



**SCOTTISHPOWER  
RENEWABLES**

# **East Anglia TWO Offshore Windfarm**

## **Appendix 10.3** **Stationary Modelling Appendix**

### **Environmental Statement Volume 3**

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## 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 TWO project	The proposed project consisting of up to 75 wind turbines, up to four offshore electrical platforms, up to one offshore 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 TWO 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 TWO 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 TWO 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 38km for stationary animals when considering the 186dB SEL<sub>cum</sub> 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<sub>cum</sub>).

**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 mod**

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 <sub>cum</sub>	Mortality and potential mortal injury	2,200	2,100	2,000	2,100	2,000	1,900
	>216 dB SEL <sub>cum</sub>	Recoverable injury	3,500	3,300	3,100	3,300	3,100	3,000
	>186 dB SEL <sub>cum</sub>	TTS	38,000	33,000	26,000	38,000	32,000	26,000
Fish (with swim bladder not involved in hearing)	210 dB SEL <sub>cum</sub>	Mortality and potential mortal injury	7,400	7,000	6,500	2,100	2,000	1,900
	203 dB SEL <sub>cum</sub>	Recoverable injury	15,000	13,000	12,000	7,100	6,700	6,300
	>186 dB SEL <sub>cum</sub>	TTS	38,000	33,000	26,000	38,000	32,000	26,000
Fish (with swim bladder involved in hearing)	207 dB SEL <sub>cum</sub>	Mortality and potential mortal injury	10,000	9,500	8,800	9,800	9,200	8,500
	203 dB SEL <sub>cum</sub>	Recoverable injury	15,000	13,000	12,000	14,000	13,000	12,000
	186 dB SEL <sub>cum</sub>	TTS	38,000	33,000	26,000	38,000	32,000	26,000

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 *Error! Reference source not found.*
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 TWO project
Fish with no swim bladder or other gas chamber	<p>Sole <i>Solea solea</i></p> <p>Plaice <i>Pleuronectes platessa</i></p> <p>Sandeels <i>Ammodytidae spp.</i></p> <p>Mackerel <i>Scomber scombus</i></p> <p>Solenette <i>Buglossidium luteum</i></p> <p>Elasmobranchs <i>Chondrichthyes spp.</i></p> <p>River and sea lamprey <i>Lampetra fluviatilis</i> and <i>Petromyzon marinus</i></p> <p>Lesser weever <i>Echiichthys vipera</i></p>
Fish with swim bladder in which hearing does not involve the swim bladder or other gas volume	<p>Atlantic salmon <i>Salmo salar</i></p> <p>Sea trout <i>Salmo trutta</i></p> <p>Smelt(*) <i>Osmerus eperlanus</i></p> <p>Seabass(*) <i>Dicentrarchus labrax</i></p> <p>Grey gurnard(*) <i>Eutrigla gurnardus</i></p> <p>Gobies <i>Gobiidae spp.</i></p>
Fish in which hearing involves a swim bladder or other gas volume	<p>Herring <i>Clupea herrangus</i></p> <p>Sprat <i>Sprattus spp.</i></p> <p>Cod <i>Gadus morhua</i></p> <p>Whiting <i>Merlangius merlangius</i></p> <p>European eel(*) <i>Anguilla Anguilla</i></p> <p>Allis and Twaite Shad <i>Alosa alosa</i> and <i>Alosa fallax</i></p>

#### 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<sub>cum</sub>) and recoverable injury at ranges of 3.5km (216dB SEL<sub>cum</sub>) 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 7.4km (210dB SEL<sub>cum</sub>) 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<sub>cum</sub>) 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<sub>cum</sub>) and recoverable injury at ranges up to a maximum of 15km (203dB SEL<sub>cum</sub>) (**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<sub>cum</sub> or >207 dB SPL<sub>peak</sub>). The criteria are based on work by Bolle et al. (2012) who reported no damage to larval fish at SEL<sub>cum</sub> 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<sub>cum</sub> or >207 dB SPL<sub>peak</sub>) 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 7.4km (210dB SEL<sub>cum</sub>) (**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

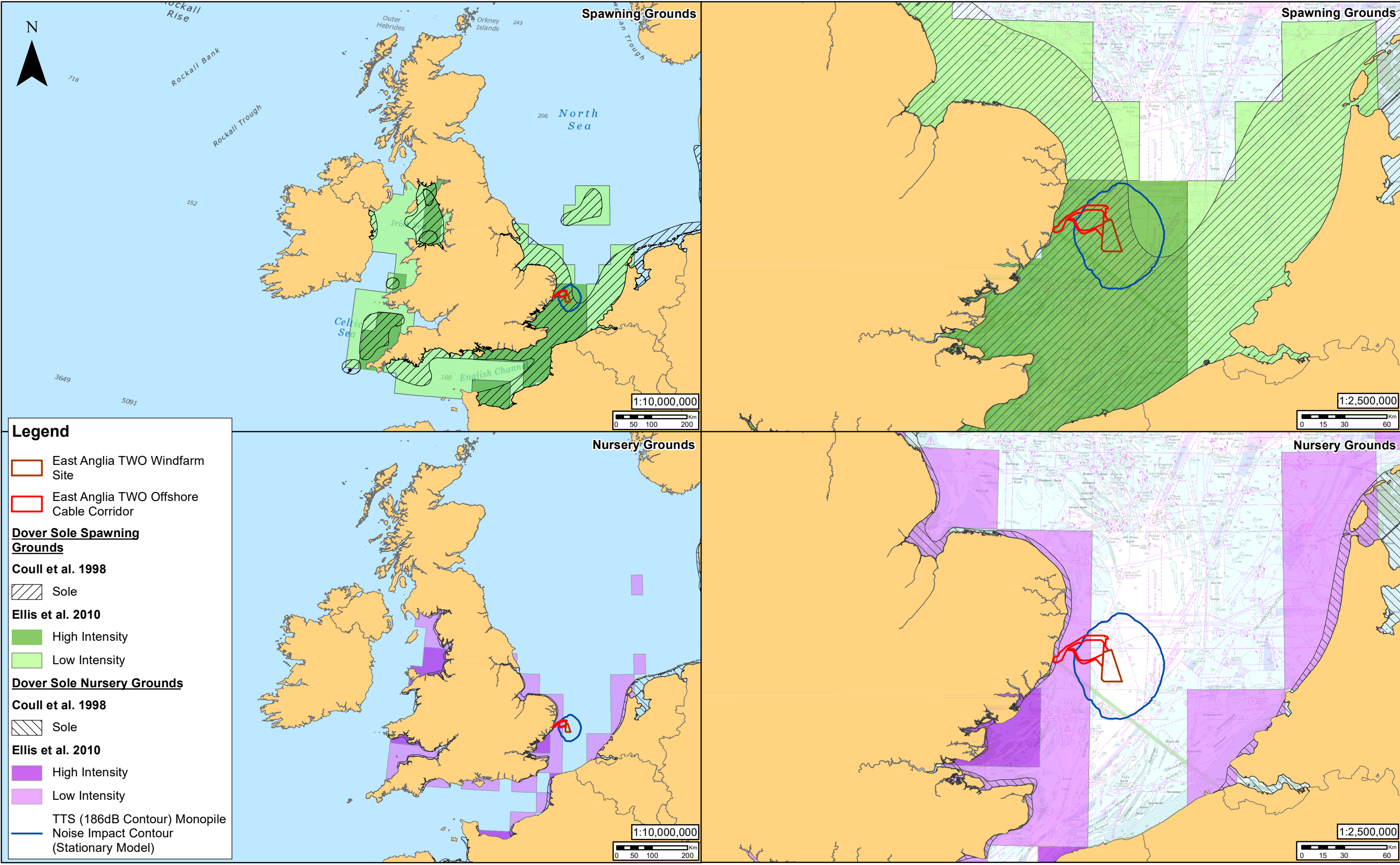
19. There are no specific criteria currently published in respect of shellfish species, however studies on lobsters have shown no effect on mortality, appendage loss or the ability of animals to regain normal posture after exposure to very high sound levels (>220 dB) (Payne et al. 2007). Similarly, studies 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

