East Anglia ONE North Offshore Windfarm

Appendix 10.3

Stationary Modelling Appendix

Environmental Statement
Volume 3

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Rev	**Page**	**Section**	**Description**
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Table of Contents

Appendix 10.3 figures are listed in the table below.

Figure number	Title
10.3.1	Dover Sole Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.2	Plaice Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.3	Cod Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.4	Whiting Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.5	Lemon sole Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.6	Herring Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.7	Sprat Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.8	Sandeel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.9	Mackerel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.10	Seabass Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.11	Tope and Thornback Ray Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)
10.3.12	10 year IHLS data (2008-2018) in relation to Worst Case Noise Impact Contour (Stationary Model)

Glossary of Acronyms

MMO	Marine Management Organisation
PEIR	Preliminary Environmental Information Report
PTS	Permanent Threshold Shift
SEL	Sound Exposure Level
SPL	Sound Peak Level
TTS	Temporary Threshold Shift

Glossary of Terminology

East Anglia ONE North project	The proposed project consisting of up to 67 wind turbines, up to four offshore electrical platforms, up to one construction, operation and maintenance platform, inter-array cables, platform link cables, up to one operational meteorological mast, up to two offshore export cables, fibre optic cables, landfall infrastructure, onshore cables and ducts, onshore substation, and National Grid infrastructure.
East Anglia ONE North windfarm site	The offshore area within which wind turbines and offshore platforms will be located.
Offshore cable corridor	This is the area which will contain the offshore export cables between offshore electrical platforms and landfall.
Offshore development area	The East Anglia ONE North windfarm site and offshore cable corridor (up to Mean High Water Springs).

10.3 Stationary Modelling Appendix

10.3.1 Introduction

1. Following from the underwater noise modelling results presented in ***Appendix 11.4*** and taking account of the feedback provided by the Marine Management Organisation (MMO) to the Preliminary Environmental Information Report (PEIR) (see ***Appendix 10.1***), additional modelling was conducted to explore the effects of using a stationary animal model for fish compared to the fleeing animal model. The sound exposure level (SEL) SEL_{cum} criteria were used for this modelling. Calculated Sound Peak Level (SPL) SPL_{peak} impact ranges would remain the same as presented in the outputs of the fleeing animal model as these do not take noise exposure over time (or receptor movement) into consideration.

2. The stationary animal model assumes that when exposed to any noise from piling, the fish do not react in any way to reduce their exposure to noise, which will remain at the highest level in the water column. It is considered unlikely that whether the fish reacts specifically to the noise or not, it would remain at the position of highest noise level for the full duration of piling. Basing the assessment on a stationary receptor is likely therefore to greatly overestimate the potential risk to fish, especially when considering the precautionary nature of the parameters already built into the cumulative exposure model.

3. There is a lack of research regarding the responsiveness of fish and shellfish species to noise however it is known that behavioural effects vary greatly, depending on the physical properties of the sound, the species investigated and methodology (Thomsen et al 2006).

4. There is evidence to suggest that fish react to noise from various sources such as acoustic deterrent devices and seismic surveys (Richardson and Würsig 1997) Responses to very high-frequency sound (ultrasound) have been shown for various clupeid species (Dunning et al. 1992; Nestler et al. 1992; Ross et al. 1993, 1996; Gregory and Clabburn 2003). Startle responses in herring shoals were caused by frequencies between 70Hz und 200Hz (Blaxter et al. 1981; Blaxter and Hoss 1981). A deterring effect of infrasound on juvenile salmonids has been demonstrated by Knudsen et al. (1992, 1994, 1997) when the fish were very close (within a few metres) of the source. Whilst these findings are from various noise sources at different frequencies the results suggest that fish species flee in response to noise and that the fleeing model is the most appropriate to use for the impact assessment. Therefore, no assessment of significance is undertaken within this report.

5. Modelling was undertaken for impact piling at the worst case location of the East Anglia ONE North windfarm site (***Table 10.20*** in ***Chapter 10 Fish and Shellfish Ecology***) (for the fish criteria given in Popper et al. (2014) (***Table 10.19*** in ***Chapter 10 Fish and Shellfish Ecology***). All parameters used for modelling were the same as those presented with regards to the fleeing animal model in ***Appendix 11.4***, with the exception of assumptions of movement of fish during piling activities.

6. ***Table A10.1*** presents the modelled impact ranges for monopiles (4,000kJ hammer energy) and pin piles (2,400 kJ hammer energy), showing the increase in predicted ranges when using a stationary animal model. Maximum ranges are predicted of 39km for stationary animals when considering the 186dB SEL_{cum} criteria for fish during installation of both monopiles and pin piles over a 12-hour period. When considering ranges in relation to mortality / mortal injury and recoverable injury, under the stationary animal approach, the greatest impact ranges would be a result of installation of monopiles over a 12-hour period (219-203dB SEL_{cum}).

Table A10.1 Underwater noise modelling results for both monopile and pin pile maximum hammer energies, for the worst-case modelling location only (using a stationary animal response). For the full set of modelling results (including for the average water depth modelling location) see *Appendix 11.4.*

Fish Group	Impact Criteria	Potential Impact	Range (m)					
			Monopile (maximum hammer energy 4,000kJ			Pin pile (maximum hammer energy 2,400kJ)		
			Max	Mean	Min	Max	Mean	Min
Fish (no swim bladder)	>219 dB SEL_{cum}	Mortality and potential mortal injury	2,200	2,100	2,100	2,100	2,000	2,000
	>216 dB SEL_{cum}	Recoverable injury	3,400	3,300	3,200	3,200	3,100	3,000
	>186 dB SEL_{cum}	TTS	39,000	33,000	28,000	38,000	33,000	28,000
Fish (with swim bladder not involved in hearing)	210 dB SEL_{cum}	Mortality and potential mortal injury	7,500	7,000	6,700	7,200	6,700	6,400
	203 dB SEL_{cum}	Recoverable injury	15,000	13,000	12,000	14,000	13,000	12,000
	>186 dB SEL_{cum}	TTS	39,000	33,000	28,000	399,000	33,000	28,000
Fish (with swim bladder involved in hearing)	207 dB SEL_{cum}	Mortality and potential mortal injury	10,000	9,400	8,900	10,000	9,100	8,600
	203 dB SEL_{cum}	Recoverable injury	15,000	13,000	12,000	14,000	13,000	12,000
	186 dB SEL_{cum}	TTS	39,000	33,000	28,000	39,000	33,000	28,000

7. The potential effect of underwater noise associated with piling activity is given below for fish and shellfish receptors. In line with Popper et al. (2014), fish receptors have been grouped into categories depending on their hearing system as outlined in ***Table A10.2.***

8. In the particular case of shellfish, given the lack of specific impact criteria, the assessment has been based on a review of literature on the current understanding of the potential effects of underwater noise on shellfish species.

