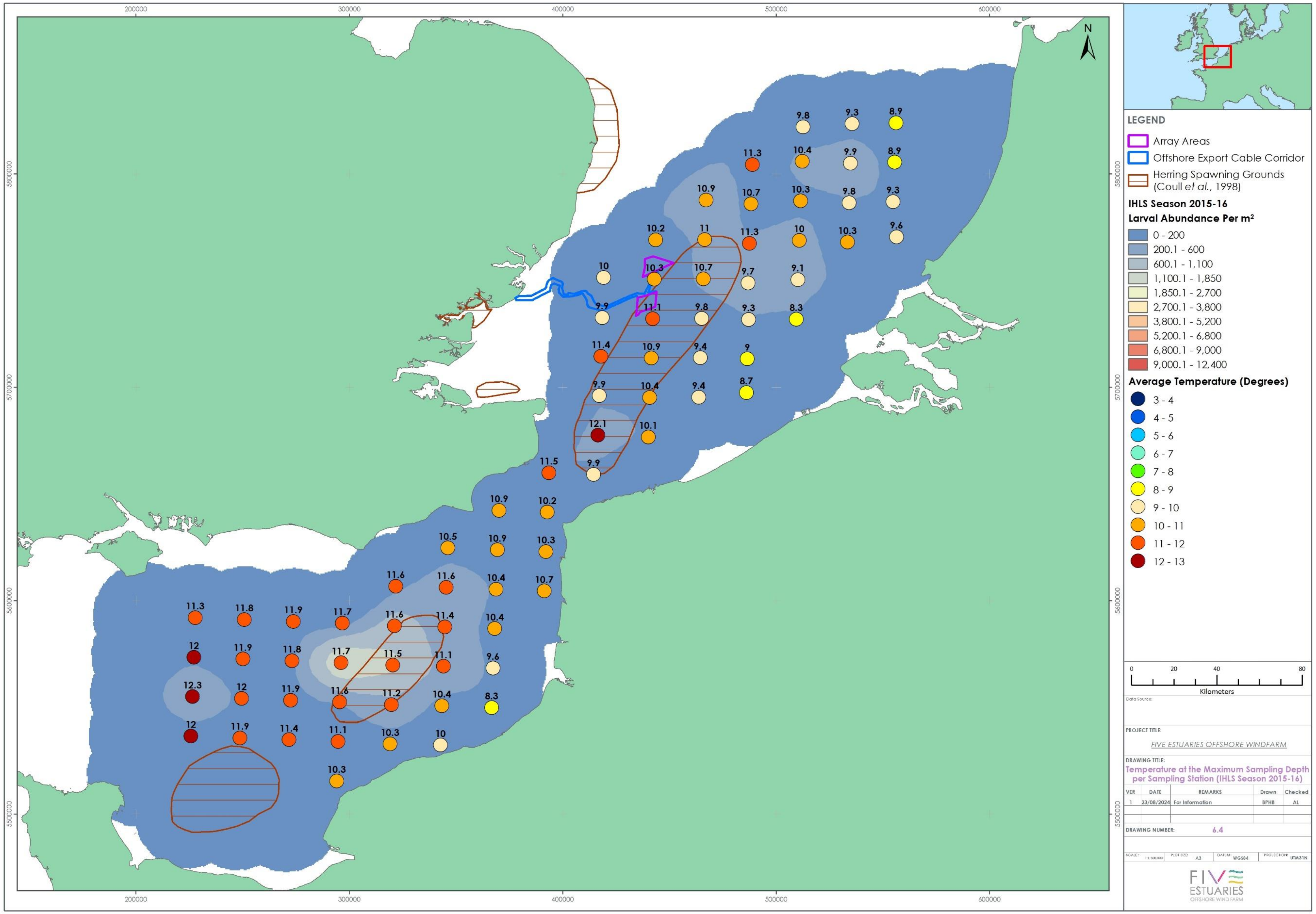


Figure 6-4: Temperature at the maximum sampling depth per sampling station (IHLS season 2015-16)

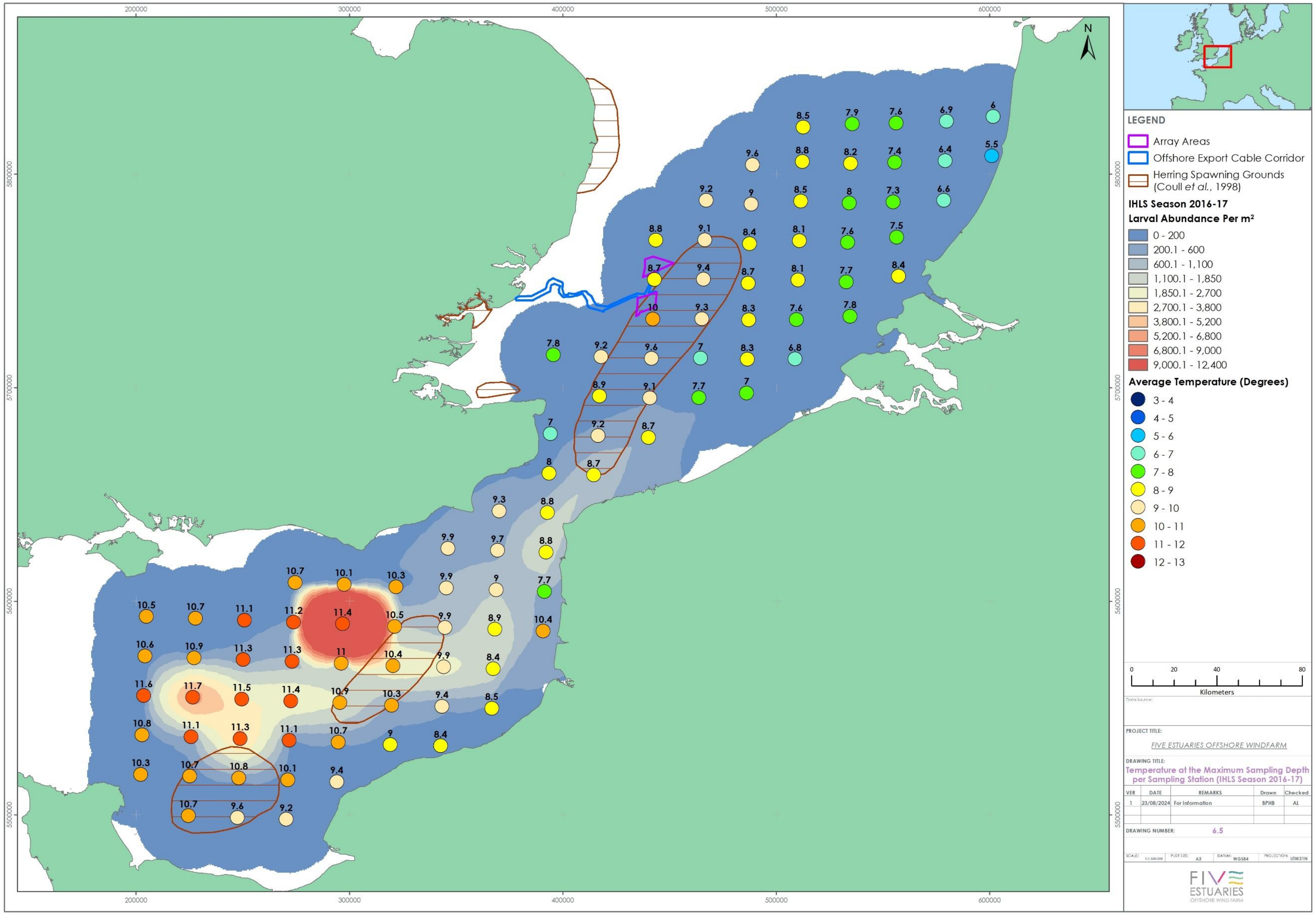


Figure 6-5: Temperature at the maximum sampling depth per sampling station (IHLS season 2016-17)

