ANGLIAN MARINE AGGREGATES REGIONAL ENVIRONMENTAL ASSESSMENT

VOLUME 2 – IMPACT ASSESSMENTS AND CONCLUSIONS

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18. IMPACT ASSESSMENT: GENERAL INTRODUCTION

18.1 PURPOSE OF IMPACT CHAPTERS

The purpose of the impact chapters (19-28) is to present the results of the MAREA regional and sub-regional cumulative impact assessment. It does not include the in-combination impact assessment as this is treated separately in Chapter 29.

It is important to remember that this assessment is not a regional scale EIA. For this reason it is appropriate to reiterate the fundamental question that forms the rationale for this assessment: "Is dredging at current levels across the Anglian Offshore MAREA region environmentally acceptable and if so, can it be continued at potentially increased levels without causing significant environmental impact?" To answer this question, a high-level MAREA was undertaken with a particular focus on cumulative and in-combination impacts (see Volume 1, Chapter 3 for methodology).

A number of cumulative impact assessment guidance documents have recommended that a thorough assessment should include all effects likely to impact a potentially sensitivity receptor (see Hyder, 1999; Cumulative Effects Working Group, 1999). For the Anglian Offshore MAREA, the impact assessment included the following nine effects. These were assessed against ten potentially sensitive receptor groups[1].

Physical effects of aggregate extraction activities:

- Seabed removal;
- Vessel displacement;
- Noise and vibration;
- Suspended sediments;
- Fine sand dispersion;
- Bathymetric changes;
- Wave changes;
- Tidal current changes ; and
- Sediment flux (proxy for sediment erosion and accretion).

Potentially sensitive receptor groups (corresponding impact chapters in parentheses):

- The coastline and inshore banks (Chapter 19);
- Benthic ecology (Chapter 20);
- Fish and shellfish ecology (Chapter 21);
- Marine mammals and turtles (Chapter 22);
- Ornithology (Chapter 23);
- Nature conservation (Chapter 24);
- Commercial and recreational fisheries (Chapter 25);
- Navigation (Chapter 26);
- Infrastructure and other marine users (Chapter 27); and
- Archaeology (Chapter 28).

To understand potential future impacts of dredging it has been necessary to assess current activity and, where relevant, take account of historical activity to ensure the MAREA presents a good understanding of baseline conditions. This knowledge is then used to assess the potential effects of the future maximum development scenario to determine significance of impacts – in other words, the maximum production from a combination of all licences, and application and prospecting licences.

18.2 INTERPRETING THE MAREA RESULTS

The effects of aggregate extraction are relatively well understood compared to other offshore industry sectors (see ICES, 2001; Boyd et al., 2002; Birklund & Wijsman, 2005; Sutton & Boyd, 2009). A number of monitoring studies are available from existing licence areas in the region that address uncertainties regarding the scale of effects and response of receptors on a site-specific level. For this reason, the MAREA can assess the potential future effects of aggregate dredging activities with a high degree of certainty.

The Anglian Offshore MAREA impact assessment methodology, described in Chapter 3, involves a number of components that distinguish it from a site-specific EIA and Strategic Environmental Assessment (SEA). These differences include:

- It is a non-statutory planning tool;
- It assigns impact significance at much larger scales, which are not necessarily applicable to site-specific assessments, although it has been designed to support decisions about cumulative impacts appropriate to individual EIAs;
- It considers large-scale issues (e.g. migration, birds and marine mammals) often poorly addressed at EIA; and
- It does not address site-specific mitigation or monitoring measures as these remain inherent to the EIA (although a suggested regional monitoring approach is described in Chapter 30).

The impact assessment has a number of characteristic features that structure the assessment process, namely:

- It is based on the maximum development scenario for extraction tonnages from all licence, prospecting and renewal areas within the region;
- It uses a range of different analytical methods including professional judgement, conceptualisation, consultation, statistical analysis, GIS, numerical modelling and field data to underpin decisions;
- It uses a standardised terminology developed specifically for the MAREA, which is used to determine and assign impact significance;
- It is objective, systematic and auditable; and
- It identifies individual licence areas where potential issues may be of concern and so should be examined in more detail at EIA level (see Chapter 30, Section 30.8).

Because decisions regarding impact significance rely, in part, on professional judgement, the MAREA impact assessment process takes an evidence-based approach to ensure the outputs are auditable and transparent. Here, the auditing method adopted uses an evidence-based approach[2].

The impact assessment process starts early in the study, during the scoping stage. It is designed to illustrate how dredging extraction activities potentially impact the receiving environment through conceptualisation of the 'source-pathway-receptor[3]' model (see Chapter 4). This model is used as an initial screening

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[1] *Receptor groups denote a collection of different receptors e.g. commercial and recreational fisheries are composed of five receptors: seiners and netters; potters, whelkers and lines; trawlers; shellfish dredgers; and charter fishermen.*

[2] *An evidence-based approach is systematic and auditable because it takes account of evidence from the scientific and grey literature to describe and interpret the impact assessment. It does not assignment quantitative weightings to information.*

[3] *The 'source-pathway-receptor' is an easy to follow method to address impacts of proposed dredging activities on the receiving environment. 'Source' describes the origin of the impact (the effect); 'pathway' the means (e.g. via the water column, ingestion etc) by which the effect reaches receptor.*

exercise for all receptors. Further screening is undertaken using GIS to determine the spatial overlap between the effects of future dredging and sensitive receptors (referred to as an 'effect-receptor interaction[4]').

The MAREA assigns 'magnitude' (assessment of extent, duration and frequency) to each of the effects associated with marine aggregate extraction activities. These magnitudes are fixed as per **Table 3:1** of the methodology chapter. It then assigns 'sensitivity' (assessment of adaptability, tolerance and recoverability [TAR]) to each receptor before calculating how much of the receptor is potentially adversely affected by each effect.

The TAR values are combined (using professional judgement) with the 'value' of the receptor to produce an overall sensitivity.

Cumulative Impact Assessment (CIA) tables have been produced for each receptor with the exception of shipping and navigation, as this assessment was based on risk and undertaken slightly different from other impact assessments. The CIA tables at the end of chapter have been designed to provide standalone assessments. They provide the detail on TAR, value and extent of spatial overlap of the effect and receptor that, taken together, provide the level of significance assigned.

GIS maps were also used to capture the spatial extent of significantly impacted receptors within the MAREA region. These maps are presented at the end of each impact chapter (where appropriate).

In addition, GIS was used to generate 'heat maps[5]' showing areas where potential cumulative impacts between multiple effects co-occur, and where multiple sector activities exploit areas potentially affected by future dredging activities. Heat maps were only used on receptors that were considered to be significantly impacted. The advantage of this approach is that it identifies areas where impacted receptors may co-occur with other effects and different sector activities exist, without having to assign significance. In this way, maps identify 'hot-spots' of interest.

18.3 CHAPTER LAYOUT

Each chapter follows a broadly similar format. The first section, describes the basis of the assessment for each receptor. This is followed by pertinent comments on the type and nature of the baseline data underpinning the assessment. An opportunity to describe newly commissioned data undertaken for the MAREA study and/or specific data capture that improves the accuracy and quality of the assessment is also described.

The second section describes the initial screening for effects and receptors using 'source-pathway-receptor' conceptualisation. It identifies those effects and receptors taken forward for further spatial assessment in GIS. The results of these screening exercises are summarised in matrix tables in each chapter.

The third section starts by describing an overview of the cumulative impact findings. This provides the context for the more detailed account of how effects potentially impact sensitive receptors in the preceding sub-sections. Where appropriate, evidence from the scientific and grey literature is referenced. The results are presented as an effect-led assessment, where impacts to sensitive receptors are described according to each of the effects (as described in sub-sections).At the end of each sub-section, the potential impacts on receptors are summarised in terms of receptor sensitivity, a statement on impact significance (at regional and sub-regional scales), and a brief account of data uncertainty.

The final section concludes the findings of the cumulative impact assessment and makes recommendations for site-specific EIAs. These are tabulated in Chapter 30. The findings of significant cumulative impacts between multiple effects that co-occur with sensitive receptors (based on heat-mapping) are also described and tabulated in Chapter 30.

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[4] An indicative 'effect-receptor interactions' is the likely spatial extent of any potential impact to potentially sensitive receptors. It is a pre-cautionary estimate based on the available data, so reflects future exceeded extraction scenarios.

[5] A heat map is a graphical representation of data mapped as a colour gradient where larger values are represented by a darker colour to denote a greater concentration or number of variables.

19. IMPACT ASSESSMENT: COASTLINE AND INSHORE BANKS

19.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

A requirement for assessing the potential cumulative impacts of aggregate extraction on the coastline and inshore banks is an understanding of the regional and sub-regional characteristics of these receptors within the MAREA region (see Appendix A, HR Wallingford 2011, Coastal Characterisation).

At a regional level, the MAREA coastline is comprised of a number of coastal morphologies. These are defined by HR Wallingford (2011) as:

- Beach ridge;
- Cliff;
- Dunes;
- Lowland; and
- Rising ground

The coastline is separated from the dredging licences by large areas of inshore banks (as identified on Admiralty Chart 1504 (Cromer to Orford Ness) e.g. Scroby Sands). For the basis of this assessment these are delineated as areas of seabed where water depths are shallower than 15 m. The vulnerability of both the coastline and inshore banks is controlled by variability in surface and subsurface geology, tidal range, atmospheric and marine forcing, orientation and bathymetry.

To determine the potential impacts of aggregate extraction on the coastline and inshore banks it is necessary to:

- Delineate and map the extent of the shoreline and areas of inshore banks located between the dredging areas and the coastline;
- Identify areas of the coast or inshore banks that may be particularly vulnerable to erosion and/or high-energy (storm) events;
- Determine where there are potential present and future interactions between the physical effects of marine aggregate extraction and the coastline and inshore banks; and
- Obtain evidence to support the source-pathway-receptor relationship between the coastline and inshore banks and dredging activities (see Effects Chapter 5).

Baseline data on the nature and spatial extent of the MAREA coastal region (Appendix A and Chapter 8) provided the following knowledge basis upon which the assessment was made:

- An overall assessment of the physical characteristics of the coastline;
- The regions of inshore banks that separate the dredging licences from the coast;
- Sediment transport directions; and
- Vulnerability of coastal segments based on physical characteristics and long term monitoring.

A number of data sources were used to characterise the coastline and inshore banks, including: Seazone and site-specific bathymetric data, REA and REC data, various Shoreline Management Plans (SMPs), HR Wallingford technical reports (Appendix A), Admiralty Chart 1504 (Cromer to Orford Ness) and published scientific and grey literature.

Box 1: Mapping the spatial extent of the Inshore Sandbanks

The spatial extent of the Inshore Sandbanks was mapped using SeaZone Solutions which:

'provides users with a definitive worldwide marine reference map incorporating large-scale, authoritatively sourced, marine geographic datasets'.

These regional SeaZone bathymetric datasets also include all recent publicly available swath bathymetry data. As a conservative approach to map the spatial distribution of the sandbanks, these were digitised to include all areas down to a water depth of 15 m.

19.1.1 Screening effect-receptor interactions

The effects of future dredging activities on the different coastal morphologies and inshore banks within the MAREA region were identified following a screening process.

Step 1 of the Impact methodology (see Chapter 3) used the source-pathway-receptor model (Chapter 5) to identify pathways between the physical effects of dredging and the coastline/inshore banks. Key scientific studies that describe the impacts of aggregate extraction activities on the coastline and inshore banks were used to underpin screening decisions – where appropriate these are referenced in the following sections.

This initial screening opportunity identified the effects for inclusion in Step 3 of the impact assessment (Chapter 3), where the effects of aggregate extraction that potentially overlap with the coastline and inshore banks were mapped in GIS. Because of the importance of coastlines and inshore banks as receptors in the Anglian Offshore region all these receptors were screened in for assessment.

Effects screened in:

The effects which have a potential impact on coastlines and inshore banks are:

- Seabed removal;
- Suspended plume;
- Fine sand dispersion;
- Bathymetric changes;
- Sediment flux (associated with tidal currents); and
- Waves.

Effects-screened out:

The following effects have no impact on the coastline or inshore banks (i.e. there is no direct or indirect effect-receptor pathway) and so have been screened out of further assessment:

- Vessel displacement; and
- Noise and Vibration.

A summary of the potential effects and their overlap (and so potential interaction) with the coastline and inshore banks is presented in **Table 19:1**.

19.2 CUMULATIVE IMPACT ASSESSMENT

Understanding potential future changes in the environment as a result of cumulative aggregate extraction activities, and how such changes may impact the coastline and inshore banks, are potential issues for many stakeholders. Accelerated sea level rise due to climate change means any future changes in wave heights as a result of aggregate extraction in the Anglian MAREA region require careful prediction. For this reason, the numerical model SWAN was used to predict changes in wave heights across the region (see Chapter 6).

Moreover, the potential for beach drawdown requires evidence to show that this is not a likely result of future extraction in the MAREA region. As a result, modelling of changes in peak tidal current speeds and sediment flux using TELEMAC and SANDFLOW, was undertaken (see Chapter 6). It was also important to examine potential changes to the physical nature of inshore banks from fine sand dispersion. In this instance, a desk-based assessment using worst-case scenarios, coupled with tidal current data, was undertaken (for details, refer to Chapter 6 and Appendix A).

Sub-region	SENSITIVE RECEPTORS							Screening Assessment
	Effect	Beach ridge	Cliff	Dunes	Lowland	Rising ground	Inshore banks (<15m) between dredging licences and coastline	
Yarmouth	Seabed removal	✓	✓	✓	✓	✓	✓	● There is no direct or indirect effect-receptor pathway for vessel displacement and noise and vibration on coastline or sandbank receptors. ● For the purpose of this impact assessment the coastline and inshore banks have been screened in for assessment, whether or not there is any overlap with the effects of dredging.
	Vessel displacement							
	Noise and vibration							
	Suspended plume	✓	✓	✓	✓	✓	✓	
	Fine sand dispersion	✓	✓	✓	✓	✓	✓	
	Bathymetry changes	✓	✓	✓	✓	✓	✓	
	Sediment flux	✓	✓	✓	✓	✓	✓	
	Tidal currents*	✓	✓	✓	✓	✓	✓	
	Waves	✓	✓	✓	✓	✓	✓	
Southwold	Seabed removal	✓	✓	✓	✓	✓	✓	● There is no direct or indirect effect-receptor pathway for vessel displacement and noise and vibration on coastline or sandbank receptors. ● For the purpose of this impact assessment the coastline and inshore banks have been screened in for assessment, whether or not there is any overlap with the effects of dredging.
	Vessel displacement							
	Noise and vibration							
	Suspended plume	✓	✓	✓	✓	✓	✓	
	Fine sand dispersion	✓	✓	✓	✓	✓	✓	
	Bathymetry changes	✓	✓	✓	✓	✓	✓	
	Sediment flux	✓	✓	✓	✓	✓	✓	
	Tidal currents*	✓	✓	✓	✓	✓	✓	
	Waves	✓	✓	✓	✓	✓	✓	

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✓	Screened in: Effect-receptor interaction – take forward to impact assessment

* Tidal currents are discussed under sediment flux, since this is the main effect directly associated with changes in tidal current speeds which may impact inshore banks

Table 19:1 Screening matrix for sub-regions – AODA MAREA coastline and inshore banks.

The impact assessment process is 'effects' led, which means the following section describes the findings of the cumulative impact assessment for effects of aggregate extraction on the coastline and inshore banks. It includes a description of the potential impacts (i.e. where overlap is predicted) and their impact significance, both sub-regionally and regionally.

For the purpose of this impact assessment the coastline and inshore banks have been screened in for assessment, whether or not there is any overlap with the effects of dredging. This is because the coastline and inshore banks are significant receptors within the Anglian region and a potential issue for many stakeholders.

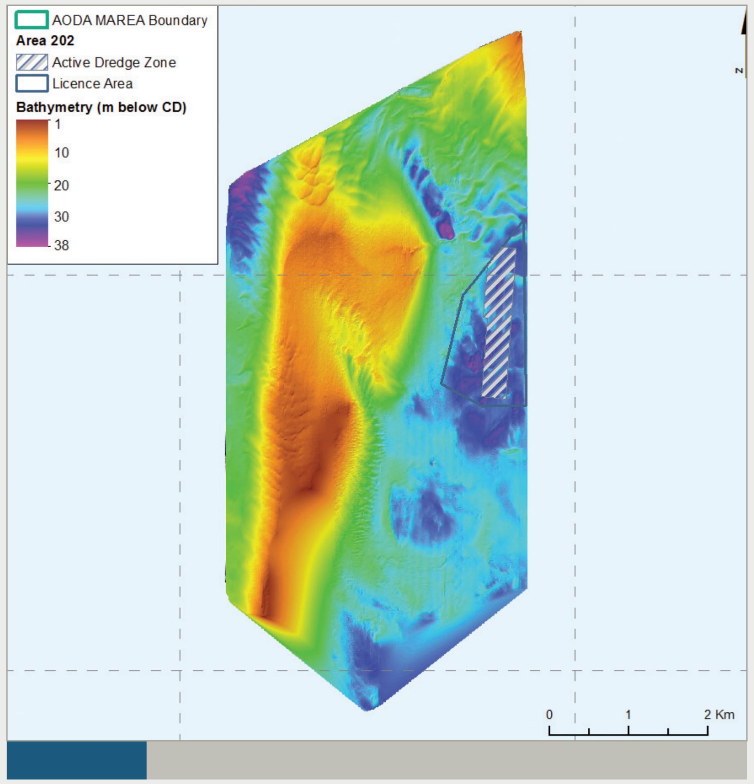
19.2.1 Seabed removal

Coastline

Seabed removal has no direct impact on the coast unless material is removed directly from the beach or intertidal zone, resulting in immediate sediment depletion and bathymetric changes. Present day and proposed aggregate extraction activities discussed in this MAREA occur from between 6-30 km offshore in water depths between approximately 20-40 m. The dredging areas are separated from the coastline by inshore banks and dredging does not occur within the coastal zone. Illustrative cross sections, showing the distance offshore and the separation of dredging areas from the coastline can be found in **Figure 8:32**.

Box 2: Potential interactions between Inshore Sandbanks and Aggregate Extraction – Case Study: Licence Area 202

Annual to bi-annual multibeam bathymetric monitoring surveys undertaken at Licence Area 202, which is the closest licence area to the Inshore Sandbanks, has shown that at present (Bathymetry monitoring survey, Gardline 2011) there is little interaction with dredging areas and inshore sandbanks (see Figure). Although previous results do not guarantee that there will not be any future potential impacts, the monitoring results do provide confidence that under current extraction rates and current sandbank conditions, impacts on the bank can be considered to be insignificant - particularly since there is no overlap between Licence Area 202 and the current boundaries of the sandbank.



SIGNIFICANCE STATEMENT: Since there is no overlap of seabed removal with the coastline the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of seabed removal on the coastline is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Inshore banks

Seabed removal will also have no direct impact on inshore banks unless sediment is removed directly from these features, resulting in sediment depletion and bathymetric changes. Since extraction does not occur on the inshore banks seabed removal does not overlap with these receptors. Illustrative cross sections, showing the separation of dredging areas from banks are presented in **Figure 8:32**.

There are several indirect impacts that may potentially arise due to seabed removal. Within the MAREA region, the indirect effects of seabed removal that interact with the inshore banks include fine sand dispersion, sediment flux, and changes to tidal currents and waves. These are discussed in sections 19.2.5, 19.2.7, 19.2.8, and 19.2.9, respectively.

SIGNIFICANCE STATEMENT: Since there is no overlap of seabed removal with inshore banks the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of seabed removal on inshore banks is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

19.2.2 Vessel displacement

This effect is associated with the displacement of other vessels from the licence area when the dredger is undertaking extraction activities. There are no potential impacts of vessel displacement on the coastline or banks.

Although some wake may be formed from dredger transits, this will be well within the background levels generated by the presence and movements of other vessels. This effect has, therefore, been screened out of the assessment.

Displacement effects do not increase traffic and/or associated increases in noise and vibration – neither of which is known to impact the coastline or inshore banks.

19.2.3 Noise and vibration

There are no known potential impacts of noise and vibration on the (physical) coastline or banks. This effect has, therefore, been screened out of the assessment.

19.2.4 Suspended sediment plume

Coastline

The maximum development scenario modelled footprints from sediment plumes due to aggregate extraction do not reach the coast anywhere in the region. Furthermore, there are no known cases of suspended material impacting the (physical) coastline, since much of the material is winnowed out and transported considerable distances offshore by tidal currents. It is also important to note that background concentrations of naturally occurring suspended sediments are relatively high in this area of the North Sea (for details, refer to Chapter 7).

SIGNIFICANCE STATEMENT: Since there is no overlap of sediment plumes with coastline receptors, the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of suspended sediment plumes on the coastline is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Inshore banks

Suspended plume concentrations > 20 mg/l above background levels are not predicted to overlap with any area of inshore banks in the Yarmouth or Southwold sub-regions. As with the coastline receptors, there are no known cases of suspended plumes impacting the stability of inshore banks. It is also important to note that background concentrations of naturally occurring suspended sediments are relatively high in this area of the North Sea (for details, refer to Chapter 7).

SIGNIFICANCE STATEMENT: Since there is no overlap of > 20 mg/l suspended plume concentrations with inshore banks, the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of suspended plumes is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

19.2.5 Fine sand dispersion

Coastline

Present day and proposed aggregate dredging areas lie a significant distance offshore (see **Figure 8:32**) and are separated from the coastline by inshore banks. Fine sand dispersion from dredging would be unlikely to affect the coastline and modelling results indicate that there is no overlap of fine sand dispersion with coastline receptors anywhere in the MAREA region.

SIGNIFICANCE STATEMENT: Since there is no overlap of fine sand dispersion with coastline receptors the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of fine sand dispersion on the coastline is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Inshore banks

Modelling results, combined with GIS, have identified two small areas of inshore banks, in the Yarmouth sub-region, where there is an overlap of the predicted footprint of fine sand dispersion (**Figure 19:1**). Overlap is predicted with the south of Middle Cross Sand (1.13 km^2 of overlap) and a much smaller area on the southern end of Newarp Banks (0.3 km^2 of overlap).

These areas of predicted fine sand dispersion are located at least 600 m from the nearest aggregate licence area. At these distances it is likely that the area of fine sand dispersion would comprise a thin and discontinuous veneer of fine sand or, at worst, the introduction of some small sandy bedforms. Coarser sand resulting from screening and overspill would be deposited very close to, or within, the Active Dredge Zones of licence areas.

Since banks are naturally comprised of sand, which is redistributed during high-energy events, a thin veneer of fine sand or small sandy bedforms would have no significant impact on the surface or subsurface integrity of the sandbank feature in question.

SIGNIFICANCE STATEMENT: In terms of their sensitivity, banks can be considered to have **high adaptability** and **high tolerance** to a small influx of fine sand. In addition, due to the natural sediment transport occurring in the region, banks will also show **high recoverability**. Their sensitivity to fine sand dispersion is ***Low***.

The cumulative effects of fine sand dispersion are confined to very small and highly localised areas of Middle Cross Sand and Newarp Banks, located in the Yarmouth sub-region. Since fine sand released from dredging activities is likely to be similar in composition to the surface sediments of the banks (comprising a thin veneer that is naturally mobilised by the hydrodynamic regime in the region), the significance of the impact can be considered to be negligible or even positive. As a precautionary principle, however, the impact from fine sand dispersion on inshore banks is considered to be of ***Minor Significance*** for the Yarmouth sub-region (**Table 19:2**). No overlap of fine sand dispersion is predicted for the Southwold sub-region and the impact is considered to be ***Not Significant***.

Since the area of overlap between fine sand dispersion and inshore banks is very small (1.42 km^2), compared with the total area of banks located in the AODA MAREA region (243.57 km^2), the cumulative impacts of fine sand dispersion on inshore banks at the **regional** scale is considered to be ***Not Significant***.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

19.2.6 Bathymetry changes

Coastline

Bathymetric changes due to dredging have no direct impact on the coast, as dredging does not occur at the coastline.

SIGNIFICANCE STATEMENT: Since there is no overlap of bathymetric changes with coastline receptors, the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of bathymetric change is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: Knowledge of future aggregate extraction areas, coupled with modelled data, provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Inshore banks

There is no overlap of changes in bathymetry due to seabed removal within areas of inshore banks. However, indirect changes to hydrodynamics from changes to bathymetry are likely. These include changes to sediment flux, tides and waves, which are discussed in sections 19.2.7, 19.2.8 and 19.2.9, respectively.

SIGNIFICANCE STATEMENT: Since there is no overlap of bathymetric change with inshore banks the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of bathymetric change on inshore banks is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: Knowledge of future aggregate extraction areas, coupled with modelled data, provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

19.2.7 Sediment flux

Coastline

Although changes in sediment flux (a proxy for sediment transport) may affect coastal areas such as beaches and mudflats, within the MAREA region there is no overlap between the maximum modelled sediment flux footprint and any part of the MAREA Coastline (**Figure 19:2**).

SIGNIFICANCE STATEMENT: Since there is no overlap of sediment flux with the coastline, the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of sediment flux on coastlines is also considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Inshore banks

Since inshore banks play a dominant role in sheltering the coast from storms and other high-energy events, it is particularly important to assess how aggregate extraction might modify residual sediment flux (sediment transport rates) in areas of banks. Any changes in sediment flux that might affect the integrity of banks are likely to be the most important effect from aggregate extraction. This is particularly the case where increased flux (associated with erosion) is predicted, since this has the potential to reduce the sheltering effects of the banks. It should also be noted that a decrease in sediment flux, which is analogous to sediment deposition, would have a neutral or even positive impact, since sediment deposition can result in sandbank accretion.

Modelling results, based on maximum extraction scenarios and peak tides for 0.4 mm size sand, have revealed that there are three main areas where predicted increases in residual sediment flux overlap with inshore sandbank areas (**Figure 19:2**). These include:

- Middle Cross Sands, where 1.12 km^2 of the bank is predicted to have increased sediment flux of mostly 500-1000 kg/m/tide, with some small and highly localised areas of 1000-3000 kg/m/tide;
- South Cross Sand, where 2.68 km^2 of the bank is predicted to have increased changes in residual sediment flux of 500-3000 kg/m/tide; and
- North Scroby Sand, where 1.02 km^2 of the bank is predicted to have increased changes in residual sediment flux of 500-1000 kg/m/tide along its eastern margin.

It is important to note that (natural) background sediment flux rates, based on a pre-dredge scenario, range from approximately 5,000-50,000 kg/m/tide for areas where changes in residual sediment flux are predicted to overlap with areas of inshore banks. These rates suggest high sediment transport rates in this area, which are a direct result of strong tidal currents. Furthermore, the total area of banks where increased sediment transport rates are predicted to occur constitutes approximately 2% of the total area of inshore banks in the Anglian MAREA region.

Inshore banks are highly dynamic large-scale features which naturally adapt to changing conditions – however it is still important to acknowledge that there are some highly localised areas where changes in sediment transport rates may interact with these features.

SIGNIFICANCE STATEMENT: Inshore banks are persistent features in the Anglian MAREA region. Natural sediment transport rates in the region are high, and the inshore banks are considered to have **medium tolerance**, **adaptability** and **recoverability** to the effects of sediment flux. They are therefore considered to have ***Medium*** sensitivity to sediment flux.

The banks are also dominant features which shelter the coastline from storms and, applying the precautionary principle, the impact of changes in sediment flux on inshore banks is considered to be of ***Minor Significance*** for the Yarmouth sub-region (**Table 19:2**). No overlap of sediment flux with inshore banks is predicted for the Southwold sub-region (**Table 19:3**).

From a regional perspective, only ~ 2% of the total area of inshore banks in the Anglian MAREA region may be impacted by a relatively small increase in residual sediment flux under a maximum extraction scenario and only during peak tidal current speeds. The impact of changes in sediment flux on inshore banks is considered to be ***Not Significant*** from a regional perspective.

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

19.2.8 Tidal currents

Coastline

Changes in peak tidal current speeds have the potential to alter coastal dynamics (e.g. longshore/cross shore currents and sediment transport patterns). However, the maximum development scenario modelled footprint from changes to peak tidal current speeds does not overlap with any part of the MAREA region coastline (for details refer to Chapter 6 Modelling the Physical Effects of Dredging).

Inshore banks

The main effect of changes to peak tidal currents with regards the integrity of inshore banks is changes in sediment flux, discussed above. As a result, to avoid double counting of the impact, this effect has not been assessed separately.

19.2.9 Waves

Offshore marine aggregate extraction has the potential to indirectly impact hydrodynamic processes and sediment transport patterns both on the coastline and on shallow areas of the seabed i.e. inshore banks (CIRIA, 1998; Van Rijn *et al.*, 2005). The most important factors which determine whether aggregate extraction has an impact on hydrodynamic processes are the total volume of material removed and the water depths where aggregate extraction takes place (ICES, 2009). The coastal impacts of aggregate extraction can only be estimated from data gathered from extraction activities from various locations around the world. Modelled and site-specific studies are provided in detail by Van Rijn *et al.* (2005).

Issues considered when assessing impacts of aggregate extraction on the coastline are as follows:

- Effects on protective banks potentially resulting in enhanced beach erosion;
- Disruption of sediment supply;
- Beach drawdown whereby coastal sediment is transported offshore into extraction areas due to waves and currents; and
- Changes in wave- and tidal-driven processes if aggregate extraction takes place close to the shore.

Seabed removal also has the potential to increase shoreface slopes, which in turn results in potentially increased wave heights reaching the shoreline (Carter, 1988).

In the United States, marine sand extraction activities are often focused on bathymetric highs such as shoals or ridges. It has been found that, due to their locations in water depths of 10-20 m or greater, impacts on the coastline are not predicted since they are isolated from active littoral processes and do not affect coastal sediment budgets or sediment supply to the coast (Nairn *et al.*, 2004; Zarillo *et al.*, 2009).

Coastline

Numerical modeling of changes in wave heights due to aggregate extraction using the SWAN model for 1 in 200 year wave events, and the more commonly occurring 25% exceedance scenarios, coupled with a maximum offtake bathymetric scenario, has predicted that there is no overlap from predicted changes in wave heights and the AODA MAREA coastline (**Figure 19:3**). Furthermore, predicted changes in wave heights are not shown to occur within approximately 2 km of the coast.

In addition, changes in wave direction and wave period are not predicted to overlap with any part of the Anglian MAREA region coastline. The fact that wave directions and period do not alter suggests that sediment transport pathways between the coast and aggregate extraction areas (if and where present) would not be significantly modified. HR Wallingford (2011) states that "*No change in wave period above 0.5 s is predicted within 1 km from the coast, or on the banks offshore of Great Yarmouth, and therefore the predicted wave fields will not change coastal processes in a noticeable way*".

SIGNIFICANCE STATEMENT: Since there is no overlap of wave changes with the coastline, the impact is considered to be ***Not Significant*** for both the Yarmouth and Southwold sub-regions. The impact of wave changes on the coastline is also considered to be ***Not Significant*** from a regional perspective.

Box 3: Potential Impacts from Marine Aggregate Extraction for area between Great Yarmouth and Inshore Section of Sandbanks

The offshore area between Great Yarmouth and the Inshore Sandbanks is an area of high importance – as such, it is important to carefully assess whether aggregate extraction may potentially impact this coastal and nearshore region. This region has been assessed as not being significantly impacted by aggregate extraction for the following reasons:

- A careful analysis of bedforms suggests that cross-shore (i.e. west to east) sediment transport pathways are not present between Great Yarmouth and the Inshore Sandbanks; sediment transport directions are predominantly north to south and aligned with the sandbanks;
- Dominant tidal currents run parallel to the shore. See for example Southern North Sea Sediment Transport Study 2 (HR Wallingford *et al.*, 2002) and Cooper *et al.*, (2008);
- Worst-case numerical modelling outputs (which have been calibrated and field validated) show that the effects from aggregate extraction (waves, tides and sediment transport) do not interact with any part of this coastal and nearshore region (refer to results from this chapter and Chapter 6); and
- There is no continuous extent of surficial sands between Great Yarmouth and the Inshore Sandbanks – instead, much of this region comprises bedrock (refer to **Figure 8:32a**).

UNCERTAINTY: A thorough desk-based assessment, coupled with modelled data using a worst case scenario, provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered **Low**.

Inshore banks

Numerical modelling of changes in wave heights for 1 in 200 year wave events shows that there are some locations where predicted changes in wave heights do overlap with areas of inshore banks (**Figure 19:3**). These include:

- 1.98 km^2 of overlap with South Cross Sand;
- 0.34 km^2 of overlap with Holm Sand;
- 0.33 km^2 of overlap with Middle Cross Sand; and
- 0.18 km^2 of overlap with Scroby Sands.

Although wave modelling results do show areas of overlap with inshore banks, the increased wave height is within 2-5% for all of the areas discussed above, which is just beyond the sensitivity of the model, and can be considered to be a small magnitude effect. It is also important to note that these increases are predicted for 1 in 200 year wave events, which are exceptionally unusual and short-lived. Wave height increases of > 2% were not predicted to overlap with any inshore sandbank areas for the (more commonly occurring) 25% exceedance scenario.

Wave directional changes due to aggregate extraction are predicted to overlap one small area of banks; however these changes are only predicted to be 2-5% and *towards* the shoreline for 1 in 200 year wave events. Wave period is not predicted to change anywhere along the inshore banks due to aggregate extraction. As a result, it is highly unlikely for any sediment transport pathways from inshore banks to be modified due to aggregate extraction.

SIGNIFICANCE STATEMENT: Banks in the MAREA region are persistent features which naturally adjust to changes in wave-driven forcing. They are assessed as having **high tolerance**, **adaptability** and **recoverability** to the effects of waves and therefore have **Low** sensitivity to this effect.

The cumulative effects of a 2-5% increase in wave heights for 1 in 200 year wave events is confined to five small areas of inshore banks in the Yarmouth sub-region. This involves a small total area of 2.82 km^2. However, since inshore banks play a crucial role in sheltering the AODA MAREA coastline from high-energy (storm) events, and applying a precautionary approach, the impact of increased wave heights due to aggregate dredging on inshore banks is considered to be of ***Minor Significance*** for the Yarmouth sub-region (**Table 19:2**). No overlap of increased wave heights and inshore banks is predicted for the Southwold sub-region (**Table 19:3**).

From a regional perspective, the impact of increased wave heights due to aggregate extraction on inshore banks is considered to be ***Not Significant***, since only 1% of the total area of banks (which are highly adaptable and tolerant to wave-forcing) may be impacted minimally by a 1 in 200 year wave event.

UNCERTAINTY: Modelled data using SWAN for waves provides a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered ***Low***.

Potential for Beach Drawdown

Sediment naturally moves cross-shore (up and down along a beach profile). Should aggregate extraction take place within this active zone of beach sediment movement, then changes to waves, tides and sediment transport would have the potential to affect the natural movement of beach and nearshore sediments. In these circumstances, sediment which moves across the beach profile into deeper water may settle in depressions offshore and be prevented from moving back onshore, resulting in a net loss of (sandy) sediment from the beach system – this is termed beach drawdown.

Beach drawdown, however, is not predicted to have any impact on the AODA MAREA coastline due to the following reasons:

- The aggregate extraction areas are located seaward of the nearshore banks, at least 9 km offshore, and are separated from the coastline by areas of deeper water and the nearshore banks (see Cross-Sectional Profiles in Chapter 8). This prevents any direct interchange of sediments between the coast and the dredging areas;
- Modelling results show that changes to waves, tides and sediment flux as a result of dredging do not overlap with any part of the AODA MAREA coastline (refer to Chapter 6);
- The dominant tidal currents and waves move parallel to the coastline (i.e. north-south) and not cross-shore (refer to Chapter 6);
- There is no evidence of any clear (cross-shore) sediment transport pathways, based on an analysis of bedforms, between the coastline and the inshore banks;
- Bathymetric profile comparisons since 1992 by the Environment Agency (2007a; 2007b) off the Anglian coast do not show measureable changes in profiles for depths greater than 10 m or distances greater than 2 km from the coast (see Chapter 8 – Regional Coastal and Geological Baseline). Aggregate licence areas are further offshore, and at greater depths than these limits; and
- A study of conditions on the east coast by Halcrow and Partners (1991) suggests a depth limit of 7 m for seasonal fluctuations in beach profile.