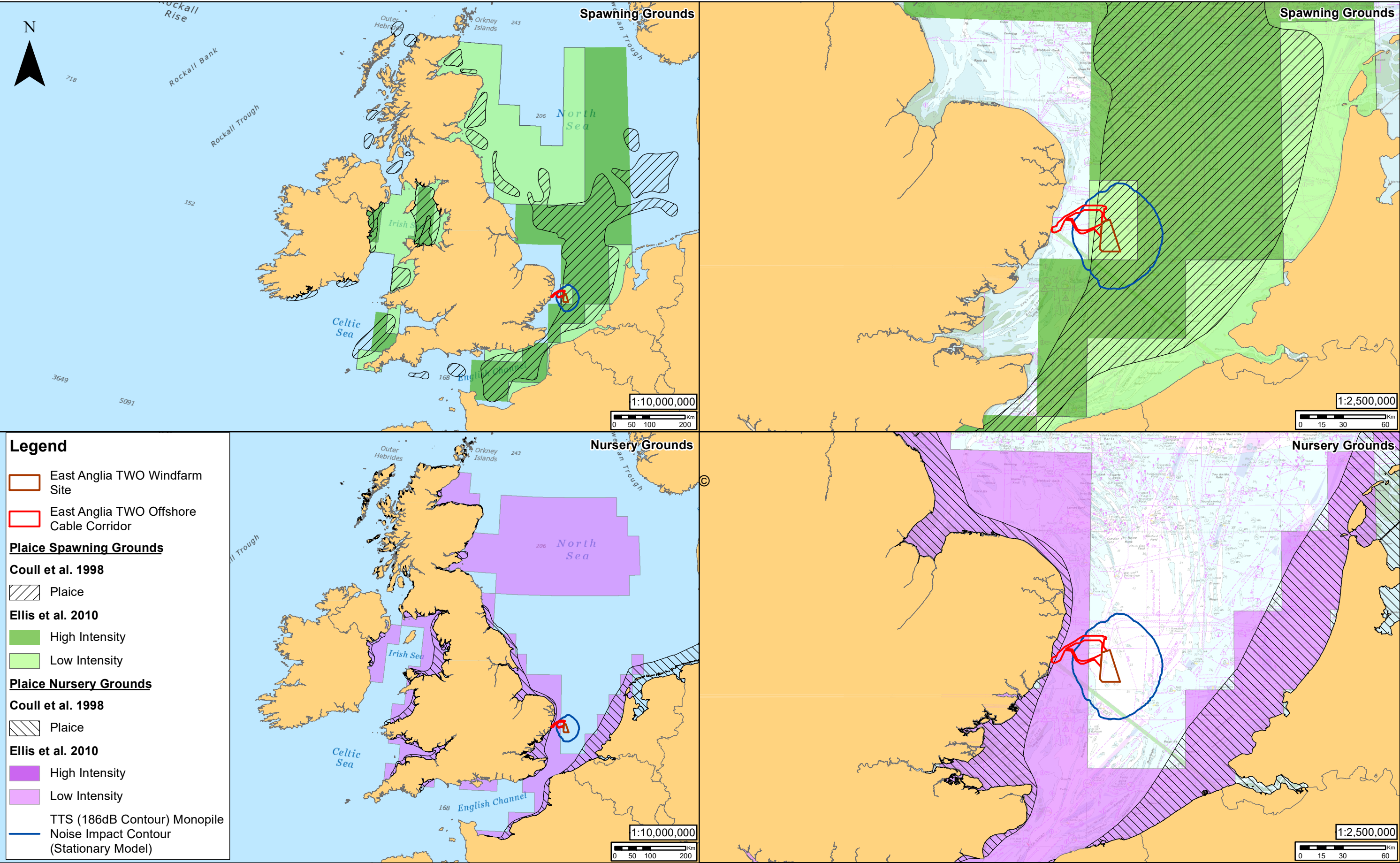
21. The outputs of the noise modelling for the spatial worst case scenario indicate that distances at which TTS may occur would increase to up to 38km (**Table A10.1**) from the installation of both pin piles and monopiles. Behavioural responses are anticipated to occur within this range and potentially 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 39.2 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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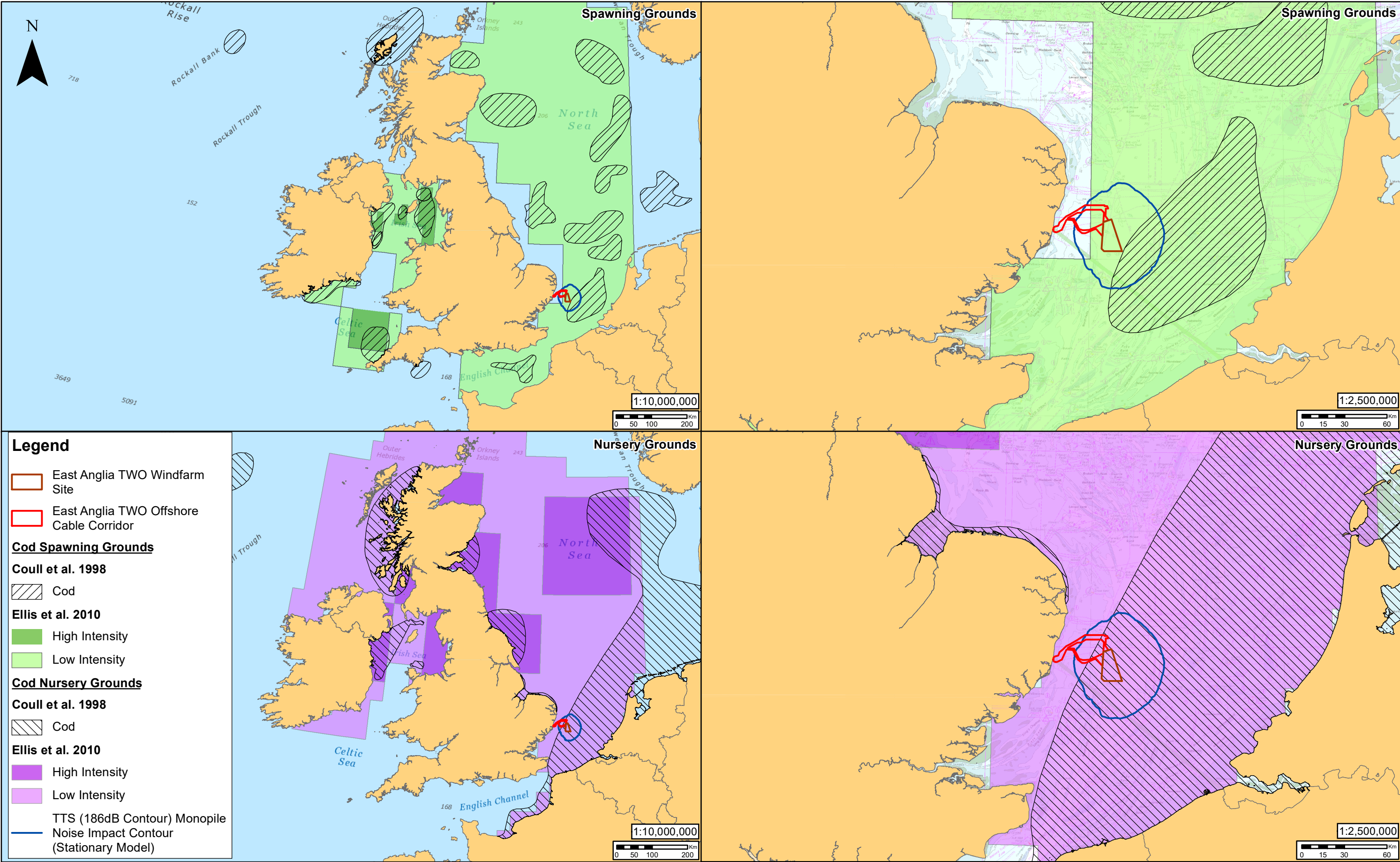
																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
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										<div><h1>East Anglia TWO</h1><h2>Plaice Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)</h2></div> <div><small>Source: © Subacoustech, 2019. © Cefas, 2018. Contains OS data © Crown copyright and database rights, 2019. © British Crown and OceanWise, 2019. All rights reserved. Licence No. EMS-EK001-548150. Not to be used for navigation. Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors.</small> <small>This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</small></div>	Drg No		EA2-DEV-DRG-IBR-000746	
											Rev	1	Datum: WGS 1984 Projection: Zone 31N	
	1	25/06/2019	FC	First Issue.	Checked:	KC					Date	25/06/19		
	Rev	Date	By	Comment	Approved:	PP					Figure	10.3.2		





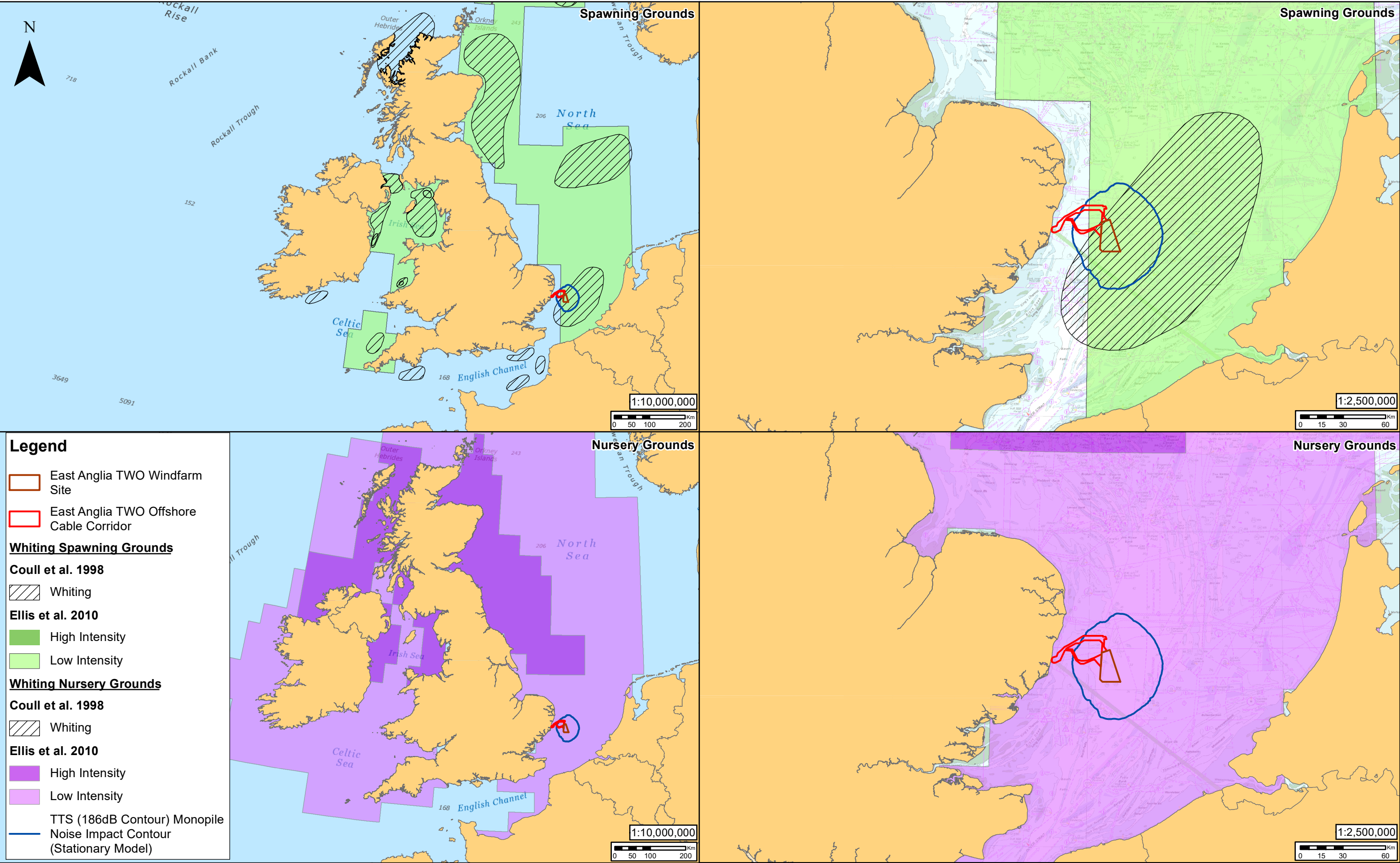
									Scale @ A3	<p>Source: © Subacoustech, 2019. © Cefas, 2018. Contains OS data © Crown copyright and database rights, 2019. © British Crown and OceanWise, 2019. All rights reserved. Licence No: EMS-EK001-548150. Not to be used for navigation. Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors.</p> <p>This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</p>
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# East Anglia TWO