Table A10.2 Hearing Categories of Fish Receptors (* denotes uncertainty or lack of current knowledge with regards to the potential role of the swim bladder in hearing)

Category	Fish Receptors relevant to the proposed East Anglia ONE North project
Fish with no swim bladder or other gas chamber	Sole *Solea solea* Plaice *Pleuronectes platessa* Sandeels *Ammodytidae spp.* Mackerel *Scomber scrombus* Solenette *Buglossidium luteum* Elasmobranchs *Chondrichthyes spp.* River and sea lamprey *Lampetra fluviatilis* and *Petromyzon marinus* Lesser weever *Echiichthys vipera*
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	Atlantic salmon *Salmo salar* Sea trout *Salmo trutta* Smelt(*) *Osmerus esperlanus* Seabass(*) *Dicentrarchus labrax* Grey gurnard(*) *Eutrigla gurnardus* Gobies *Gobiidae spp*.
Fish in which hearing involves a swim bladder or other gas volume	10.3 Herring *Clupea herrangus* Sprat *Sprattus spp.* Cod *Gadus morhua* Whiting *Merlangius merlangius* European eel(*) *Anguilla Anguilla* Allis and Twaite Shad *Alosa alosa* and *Alosa fallax*

10.3.1.1 Mortality and Recoverable Injury

10.3.1.1.1 Fish with no swim bladder

9. There is potential for mortality / potential mortal injury to occur on fish with no swim bladder at ranges of up to 2.2km (219dB SEL_{cum}) and recoverable injury at ranges of 3.4km (216dB SEL_{cum}) from the installation of monopiles ***(Table A10.1)***. The majority of fish receptors included within the group "fish with no swim bladder" ***(Table A10.2***) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling.

10. An exception to this are sandeels, which given their burrowing behaviour and substrate dependence, may have limited capacity to flee the area compared to other fish species.

10.3.1.1.2 Fish with swim bladder not involved in hearing

11. There is potential for mortality / potential mortal injury at ranges up to a maximum of 7.5km (210dB SEL_{cum}) for the installation of monopiles (***Table A10.1)***. There is, however, the potential for recoverable injury to occur on fish with swim bladders not involved in hearing at ranges up to a maximum of 15km (203dB SEL_{cum}) from the installation of monopiles (***Table A10.1***).

12. The majority of fish receptors included within the group "fish with swim bladders not involved in hearing" ***(Table A10.2***) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling.

13. An exception to this are sand gobies as they have limited mobility and therefore potentially a reduced capacity to escape the areas affected by the greatest noise levels. Gobies are, however, abundant over wide areas of the North Sea and therefore any noise effects would impact only a small proportion of the population. Further, given the relatively short life cycle of this species (Teal et al. 2009), the population would be expected to recover quickly if subject to localised impacts associated with piling.

10.3.1.1.3 Fish with a swim bladder involved in hearing

14. There is potential for mortality / potential mortal injury at ranges up to a maximum of 10km (207dB SEL_{cum}) and recoverable injury at ranges up to a maximum of 15km (203dB SEL_{cum}) (***Table A10.1***).

15. Whilst all the fish receptors included within the group "fish with swim bladders involved in hearing" (***Table A10.2***) are mobile and would be expected to vacate the area in which the impact could occur with the onset of 'soft start' piling they are susceptible to barotrauma and detect sound pressure as well as particle motion.

10.3.1.1.4 Eggs and Larvae

16. Impact criteria for potential mortality / potential mortal injury in eggs and larvae have been described in Popper et al. (2014) (>210 dB SEL_{cum} or >207 dB SPL_{peak}). The criteria are based on work by Bolle et al. (2012) who reported no damage to larval fish at SEL_{cum} as high as 210 dB re 1 μPa 2·s. Therefore, the levels adopted in Popper et al (2014) are likely to be conservative. Given that the levels proposed in Popper et al (2014) are similar to those described for fish species with a swim bladder not involved in hearing (210 dB SEL_{cum} or >207 dB SPL_{peak}) the modelled impact ranges for this category have been used to provide an indication of the potential impacts on fish eggs and larvae.

17. As outlined in ***Table A10.1***, mortality / potential mortal injury would be expected at ranges up to a maximum of 7.5km (210dB SEL_{cum}) (***Table 10.23***). Eggs and larvae would not be able to flee the vicinity of the foundations during piling, however prolonged exposure could be reduced by any drift of eggs / larvae due to water currents which may reduce the risk of mortality.

18. The distribution of eggs and larvae of a given species extends over wide areas at a given time. Whilst eggs and larvae would not be able to flee the vicinity of piling, the probability and frequency of interaction with piling events is expected to be low. In this context, the small amount of egg / larval mortality associated with piling in relation to the naturally high mortality rates during these life stages should be noted.

10.3.1.1.5 Shellfish

19. There are no specific criteria currently published in respect of shellfish species, however studies on lobsters have shown no effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne et al. 2007). Similarly, studies of marine bivalves (e.g. mussels *Mytilus edulis* and periwinkles *Littorina spp*) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Kosheleva 1992).

20. The potential for piling noise to result in mortality / potential mortal injury or recoverable injury is therefore considered to be very low. Given the relatively low mobility of shellfish species in comparison to most fish species they have reduced ability to avoid areas in the proximity of piling.

10.3.1.2 Temporary Threshold Shift (TTS) and Behavioural Impacts

21. The outputs of the noise modelling for the spatial worst case scenario indicate that distances at which TTS may occur would increase to up to 39km (***Table A10.1***) from the installation of both pin piles and monopiles. Behavioural responses are anticipated to occur within this range and potentially in wider areas depending on the hearing ability of the species under consideration.

22. Impacts associated with TTS could result in reduced fitness of some species. For example, behavioural responses to underwater noise could result in decreased feeding activity, lead to the potential avoidance of spawning grounds, and act as a potential barrier to migration. Consequently, there is concern that behavioural responses could have an adverse impact on spawning behaviour and migration of certain species. However, impacts on feeding activity are considered unlikely to cause long term, larger scale effects on fish populations given the wider availability of suitable feeding grounds in the region.

23. As shown in ***Table 10.2*** in ***Chapter 10 Fish and Shellfish Ecology***, in terms of the temporal worst case scenario, the maximum duration of piling would be equivalent of 29.3 days.

24. ***Figures 10.3.1*** to ***10.3.12*** below present the extent of TTS / behavioural impact on particular fish species from the installation of monopiles

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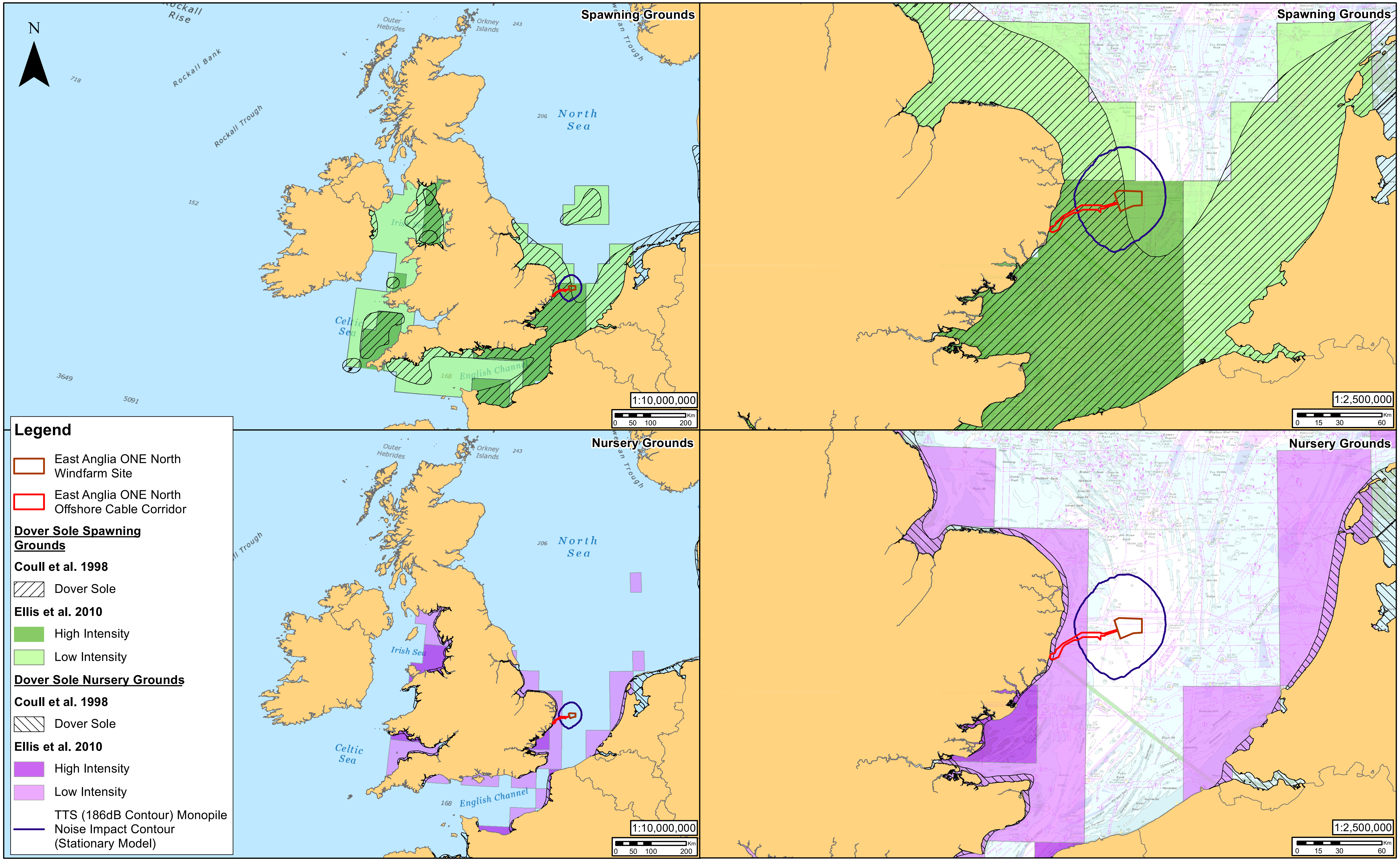