19.3 CONCLUSIONS

19.3.1 Yarmouth sub-regional impacts

Coastline

Marine aggregate dredging effects will have no impact on the Anglian MAREA region coastline since none of the effects is predicted to overlap with the coastline, even assuming worst-case scenarios.

Inshore Banks

Some small areas of overlap between inshore banks and the effects of fine sand dispersion, sediment flux (attributed to changes in peak tidal current speeds) and increases in wave heights have been identified. However, banks play an important role in sheltering the coast from storms, and as a precautionary principle, the impact of these effects is considered to be of ***Minor Significance***.

19.3.2 Southwold: sub-regional impacts

Coastline and Inshore Banks

Marine aggregate dredging effects are predicted to have no impact on the AODA MAREA coastline or inshore banks since none of the effects are predicted to overlap with these receptors. Therefore the potential impacts from aggregate extraction on this sub-region are assessed as being ***Not Significant***.

19.3.3 Regional impacts

Coastline

Modelling results show that there are no overlaps of cumulative effects from aggregate extraction with any areas of coastline, for either the Yarmouth or Southwold sub-regions. All effects of aggregate extraction are therefore assessed as being ***Not Significant*** from a regional perspective.

Inshore Banks

Modelling results indicate that the cumulative effects from aggregate extraction which may potentially impact the inshore banks are fine sand dispersion, residual sediment flux (associated with tidal currents) and waves. However, these effects, which are of small magnitude are predicted to potentially interact with no more than 2% of the total area of banks in the region. Therefore the effects of increased fine sand dispersion, sediment flux and waves are considered to be ***Not Significant*** from a regional perspective.

Table 19:2 CUMULATIVE IMPACT ASSESSMENT TABLES FOR COASTLINE AND INSHORE BANKS FOR SUB-REGION YARMOUTH

EFFECT	SENSITIVE RECEPTOR					
	Beach Ridge	*Cliff*	*Dunes*	*Lowland*	*Rising ground*	*Inshore banks*
SEABED REMOVAL *(Magnitude = Medium)*	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****
SUSPENDED PLUME *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****
FINE SAND DISPERSION *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** Two small areas of inshore banks (1.13 and 0.3 km^2) overlap with predicted areas of fine sand dispersion **NB:** Since inshore banks protect the coastline from storms, a precautionary principle is applied. However, fine sand dispersion is likely to be beneficial for sandbanks
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Minor Significance*****
BATHYMETRY CHANGE *(Magnitude = Medium)*	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****
SEDIMENT FLUX *(Magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** Several small localised areas of increased sediment flux overlap with sandbanks
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Minor Significance*****
WAVES *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation. **Spatial Overlap:** A 2-5% increase in wave heights for 1 in 200 year wave events is predicted for several localised areas of sandbanks.
	Not significant***	**Not significant*****	**Not significant*****	**Not significant*****	**Not significant*****	**Minor Significance*****

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment.

☐ Not significant
▨ Minor significance
▨ Moderate significance
▨ Major significance

Uncertainty: *High **Moderate *** Low

Table 19:3 CUMULATIVE IMPACT ASSESSMENT TABLES FOR COASTLINE AND INSHORE BANKS FOR SUB-REGION SOUTHWOLD

EFFECT	SENSITIVE RECEPTOR					
	Beach Ridge	*Cliff*	*Dunes*	*Lowland*	*Rising ground*	*Inshore banks*
SEABED REMOVAL *(Magnitude = Medium)*	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **
SUSPENDED PLUME *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection. **Spatial Overlap:** No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **
FINE SAND DISPERSION *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **
BATHYMETRY CHANGE *(Magnitude = Medium)*	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Low, **A:** Low; **R:** Low **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **
SEDIMENT FLUX *(Magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection **Spatial Overlap:** No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **
WAVES *(Magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation **Spatial Overlap:** No overlap	**T:** High, **A:** High; **R:** High **Value:** Relatively common coastal type across southern North Sea. Coastal protection/recreation Spatial Overlap: No overlap
	Not significant* **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **	**Not significant*** **

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment.

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

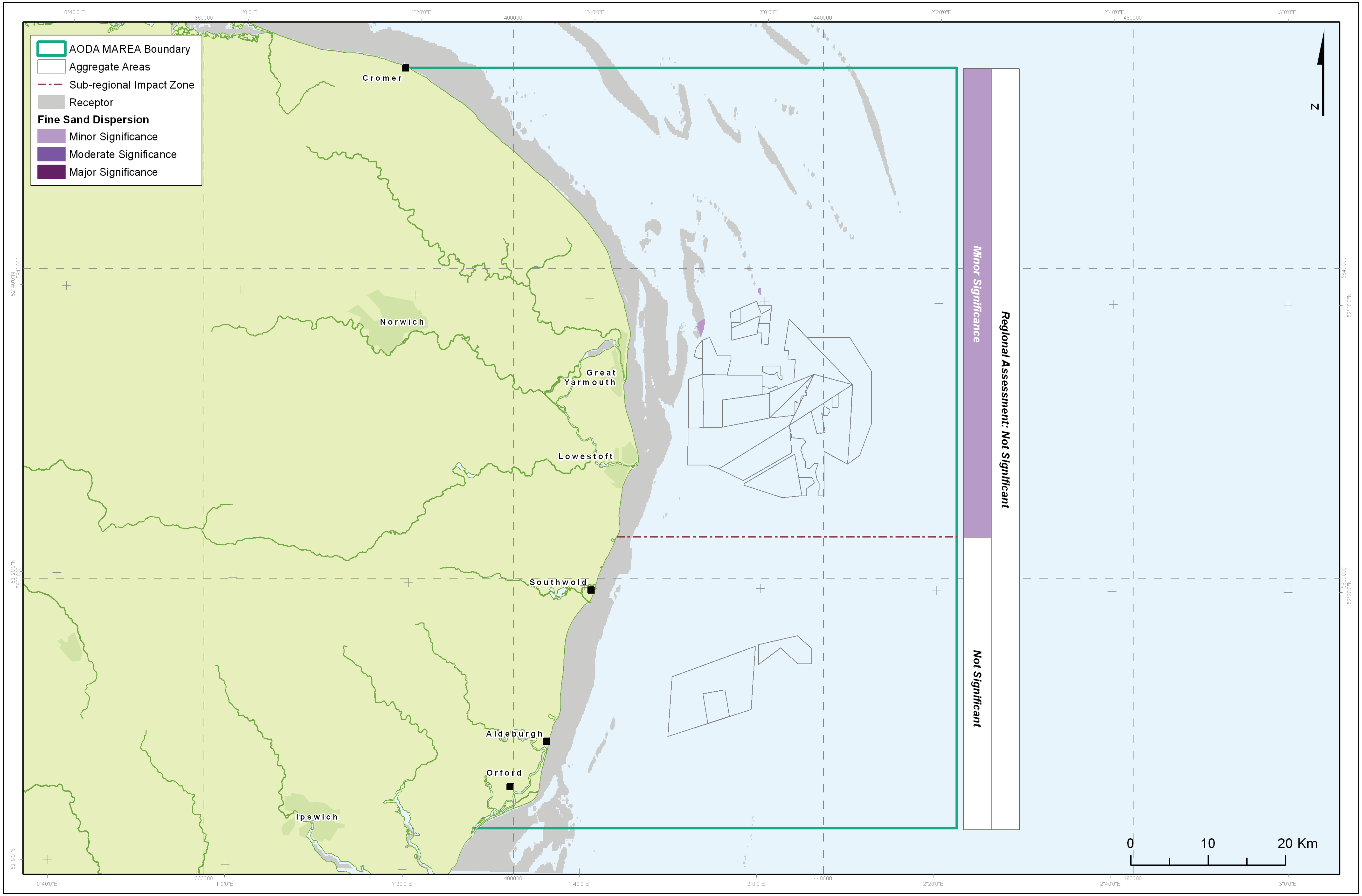


Figure 19:1 Impact significance map for fine sand dispersion across regional and sub-regional areas. Identified areas of overlap with inshore banks (shown in purple) are only predicted for the Yarmouth sub-region. There is no overlap of fine sand dispersion with the coastline

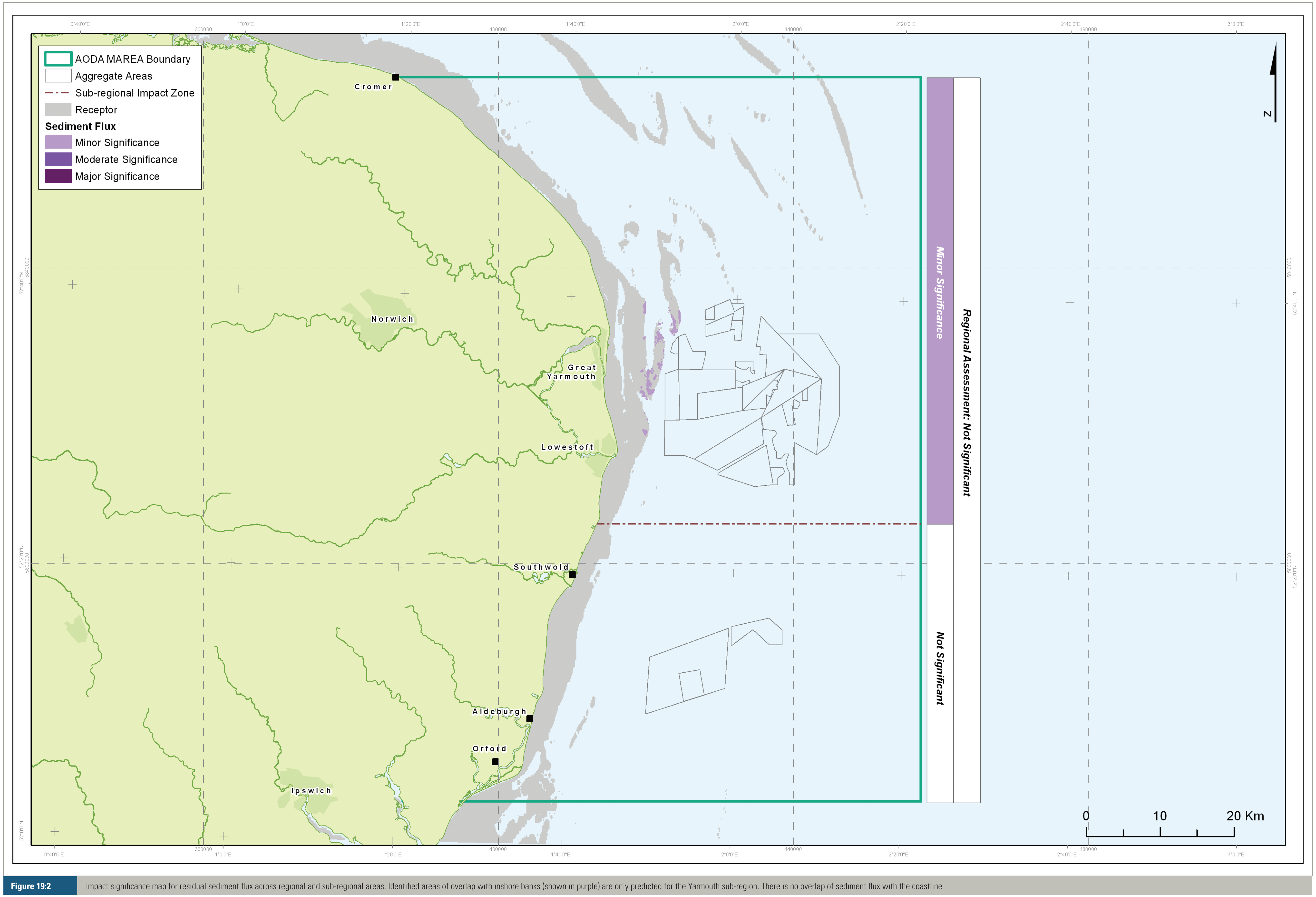


Figure 19:2 Impact significance map for residual sediment flux across regional and sub-regional areas. Identified areas of overlap with inshore banks (shown in purple) are only predicted for the Yarmouth sub-region. There is no overlap of sediment flux with the coastline

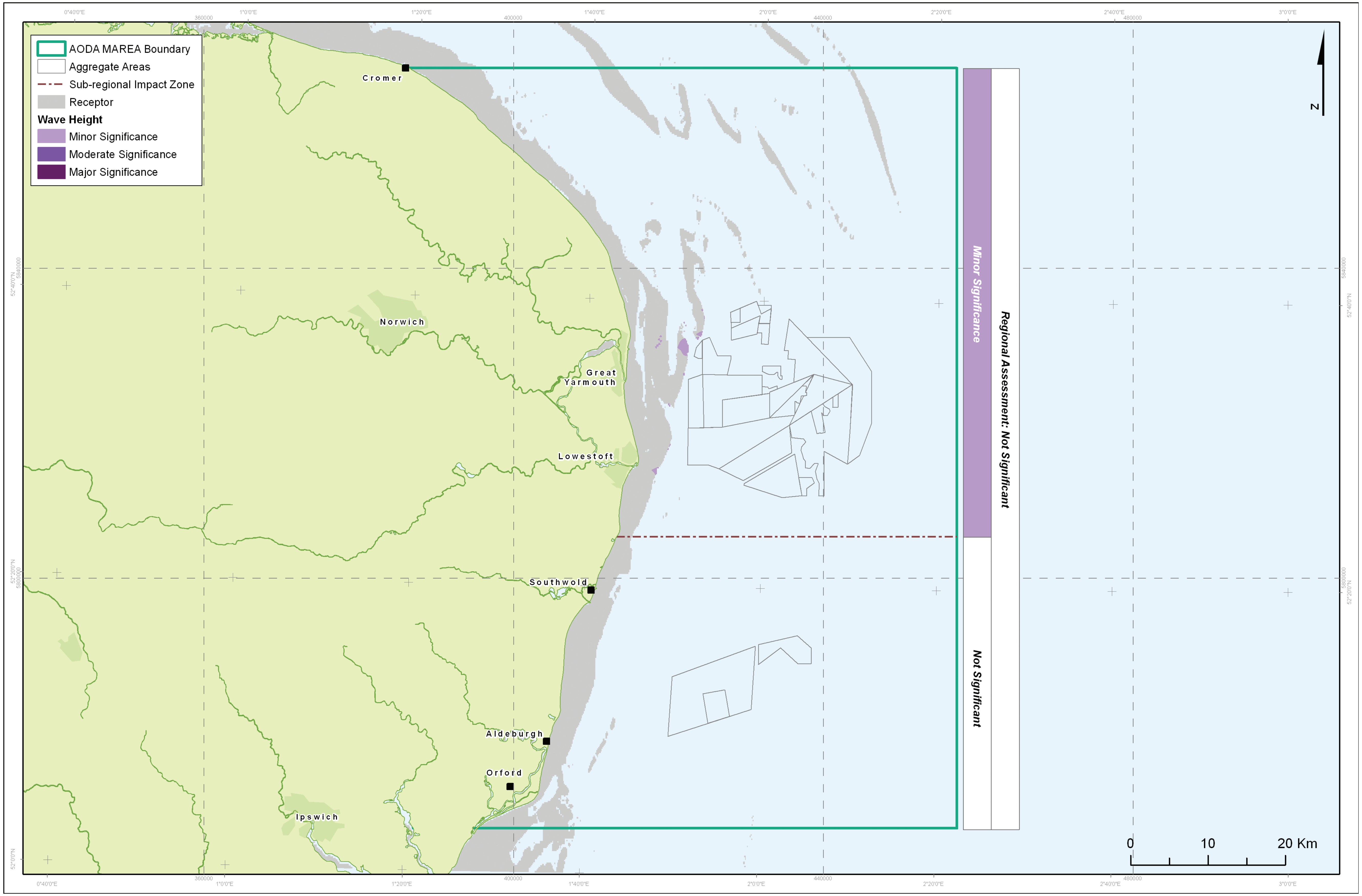


Figure 19:3 Impact significance map for increased wave heights across regional and sub-regional areas. Identified areas of overlap with inshore banks (shown in purple) are only predicted for the Yarmouth sub-region. There is no overlap of increased wave height with the coastline

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20. IMPACT ASSESSMENT: BENTHIC ECOLOGY

20.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

For the Anglian Offshore MAREA, biotope classifications (as defined in the Marine Habitat Classification for Britain and Ireland version 04.05; see Connor *et al.*, 1997; Connor *et al.*, 2004), were utilised to summarise the region's benthic ecology and as a basis for impact assessments (see Chapter 9). This system provides a hierarchical structure, varying in resolution from broad habitats (e.g. rock or sediment) with a basic description of position (e.g. littoral - onshore, sublittoral - offshore), to a range of biotope types incorporating more detailed information on substrate type (e.g. coarse sand), position (e.g. infralittoral – algal dominated zone in the region of shallow water nearest the shore), environmental conditions (e.g. exposed, shallow) and plant-animal assemblages (see **Table 9:1**, Section 9.4.2, in Chapter 9 Benthic Ecology for a biotope hierarchical structure summary). Biotopes are widely used in marine conservation and management, providing a tool for marine area characterisation and inter-site comparisons, and are appropriate for use in impact assessments.

Assigning 'sensitivity' to habitats and biotopes requires a sound knowledge of floral and faunal traits and an understanding of their regional and sub-regional distributions. For this to be achieved, it is necessary to:

- Characterise point source benthic fauna data (video and benthic grab);
- Identify biotopes and associated species/habitats of conservation importance where these are considered to be rare;
- Obtain existing literature and survey data to support understanding of receptor sensitivities to dredging activities; and
- Determine existing and potential future effects of marine aggregate extraction on biotopes.

A key component of the assessment has been the application of peer-reviewed biological sensitivity data (to various potential effects of aggregate extraction, such as substratum loss, increased suspended sediment, turbidity) available on the MarLIN website (http://www.marlin.ac.uk/biotic) to the characteristic species of benthic habitats (biotopes) based on the Marine Nature Conservation Review (MNCR) habitats classification scheme. The marine ALSF-funded genus traits handbook (MES, 2008) was used to provide supporting information on overall effects of dredging and indicators of potential recovery. The genus traits handbook was used as a secondary source of information in order to define potential sensitivity when gaps in the MarLIN data were identified, or where there was a low proportion of biotope characteristic taxa with sensitivity data and hence where there would otherwise have been a relatively high level of uncertainty. This was because the MarLIN dataset provides sensitivities to specific effects (e.g. relating to sediment removal, sediment plume), whereas the genus traits handbook is limited to estimating sensitivity to overall dredging effects and recoverability. In this way the potential tolerances of recorded biotopes to specific effects of aggregate extraction could be used to identify key sensitivities and potential cumulative effects from models generated by HR Wallingford (Appendix D, HR Wallingford 2010). The MAREA process took a regional approach to the habitats' tolerance, adaptability and recoverability. In most cases, by increasing the resolution of impacts to a regional level, reduced the apparent sensitivity of the receptors to direct impacts.

Low biotope diversity was recorded in the Anglian MAREA region, with the region dominated (96%) by sub-divisions of the 'sublittoral unstable coarse sediments' (SS.SCS) habitat complex (see Chapter 9). This complex is widespread in the North Sea and around the coast of Britain.

In most cases it was not possible to raise the level of biotope resolution for the Anglian MAREA region beyond habitat (level 3) / biotope (level 4) complex (Chapter 9). This illustrates a difficulty regarding the current paucity of classified circalittoral (the region beyond the infralittoral and dominated by sessile animals) biotopes within the Marine Habitat Classification system. This is because of the limited offshore field data available upon which classifications may be based, and is particularly acute in the disturbed, depauperate communities which dominate the Anglian Offshore MAREA region. To compound this, the low number of characterising fauna for the various biotope options rendered the possibility of further discrimination to biotope level inappropriate.

Based on the screening process (see Section 20.1.1), the four biotope complexes and one biotope found within the Anglian MAREA region were taken forward to the final impact assessment stages. Habitat complexes, which describe broad habitats, were not assessed as these solely incorporate physical information, and the impact assessment is based on species sensitivities. However, scores for the relevant sub-divisions can subsequently be extrapolated for habitat complex assessment at the EIA level.

20.1.1 Screening effect-receptor interactions

Screening identified the effects most likely to impact benthic habitats and biotopes (including their associated fauna and/or species of conservation importance). Based on an initial conceptualisation of the effect-receptor interactions (see source-pathway-receptor model in Chapter 5) a number of potential direct and indirect impacts were identified (**Table 20:1**). These impacts were taken forward to Step 3 of the impact assessment (see Chapter 3) for spatial analysis in GIS. Here, potential effects were overlaid on habitats and biotopes to determine extent of overlap. Based on this analysis, the following effects and potential sensitive biotopes (receptors) were screened in for the cumulative impact assessment:

Effects screened in:

The effects which have a potential impact on coastlines and inshore banks are:

- Seabed removal;
- Suspended sediment plume;
- Fine sand dispersion;
- Bathymetric changes; and
- Sediment flux

Effects-screened out:

- Vessel displacement; and
- Noise and vibration;

In addition the predicted changes to the following two effects were considered to be well within those aspects to which benthic fauna and habitats (and associated biotopes) are exposed, thus have been screened out.

- Tidal current changes; and
- Wave changes.

Biotope receptors screened in:

The screening process resulted in all four biotope complexes and the one biotope found within the Anglian Offshore MAREA region (see Chapter 9) being screened in. These are:

- Sublittoral coarse sediment (SS.SCS) - two associated biotope complexes in the infralittoral (SS.SCS.ICS) and circalittoral (SS.SCS.CCS) zones;
- Sublittoral sand (SS.SSa) - two associated biotope complexes from infralittoral (SS.SSa.IFiSa) and circalittoral (SS.SSa.CMuSa) zones; and
- Sublittoral biogenic reef (SS.SBR) encompassing one associated biotope (SS.SBR.PoR.SspiMx).

20.1.2 Potential impacts to benthic ecology

The likely impacts on benthic ecology can be broadly described as follows:

- Seabed removal will result in loss and/or damage of benthic habitat (biotope), change in nature of the seabed, removal of reproductive faunal populations and prey/food items;
- Suspended sediment plume may increase turbidity, which could potentially inhibit visual predator's success rate in prey capture. In addition, siltation may inhibit feeding by filter-feeders. Organic material in suspension and the deposition of damaged/dead fauna will increase presence of scavenger species to the area, and have potential implications for survivability and reproductive

success across sensitive benthic communities;

- Seabed erosion/deposition, fine sand dispersion and flux could result in scour and smothering of sessile benthic communities so may have implications for habitat loss/damage and survivorship of individual species/populations; and
- Bathymetric changes could result in changes in biotope structure/species composition, creation of new foraging and/or refuges for epibenthic mobile species able to exploit these areas.

20.2 CUMULATIVE IMPACT ASSESSMENT

Spatial differences in habitat and species distribution correlate with the physical characteristics of seabed sediments (Rosenberg, 1995; Freeman and Roger, 2003), however other factors may also influence faunal abundances and presence/absence (Seiderer and Newell, 1999). Coarse seabed sediments, for example, tend to have different faunal characteristics to fine material. These differences are strongly associated with changes in biotope. The sensitivity of a given biotope to environmental change can be assessed using the community structure of species known to characterise it. Species sensitivity and the spatial extent of biotopes within the MAREA region are a critical component in this assessment.

For this reason, the total area (km^2) of overarching habitats (the lowest classification resolution possible) was used to determine their commonality in the region (**Table 20:2**). Using GIS, the habitat/biotope area potentially influenced by the future effects of dredging was estimated. This is intended to indicate the appropriate

Sub-region	Effect	SENSITIVE RECEPTORS					Screening Assessment
		Sublittoral coarse sediment biotopes		Sublittoral coarse sediment biotopes		Sublittoral biogenic reef biotope	
		Circalittoral coarse sediment (SS.SCS.CCS)	Infralittoral coarse sediment (SS.SCS.ICS)	Circalittoral muddy sand (SS.SSa.CMuSa)	Infralittoral fine sand (SS.SSa.IFiSa)	*Sabellaria spinulosa* on stable circalittoral mixed sediment	
Yarmouth	Seabed removal	✔	✔	✗	✔	✔	● Vessel displacement, noise and vibration, tidal current and wave changes were considered to have no impact on any receptor so are screened out and not considered further for impact assessment. ● There is no overlap of seabed removal and suspended plume with areas of circalittoral muddy sand (SS.SSa.CMuSa) and this is therefore screened out of the impact assessment.
	Vessel displacement						
	Noise and vibration						
	Suspended plume	✔	✔	✗	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	
	Bathymetry changes	✔	✔	✔	✔	✔	
	Sediment flux	✔	✔	✔	✔	✔	
	Tidal currents	✔	✔	✔	✔	✔	
	Waves	✔	✔	✔	✔	✔	
Southwold	Seabed removal	✔	✔	✗	✔	✔	● Vessel displacement, noise and vibration, tidal current and wave changes were considered to have no impact on any receptor so are screened out and not considered further for impact assessment. ● There is no overlap of seabed removal with areas of circalittoral muddy sand (SS.SSa.CMu.Sa) and this is therefore screened out of the impact assessment.
	Vessel displacement						
	Noise and vibration						
	Suspended plume	✔	✔	✗	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	
	Bathymetry changes	✔	✔	✔	✔	✔	
	Sediment flux	✔	✔	✔	✔	✔	
	Tidal currents						
	Waves						

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 20:1 Screening assessment matrix for sub-regions.

direction of pressure i.e. the greater the area affected (as a result of dredging) the greater the potential impact. The full methodology for impact assessment and future impacts is provided in Chapter 3. It is important to stress again that the MAREA takes a precautionary approach to every impact assessment and assumes the future extraction scenario exceeds current production by a factor of four. Dredging at this magnitude is unlikely to occur, although the approach is intended to accommodate the maximum production from a combination of all licences, applications and prospecting licences (as previously discussed in Chapter 2).

Benthic surveys indicated that the most commonly occurring biotopes in the Anglian Offshore MAREA region were sub-divisions of the Sublittoral Coarse Sediments (SS.SCS) habitat complex, occurring from the infralittoral to the circalittoral zone at around 30 m. This covers an estimated 96% of the region and includes sands, gravels, pebbles, shingle and cobbles with low silt content. Strong tidal currents result in high levels of suspended sediment and, accordingly, the area typically supports an impoverished mobile sediment fauna, which may not achieve a developed community status (see Chapter 9). Sublittoral coarse sediments are widespread around the UK (see MESH habitat map, JNCC, 2011) and have a low protection status. However, they are recorded as being of conservation interest. This is illustrated by their inclusion on the list of priority habitats under the UK Biodiversity Action Plan (BAP) and on the lists of broad-scale representative habitats and Features of Conservation Importance (FOCI) to be protected in Marine Conservation Zones (MCZ).

Surveys indicated that, in places, Sublittoral Coarse Sediments graded into Sublittoral Sands (also a BAP/MCZ habitat) and *Sabellaria spinulosa* on stable circa-littoral mixed sediment (SS.SBR.PoR.SspiMx) (See Chapter 9). The latter biotope is found in the subtidal and lower intertidal / sublittoral fringe and has a wide, but restricted, distribution throughout the northeast Atlantic, the North Sea and the English Channel (Hayward and Ryland, 1990; Holt *et al.*, 1997). It is known from all European coasts except for the Baltic, and is common around the British Isles, especially in areas of turbid seawater with high sediment loads.

Overarching habitat and high-level biotope	Indicative Area[1] (Km^2) and % of total biotope		
	Sub-region		
	Yarmouth	Southwold	Regional
SS.SCS	2707 (96%)	1833 (97%)	4540 (96%)
SS.SSa	35 (1%)	4 (<1%)	39 (<1%)
SS.SCS.CCS/ SS.SSa	7 (<1%)	8 (<1%)	14 (<1%)
SS.SBR	81 (3%)	37 (2%)	118 (3%)
Total	2829 (100%)	1881 (100%)	4711 (100%)

Table 20:2 Assumed sub-regional tonnages and number of dredgers operating within the MAREA region assessment.

The biotope **SS.SBR.PoR.SspiMx** was assigned to a group of sites (19.5%) characterised by generally high numbers of *Sabellaria spinulosa* together with 39 of the characterising species of this biotope including Nemertea, *Abra alba*, *Ophiura albida* and *Lagis koreni* (for full details of the Primer cluster analysis groupings see Section 3.6 of the site-specific survey report, Appendix B of the Baseline). The *Sabellaria spinulosa* biotope classification available within the current system represents *Sabellaria spinulosa* biogenic reef on mixed substrate, although such reef was either not present, or not known to be present, at the majority of sites assigned this biotope (For distribution of Sabellaria reef based on current and previous survey data see Benthic Baseline Chapter 9, Section 9.4.2, **Figure 9:3**). However, this was still the most appropriate classification for the community composition of sites to which it was assigned.

It is important that the relatively wide *Sabellaria spinulosa* biotope distribution within the Anglian Offshore MAREA region does not lead to a misinterpretation of the habitat's conservation interest. *Sabellaria spinulosa* is a very common UK species, and is not an obligatory reef-builder, hence the worm itself is not of conservation interest. The distinct biogenic reef formations which can develop from the aggregations of many *Sabellaria spinulosa* colonies are listed on Annex I of the EC Habitats Directive, as a priority habitat under the UK BAP, and are encompassed within future MCZ protected habitats, because of their contribution to biodiversity and ecosystem functioning.

Data available at the time of the study included raw data from the REC survey (the final full report was not available), previous (e.g. MES , 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008a & b), REC and current survey video data indicate that *Sabellaria spinulosa* biogenic reef structures are present within the region, although their extent and precise location is less well understood. During the East Coast REC study, Limpenny *et al.* (2011) found that *S. spinulosa* reef habitat is likely to occur in moderately deep water with moderate tide and has no clear sediment preference, although reef growth appeared to be negatively associated with small and large sandwaves. Three main *Sabellaria spinulosa* reef areas within and around the following licence areas are indicated (see Benthic Baseline Chapter 9, Section 9.4.2, **Figure 9:3**):

- Area 430 in the Southwold sub-region;
- Area 401/2 in the Yarmouth sub-region; and
- Areas 202/ 254 in the Yarmouth sub-region.

As with the other biotopes assessed, the significance level for the SS.SBR.PoR. SspiMx biotope was determined from the sensitivities of the characteristic biological community to a range of effects of aggregate extraction. The extent of these effects (i.e. % of total area of biotope affected) was also taken into account in the assessment. In addition, the protection status was considered, but in a realistic manner. To achieve this, the SspiMx biotope was not treated as biogenic reef (as the code suggests), but as a biotope with an aggregation of *Sabellaria spinulosa*. This decision is crucial as relatively high abundances of *Sabellaria spinulosa* can be recorded in grab samples that are not associated with a reef, but rather in clumps, crusts, associated with larger particle sizes such as pebbles or cobbles, and in relatively small patches (at scales too small to be classified as reef).

As reef has been previously identified within the survey area (e.g. MES , 2007; Emu Ltd., 2000, 2002, 2004, 2005, 2006, 2007, 2008a & b), within the REC and at three sites in the current surveys video data, the precautionary principle was applied. Identification of which sites assigned the SspiMx biotope contain *Sabellaria spinulosa* reef requires verification using acoustic and video techniques. This is more appropriate at the EIA level due to the difficulty in assessing surface coverage of existing reefs at the regional scale.

In consideration of the benthic community and habitat information discussed (also see Chapter 9), the following sections describe the impact assessment findings for all screened in dredging effects.

20.2.1 Seabed removal

The primary aggregate extraction impact is the direct removal of seabed sand and gravel (Boyd and Rees, 2003; Cooper *et al.*, 2007), as it removes benthic habitats and species that adhere to seadbed sediment or live within it (this impact is not considered permanent[1]). Seabed removal will result in modification of biotopes and associated fauna and prey/food items available to high trophic level species (Moulaert *et al.*, 2005).

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[1] *Indicative area is used as the precise extent is unknown. GIS maps developed for this analysis were based on spatial interpolation of biotopes using an iterative interpretation of data sources (e.g. sediment type, MESH habitats and sidescan data) to best delineate boundaries where possible. Biotope data were point source.*

Removal is restricted to areas where dredging occurs. This is supported by evidence from Newell *et al*. (2004) that shows impacts to benthic communities (and therefore biotopes) outside the immediate Active Dredge Zone (ADZ) boundary are unlikely to occur. In addition to this, dredging intensity is strongly associated with direct habitat and faunal composition changes (Boyd and Rees, 2003).

Environmental characteristics, including sediment type and hydrodynamics, also have an important influence on infilling rates and the time-scale for successful regeneration of benthic assemblages (Boyd *et al*., 2004; Dernie *et al*., 2003; Foden *et al*., 2009). The natural sediment mobility in the region is likely to result in the rapid infilling of dredge tracks (Dernie *et al*., 2003; Cooper *et al*., 2007) in contrast to more stable areas where these features can persist for several years after the cessation of dredging (Millner *et al*., 1977; Cooper *et al*., 2007).

The composition and structure of the sparse benthic macrofaunal assemblages observed within the Anglian MAREA region are typical of high-energy sedimentary environments in the North Sea (Barrio Frojan *et al*., 2008). Numerically dominant species (*Sabellaria spinulosa*, *Abra alba*, *Lanice conchilega*, *Ophelia borealis*), and those caught most frequently in this MAREA (*O. borealis*, Nemertea, *Nephtys cirrosa*, *Spiophanes bombyx*, *Ophuira* spp.), are known to be associated with mobile sandy sediments. In ecological terms they are characterised as 'r selected' species, known to be associated with unstable environments and having rapid reproduction, numerous offspring, short life spans and high dispersal potential (Cooper *et al*., 2007; Barrio Frojan *et al*., 2008).

As a result, following seabed removal, the early successional assemblages naturally found within the region have the potential to recover quickly. This is in contrast to more stable seabed habitats (e.g. rock) where stable communities will develop and persist.

In ADZs with regular dredging operations, increased predator and scavenger numbers may be evident. This can cause a shift in community structure from predominantly primary consumers (e.g. filter feeders such as dead man's fingers, *Alcyonium digitatum*) to a more scavenger/consumer-dominated habitat with reduced structural heterogeneity (due to the removal of larger sessile epifauna). However, with its associated impoverished faunal communities, such an effect is likely to be less apparent within the naturally disturbed environment of the Anglian MAREA region.

All assessed biotopes, except for SS.SSa.CMuSa (**Table 20:1**), will potentially be impacted by seabed extraction. Sublittoral coarse sediment (SS.SCS) and sand (SS.SSa) habitat complexes, and their sub-divisions, fall under the UK BAP priority habitat 'subtidal sands and gravels'; they are also contained on lists of broad-scale habitats and Features of Conservation Importance in Marine Conservation Zones. MESH data indicate that sublittoral coarse sediments and sands are widespread both within the Anglian MAREA region and more widely around the British Isles (JNCC, 2011).

The Ross worm (*Sabellaria spinulosa*) is widespread across the MAREA region. Evidence indicates that dredging activities do not alter the seabed in a way that is detrimental to the recolonization of *Sabellaria spinulosa* (Pearce *et al*., 2007). The authors reported a high recruitment success of this species following aggregate extraction at Hastings Shingle Bank site with the species showing a period of rapid growth soon after settlement. Similarly, in a study of the Wash, the most developed reefs were reported to occur in grounds which showed scars of dredging activities (Foster-Smith, 2001 cited in Limpenny *et al*., 2010).

SIGNIFICANCE STATEMENT: Potentially 7% of the overarching habitat and associated biotopes may be affected by seabed removal in the Anglian region, with the majority of this in the Yarmouth sub-region. (The percentage calculated as area of modelled effect / area of biotope interpretation (which is basically the seaward extent of the AODA boundary) x 100). Although habitat loss arising from dredging may be relatively long term, it is not a permanent effect (see ABPmer, 2007) and the environmental characteristics of a region have a strong influence on the rate of 'recovery' of benthic communities (Dernie *et al*., 2003; Boyd *et al*., 2004; Foden *et al*., 2009). Based on the adaptive strategies of assemblages associated with the highly mobile sediments and strong tidal currents in the Anglian MAREA region, information suggests that following physical disturbance communities are likely to recover more quickly than those found in less energetic environments (Dernie *et al*., 2003; Mouleart *et al*., 2005

Due to the widespread occurrence of sublittoral coarse sediments and sublittoral sand, the extent of habitat loss arising from future aggregate extraction is considered to be relatively small at regional scales and unlikely to damage ecosystem structure and function. It is assessed that the region's mobile sublittoral coarse sediment (SS.SCS) and sand (SS.SSa) habitat complexes, and their sub-divisions, will have **high tolerance** and **high adaptability** to low magnitude disturbance effects and will have **high recoverability** from direct habitat loss of the magnitude envisaged here. Accordingly, the overall cumulative effect of seabed removal on these complexes in both the Yarmouth and Southwold sub-regions is considered to be ***Not Significant***.