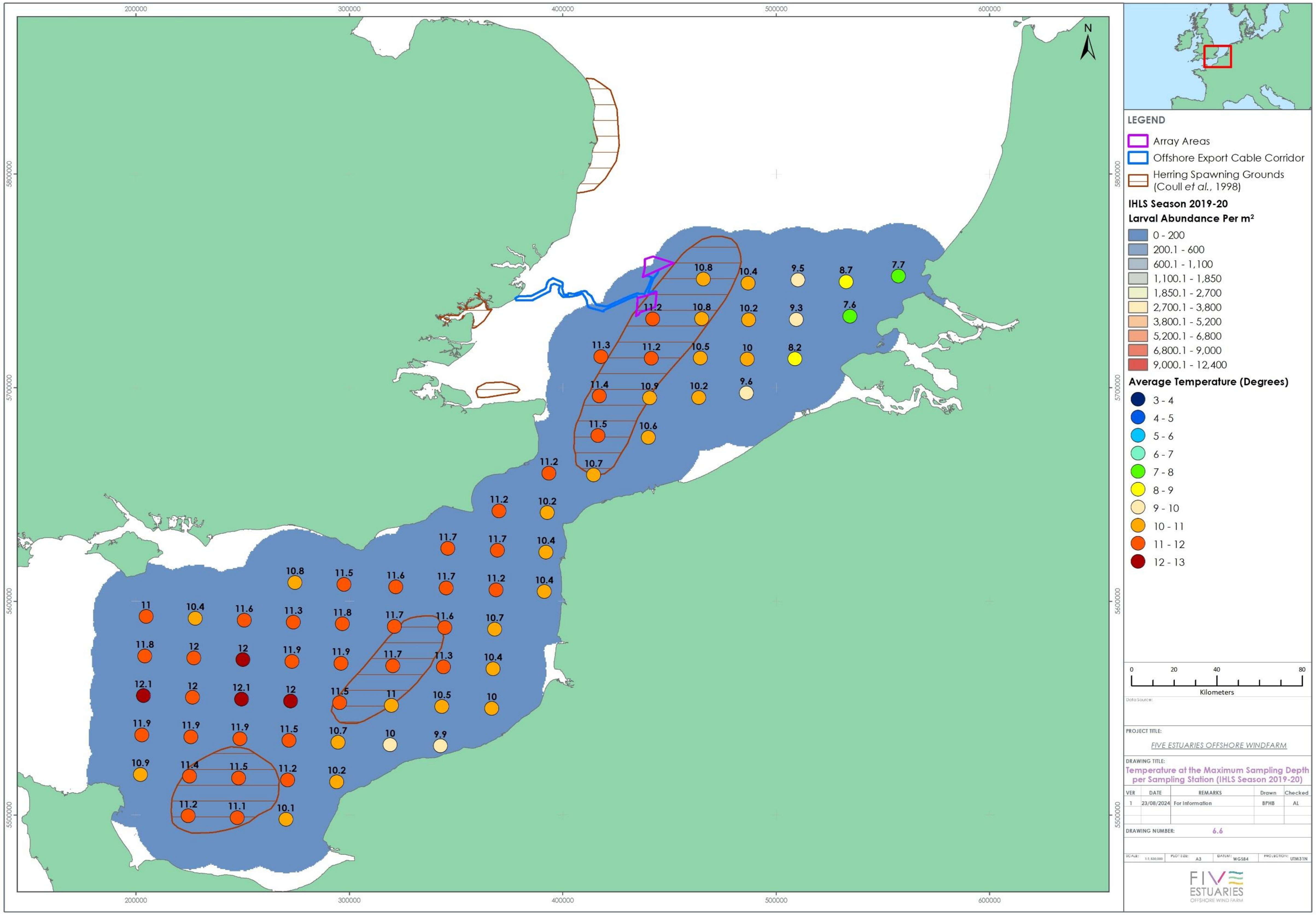


Figure 6-6: Temperature at the maximum sampling depth per sampling station (IHLS season 2019-20)

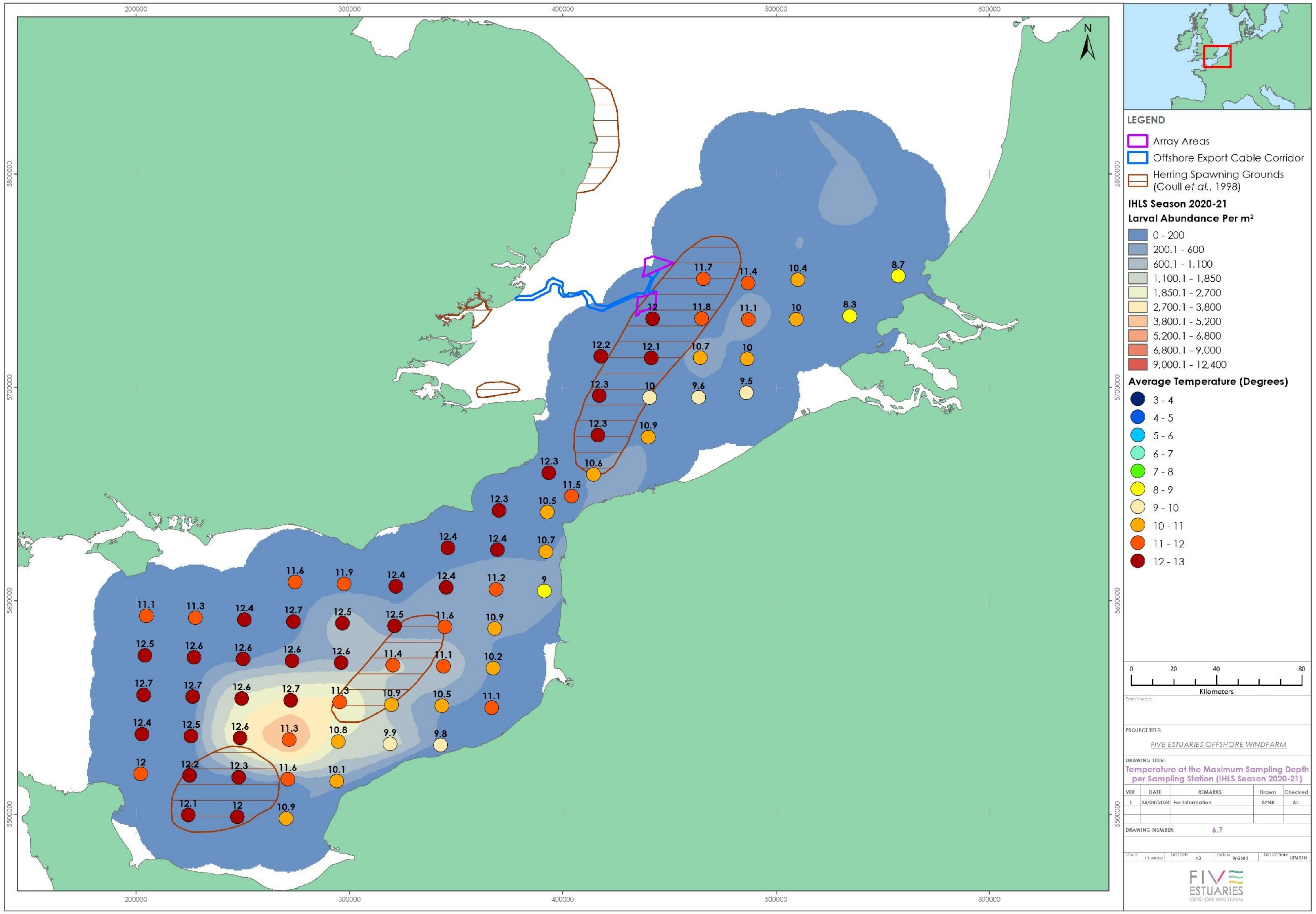


Figure 6-7: Temperature at the maximum sampling depth per sampling station (IHLS season 2020-21)