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East Anglia ONE North
Dover Sole Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

Drg No	EA1N-DEV-DRG-IBR-000901	
Rev	1	Datum: WGS 1984 Projection: Zone 31N
Date	16/07/19	
Figure	10.3.1	

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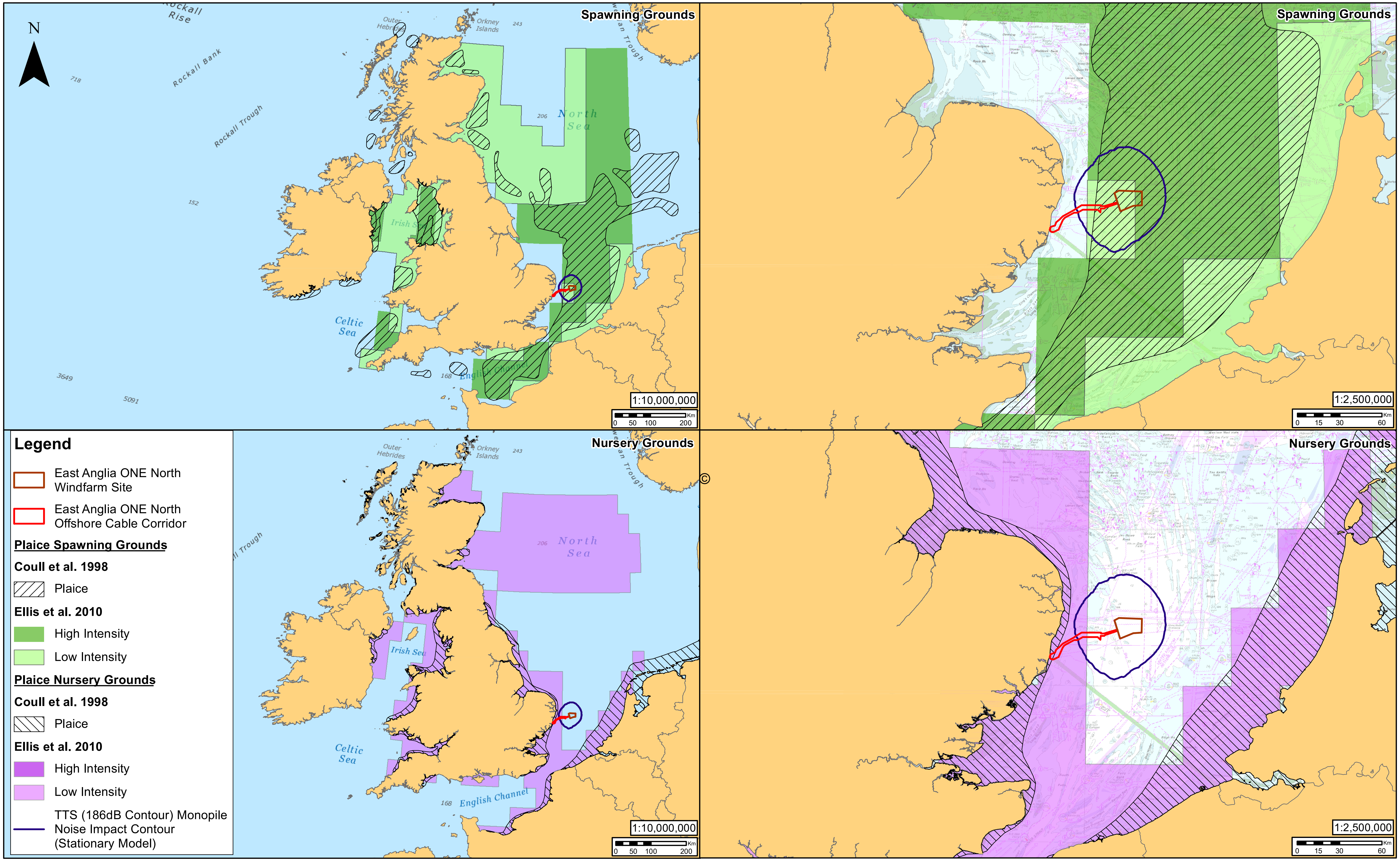

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Plaice Spawning and Nursery Grounds in Relation to Worse Case Noise Impact Contour (Stationary Model)