In contrast to these complexes, the SS.SBR.PoR.SspiMx biotope is more sensitive to physical disturbance. For example, MarLIN (2011) indicates that "*Sabellaria spinulosa reefs are particularly affected by dredging or trawling and in heavily dredged or disturbed areas an impoverished community may be left, particularly if the activity or disturbance is prolonged*". The SS.SBR.PoR.SspiMx biotope has a **low tolerance** to seabed removal and a **low adaptability**.

It is also likely, however, that reefs of *Sabellaria spinulosa* can recover quite quickly from short term or intermediate disturbance levels (e.g. see Vorberg, 2000) and that recovery will be accelerated if some of the reef is left intact as this will facilitate localised larval production and settlement. The potential recovery rate for the SS.SBR.PoR.SspiMx biotope is therefore assessed as **high**. Because of the high level of protection afforded to *Sabellaria spinulosa* reef habitat, and applying the precautionary principle, the overall cumulative impact on the SS.SBR.PoR.SspiMx biotope due to seabed removal for both the Yarmouth and Southwold sub-regions, is considered to be of **Minor Significance**.

Mapped impact significance for region and sub-region is provided in **Figure 20:1**. Individual impact significance for biotopes is provided in **Tables 20:2** and **20:3**.

At the **regional** scale, the cumulative seabed removal impact on biotopes is considered to be of ***Minor Significance***.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with the exact location and classification of biotopes in the MAREA region. In particular, data coverage is less extensive in the southern sub-region and the distribution of *S. spinulosa* reef needs confirmation. Uncertainty in the areas of future seabed removal is considered Low. However, overall uncertainty in the assessment for individual biotopes groups is considered to be ***Moderate*** due to the knowledge gaps on their extent and distribution.

20.2.2 Suspended sediment plume

In areas adjacent to aggregate extraction, increased suspended sediment concentrations may have both positive and negative effects on benthic habitats. The degree and type of effect will vary with distance from the extraction site. This is related to suspended sediment settling rates (affected by particle size) which may be influenced by hydrodynamics and bathymetric features.

In general, in the Anglian MAREA region, increases in suspended sediment concentrations of less than 20 mg/l will be experienced outside the licence areas. However, when dredging occurs close to the boundary of an ADZ, concentrations may rise to more than 100 mg/l above background levels within 200 m of the ADZ (HR Wallingford, 2010). For an assessment, this must be compared with natural background turbidity levels, considered by HR Wallingford (2010) to be in the range of 8-32mg/l (summer) and 16-64mg/l (winter) under normal conditions, with much higher values expected in storm events. In addition, data from the Scroby Sands wind farm show suspended sediment concentrations between 50-100 mg/l (Cefas, 2006).

[1] *Licence conditions dictate that habitats and their associated fauna are to be restored once the active dredge area is relinquished.*

The sediment plume is predominantly composed of inorganic sediment with a particulate organic component. The inorganic particles have a number of physical and energetic negative effects, which may impact survivability or reproductive success of marine benthic organisms. For example, scouring may damage soft structures of fauna such as hydroid stalks and polyps, and physically removing particles clogging breathing/filtering apparatus (e.g. for bivalves such as *Mytilus edulis*) has associated energy costs. Increased turbidity and suspended sediment also reduces light penetration, and this may affect visual cues such as predator/prey dynamics in capture and avoidance behaviour (Wilber and Clarke, 2001).

The negative effects of suspended sediment may be particularly important during larval settlement in spring, with settling stages potentially being more sensitive to effects such as scour; however, this is generally thought to be of less concern where fauna are adapted to naturally high levels of suspended sediments such as those found within the Anglian MAREA region (Boyd *et al.*, 2004). Moreover, a number of species of ecological interest are not thought to be sensitive to suspended sediment concentration fluctuation unless they represent an acute change in background levels; e.g. a change of 100mg/l for a month (HR Wallingford, 2010).

The biological component of extracted sediment can be washed back overboard, damaged or dispersed as particulate organic matter within the sediment plume. Eventually, this biological discharge settles to the seabed and the presence of organic material may attract mobile predators and scavengers, such as the starfish *Asterias rubens* and the hermit crab *Pagurus bernhardus*, in response to this new food source (Cook and Burton, 2010). This can result in a shift in community structure although this is usually a short term phenomenon (Cook and Burton, 2010), and such an effect is likely to be less apparent within the naturally disturbed environment of the Anglian MAREA region.

Survivability of fauna washed back overboard is likely to relate to the physical robustness of the animal. For example, brittlestars (*Ophiothrix fragilis*: see section 9.7) are likely to have a low survivability in comparison with animals with a protective shell such as the common whelk (*Buccinum undatum*) and the hermit crab (*Pagurus bernhardus*) (see Bergmann, 2001; Bergmann & Moore, 2001). Moreover, physical damage is also known to reduce long-term survivability of crustaceans such as *Liocarcinus* sp. (Bergmann and Moore, 2001).

Potential positive effects of the suspended sediment plume include the organic particulate component providing an additional food resource for filter and surface deposit feeders. Because of the settlement of heavier inorganic particulates from the water column and the slower settlement rate of finer organic particles, a narrow zonation of habitats may occur with increased distance from an ADZ. With increasing distance from the ADZ, the removal of larger inorganic particles from the water column reduces scouring levels and the energetic cost of filtering organic material. Accordingly, populations of robust filter feeders (such as the fan worm, *Pomatoceros triqueter*) may initially dominate. Larger filter feeders (such as the soft coral, *Alcyonium digitatum*) may follow where conditions are more favourable, for example a reduction in the proportion of larger particle sizes in the water column.. However, the tidally-induced sediment mobility and abrasive effects of sand in suspension within the Anglian MAREA region are likely to inhibit the formation of such a well-developed epifaunal community. The epifaunal community in the region is naturally relatively impoverished and dominated by 'resilient' motile species including hermit crabs and the starfish *Asterias rubens* with a much reduced sessile faunal component

In areas adjacent to aggregate extraction, the impacts on biogenic reefs from sediment plumes and sediment deposition are presently less clear (Limpenny *et al.*, 2010). Research is currently being conducted into the effects of suspended sediment plumes on *Sabellaria spinulosa* with initial results suggesting that effects from plumes may not be entirely detrimental (Last *et al.*, 2011). Jackson and Hiscock (2008), for example, report that: *Sabellarid organisms live in dynamic sedimentary environments and their populations can certainly persevere in turbid conditions, despite 'typical' natural levels of burial. Indeed some degree of sediment transport is essential for their tube-building, although an increase in siltation may clog feeding apparatus*. Results from studies on Hasting Shingle Bank (Pearce *et al.*, 2007) support the suggestion that *Sabellaria spinulosa* is not negatively impacted by suspended sediment plumes. In fact, significant *Sabellaria spinulosa* aggregations have been found in the immediate vicinity of actively dredged areas, with rapid species recolonisation and recovery rates even within the boundaries of sites being dredged (Limpenny *et al.*, 2010).

From the preceding information, for all assessed biotopes, with the exception of SS.SSa.CMuSa where there is no effect-receptor overlap, there will potentially be suspended sediment plume impacts.

SIGNIFICANCE STATEMENT: Potentially 10% of the overarching habitat and associated biotopes may be affected by suspended sediment plumes in the Anglian region, with the majority in the Yarmouth sub-region.

Research by HR Wallingford (2010) indicates that predicted increases in suspended sediment concentrations will only occur during dredging operations and for a short time afterwards. Therefore for the majority of the time there will be no concentration increase above background levels anywhere in region. Notably, even when concentration increases occur, these are reported to be of a similar magnitude to those which occur naturally (HR Wallingford, 2010). Thus in physical terms, the plumes resulting from proposed dredging will have a minimal effect on suspended sediment concentrations within the study area (HR Wallingford, 2010).

Because of the region's natural sediment mobility, the majority of biotopes identified are considered to be well adapted to turbid conditions. Thus, they are assessed as having a **high tolerance**, **high adaptability** and **high recoverability** to suspended sediment plume effects. As such, the overall cumulative impact from a suspended sediment plume on the majority of biotopes for both the Yarmouth and Southwold sub-regions is considered to be ***Not Significant***.

An exception is the *Sabellaria spinulosa* biotope, which can afford a high level of protection when reef is present, hence it necessitates the application of the precautionary principle. Research suggests that suspended sediment plumes do not have detrimental effects on the habitat , which is assessed as having a **high tolerance**, **high adaptability** and **high recoverability** to the effects of the sediment plume (e.g. Pearce *et al.*, 2007; Jackson and Hiscock, 2008; Limpenny *et al.*, 2010). Applying the precautionary principle, however, the potential impact for both sub-regions is considered to be of ***Minor Significance***.

Mapped impact significance for region and sub-region is provided in **Figure 20:2**. Individual impact significance for biotopes is provided in **Tables 20:2** to **20:3**.

The cumulative impact on all biotopes due to suspended sediment plume at the regional scale is considered to be of ***Minor Significance***.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with the exact location and classification of biotopes in the MAREA region. In particular, data coverage is less extensive in the Southwold sub-region and the full distribution and extent of *Sabellaria spinulosa* reef is unknown. However, while the uncertainty in the modelled effects is ***Low***, there are gaps in the knowledge on the potential impacts of plumes on benthic habitat and species, and therefore the overall uncertainty in the assessment for individual biotope groups is considered ***Moderate***.

20.2.3 Fine sand dispersion

Fine sand dispersion results from transport of sand under the influence of tidal currents. The spatial extent of fine sand dispersion can be among the largest footprints of all aggregate extraction effects, occurring beyond the ADZ (Hitchcock and Bell, 2004). It can have an effect on both the physical and biological components of biotopes. Associated bedforms can extend up to 2.5 km from the dredging area, while statistical differences in particle characteristics may be measured up to 4 km from the ADZ (HR Wallingford, 2010) although these figures represent the upper limits of dispersion.

The effects of fine sand dispersion have implications for changes in the rate of sediment oxygenation by seawater percolation. A layer of fine particles or infilling of sediment pore (interstitial) spaces by fine particles will reduce water flow rates into sediments. This reduces the depth of the oxidised layer and brings the anoxic layer closer to the surface. This has a direct effect on the benthic infauna, in terms of oxygen availability, and also potential for affecting faunal motility and prey availability within sediments (e.g. meiofaunal prey of macrofaunal predators).

Epibenthic sessile and encrusting fauna such as filter feeders (e.g. sponges) may be significantly impacted by deposited fine sand. However, in the Anglian MAREA region any increase in sand is likely to be temporary due to the reworking capabilities of tides and waves (Stride, 1982). The fauna inhabiting the region also tend to be adapted to naturally occurring bedforms and high suspended sediment concentrations, thus the effects are likely to be tolerated (Millner *et al.*, 1977; Cooper *et al.*, 2005).

In other regions fine sand dispersion may significantly alter the natural character of the seabed surface and effects may be more significant in gravelly habitats dominated by encrusting epifaunal taxa, due to the abrasive impacts of suspended sediments (Desprez, 2000; Boyd and Rees, 2003; Boyd *et al.*, 2004). The Anglian MAREA region is, however, characterised by natural variation between sandy veneers and isolated sand wave or mega ripple fields. In this sense, while there may be local physical changes associated with local dispersion of fine sands from dredging activity, these physical changes will merely reflect the variation that occurs in the region as a whole. In common with a previous study by Seiderer and Newell (1999) into the effects of aggregate extraction, results from this MAREA show little evidence of a close correspondence between the distribution of sediment types and benthic communities, suggesting factors other than sediment composition play a significant part in controlling biological structure in the region. Although mobile fauna are also exposed to sedimentation, their ability to move or remove deposited materials results in a lesser direct effect (even after heavy burial - e.g. 32 cm of sand; Birklund and Wijsman, 2005).

The change in conditions may allow the settlement stages of different species to outcompete components of the original faunal community. However, the high energy environment within the Anglian MAREA region means the relatively impoverished faunal community is naturally dominated by 'r strategy' infaunal species (see 20.2.1) and resilient motile epifaunal species with the potential to recover quickly from disturbance.

The *Sabellaria spinulosa* biotope, SS.SBR.PoR.SspiMx, will potentially be affected by fine sand dispersion in both sub-regions. The Ross worm (*Sabellaria. spinulosa*) is considered to have a low intolerance to smothering (Jackson and Hiscock, 2008; Hendrick *et al.*, 2011), in fact, recent research shows that it can survive episodic sand burial, of several centimetres, for up to 32 days, in some cases extending their tubes to the point that they can re-surface (Last *et al.*, 2011.; Hendrick *et al.*, 2011). On the other hand, losses of some sabellarid reefs have been attributed to burial (Zale and Merrifield, 1989; Porras *et al.*, 1995 both cited in Hendrick *et al.*, 2011), though no indications of the maximum tolerance could be found. A reef off the coast of Dorset, for example, appears to be periodically overwhelmed by large mobile sandwaves without loss (Hiscock, 2004).

SIGNIFICANCE STATEMENT: Up to 12% of the overarching habitat and associated biotopes may be affected by fine sand dispersion within the Anglian MAREA region. (The percentage calculated as area of modelled effect / area of biotope interpretation (which is basically the seaward extent of the AODA boundary) x 100). Organisms in sediments with a higher sand content (e.g. SS.SSa) are likely to be well adapted to the effects of fine sand dispersion, particularly in the high-energy Anglian MAREA region where naturally occurring sand bedforms are widespread. In the MAREA region, infralittoral coarse sediments are also unlikely to be significantly impacted by fine sand dispersion as the development of sand bedforms over coarse substrates is a natural occurrence in the area and local sediment transport pathways are likely to disperse deposited sand more quickly than in low energy environments. These biotopes are therefore considered to have **high tolerance**, **high adaptability** and **high recoverability** to the effects of fine sand dispersion and the impacts on these biotopes are considered to be ***Not Significant*** for both sub-regions.

The *Sabellaria spinulosa* biotope is affected by sand dispersion in both sub-regions in this assessment. Whilst research indicates that *Sabellaria spinulosa* populations have a naturally **high tolerance**, **high adaptability** and **high recoverability** to fine sand dispersion, the *Sabellaria* reef structures themselves may be highly vulnerable to sand deposition. This necessitates the application of the precautionary principle to the potential impact on this biotope which is considered to be of ***Low Significance*** for both sub-regions.

Mapped impact significance for region and sub-region is provided in **Figure 20:3**. Individual impact significance for biotopes is provided in **Tables 20:2** and **20:3**. The cumulative impact on biotopes due to cumulative fine sand dispersion at the **regional** scale is considered to be of ***Minor Significance***, provided appropriate mitigation is conducted. Specifically, surveys need to be conducted as part of any future site specific EIAs to ascertain *Sabellaria* reef distribution and extent.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with the exact location and classification of biotopes and that data coverage is less extensive in the Southwold sub-region. The overall uncertainty in the assessment for individual biotope groups is considered to be ***Moderate***.

20.2.4 Bathymetric changes

An increase in water depths could potentially affect biotopes if post-dredging water depths were outside the range at which those biotopes could occur. An increase in water depth may result in a slight reduction in tidal current speeds, sediment flux and wave height at an extraction area, but an increase in these conditions outside of the area. Site-specific effects from bathymetric changes are discussed in detail in the modelling Chapter (Chapter 6). Development of seabed features (e.g. sandwaves) on top of the original habitat may change the bathymetry, although at the local or sub-regional scale the significance of this is likely to be greatly reduced. The potential impact on biotopes may include changes in biotope structure/species composition and distribution, creation of new foraging and/or refuges for epibenthic mobile species able to exploit these areas. These affects are likely to be localised.

SIGNIFICANCE STATEMENT: Potential future changes in bathymetry are localised, although in some cases bedform variation, associated with small changes in depth, may extend beyond the ADZ over time. The predicted depth changes are unlikely to cause significant change to biotope composition and/or their associated species distribution patterns and therefore biotopes are assessed as having a **high tolerance**, **high adaptability** and **high recoverability** to the effects of bathymetric change at a sub-regional and regional scale. No biotopes are considered to be potentially impacted cumulatively by bathymetric changes.

The cumulative impact on biotopes due to cumulative bathymetric changes at the **sub-regional** and **regional** scale is considered to be ***Not Significant***.

UNCERTAINTY: Data certainty in the areas where bathymetric change is likely to occur is high. However there is limited survey coverage and consequently there is uncertainty in exact distribution and extents of biotopes in the region. The overall uncertainty in the assessment for individual biotope groups is therefore ***Moderate***.

20.2.5 Sediment flux

Increased erosion from scour due to increased seabed current speeds, and deposition due to reduced seabed current speeds, can potentially affect benthic habitats (see Turk and Risk, 1981; Maurer *et al.*, 1982; Schratzberger *et al.*, 2000). Localised potential impacts may include the formation or removal of bedforms and hence also epifaunal communities. Other localised changes may alter sediment composition and hence potentially cause changes in infaunal communities. Both have a direct and indirect effect on biological communities and can change the nature of the habitat e.g. early life stages (larvae and eggs) may be vulnerable and sensitive to sediment flux effects. However, many communities in the region are well adapted to changes in sediment and bedform changes.

SIGNIFICANCE STATEMENT: Organisms in sediments with a higher sand content (e.g. SS.SSa) are likely to be well adapted to the effects of sediment flux, particularly in the high-energy Anglian MAREA region where naturally occurring sand bedforms are widespread. In the MAREA region, infralittoral coarse sediments are also unlikely to be significantly impacted by sediment flux as bedform migration occurs naturally and the biotopes are considered to have **high tolerance**, **high adaptability** and **high recoverability** to the effects of sediment flux. The impacts of sediment flux on these biotopes are considered to be ***Not Significant*** for both sub-regions.

There is an overlap of the sediment flux effect envelope with the *Sabellaria spinulosa* biotope in the Yarmouth sub-region, but not within the Southwold sub-region. While research again indicates the habitat has **high tolerance**, **high adaptability** and **high recoverability** to sand transport, employing the precautionary principle the potential impact on this biotope is considered to be of ***Low Significance*** for the Yarmouth sub-regions.

Mapped impact significance for region and sub-region is provided in **Figure 20:4**. Individual impact significance for biotopes is provided in **Tables 20:2** and **20:3**. The cumulative impact on biotopes due to cumulative sediment flux at the regional scale is considered to be ***Not Significant***.

UNCERTAINTY: Sediment flux is a proxy for erosion, deposition and sediment transport and so is not a direct measure of these potential changes in the environment. For this reason, the overall uncertainty in the assessment for individual biotopes groups is assessed as ***Moderate***.

20.3 CONCLUSIONS AND RECOMMENDATIONS

A low diversity of biotopes was found in the Anglian MAREA region, with sublittoral unstable coarse sediments (SS.SCS) and its sub-divisions dominating the region (96%). These are of national conservation importance, both as BAP habitats and MCZ protected habitats. The relatively widespread *Sabellaria spinulosa* biotope designated within the region is afforded international protection under the Habitats Directive (92/43/EEC) only when reef is present.

All biotopes screened in for this impact assessment are potentially impacted by predicted future cumulative aggregate extraction effects. Substrate removal and loss of associated communities is the primary impact of aggregate extraction activities and fine sand dispersion and suspended sediment plume are considered the most spatially extensive impacts regionally.

In terms of potential (indicative) area impacted SS.SCS.CCS is likely to be most affected by future dredging activities, however the high-energy environment of the Anglian MAREA region suggests the biotopes and associated species are likely to be highly adapted to disturbance. Moreover, the extensive coverage of the region's sublittoral coarse sediments and sands is likely to provide sufficient resources to ensure species recoverability and survivability in the longer term through recruitment.

With respect to the significance of impacts, under the precautionary principle, SS.SBR.PoR.SspiMx was considered to have the potential to be significantly impacted by future dredging, due to its high level of protection associated with the presence of reefs . Current regional distribution and extents of the protected *Sabellaria spinulosa* reef feature are largely unknown and would need to be assessed in future site-specific Environmental Impact Assessments (EIAs), to enable a more accurate assessment of potential dredging impacts.

The results of the significance assessment provide important additional information for the appropriate management and regulation of aggregate extraction in the Anglian MAREA region and can be used to inform future EIAs for licence areas within the region. Sub-regional differences in the potential impact of future aggregate extraction are summarised in the sections below.

20.3.1 Yarmouth: sub-regional impacts

The overall sub-regional cumulative impact assessment for the Yarmouth sub-region is ***Not Significant*** for the sublittoral coarse sediment and sublittoral sand biotopes and complexes. These biotopes are considered generally adaptable to disturbance given their widespread occurrence (JNCC, 2011) and the natural mobility of sediments within the regions high-energy environment.

In the Yarmouth sub-region the highly-protected *Sabellaria spinulosa* biotope, SS.SBR.PoR.SspiMx, is significantly impacted by seabed removal, suspended sediment plume, fine sand dispersion and sediment flux. Recent research (Last *et al.*, 2011) suggests that impacts of aggregate dredging effects on *Sabellaria spinulosa* may not be entirely detrimental. . All the potential impacts are considered of ***Minor Significance***.

20.3.2 Southwold: sub-regional impacts

As for the Yarmouth sub-region, the cumulative impact assessment for the Southwold sub-region is ***Not Significant*** for the sublittoral coarse sediment and sublittoral sand biotopes and complexes.

In the Southwold sub-region there is also overlap between the effect envelopes for seabed removal, suspended sediment plume, fine sand dispersion and sediment flux and the *Sabellaria spinulosa* biotope. Again, the potential impacts are considered of ***Minor Significance*** for the sub-region.

20.3.3 Regional impacts

It must be reiterated that these assessments have been undertaken at the regional level to provide a regional perspective within which to view the site specific EIAs. The resolution of impacts does have a huge bearing on each significance level given for each receptor and effect. A receptor can have low tolerance at the site specific level but high tolerance at the regional level. This is the reason why assessments at the site specific level are vital.

At the MAREA regional scale, the overall cumulative impact significance on biotopes as a result of future dredging activities is ***Not Significant***. This is largely because most of the biotopes fall under the overarching habitat type sublittoral coarse sediments that comprise 96% of the region. These are considered generally adaptable to change given their wide distribution throughout the UK and their adaptation to the naturally disturbed conditions within the region.

Any future site specific EIAs should scope in an assessment of *Sabellaria spinulosa* reef distribution, extent and condition. Regional assessment of *Sabellaria spinulosa* has shown that the individuals are common within across the region, but reef structures are not. Sabellaria spinulosa is very tolerant to disturbance as an individual but becomes more vulnerable to direct impact when contained within a reef structure. Therefore, the presence of individuals by themselves must be appropriately assessed with regard to their regional abundance and vunerability. It is recommended that appropriate mitigation is carried out, specifically, assessment of the distribution and extent of

Sabellaria spinulosa reef should be scoped in at site-specific EIA level. Current best practice dictates that any 'potential' *Sabellaria spinulosa* reefs are zoned out of ADZs through the establishment of exclusion zones around the potential reef areas to avoid both direct and indirect impacts.

Although not afforded a high level of protection, it is considered good practice to limit the extent of subtidal sand and gravel habitat loss arising from dredging.

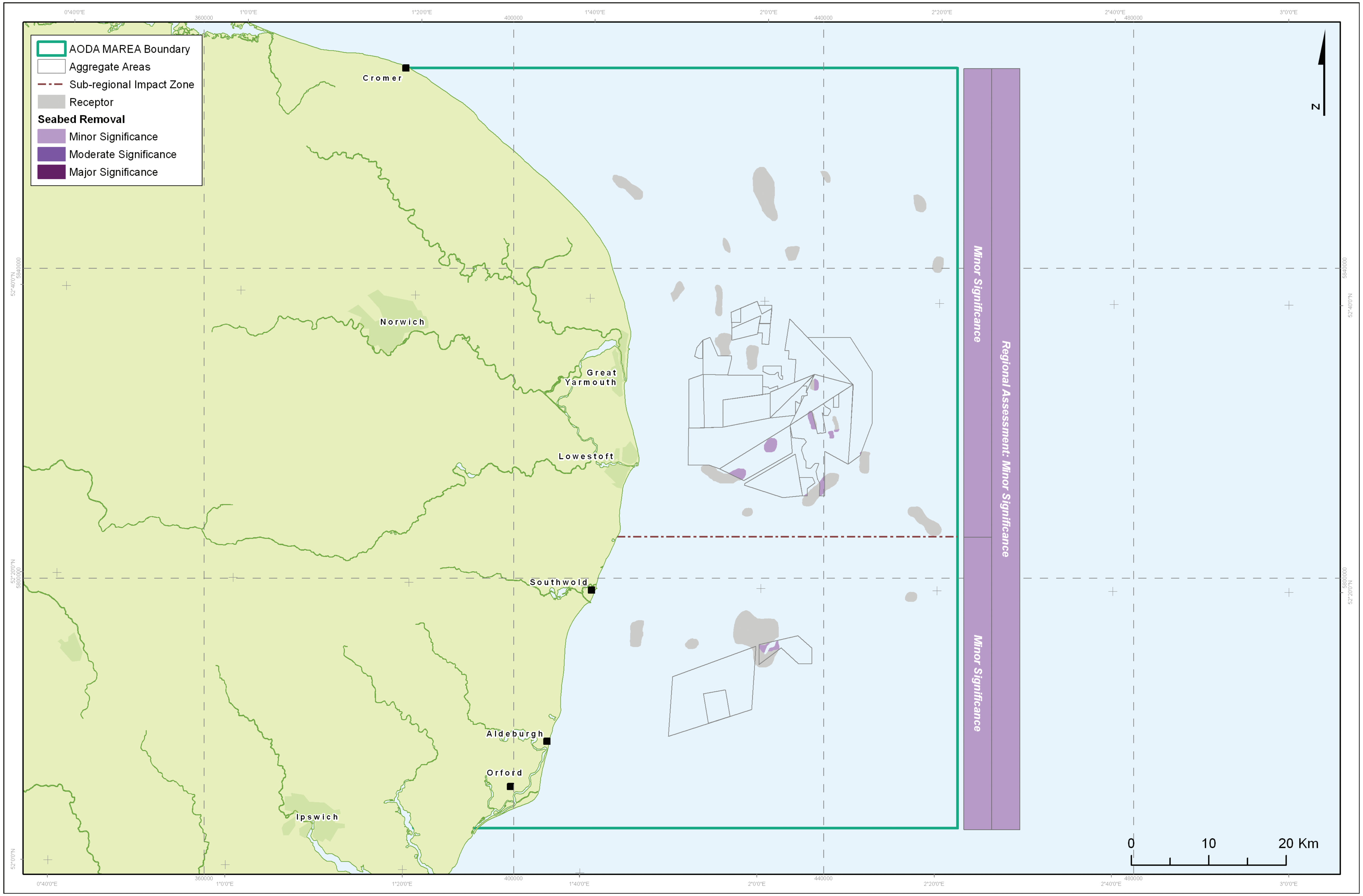

Figure 20:1 Map of seabed removal impact significance across regional and sub-regional areas

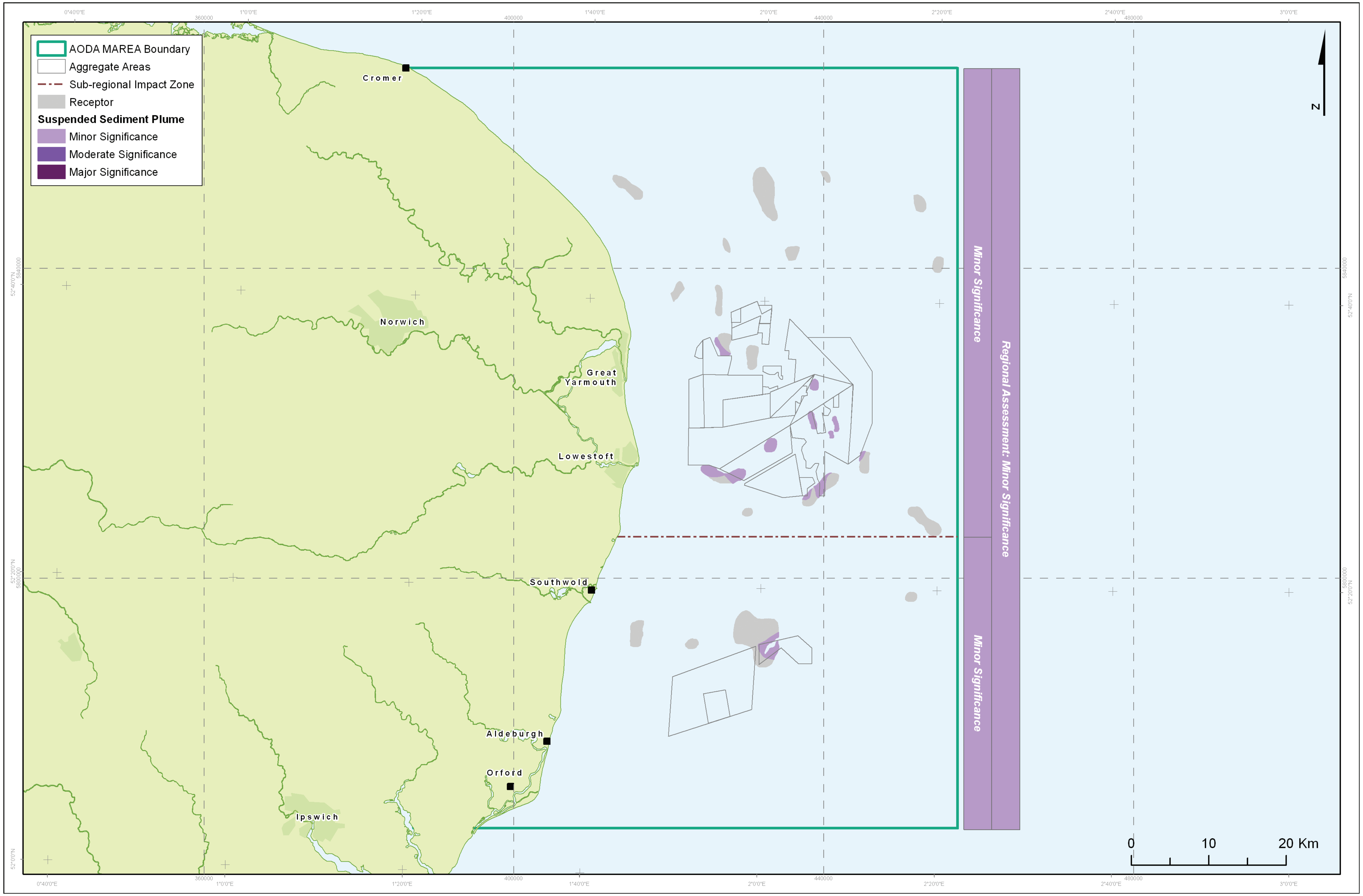

Figure 20:2 Map of suspended sediment plume impact significance across regional and sub-regional areas

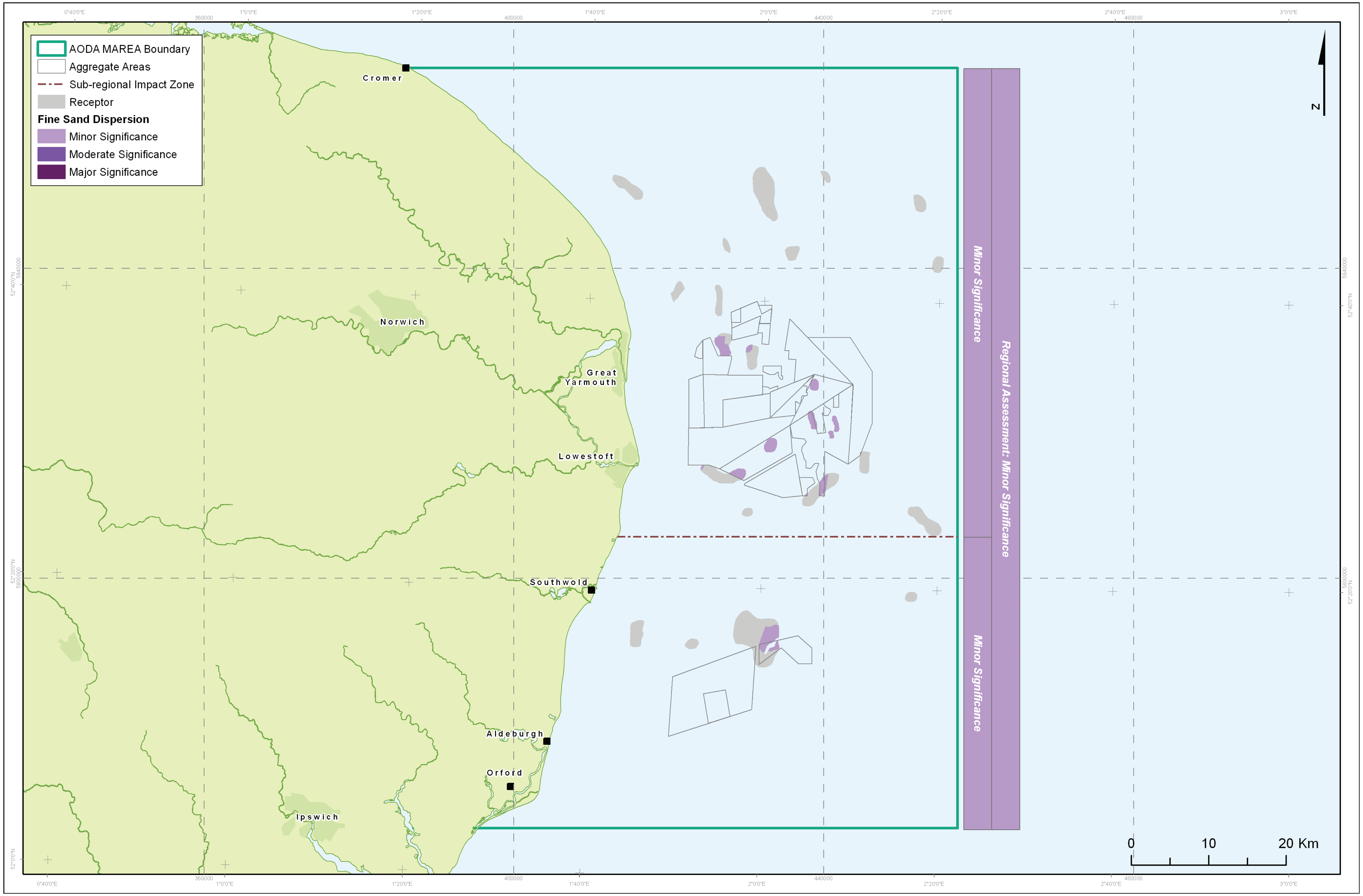

Figure 20:3 Map of fine sand dispersion impact significance across regional and sub-regional areas