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

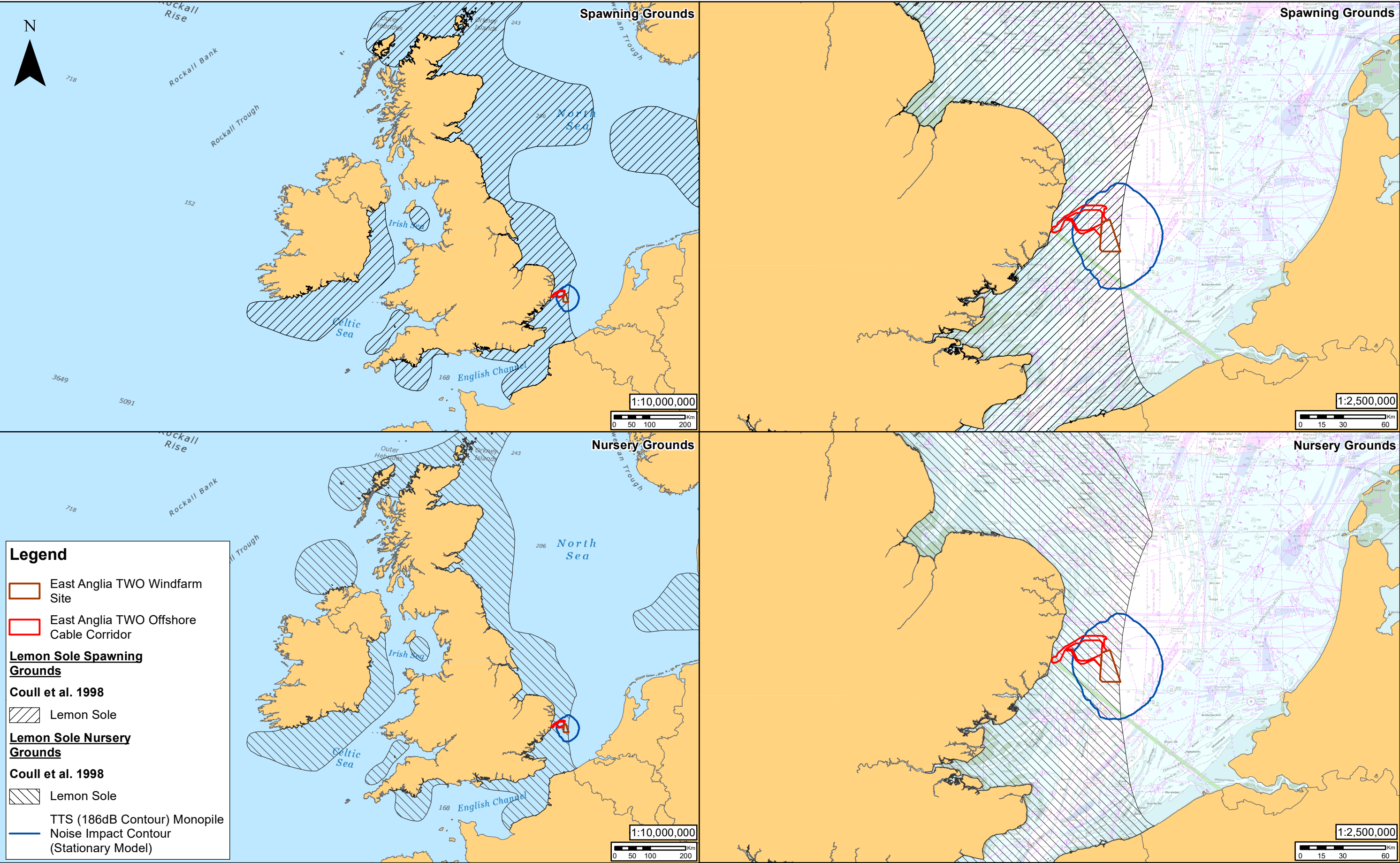
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Date	25/06/19		
Figure	10.3.3		