Drg No	EA1N-DEV-DRG-IBR-000902
Rev	1
Date	16/07/19
Figure	10.3.2

Datum: WGS 1984
Projection: Zone 31N

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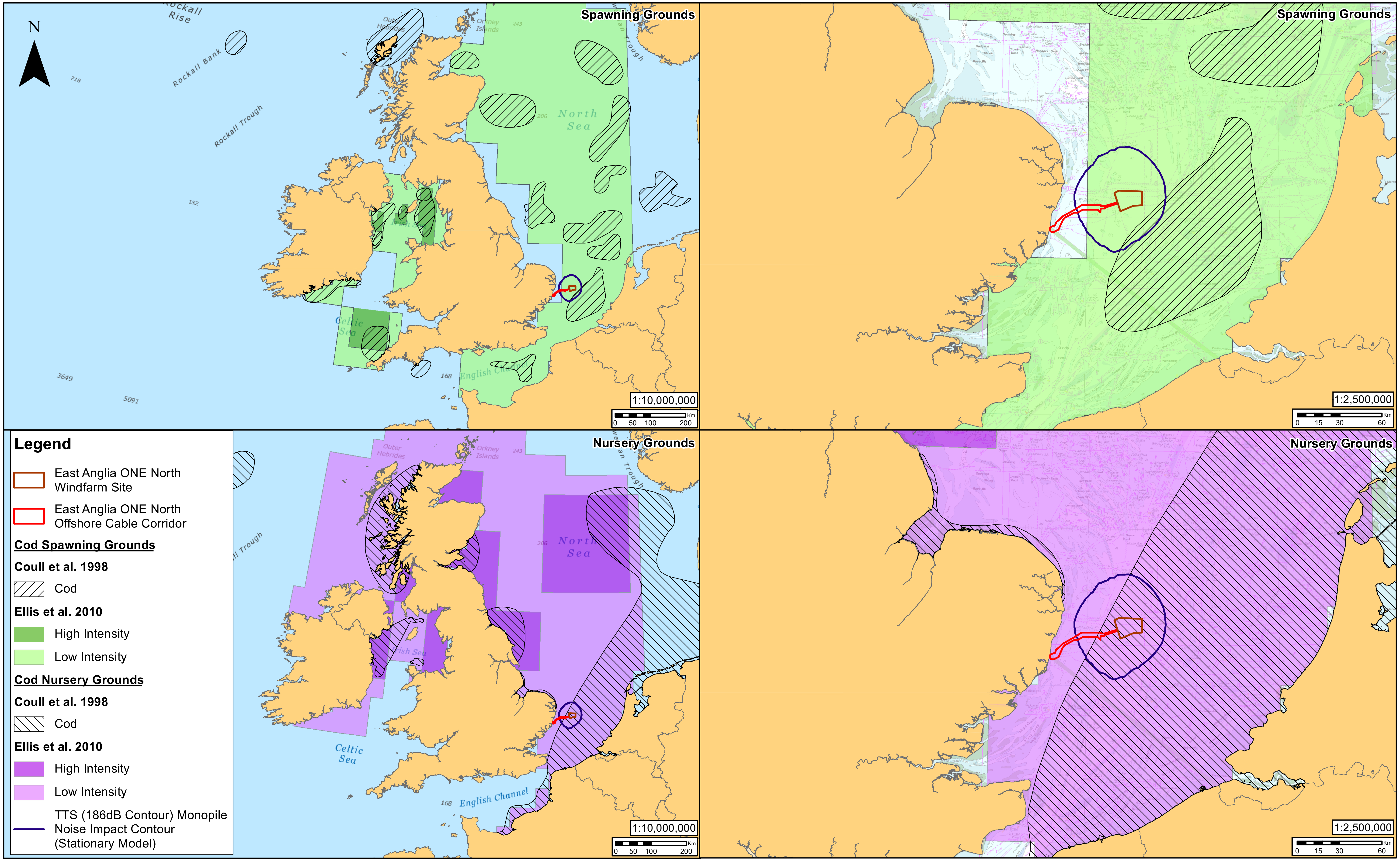

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Cod Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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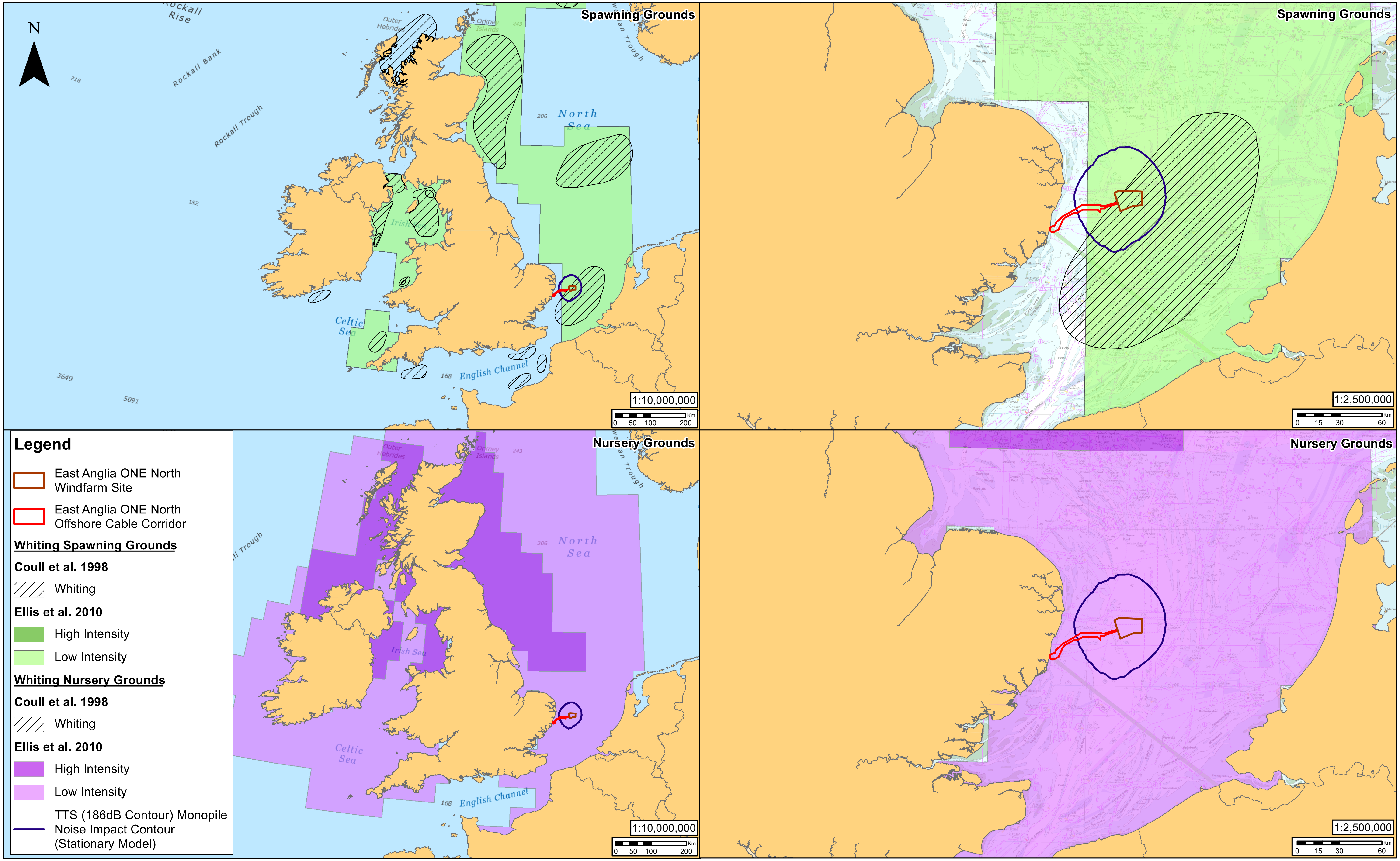

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Whiting Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

Drg No	EA1N-DEV-DRG-IBR-000904
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Date	16/07/19
Figure	10.3.4