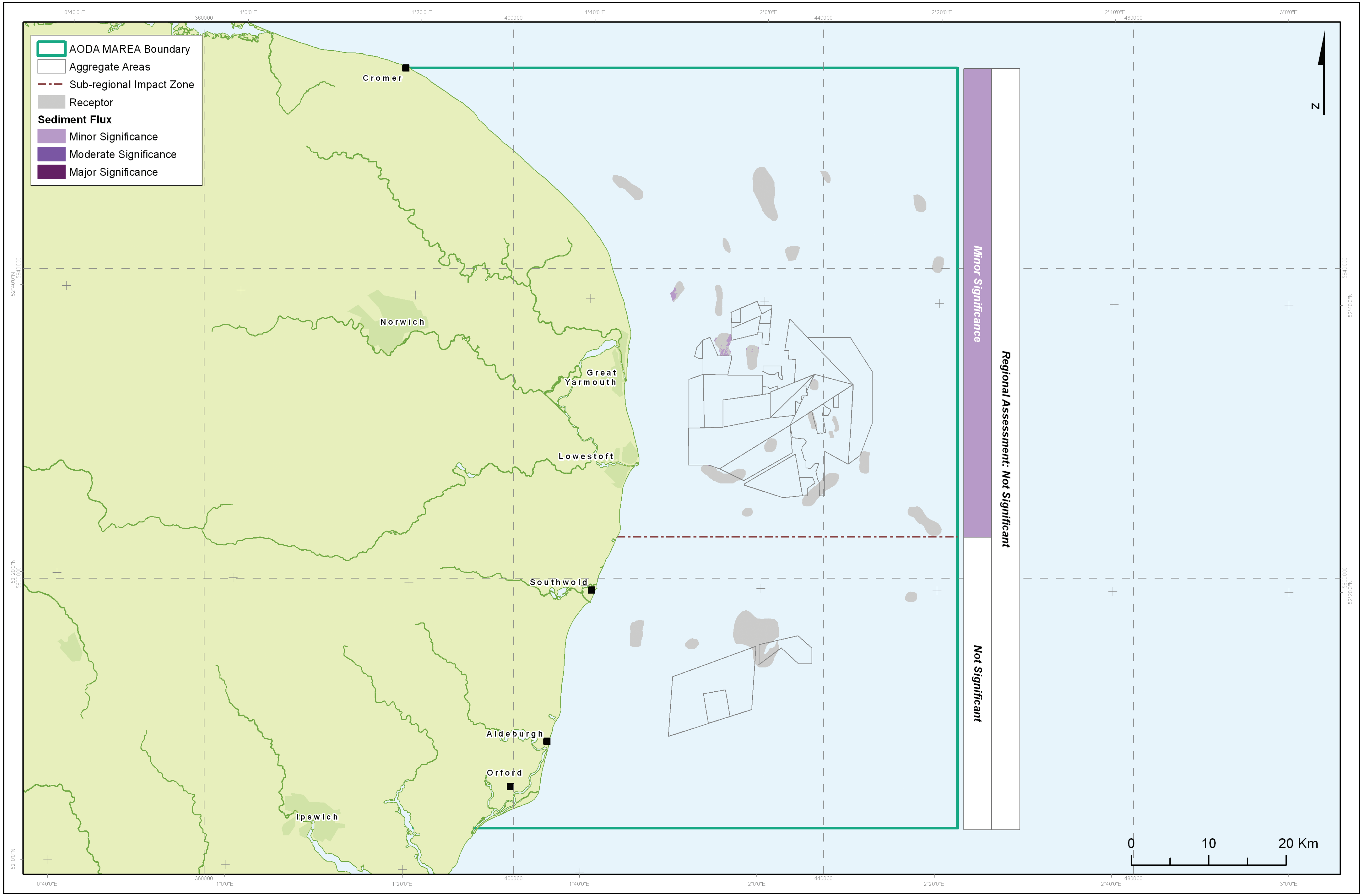

Figure 20:4 Map of sediment flux impact significance across regional and sub-regional areas

Table 20:3 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR SUB-REGION YARMOUTH.** *Grey shading on table denotes effect and/or receptor screened out of assessment*

EFFECT	SENSITIVE RECEPTOR				
	Sublittoral coarse sediment (SS.SCS)/biotopes/complexes		*Sublittoral sand (SS.SSa)/biotopes/complexes*		*Sublittoral biogenic reef (SS.SBR)* *(NOTE: this biotope was not treated as biogenic reef, but as a biotope with an aggregation of S. spinulosa as a minority of specific locations confirmed 'reef')*
	SS.SCS.CCS	*SS.SCS.ICS*	*SS.SSa.IFiSa*	*SS.SSa.CMuSa*	*SS.SBR.PoR.SspiMx*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope common throughout region and in licence areas. Direct effects from removal of reproductive fauna and prey/food. Reduced heterogeneity.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource. Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sand is not targeted. Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** Low, **A:** Low; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** This biotope does overlap with the resource in specific licence areas. Direct effects from removal of reproductive fauna and prey/food. Reduced heterogeneity. General populations of *Sabellaria* are expected to recover rapidly on cessation of dredging. However, reef structures are particularly vulnerable to direct removal. Recovery will be dependent on amount of reef damaged and suitablility of environmental conditions for re-growth. As 'biogenic reef' does exist within this biotope designation, and there is potential for reef formation, the precautionary principle has been applied to the regional impact assessment.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****
VESSEL DISPLACEMENT					
NOISE AND VIBRATION					
SUSPENDED SEDIMENT PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope common throughout region and in licence areas. Temporary inhibit prey capture for visual predator and feeding by filter-feeders	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Temporary inhibit prey capture for visual predator and feeding by filter-feeders	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sand is not targeted. Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** The SspiMx biotope does overlap with the resource in specific licence areas. Research suggests that suspended sediment plumes do not have a negative effect on general *Sabellaria* populations. Considered well adapted to disturbance and turbid conditions in the region. Reef may be more vulnerable to suspended sediments. As 'biogenic reef' may be encountered in specific locations the precautionary principle has been applied to the impact assessment
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Biotope common throughout region and in licence areas. Decrease survivorship of species/populations if habitat is lost or damaged. Scour/smothering around sessile benthic communities.	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Biotope not generally part of targeted resource Decrease survivorship of species/populations if habitat is lost or damaged. Scour/smothering around sessile benthic communities.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** The SspiMx biotope does overlap with the resource in specific licence areas. This biotope is affected by sand dispersion in both sub-regions in this assessment. *Sabellaria spinulosa* populations have a naturally high tolerance, high adaptability and high recoverability to fine sand dispersion, however, the *Sabellaria* reef structures themselves may be highly vulnerable to sand deposition.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐	Not significant
▨	Minor significance
▨	Moderate significance
■	Major significance

Uncertainty: *High **Moderate *** Low

Table 20:3 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR SUB-REGION YARMOUTH.** *Grey shading on table denotes effect and/or receptor screened out of assessment*

EFFECT	SENSITIVE RECEPTOR				
	Sublittoral coarse sediment (SS.SCS)/biotopes/complexes		*Sublittoral sand (SS.SSa)/biotopes/complexes*		*Sublittoral biogenic reef (SS.SBR)* *(NOTE: this biotope was not treated as biogenic reef, but as a biotope with an aggregation of S. spinulosa as a minority of specific locations confirmed 'reef')*
	SS.SCS.CCS	*SS.SCS.ICS*	*SS.SSa.IFiSa*	*SS.SSa.CMuSa*	*SS.SBR.PoR.SspiMx*
BATHYMETRY CHANGE *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Not significant****
SEDIMENT FLUX *(Effect magnitude = Medium)*	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Many communities in the region well adapted to these changes	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Many communities in the region well adapted to these changes	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Considered well adapted to disturbance.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Potential localised changes in structure and species composition. Early life stages more vulnerable. Considered well adapted to disturbance.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** There is an overlap of the sediment flux effect envelope with this biotope in the Yarmouth sub-region, but not within the Southwold sub-region. Potential localised changes in structure and species composition. Early life stages more vulnerable. *Sabellaria spinulosa* populations considered well adapted to disturbance, however, the *Sabellaria* reef structures themselves may be highly vulnerable to scour and changes in sediment and bedform changes. The precautionary principle is applied for potential impact on 'reef' structures.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****
TIDAL CURRENTS					
WAVES					

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ▨ Major significance **Uncertainty:** *High **Moderate *** Low

Table 20:4 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR SUB-REGION SOUTHWOLD.** *Grey shading on table denotes effect and/or receptor screened out of assessment*

EFFECT	SENSITIVE RECEPTOR				
	Sublittoral coarse sediment (SS.SCS)/biotopes/complexes		*Sublittoral sand (SS.SSa)/biotopes/complexes*		*Sublittoral biogenic reef (SS.SBR)* *(NOTE: this biotope was not treated as biogenic reef, but as a biotope with an aggregation of S. spinulosa as a minority of specific locations confirmed 'reef')*
	SS.SCS.CCS	*SS.SCS.ICS*	*SS.SSa.IFiSa*	*SS.SSa.CMuSa*	*SS.SBR.PoR.SspiMx*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope common throughout region and in licence areas. Direct effects from removal of reproductive fauna and prey/food. Reduced heterogeneity.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource. Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sand is not targeted. Removal of reproductive faunal and prey/food if habitat is lost or damaged.	**T:** Low, **A:** Low; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** This biotope does overlap with the resource in specific licence areas. Direct effects from removal of reproductive fauna and prey/food. Reduced heterogeneity. General populations of *Sabellaria* are expected to recover rapidly on cessation of dredging. However, reef structures are particularly vulnerable to direct removal. Recovery will be dependent on amount of reef damaged and suitablility of environmental conditions for re-growth. As 'biogenic reef' does exist within this biotope designation, and there is potential for reef formation, the precautionary principle has been applied to the regional impact assessment.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****
VESSEL DISPLACEMENT					
NOISE AND VIBRATION					
SUSPENDED SEDIMENT PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope common throughout region and in licence areas. Temporary inhibit prey capture for visual predator and feeding by filter-feeders.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Temporary inhibit prey capture for visual predator and feeding by filter-feeders	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sand is not targeted. Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** The SspiMx biotope does overlap with the resource in specific licence areas. Research suggests that suspended sediment plumes do not have a negative effect on general *Sabellaria* populations. Considered well adapted to disturbance and turbid conditions in the region. Reef may be more vulnerable to suspended sediments. As 'biogenic reef' may be encountered in specific locations the precautionary principle has been applied to the impact assessment
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Biotope common throughout region and in licence areas. Decrease survivorship of species/populations if habitat is lost or damaged. Scour/smothering around sessile benthic communities.	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Biotope not generally part of targeted resource Decrease survivorship of species/populations if habitat is lost or damaged. Scour/smothering around sessile benthic communities.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Biotope not generally part of targeted resource Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Considered well adapted to disturbance and turbid conditions in the region.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** The SspiMx biotope does overlap with the resource in specific licence areas. This biotope is affected by sand dispersion in both sub-regions in this assessment. *Sabellaria spinulosa* populations have a naturally high tolerance, high adaptability and high recoverability to fine sand dispersion, however, the *Sabellaria* reef structures themselves may be highly vulnerable to sand deposition.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Minor significance (if reef) ****

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ▨ Major significance **Uncertainty:** *High **Moderate *** Low

Table 20:4 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR SUB-REGION SOUTHWOLD.** *Grey shading on table denotes effect and/or receptor screened out of assessment*

EFFECT	SENSITIVE RECEPTOR				
	Sublittoral coarse sediment (SS.SCS)/biotopes/complexes		*Sublittoral sand (SS.SSa)/biotopes/complexes*		*Sublittoral biogenic reef (SS.SBR)* *(NOTE: this biotope was not treated as biogenic reef, but as a biotope with an aggregation of S. spinulosa as a minority of specific locations confirmed 'reef')*
	SS.SCS.CCS	*SS.SCS.ICS*	*SS.SSa.IFiSa*	*SS.SSa.CMuSa*	*SS.SBR.PoR.SspiMx*
BATHYMETRY CHANGE *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** Potential localised changes in biotope structure or species composition. No biotopes are believed to be impacted.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Not significant****
SEDIMENT FLUX *(Effect magnitude = Medium)*	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Many communities in the region well adapted to these changes	**T:** Medium, **A:** High; **R:** High **Value:** UK BAP biotope **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Many communities in the region well adapted to these changes	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope. **Spatial Overlap:** Potential localised changes in structure and species composition. Early life stages more vulnerable. Considered well adapted to disturbance.	**T:** High, **A:** High; **R:** High **Value:** UK BAP biotope and possible presence of Annex I habitat (Sandbanks). **Spatial Overlap:** Muddy sands are not part of targeted resource but may be subject to peripheral impacts. Potential localised changes in structure and species composition. Early life stages more vulnerable. Considered well adapted to disturbance.	**T:** High, **A:** High; **R:** High **Value:** UK BAP and presence of Annex I habitat in some areas **Spatial Overlap:** There is no overlap of the sediment flux effect envelope with this biotope in the Southwold sub-region.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Not significant****
TIDAL CURRENTS					
WAVES					

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ▨ Major significance

Uncertainty: *High **Moderate *** Low

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21. IMPACT ASSESSMENT: FISH AND SHELLFISH ECOLOGY

21.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

The potential for fish and shellfish to be impacted at the regional and sub-regional level by aggregate extraction activities depends on a number of variables that need to be considered, including:

- The species present and their use/behaviour across the region;
- The distribution of habitats crucial to key life stages of fish and shellfish within the region; and
- The feeding behaviour of fish and shellfish present in the region.

A key element in the MAREA impact assessment is consideration of geographical boundaries and the spatial extent of receptors. This is particularly important for receptors that rely on a specific habitat or area during part of their life-cycle (e.g. an area of sandbanks or clean gravel for spawning). However, it is considered unrealistic to define fixed boundaries for mobile species.

The ecology of fish and shellfish are temporally and spatially complex involving seasonal variations in the abundance and distribution. This is largely due to the physical environment in which they live, namely substrate type, availability of food, water depth and tidal currents.

For the purpose of this MAREA assessment, maps showing potential and/or indicative spawning and nursery areas, including known fishing grounds, were evaluated against seabed sediment maps, together with background information on adult stock behaviour and their likely distribution patterns.

21.2 SCREENING EFFECT-RECEPTOR INTERACTIONS

Screening was used to identify the effects of future dredging activities most likely to impact fish and shellfish, and so improve the efficiency of the assessment process. Key scientific studies that describe the impacts of aggregate extraction on these receptors were used to underpin screening decisions and are appropriately referenced in the proceeding sections.

Using the source-pathway-receptor model presented in Step 1 of the impact methodology (see Chapter 3), all direct and indirect pathways between the physical effects of dredging and fish and shellfish were identified. This process identified the effects for inclusion in Step 3 of the assessment and subsequent spatial analysis in GIS. This identified effect-receptor interactions for each licence/application area across the entire region, and either screened in or out the following effects and receptors.

Effects screened in:

- Seabed removal;
- Noise and vibration and
- Suspended sediment

Effects-screened out:

- Vessel displacement;
- Bathymetry;
- Waves;
- Tidal currents; and
- Sediment flux (proxy for seabed erosion/deposition).

At a regional and sub-regional level, the MAREA region is known to support critical habitats for key life phases of many species; spawning grounds, nursery grounds, over-wintering and migratory pathways.

Fish and shellfish receptors screened in:

- Adult stocks of key fish species;
- Adult stocks of key shellfish species;
- Spawning – pelagic (e.g. those species present that spawn into the water column e.g. scad, sprat, whiting);
- Spawning – demersal (i.e. those species present that spawn directly onto the seabed e.g. black sea bream, herring and sandeels);
- Nursery – all fish species (i.e. demersal and pelagic species); and
- Migratory species (e.g. those that transit through the region from deeper waters to shallower or vice versa).

Fish and shellfish receptors screened out:

- Diadromous fish species (sea and river lamprey, salmon, shads, european eel and smelt).

Diadromous fish species have been screened out of further assessment. The data collected for Chapter 10 did not find any evidence of critical habitats or pathways for any species. Should additional data or studies be made available or undertaken for any species, it is recommended that this is incorporated into future EIAs.

21.3 POTENTIAL IMPACTS ON FISH AND SHELLFISH

The likely impacts on fish and shellfish from the effects of marine aggregate extraction can be broadly described as follows:

- Removal of suitable habitat for spawning, nursery or overwintering;
- Damage or behavioural response to noise and vibrations;
- Smothering of filter feeders by increased suspended sediment and sediment deposition; and
- Direct uptake and damage of individuals.

21.4 CUMULATIVE IMPACT ASSESSMENT

The MAREA region is an important area for adult stocks of commercial and non-commercial fish and shellfish, supporting a thriving and diverse fishing industry, but also supporting spawning, nursery and migratory habitats for some fish and shellfish species.

Fish and shellfish form an important component of the marine ecosystem, and have the potential to be adversely affected by marine aggregate extraction activities. The main likely impacts of dredging on fish and shellfish relate to loss of seabed containing potential prey and/or critical habitats; disturbance due to noise and vibration, increases in turbidity and fine sand dispersion.

Understanding potential future changes in the environment as a result of cumulative aggregate extraction activities, and how such changes impact on fish and shellfish, are central to the purpose of this assessment. They require knowledge of the current interactions between existing populations and dredging activity within the MAREA region.

Baseline data from *Chapter 10 – Fish and Shellfish Ecology* and *Chapter 14 – Commercial Fisheries* identified concerns from the fishing industry sector that current levels and locations of aggregate extraction are impacting upon fish and shellfish receptors.

21.4.1 Seabed removal

The removal of seabed has the potential to impact on fish and shellfish in a number of ways; through changes in the predator – prey dynamics as a result of a potential shift in the species composition of benthic fauna, through removal of key habitats crucial to their survival (e.g. spawning habitats) and through direct uptake.

Changes to prey dynamics have the potential to impact on the feeding behaviour of adult stock and consequently their distribution. The baseline chapter

		SENSITIVE RECEPTORS						
Sub-region	Effect	Adult stock - Fish	Adult stock - Shellfish	Pelagic Spawning	Demersal Spawning	Nursery - all	Migratory Species	Screening Assessment
Yarmouth	Seabed removal	✔	✔	✔	✔	✔	✔	● Vessel displacement, bathymetry change, sediment flux, tidal currents and waves were considered to have no impact on any receptor so are screened out and not considered further for impact assessment. ● Because spatial extents cannot be rigidly fixed, all receptors are screened in. ● Diadromous fish species have been screened out of further assessment. The study did not find any evidence of critical habitats or pathways for any species.
	Vessel displacement							
	Noise and vibration	✔	✔	✔	✔	✔	✔	
	Suspended plume	✔	✔	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	✔	
	Bathymetry changes				✗			
	Sediment flux				✗			
	Tidal currents				✗			
	Waves				✗			
Southwold	Seabed removal	✔	✔	✔	✔	✔	✔	● Vessel displacement, bathymetry change, sediment flux, tidal currents and waves were considered to have no impact on any receptor so are screened out and not considered further for impact assessment ● Because spatial extents cannot be rigidly fixed, all receptors are screened in.
	Vessel displacement							
	Noise and vibration							
	Suspended plume	✔	✔	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	✔	
	Bathymetry changes				✗			
	Sediment flux				✗			
	Tidal currents				✗			
	Waves				✗			

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 21:1 Screening assessment matrix for sub-regions

provides a comprehensive overview of the feeding habits of the key species present. Many species are generalist feeders and it is unlikely that species which feed on a range of pelagic prey including other fish and planktonic organisms will be impacted by any changes to seabed communities. Fish and shellfish species which target benthic prey have more potential to be impacted by aggregate extraction. Given fish and most shellfish are mobile, the scale of any potential impact will be dependent upon the availability of suitable or alternative prey in the wider region and the timescales for impact, together with the predicted rate of recovery of the seabed.

One factor that contributes to the scale of impact is the timescale for recovery of benthic communities. The recovery of the seabed after aggregate extraction is dependent on the method of extraction, bedload transport, local hydrodynamic conditions and the availability of juveniles for recruitment from surrounding areas; and is highly variable. Recovery time can fluctuate between one month and more than 15 years (ICES, 2001; in Birklund and Wijsman, 2005). Some studies show that distinct differences in the nature of assemblages could still be observed in dredging sites six years after cessation of dredging (Boyd *et al*., 2005).

However, the extent of the impact is site-specific, occurring only within those parts of the licence area that are currently or predicted to be dredged. The availability of prey and the mobile nature of the majority of species, together with the fact that most species are opportunistic and generalist feeders and not reliant on a single prey item, suggest that any impact on these species will be minimal.

Seabed removal could potentially impact on spawning and migratory routes through removal of suitable habitats present in the dredging area. Fish species that spawn directly onto the seabed will be more sensitive to the effects of seabed removal than those that spawn into the water column. Of particular relevance within the Anglian MAREA region are the presence of herring and sandeel spawning areas, both of which target specific substrates (clean gravel and sand respectively), which may also be targeted for aggregate extraction.

An analysis on sandeel habitats undertaken by Holland *et al.* (2005) that compares the proportion of all grab samples assigned to a particular sediment category, with the proportion of samples containing sandeels assigned to the same category, reveals clear patterns of either selection for, or avoidance of, seabed habitats. As the proportion of Coarse Gravel, Fine Gravel, Fine Sand, Coarse Silt, Medium Silt and Fine Silt in the seabed habitat increases, sandeels show reduced selection for and increased avoidance of the habitat. Conversely, as the proportion of Coarse Sand and Medium Sand in the sediment increases, sandeels show reduced avoidance of and increased selection for the habitat.

Laboratory-based choice experiments have shown that sandeels preferred sand habitat over gravel habitat (Pinto *et al*., 1984), and Wright *et al*. (2000) (referenced in Holland *et al*., *(2005)*) demonstrated that whilst sandeels showed a strong preference for medium to very coarse sands (sediment habitats with a median particle size of 0.25 to 2.0 mm) they avoided sediment habitats with a silt content of more than 10%.The critical importance of silt was also noted by Holland *et al.* (2005) in defining suitable sandeel habitat is underlined by these extremely low percentages. If the silt content was greater than approximately 4%, then the sediment habitat was rarely occupied by sandeels. Silt contents in excess of this amount rendered the seabed habitat unsuitable.

Ellis *et al. (2012)* states that there are five species of sandeel in UK waters and these are widely distributed and abundant on suitable habitats, suggesting that sandbanks and other sandy substrates may be important habitats. The spatial data collated from Coull *et al.* (1998) and Ellis *et al. (2012)* suggest the presence of spawning and nursery grounds but these are low intensity usage. The data also indicate that grounds are extensive across the North Sea.

Figure 8:21 in Chapter 8 indicates that the seabed sediments within the licence areas are typically comprised of sandy gravel and gravelly sand. This sediment type is coarser than the preferred habitat type identified by Holland *et al. (2005)* and other studies referenced, which suggests that the licence areas are unlikely to support preferred habitat but this does not necessarily rule out the use of the licence areas by sandeels. However, other areas of the AODA region outside of the licence areas, particularly in the nearshore, offshore along the eastern boundary and sandbanks are sandier and are more likely to be a more suitable habitat for sandeels.

It is acknowledged that fishermen hold the view that changes to bathymetry as a result of seabed removal have the potential to impact on migratory species, e.g. flatfish and some elasmobranchs that migrate between shallower inshore waters and the deeper waters offshore of the Anglian region. Esseen (2005) reported that many fishermen consulted as part of the Area 401/2 fisheries activity study thought that grounds inshore of the licence area held lower sole stocks and that sole had stopped migrating inshore across areas that had been dredged. There are, however, no scientific data to support this view and a recent study (Kenny *et al*., 2010) identified that long term trends off the east coast aggregate region appear to be dominated by factors which also govern the trends observed at the North Sea scale e.g. declines in fish stocks are observed across both the North Sea and ALSF study areas.

Adult stocks of fish are considered insensitive in terms of their adaptability and tolerance by way of their mobile nature and generalist feeding behaviour. Any impacts from the direct uptake of fish and shellfish are unlikely given their mobile nature.

SIGNIFICANCE STATEMENT: Compared with the potential seabed affected by dredging activities and the wide variety of benthic and pelagic prey in the region available to mobile, generalist feeders the majority of fish receptors (Adult stock – fish; Adult stock – shellfish; Pelagic spawning; Nursery – all fish; Shellfish – overwintering and migratory) are considered to show **high tolerance**, **high adaptability** and **high recoverability** to the effects of seabed removal. The potential, therefore, for cumulative impacts of seabed removal across both sub-regions is considered ***Not Significant***.

It is worthy of note that herring and sandeels spawn directly onto the seabed onto sediments also targeted for aggregate extraction. Sandeel spawning is considered to have a **low tolerance**, **low adaptability** and **medium recoverability** to the effects of seabed removal where their specific habitat requirements are targeted. Sandeels are considered to have a high ecological value given their importance as a prey item to many bird and marine mammals species. Spatially, recent data published by Defra (2010) indicate that sandeel spawning grounds are extensive across the region and beyond and their use is of a **low intensity**. The seabed sediments targeted by the aggregate companies tend to be of a higher gravel content than surrounding sediments, which offer more suitable sediments for sandeels. Therefore the impacts of seabed removal across both sub regions are assessed as ***Not Significant***.

Data from Coull *et al*. (1998) indicate however that herring spawning grounds occur in a narrow band which overlaps with several licences in the Yarmouth sub-region. This is confirmed by Ellis *et al.* (2012), however, studies undertaken for Area 401/2 further east suggest patches of suitable habitat exist across the region. Although the new Defra data (Defra, 2010) do not identify the presence of spawning grounds, it is acknowledged that the importance of spawning grounds is related to the overall health of the stock of autumn-spawning herring (see Schmidt *et al*., 2009), and some historic spawning grounds currently have no, or very little, spawning activity. Nevertheless, it should be recognised that spawning grounds can be "recolonised" over time (e.g. Corten, 1999) and so ensuring that changes in the physical nature of these grounds does not restrict recolonisation or continued use is an appropriate management measure.

Taking the precautionary approach, given the specific requirements for herring spawning and the spatial limits of these grounds within the region, herring are considered to have **low tolerance, low adaptability** and **medium recoverability** to the effects of seabed removal. It should be noted however that should all suitable habitat be removed from the region then recoverability will be **low.** The potential for cumulative impacts based on available data, herring spawning habitat for the Yarmouth sub region is therefore considered to be of ***Minor Significance***.

Species	Strong behavioural avoidance range (90 dB$_{ht}$)	Mild behavioural avoidance range (75dB$_{ht}$)	Low likelihood of disturbance (50dB$_{ht}$)	Range to background sea noise
Herring	6 m	60 m	1900 m	7000 m
Cod	4 m	30 m	1100 m	7000 m
Dab*	< 1 m	3 m	130 m	4000 m

* Considered to be the most sensitive flatfish to underwater sound.

Table 21:2 Noise disturbance thresholds for three fish species to underwater noise (from Parvin *et al.*, 2008)

The cumulative impact on fish and shellfish ecology due to cumulative seabed removal at the regional scale is considered to be ***Not Significant***.

UNCERTAINTY: Despite recent updates in the data by Defra (2010), there is **High Uncertainty** in the distribution and extent of preferable habitats and their spatial and temporal use by key species. This assessment has been undertaken on the presence of known grounds, however a number of other species are thought to spawn or have nursery grounds in the region but the extent of these areas is less well-known. In addition, since the use of the area is dependent upon a large number of variables, including natural variation, it is difficult to assess an isolated effect such as aggregate extraction.

Given the level of uncertainty it is recommended that any future EIAs or monitoring studies consider the suitability of available habitat for herring spawning and manage this resource accordingly to ensure that post dredging suitable habitat is still available.

21.4.2 Noise and vibration

The ability to detect and localise the source of a sound is of considerable biological importance to many fish species, and is often used to assess the suitability of a potential mate or during territorial displays and during predator-prey interactions (Parvin *et al.*, 2008). Parvin ***et al.*** (2008) also suggest that crustaceans utilise sound in much the same way.

Noise associated with dredging is mainly of low frequency – below 1kHz – with estimated source sound pressure levels ranging between 168 and 186 dB re. 1 µPa at 1 m.

There are five types of noise associated with dredging activity (Thomsen *et al.*, 2009):

- Collection noise: noise arising from the collection of material from the seafloor. This depends on the seafloor's structure;
- Pump noise: noise of the pump driving the suction through the pipe;
- Transport noise: noise of the material being lifted from the seafloor to the dredger;
- Deposition noise: noise associated with the placement of the material within the barge or hopper; and
- Ship/machinery noise: noise associated with the dredger itself.

Robinson *et al.* (2011) undertook studies at a number of licence areas around the UK, including two within the Anglian region. This study concluded that source levels from dredger vessels at frequencies below 500 Hz are generally in line with those expected for a cargo ship travelling at modest speed (between 8-16 knots), whereas source levels at frequencies above 1 kHz show elevated levels of broadband noise generated by the extraction process itself. The report also states that when placed in context, dredgers are considered to be basically 'noisy ships'.

Among fish, there is a wide diversity in hearing structures which leads to different auditory capabilities across species. Fish are classified as either hearing generalists or hearing specialists. Hearing specialists, e.g. herring, have a high sensitivity to underwater sound and vibration and have a mechanical coupling between the swim bladder and the inner ear which allows them to have high sound pressure sensitivity and generally lower hearing thresholds than generalists. Their best sensitivity is from 300-1,000 Hz and can detect sounds to over 3 kHz.

Most fish classified as hearing generalists only detect sounds up to 500-1,000 Hz with some exceptions which hear from 100-400 Hz (Popper *et al.*, 2003). Fish hearing generalists can be divided into those species that contain a swimbladder, and species such as flatfish that do not. For those fish species that possess a swimbladder, sensitivity to sound and vibration is related to the proximity of the swimbladder to the ear (Parvin *et al.*, 2008). Demersal species such as flatfish (e.g. dab and plaice) have no swimbladder and so are less sensitive to sound and vibration (Parvin *et al.*, 2008). However, more information is needed to understand how coupling of vibrations to the substrate will affect bottom dwelling flatfish.

Studies looking at crustacean species have indicated that they are able to respond to a wide frequency bandwidth, although the sensitivity to underwater sound and vibration is very much lower than fish (Parvin *et al.*, 2008).

Based on data in the studies of Yelverton (1975), Turnpenny *et al.* (1994), Hastings and Popper (2005), and reported in Parvin *et al.* (2008), potential noise effects on marine organisms are:

- Lethal effect: where peak-to-peak levels exceed 240 dB re.1 µPa at 1 m, or an impulse of 100 Pa.s.; and
- Physical injury: where peak-to-peak levels exceed 220 dB re. µPa at 1 m, or an impulse of 35 Pa.s.

The source sound pressure levels associated with dredging range between 168 and 186 db re. 1 µPa at 1 m and so are unlikely to have a lethal effect or physical injury on fish (Parvin *et al.*, 2008). This is also valid for smaller fish sizes of mass 0.01 g (no injury criteria for fish exposed to level of 214 dB re. 1 µPa at 1 m, peak-to-peak level) (Hasting and Popper, 2005; Popper *et al.*, 2006 all cited in Parvin *et al.*, 2008).

The aversion of fish to noise is based on the level above hearing threshold for the species and so the noise from the dredging operation is likely to cause a behavioural avoidance response (Parvin *et al.*, 2008). The values in **Table 21:2** are specifically for the Hastings Shingle Bank but species are relevant to the Anglian region, and the conditions and activities are considered representative for the Anglian region.

The findings from the Parvin *et al.* (2008) study on the Hastings Shingle Bank were used to provide spatial extent of likely impact zones. The report states that since the dredging vessel is moving, and fish are not constrained and able to move away from the source of the noise, it is unlikely that any auditory injury would occur. Models by Parvin *et al.* (2008) suggests that a strong behavioural avoidance response for species of fish that are sensitive to underwater sound may occur up to 6 m from the source. For species that are relatively insensitive, such as demersal flatfish and crustaceans (e.g. brown crab and lobsters), the strong avoidance response may be limited to the immediate vicinity of the dredging operation (**Table 21:2**). **Table 21:2** shows that sensitive hearing fish may detect the disturbance up to 7000 m away.

Thomsen *et al.* (2009) identified the occurrence of fish species in the region, together with the presence of spawning and nursery grounds, to determine an assessment of the sensitivity of fish to aggregate dredging. The sensitivity of fish to aggregate extraction in the MAREA region was considered to be relatively high (when using a sensitivity index devised by Stelzenmuller *et al.* based on variables including threat status, distribution and habitat vulnerability etc. and referenced in Thomsen *et al.*, 2009). The report stated that the main fish species of concern with respect to spawning areas in the region are (in order of overlap) lemon sole, sole, sandeels, herring, sprat and possibly plaice. The report also identified the presence of elasmobranchs; thornback rays, small smoothounds and occasional spotted and blonde rays and thresher sharks.

Despite the report concluding a high sensitivity, it should be noted that the demersal species and elasmobranchs have poor hearing sensitivity, are hearing generalists, and are therefore less likely to be significantly affected by noise and vibration effects caused by dredging.

SIGNIFICANCE STATEMENT: Impacts on fish and shellfish are primarily restricted to behavioural changes through avoidance, which are limited to a localised area for most demersal species and crustaceans. The majority of fish receptors occurring in the region (Adult stock – fish; Adult stock – shellfish; Pelagic spawning; Nursery – all fish; Shellfish – overwintering and migratory) are considered to have **high recoverability, high tolerance** and **high adaptability**, given noise effects are temporary and mobile species are able to avoid the area and return once dredging activity has ceased. The effects of noise and vibration on fish and shellfish are therefore considered ***Not Significant*** across both sub-regions given the temporary and localised nature of the effect and low sensitivity of the receptor.

An exception is herring, which is a hearing specialist and which targets a narrow band of available spawning ground. Any disturbance and resulting avoidance behaviour triggered by effects of noise and vibration would potentially result in a reduction of available spawning ground. Given the temporary nature of this effect, herring are considered to have **medium recoverability, medium tolerance** and **medium adaptability** to the effects of noise and the impact is therefore considered to be of ***Minor Significance*** for the Yarmouth sub-region.

The cumulative impact on fish and shellfish ecology due to noise effects at the **regional** scale is also considered to be ***Not Significant***.

UNCERTAINTY: This assessment acknowledges that there is some uncertainty related to the actual response of fish and shellfish to noise and the exact locations of mobile receptors. With regard to the seabed vibration, since a number of bottom-dwelling fish species are known to be sensitive to vibration, this is an area where further research is needed. There is little data on what typical ambient seabed vibration levels exist, or what levels might be considered to cause damage of disturbance to fish (Robinson *et al.,* 2011). The overall uncertainty for individual receptor groups is ***Moderate*** (see **Table 21:3** to **21:4**).

21.4.3 Suspended sediment plume

Production of a sediment plume depends on the method of extraction, sediment composition in the extraction area, the rate and amount of sediment overspill and the local hydrodynamic conditions. Plumes may extend several kilometres downstream of a vessel. Sediment plumes generated are temporary, lasting for a period of hours before settling back onto the seabed.

This increase in turbidity and particulate suspended matter could potentially affect activities such as filter feeding, migrations and movements of fish, survival of pelagic egg and larvae of fish and forage opportunities of visual predators like fish (Birklund and Wijsman, 2005). ABP Research (1997) stated that juvenile fish are more susceptible than adult fish to plumes, as adult fish would normally be able to detect significantly elevated levels of suspended sediment and avoid the affected area. Shellfish are considered particularly susceptible during spring when spatfall occurs.

The sensitivity of marine species varies greatly and is largely dependent upon the natural background levels of turbidity to which they are accustomed. Natural background levels of suspended sediment within the Anglian MAREA region are relatively high (see *Chapter 7 - Regional Hydrographic Environment*). Species present in the region are therefore likely to be less sensitive to sediment plumes generated by dredging than species in areas where suspended sediment concentrations are naturally low. It has been suggested that most benthic filter feeders could potentially be impacted by dredging activities in the near field due to excessive concentrations of suspended matter and increased deposition on the seabed (Birklund and Wijsman, 2005).

Sediment plumes may affect migration and movement of fish relying on their vision. For example, high avoidance behaviour of herring *Clupea harengus* and cod *Gadus morrhua* was recorded with sediment plume concentrations between 2 mg/l and 8-9 mg/l (Westerberg *et al*., 1996; in Birklund and Wijsman, 2005).

A number of fish spawn within the region, such as cod and plaice, and have pelagic eggs. A high concentration of silt (e.g. higher than 200 mg/l for cod) could potentially increase the sinking rate of pelagic eggs due to the adherence of silt to their surface, making them heavier (Westerberg *et al*., 1996; in Birklund and Wijsman, 2005). As a result, an increase in mortality of pelagic eggs may be observed if the eggs hit the bottom before the pelagic phase of the development is completed. However, newly hatched larvae are generally more sensitive than eggs to suspended sediment (e.g. mortality of cod larvae is about 50% after one day of exposure in 200 mg/l of silt; Westerberg *et al*., 1996 in Birklund and Wijsman, 2005). However, this is of a longer duration and higher than levels predicted to extend significantly outside the dredging areas.