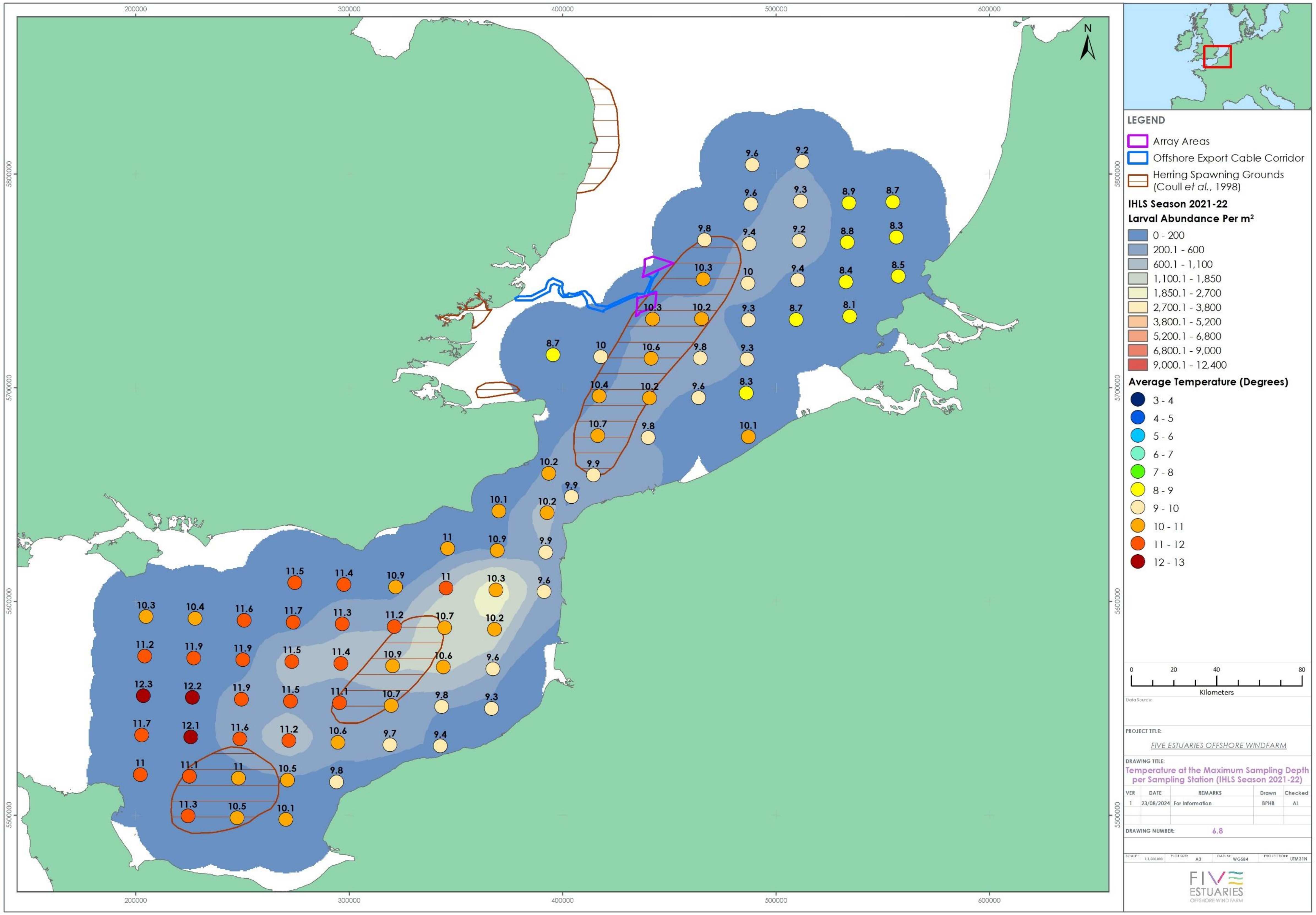


Figure 6-8: Temperature at the maximum sampling depth per sampling station (IHLS season 2021-22)

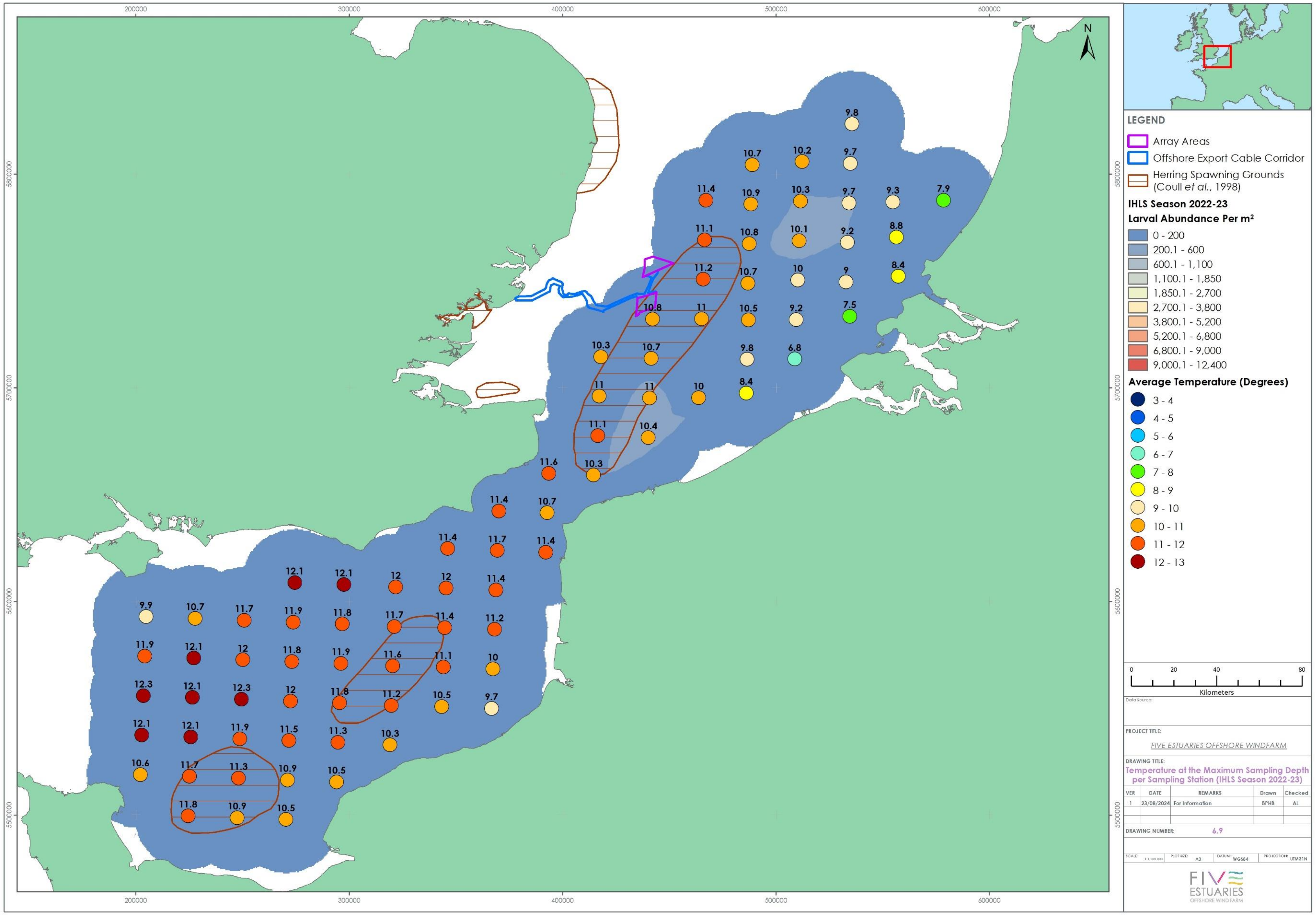


Figure 6-9: Temperature at the maximum sampling depth per sampling station (IHLS season 2022-23)