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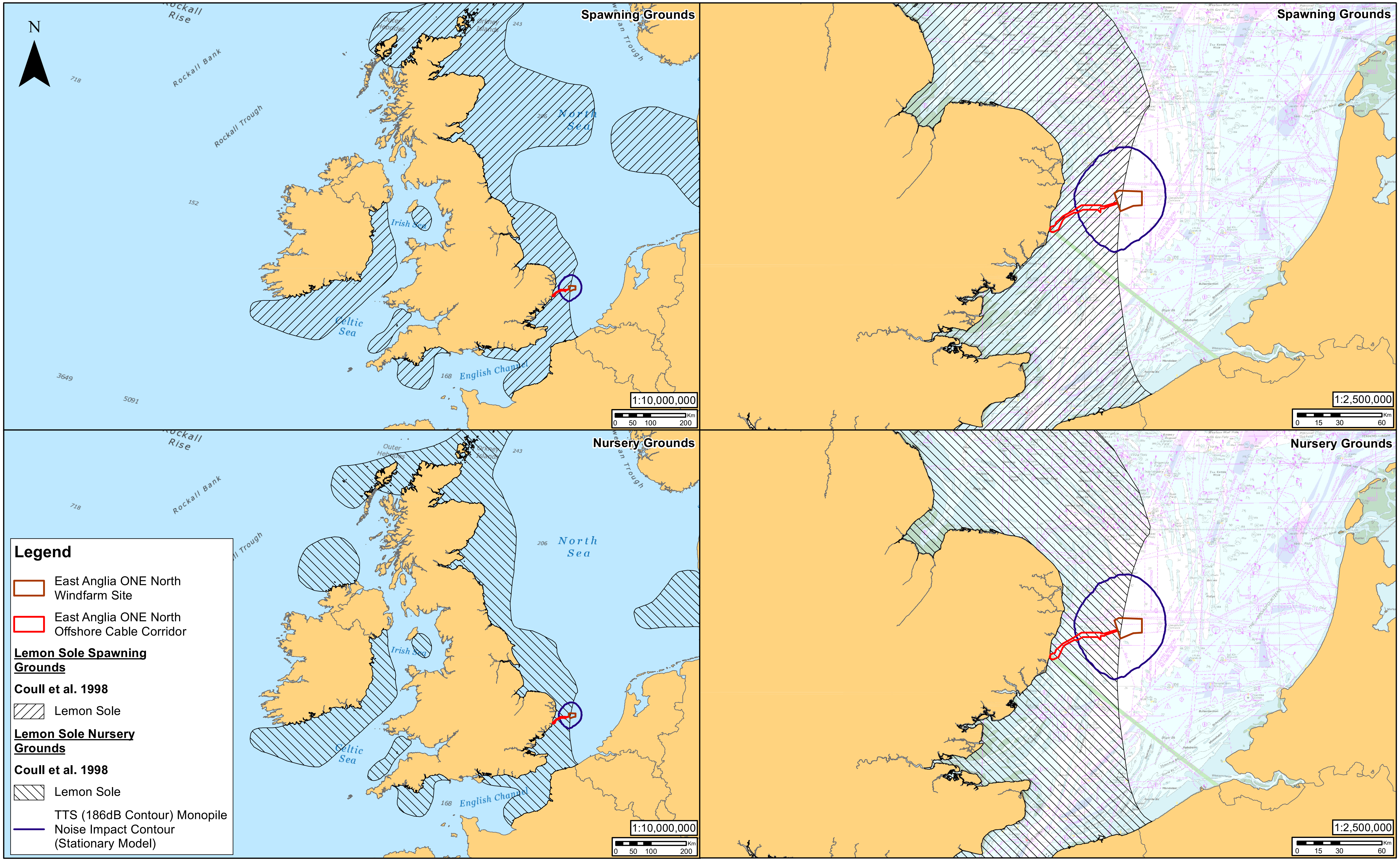

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Lemon Sole Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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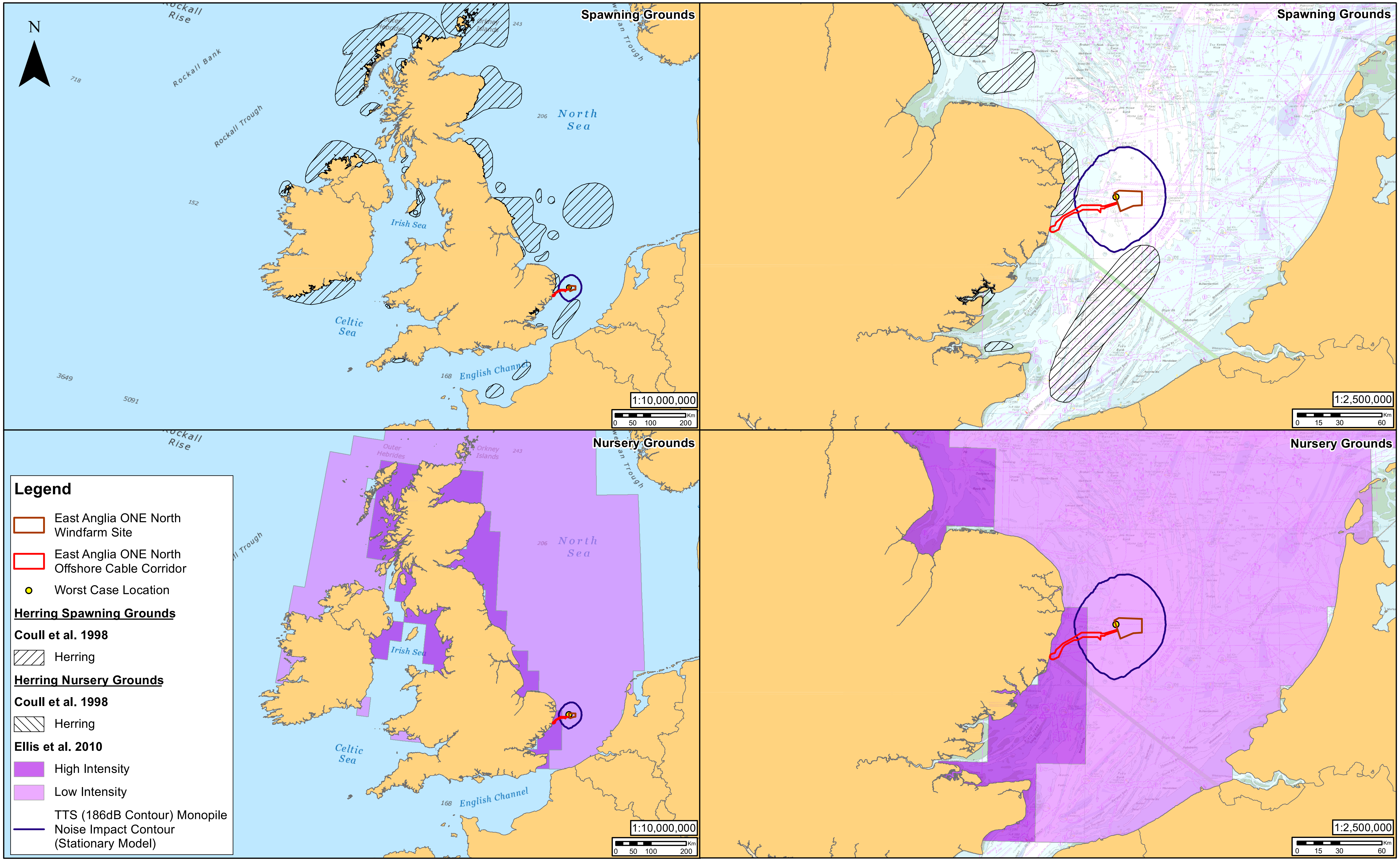

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Herring Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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Figure	10.3.6	