Increased turbidity due to increased suspended sediment concentrations in the water column can irritate adult fish gills and lead them to avoid affected areas. Long term impacts are unlikely to occur as fish are mobile, will avoid an area affected by increased suspended sediment, and are able to return to the area once suspended sediment concentrations revert to natural background levels, however short term impacts are predicted by Posford Duvivier Environment and Hill (2001).

SIGNIFICANCE STATEMENT: The majority of fish receptors occurring within the region are considered to have a **low sensitivity** because of their **high recoverability**, **high adaptability** and **high tolerance** to the effects of increased suspended sediment. This is because they are able to avoid affected areas and return once the plume has settled. Spawning and nursery fish are considered to be more sensitive to the effects of increased suspended sediment as newly hatched larvae are considered more sensitive than adults. The cumulative impact on fish and shellfish ecology due to cumulative suspended sediment plumes at both the **sub-regional** and the **regional** scale is considered to be ***Not Significant***.

UNCERTAINTY: This assessment acknowledges that there is some uncertainty related to the actual impact of sediment plumes on fish and shellfish species, and whether sensitivity differs for different life stages e.g. larvae stages and the exact locations of mobile receptors. The overall uncertainty for individual receptor groups is ***Moderate*** (see **Table 21:3** to **21:4**).

21.4.4 Fine sand dispersion

The effect of fine sand dispersion depends on a number of factors such as rate of sedimentation, sediment type and the ability of species present to cope with changes in bed sediment. In general, extraction in naturally sandy habitats is likely to have less impact than in gravel habitats where many sessile and encrusting epibenthic species may be unaccustomed to fine sediment (Boyd and Rees, 2003). Increased sedimentation and resuspension caused by dredging in mobile sand is generally thought to be of less concern due to the fact that fauna inhabiting such areas is more adapted to naturally high levels of suspended sediment resulting from wave and tidal current action (Millner *et al*., 1977; Newell *et al*., 2002; Cooper *et al*., 2005 in Sutton and Boyd, 2009).

Within the Anglian MAREA region, levels of mobile sediment are naturally high and therefore fish species and their respective prey will be adapted to naturally high exposure. However, the sensitivity of organisms to fine sand dispersion is species specific and dependent upon critical life stages.

Certain critical phases require a particular sediment type e.g. species which spawn directly onto the seabed. Of particular importance within the MAREA region is herring, which spawns on gravelly sediments and produces demersal eggs, which are more sensitive to an increase in fine sediment. Herring are known to produce eggs that become attached to clean gravel substrates, the deposition of fine sediment in such areas on a regular basis could affect the reproductive success in specific gravel beds (Gubbay, 2003). In addition, herring are known to regularly revisit the same spawning ground so any medium to long term changes in the sediment composition of their spawning grounds will have an impact on their ability to recover post dredging.

A study by Griffin e*t al.* (2009) looked at the impacts of suspended sediments on fertilisation, embryonic development and early larval life stages of the Pacific herring. The study noted that several laboratory studies (Atlantic and Pacific species) have concluded that sediment levels of 1000 mg/l or greater were required to produce significant mortality in embryos or larvae. It was noted however, that previous studies did not test the impacts of the presence of sediments during the early post fertilisation period when eggs and embryos are sticky and still forming the adhesive layer that will anchor them to substrata. The study concluded that the development of the adhesive layer of herring embryos requires at least two hours and sediment particles that attach during this two hour window remain bound throughout development. The findings of the study indicated that if suspended sediments were present at concentrations of 250 or 500 mg/l during the initial two hour window, particles attached permanently to eggs; eggs could aggregate into multiple layers and even in the absence of egg aggregation, significant developmental effects occurred that included precocious hatching of larvae, increases in larval abnormalities and a decrease in survival of yolk-sac larvae after hatching.

The lesser sandeel, which is a key food item for many other species, is also sensitive to sediment changes due to their specific habitat requirements (i.e. clean sand with less than 2% silt/clay), although in the region they will be adapted to relatively high mobile fine sediment and therefore less sensitive to effects than herring.

SIGNIFICANCE STATEMENT: As noted earlier the sensitivity of organisms to fine sand dispersion is species specific. The majority of fish and shellfish receptors in the region (Adult stock – fish; Adult stock – shellfish; Pelagic spawning; Nursery – all fish; Shellfish – overwintering and migratory) show a **high adaptability**, **high tolerance** and **high recoverability** to the effects of fine sand dispersion. Permanent changes in sediment composition will result in certain species, in particular herring, having a **low adaptability**, **low tolerance** and **low recoverability**. It is unlikely that the effects will result in complete loss of suitable habitat, however within the region herring spawning grounds are confined to a narrow band that overlaps with the most westerly licences of the Yarmouth sub-region (Coull *et al*., 1998) and therefore sensitivity of this species for this sub-region is considered **moderate to high**.

Taking the precautionary approach therefore, the effect of fine sand dispersion on the demersal spawners receptor, within the Yarmouth sub-region, is considered of ***Minor Significance*** for herring. For all other receptors in the Yarmouth sub-region, and all receptors in the Southwold sub-region the effects of fine sand dispersion are considered ***Not Significant***.

The cumulative impact on fish and shellfish ecology due to fine sand dispersion at the **regional** scale is also considered to be ***Not Significant***.

UNCERTAINTY: This assessment acknowledges that there is some uncertainty related to the actual impact of fine sand dispersion on fish and shellfish species, and the exact location of the mobile species. The overall uncertainty for individual receptor groups is ***Moderate*** (see **Table 21:3** to **21:4**).

For herring that spawns directly onto a gravel seabed the precautionary approach has been taken to allow for the uncertainties regarding spatial overlap between the effects and receptor. It is worthy of note that although Coull *et al*. (1998) identify a defined band for herring spawning grounds, new data from Defra do not provide any qualification of this. It is also worth noting that other studies within the region indicate the presence of suitable habitat is wider but uncertainties still arise over use.

21.5 CONCLUSIONS

The MAREA region supports suitable habitats and feeding grounds for maintaining adult stocks of several fish and shellfish species, and also critical habitats required for their survival and long term success. The sensitivity of fish to effects of aggregate dredging in the region was studied by Stelzenmuller *et al*., (as reported in Thomsen *et al*., 2009). This considered twelve species of fish and shellfish (including several with spawning and/or nursery grounds in the region; sole, plaice, whiting, brown crab and lobster), and looked at variables including threat status, distribution, habitat, vulnerability etc. This report confirmed that the waters off the East Anglian coast were of relatively high sensitivity. However, in most cases where overlap of spawning and nursery grounds occur with aggregate licences, the availability of suitable grounds is widespread both within the region and beyond.

21.5.1 Yarmouth: sub-regional impacts

The sub-regional cumulative impact assessment for the Yarmouth sub-region is overall ***Not Significant***. The sub-region supports spawning and nursery grounds for a number of species but where overlap with licence areas occur, the availability of alternative grounds is widespread. The exception being for herring which is considered of ***Minor Significance*** as the species has a specific habitat preference and a high level of uncertainty surrounds the presence and use of available habitat.

21.5.2 Southwold sub-regional impacts

The sub-regional cumulative assessment for the Southwold sub-region is overall ***Not Significant***. As noted for Yarmouth where overlap does occur with spawning and nursery grounds, the presence and use of alternative habitats is considered widespread.

21.5.3 Regional impacts

At the MAREA regional scale, the overall cumulative impact significance on fish and shellfish populations as a result of future dredging activities is ***Not Significant***. Although the region supports a number of commercially and ecologically important species and spawning and nursery grounds, in most cases where overlap with any licence areas or effects footprints occur, the extent of alternative habitat is considered widespread across the region and in many cases beyond. However, a precautionary assessment of ***Minor Significance*** is assigned to herring within the Yarmouth sub region.

Table 21:3 SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR FISH ECOLOGY-SUB-REGION YARMOUTH

EFFECT	SENSITIVE RECEPTOR					
	Adult stock - Fish	*Adult stock – Shellfish*	*Spawning – Pelagic*	*Spawning – Demersal* *Species screened in: herring and sandeel*	*Nursery – All Fish*	*Migratory species*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species. Species covered by grouped BAP present in region include herring, cod, whiting, plaice, mackerel, scad and Dover sole. **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Sub-region supports commercial shrimp and lobster fishery with brown crab caught along north Norfolk coast. Cockles fished commercially inshore. **Spatial overlap:** No evidence of the importance of region for any species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species, species covered by commercial fish group BAP spawning in region include whiting, plaice, mackerel and Dover sole. **Spatial overlap:** Known grounds for whiting, plaice, cod, Dover sole, lemon sole, mackerel and sprat	**T:** Low, **A:** Low; **R:** Medium **Value:** Commercial species. Sandeel UK BAP species, herring grouped BAP species. Sandeel and herring both ecologically important prey species **Spatial overlap:** Known spawning grounds exist for commercial species herring and sandeel. Sandeel breed throughout the region at low intensity. The license areas overlie herring spawning grounds in some areas. Ecologically important species including gobies and sea scorpions lay eggs on substrate. These species are very common, as is the habitat which they inhabit during spawning activity. **NB:** It is recognised that although some grounds may have little or no activity, spawning grounds can be recolonized over time and physical nature of suitable grounds should be considered at an EIA level to maintain integrity of spawning grounds.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Nursery areas exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Flatfish species known to migrate inshore from deeper waters – these include Sole, plaice as well as thornback rays. Also diadromous species may pass through the MAREA region on their way to natal grounds. No impact has been proven to occur with the sole population and aggregate licence areas (EMU 2011)
	Not significant* **	**Not significant***	**Not significant****	**Minor Significance (herring only) ***	**Not significant****	**Not significant***
NOISE AND VIBRATION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Effect likely to prompt avoidance behaviour. **NB:** Studies to date have shown no conclusive evidence that noise from dredging is deleterious to fish (Robinson *et al* 2011), significance rating is precautionary	**T:** High, **A:** High; **R:** High **Value:** Commercial species. **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Spawning grounds extend beyond Anglian region and pelagic eggs disperse over a wider area compared to localised nature of effect.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Known spawning grounds exist for commercial species herring and sandeel. Herring spawning grounds overlap with number of licences. Herring are considered to be hearing specialist sensitive to noise disturbance.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Nursery grounds appear extensive across region, slight overlap with an area of high intensity use for herring in south west of sub region **NB:** Juveniles thought to be more sensitive than adults, effect likely to prompt avoidance behaviour.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Flatfish species known to migrate inshore from deeper waters. Demersal species such as flatfish (e.g. dab and plaice) have no swimbladder and so are less sensitive to sound and vibration (Parvin *et al.*, 2008)
	Not significant* **	**Not significant****	**Not significant****	**Minor Significance (herring only) ***	**Not significant****	**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Plume effects temporary and fish species highly mobile.	**T:** Medium, **A:** Medium; **R:** High **Value:** Commercial species **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Known spawning grounds are extensive across region and beyond and pelagic eggs disperse over a wider area compared to localised nature of effect	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Herring spawning grounds overlap with number of licences	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Nursery grounds exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond Newly hatched larvae are considered more sensitive than adults but uncertainty exists.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** flatfish species known to migrate inshore from deeper waters
	Not significant* **	**Not significant****	**Not significant****	**Not significant***	**Not significant****	**Not significant***
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Effect likely to prompt avoidance behaviour.	**T:** Medium, **A:** Medium; **R:** High **Value:** Commercial species **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Known spawning grounds are extensive across region and beyond and pelagic eggs disperse over a wider area compared to localised nature of effect	**T:** Low, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Herring thought to spawn in region on coarse sediments, high sensitivity to change in sediment type. Herring thought to spawn in region, with preference for coarse sediments where there is a low proportion of fine sediment (Coull *et al.*, 2012).	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Nursery areas exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** flatfish species known to migrate inshore from deeper waters
	Not significant* **	**Not significant****	**Not significant****	**Minor Significance (herring only) ***	**Not significant****	**Not significant***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant
▨ Minor significance
▨ Moderate significance
■ Major significance

Uncertainty: *High **Moderate *** Low

Table 21:4 SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR FISH ECOLOGY-SUB-REGION SOUTHWOLD

EFFECT	SENSITIVE RECEPTOR					
	Adult stock - Fish	*Adult stock – Shellfish*	*Spawning – Pelagic*	*Spawning – Demersal Species screened in: herring and sandeel*	*Nursery – All Fish*	*Migratory species*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species. Species covered by grouped BAP present in region include herring, cod, whiting, plaice, mackerel, scad and Dover sole. **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Sub-region supports commercial shrimp and lobster fishery with brown crab caught along north Norfolk coast. Cockles fished commercially inshore. **Spatial overlap:** No evidence of the importance of region for any species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species, species covered by commercial fish group BAP spawning in region include whiting, plaice, mackerel and Dover sole. **Spatial overlap:** Known grounds for whiting, plaice, cod, Dover sole, lemon sole, mackerel and sprat, all grounds extensive, e.g. high intensity grounds for sole spawning extend as far south west as the IOW.	**T:** Low, **A:** Low; **R:** Medium **Value:** Commercial species, Sandeel UK BAP species, herring grouped BAP species. Sandeel and herring both ecologically important prey species **Spatial overlap:** Known spawning grounds exist for commercial species herring offshore of the sub-region. No overlap with known grounds in the sub-region. Sandeel breed throughout the region at low intensity. **NB:** It is recognised that although there is no overlap with known grounds, EIA studies should consider the availability of suitable grounds to maintain integrity of spawning grounds.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Nursery areas exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond. All grounds with exception of herring are of low intensity use with ranges extending into the North Sea and southwards.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Flatfish species known to migrate inshore from deeper waters – these include Sole, plaice as well as thornback rays. Also diadromous species may pass through the MAREA region on their way to natal grounds. No impact has been proven to occur with the sole population and aggregate licence areas (EMU 2011)
	Not significant***	**Not significant***	**Not significant****	**Not significant***	**Not significant****	**Not significant***
NOISE AND VIBRATION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species. **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Effect likely to prompt avoidance behaviour. **NB:** Studies to date have shown no conclusive evidence that noise from dredging is deleterious to fish and shellfish (Robinson *et al.*, 2011), significance rating is precautionary.	**T:** High, **A:** High; **R:** High **Value:** Commercial species. **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Spawning grounds extend beyond Anglian region and pelagic eggs disperse over a wider area compared to localised nature of effect.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Known spawning grounds exist for commercial species herring and sandeel Herring spawning grounds overlap with number of licences, Herring are considered to be hearing specialist sensitive to noise disturbance.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Nursery grounds appear extensive across region, overlap with an area of high intensity use for herring across inshore waters of the sub region with overlap with licence area that extends beyond boundaries of the region. **NB:** Juveniles thought to be more sensitive than adults, effect likely to prompt avoidance behaviour.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Flatfish species known to migrate inshore from deeper waters. Demersal species such as flatfish (e.g. dab and plaice) have no swimbladder and so are less sensitive to sound and vibration (Parvin *et al.*, 2008)
	Not significant***	**Not significant****	**Not significant****	**Not significant****	**Not significant****	**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species. **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Plume effects temporary and fish species highly mobile.	**T:** Medium, **A:** Medium; **R:** High **Value:** Commercial species **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Known spawning grounds are extensive across region and beyond and pelagic eggs disperse over a wider area compared to localised nature of effect	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** No overlap with known herring grounds in the sub-region. Sandeel breed throughout the region at low intensity.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Nursery grounds exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond Newly hatched larvae are considered more sensitive than adults but uncertainty exists.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** flatfish species known to migrate inshore from deeper waters
	Not significant***	**Not significant****	**Not significant****	**Not significant***	**Not significant****	**Not significant***
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** All species considered common throughout region and UK. Commercial species **Spatial overlap:** Range of species thought to be extensive across region and wider North Sea. Effect likely to prompt avoidance behaviour.	**T:** Medium, **A:** Medium; **R:** High **Value:** Commercial species **Spatial overlap:** No known critical use of the region by any shellfish species, little overlap with shellfish beds which lie within inshore waters.	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** Known spawning grounds are extensive across region and beyond and pelagic eggs disperse over a wider area compared to localised nature of effect	**T:** Low, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Herring thought to spawn in region on coarse sediments, high sensitivity to change in sediment type. No overlap with known grounds but consideration should be given at EIA level to ensure integrity of any suitable grounds is maintained.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial species **Spatial overlap:** Nursery areas exist for whiting, plaice, herring, cod, Dover sole, lemon sole, mackerel, sprat, sandeel and monkfish. All grounds extensive across region and beyond	**T:** High, **A:** High; **R:** High **Value:** Commercial species **Spatial overlap:** flatfish species known to migrate inshore from deeper waters
	Not significant***	**Not significant****	**Not significant****	**Not significant***	**Not significant****	**Not significant***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

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22. IMPACT ASSESSMENT: MARINE MAMMALS AND TURTLES

22.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

To assess the potential regional and sub-regional cumulative impacts of aggregate extraction on marine mammals and turtles requires an understanding of the distribution of these species within the MAREA region and the wider North Sea, and their sensitivity to existing and future aggregate extraction activities.

The potential for marine mammals and turtles to be impacted by aggregate extraction activities is dependent upon consideration of variables including:

- Location of the activity, particularly the proximity to marine mammal habitats;
- The physical presence and numbers of animals, either year round, seasonal, migrants or occasional visitors (for this assessment sightings data from 1975 to 2009 were used);
- Species behaviour and habitat preferences;
- Species feeding habits and preferences; and
- The conservation importance of species.

A number of limitations in the data require discussion. Data are primarily from opportunistic sightings of individuals and small groups, largely from land based positions rather than dedicated surveys. Consequently, the sightings data of marine mammals and turtles are more likely to reflect the nature of observer schemes than a true record of their seasonal distribution and/or ecological habits (see Evans, 2000). Sightings data were very sparse and knowledge of species and their interaction with dredging activities are poorly understood.

It should also be noted that all marine mammals and turtles discussed in this chapter are highly mobile species, and known to range over hundreds of kilometres (Mate *et al.*, 1995; Tanaka, 1987). Therefore, it is likely that animals range throughout the entire MAREA region and beyond.

For the purposes of this Impact Assessment, sightings data have been used to indicate presence only and not to provide any qualification of the spatial distribution of the receptor within the MAREA region.

Given this assumption of presence across the region, both sub regions have been assessed together to account for this.

22.1.1 Screening effect-receptor interactions

Screening was used to identify the effects of future dredging activities most likely to impact marine mammals and turtles, and so better target the assessment early in the process. Key scientific studies that describe the impacts of aggregate extraction activities on these receptors were used to underpin screening decisions and, where appropriate, are referenced in the following sections.

Using the source-pathway-receptor model presented in Step 1 of the Impact methodology (see Chapter 3), all direct and indirect pathways between the physical effects of dredging and marine mammals and turtles were identified. This screening opportunity identified the effects for inclusion in Step 3 of the impact assessment (see Chapter 3), where the effect-receptor footprints were mapped in GIS. This spatial analysis identified effect-receptor interactions for each licence/application area across the entire region, and screened in and out of the assessment the following effects and receptors (i.e. marine mammals that are rare in the MAREA region and their ranges do not overlap with predicted future effects of dredging).

Effects screened in:

- Seabed removal;
- Vessel displacement;
- Noise and vibration; and
- Fine sediment plume.

Effects-screened out:

- Fine sand dispersion
- Bathymetric changes;
- Sediment flux (a proxy for seabed erosion/deposition);
- Tidal currents; and
- Waves.

Marine mammal[1] and turtle receptors screened in:

- Harbour porpoise *Phocoena phocoena*;
- Bottlenose dolphin *Tursiops truncatus*;
- Common seal *Phoca vitulina*; and
- Grey seal *Halichoerus grypus*.

Marine mammal and turtle receptors screened out:

- Northern bottlenose whale *Hyperoodon ampullatus*;
- Short-beaked common dolphin *Delphinus delphis*;
- White-beaked dolphin *Lagenorhynchus albiorostris*;
- Risso's dolphin *Grampus griseus*;
- Atlantic white-sided dolphin *Lagenorhynchus acutus*;
- Minke whale *Balaeonoptera acutorostrata*;
- Sei whale *Balaenoptera borealis*;
- Fin whale *Balaenoptera physalus*;
- Killer whale *Orcinus orca*;
- Humpback whale *Megaptera novaeangliae*;
- Long-finned pilot whale *Globicephala melas*;
- Striped dolphin *Stenella coeruleoalba*;
- Leatherback turtle *Dermochelys coriacea*; and
- Loggerhead turtle *Caretta caretta*.

Species have been screened out on the basis of lack of sightings and/or lack of important habitat in the region. However, should additional data become available this should be taken into consideration for EIAs. Of particular note are new distribution, abundance and trend maps for cetaceans in NE European waters currently being produced as part of the Joint Cetacean Programme (JCP).

22.2 POTENTIAL IMPACTS ON MARINE MAMMALS

The potential impacts on marine mammals from the effects of aggregate extraction are summarised below:

- Potential decrease in feeding success and prey availability due to removal of prey species from the seabed and increased turbidity;
- Potential death or injury due to collisions with dredging and other activity related vessels; and
- Potential behavioural and stress related reactions to increased noise and activity.

A summary of the potential effects and their overlap (and so potential interaction) with marine mammals is presented in **Table 22:1**.

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[1] *Live sightings only of marine mammals and turtles have been taken into consideration. Sightings from strandings have been discounted as it is unlikely that their presence represents the normal range of species/individuals.*

22.3 CUMULATIVE IMPACT ASSESSMENT

Marine mammal diversity and abundance is generally low off eastern England and marine mammals appear to be less common in the MAREA region than in the wider North Sea. For this reason, more species are listed as being screened out of this assessment than are screened in (see section 22.1.1).

Understanding potential future impacts on marine mammals as a result of cumulative aggregate extraction activities is central to the purpose of this assessment. It requires knowledge of the current interactions between existing receptor presence and dredging activity within the MAREA region (see *Chapter 11 – Marine Mammals and Turtles*).

There are no known impacts reported from current aggregate extraction activities on marine mammals within the MAREA region. That said, no previous assessment has considered the future cumulative impacts of maximum extraction from all licence areas.

The following sections describe the findings of the cumulative impact assessment caused by the potential effects of aggregate extraction. They include a description of their impacts on sensitive receptors for the region, and their impact significance (**Table 22:2**).

Because insufficient data exist on the distribution of marine mammals at both a regional or sub-regional level, the precautionary principle has been adopted and presence assumed across the entire MAREA region.

		SENSITIVE RECEPTORS				
Sub-region	**Effect**	**Harbour porpoise**	**Bottlenose dolphin**	**Common seal**	**Grey seal**	**Screening Assessment**
Yarmouth	Seabed removal	✔	✔	✔	✔	● Fine sand dispersion, bathymetry change, sediment flux, tidal currents and waves are assessed as having no impact on any receptor so are screened out and not considered further for Impact Assessment.
	Vessel displacement	✔	✔	✔	✔	
	Noise and vibration	✔	✔	✔	✔	
	Suspended plume	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					
Southwold	Seabed removal	✔	✔	✔	✔	● Fine sand dispersion, bathymetry change, sediment flux, tidal currents and waves are assessed as having no impact on any receptor so are screened out and not considered further for Impact Assessment.
	Vessel displacement	✔	✔	✔	✔	
	Noise and vibration	✔	✔	✔	✔	
	Suspended plume	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 22:1 Screening assessment matrix for sub-regions

22.3.1 Seabed removal

The removal of sediment and associated benthos has the potential to indirectly affect the availability of prey species on which marine mammals feed. This may impact on the feeding success of those species that depend on the seafloor for prey, for example the diet of both bottlenose and common dolphins comprises demersal fish, cephalopods and crustaceans; or species that feed on fish prey which live close to the seafloor or prey themselves on benthic fauna. Harbour porpoise, for example, take predominantly small schooling fish close to the seafloor.

Common seals and grey seals have a wide diet that includes sandeels, whitefish, herring and sprat, flatfish, octopus and squid. The diet of both seal species is known to vary seasonally and from region to region, which makes them more adaptable to accommodating potential localised changes in prey availability. The regular sightings of common and grey seals at haul-outs around Scroby Sands and Horsey Gap (NNNS, 2009) may indicate the importance of this area for these species. However, seal are generalist feeders targeting mobile prey over a wide area. Recent studies have shown that common seals from Scotland, Denmark and the Netherlands are distributed widely across the North Sea. Grey seals forage between 50-145 km from haul-out sites (McConnell *et al.*, 1999; Hammond *et al.*, 2008). For these reasons, loss of benthos in the MAREA region is unlikely to impact significantly upon these populations.

Recent studies by Sharples *et al* (2008) indicate that common seals show a dense area of usage close to haul out sites but animals in the Wash are known to forage at much greater distances from haul out sites, with a range that encompasses the Anglian region.

Marine mammals are opportunistic and generalist feeders, feeding in a wide range of water depths across a wide spatial area, targeting prey within and beyond the MAREA region. There is no evidence to suggest any of the species present are reliant on a particular habitat or prey species within the MAREA region. Consequently, any reduction in benthic and/or demersal prey associated with future seabed removal is unlikely to have an impact.

The scarcity of sightings data for the MAREA region means it is unclear if any critical habitats that play a role in the life-cycle of marine mammals exist (e.g. breeding, nursing area etc). Moreover, it is likely that sightings of marine mammals reflect animals in transit to other more suitable feeding and/or breeding grounds.

SIGNIFICANCE STATEMENT: Given the low density of sightings, and the small scale of the area affected by future dredging activities in comparison to the seabed area available for marine mammals to feed within and beyond the MAREA region, marine mammals are assessed to have **high tolerance**, **high adaptability** and **high recoverability** to the effects of seabed removal. The potential cumulative impacts on marine mammals due to cumulative seabed removal at both the **sub-regional** and **regional** scale are considered to be ***Not Significant***.

Individual impact significance for each receptor group is provided in **Table 22:2**.

UNCERTAINTY: There is considerable uncertainty in the coverage of sightings data and the general knowledge of life-history patterns of marine mammals in the MAREA region. The extent to which these receptors are dependent on the region for survival is unclear, and so uncertainty in the data is considered ***High***. By contrast, uncertainty in the areas for future seabed removal is considered ***Low***. Because the effects of dredging cannot be overlaid on species distributions in the region, the overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 22:2**).

22.3.2 Vessel displacement

This effect was screened in for assessment as it is associated with the displacement of other vessels from the licence area when dredging is operational. Displacement does not necessarily increase traffic and/or associated noise and vibration levels, but the presence of the dredger or other displaced vessels does present the potential for injury due to collision and potential to prompt a behavioural or stress related response. It is considered highly unlikely for collisions to arise with any species of marine mammals as they are highly mobile and able to detect and avoid vessels. Marine mammals are most susceptible to collision where vessels display erratic behaviour and/or operate at high speeds. The typical speed of a dredger when in operation is 2-3 knots and the vessel will transit along a pre-determined route within defined dredging lanes. Both factors are likely to mitigate against any potential collision risks.

Behavioural and stress-related responses are more difficult to assess. Species are considered more sensitive to disturbance when their ability to survive, breed or rear or nurture their young is compromised or where their local distribution and abundance is affected. It is considered unlikely that any impact on individual animals will result in ecological impacts on the wider population or the ability of those individuals to function. The JNCC draft guidance (JNCC, 2010) states that in reality, the likelihood of vessel traffic impacts causing disturbance is low, since the area affected is small and all marine mammal species are highly mobile.

SIGNIFICANCE STATEMENT: The data available indicate that, for all species sighted, the MAREA region forms only a small proportion of their potential range and although there is uncertainty regarding the role of the MAREA region in the life cycle of species present, there is no evidence to suggest temporary exclusion or avoidance will result in significant impact. Marine mammals are assessed to have **high tolerance**, **high adaptability** and **high recoverability** to the effects of vessel displacement. Based on future levels of shipping predicted for the MAREA region and the increase in vessel movements due to future aggregate dredging activities, the potential cumulative impacts on marine mammals due to cumulative vessel displacement at both the **sub-regional** and **regional** scale are considered to be ***Not Significant***.

Individual impact significance for each receptor group is provided in **Table 22:2**.

UNCERTAINTY: As previously stated there is considerable uncertainty in the coverage of sightings data and the general occupancy of marine mammals in the MAREA region. The extent to which these receptors are dependent on the region for survival remains unclear and so uncertainty in the data is considered ***High***. Because the effects of dredging cannot be overlaid on species distributions in the region, the overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 22:2**).

22.3.3 Noise and vibration

Noise attenuation depends upon a number of environmental factors including the level of background noise at a site. For this reason, the effects of dredging noise on sensitive receptors vary significantly from site to site. Moreover, limited data exist regarding underwater noise production during dredging operations and the effects on marine mammals. Thomsen *et al.* (2009) provisionally conclude that dredging might be audible for most marine mammals over considerable distances up to several kilometres from the source, depending on conditions. Since dredging noise is predominantly of low frequency it will potentially affect low frequency cetaceans (such as minke whales) to a greater extent than mid- or high frequency cetaceans. As the harbour porpoise has a relatively high sensitivity across most frequencies, and both common and grey seals have relatively good underwater hearing at frequencies below 1kHz, these species may also be subject to potential effects (Thomsen *et al*, 2009).

There is the potential for behavioural and stress-related reactions to increased noise and activity of both vessels and dredger activity, although the response by marine mammals is difficult to predict. Behavioural responses can occur anywhere within the zone of audibility and are dependent on a number of external and internal factors including age, condition, sex, behaviour, season and social state influence the level of stress (Thomsen *et al.*, 2009). For this reason, no estimates on ranges can be undertaken. The injury criteria proposed by Southall *et al.* (2007) include M-weighted exposure levels (which take into account the known or derived species specific audiogram). For low-, mid- and high frequency cetaceans proposed injury criteria are an M-weighted sound exposure level of 215 dB re: 1 μPa^2-s for non-pulsed sounds (such as those emitted during dredging). For pinnipeds, the respective criteria are 203 dB re: 1 μPa^2-s.

Source levels of trailing suction hopper dredgers (TSHDs) have been measured at 186 dB re: 1 μPa @ 1 m (Parvin *et al*, 2008; Richardson *et al.*, 1995 and Greene, 1987). When compared with injury criteria of Southall *et al.* (2007) it would be expected that injury due to underwater noise from dredging would be unlikely for marine mammals. However, these values are based on limited datasets so a precautionary approach should be taken to the assessment of injury and disturbance.

Data are available for bottlenose dolphin, harbour porpoise and common seal and, based on criteria whereby the aversion to the noise is based on the level above the hearing threshold for the species, the noise from the dredging operation has the potential to cause a behavioural avoidance response as summarised in **Table 22:2** (after Parvin et al., 2008).

The study by Robinson *et al* (2011) found that the noise output of dredging vessels was mainly of low frequency with estimated source levels ranging between 168 and 186dB re. 1 *μ*Pa at 1 m. This is range is similar to merchant vessels travelling between 8-16 knots (Robinson *et al.*, 2011). Data presented in Southall *et al*. (2007) show considerable variability in received sound pressure levels associated with behavioural responses to non-pulsed sounds for low-, mid- and high-frequency cetaceans and pinnipeds in water. Experiments with non-pulsed sounds (similar to those produced during dredging) showed strong behavioural responses to received sound pressure levels of 130 - <150 dB re 1 microPa (low-frequency cetaceans) and 180 - <200 dB re 1 microPa (mid-frequency cetaceans) (Southall *et al.*, 2007). It is considered likely that marine mammals are already exposed to high levels of ship traffic and associated noise and (may) exhibit habituation to these noise levels within the MAREA region. It remains unclear if received levels of vessel noise from a dredger over background noise actually impact marine mammals.

Response	Bottlenose dolphin	Harbour porpoise	Common seal
Strong behavioural avoidance range (90dB$_{ht}$)	300m	500m	70m
Mild behavioural avoidance range (75dB$_{ht}$)	1,300m	2,000m	500m
Low likelihood of disturbance (50dB$_{ht}$)	5,000m	5,000m	7,000m
Range to background sea noise	5,000m	5,000m	8,000m

Table 22:2 Marine mammal response to noise levels. Source: Parwin *et al* (2008)

Since noise and vibration are a function of dredger presence, consideration of the relative existing and future vessel traffic volumes were used to inform this aspect of the assessment. According to the navigation assessment for this MAREA study, there will be a slight increase in traffic associated with future maximum extraction at the current licence and application areas. However, the additional dredging vessels will not significantly alter the overall traffic picture in the region (see Appendix E).

SIGNIFICANCE STATEMENT: Marine mammals are assessed as having a **high tolerance** to noise as a result of aggregate extraction, and given the scale of the region they are assessed as having a **high adaptability** to its effects. In addition once dredgers have departed any additional noise sources will be removed and marine mammals will show a **high recoverability**.

Based on future levels of dredging activity predicted for the MAREA region, the potential cumulative impacts on marine mammals due to future increases in noise and vibration at the **sub-regional** and **regional** scale are considered to be ***Not Significant***.

Individual impact significance for each receptor group is provided in **Table 22:2**.

UNCERTAINTY: As previously stated there is considerable uncertainty in the sightings data and the general distribution of marine mammals in the MAREA region. The extent to which these receptors are dependent on the region for survival remains unclear, as is the precise impact of noise and vibration generated by dredging on receptors. Moreover, there are no modelled results for noise, and so these cannot be overlaid on species distributions in the region. Therefore, the overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 22:2**).

22.3.4 Suspended sediment plume

The presence of surface and sub-surface plumes during active dredging operations has the potential to reduce the ability of visual-feeding marine mammals to locate their prey resulting in an impact upon feeding success. Species that use their auditory or olfactory senses for feeding will be less sensitive to impacts than those that use visual stimuli. Most marine mammals are likely to avoid areas of elevated suspended sediment plumes, as prey abundance is likely to be lower.

The effects of suspended sediment plume are temporary and likely to last at most a few hours beyond the cessation of dredging. Marine mammals are able to avoid these areas and return after the plume has settled. It is therefore considered that the feeding ability or efficiency of these receptors is unlikely to be adversely affected.

SIGNIFICANCE STATEMENT: Due to their localised nature and temporary duration, and the area available to these opportunistic feeders within the MAREA region, marine mammals are assessed as having **high tolerance**, **high adaptability** and **high recoverability** to the effects of the sediment plume. The potential cumulative impacts on marine mammals due to suspended sediment plumes at the **sub-regional** and **regional** scale are considered to be ***Not Significant***.

Individual impact significance for each receptor group is provided in **Table 22:2**.

UNCERTAINTY: Uncertainty in the sightings data, and the extent to which these marine mammals use the region, make it difficult to assess potential impacts. Despite limited information on turbidity impacts on feeding success, it is very unlikely that marine mammals will be impacted by the cumulative effects of suspended sediment plumes. The uncertainty in the modelled result for this effect is considered ***Low***. The overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 22:2**).

22.3.5 Fine sand dispersion

This effect was screened out of the assessment as there was no direct or indirect pathway to the receptors.

22.3.6 Bathymetric changes

This effect was screened out of the assessment as there was no direct or indirect pathway to the receptors.

22.3.7 Waves

This effect was screened out of the assessment as there was no direct or indirect pathway to the receptors.

22.3.8 Tidal currents

This effect was screened out of the assessment as there was no direct or indirect pathway to the receptors.

22.3.8 Sediment flux

This effect was screened out of the assessment as there was no direct or indirect pathway to the receptors.

22.4 CONCLUSIONS

Historically, sightings data indicate the Anglian offshore MAREA region is not considered an important area for marine mammals.

It is acknowledged that since sightings data are generally opportunistic and little systematic data are available from the region as a whole, uncertainty in the data is high for marine mammals with regard to their presence and use of the region. However, based on the sightings data available and consultations undertaken, there is no indication that the region provides critical habitats or prey to support any species of marine mammal or turtle. Many species are considered to be in transit to other suitable feeding and breeding grounds outside the region, the exception being common and grey seals, which are considered to be resident year round (JNCC, 1995; NNNS, 2009).

This assessment has taken the precautionary approach and assumed that where sightings have occurred, species are present across the entire MAREA region.

22.4.1 Sub-regional and Regional impacts

At both the MAREA sub-regional and regional scales, the overall cumulative impact significance on marine mammals as a result of future dredging activities is considered ***Not Significant***. Marine mammal diversity is generally low off eastern England. In addition, all species appear to be less common in the MAREA region than the wider North Sea.