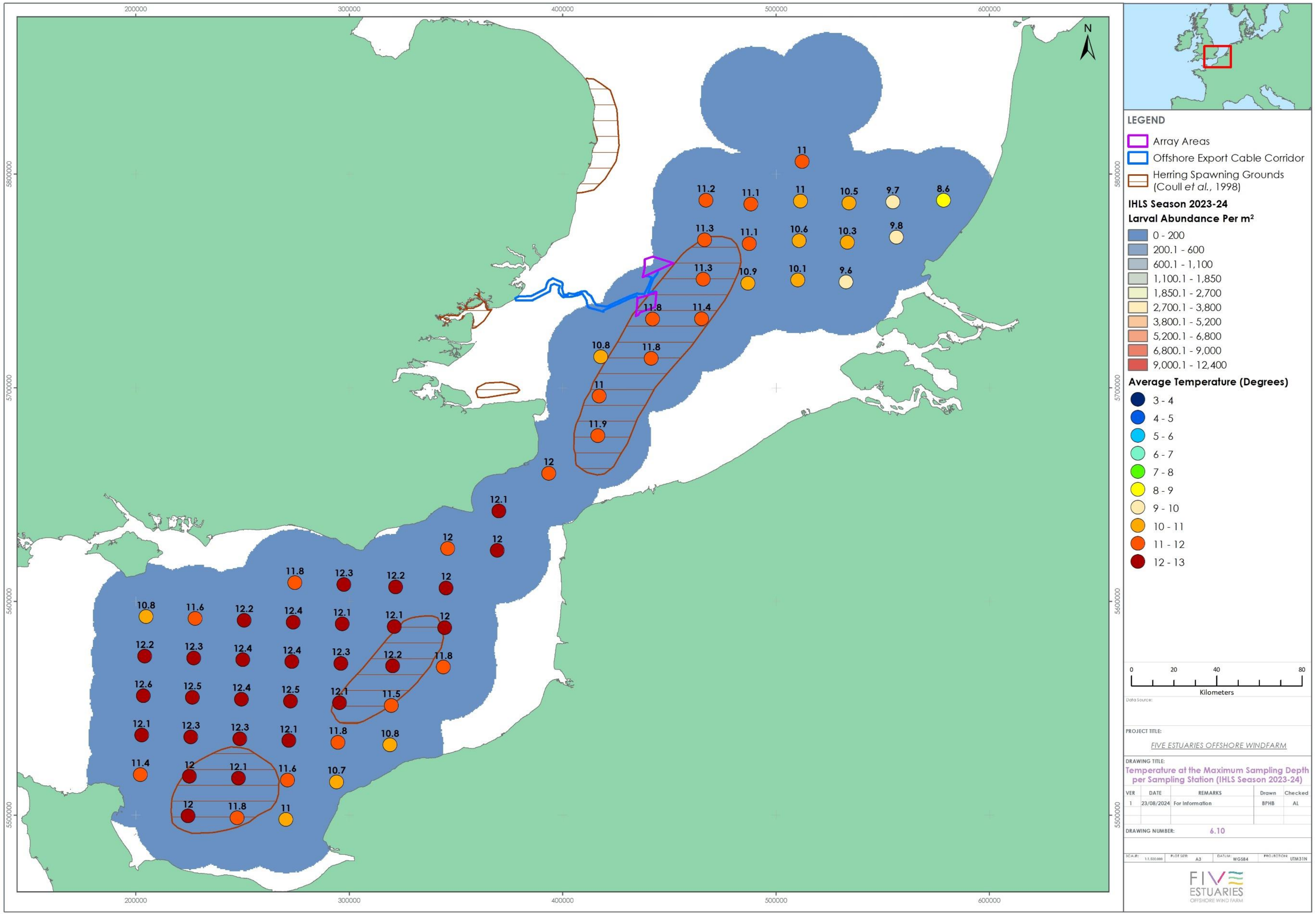
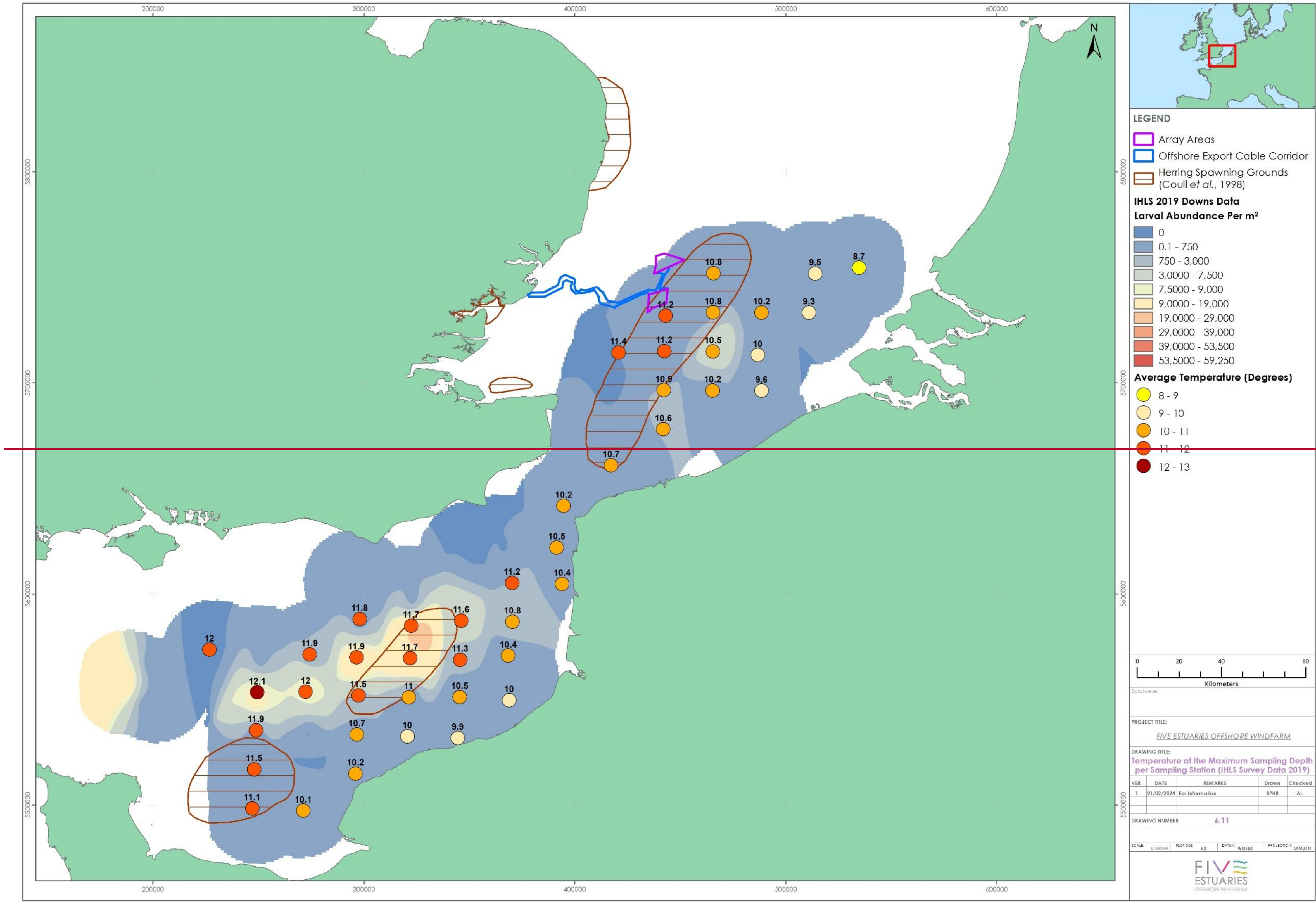
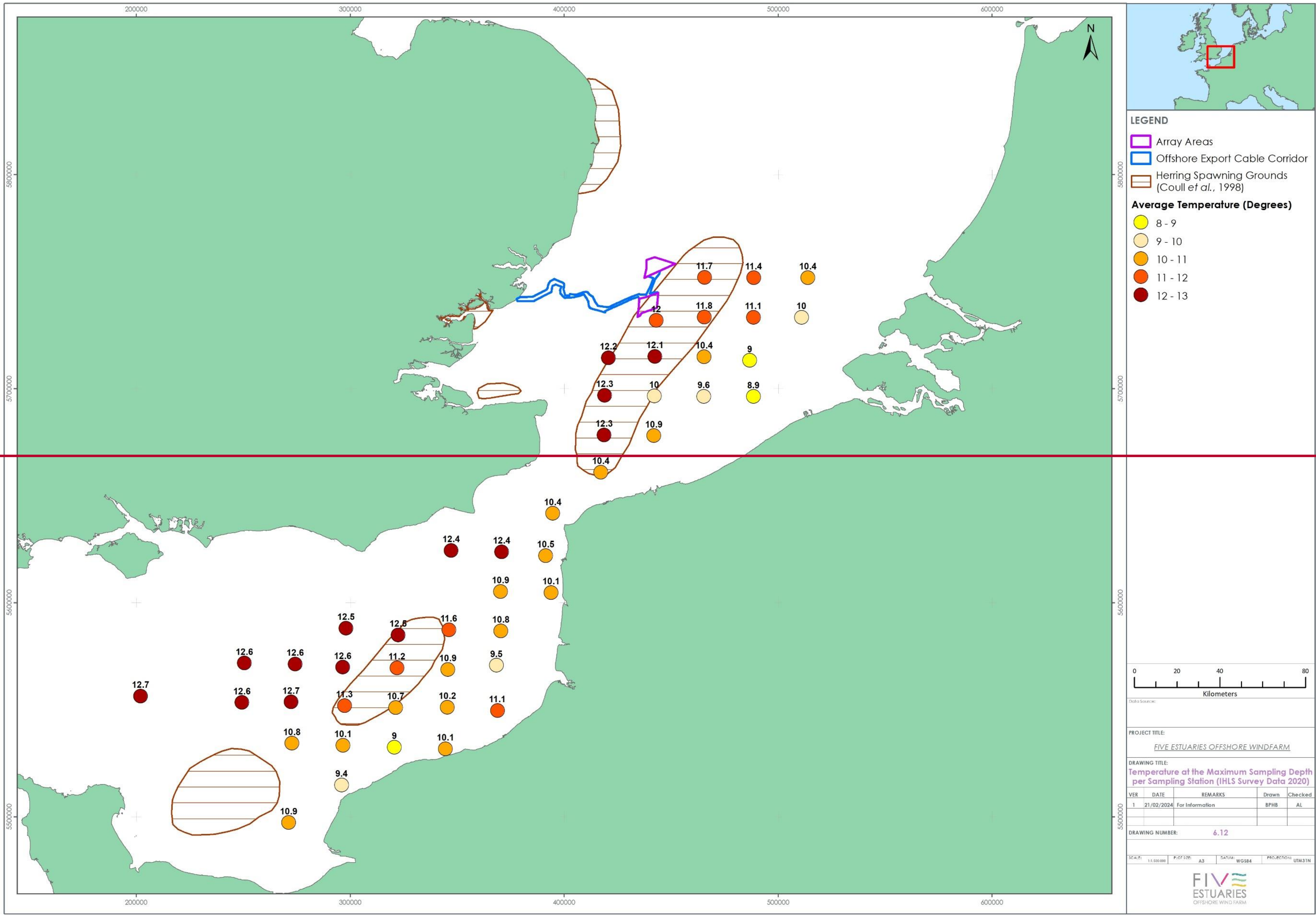