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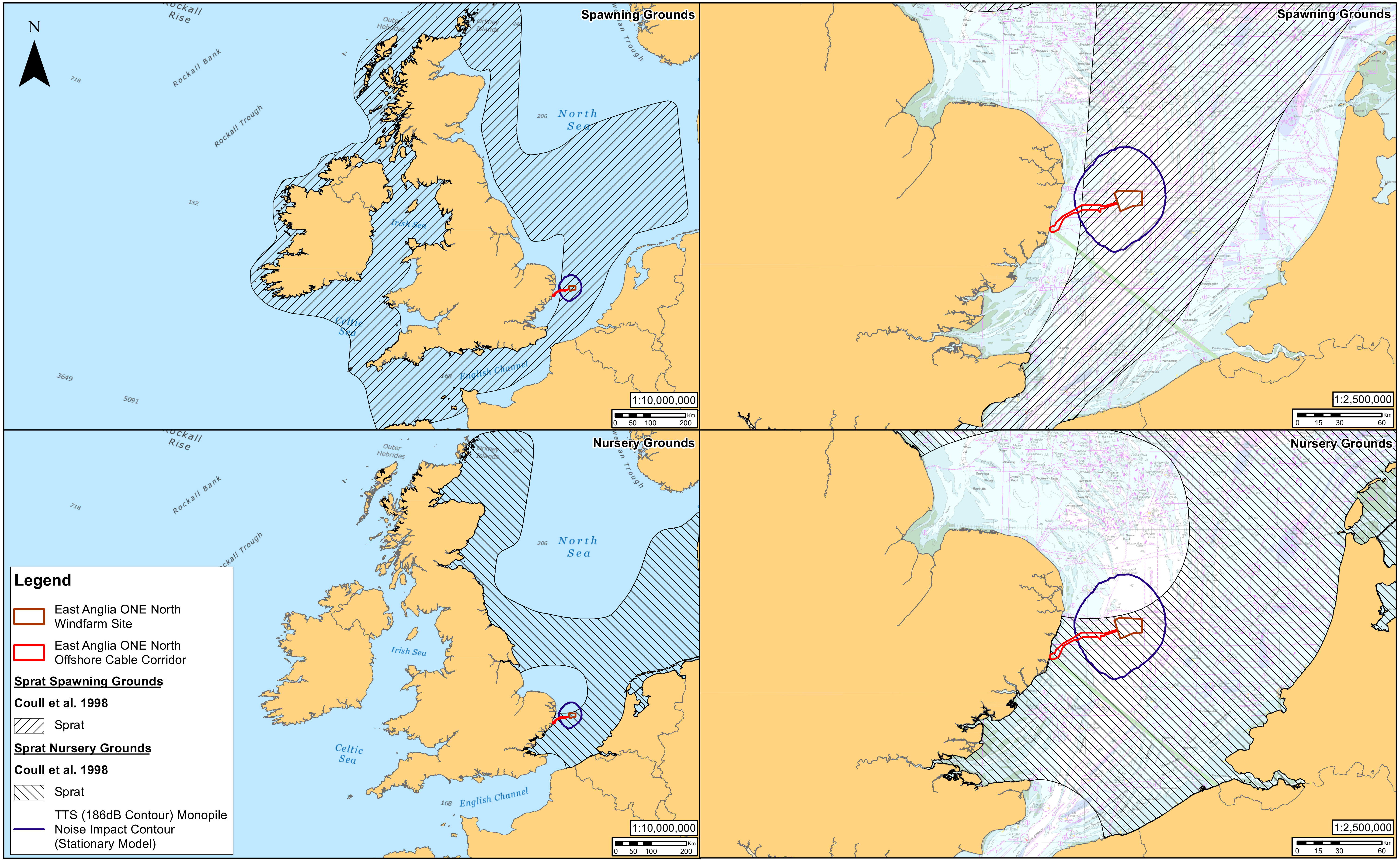

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Sprat Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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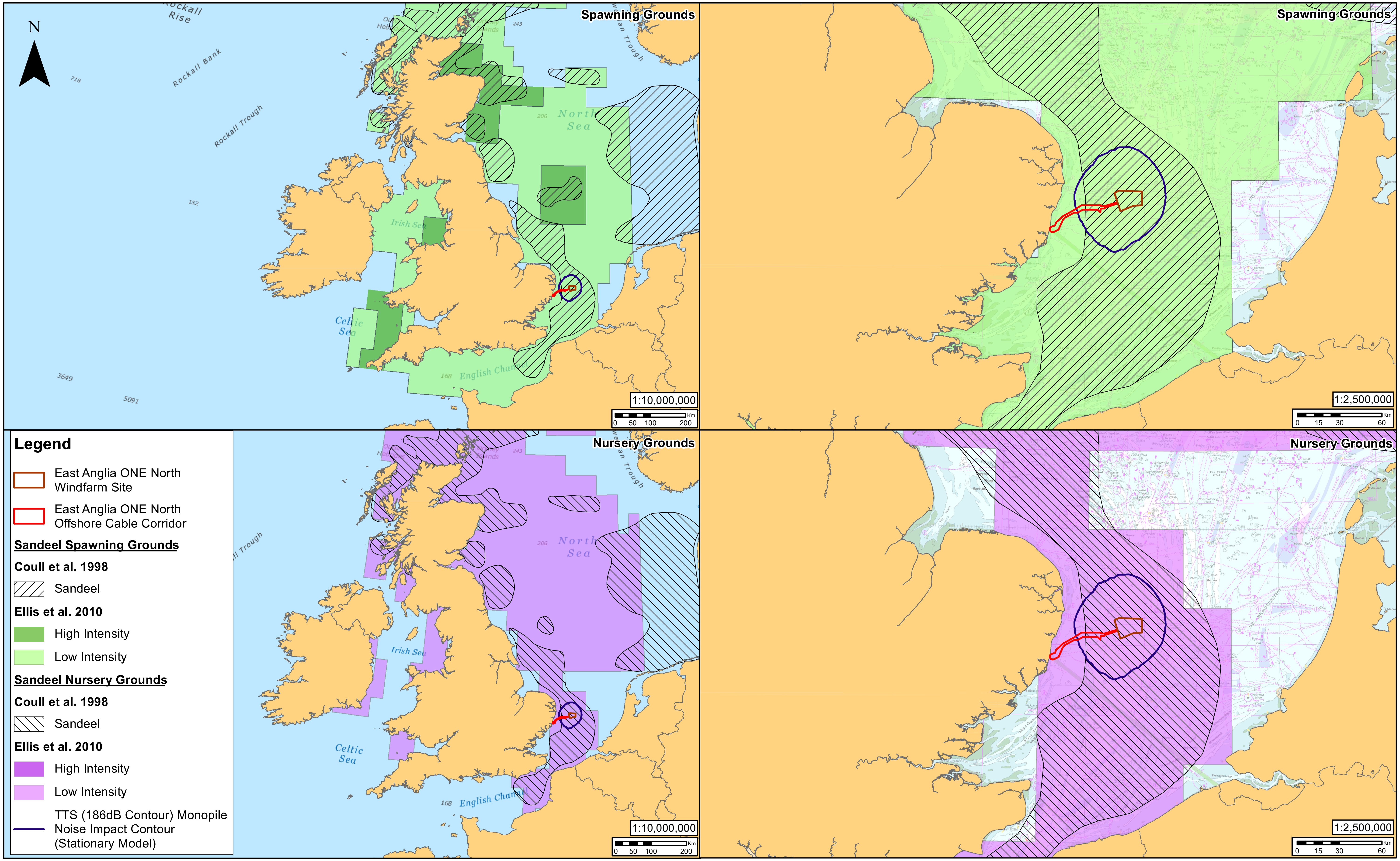

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Sandeel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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Figure	10.3.8	