All species of marine mammals sighted are mobile species that can avoid areas of active dredging and resulting effects from seabed removal, vessel displacement, noise and vibration, and suspended sediment plumes, and are able to return to the area once dredging has ceased. Moreover, their feeding habits and behaviour suggest they are unlikely to be reliant upon resources within dredging areas and are highly adaptable to changes in physical conditions.

Scroby Sands is the only haul-out site for common seals within the MAREA region and supports 3.1% of the regional total (Flamborough Head to Great Yarmouth) (JNCC, 1995). As mentioned previously, common seals are inshore foragers, however, prey species are common throughout the MAREA area and wider region.

Sightings of marine turtles are thought to represent animals at the extreme limits of their range and the recorded leatherback turtle stranding is almost certainly a result of migratory movements.

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Table 22:2 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR MARINE MAMMALS ACROSS YARMOUTH AND SOUTHWOLD SUB-REGIONS**

EFFECT	SENSITIVE RECEPTOR			
	Harbour porpoise	*Bottlenose dolphin*	*Common seal*	*Grey seal*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** Group BAP, Annex II species (No current designations in region*), Schedule II European Protected Species EPS **Spatial overlap:** SCANS II data indicates presence across region with higher density offshore. Assumed presence across region.	**T:** High, **A:** High; **R:** High **Value:** BAP species, Annex II species (No current designations in region*), Schedule II EPS **Spatial overlap:** Assumed presence but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence given known haul out sites and foraging ranges from Wash populations but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence but abundance low across region
	Not significant*	**Not significant***	**Not significant***	**Not significant***
VESSEL DISPLACEMENT *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Group BAP, Annex II species (No current designations in region*), Schedule II European Protected Species EPS **Spatial overlap:** SCANS II data indicates presence across region with higher density offshore. Assumed presence across region	**T:** High, **A:** High; **R:** High **Value:** BAP species, Annex II species (No current designations in region*), Schedule II EPS **Spatial overlap:** Assumed presence but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence given known haul out sites and foraging ranges from Wash populations but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence but abundance low across region
	Not significant*	**Not significant***	**Not significant***	**Not significant***
NOISE AND VIBRATION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Group BAP, Annex II species (No current designations in region*), Schedule II European Protected Species EPS **Spatial overlap:** SCANS II data indicates presence across region with higher density offshore. Assumed presence across region	**T:** High, **A:** High; **R:** High **Value:** BAP species, Annex II species (No current designations in region*), Schedule II EPS **Spatial overlap:** Assumed presence but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence given known haul out sites and foraging ranges from Wash populations but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence but abundance low across region
	Not significant*	**Not significant***	**Not significant***	**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Group BAP, Annex II species (No current designations in region*), Schedule II European Protected Species EPS **Spatial overlap:** SCANS II data indicates presence across region with higher density offshore. Assumed presence across region	**T:** High, **A:** High; **R:** High **Value:** BAP species, Annex II species (No current designations in region*), Schedule II EPS **Spatial overlap:** Assumed presence but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence given known haul out sites and foraging ranges from Wash populations but abundance low across region	**T:** High, **A:** Medium; **R:** High **Value:** Annex II species (No current designations in region) **Spatial overlap:** Assumed presence but abundance low across region
	Not significant*	**Not significant***	**Not significant***	**Not significant***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant 🟪 Minor significance 🟪 Moderate significance 🟪 Major significance **Uncertainty:** *High **Moderate *** Low

23. IMPACT ASSESSMENT: ORNITHOLOGY

23.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

To determine the potential regional and sub-regional cumulative impacts of aggregate extraction on marine and coastal birds it is necessary to:

- Establish the population levels of bird activity across the region;
- Identify the species of conservation importance; and
- Determine where there are possible conflicts between existing and future marine aggregate extraction activities and bird communities.

Baseline data on the nature and spatial extent of marine and coastal birds within the MAREA region (Chapter 8) formed the basis of this assessment by providing:

- An overall assessment of the bird populations and species in the vicinity of each licence/application area and their seasonal changes;
- The location and importance of feeding and roosting sites, and breeding colonies; and
- Identification of bird species of conservation importance and their habitats.

A key component of the assessment process has been the integration of JNCC (2009) data with the European Seabird at Sea (ESAS), Seabird Nesting Count Information and Seabird Monitoring Program (OBIS-SEAMAP, 2010), RSPB data (2010) and the Wetland Birds Survey Projects (Holt *et al.*, 2009). These latter data focus on coastal feeding and roosting locations whilst the JNCC & ESAS data provide good overall coverage of offshore seabirds within the MAREA region as average number of birds per km^2 recorded per survey visit across the year. In addition, relevant nature conservation site data have been incorporated to ensure any species of conservation importance are identified.

23.1.1 Screening effect-receptor interactions

Screening was used to identify the effects of future dredging activities most likely to impact birds and their associated habitats and prey, and so better target the assessment early in the process.

Key scientific studies that describe the impacts of aggregate extraction activities on birds were used to underpin screening decisions – where appropriate these are referenced in the following sections.

Step 1 of the impact methodology (see Chapter 3) used the source-pathway-receptor model (presented in Chapter 4) to identify direct and indirect pathways between the physical effects of dredging and birds. This initial screening opportunity identified the effects for inclusion in Step 3 of the impact assessment (see Chapter 3).

Here, the effects of aggregate extraction that potentially interact with birds were further screened by mapping their footprints with receptor footprints in GIS. This spatial analysis identified effect-receptor interactions for each licence/application area across the entire region. Using this approach the following effects and receptors were either screened in or out of the assessment.

Effects screened in:

- Seabed removal;
- Noise and vibration[1];
- Suspended sediment plume;
- Fine sand dispersion;
- Bathymetry changes; and
- Sediment flux (a proxy for seabed erosion / deposition).

Effects-screened out:

- Vessel displacement;
- Tidal currents;
- Waves.

Bird receptors (screened in):

Species selected for further assessment typify characteristic species for the region, and those protected under SPA designation. The selection of species for assessment has been guided by the outputs of Cook and Burton (2010), East Coast Regional Environmental Characterisation (Limpenny *et al.*, 2011) and the baseline data provided in Chapter 12.

- Gulls; (Mediterranean gull, lesser black backed gull, black legged kittiwake, black headed gull, herring gull)
- Terns; (little tern, sandwich tern, common tern and roseate tern)
- Auks; (puffins, guillemot and razorbill)
- Seaducks; (common scoter and velvet scoter)
- Divers, grebes and mergansers; (red throated diver, slavonian grebe, red breasted merganser, black necked grebe and great crested grebe)
- Others (Manx shearwater, northern gannet and great cormorant).

[1] *For the purposes of this assessment, noise and vibration incorporates general disturbance including visual and general boat presence.*

Bird receptors screened out:

- Wildfowl; and
- Waders.

Please note that given uncertainties in the distribution and use of the region by bird species, presence is assumed across the entire region but consideration is given to likely foraging ranges where relevant.

23.2 CUMULATIVE IMPACT ASSESSMENT

Coastal and marine birds form an important component of the marine ecosystem, and have the potential to be impacted by marine aggregate extraction activities. The main potential impacts of dredging on birds relate to disturbance due to noise and vibration associated with dredging operations and the visual presence of vessels within and on transit to licence areas, increased turbidity and the indirect effects on benthic and fish communities from seabed removal as well as the indirect effect of sedimentation on potential prey (Cook and Burton, 2010). Cook and Burton (2010) note that species vulnerabilities to these effects are likely to be highly variable. The report states that divers, grebes and seaducks are likely to be among the most vulnerable, whilst gannets and gulls are likely to be the least vulnerable.

Although this study looks implicitly at the impacts from aggregate dredging, Cook and Burton (2010) do note that it is important to consider how the potential impacts compare to those from other industries and, for the purposes of EIAs, the potential cumulative effects across industries.

Understanding potential future changes in the environment as a result of cumulative aggregate extraction activities, and how such changes impact on birds, are central to the purpose of this assessment. They require knowledge of the current interactions between existing bird populations and dredging activity within the MAREA region.

Using baseline data from Chapter 8, it is concluded that there are no impacts from current aggregate extraction activities on marine and coastal bird populations within the MAREA region. However, no previous assessment has considered the cumulative impacts of maximum extraction from all licence areas in the future. For this reason, the precautionary principle has been adopted.

The assessment is an ‘effects’ led approach, and the following sections describe the findings of the cumulative impact assessment by the effects of aggregate extraction. It includes a description of their impacts on sensitive bird receptors for both sub-regions and the region as a whole, and their impact significance (**Table 23:2**).

23.2.1 Seabed removal

Seabed removal has the potential to impact seabird receptors, excluding waders and wildfowl which do not feed in aggregate dredging areas (Barton and Pollock, 2007). Removal of seabed sediments causes a physical loss of supporting habitats and has the potential to reduce prey availability (a small reduction in prey availability may also be due to by-catch during the extraction process), affect prey spawning habitat, and thus impact upon the foraging success of seabirds.

Seabed removal will impact on those species in particular that target benthic invertebrates or bivalves and some species of fish (e.g. sandeel and herring) as prey. Species which also have small foraging ranges will be particularly sensitive to impacts on prey population changes. Species of particular concern in the region are terns and red throated diver. Potential impacts on prey species has also been considered given that many species feed exclusively on fish and/or benthic invertebrates so any impacts on these receptors will have a knock on effect on birds. Analysis of prey fish stomach contents shows that benthic invertebrates, in particular crustaceans which may be removed through the dredging process, are a key part of the diet for many species (Pearce, 2008). Piscivorous seabirds including the gulls, terns, auks, divers, grebes and mergansers and others may all, therefore, be potentially impacted by seabed removal. Cook and Burton (2010) acknowledge the sensitivity of terns and red throated divers to loss of habitat and prey in the region. Terns and red throated divers target sandeels and are likely to be encountered near offshore sandbanks which act as important foraging grounds.

		SENSITIVE RECEPTORS								
Sub-region	**Effect**	**Gulls**	**Terns**	**Auks**	**Seaducks**	**Divers, Grebes & Mergansers**	**Wildfowl**	**Waders**	**Others**	**Screening Assessment**
Yarmouth	Seabed removal	✔	✔	✔	✔	✔	✗	✗	✔	● There is no overlap between the effects of aggregate dredging and wader and wildfowl populations so these receptors are screened out and not considered further for Impact Assessment. ● There is no overlap of wave changes with the coast, so there are no impacts on coastal nesting birds. ● Tidal currents are considered to have no potential impact on any receptor so are screened out and not considered further for Impact Assessment. ● For the purposes of the MAREA, vessel displacement is purely the displacement of other ships and boats from a dredging area and therefore birds are not a receptor for this effect and it is screened out.
	Vessel displacement						✗	✗		
	Noise and vibration	✔	✔	✔	✔	✔	✗	✗	✔	
	Suspended plume	✔	✔	✔	✔	✔	✗	✗	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	✗	✗	✔	
	Bathymetry changes	✔	✔	✔	✔	✔	✗	✗	✔	
	Sediment flux	✔	✔	✔	✔	✔	✗	✗	✔	
	Tidal currents						✗	✗		
	Waves	✗	✗	✗	✗	✗	✗	✗	✗	
Southwold	Seabed removal	✔	✔	✔	✔	✔	✗	✗	✔	● There is no overlap between the effects of aggregate dredging and wader and wildfowl populations so these receptors are screened out and not considered further for Impact Assessment. ● There is no overlap of wave changes with the coast, so there are no impacts on coastal nesting birds. ● Tidal currents are considered to have no potential impact on any receptor so are screened out and not considered further for Impact Assessment. ● For the purposes of the MAREA, vessel displacement is purely the displacement of other ships and boats from a dredging area and therefore birds are not a receptor for this effect and it is screened out.
	Vessel displacement						✗	✗		
	Noise and vibration	✔	✔	✔	✔	✔	✗	✗	✔	
	Suspended plume	✔	✔	✔	✔	✔	✗	✗	✔	
	Fine sand dispersion	✔	✔	✔	✔	✔	✗	✗	✔	
	Bathymetry changes	✔	✔	✔	✔	✔	✗	✗	✔	
	Sediment flux	✔	✔	✔	✔	✔	✗	✗	✔	
	Tidal currents						✗	✗		
	Waves	✗	✗	✗	✗	✗	✗	✗	✗	

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 23:1 Screening assessment matrix for sub-regions

Terns generally forage within 10 km (see Table 12.3) of the coast. Their prey vary depending on availability but will include within the region, sandeel and herring. As noted in Chapter 21 sandeel prey species are likely to favour areas within the region outside of the licence areas given the sediment types present, and in particular the sandbank features to the north and inshore of the Yarmouth sub-region. Therefore the potential for spatial overlap of preferred feeding areas for terns in particular is unlikely to coincide with the direct effects of seabed removal. All species of terns found within the region are categorised as highly sensitive to impacts on benthic communities resulting from seabed removal.

SIGNIFICANCE STATEMENT: The potential seabed affected by future dredging activities is small compared with the seabed area within the MAREA region available for coastal and marine birds to feed. In line with the findings of Cook and Burton (2010), gulls and other species including gannet and corrmorants are assessed as having a **high level of tolerance**, **high adaptability** and **high recoverability** to seabed removal. The potential overall cumulative impacts of seabed removal on prey availability to these receptors across both sub-regions are therefore considered ***Not Significant***. Individual impact significance for each bird receptor group is provided in **Tables 23:2**.

Exceptions arise for tern species and seaducks (common and velvet scoter) who are considered to be very sensitive to the effects of seabed removal with auks and red throated divers considered to be of moderate sensitivity. The precautionary principle, dictates that the impact due to seabed removal to potential feeding grounds of the tern colonies and red throated diver and common and velvet scoter is considered ***Minor Significance*** for both sub-regions. Although red throated divers are considered less sensitive to the effects of reduced prey availability from seabed removal, the value of the species as a designated features of the Outer Thames SPA has been considered and a precautionary approach taken for this species.

The cumulative impact on birds due to cumulative seabed removal at the **regional** scale is also considered to be ***Not Significant***.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with the exact feeding areas of birds in the MAREA region. However, uncertainty in the modelled effects is considered ***Low***. Therefore, overall uncertainty in the assessment for individual receptor groups is ***Moderate*** (see **Table 23:2**).

23.2.2 Vessel presence

This effect was screened out of the assessment because there was no direct or indirect pathway to receptors. Under the definitions of the MAREA this effect is simply the displacement of other vessels from the licence area when the dredging vessel is undertaking extraction activities. Displacement of vessels may change the spatial location of noise and vibration associated with vessels and this is described further in section 23.2.3.

23.2.3 Noise and vibration

For the purposes of this assessment, this effect has been taken to incorporate general disturbance generated by visual presence of vessels as well as noise and vibration.

Seaducks, auks, divers, grebes and mergansers are regularly occurring migratory species to the MAREA region and disturbance from dredging activity and vessel presence have the potential to impact all these seabird groups. There are limited data available regarding noise and vibration production during dredging operations and the effects on seabirds (Parvin *et al*., 2008). This assessment is an estimate and by no means definitive, although Parvin *et al*. (2008) indicate that noise and vibration, both from dredging and from vessels displaced from licence areas (see section 23.2.2), are likely to cause a behavioural avoidance response in fish and this may temporarily affect seabird foraging behaviour.

Disturbance can cause birds to cease feeding or fly away; and in response they can increase their energy requirements at their present (disturbed) feeding sites, or move to an alternative less favoured feeding or roosting site. Such responses affect energy budgets and food intake rates, and possibly survival (Kaiser, 2002). Overwintering birds (divers, grebes, mergansers, auks and seaducks), which are frequently subject to harsh weather conditions and must lay down fat reserves in order to migrate to breeding grounds, are particularly susceptible to adverse effects resulting from disturbance.

It may be that along regularly used shipping lanes birds might become habituated to the presence of vessels. However the lack of overlap between intensively utilised shipping and wintering rafts of scoter and divers suggests that this does not occur to a significant degree (Kaiser, 2002). Displacement has been identified as a key issue for seaducks and divers during the construction of wind farms (Kaiser, 2002). Garthe and Hüppop (2004) developed a sensitivity index for seabirds in relation to offshore wind farms that identified red throated divers as one of the most sensitive species, followed by sandwich terns. Displacement studies around turbines and boat related activity reported in Natural England (2010) showed that up to 80-100% of red throated divers were displaced from the development footprint and surrounding area. Although these studies relate directly to operational wind farms, disturbance associated with marine aggregate extraction and related vessel presence could have similar effects for these seabirds. Garthe and Hüppop (2004) stated that red throated divers are especially sensitive to disturbance at sea and avoid boats.

In addition to impact directly on birds, consideration has been given to impacts on prey species. It is thought that some fish may be attracted by the prey species associated with dredging tracks (Cook and Burton, 2010). However, it is thought that herring may be more sensitive to dredging noise than other prey species (Thomsen *et al*., 2009), as sound may play a role in guiding them to spawning sites (de Groot, 1980).

Since noise and vibration are a function of dredger presence, consideration of the relative existing and future vessel traffic volumes were used to inform this aspect of the assessment. According to the navigation assessment for this MAREA study, there will be a slight increase in traffic associated with future maximum extraction; however the additional dredging vessels will not significantly alter the overall traffic picture in the region. In addition, the potential foraging area available to seabirds within the region is considerably larger than that potentially impacted by noise and vibration and so impacts of this nature will be unlikely.

Cook and Burton (2010) state that due to its limited temporal extent, the shipping associated with marine aggregate dredging is unlikely to contribute significantly to total shipping within regions as a whole.

Robinson *et al*. (2011) concluded that noise from dredger vessels radiated at frequencies less than 500 Hz, similar to that of a merchant vessel travelling at reasonable speed, but generated higher frequency noise because of the impact/abrasion of the aggregate material passing through the draghead, suction pipe and pump. The report states that when placed in context, dredgers are basically ‘noisy ships’ and substantially quieter than other activities such as marine piling and seismic arrays.

SIGNIFICANCE STATEMENT: Based on future levels of shipping predicted for the MAREA region, the increase in vessel movements due to future aggregate dredging activities, and the large foraging area available, the majority of seabird receptors show a **high level of tolerance**, a **high adaptability** and **high recoverability**. The potential impact of disturbance from noise and vibration generated from dredging activities on seabirds, in general, is considered to be ***Not Significant*** for both sub-regions.

The exceptions to this are the potential impacts on seaducks (specifically common scoter and velvet scoter), and divers (red throated divers). Seaducks are assessed as having a **low tolerance**, **low adaptability** and **medium recoverability**, with divers assessed as having a **medium tolerance**, **medium adaptability** and **medium recoverability** to the effects of noise and vibration. While the spatial area affected is small, relative to the area of the MAREA region, the precautionary principle dictates that the potential impact of displacement on these receptors is considered to be of ***Minor Significance*** for both sub-regions.

The cumulative impact on seabirds due to future increases in noise and vibration at the **regional** scale is considered to be ***Not Significant***.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with the effects of noise and vibration on birds in the MAREA region. A recent ALSF report attempted to address data gaps in noise levels from dredging activity (Robinson *et al.* 2011), but data on the precise impact of noise are poorly documented and uncertainty in the spatial extent is ***High***. Overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 23:2**).

23.2.4 Suspended sediment plume

Increases in turbidity as a result of suspended sediment plumes during active dredging operations exceed background levels, and where plumes are predicted, can approach and potentially exceed those expected during storms. The spatial extent of this effect has been modelled and extends for a limited distance beyond the licence area boundaries (HR Wallingford, 2010).

Vision has been identified as an important component in the foraging activity of a number of seabird species including terns, guillemot and northern gannet (Cook and Burton, 2010). Consequently changes to water clarity could impact directly on the foraging success of species where overlap with prey species/habitats occurs. Cook and Burton (2010) reference an example for sandwich tern, where a negative impact on populations has been linked to increases in turbidity in the Netherlands.

The suspended sediment plume is temporary and likely to last at most a few hours after the cessation of dredging. The increased turbidity has the potential to impact feeding success of seabirds that forage visually, in the immediate vicinity of the dredger and licence area for short timescales e.g. terns and auks (Cook and Burton, 2010).

SIGNIFICANCE STATEMENT: Due to their localised nature and temporary duration, and the vast area available for coastal and marine birds to feed within the MAREA region, seabird receptors are assessed as having a **high level of tolerance**, a **high adaptability** and **high recoverability** to the effects of a sediment plume. The potential overall cumulative impacts on feeding and/or foraging success, across both sub-regions are considered to be ***Not Significant***. Individual impact significance for each bird receptor group is provided in **Table 23:2**.

It is noted however, that terns, red throated divers and auk species (guillemot, razorbill and puffin) are protected in the region within a number of SPAs and have a range that overlaps with the aggregate areas in both sub-regions and are identified in Cook and Burton (2010) as being particularly sensitive to the effects of increased turbidity. These species are considered specialist feeders and therefore any potential reduction in foraging success should be noted, however it is considered that both species feed on mobile prey and the plume is both localised and temporary in nature. Precautionary approach has been taken with a ***Minor Significance*** noted for tern species, red throated diver and auk species. Although this effect is considered to be ***Not Significant*** at the **regional** scale, consideration should be given to the outcomes of Chapter 20 and likely changes to community composition.

The cumulative impact on birds due to suspended sediment plumes at the regional scale is also considered to be ***Not Significant***.

UNCERTAINTY: As previously stated, uncertainties are associated with the exact feeding areas of birds in the MAREA region. Similarly, data on the precise impact of suspended sediment plumes on seabird feeding and/or foraging success are poorly documented. However, uncertainty in the modelled effects is considered ***Low***. Therefore, uncertainty in the assessment for individual receptor groups is ***Moderate*** (see **Table 23:2**).

23.2.5 Fine sand dispersion

As sediment is dredged from the seabed, screened sediment is returned to the water column (HR Wallingford, 2010). This sediment may affect benthic communities both within and outside the licence areas. However, the availability of potential prey to seabirds in the MAREA region is extensive, and the region is also subject to natural sediment movement so much of the benthic community is adapted to sand dispersion. In addition, as many seabirds feed on pelagic prey the likely cumulative impacts of fine sand dispersion are only likely to be indirect. These cumulative effects are also relatively localised and dependent on the precise future location and extent of dredging within licence areas. Cook and Burton (2010) identify common scoter and velvet scoter as being particularly sensitive the effects of fine sand dispersion.

SIGNIFICANCE STATEMENT: The cumulative effects of fine sand dispersion are dependent on the supply of sediment to the region. Given the potential spatial extent of the effect and the vast area available for coastal and marine birds to feed within the MAREA region and the adapted benthic community, seabird receptors are assessed as having **high tolerance**, **high adaptability** and **high recoverability** to the effects of fine sand dispersion. The potential overall cumulative impacts on feeding and/or foraging success for both sub-regions are considered ***Not Significant***. Individual impact significance for each bird receptor group is provided in **Table 23:2**.

The cumulative impact on birds due to fine sand dispersion at the **regional** scale is considered to be ***Not Significant***.

UNCERTAINTY: As previously stated, uncertainties are associated with the exact feeding areas of birds in the MAREA region. Moreover, data on the precise impact of fine sand dispersion on seabird feeding and/or foraging success is poorly documented. Uncertainty in the modelled effects is considered ***Low***. Therefore, the overall uncertainty in the assessment for individual receptor groups is ***Moderate*** (see **Table 23:2**).

23.2.6 Bathymetry changes

Increases in bathymetry occur within the dredging footprint and this can have long term effects on seabed morphology, which can potentially affect the availability of food to diving birds. The deeper the water the further birds must dive to reach their prey species. This can potentially affect foraging success and energy budgets by lowering food intake rates. It is considered that this potential impact on foraging is less of an issue at sites greater than 20 m (see Kaiser, 2002). Of all the birds that occur within the MAREA region, only auks are known to forage at depths greater than 20 m. In certain licence areas it is possible that accessible feeding sites could become inaccessible to birds including cormorant, red throated diver, grebes and mergansers. However the area of seabed concerned is not significant when considered at a regional scale.

SIGNIFICANCE STATEMENT: The cumulative effects of bathymetric changes are confined to licence areas and will vary from site to site. Given the potential spatial extent of this effect and the vast area available for coastal and marine birds to feed within the MAREA region, seabird receptors are assessed to have a **high level of tolerance**, **high adaptability** and **high recoverability** to bathymetric change. The potential overall cumulative impacts on feeding and/or foraging success, across both sub-regions, are considered ***Not Significant***. Individual impact significance for each bird receptor groups is provided in **Table 23:2**.

The cumulative impact on birds due to bathymetric changes at the **regional** scale is also considered to be ***Not Significant***.

UNCERTAINTY: As previously stated, uncertainties are associated with the exact feeding areas of birds in the MAREA region. Data on the precise impact of bathymetric changes on seabird feeding and/or foraging success are poorly documented. Uncertainty in the modelled effects is considered ***Low***. Therefore, the overall uncertainty in the assessment for individual receptor groups is ***Moderate*** (see **Table 23:2**).

23.2.7 Sediment flux

Modelled changes to sediment flux as a result of proposed dredging activities are spatially relatively large and considered to have a sub-regional extent (see HR Wallingford, 2010). The potential impact on seabirds is access to prey located on the seabed and so the only likely birds affected are plunge or diving birds.

SIGNIFICANCE STATEMENT: The cumulative effects of sediment flux extend beyond licence areas. However given the spatial extent of this effect compared with the vast area available for coastal and marine birds to feed within the MAREA region, seabird receptors are assessed as having **high tolerance**, **high adaptability** and **high recoverability** to the effects of sediment flux. The potential overall cumulative impacts on feeding and/or foraging success, across the two sub-regions, are considered ***Not Significant***. Individual impact significance for each bird receptor groups is provided in **Table 23:2**.

The cumulative impact on birds due to sediment flux at the **regional** scale is also considered to be ***Not Significant***.

UNCERTAINTY: As previously stated, uncertainties are associated with the exact feeding areas of birds in the MAREA region. Data on the precise impact of sediment flux changes on seabird feeding and/or foraging success are poorly documented. Uncertainty in the modelled effects is considered ***Moderate***. Therefore, the overall uncertainty in the assessment for individual receptor groups is ***High*** (see **Table 23:2**).

23.2.8 Tidal currents

This effect is screened out of the assessment because there is no direct or indirect pathway to receptors. However, tidal currents are used by seabirds when feeding in order to maintain position and intercept food, particularly when wind is not a factor. The impacts of current speed may also affect prey species distribution (e.g. fish, and fish and invertebrate larvae) that need favourable tidal currents to settle. It has been postulated that disruption due to changes in currents could have repercussions up the food chain; however there is no reasonable linkage to the foraging success of seabirds as a result. According to MarLIN (2010) an increase or decrease of at least 50% in water flow rate is required to have a significant impact. HR Wallingford models for the MAREA region demonstrate that changes in tidal currents are well below 50% for all parts of the MAREA region and therefore are not likely to have an impact.

23.2.9 Waves

This effect is screened out of the assessment because there is no direct or indirect pathway to receptors. An increase in wave force reaching the coast could potentially affect the breeding success of birds that nest on sand and shingle beaches, spits and low lying islets, such as terns (Mitchell *et al.*, 2004). HR Wallingford models for the MAREA region demonstrate that changes in waves do not reach the coast and will not, therefore, have an impact.

23.3 CONCLUSION AND RECOMMENDATIONS

The coastline and waters of the MAREA region support suitable habitats and feeding grounds for maintaining breeding, wintering and migratory bird populations of international, national and local importance. In particular, gulls, terns, divers, grebes and mergansers, and auks all have the potential to be impacted by predicted future cumulative aggregate extraction effects. Initially the effects of seabed removal, noise and vibration, suspended sediment plume, fine sand dispersion, bathymetry changes and sediment flux were considered to have potential impact on these birds. However, based on the regional cumulative impact assessment, the majority of species and habitats are unlikely to be significantly impacted.

23.3.1 Yarmouth sub-regional impacts

For the purposes of this assessment given their mobile nature, an assumption has been made that all species are present across both sub-regions therefore no specific sub regional assessment has been undertaken for birds. The sub-regional cumulative impact assessment for bird receptors in the Yarmouth sub-region is overall ***Not Significant*** (**Table 23:2**). The exceptions to this are seabed removal, suspended sediment and noise and vibration (disturbance) which were assessed to be of ***Minor Significance*** in relation to seaducks, red throated divers, auks and terns in the Yarmouth sub-region (due to their restricted foraging range coincident with a number of licence areas).

23.3.2 Southwold sub-regional impacts

The sub-regional cumulative Impact Assessment for bird receptors in the Southwold sub-region is ***Not Significant*** (**Table 23:3**). The exceptions to this are seabed removal, suspended plume and avoidance due to noise and vibration for seaducks, red throated divers and terns, which were assessed to be of ***Minor Significance***.

23.3.3 Regional impacts

At the MAREA regional scale, the overall cumulative impact significance on bird populations as a result of future dredging activities is assessed as ***Not Significant***. This is because the majority of seabirds that occur in the MAREA region are generally adaptable to change given their wide feeding preferences and presence throughout the region.

Noteworthy is the presence of the internationally and nationally important species protected by SPAs in the region, in particular the red throated diver which is protected by the Outer Thames SPA which overlaps directly with licence areas in both sub-regions. Applying the precautionary principle, the impact on these species as a result of seabed removal and noise and vibration was assessed as ***Minor Significance***.

Table 23:2 **SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR BIRD RECEPTORS FOR YARMOUTH AND SOUTHWOLD SUB-REGIONS.**

EFFECT	SENSITIVE RECEPTOR							
	Gulls *Mediterranean gull, lesser black backed gull, great black backed gull, little gull, black headed gull and herring gull)*	***Terns*** *(little tern, sandwich tern, common tern and roseate tern)*	***Auks*** *(puffins, guillemots and razorbills)*	***Seaducks*** *(common scoter, velvet scoter)*	***Divers, Grebes & Mergansers*** *(red throated diver, slavonian grebe, red breasted merganser, black necked grebe, great crested grebe)*	***Wildfowl***	***Waders***	***Others*** *e.g. (Manx shearwater, northern gannet and great cormorant)*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species within the region. **Spatial overlap:** Gulls have a wide range encompassing a variety of habitats and prey **NB:** Kittiwakes are less flexible than other gull species in their habitat use. Their population is linked to sandeel availability. Any removal of sandeel habitat could have knock on effects for Kittiwake.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km. Cook and Burton (2010) state tern species are highly vulnerable to reduced food availability, thus any changes in food availability at a local level could have dramatic impact on populations.	**T:** Medium, **A:** Medium, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 50 km.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast. **NB:** prey items bivalves and crustaceans, non mobile species	**T:** Medium, **A:** Medium, **R:** Medium **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present within designated Outer Thames SPA.			**T:** High, **A:** Medium, **R:** High **Value:** Northern gannet is a designated species likely to forage within the region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant**	**Minor significance****	**Not significant****	**Minor significance****	**Minor significance****			**Not significant****
VESSEL DISPLACEMENT								
NOISE AND VIBRATION *(Effect magnitude = Low)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species. **Spatial overlap:** Gulls have a wide range encompassing a variety of habitats.	**T:** Medium, **A:** Medium, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 50 km.	**T:** Low, **A:** low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast.	**T:** Low, **A:** low, **R:** Medium **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present at Outer Thames SPA, to which this effect will overlap.			**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant*	**Not significant***	**Not significant***	**Minor significance****	**Minor significance****			**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species. **Spatial overlap:** Gulls have a wide range encompassing a variety of habitats.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km. **NB:** Plunge divers requiring clear waters, although generally tolerant of other disturbance.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 50 km. Cook and Burton identify auks as highly sensitive to impacts from increased turbidity. However, given large range, significance rating is precautionary.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast.	**T:** Medium, **A:** Medium, **R:** Medium **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present at Outer Thames SPA. Given the significance of species within designated marine SPA, significance is precautionary.			**T:** High, **A:** Medium, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant**	**Minor significance****	**Minor significance****	**Not significant****	**Minor Significance****			**Not significant****

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant
🟪 Minor significance
🟪 Moderate significance
🟪 Major significance

Uncertainty: *High **Moderate *** Low

continued over…

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Table 23:2 SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR BIRD RECEPTORS FOR YARMOUTH AND SOUTHWOLD SUB-REGIONS.

EFFECT	SENSITIVE RECEPTOR							
	Gulls *Mediterranean gull, lesser black backed gull, great black backed gull, little gull, black headed gull and herring gull)*	***Terns*** *(little tern, sandwich tern, common tern and roseate tern)*	***Auks*** *(puffins, guillemots and razorbills)*	***Seaducks*** *(common scoter, velvet scoter)*	***Divers, Grebes & Mergansers*** *(red throated diver, slavonian grebe, red breasted merganser, black necked grebe, great crested grebe)*	***Wildfowl***	***Waders***	***Others*** *e.g. (Manx shearwater, northern gannet and great cormorant)*
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species. **Spatial overlap:** Gulls have a wide range encompassing a variety of habitats.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 50 km.	**T:** Low, **A:** Low, **R:** Medium **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast. **NB:** Both Species considered highly sensitive to impacts by Cook and Burton (2010).	**T:** Medium, **A:** Medium, **R:** Medium **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present at Outer Thames SPA.			**T:** High, **A:** Medium, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Not significant****			**Not significant****
BATHYMETRY CHANGES *(Effect magnitude = Medium)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species. **Spatial overlap:** Gulls have a wide range encompassing a variety of habitats.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km.	**T:** Medium, **A:** Medium, **R:** Medium **Value:** Designated species likely to forage within region. Auks known to forage at depths greater than 20 m and are only species likely to be impacted by changes to water depths, however given small spatial scale of the effects, impacts are unlikely.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast.	**T:** High, **A:** High, **R:** High **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present at Outer Thames SPA.			**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant**	**Not significant****	**Not significant****	**Not significant****	**Not significant****			**Not significant****
SEDIMENT FLUX *(Effect magnitude = Medium)*	**T:** High, **A:** High, **R:** High **Value:** The black headed gull, Mediterranean gull and lesser black backed gull are designated species. **Spatial overlap:** Gulls have a wide range encompassing a variety.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 10 km.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Effect overlaps with receptor foraging range of up to 50 km.	**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Presence on North Norfolk coast.	**T:** High, **A:** High, **R:** High **Value:** The red-throated diver is a designated species. **Spatial overlap:** Species populations present at Outer Thames SPA.			**T:** High, **A:** High, **R:** High **Value:** Designated species likely to forage within region. **Spatial overlap:** Large foraging range overlaps with effect, but species have wide range of prey.
	Not significant*	**Not significant***	**Not significant***	**Not significant****	**Not significant***			**Not significant***
TIDAL CURRENTS								
WAVES								

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

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24. IMPACT ASSESSMENT: NATURE CONSERVATION

24.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

An assessment of nature conservation captures ecological and geological features currently designated and/or proposed for their conservation importance, either internationally, nationally or locally. For protected areas within the MAREA region, an assessment has been undertaken on designated features and/or sub features where relevant. Reference is also made to the assessments undertaken for birds, benthic ecology and marine mammals in Chapters 20, 22 and 23. However of note where non qualifying features are present these have not been assessed and reference should be made to the relevant chapter for further information.

The basis for this regional and sub-regional Cumulative Impact Assessment is to evaluate the interaction between the potential future effects of aggregate extraction on marine and coastal nature conservation designations and their associated features of interest. To achieve this, the following information was required:

- Establishing the location of protected sites across the region and assess the extent and area of the nature conservation designations in the vicinity of each individual licence and application area that lie within effects footprints;
- Establish the location of any sites outside the MAREA boundary which support species that are likely to be present within the region;
- Identification of the habitats and species that constitute their interest features and sub features;
- Determine where there are possible conflicts between existing and future marine aggregate extraction activities and designated sites; and
- Identification of any potential future designations within the MAREA region.

Baseline data on the nature and spatial extent of marine and coastal designations within the MAREA region (Chapter 13) were used to inform this assessment process.

At a regional and sub-regional level the MAREA region is known to support numerous designations which form an important conservation component to the marine, coastal and intertidal ecosystems of the region.

24.2 SCREENING EFFECT-RECEPTOR INTERACTIONS

Screening was used to identify the effects of future dredging activities most likely to impact designated sites and their associated species and habitats, and so better target the assessment early in the process (as shown in **Table 24:1**).