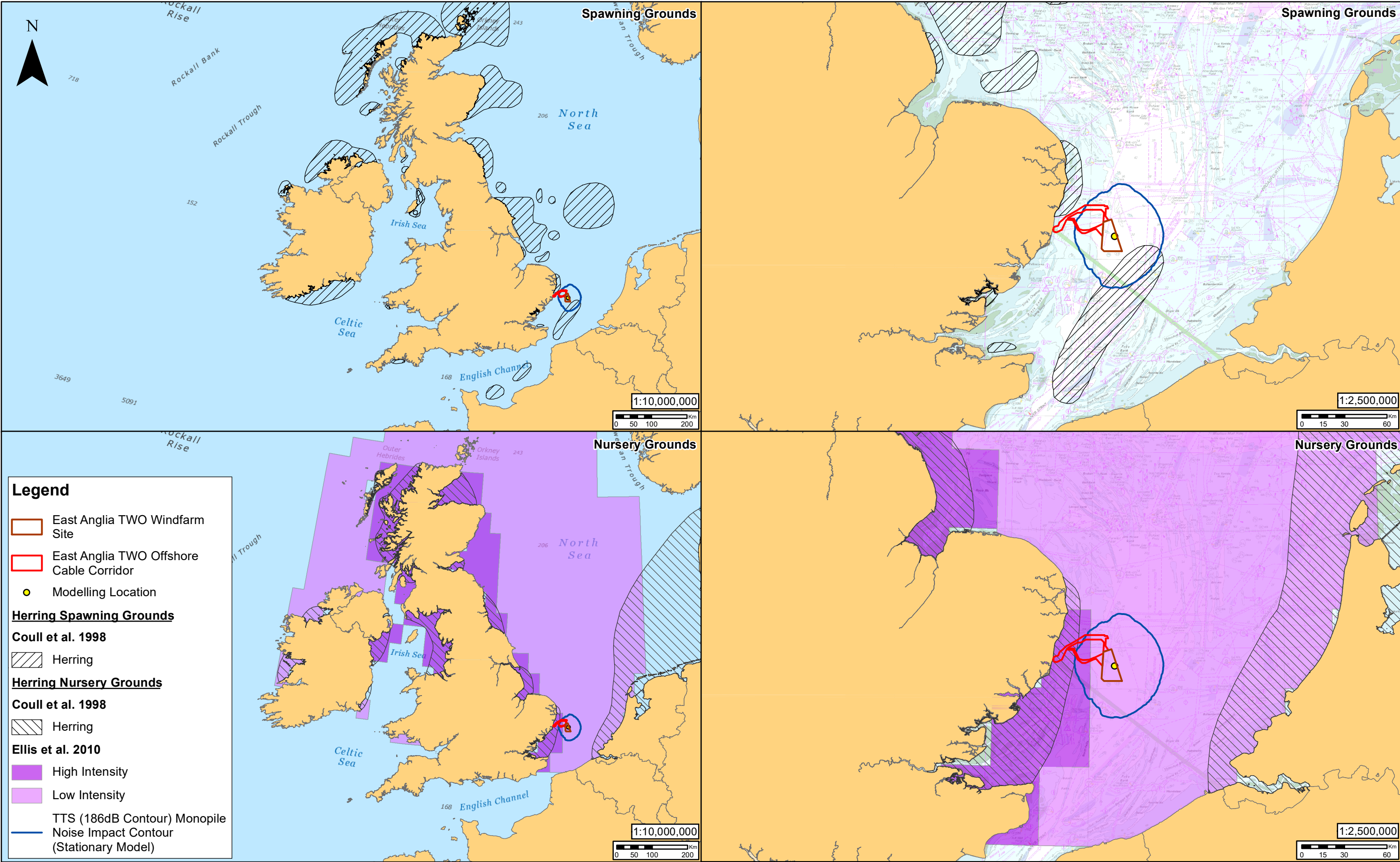
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					Prepared:	FC		Scale @ A3			<b>Rev</b>	1	Datum: WGS 1984 Projection: Zone 31N
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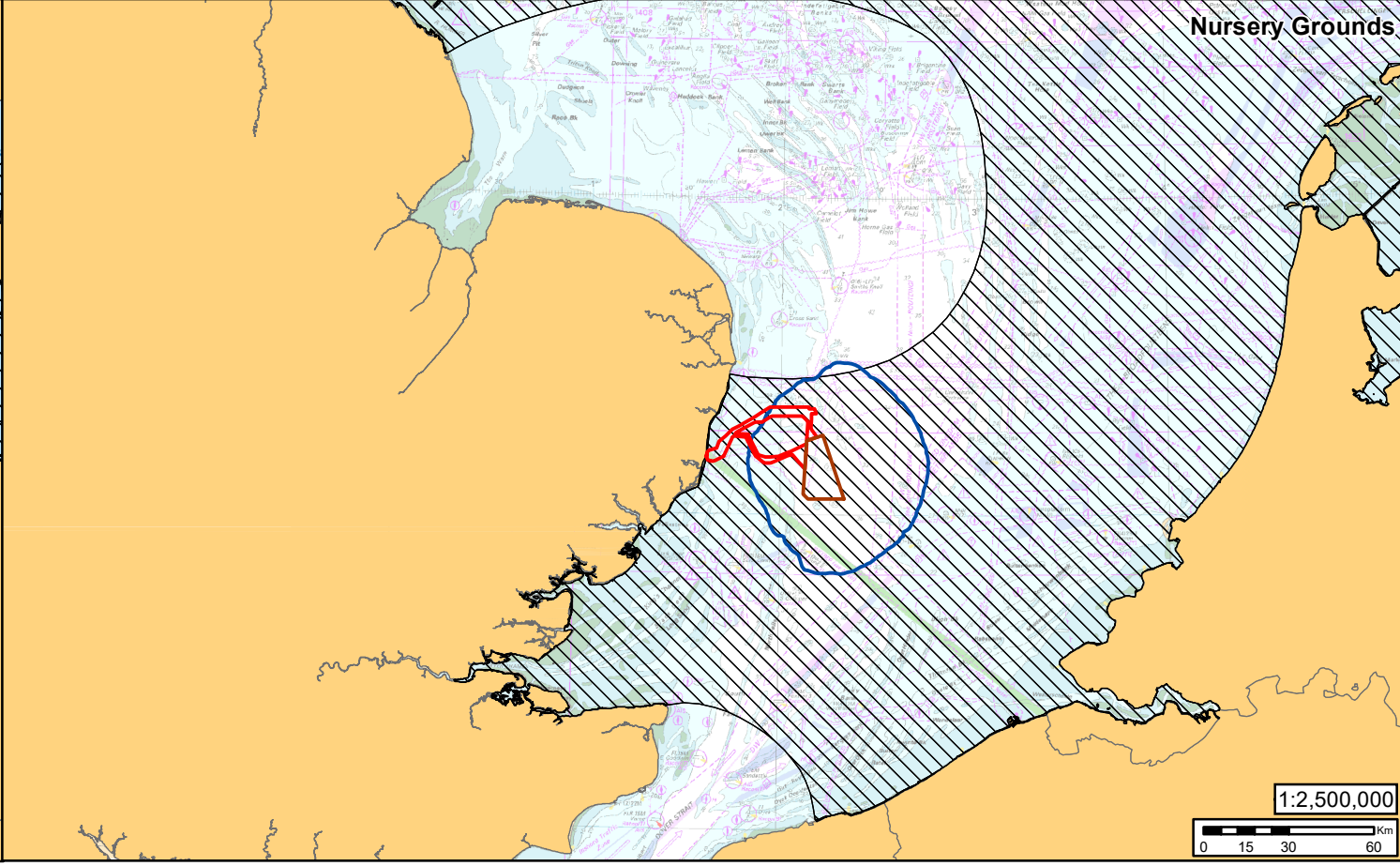
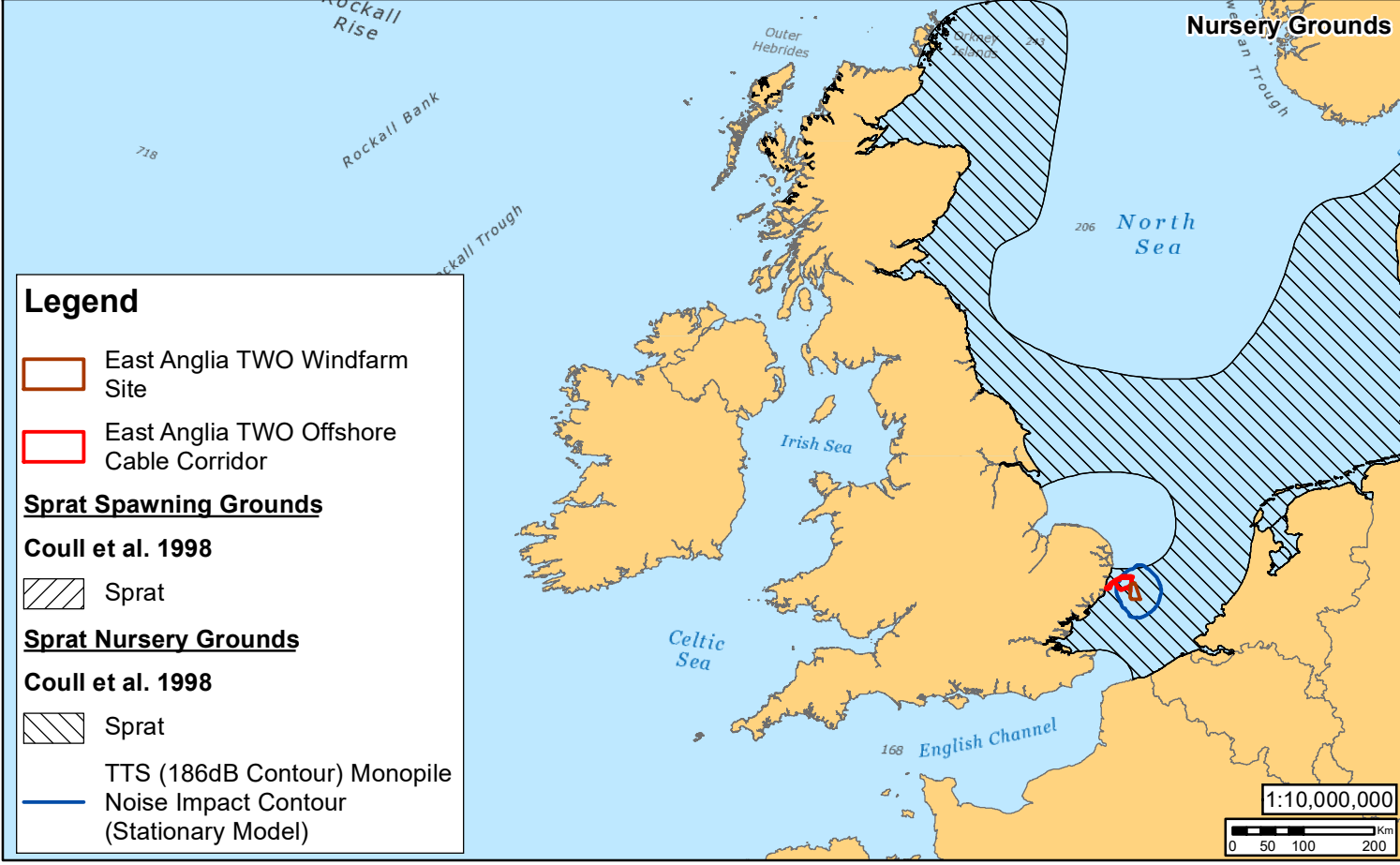
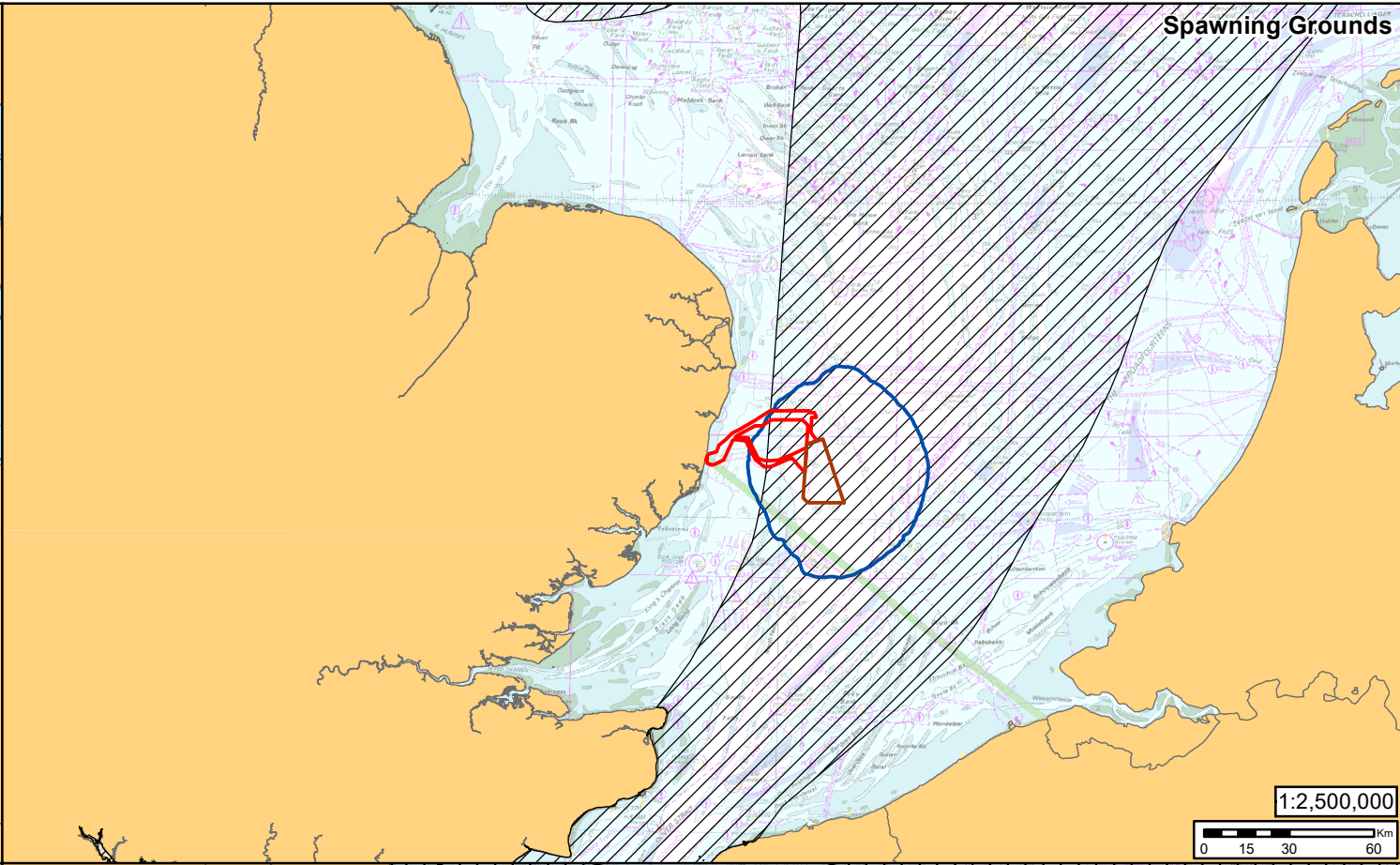
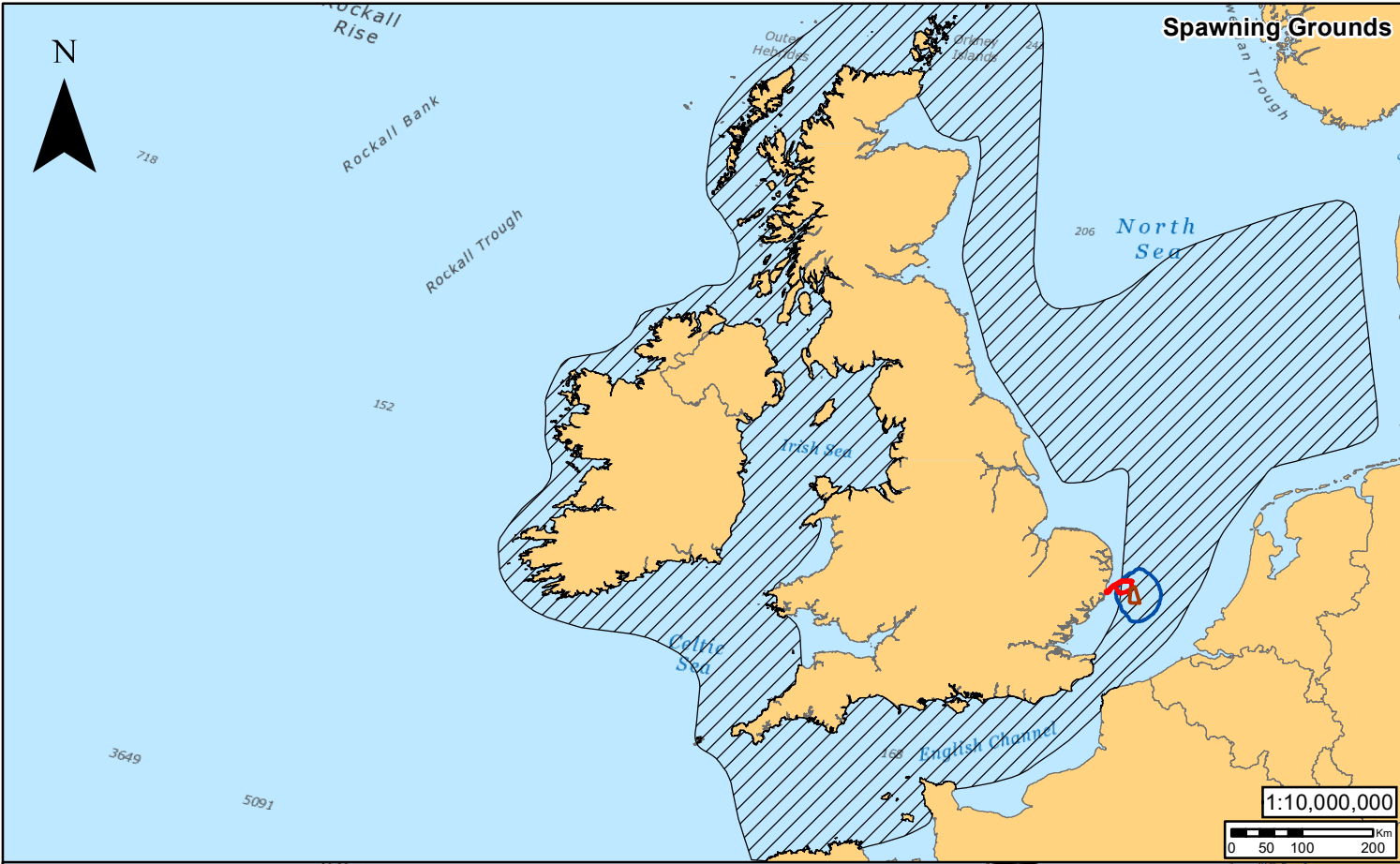
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	1	25/06/2019	FC	First Issue.	Checked:	KC	<small>Source: © Suba-coustech, 2019. © Cefas, 2018. Contains OS data © Crown copyright and database rights, 2019. © British Crown and OceanWise, 2019. All rights reserved. Licence No. E143-18/001-04818/0. Not to be used for navigation. Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors.</small>				
	Rev	Date	By	Comment	Approved:	PP	<small>This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</small>				
<div>East Anglia TWO Lemon Sole Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)</div>									<div>Drg No Rev Date Figure</div>	<div>EA2-DEV-DRG-IBR-000749 1 25/06/19 10.3.5</div>	<div>Datum: Projection: Zone 31N</div>