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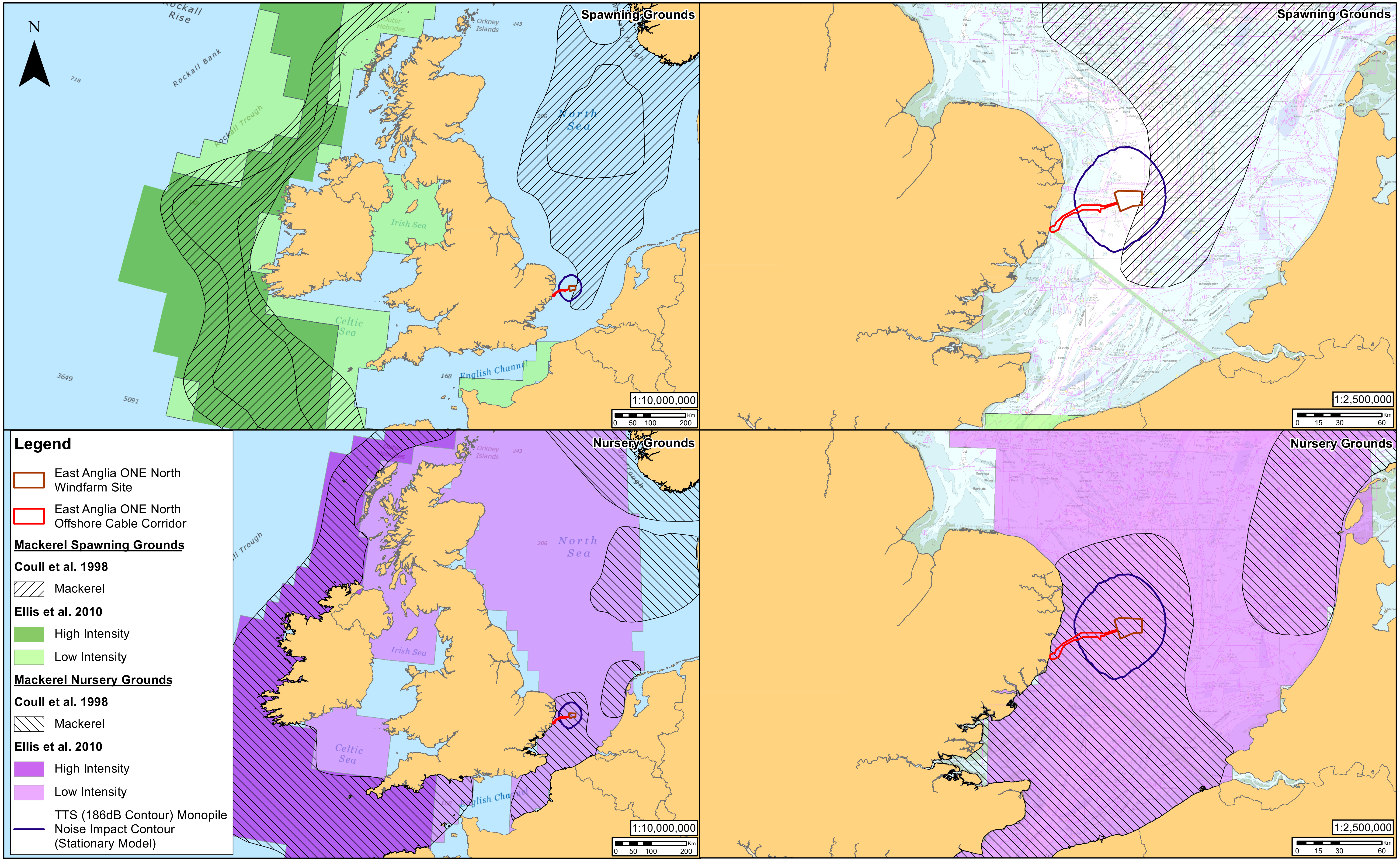

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Mackerel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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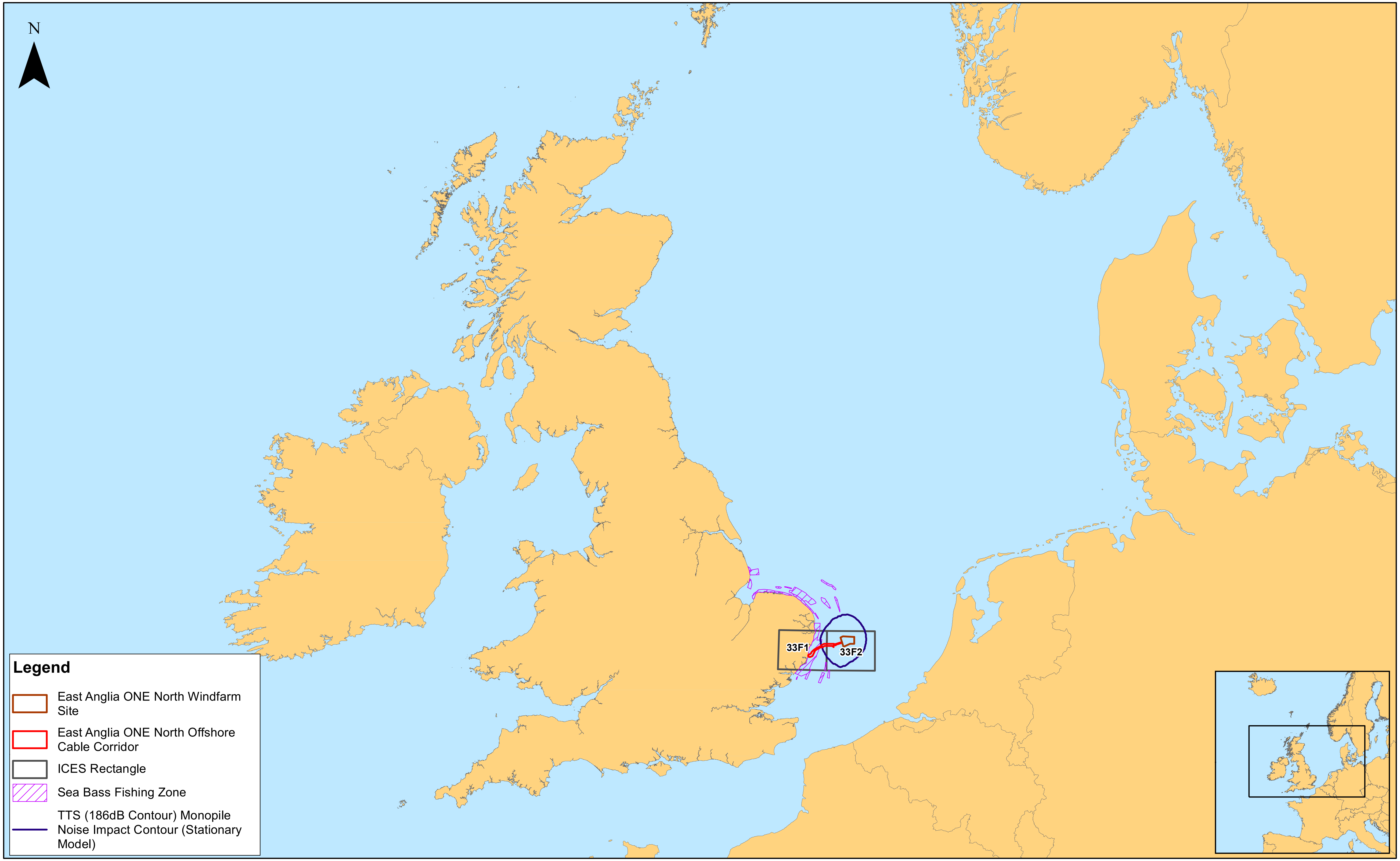

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Sea Bass Historic Fishing Areas in Relation to Worst Case Noise Impact Contour (Stationary Model)