Key scientific studies that describe the impacts of aggregate extraction activities on features of conservation importance were used to underpin screening decisions – where appropriate these are referenced in the following sections.

Step 1 of the impact methodology (see Chapter 3) used the source-pathway-receptor model (presented in Chapter 5) to identify direct and indirect pathways between the physical effects of dredging and nature conservation sites. This initial screening opportunity identified the effects for inclusion in Step 3 of the impact assessment (see Chapter 3).

The effects of aggregate extraction that potentially interact with nature conservation features were further screened by mapping their footprints with receptor footprints in GIS. This spatial analysis identified effect-receptor interactions for each licence/application area across the entire region. Using this approach the following effects and receptors were screened in and out of the assessment (i.e. sites that do not overlap with predicted future effects of dredging). For completeness the potential impacts of effects on designated sites that were screened out are briefly reported in this chapter.

Effects screened in:

- Seabed removal;
- Noise and vibration;
- Suspended sediment plume;
- Fine sand dispersion;
- Bathymetry changes;
- Sediment flux; and
- Waves.

Effects screened out:

- Vessel displacement; and
- Tidal currents.

Nature conservation designations screened in:

- Alde-Ore Estuary SPA: (little tern, sandwich tern, lesser black backed gull);
- Benacre to Easton Bavents SPA: (little tern);
- Breydon Water SPA:(common tern and cormorant);
- Minsmere to Walberswick SPA: (little tern);
- Great Yarmouth North Denes: (little tern);
- Outer Thames SPA: (red throated diver);
- Flamborough Head and Bempton Cliffs SPA: (kittiwake, auks, gannet);
- North Norfolk Coast SPA: (common tern, little tern, med gull, roseate tern and sandwich tern); and
- Haisborough, Hammond and Winterton cSAC.

Sites selected for further assessment has been informed by the outputs of Cook and Burton (2010), the baseline data and feedback from the statutory nature conservation bodies provided in Chapter 12.

Nature conservation designations screened out:

- All coastal designations including Ramsar, SSSI, NNR, LNR, National Parks, OSPAR and AONB which support habitats and/or coastal species;
- All SACswith primary qualifying habitat features that are either terrestrial, estuarine or coastal in nature; and
- Future Marine Conservation Zones (MCZs).

Based on current knowledge and discussions with JNCC, MCZ have been screened out on the basis of uncertainty and no formal designations currently existing. The recommendations are currently being reviewed by an Independent Science Advisory Panel, JNCC and Natural England. Once JNCC and Natural England have submitted their statutory advice to Government, Ministers will consider the supporting evidence and potential environmental, social and economic impacts, before deciding which sites to take forward for designation. Current timescales indicate that designation of MCZs projects is expected in December 2012. All future EIAs for the region should take note of any updates to the designation process.

24.3 POTENTIAL IMPACTS ON NATURE CONSERVATION

The likely impacts on the nature conservation features of those effects can be broadly described as follows:

- Loss/damage and/or disturbance of qualifying habitats and species;
- Reduced ecological function; and
- Degradation of site integrity and quality.

24.4 CUMULATIVE IMPACT ASSESSMENT

The coastal and marine nature conservation designations throughout the MAREA region encompass a variety of habitats and their associated species, ranging from rocky cliffs, estuarine mudflats and sandflats, saltmarshes, reefs, sand dunes, and coastal lagoons. Many of the international designations overlap with each other and are often underpinned by national designations, providing a further level of protection to the habitats and species, for example Sites of Special Scientific Interests (SSSIs) underlie Special Protection Areas (SPAs) and also support Special Areas of Conservation (SACs) and Ramsar designations.

Sub-region	Effect	Outer Thames pSPA	Alde Ore Estuary	Benacre to Easton Bavents	Breydon Water	Minsmere-Walberswick	Great Yarmouth North Denes Outer Thames	Flamborough Head and Bempton Cliffs	North Norfolk Coast	Haisborough Hammond & Winterton cSAC	Net Gain (MCZ)	Balanced Sea (MCZ)	Coastal Designations	Screening Assessment
Yarmouth	Seabed removal	✔	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	● Seabed removal, noise and vibration, suspended plume, fine sand dispersion, bathymetry changes, sediment flux and waves have the potential to impact conservation designations within the Yarmouth sub-region. ● There is no overlap of effects with any coastal designations in the Yarmouth sub-region and these are screened out and not considered further for Impact Assessment. ● Marine Conservation Zones are screened out on the basis of absence of formal designated sites. However current knowledge indicates no overlap of draft sites with effect footprints. ● Vessel presence was screened out: under the definitions of the MAREA this effect is simply the displacement of other vessels from the licence area when dredging is taking place. Any potential impacts associated with visual disturbance and noise are captured under the assessment of Noise and vibration effect.
	Vessel displacement													
	Noise and vibration	✔	✔	✔	✔	✔	✔	✔	✔		✗	✗	✗	
	Suspended plume	✔	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	
	Fine sand dispersion	✔	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	
	Bathymetry changes	✔	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	
	Sediment flux	✔	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	
	Tidal currents	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	
	Waves	✔	✔	✗	✔	✔	✔	✔	✔	✔	✗	✗	✗	
Southwold	Seabed removal	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	● Seabed removal, noise and vibration, suspended plume, fine sand dispersion, bathymetry changes, sediment flux and waves have the potential to impact conservation designations within the Southwold sub-region. ● The Haisborough, Hammond and Winterton cSAC does not extend into the Southwold sub-region. There is therefore no overlap of effects with this receptor for this sub-region. Non qualifying features grey seal and harbour porpoise have not been considered as part of this assessment, reference should be made to Chapter 22 ● There is no overlap of effects with any coastal designations in the Southwold sub-region and these are screened out and not considered further for Impact Assessment.
	Vessel displacement													
	Noise and vibration	✔	✔	✔	✔	✔	✔	✔	✔		✗	✗	✗	
	Suspended plume	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	
	Fine sand dispersion	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	
	Bathymetry changes	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	
	Sediment flux	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	
	Tidal currents									✗	✗	✗	✗	
	Waves	✔	✔	✔	✔	✔	✔	✔	✔	✗	✗	✗	✗	

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 24:1 Screening assessment matrix for the sub-regions

The majority of designations within the region, with the exception of the SACs and SPAs which have a marine component, are limited to the coastal zone. Where the effects footprints do not overlap with the coastline and designated habitats or species (see Chapter 19) coastal designations have been screened out for further assessment.

Where overlap between the potential future effects of dredging and nature conservation designations and their protected species and habitats occurs, reference has been made to any conservation objectives which exist for interest features and sub features. This assessment draws on this knowledge. As a precautionary approach, any features of conservation interest that meet the selection criteria for future designations are encompassed where necessary in this assessment.

The assessment for Haisborough, Hammond and Winterton SAC has where possible taken into consideration the sub features and assessed the physical integrity of the features and potential biological impacts on the associated communities.

The following sections describe the findings of the cumulative impact assessment by the effects of aggregate extraction. It includes a description of their impacts on sensitive receptors for each sub-region and the region as a whole, as well as their impact significance (**Table 24.2**).

24.4.1 Seabed removal

The extraction of marine sand and gravel has its primary impact at the seabed. The impact of removal of seabed sediments is highly localised and restricted to those parts of the licence areas where dredging has occurred. Features and habitats that are present within the intertidal waters and coastline, outside of the extraction areas of the MAREA, will not be impacted by seabed removal.

Newell *et al*. (2004) demonstrated there is little evidence of an impact on community structure outside the immediate boundaries of an Active Dredge Zone (ADZ), therefore seabed removal will impact only upon those interest features and sub-features that overlap with the licence areas.

There are two designated sites which directly overlap with present and future aggregate licence areas within the MAREA region. These are the Outer Thames SPA and the Haisborough, Hammond and Winterton cSAC.

In total, 5.6% of the area to be potentially designated within the Outer Thames SPA overlaps with marine aggregate dredging areas within the Anglian Offshore MAREA region. The qualifying feature of the Outer Thames SPA is the wintering population of the red throated diver. According to the UK SPA data sheet, the effects of marine aggregate dredging activities and shipping tend to be temporary and localised in nature, and red throated divers are already known to avoid these areas of activity within the area (UK SPA data form UK9020309). However Cook and Burton (2010) note that herring are key prey species for red throated diver, which have the potential to be impacted by seabed removal through loss of spawning habitat and therefore the divers may be exposed to a decrease in local prey activity. This is discussed further in *Chapter 23 - Impact Assessment: Ornithology*.

The effects of seabed removal have the potential to impact on other seabird species that are sensitive to loss of preferred habitat and prey and/or which have a small foraging range. Of note is the potential impact on tern species; roseate tern, sandwich tern and common tern are all either designated within the region or whose range extends from designated sites outside of the region.

The Haisborough Hammond and Winterton cSAC has been put forward for designation. This is because of the identification of reefs and sandbanks slightly covered by seawater within the area, that both qualify as designation features under Annex II of the Habitats Directive and the sub features of sandbanks: low diversity dynamic sand communities and moderate diversity stable sand communities. The cSAC does not extend into the Southwold sub-region, so no aggregate dredging areas from this sub-region are coincidental with designated features of the cSAC. There is however some overlap of the cSAC boundary with the boundaries of Licence Areas 202, 254 and 296, and the boundary of Prospecting Area 494.

The JNCC (2010) site selection guidelines v 6 for the site identifies the location of sandbanks and reefs within the boundaries of the cSAC, however these features are not targeted for aggregate extraction. Furthermore, Chapter 19 concluded that no impact on sandbanks across the region (including those designated within the SAC) would arise from effects of seabed removal. Based on the assessment on sandbanks, it is concluded that there is no potential for impact upon the physical integrity of the sandbank feature. The target aggregate in the region is relict sand and gravel that does not form the Annex II habitat features (JNCC, 2010). No direct impact on cSAC sandbank features, through seabed removal, is therefore predicted. However, in line with Chapter 20 a more precautionary approach has been taken for *Sabellaria* reef in general given its ephemeral nature and potential for future reef to develop.

Consideration has also been given to any potential effects of seabed removal on the sub-features and biological communities supported by the sandbank. The biotopes identified as part of the sub features were listed within the v4 advice on operations document as comparable to those present within the SAC are **SS.SCS.ICS.SLan** and **SS.SSA.IFiSa.NcirBat**. Both these biotpoes are captured within the biotope complexes assessed as part of this MAREA, **SS.SCS** and **SS.SSa** respectively. Both communities/biotopes are considered to be high energy habitats with a good ability to recover from physical disturbance but it is noted within JNCC (2010b) that any loss of distinct assemblages within the habitat through seabed removal may result in a decrease of overall diversity.

Bird species designated by coastal SPAs or sites outside of the MAREA region but likely to forage within the region are considered further within Chapter 23, with additional detail provided on the foraging ranges of designated species with distance from each SPA provided within **Tables 24:2** and **24:3**. The effects of seabed removal have the potential to impact on species that are sensitive to loss of preferred habitat and prey and/or which have small foraging range. Chapter 23 concludes the potential Minor significance impacts on tern species, common and velvet scoter and red throated diver, all of which are designated by SPAs screened in for assessment. The assessment for birds in Chapter 23 takes a precautionary approach and assumes a presence across the region. The assessment for nature conservation sites takes into consideration the location of designated sites and the likely foraging ranges for individual species and uses this as a basis for assessment. Of note was the potential impact on common and velvet scoter and tern species: little, sandwich, common and roseate tern, all of which are designated by SPAs and have the potential to forage within the region.

SIGNIFICANCE STATEMENT: The potential for cumulative impacts of seabed removal to impact upon conservation designations is confined to the Outer Thames SPA, specifically effects on the red throated diver, and the Haisborough, Hammond and Winterton cSAC, specifically effects on sandbanks and reef features.

The primary impacts of seabed removal will be confined to within the footprint of active dredging operations. It has already been recognised that the red throated divers within the Outer Thames SPA avoid areas of dredging activity and associated shipping movements, and have been assessed as having a **low tolerance**, but **high adaptability** and **high recoverability** to seabed removal on a regional scale. However it is also recognized that the red throated diver is a specialist feeder targeting principally herring as its main sources of prey. It is known to forage to a distance offshore that overlaps with the licence areas in both sub-regions (see *Chapter 23 – Impact Assessment: Ornithology*). Applying the precautionary principle dictates that the potential impact to the red throated diver due to seabed removal, and hence to the SPA, is considered to be of ***Minor Significance*** for both sub-regions. Other species of birds that are linked with SPAs within foraging range have also been considered in light of the findings in Chapter 23. However, given the foraging ranges for all species are in most cases considerably less than the distance to the SPA. One possible exception is the presence of little terns from Great Yarmouth and North Denes SPA. It is expected that some overlap with the licence areas and foraging range for this colony will arise, however this forms the outer limit of their range and the birds are more likely to target the sandbanks for sandeel that lie inshore of the licence areas and within the foraging range from the SPA.

The Haisborough, Hammond and Winterton cSAC does not extend into the Southwold sub-region and none of the qualifying sandbanks of the cSAC coincides with licensed aggregate dredging areas in the Yarmouth sub-region. The assessment for sandbanks takes consideration of the findings of the impact assessment on the coastline and nearshore banks which concluded no overlap with the effects of seabed removal. In addition the target aggregate is relict sand and gravel that does not form part of the Annex II feature. Therefore the potential impact on sandbanks through seabed removal was considered ***Not Significant***.

The communities and biotopes typical of the sandbank sub feature are considered to have a high adaptability and medium tolerance and recoverability resulting in moderate sensitivity in line with JNCC (2010b).

The assessment for the designated reef feature took note of the findings of Chapter 20 which included a precautionary assessment of ***Minor Significance*** for the biotope **SS.SBR.PoR.SspiMx**. It was noted that there is potential for future reef formation therefore the precautionary approach was considered appropriate.

Chapter 22 – Impact Assessment: Marine Mammals and Turtles considers the potential impacts of seabed removal on the non qualifying features of harbour porpoise and grey seals as not significant. The impact significance upon these features is considered ***Not Significant*** for both sub-regions.

Chapter 19 concluded there was no direct overlap with sandbank features suggesting the potential for impact from the direct effects of seabed removal was ***Not Significant***. In terms of the spatial overlap, the cumulative impacts on conservation designations from the effects of seabed removal at the regional scale are considered to be of ***Minor Significance*** **(Figure 24:1)**.

UNCERTAINTY: The location and extent of conservation designations and the interest features they support is well understood throughout the MAREA region. Uncertainty in the assessment for the receptor group is considered ***Low*** (see **Tables 24:2** and **24:3**).

24.4.2 Noise and vibration

As has been described in Section 24.4.1 the qualifying feature of the Outer Thames SPA is the population of red throated diver. *Chapter 23 – Impact Assessment: Ornithology* assesses the effects of noise on seabirds in detail. However, in summary, disturbance can cause birds to cease feeding or fly away; and in response they can increase their energy requirements at their present (disturbed) feeding sites, or move to an alternative less favoured feeding or roosting site. Such responses affect energy budgets and food intake rates, and possibly survival (Kaiser, 2002). Overwintering divers, which are frequently subject to harsh weather conditions and must lay down fat reserves in order to migrate to breeding grounds, are particularly susceptible to adverse effects resulting from disturbance. There is, therefore, the potential to affect the SPA by impacting the qualifying feature – the red throated divers.

In addition to the red throated diver, there are other species of birds that are likely to forage in the region and therefore be exposed to disturbance impacts that are considered sensitive to disturbance. The species of note from Chapter 23 are velvet and common scoter, both designated as non breeding populations at North Norfolk Coast SPA.

It is not assessed that noise has any effect on qualifying features for the Haisborough Hammond and Winterton cSAC and was screened out within Chapter 20 in relation to habitats and communities therefore been scoped out of the impact assessment.

SIGNIFICANCE STATEMENT: Species that are considered particularly sensitive to disturbance from presence of vessels and noise effects are red throated diver and scoters (common and velvet) (Cook and Burton, 2010), all of which are designated within the region. All species above are assessed as having a high sensitivity to effects of disturbance with a **low tolerance** and **adaptability** and **medium recoverability**. However the level of spatial overlap for species designated at coastal SPAs (all receptors screened in with exception of Outer Thames) is limited given the distances involved and limited foraging ranges for tern species and scoters (up to 10 km). Therefore the potential for impact on SPAs is considered ***Not Significant***, with the exception of the Outer Thames SPA. Noise effects are temporary, localised and likely to be reduced in frequency during winter months which are a particularly important period for red throated divers. The Outer Thames Estuary SPA Final Impact Assessment Natural England (2010) that provides the evidence base for designation states that any effects from aggregate extraction are not expected to be significant as the area under extraction is small relative to the entire SPA and to date little overlap has been noted between areas used by the red throated diver and licence areas. Put into context with other shipping activity within the region, the effects are small. However, given the direct overlap of the SPA and a number of licences in both sub regions, the precautionary principle dictates that the potential impact of noise on red throated divers, and hence on the SPA is considered to be of ***Minor Significance*** for both sub-regions, although effects will be localised.

This approach takes into consideration the predicted increases in traffic associated with the worse case scenario modelled for this MAREA. The navigation study undertaken to support this MAREA, collected AIS data for a 14 day period in October 2009 (Yarmouth sub-region) and April 2010 (Southwold) and showed that dredgers accounted for between 6-16% of the total activity across the region, with the majority of vessels being general cargo and large tankers. Dredging activity within the sub-regions is relative to the overall activity with a greater number of licences (where increases in activity will be more noticeable) in the Yarmouth sub-region where the greatest traffic overall occurs.

The cumulative impact on the SPA due to future increases in noise and vibration at the **regional** scale is considered to be of ***Minor Significance***. No models of noise propagation are available and therefore this significance is not mapped.

UNCERTAINTY: It is acknowledged that there are some uncertainties associated with noise and vibration on divers, and hence the SPA, in the MAREA region. Data on the precise impact of noise are poorly documented and uncertainty in the spatial extent is ***High***. Overall uncertainty in the assessment is ***High*** (see **Tables 24:2** and **24:3**).

24.4.3 Suspended sediment plume

Suspended sediment plumes resulting in increases in turbidity and settlement have the potential to impact on conservation sites through smothering or blocking the feeding and respiratory organs of marine animals. Plumes can affect recruitment processes of both marine fauna and flora and contribute to a reduction in light penetration through the water column (Cole *et al*., 1999). In turbid waters where light penetration is low, algae growth occurs only at shallow depths or in the littoral zone (Cefas, 2001).

The effects of suspended sediment plume, whilst in suspension, are temporary however the effects of settlement of the plume are considered to occur over a period of days and weeks (within the conceptualised effect-receptor pathway models presented in Chapter 5). The subsequent permanence of the deposits will be controlled by local hydrodynamic conditions, with sediments being rapidly transported where tidal currents and wave action are strong and persisting where they are weak (Cefas, 2001) described further within Chapter 23.

Potential impacts on bird species are considered further within Chapter 23, which notes that vision is an important component in the foraging activity of a number of seabird species. In terms of designated species this is of particular note for tern species, auks (guillemot, razorbill and puffin) and the red throated diver. All species of tern and the red throated diver are considered to have a **low tolerance**, **adaptability** and **medium recoverability** to increases in suspended sediment.

The qualifying feature of the Outer Thames SPA is the overwintering population of the red throated diver. The effect of the sediment plume upon the red throated diver is considered of ***Minor Significance*** in line with the assessment in Chapter 23.

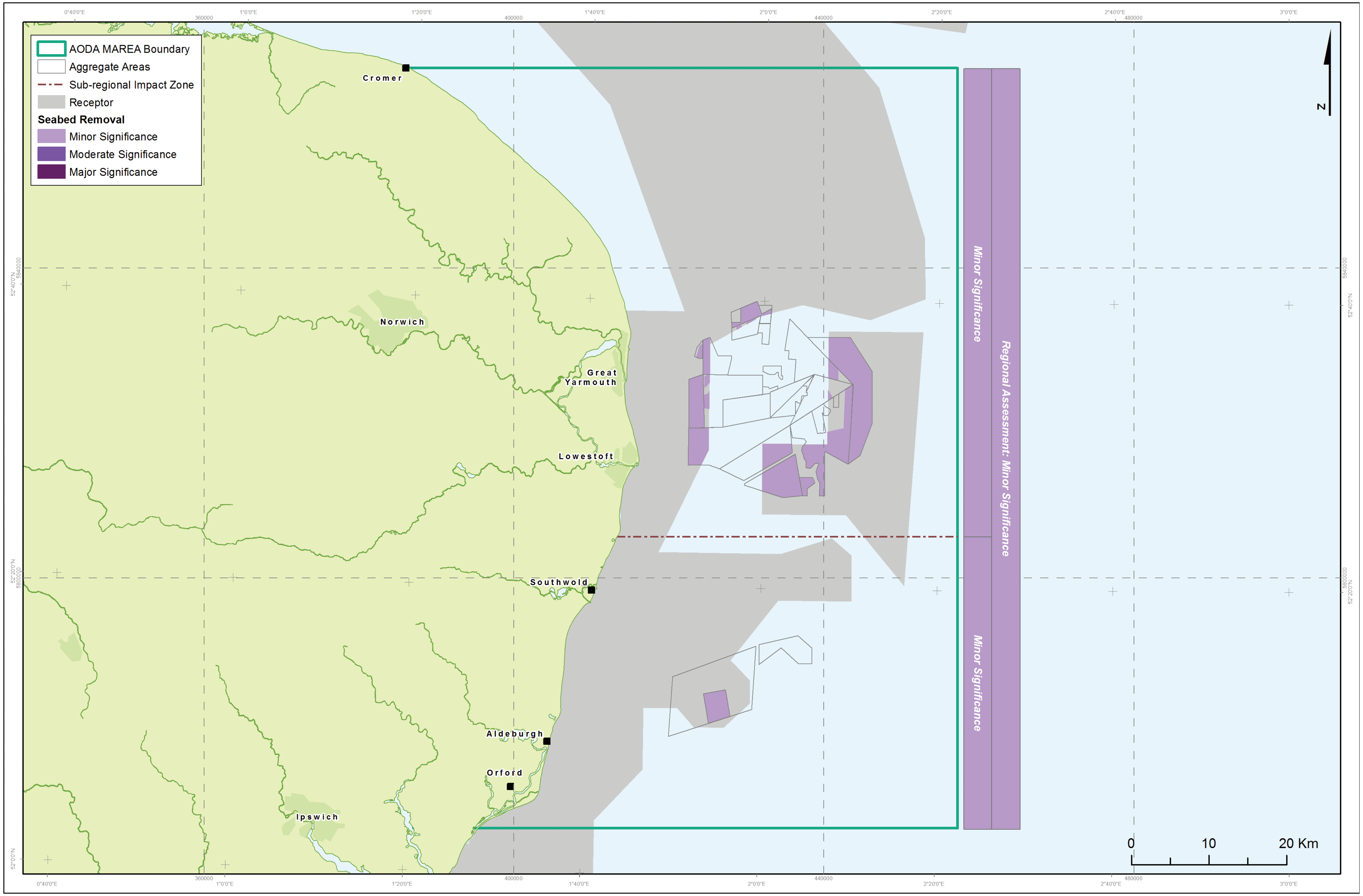

Figure 24:1 Impact significance for seabed removal upon pSPA conservation designations for the Anglian MAREA Region

The Haisborough, Hammond and Winterton cSAC key qualifying features are the presence of sandbanks slightly covered by sea water all of the time, and reefs (principally *Sabellaria spinulosa*). No dredging areas coincide with any of the principal features of designation identified within JNCC (2010). However, the modelling of the 20 mg/l portion of the sediment plume for Prospecting Area 494 in the north of the Yarmouth sub-region does overlap with the southern tip of Newarp Banks, one of the qualifying sandbanks within the cSAC. As noted above the effects of sediment plume are temporary and fine grained material deposited as a result of the plume will be dispersed and controlled by the natural hydrodynamic conditions within the area.

In terms of the potential for impact on the biological communities associated with the sandbank sub-features, JNCC (2010b) states that studies have shown that high suspended sediment loads would be unlikely to affect the communities in the area as they are evolved to exist in high natural turbidity waters. The low diversity sand communities are highly adapted to and have a high recoverability from recurrent erosion and accretion. The moderate diversity stable communities are more sensitive than the low diversity communities but given the high natural suspended sediment loads in the region and the temporary nature of the effect, it is not considered significant. Chapter 20 does identify the potential for a temporary reduction in prey capture for visual predators and feeding by filter feeders but this is not considered significant given the region's naturally high suspended sediment levels.

SIGNIFICANCE STATEMENT: The footprints for suspended plume, identified by HR Wallingford, overlap with the Outer Thames SPA and the Haisborough Hammond and Winterton SAC. All species of tern, auks are considered to have a **low tolerance**, **adaptability** and **medium recoverability** to increases in suspended sediment with red throated divers considered to have medium tolerance, recoverability and adaptability to increases. The assessment for individual species in Chapter 23, identifies the potential impacts on terns, auks and seaduck receptors as of ***Minor Significance***, however the assessment for individual species assumes a presence across the entire region, whereas the assessment for designated sites takes account of foraging distances against distances between SPAs and the sub regions, therefore potential impacts on the sandbank features of the SPA are considered ***Not Significant***. A precautionary approach to the assessment of designated reef features has been taken to ensure any future reefs which may develop are mitigated accordingly.

Impacts on the Outer Thames SPA are considered of ***Minor Significance*** given the direct overlap. This assessment is precautionary given that the suspended sediment plume is temporary and likely to last at most a few hours after the cessation of dredging so any impacts will be localised in the immediate vicinity of the dredger and licence area and last for short timescales.

The effects of the sediment plume on the Haisborough Hammond and Winterton cSAC overlap a small area of the Newarp Banks, which comprises a portion of the qualifying features of the cSAC. The sediment plume is not considered to have an effect on the Newarp Banks and therefore the impacts upon the cSAC are assessed as being ***Not Significant***. A precautionary approach to the assessment of designated reef features has been taken to ensure any future reefs which may develop are mitigated accordingly.

The cumulative impacts on nature conservation designations from the effects of increased suspended sediment plume at the regional scale are considered to be ***Not Significant***.

UNCERTAINTY: The location and extent of conservation designations and the interest features they support is well understood throughout the MAREA region. The precautionary approach has been taken where overlap occurs with a potential effect and a designation to ensure any features not currently designated but which meet selection criteria are encompassed within the assessment. Uncertainty in the modelled effects is considered ***Low***. Therefore uncertainty in the assessment for individual receptor groups is ***Low*** (see **Table 24:2** and **24:3**).

24.4.4 Fine sand dispersion

Deposition of fine sand can potentially modify the superficial sediment composition. Newell *et al*. (1998) and Last *et al*. (2011) are among studies that demonstrate some mobile benthic organisms are able to migrate vertically through more than 30 cm of deposited sediment, however significant change in the seabed sediment composition (e.g. development of sandy bedforms) may result in the habitats becoming unsuitable for some mobile benthic species. Possible relocation of individuals may occur if the superficial sediment composition is altered on a large scale (Posford Duvivier and Hill, 2001).

Fine sand dispersion overlaps with the boundaries of the Outer Thames SPA and the Haisborough Hammond and Winterton cSAC. The impact upon the red throated diver of fine sand dispersion is considered negligible because of the limited spatial extent of the effect relative to the vast feeding area available (Chapter 23). Of note is the presence of common scoter and velvet scoter, both recognised in Cook and Burton (2010) as being particularly sensitive to indirect effects on prey through deposition of sediment generated during dredging. Both species are inflexible in their habitat use and have a limited range, generally of within 10 km of the coast and are both designated features of the North Norfolk coast SPA. However, given North Norfolk coast SPA lies approximately 66 km from the centre of the Yarmouth sub region and 101 km from Southwold sub-region, it is not considered significant.

The modelling results for the fine sand dispersion show an overlap between fine sand dispersion from Licence Areas 254, 202, 494, 212, 296 and Prospecting Area 494 in the Yarmouth sub-region and the qualifying sandbanks feature of the Haisborough, Hammond and Winterton cSAC. However, the dispersion of fine sediment in this area will not cause any changes to seabed bathymetry and the effect will be negligible with respect to the sediment transport regime within the area.

SIGNIFICANCE STATEMENT: The red throated diver is assessed as having a **medium tolerance**, **adaptability** and **recoverability** to the effects of fine sand dispersion. The potential for fine sand dispersion to have an adverse effect on the Outer Thames SPA is considered ***Not Significant*** for both sub-regions because of the lack of effect on the red throated diver which is the principal qualifying feature of the SPA.

The model information for the fine sand dispersion shows an overlap with the banks of the Haisborough, Hammond and Winterton cSAC. Increasing the amount of sand on a sandbank feature is not considered to have an adverse impact, and the fine grained sediments will also tend to be naturally dispersed as part of the regional sediment transport pathways. Therefore the effect of fine sand dispersion on the Haisborough, Hammond and Winterton cSAC is assessed as ***Not Significant***.

The cumulative impacts on nature conservation designations from the effects of fine sand dispersion at the regional scale are considered to be ***Not Significant***.

UNCERTAINTY: The location and extent of conservation designations and the interest features they support is well understood throughout the MAREA region. The precautionary approach has been taken where overlap occurs with a potential effect and a designation to ensure any features not currently designated but which meet selection criteria are encompassed within the assessment. Uncertainty in the modelled effects is considered ***Low***. Therefore uncertainty in the assessment for individual receptor groups is ***Low*** (see **Tables 24:2** and **24:3**).

24.4.5 Bathymetry

Bathymetric changes due to dredging activity do overlap with the boundaries of the two prospective designated areas within the region.

However, it is not considered that bathymetric changes will have an impact on the population of the red throated diver, the qualifying feature of the Outer Thames SPA. Chapter 23 identified that any potential impact on foraging is less of an issue at sites greater than 20 m (see Kaiser, 2002). Of all the birds that occur within the region, only auks are known to forage at depths greater than 20 m. Auks are pursuit feeders targeting fish species, including sandeel. Although auk species are of note, any impact is considered ***Not Significant*** given the distance from the designated site (Flamborough Head and Bempton Cliffs SPA lies 210 km from the Yarmouth sub-region).

Even though bathymetric changes do overlap with the Haisborough, Hammond and Winterton cSAC boundary none of these bathymetric changes coincides with the qualifying reefs sandbanks within the proposed designation.

SIGNIFICANCE STATEMENT: Bathymetric changes within the Outer Thames SPA will not affect the red throated diver and therefore the impact is considered to be ***Not Significant*** for both sub-regions. Although auk species are of note, any impact is considered ***Not Significant*** given they target mobile prey and the effect is limited to the immediate aggregate area which does not overlap with any significant sandeel habitats (predominantly sandbank features).

Bathymetric changes do not overlap with the sandbanks or reef features which are the qualifying features of the Haisborough Hammond and Winterton cSAC, and are confined to aggregate dredging areas. The impacts of bathymetric change on the cSAC are therefore considered to be ***Not Significant***.

The cumulative impacts on conservation designations from the effects of bathymetry changes at the regional scale are considered to be ***Not Significant***.

UNCERTAINTY: The location and extent of conservation designations and the interest features they support are well understood throughout the MAREA region. The precautionary approach has been taken where overlap occurs with a potential effect and a designation to ensure any features not currently designated but which meet selection criteria are encompassed within the assessment. Overall uncertainty for individual receptor groups is therefore considered ***Low*** (see **Table 24:2** and **24:3**).

24.4.6 Waves

Increased wave heights may lead to more energetic shallow water conditions potentially resulting in changes to seabed morphology. The modelling of wave effects shows overlap of changes to the wave environment with the outer Thames SPA and the Haisborough, Hammond and Winterton cSAC.

A more energetic environment can lead to the re-mobilisation of sediments (Sutton and Boyd, 2009), potentially increasing suspended sediment concentrations (indirectly affecting turbidity level, light penetration).

The impact of changes to the wave regime was screened out of the ornithology impact chapter (Chapter 23) and therefore the effects on the SPAs will not be considered further.

Changes to the wave regime do overlap with the Haisborough, Hammond and Winterton cSAC. The principal wave portion that overlaps the cSAC is the 2-5% increase in the 1 in 200 wave event, which in this case equates to a maximum increase of 0.47 m upon the predicted 9.5 m wave. The prominent wave direction in this area is from the north and therefore the major effect of this increase in wave height will be to the south, away from the qualifying features of the cSAC.

SIGNIFICANCE STATEMENT: Waves effects were screened out for the assessment on bird species, an increase in wave force reaching the coast could potentially affect the breeding success of birds that nest on sand and shingle beaches, spits and low lying islets, such as terns (Mitchell *et al*., 2004). HR Wallingford models for the region demonstrate that changes in waves do not reach the coast and will not, therefore, have an impact.

The impact of changes to wave regime upon the Haisborough Hammond and Winterton cSAC are considered to be negligible as there is minimal overlap between the changes to the wave regime and the qualifying features of the cSAC. The principal overlap is on the southern side of the sandbanks and the principal effect direction is to the south, away from the sandbanks, therefore the impact of waves on the Haisborough Hammond and Winterton cSAC is considered ***Not Significant***.

UNCERTAINTY: The location and extent of conservation designations throughout the MAREA region, and the features of interest they support, are well understood. The precautionary approach has been taken where overlap occurs between a potential effect and a nature conservation designation, to ensure that any features not currently designated but which meet selection criteria are encompassed within the assessment. Modelled data for waves provide a high degree of confidence in the assessment. For this reason, uncertainty in the assessment is considered **Low**.

24.4.7 Sediment flux

Sediment flux is the net transport of sediment, a proxy for potential erosion or deposition of seabed sediments. The transport of sediment away from the site of origin is largely determined by the prevailing tidal currents and wave action (Cefas, 2001).

Increased sediment flux can potentially result in increased scour, which could potentially lead to the erosion and degradation of habitats (Birklund & Wijsman, 2005).

There is overlap between the effect of changes in sediment flux upon the two proposed offshore designations within the MAREA region. However, the effect of sediment flux on bird populations is considered negligible and therefore the impact upon the designated SPAs is also considered negligible.

There is also overlap between the effects of sediment flux and the Newarp and Middle Cross Sands sandbanks in the north of the region, which comprise a portion of the qualifying features of the Haisborough, Hammond and Winterton cSAC. However, the impacts from sediment flux upon these features is only just within the discernible range of the sediment flux modelling algorithm, 500 kg/m/tide, (HR Wallingford, 2011) and is concentrated around the base of the sandbanks. Therefore impacts upon the sandbanks, and therefore the Haisborough Hammond and Winterton cSAC, are considered negligible.

SIGNIFICANCE STATEMENT: The effect of sediment flux upon the Outer Thames SPA directly or indirectly on SPAs inside or outside of the region is negligible and therefore the impact is considered ***Not Significant***.

The effect of sediment flux upon the sandbanks within the Haisborough, Hammond and Winterton cSAC is also negligible and therefore the impact of sediment flux upon the cSAC is considered ***Not Significant***.

UNCERTAINTY: The location and extent of conservation designations and the interest features they support is well understood throughout the MAREA region. Uncertainty in the modelled effects is considered ***Low***. Therefore uncertainty in the assessment for individual receptor groups is ***Low*** (see **Table 24:1**).

24.4.8 Effects screened out

Vessel displacement and tidal currents are screened out as no direct or indirect impacts are predicted on any designated sites or interest features or sub-features.

24.5 CONCLUSIONS

The MAREA region supports a large number of statutory and non statutory designations at a local, national and international level. However, a large number of these are restricted to the coastal zone, with only a small number having a marine component. Direct impacts from aggregate extraction which are restricted to the licence area footprint are only predicted where overlap between licence areas and designated sites occur. This is limited to the Outer Thames SPA and the Haisborough, Hammond and Winterton cSAC. The effects of noise and vibration overlap with the Outer Thames SPA boundaries, and will have an impact on the qualifying feature for the SPA (the red throated diver). Indirect impacts may arise on designated SPAs, both within the region and beyond where designated species are known to forage within the Anglian region as defined by this study.

24.5.1 Yarmouth: sub-regional impacts

Potential direct impacts on nature conservation sites within the Yarmouth sub-region are limited to the Outer Thames SPA and Haisborough, Hammond and Winterton cSAC (reef feature). This is due to the potential impacts of seabed removal and noise and vibration, suspended plume and fine sand dispersion. For these effects the impact significance for the Yarmouth sub-region is assessed as being of ***Minor Significance***.