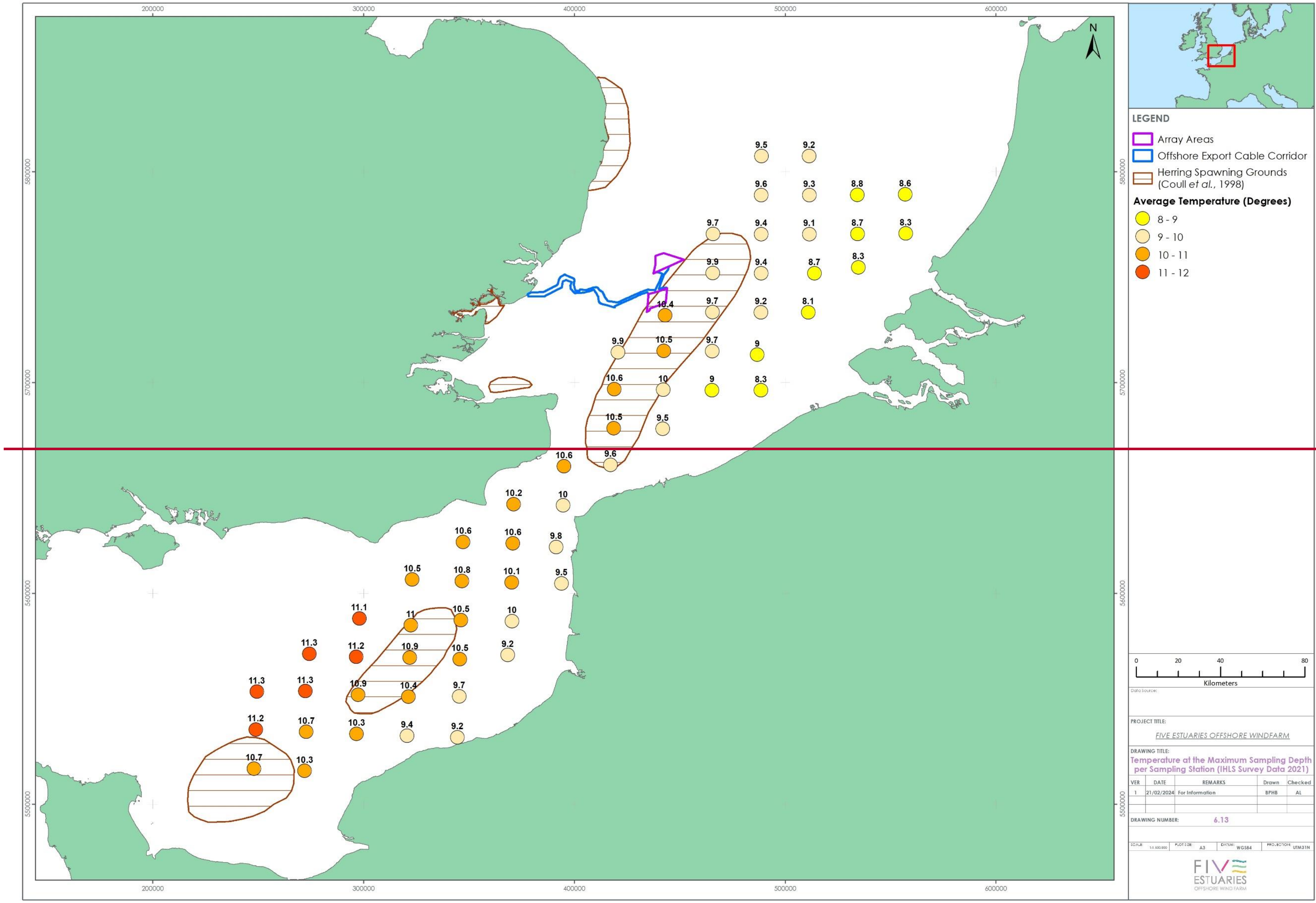
Figure 6-10: Temperature at the maximum sampling depth per sampling station (IHLS season 2023-24)