																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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**Legend**

East Anglia TWO Windfarm Site

East Anglia TWO Offshore Cable Corridor

**Sprat Spawning Grounds**

Coull et al. 1998

Sprat

**Sprat Nursery Grounds**

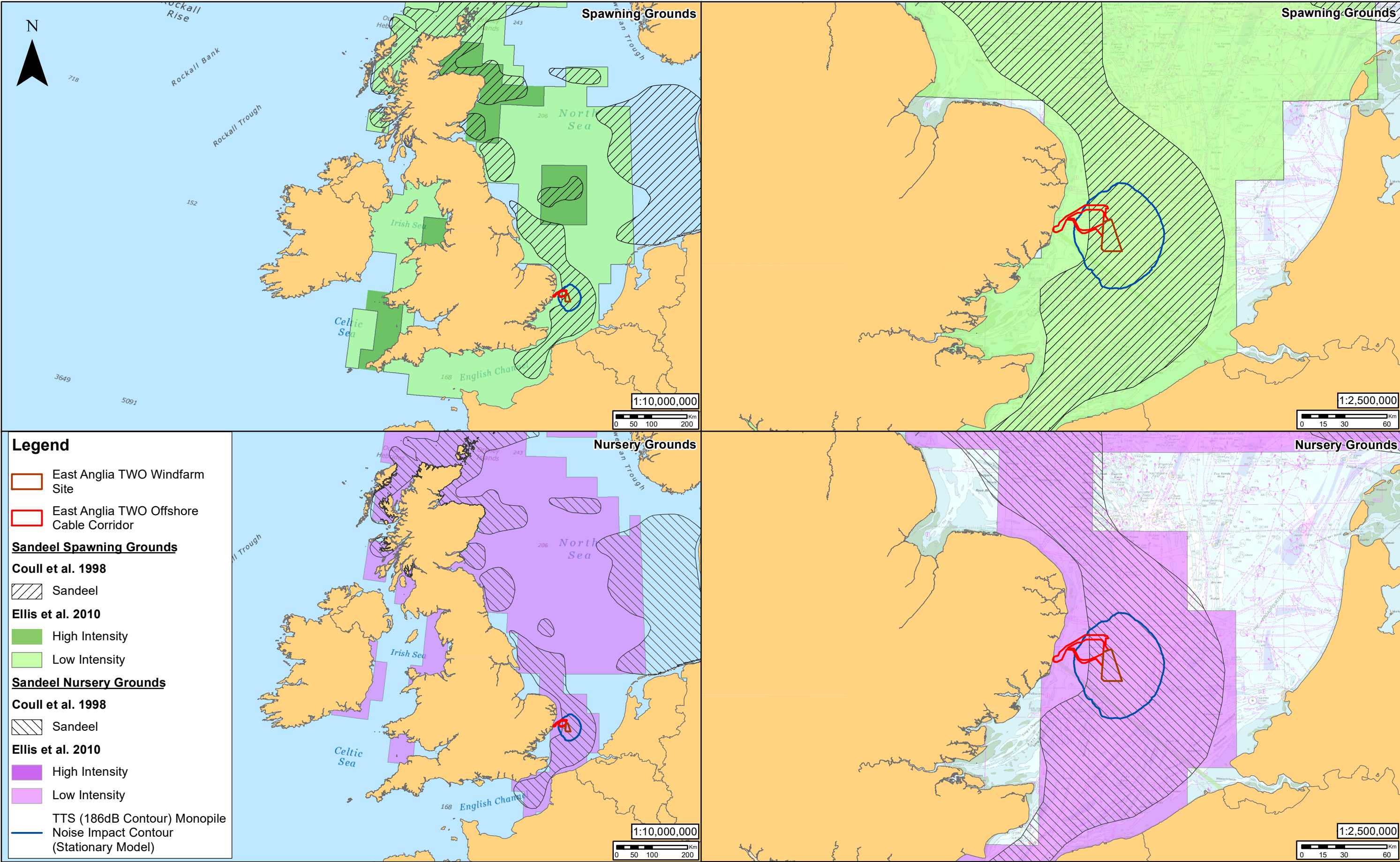
Coull et al. 1998


Sprat

TTS (186dB Contour) Monopile Noise Impact Contour (Stationary Model)