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Figure	10.3.10	

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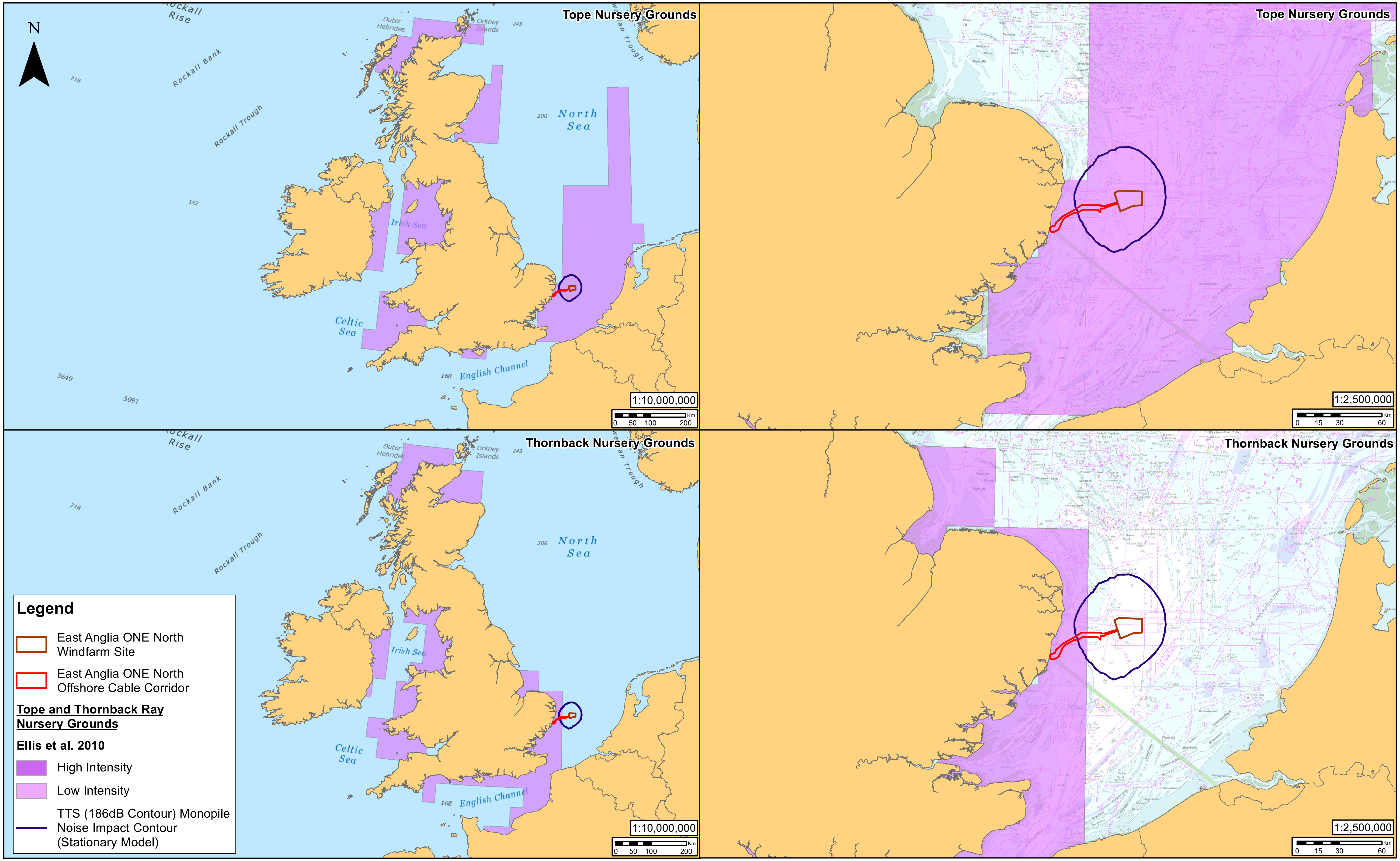

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Tope and Thornback Ray Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)

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Date	16/07/19	
Figure	10.3.11	

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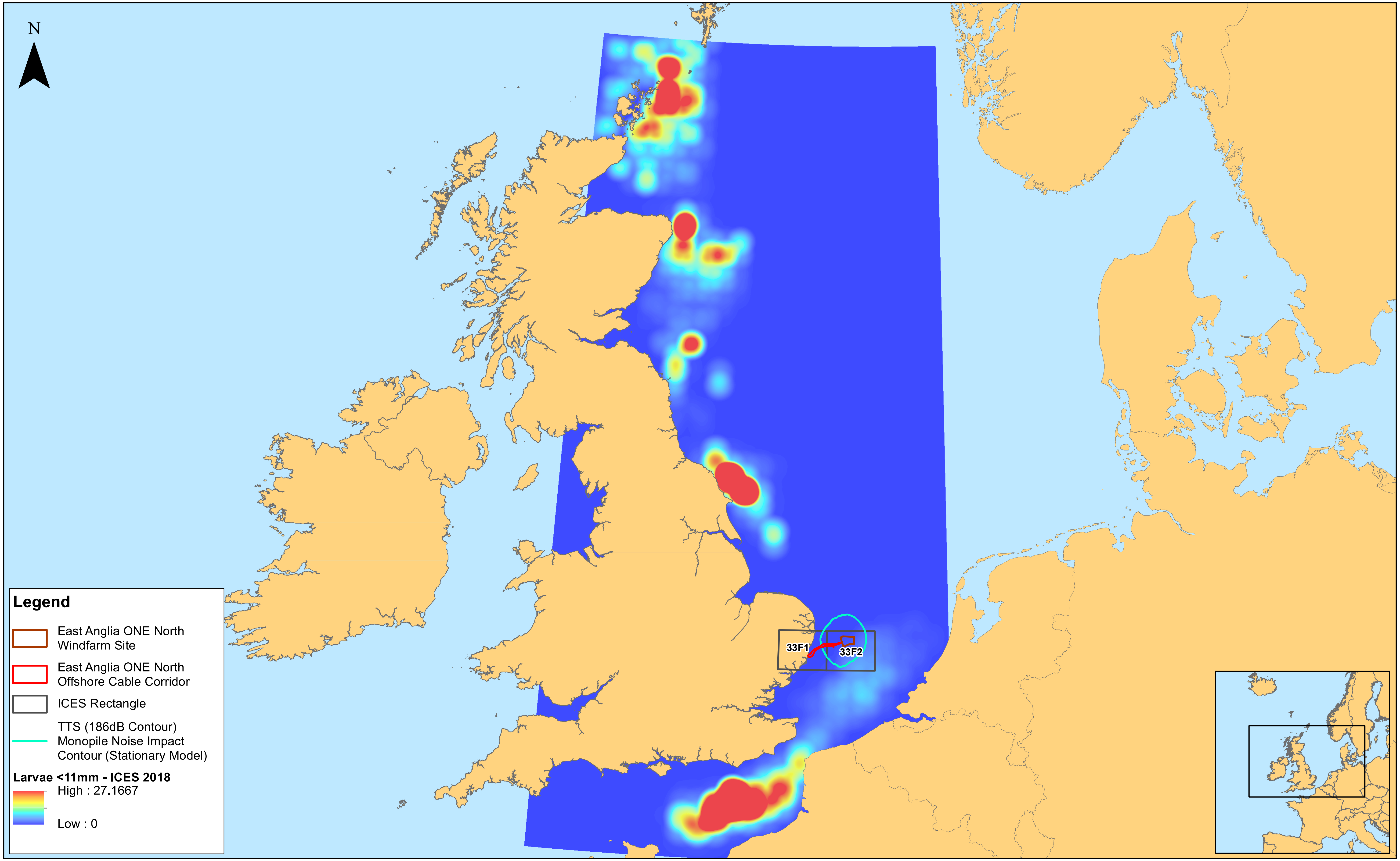

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0 50 100 200 Km

East Anglia ONE North

IHLS Herring Small Larvae Abundance (2007 - 2017) in Relation to Worst Case Noise Impact Contour (Stationary Model)

Drg No	EA1N-DEV-DRG-IBR-000919
Rev	1
Date	16/07/19
Figure	10.3.12

Datum: WGS 1984
Projection: Zone 31N

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10.3.2 References

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