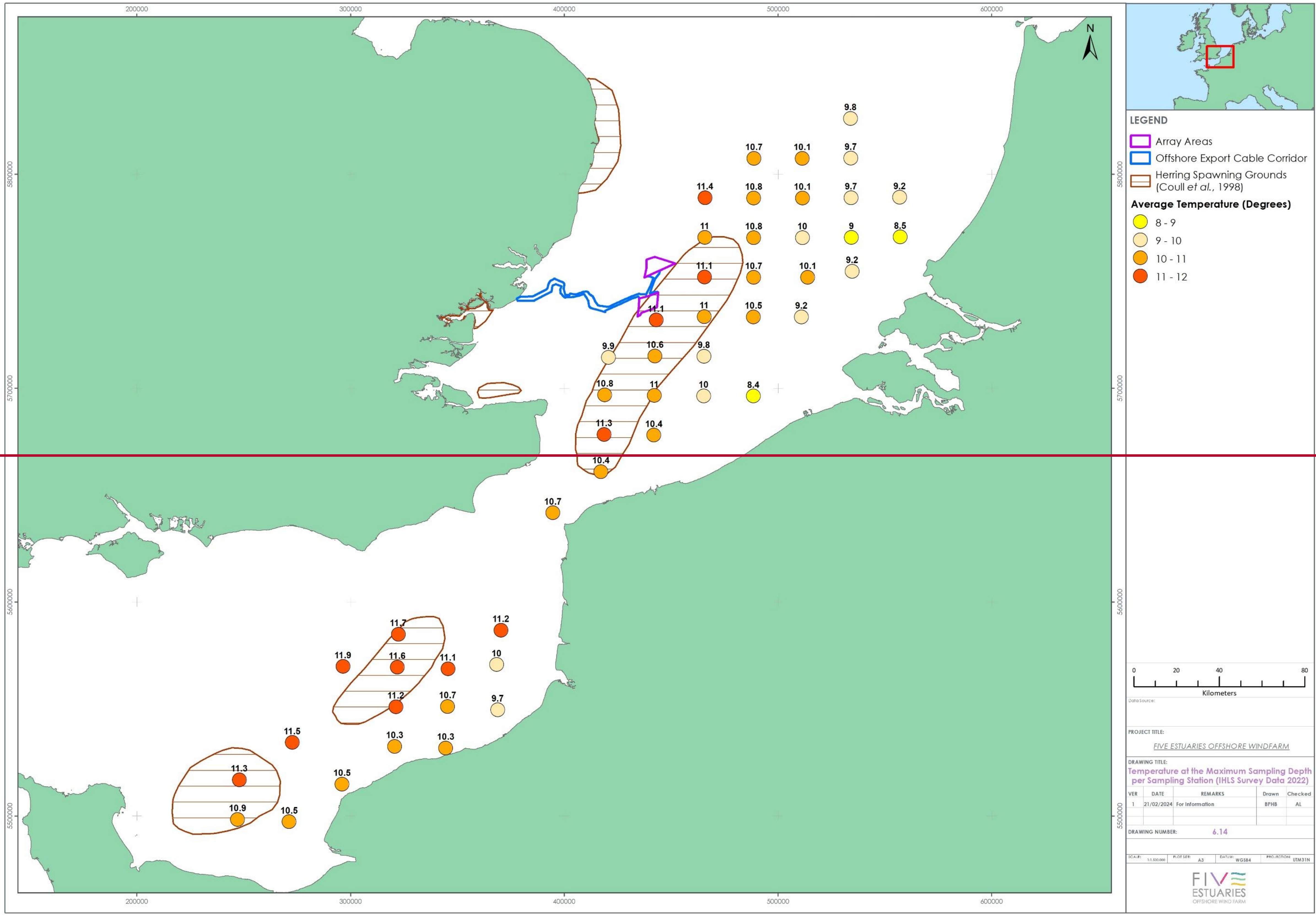
~~**Figure 6.11: Temperature at the maximum sampling depth per sampling station (IHLS survey data 2019)**~~



~~Figure 6.12: Temperature at the maximum sampling depth per sampling station (IHLS survey data 2020)~~



~~**Figure 6.13: Temperature at the maximum sampling depth per sampling station (IHLS survey data 2021)**~~



~~**Figure 6.14: Temperature at the maximum sampling depth per sampling station (IHLS survey data 2022)**~~

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

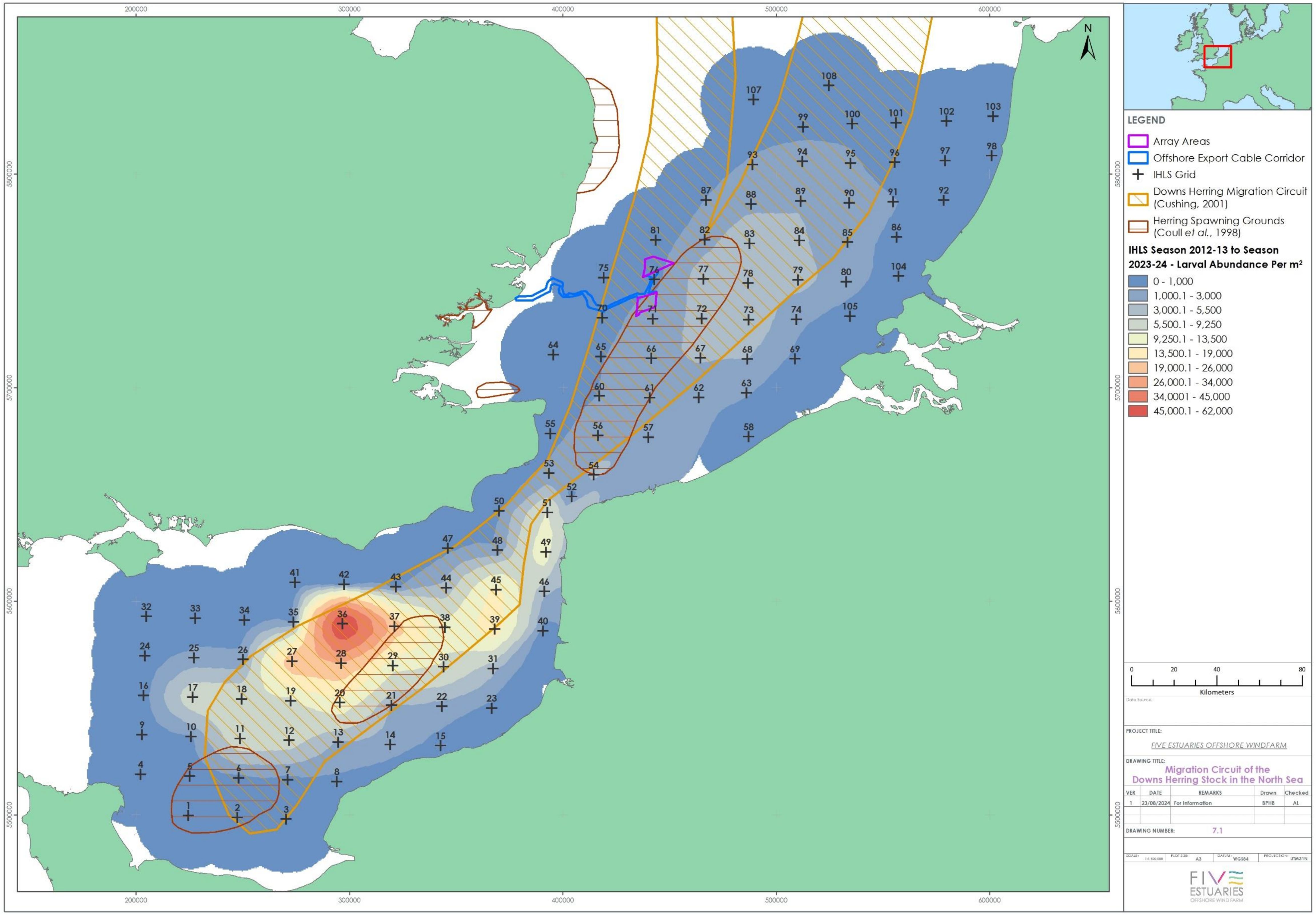


Figure 7-1: Migration circuit of the Downs herring stock in the North Sea

8 APPENDIX D - REVISED HERRING AND SANDEEL HABITAT SUITABILITY FIGURES, WITH UNDERWATER NOISE IMPACT CONTOURS

8.1.1 Following the submission of the DCO Application, the Applicant has since been made aware of several amendments required to the sandeel and herring habitat suitability assessments undertaken and presented in 6.2.6 Fish and Shellfish Ecology [APP-075], to ensure accordance with the methodologies as detailed by Latto et al. (2013) (as adapted from MarineSpace et al. (2013a)) for sandeel, and Reach et al., (2013) (as adapted from MarineSpace et al. (2013b)) for herring. The required revisions have subsequently been made and are reflected in Figure 8-1 to

8.1.2

8.1.3

8.1.4 Figure 8-4 below, submitted to Examination at Deadline 1. The updates include the following:

- The inclusion of the most recent publicly available IHLS data (2017-2024);
- The inclusion of the data from the Eastern Sea Fisheries Joint Committee (ESFJC) Fisheries Mapping Project (ESFJC, 2010), and Vessel Monitoring Systems (VMS) data from 2007 to 2020 (MMO, 2024);

- The classification of confidence scores into qualitative categories (low, medium, high and very high) in accordance with the methodologies defined by Latto et al. (2013) and Reach et al (2013); and
- The application of a confidence score of 5 to areas where herring larvae are present, in accordance with the methodology as detailed by Reach et al. (2013) (for the herring habitat suitability assessment).