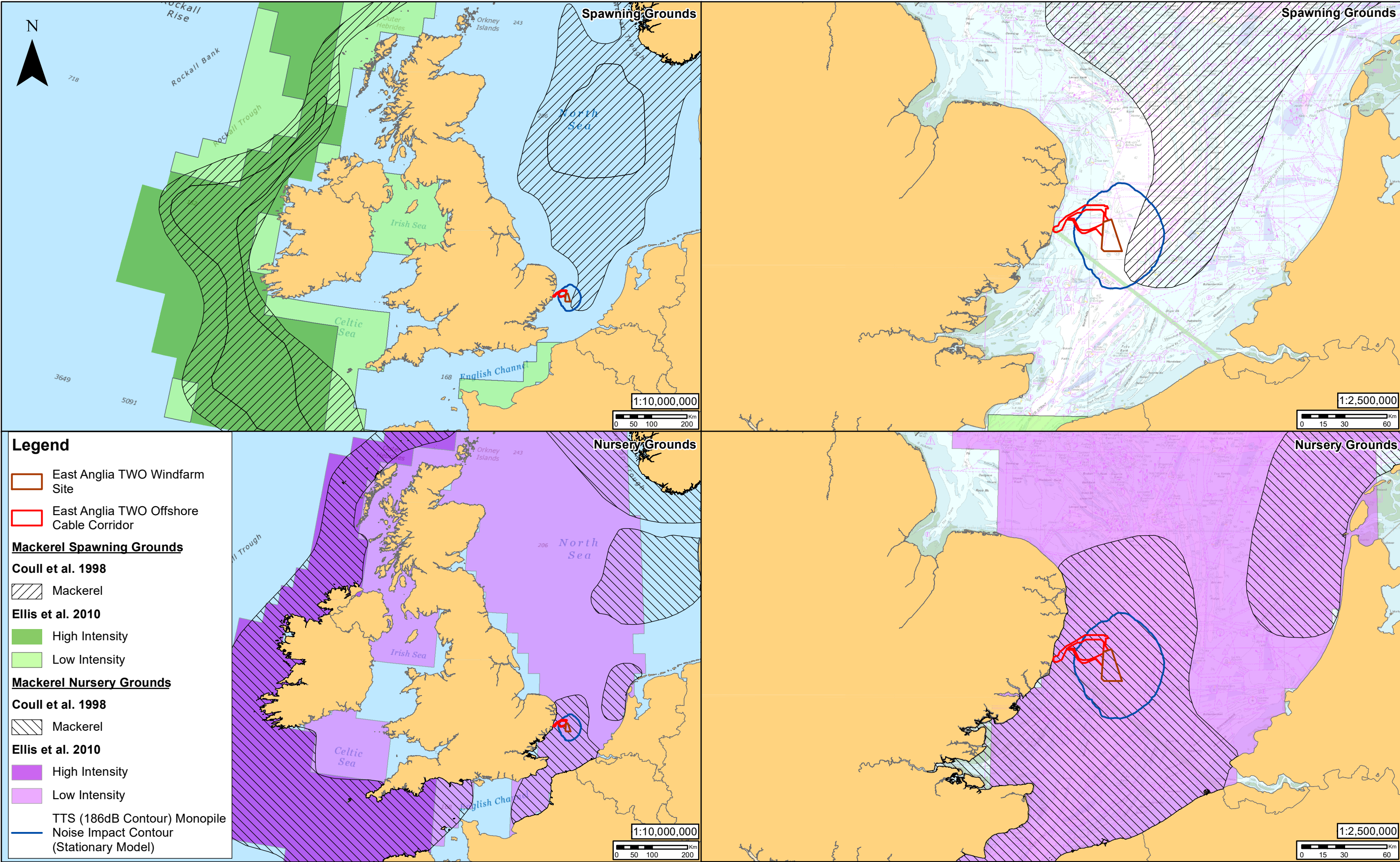
<div><div><div></div></div><div>SCOTTISHPOWER RENEWABLES</div></div>										<div><div>East Anglia TWO</div><div>Sprat Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)</div></div>	<div>Drg No</div>	EA2-DEV-DRG-IBR-000751	
											<div>Rev</div>	1	<div>Datum: WGS 1984 Projection: Zone 31N</div>
											<div>Date</div>	25/06/19	
											<div>Figure</div>	10.3.7	

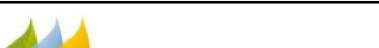


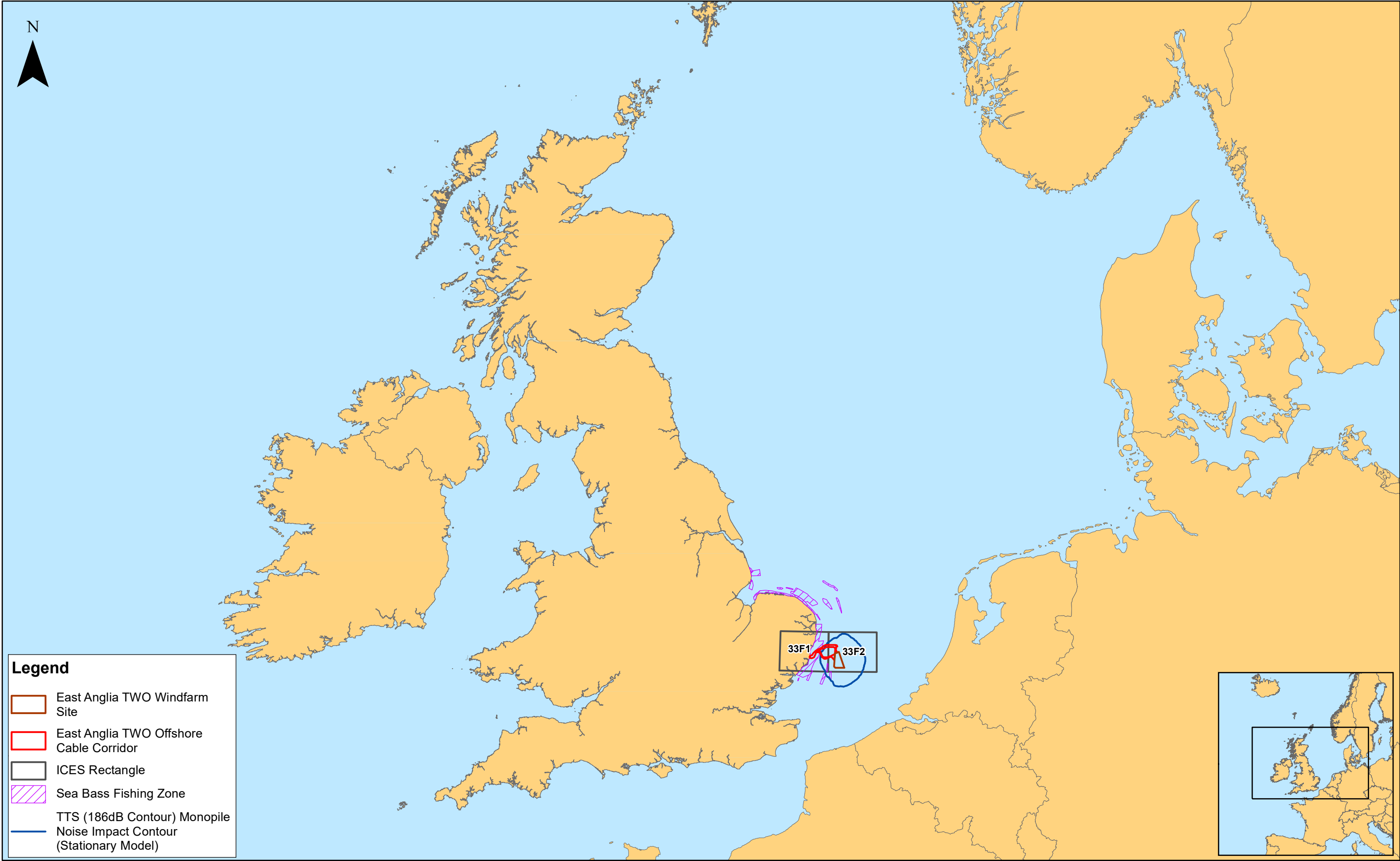



									<div>Source: © Subacoustech, 2019. © Cefas, 2018. Contains OS data © Crown copyright and database rights, 2019. © British Crown and OceanWise, 2019. All rights reserved. Licence No. EMS-EK001-548150. Not to be used for navigation. Service Layer Credits: Sources: Esri, GEBCO, NOAA, National Geographic, Garmin, HERE, Geonames.org, and other contributors.</div> <div>This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</div>	<div><b>East Anglia TWO</b> Sandeel Spawning and Nursery Grounds in Relation to Worst Case Noise Impact Contour (Stationary Model)</div>	<b>Drg No</b>	EA2-DEV-DRG-IBR-000752		
	<b>Rev</b>	1	<b>Datum:</b> WGS 1984 <b>Projection:</b> Zone 31N											
	<b>Date</b>	25/06/19												
	<b>Rev</b>	<b>Date</b>	<b>By</b>	<b>Comment</b>	<b>Approved:</b>	PP	<b>Figure</b>	10.3.8						
				Prepared:	FC	Scale @ A3								
1	25/06/2019	FC	First Issue.	Checked:	KC									