8.1.5 Further, on request of the MMO in their Relevant Representations, the underwater noise contours (injurious impacts, TTS and behavioral effect contours) for sandeel and herring have been overlaid over their respective habitat suitability assessments in Figure 8-1 to

8.1.6

8.1.7

8.1.8 Figure 8-4 below.

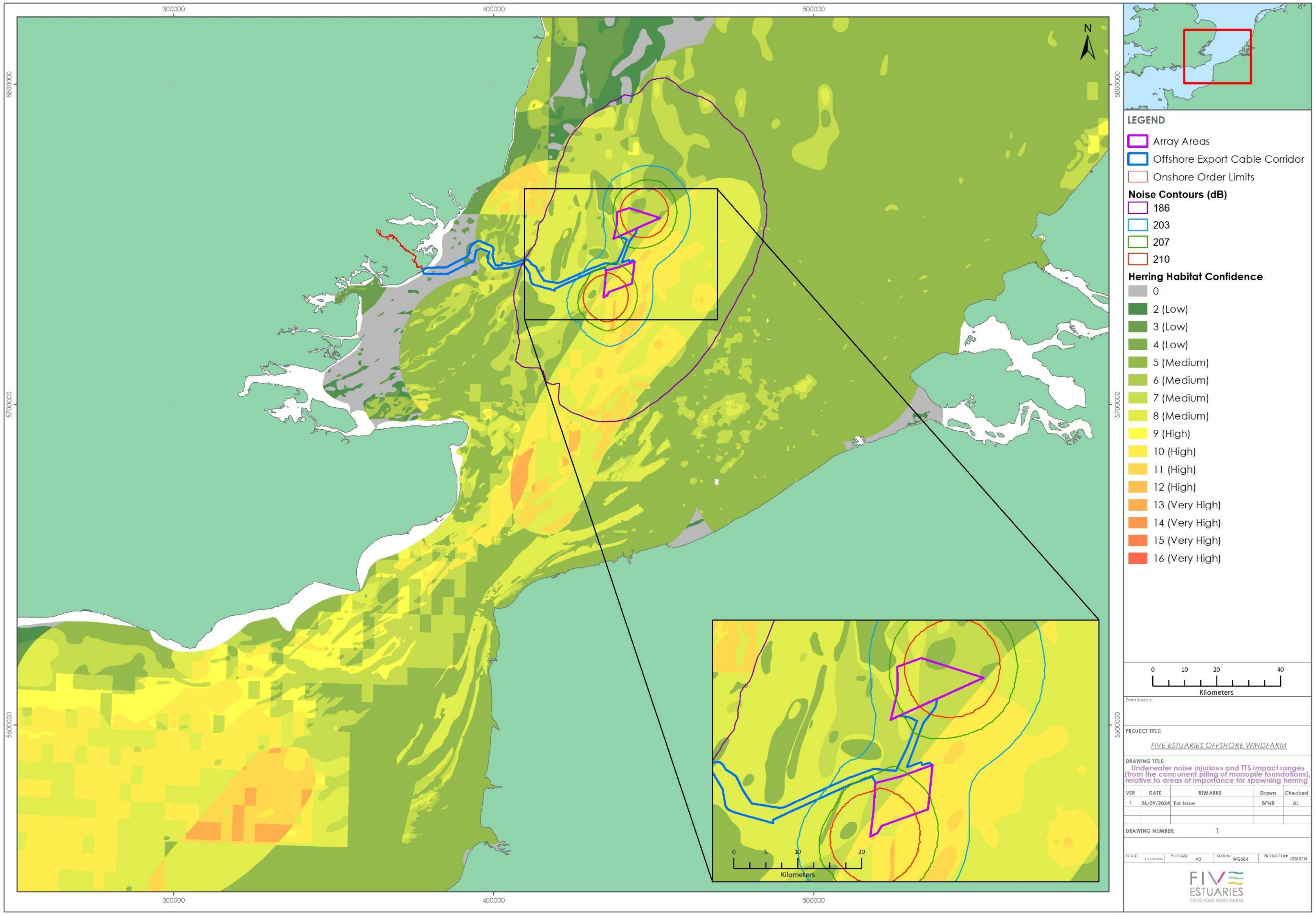


Figure 8-1 Underwater noise injurious and TTS impact ranges (from the concurrent piling of monopile foundations) relative to areas of importance for spawning herring

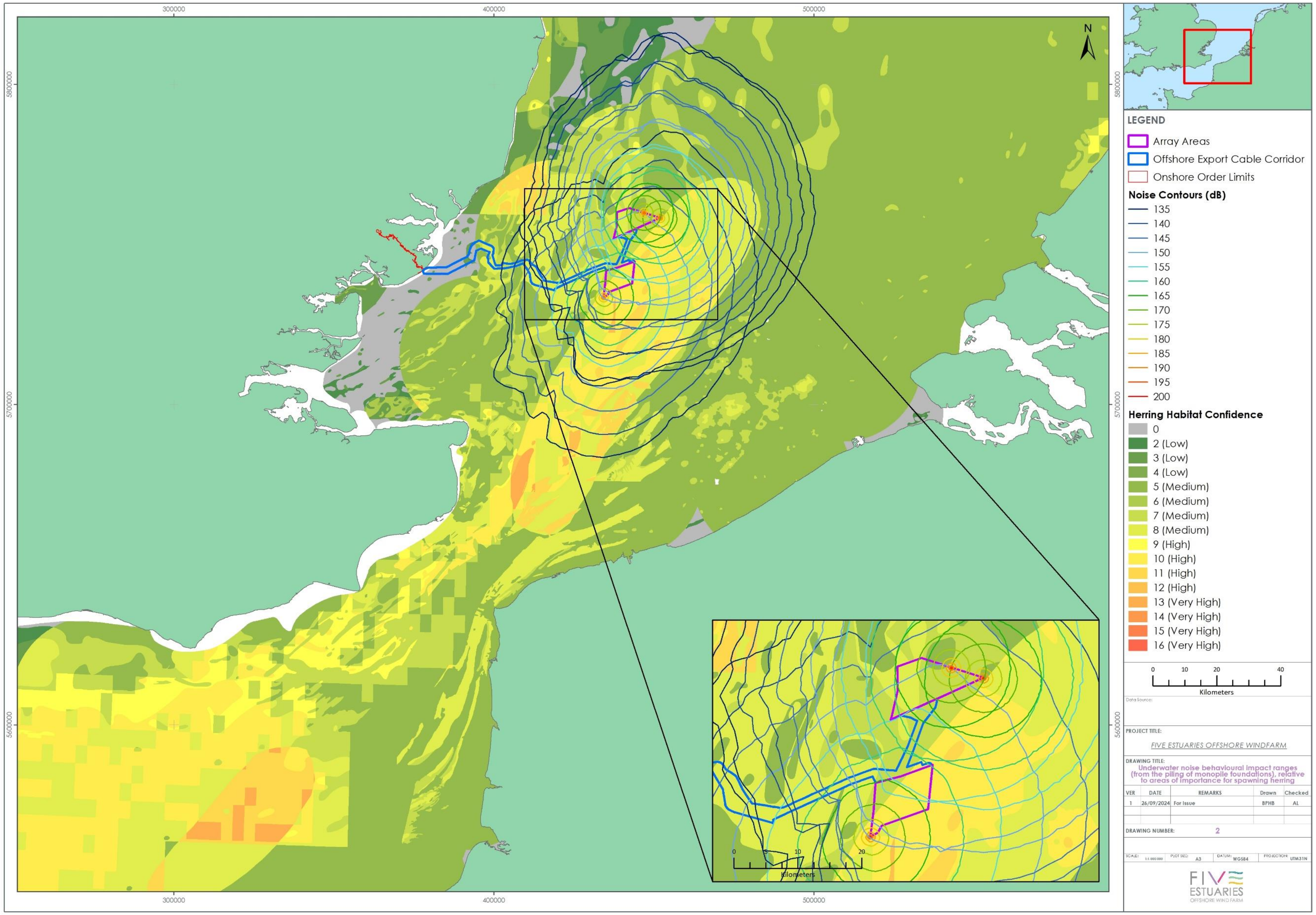


Figure 8-2: Underwater noise behavioural impact ranges (from the piling of monopile foundations) relative to areas of importance for spawning herring

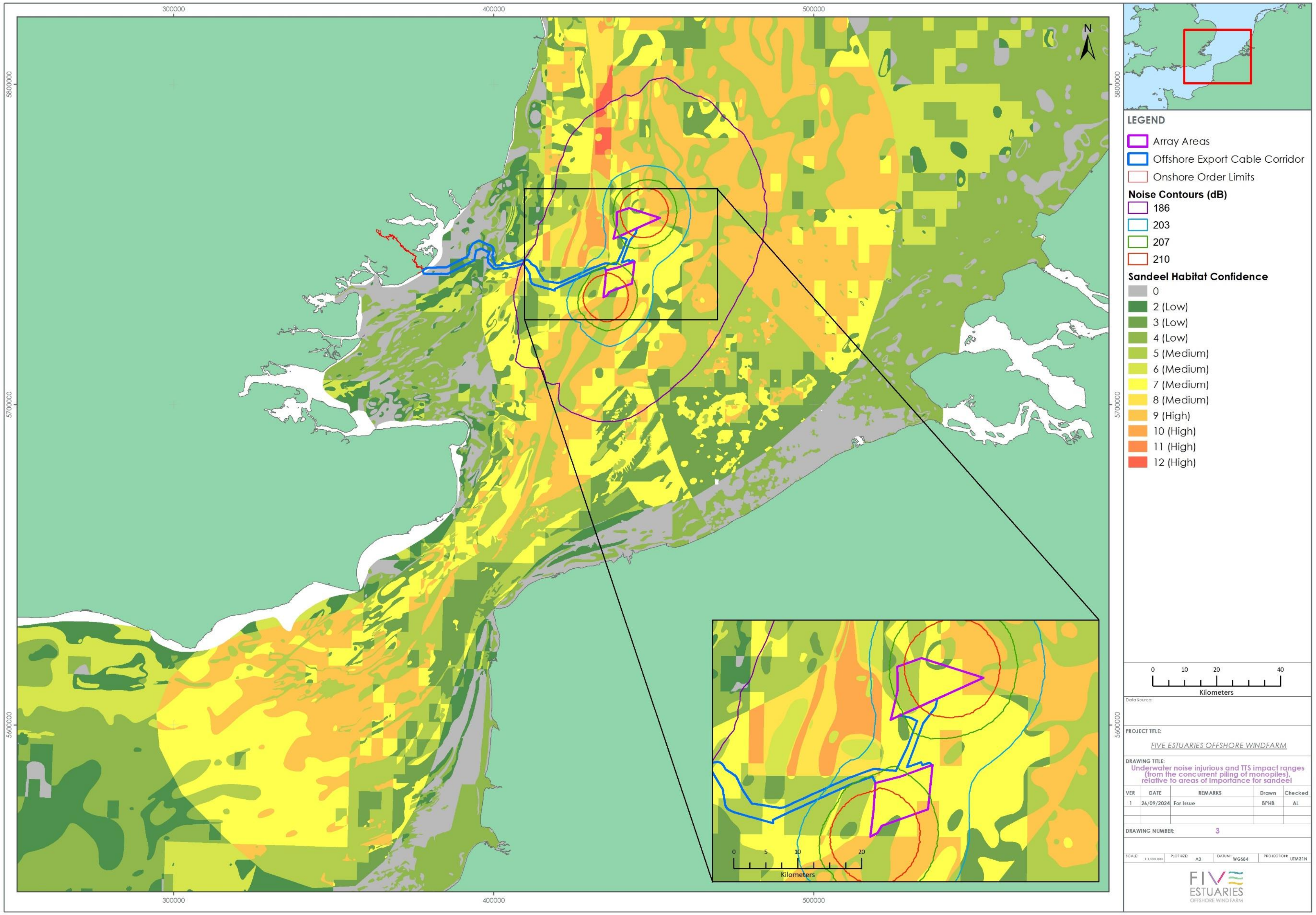


Figure 8-3 Underwater noise injurious and TTS impact ranges (from the concurrent piling of monopile foundations) relative to areas of importance for sandeel

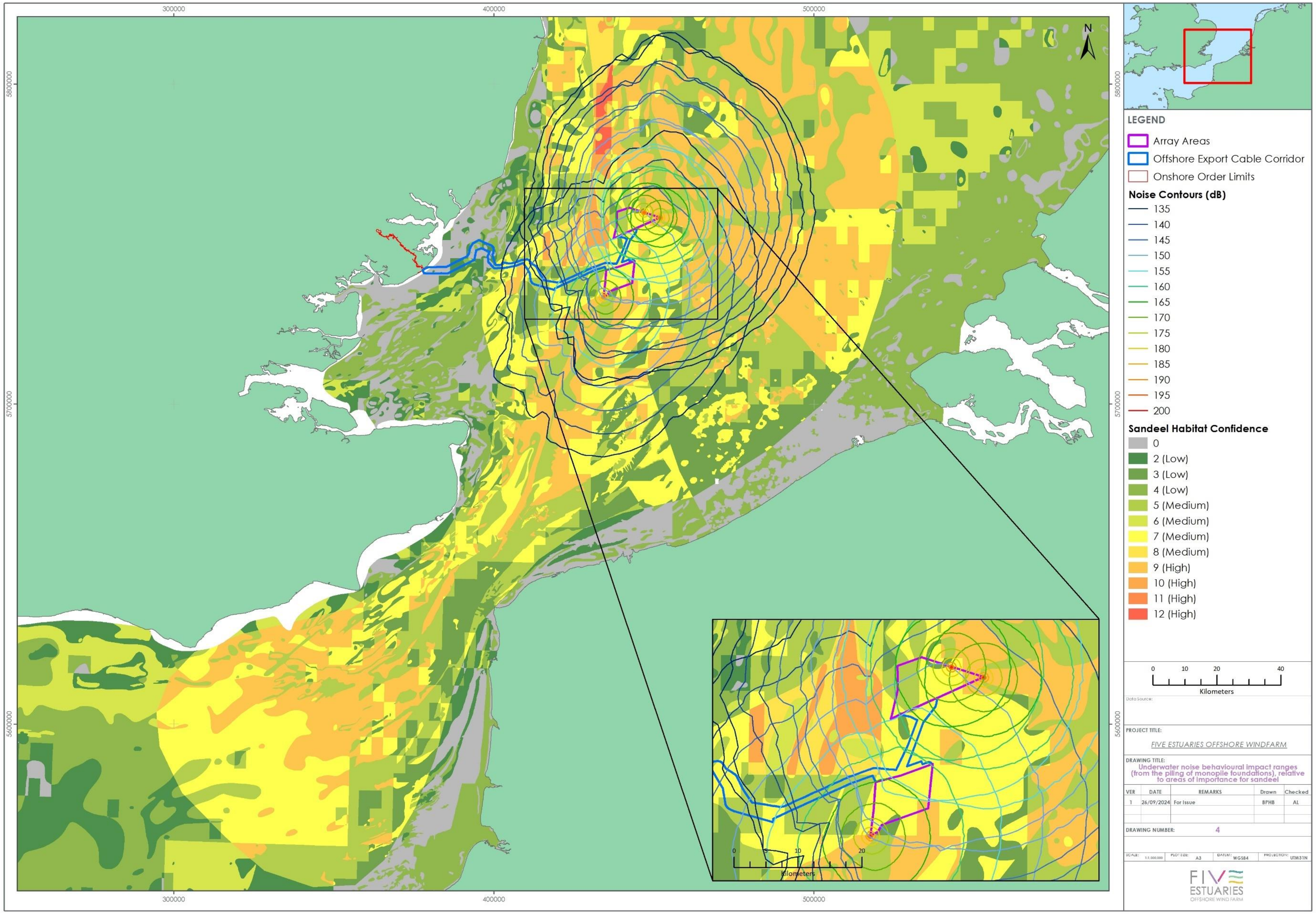


Figure 8-4 Underwater noise behavioural impact ranges (from the piling of monopile foundations) relative to areas of importance for sandeel