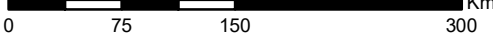




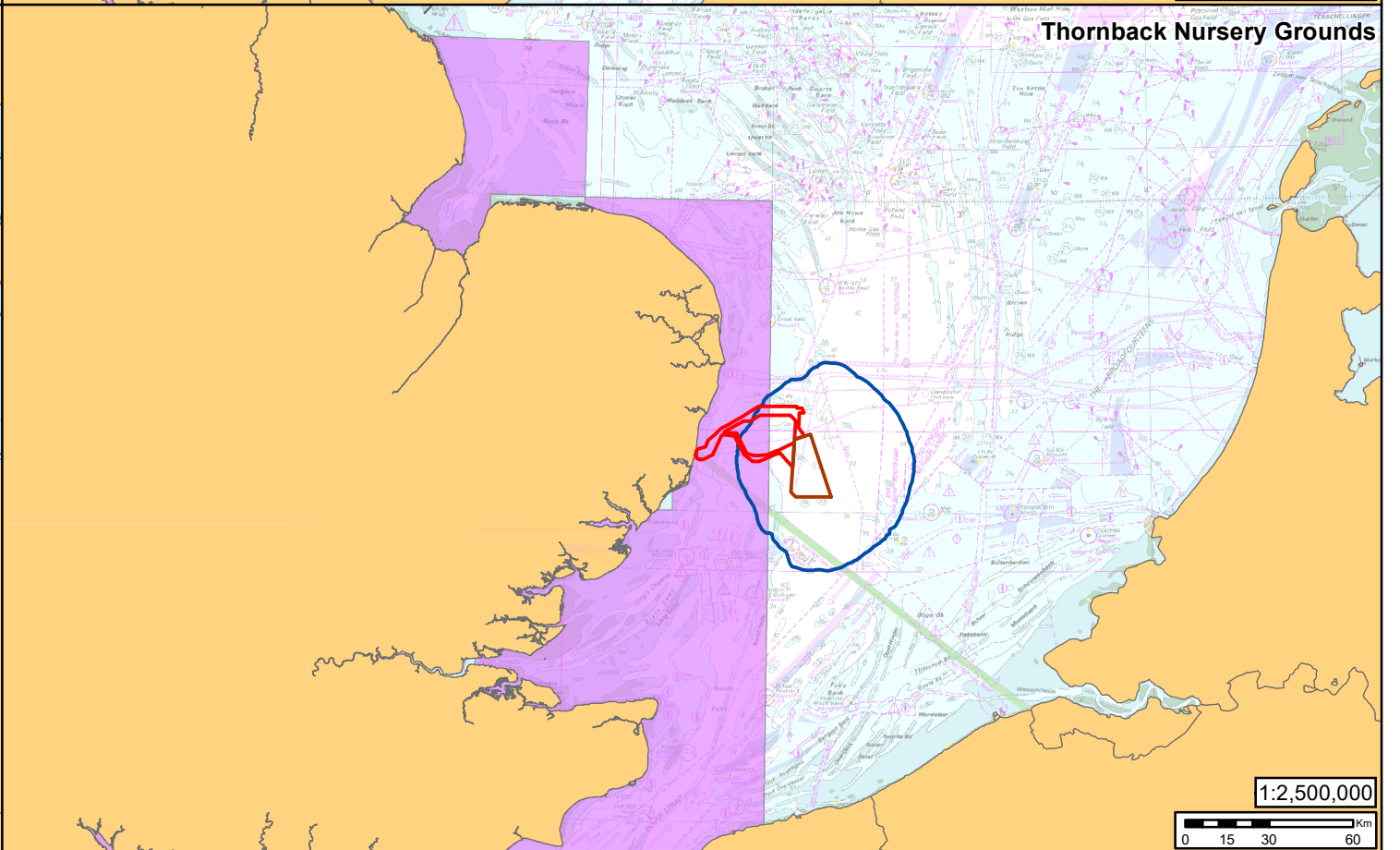
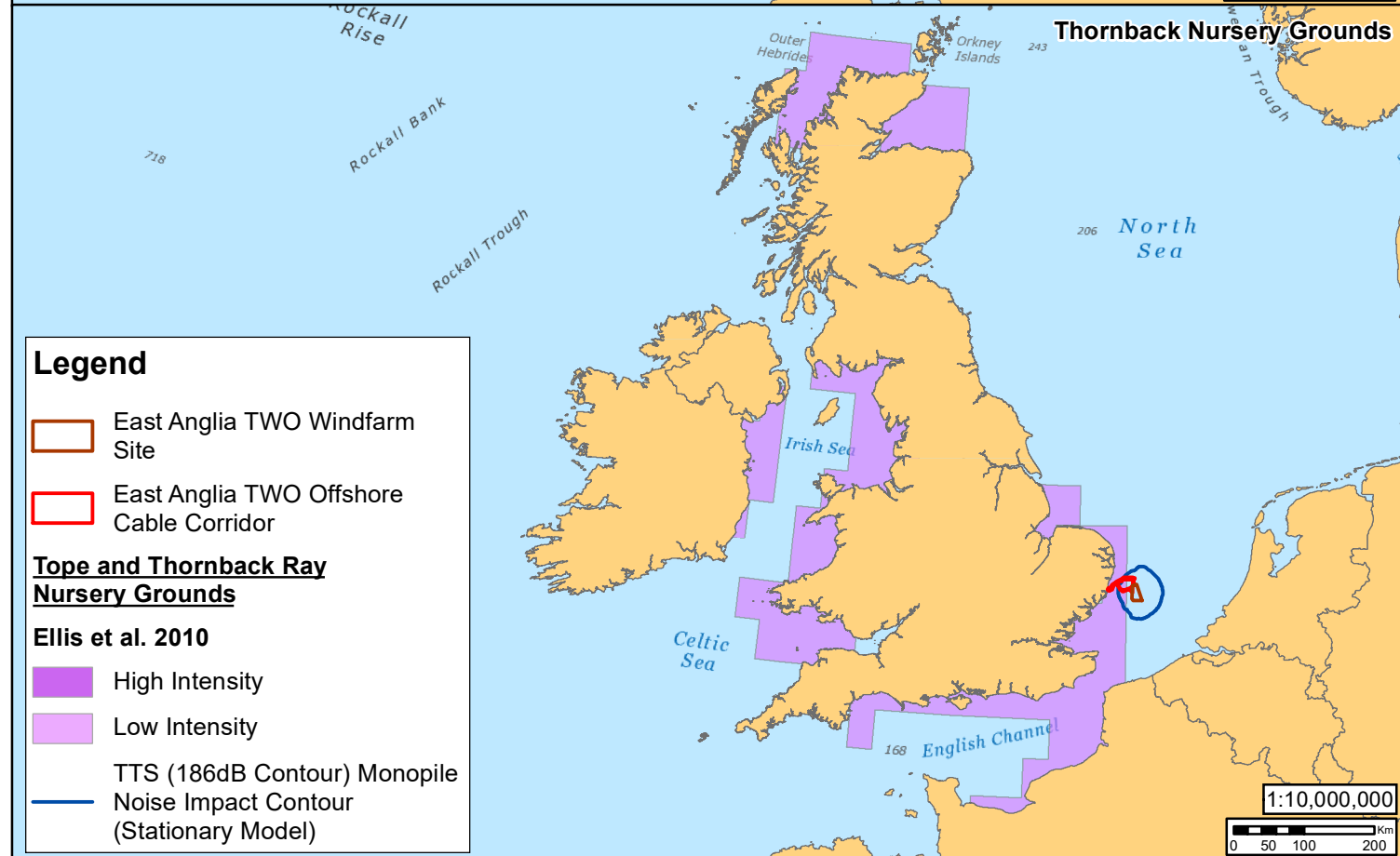
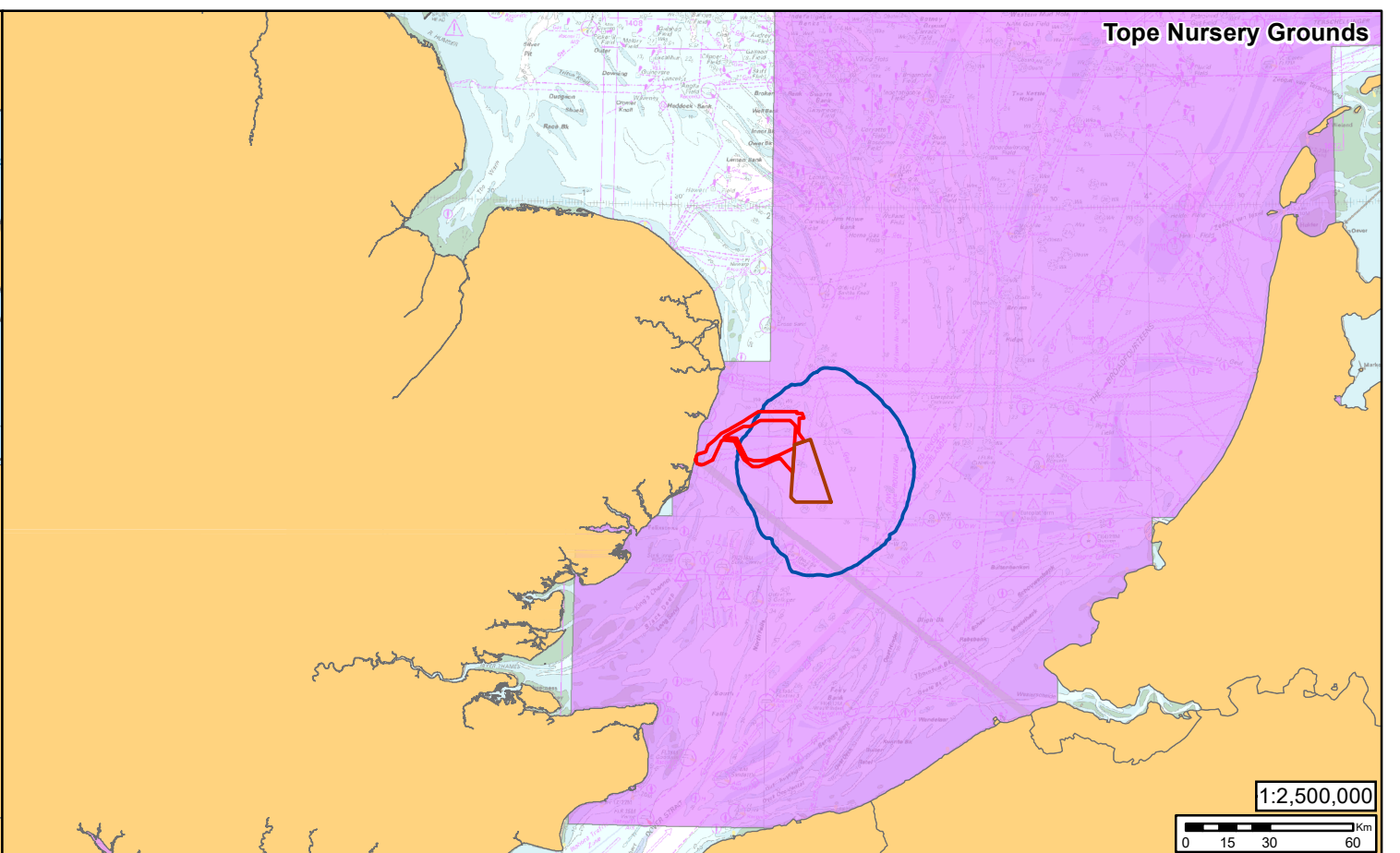
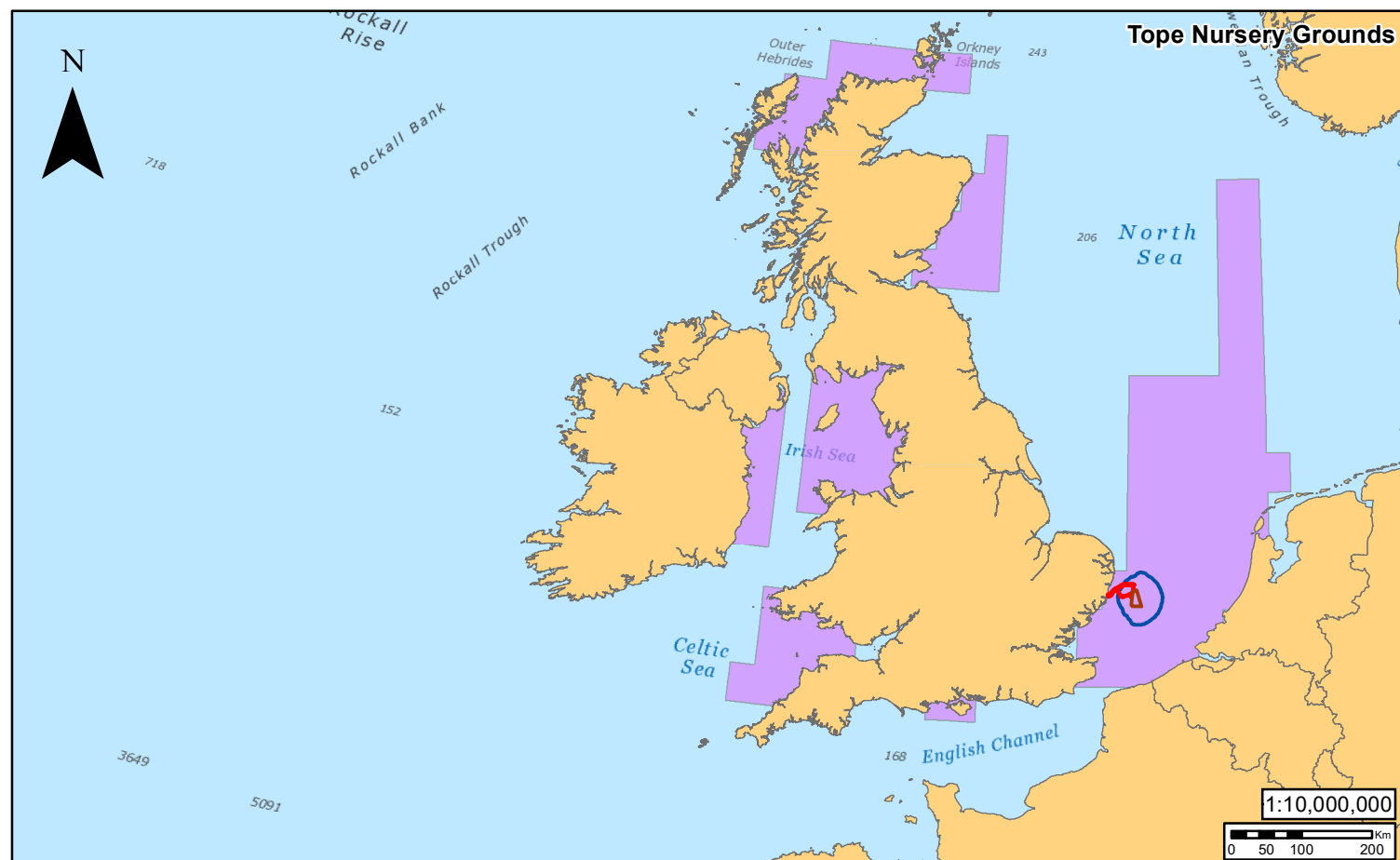
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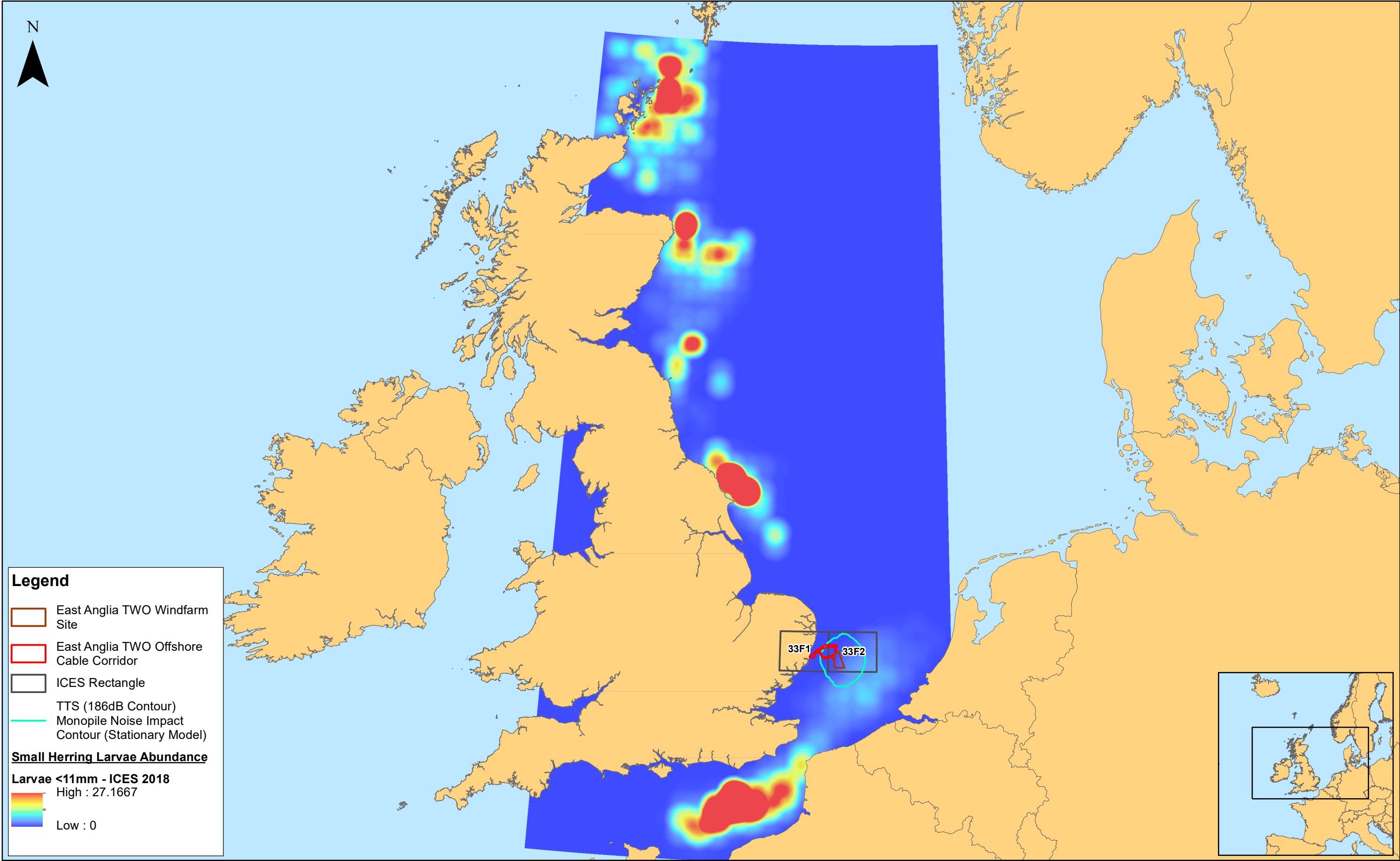




						1:5,000,000		<b>East Anglia TWO</b> Sea Bass Historic Fishing Areas in Relation to Worst Case Noise Impact Contour (Stationary Model)	<b>Drg No</b>	EA2-DEV-DRG-IBR-000754	
				Prepared:	FC	Scale @ A3			<b>Rev</b>	1	Datum: WGS 1984 Projection: Zone 31N
1	25/06/2019	FC	First Issue.	Checked:	KC	<small>Source: © Subacoustech, 2019. © Eastern Sea Fisheries Joint Committee, 2010. © ICES, 2019. Contains OS data © Crown copyright and database rights, 2019. This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</small>	<b>Date</b>	25/06/19			
<b>Rev</b>	<b>Date</b>	<b>By</b>	<b>Comment</b>	<b>Approved:</b>	<b>PP</b>		<b>Figure</b>	10.3.10			



[illegible]



**Legend**

East Anglia TWO Windfarm Site

East Anglia TWO Offshore Cable Corridor

ICES Rectangle

TTS (186dB Contour)


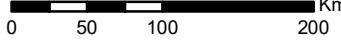
Monopile Noise Impact Contour (Stationary Model)

**Small Herring Larvae Abundance**

Larvae <11mm - ICES 2018

High : 27.1667

Low : 0

						1:5,000,000		<b>East Anglia TWO</b> IHLS Herring Small Larvae Abundance (2007 - 2017) in Relation to Worst Case Noise Impact Contour (Stationary Model)		<b>Drg No</b>	EA2-DEV-DRG-IBR-000756			
					Prepared:	FC				Scale @ A3	<b>Rev</b>	1	Datum: WGS 1984 Projection: Zone 31N	
	1	25/06/2019	FC	First Issue.	Checked:	KC	<small>Source: © Subacoustech, 2019. © ICES Eggs and Larvae Database, 2018. © ICES, 2019. Contains OS data © Crown copyright and database rights, 2019. This map has been produced to the latest known information at the time of issue, and has been produced for your information only. Please consult with the SPR Offshore GIS team to ensure the content is still current before using the information contained on this map. To the fullest extent permitted by law, we accept no responsibility or liability (whether in contract, tort (including negligence) or otherwise in respect of any errors or omissions in the information contained in the map and shall not be liable for any loss, damage or expense caused by such errors or omissions.</small>			<b>Date</b>	25/06/19			
	<b>Rev</b>	<b>Date</b>	<b>By</b>	<b>Comment</b>	<b>Approved:</b>	<b>PP</b>				<b>Figure</b>	10.3.12			

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