24.5.2 Southwold: sub-regional impacts

The boundary of the Outer Thames SPA also extends into the Southwold sub-region and the potential impacts of seabed removal and noise and vibration and suspended plume also impact the qualifying feature of the SPA, the red throated diver, in this sub-region. For both of these effects the impact significance for the Southwold sub-region is assessed as being of ***Minor Significance***.

24.5.3 Regional impacts

At the MAREA regional scale, the overall significance of the cumulative impact upon nature conservation sites, features and sub features as a result of future dredging activities is, in general, considered ***Not Significant***. The majority of designated sites lie within the coastal zone and therefore there is on overlap with the effect footprints.

The effect footprints do overlap directly with the qualifying features of two marine designated areas within the region, the Outer Thames SPA and the Haisborough, Hammond and Winterton cSAC. All assessments for designated bird species are based on an assumption of the presence of bird species and use across the region as a whole therefore assessment are made at a regional as opposed to sub-regional level

Potential impacts on designated bird species that forage within the region are noted from the effects of seabed removal, noise and vibration and suspended sediments. The assessment undertaken for birds (Chapter 23) takes a precautionary approach and assumes a presence across the region. However for this assessment, foraging ranges were considered and this was used as an indicator to screen out SPAs. However consideration should be given to the findings of Chapter 23, together with site specific data at an EIA level.

The majority of the sandbanks that comprise the qualifying features of the Haisborough, Hammond and Winterton cSAC lie to the north of the MAREA region. There is overlap between effects envelopes and the Newarp and Middle Cross Sands sandbanks but these effects were considered to be negligible and therefore ***Not Signficant***.

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Table 24:2 **CUMULATIVE IMPACT ASSESSMENT TABLES FOR NATURE CONSERVATION FOR SUB-REGION YARMOUTH**

	SENSITIVE RECEPTOR									
EFFECT	***Haisborough Hammond and Winterton cSAC***	***Outer Thames SPA;*** **Direct Overlap*	***Alde-Ore Estuary SPA;*** **65km Yarmouth*	***Benacre to Easton Bavents SPA;*** **36km*	***Breydon Water SPA;*** **21km*	***Minsmere to Walberswick SPA;*** **47km*	***Great Yarmouth North Denes;*** **18km*	***Flamborough Head and Bempton Cliffs SPA;*** **210km*	***North Norfolk Coast SPA;*** **66km*	***Netgain & Balanced Seas***	***Coastal sites (AONB)***
SEABED REMOVAL *(Effect magnitude = Medium)*	**Sandbank feature:** **T:** Medium, **A:** Medium; **R:** Medium **Sub-features:** ***Low diversity dynamic sand communities*** **T:** Medium, **A:** High; **R:** Medium ***Moderately diverse stable sand communities*** **T:** Medium, **A:** High; **R:** Medium **Value:** Designated Annex I habitat. **Spatial overlap:** SAC lies to the north of the sub region, overlap occurs with the SAC boundary Chapter 8 and 19 identify sandbank features, but no overlap occurs with licence areas so no impact is predicted on the physical integrity of the bank or through direct impact on the associated biological communities. ***Sabellaria spinulosa* reef** **T:** Low, **A:** Low; **R:** High **Value:** Designated Annex I habitat. **Spatial overlap:** SAC Site Selection Assessment report v6 (2010) identifies the presence of reef feature within the central area of the SAC. The license areas which overlap with the SAC occur only on its southern boundary. Outside of the SAC a review of the REA and REC datasets indicates the presence of *Sabellaria* reef around a number of licence areas; Areas 430, 401/2 and 202/254. With the exception of Area 254 (the northern extent of this licensed area falls within the SAC but the ADZ is south of the SAC southern boundary), these licence areas fall outside of the SAC, nevertheless, consideration should be given to any assessment or verification of suitable Annex I habitat at EIA level and operational mitigation instigated accordingly.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** The red-throated diver is a designated species (non breeding) **Spatial overlap:** Species populations present at high densities and frequencies within designated Outer Thames SPA. Direct overlap.	**Gulls** *(black headed, lesser black backed, herring gull)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Gulls have large range and highly adaptable to range of habitats and prey. **Terns** *(little and sandwich)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to a maximum of 10km so it is unlikely any impacts on breeding colony designated by this SPA will occur.	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km so it is unlikely any significant impacts on the breeding colony for this SPA will occur.	**Common tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 6.3km so it is unlikely any impacts on designated species for this SPA will occur, however it is assumed that some overlap with the foraging range may occur for inshore licences. Sandbank features where terns are likely to forage for sandeels lie inshore of the licence area so any overlap will be outside of critical habitat for this species.	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km so it is unlikely any significant impacts on designated species for this SPA will occur	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km, there is potential for overlap with inshore licences, although it is unlikely any significant impacts on designated species for this SPA will occur, species likely to target inshore sandbanks for sandeels that lie inshore of licence areas and within foraging range.	**Gulls** *(kittiwake, herring gull)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Gulls have large range and highly adaptable to range of habitats and prey. Sub region is likely outside the foraging range for these species. **Auks** *(razorbill, guillemot)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Given distance it is expected that the sub region lies outside of any critical feeding areas for these species. **Gannets** **T:** High, **A:** Medium; **R:** High **Value:** Annex I species **Spatial overlap:** gannets have an extensive range that is likely to overlap with the sub-region, however this range mitigates any likely impacts given availability of suitable habitats and prey across range.	**Terns** *(common, little, roseate and sandwich)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Common and velvet Scoter** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range for both terns and scoters are limited to a maximum of around 10km, so it is unlikely any significant impacts on the breeding colony for this SPA will occur.		
	Minor Significance (reef feature)	**Minor Significance**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
NOISE AND VIBRATION *(Effect magnitude = Low)*		**Red throated diver** **T:** Low, **A:** Low; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap with the SPA and licence areas, dredging and transit of vessels occurs within an already busy shipping area	**Gulls** *(as above)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** large and varied habitat/prey range **Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** Licence areas fall outside the foraging range for these species and therefore any disturbance effects are unlikely to result in exclusion from critical habitat for this species.	**Terns** *(as above)* **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** *(kittiwake, herring gull)* **T:** High, **A:** High; **R:** High **Auks** *(razorbill, guillemot)* **T:** High, **A:** High; **R:** High **Gannets** **T:** High, **A:** Medium; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)* **Common and velvet Scoter** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species		
		Minor Significance	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment. ***distance (km) from closest point of the SPA to centre point of the sub-region. Distances are indicative only.**

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

Table 24:2 **CUMULATIVE IMPACT ASSESSMENT TABLES FOR NATURE CONSERVATION FOR SUB-REGION YARMOUTH** *- continued*

EFFECT	SENSITIVE RECEPTOR									
	Haisborough Hammond and Winterton cSAC	*Outer Thames SPA;* **Direct Overlap*	*Alde-Ore Estuary SPA;* **65km Yarmouth*	*Benacre to Easton Bavents SPA;* **36km*	*Breydon Water SPA;* **21km*	*Minsmere to Walberswick SPA;* **47km*	*Great Yarmouth North Denes;* **18km*	*Flamborough Head and Bempton Cliffs SPA;* **210km*	*North Norfolk Coast SPA;* **66km*	*Netgain & Balanced Seas*	*Coastal sites (AONB)*
SUSPENDED PLUME *(Effect magnitude = Low)*	**Sandbanks** **T:** High, **A:** High; **R:** High **Low diversity communities** **T:** High, **A:** High; **R:** High **Moderate diversity communities** **T:** Medium, **A:** Medium; **R:** Medium **Reef features** **T:** High, **A:** High; **R:** High **Value:** Designated Annex I habitat. **Spatial overlap:** limited overlap with sandbank features and sub-features but potential for overlap with designated or potential reef. Chapter 20 identifies likely overlap therefore precautionary approach has been applied. **NB:** Naturally high suspended sediment loads in the region result in communities evolved to adapt.	**Red throated diver** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap Visual feeders so potential for direct impact, given temporary nature of plume, significance is precautionary.	**Gulls** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)* **Terns** **T:** Low, **A:** Low; **R:** Medium	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)* **Common and velvet Scoter** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species		
	Minor Significance (reef feature)*	**Minor Significance**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
FINE SAND DISPERSION *(Effect magnitude = Low)*	**Sandbanks** **T:** High, **A:** High; **R:** High **Low diversity communities** **T:** High, **A:** High; **R:** High **Moderate diversity communities** **T:** Medium, **A:** Medium; **R:** Medium **Reef features** **T:** Medium, **A:** Medium; **R:** High **Value:** Designated Annex I habitat. **Spatial overlap:** limited overlap with sandbank features and sub-features but potential for overlap with designated or potential reef. Chapter 20 identifies likely overlap therefore precautionary approach has been applied.	**Red throated diver** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap, impact potential associated with impacts on distribution and disturbance to prey, **NB:** Any impacts on herring populations (key prey) as a result of impacts on spawning habitat should be considered for red throated diver.	**Gulls** **T:** High, **A:** High; **R:** High **Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*		
	Minor Significance (reef feature)*	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
BATHYMETRY CHANGES *(Effect magnitude = Medium)*	**Sandbanks** **T:** Medium, **A:** Medium; **R:** Medium **Reef features** **T:** High, **A:** High; **R:** High	**Red throated diver** **T:** High, **A:** High; **R:** High **Value:** Designated species **Spatial overlap:** direct overlap	**Gulls** **T:** High, **A:** High; **R:** High **Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*		
	Not significant	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
SEDIMENT FLUX *(Effect magnitude = Medium)*	**Sandbanks** **T:** Medium, **A:** Medium; **R:** Medium **Reef features** **T:** Medium, **A:** Medium; **R:** High	**T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*		
	Minor Significance	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
WAVES	**Sandbanks only** **T:** High, **A:** High; **R:** High Dependent on magnitude of change										

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment. ***distance (km) from closest point of the SPA to centre point of the sub-region. Distances are indicative only.**

☐ Not significant ▨ Minor significance ▨ Moderate significance ▨ Major significance **Uncertainty:** *High **Moderate *** Low

Table 24:3 CUMULATIVE IMPACT ASSESSMENT TABLES FOR NATURE CONSERVATION FOR SUB-REGION SOUTHWOLD

EFFECT	SENSITIVE RECEPTOR										
	Haisborough Hammond and Winterton cSAC	*Outer Thames SPA;* **Direct Overlap*	*Alde-Ore Estuary SPA;* **29km Yarmouth*	*Benacre to Easton Bavents SPA;* **27km*	*Breydon Water SPA;* **47km*	*Minsmere to Walberswick SPA;* **25km*	*Great Yarmouth North Denes;* **48km*	*Flamborough Head and Bempton Cliffs SPA;* **252km*	*North Norfolk Coast SPA;* **101km*	*Netgain & Balanced Seas*	*Coastal sites (AONB)*
SEABED REMOVAL *(Effect magnitude = Medium)*		**T:** Medium, **A:** Medium; **R:** Medium **Value:** The red-throated diver is a designated species (non breeding) **Spatial overlap:** Species populations present at high densities and frequencies within designated Outer Thames SPA. Direct overlap.	**Gulls** *(black headed, lesser black backed, herring gull)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Gulls have large range and highly adaptable to range of habitats and prey. **Terns** *(little and sandwich)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to a maximum of 10km so it is unlikely any impacts on breeding colony designated by this SPA will occur.	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km so it is unlikely any significant impacts on the breeding colony for this SPA will occur.	**Common tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 6.3km so it is unlikely any impacts on designated species for this SPA will occur, however it is assumed that some overlap with the foraging range may occur for inshore licences. Sandbank features where terns are likely to forage for sandeels lie inshore of the licence area so any overlap will be outside of critical habitat for this species.	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km so it is unlikely any significant impacts on designated species for this SPA will occur	**Little tern** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range of terns is limited to around 4.6km, there is potential for overlap with inshore licences, although it is unlikely any significant impacts on designated species for this SPA will occur, species likely to target inshore sandbanks for sandeels that lie inshore of licence areas and within foraging range.	**Gulls** *(kittiwake, herring gull)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Gulls have large range and highly adaptable to range of habitats and prey. Sub region is likely outside the foraging range for these species. **Auks** *(razorbill, guillemot)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** Given distance it is expected that the sub region lies outside of any critical feeding areas for these species. **Gannets** **T:** High, **A:** Medium; **R:** High **Value:** Annex I species **Spatial overlap:** gannets have an extensive range that is likely to overlap with the sub-region, however this range mitigates any likely impacts given availability of suitable habitats and prey across range.	**Terns** *(common, little, roseate and sandwich)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** foraging range limited to a maximum of around 10km, so it is unlikely any significant impacts on the breeding colony for this SPA will occur.		
		Minor Significance	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
NOISE AND VIBRATION *(Effect magnitude = Low)*		**Red throated diver** **T:** Low, **A:** Low; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap with the SPA and licence areas, dredging and transit of vessels occurs within an already busy shipping area	**Gulls** *(as above)* **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** large and varied habitat/prey range **Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** Licence areas fall outside the foraging range for these species and therefore any disturbance effects are unlikely to result in exclusion from critical habitat for this species.	**Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** *(kittiwake, herring gull)* **T:** High, **A:** High; **R:** High **Auks** *(razorbill, guillemot)* **T:** High, **A:** High; **R:** High **Gannets** **T:** High, **A:** Medium; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** *(as above)* **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*		
		Minor Significance	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment. ***distance (km) from closest point of the SPA to centre point of the sub-region. Distances are indicative only.**

☐ Not significant
▨ Minor significance
▨ Moderate significance
■ Major significance

Uncertainty: *High **Moderate *** Low

Table 24:3 CUMULATIVE IMPACT ASSESSMENT TABLES FOR NATURE CONSERVATION FOR SUB-REGION SOUTHWOLD *- continued*

EFFECT	SENSITIVE RECEPTOR									
	Haisborough Hammond and Winterton cSAC	*Outer Thames SPA;* **Direct Overlap*	*Alde-Ore Estuary SPA;* **29km Yarmouth*	*Benacre to Easton Bavents SPA;* **27km*	*Breydon Water SPA;* **47km*	*Minsmere to Walberswick SPA;* **25km*	*Great Yarmouth North Denes;* **48km*	*Flamborough Head and Bempton Cliffs SPA;* **252km*	*North Norfolk Coast SPA;* **101km*	*Netgain & Balanced Seas*	*Coastal sites (AONB)*
SUSPENDED PLUME *(Effect magnitude = Low)*		**Red throated diver** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap Visual feeders so potential for direct impact, given temporary nature of plume, significance is precautionary.	**Gulls** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)* **Terns** **T:** Low, **A:** Low; **R:** Medium	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*		
		Minor Significance	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
FINE SAND DISPERSION *(Effect magnitude = Low)*		**Red throated diver** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Designated species **Spatial overlap:** direct overlap, impact potential associated with impacts on distribution and disturbance to prey, **NB:** Any impacts on herring populations (key prey) as a result of impacts on spawning habitat should be considered for red throated diver.	**Gulls** **T:** High, **A:** High; **R:** High **Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** Low, **A:** Low; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*		
		Not significant	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
BATHYMETRY CHANGES *(Effect magnitude = Medium)*		**Red throated diver** **T:** High, **A:** High; **R:** High **Value:** Designated species **Spatial overlap:** direct overlap	**Gulls** **T:** High, **A:** High; **R:** High **Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** Medium, **A:** Medium; **R:** Medium **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*		
		Not significant	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
SEDIMENT FLUX *(Effect magnitude = Medium)*		**T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Gulls** **T:** High, **A:** High; **R:** High **Auks** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*	**Terns** **T:** High, **A:** High; **R:** High **Value:** Annex I species **Spatial overlap:** *(as above)*		
		Not significant	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**	**Not significant**		
WAVES											

T: Tolerance; **A:** Adaptability; **R:** Recoverability *(for full definitions see Chapter 3).* **Grey shading;** denotes receptor screened out of assessment. ***distance (km) from closest point of the SPA to centre point of the sub-region. Distances are indicative only.**

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

25. IMPACT ASSESSMENT: COMMERCIAL AND RECREATIONAL FISHERIES

25.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

To determine the potential impacts of aggregate extraction on the commercial and recreational fisheries sector, it is necessary to:

- Establish the level of commercial and recreational activity across the region;
- Map the spatial extent and distribution of fishing activity using a combination of knowledge collated from consultation with regional fishermen and official fisheries statistics;
- Identify the target species of commercial and recreational importance; and
- Determine existing and potential future conflicts between the marine aggregate and commercial and recreational fishing sectors.

Fishing in the Anglian Offshore MAREA region is characterised predominantly by small inshore vessels under 10 m length that are currently not captured by official statistics. To capture the knowledge of this inshore fleet, a dedicated consultation exercise was undertaken at all regional ports, and these data were considered in context with findings from previous studies from historical licence applications and renewals and other regional studies. It is considered that these data, taken in parallel with official statistics, are sufficient to provide an indicator of the overall regional distribution of activity, and inform this assessment.

It is noted that the consultation exercise undertaken, although extensive in geographical range across the region, only provides representative data for fisheries contacts. Given the dynamic and opportunistic nature of the fleet, caution in using the spatial extents as fixed boundaries is recommended. The assessment takes the precautionary approach, assuming activity is widespread across the region, with preferred areas identified through consultation taken as areas of greatest intensity.

Data for recreational fisheries are largely based on grey literature derived from published reports, and web based searches. It should be noted that data for recreational fisheries are not supported by official data so any assessment on uncertainty is more subjective.

25.1.1 Screening effect-receptor interactions

Screening was used to identify the effects of future dredging activities most likely to impact the commercial and recreational fishing sector and target species, and so better start the assessment early in the process. Key scientific studies that describe the impacts of aggregate extraction activities on these receptors were used to underpin screening decisions and, where appropriate, are referenced in the following sections.

Using the source-pathway-receptor model presented in Step 1 of the Impact methodology (see Chapter 3), all direct and indirect pathways between the physical effects of dredging and commercial and recreational fisheries were identified. This screening opportunity identified the effects for inclusion in Step 3 of the impact assessment (see Chapter 3), where the effect-receptor footprints were mapped in GIS. This spatial analysis identified effect-receptor interactions for each licence/application area across the entire region, and screened in and out of the assessment the following effects and receptors.

Effects screened in:

- Vessel displacement;
- Seabed removal;
- Suspended sediment plume; and
- Fine sand dispersion (ecological context only).

Effects screened out:

- Noise and vibration;
- Bathymetric changes;
- Waves;
- Tidal currents; and
- Sediment flux.

Commercial and recreational fishing receptors screened in:

Defined on the basis of fleet and gear type, the following will be considered:

- Inshore fleet (opportunistic all gear types);
- Middle ground fleet (long lines, trawling and netting);
- Offshore fleet (trawl and long liners); and
- Recreational /charter vessels.

Commercial and recreational fishing receptors screened out:

- Seiner netting (all fleets)

25.1.2 Potential impacts to commercial and recreational fisheries

The potential impacts on the commercial and recreational fishing sector of the effects screened in have been described by identifying impacts on target species as well as potential impacts on the ability of vessels to operate in preferred/traditional areas. Potential impacts include:

- Extraction activity may cause a change in the distribution of target fish and shellfish species altering fishing patterns;
- Extraction may impact on the available stocks;
- Presence of the dredger may result in temporary exclusion of fishing vessels from the licence areas;
- Changes to the seabed could impact on seabed trawl routes due to potential for topographical changes; and
- Direct damage to static fishing gear that may lie in the path of the dredger.

25.2 CUMULATIVE IMPACT ASSESSMENT

The Anglian Offshore MAREA region supports a range of fishing types targeting seasonally available catch. The fleet can be defined by its spatial limits into inshore, middle ground and offshore fleets. Since the 1970s, the overall fleet has seen a serious decline with landings and vessel numbers reduced. This has been attributed by fishermen to a number of factors including reduction in fish stocks, restrictive quotas but also in combination impacts with other activities including marine aggregate extraction (Plumb, 2009).

A recent ALSF study (Kenny *et al.*, 2010) concluded, however, that the long term trends of the ecological status of the Anglian region appear to be dominated by factors which also govern the trends observed at the North Sea scale i.e. declines in fish stocks are observed across both the North Sea and ALSF study areas. Kenny *et al.* (2010) also concluded that there is no evidence of dredging having displaced the main areas of fishing activity and that trends in both dredging and fishing effort off the east coast have to a large extent been similar since the mid 1980s.

The regional ports support a fleet characterised by a large number of relatively small boats (mostly <10 m), each using a variety of fishing methods according to season and abundance of target species. These smaller vessels are more reliant on regional ports given their limited range – operating up to 8 km offshore for the inshore fleet and between 8 and 50 km offshore for the middle ground fleet. In contrast, the offshore fleet has a greater range and will target fishing grounds that overlap with aggregate areas, where the opportunity arises.

This dependency on the regional grounds makes the fleet more sensitive to impacts from displacement, and to disturbance of traditional grounds by aggregate extraction. This sensitivity is balanced by a highly versatile fleet that can operate up to four or five different gear types reacting opportunistically to changing abundance, accessibility, market prices or regulations (Esseen, 2005).

The assessment process considers the nature of the fleet, together with the value of target species landed, and the ecological function of the region.

25.2.1 Seabed removal

Seabed removal has the potential to directly impact upon certain gear types employed by the fishing industry directly through changes to bathymetry and sediment composition.

Anecdotal observations documented by Esseen (2005) identified a number of concerns raised by one trawler skipper consulted as part of the Area 401/2 fisheries activity study. This skipper suggested that damage to gear had been caused by changes in topography, the exposure of boulders that were previously buried or snagging on other obstructions such as lost dredge gear. It is noted however, that loss of dredge gear of a sufficient size to cause damage is a rare occurrence in practice; and any significant losses would be notified to the MMO and UKHO and consequently fishermen would be made aware.

Seabed removal also has the potential to indirectly impact fishing through a reduction in the benthic communities that are prey for fish and shellfish. This has the potential to alter the distribution and presence of target species in the region e.g. the absence of cod in the region was often, anecdotally, attributed to aggregate dredging (Esseen, 2005). It was widely reported to Esseen (2005) that, historically, cod would stay in the region for up to three weeks whereas they no longer stay in the region for any time, moving through the area quickly. This was widely attributed by the fishermen to the lack of food on the grounds post-dredging (Esseen, 2005).

Sub-region	Effect	Inshore fleet	Middle ground	Offshore	Recreational	Screening Assessment
Yarmouth	Seabed removal	✔	✔	✔	✔	● Noise and vibration, bathymetry changes, sediment flux, tidal currents and waves are assessed as having no impact on any receptor so are screened out and not considered further for impact assessment. ● There is no overlap of any effects with seine netting for all fleets. ● Given the opportunistic nature of the inshore fleet, and to some extent the middle ground fleet, all other gear types are screened in.
	Vessel displacement	✔	✔	✔	✔	
	Noise and vibration					
	Suspended plume	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					
Southwold	Seabed removal	✔	✔	✔	✔	● Noise and vibration, bathymetry changes, sediment flux, tidal currents and waves are assessed as having no impact on any receptor so are screened out and not considered further for impact assessment. ● There is no overlap of any effects with seine netting for all fleets. ● Given the opportunistic nature of the inshore fleet, and to some extent the middle ground fleet, all other gear types are screened in.
	Vessel displacement	✔	✔	✔	✔	
	Noise and vibration					
	Suspended plume	✔	✔	✔	✔	
	Fine sand dispersion	✔	✔	✔	✔	
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 25:1 Screening assessment matrix for the Anglian Offshore MAREA region.

This perception would appear to be disproved by Kenny et al. (2010) who concluded that the long term trends within the Anglian region appear to be dominated by factors which also govern the trends observed at the North Sea scale. Plumb (2009) reported that fishermen at Aldeburgh acknowledged that a relinquished dredging area outside the Aldeburgh Ridge had become a very productive ground for cod and skate during the winter and for shellfish during the summer.

The removal of seabed has the potential to impact on the ecological functioning of a region, through an impact on critical habitats such as spawning, nursery and overwintering grounds. It is acknowledged that any ecological changes in the distribution and numbers of fish and shellfish populations will have an indirect impact on the commercial and recreational fishing sector; and further information on this is detailed in Chapter 21 Impact Assessment: Fish and Shellfish Ecology.

The region supports spawning and nursery grounds for a number of commercial species including mackerel, cod, whiting, plaice, lemon sole and sole. Additionally herring and sandeel spawning grounds overlap with a number of licence areas, and since these species spawn directly on the seabed they will, consequently, be more sensitive to the effects of seabed removal.

Changes in bathymetry could also affect the migration routes of certain species, and so potentially affect catch rate (Posford Duvivier Environment and Hill, 2001). This is primarily a concern for flatfish species which move onshore in the spring from deeper water. Fishermen rely on these migrations because they know where the fish will be at a particular time of the year. There is a perception amongst some fishermen that dredging interrupts the migration of these fish, although Posford Duvivier Environment and Hill (2001) did not identify any scientific evidence to support this concern. Within the region, several fishermen reported that inshore grounds now support lower sole stocks as sole have stopped migrating inshore across dredged areas (Esseen, 2005).

SIGNIFICANCE STATEMENT: Dredging in the MAREA region is by trailer dredging. Static dredging is licensed for a number of areas but not currently employed. The sensitivity of fishing practices to the effects of seabed removal is highly dependent on gear type. Fishing techniques employing static gear or mobile gear that do not interact with the seabed are considered to have **medium tolerance** as the gear can be placed in discrete locations and show **high adaptability** and **recoverability** to the effects of seabed removal. They are assessed as having a low sensitivity to seabed removal.

Mobile gear that is trawled or dragged along the seabed is considered to have **medium tolerance** and show **medium adaptability** and **recoverability** to the effects of seabed removal. It is assessed as being **moderately** sensitive to significant changes in bathymetry as a result of seabed removal, since it is this fishing technique that is most likely to overlap with the licence areas. In the Anglian region, the primary mobile fishing technique is trawling (both beam and otter trawls). Consideration of official data, consultation feedback and outputs from Vanstaen *et al.* (2010) indicates that low intensity otter trawling occurs across the region, whereas beam trawling is more widespread. The level of trawling is greatest in the Southwold sub-region, however the focus of activity appears to lie inshore of the current/proposed licence areas.

Seabed removal, and the dredge furrows arising from trailer dredging are considered unlikely to impact on the majority of fishing within the region. The effect of seabed removal on commercial and recreational fishing gear for both sub regions, and across the region as a whole is considered to be ***Not Significant***.

It is also acknowledged that seabed removal may have an impact on fish receptors that spawn directly onto the seabed e.g. herring and sandeel, and these impacts are considered in Chapter 21 Impact Assessment: Fish and Shellfish Ecology.

UNCERTAINTY: Data collated from formal and informal sources correlate well and provide an overview of the fishing distribution and patterns across the region. However given the highly dynamic and variable nature of the industry, there was insufficient data to accurately map potential areas of interaction and uncertainty is therefore ***High***.

25.2.2 Vessel presence

The presence of a dredging vessel in a fishing area that may temporarily exclude access, or disturb and cause damage to gear set within active dredge areas. The significance of this depends on the duration and timing of extraction activity, the level of fishing activity that exists within the immediate and wider area and the scale and extent of any additional restrictions imposed on the fishing industry.

Displacement of vessels is likely to be of greatest concern where the area is a particularly rich fishing ground, where the range of the fleet is limited, and/or where displacement would force vessels beyond the 12 nm limit. This would result in an increased level of competition from larger and/or foreign vessels for space and resources. The small inshore vessels (less than 10 m) characteristic of the region are limited in their range by a number of factors including size, fuel costs and exposure to bad weather and displacement beyond 12 nm is therefore less likely.

Of particular relevance to the Anglian offshore region is the nature of the inshore and middle ground fleets. In general, both fleets utilise the licence areas in the Yarmouth sub-region, while the inshore fleet in the Southwold sub-region is predominantly inshore of the licence area and prospecting area, but there will be an element of overlap.

Both fleets are sensitive to displacement. The inshore grounds are exploited by smaller vessels with limited range, whilst the middle ground fleet is exposed to greater competition from offshore and foreign vessels from ports outside of the region. The offshore fleet is considered less sensitive to any impacts of displacement given that it is not restricted by range or use of home ports within the region and its main fishing grounds extend beyond the boundaries of the Anglian MAREA region into the southern North Sea.

The consultation data collected have been used to identify any rich and/or traditional grounds and Plumb (2009) indicated that the preferred grounds for a number of gear types overlap with licence areas in both the Yarmouth and Southwold sub-regions. The principal gear types in operation for the inshore and middle ground fleets are trawling (single and pair boat), beam trawling for whitefish and shrimps, fixed and drift netting, long lining and potting (Plumb, 2009). To account for spatial uncertainties, an assumption has been made that an activity occurs across an entire sub-region however the data do indicate that preferred areas exist.

Trawling takes place throughout the region but the main concentrations identified are in the southwest of the MAREA region, predominantly in the Southwold sub-region where the main areas of intensity lie inshore of the current prospecting area and licence area. Although trawling activity occurs within the Yarmouth sub-region there is little overlap with licence areas, with the focus being to the north around The Would, Winterton Ridge and Smith Knoll Ridge, and within the inshore coastal waters as far north as Cromer.

Trawling for shrimp takes place inshore of the licence areas, with little overlap, in two distinct bands – within 5 nm of the coast from Southwold south; and within 3 nm of the coast from Lowestoft north, up to Cromer. Few official data are available for 2009 and 2010.

Netting takes place across the region with favoured areas inshore of the licence areas, off Aldeburgh Napes, Sizewell and Dunwich Banks and within 3-4 nm of the coast. A distinct area was also identified in the northeast of the Anglian region, in the Yarmouth sub-region, but remote from the block of licence areas.

The greatest overlap in the Yarmouth sub-region, for any gear type, is with long-lining and potting activity. Potting activity occurs throughout the region within 12 nm of the coast. However, long lining appears to occur in distinct bands that overlap with the northernmost licence areas. These bands extend northeasterly from Great Yarmouth, through the main dredging areas to the Smith Knoll light vessel; and from Caister Sands in a northeasterly direction through the Winterton Ridge to the Camelot Field.

Long-lining is considered the most sensitive fishing technique to displacement within the Yarmouth sub-zone. This will involve vessels from both the inshore and middle ground fleets. Overlap does occur in the Southwold sub-region, but activity generally occurs inshore of the licence area and prospecting area. Esseen (2005) acknowledges that sensitivity to displacement is increased by the long-lining fleet deploying their gear at right angles to the tide, where dredgers operate parallel to the tidal flow. This can result in a displacement area whose boundaries are defined by the length of a long-line (5-6 km) and the length of a dredge lane (up to 3 km).

The smaller vessels that operate long-lining gear, typical of the inshore fleet, have a limited range and interaction with dredgers will be limited. Long-liners of the middle ground fleet are more likely to be sensitive to impact by displacement. It is also noted that displacement of one gear type results in increased conflict of space for all other gear types in the area.

SIGNIFICANCE STATEMENT: Future extraction with the Anglian MAREA region will not permanently exclude or displace vessels from fishing grounds. They are therefore assessed as having a **high tolerance**, **adaptability** and **recoverability** to the effects of vessel displacement. It is acknowledged that under the maximum extraction scenario there will be a potential for increased conflict for space between different gear types (with particular pressure on the long lining) of the inshore and middle ground fleet.

The boundaries of the MAREA region straddle the 12 nm limit. Within this, fishing vessels are protected from competition with the foreign fleet that is only entitled to fish outside the 12 nm limit (Esseen, 2005). It is, however, considered that the offshore fleet has access to a far greater target area, and has a greater ability to accommodate any displacement pressures. It is also unlikely that any single vessel, from any fleet, relies exclusively on a particular licence area for their fishing ground.

In order to assess the cumulative impact on commercial fishing of vessel displacement, all gear types were taken as a single receptor. The greatest intensity of activity for all gear types occurs in the Southwold sub-region, with the greatest intensity westwards of the current licence and prospecting area and within 8 nm of the coast. A second area of concentration exists in the Yarmouth sub-region, and long-lining and potting show a particular overlap with the most northerly licence areas.

The data suggest that fishing using several gear types co-occurs across the region, and feedback from the consultation process by Plumb (2009) indicates that relationships between the two sectors are generally very good. A recent ALSF report concluded that there is no evidence of dredging having displaced the main areas of fishing activity and that both trends in dredging and fishing effort off the east coast have to a large extent been similar since the mid 1980s (Kenny *et al.*, 2010).

Given the nature of the fleet, characterised by small vessels with limited range and the acknowledged uncertainties, a precautionary approach has been taken in terms of the level of overlap between current activity and licence areas. Under this precautionary approach, the impact of vessel presence has been assessed as being ***Minor Significance*** for the trawling activity of the inshore and middle ground fleet in the Southwold sub-region. It has also been assessed as of ***Minor Significance*** for long lining for both the inshore and middle ground fleet in the Yarmouth sub region and potting across both sub-regions for the inshore and middle ground fleets.

Overall, therefore, the impacts from vessel displacement across both sub-regions and the region for the inner and middle ground fleets are considered to be of ***Minor Significance***.

This assessment has been made subject to a requirement to provide up to date site specific fisheries data for future licences and to continue with current communication channels to identify and address concerns.

UNCERTAINTY: Data collated from formal and informal sources correlate well and provide an overview of the fishing distribution and patterns across the region. Particular reference is made to the use of consultation data which is representative only and use of official statistics to quantify small vessels that are unreported under the current system. However given the highly dynamic and variable nature of the industry, there was insufficient data to accurately map potential areas of interaction and uncertainty is therefore ***High***.

25.2.3 Suspended sediment plume

The suspended plume is not predicted to directly impact upon commercial or recreational fisheries. However, deposition of sediments can impact on sensitive target species by smothering filter feeding shellfish and/or causing avoidance behaviour from these impacted areas. The effects of deposition where tidal current speeds are sufficiently weak to allow the plume to settle are more pronounced. However, the effects of the dredge plume are only temporary and localised.

The ecological implications of sediment plume and increased turbidity, and an assessment on their impact on fish and shellfish have been considered within Chapter 21. This assessment has been taken into consideration when assessing indirect impacts on the fishing sector. No potential ecological impacts were identified in Chapter 21.

SIGNIFICANCE STATEMENT: Overall the impacts of increased suspended sediment on fisheries receptors are assessed as being ***Not Significant*** across both sub regions.

The cumulative impact on commercial and recreational fishing sector due to suspended sediment at the regional scale is considered ***Not Significant***.

UNCERTAINTY: Data collated from formal and informal sources appear to correlate well and provide an overview of the fishing distribution and patterns across the region. This assessment acknowledges that there is some uncertainty related to any ecological impact of sediment plumes on target species, and the exact locations of mobile fish receptors. The overall uncertainty for this assessment is considered ***Moderate***.

25.2.4 Fine sand dispersion

Impacts from fine sand dispersion were identified as part of a consultation exercise undertaken by Esseen (2005), which included reference to feedback from fishermen that wrecks in the vicinity of dredge areas are covered in silt and therefore are not attracting fish. It is acknowledged however, that no other evidence exists for this occurrence (Esseen, 2005). Esseen also reports that there is a suggestion that seabed type has changed from stable mixed sediment to more mobile sediment of finer particles and this mobile sediment is resulting in certain gear types, in particular long lines becoming buried.

Chapter 8 confirms that the present distribution of seabed sediments and bedforms in the MAREA region is a reflection of past and present sediment supply, sedimentary characteristics, and the contemporary action of waves, tides, wind and storm surges in the region.

The present distribution of seabed sediments suggests that tidal and wave processes are strong enough to mobilise and erode finer grained sediments (such as muds and fine sands), which are not as prevalent as the other (coarser) sediment types in the MAREA region (HR Wallingford *et al.*, 2002).

There is little evidence from historical or recent studies to suggest that fine sand is liberated by the dredging process to the extent that impacts on fishing gear would arise.

The potential for indirect impact on fish ecology was assessed in Chapter 21, in particular, changes to critical habitats such as spawning grounds for herring. Impacts on herring spawning were considered of minor significance given their requirement for clean gravel substrate and that their grounds overlap to the west of the main Yarmouth block with the footprints for fine sand dispersion.

SIGNIFICANCE STATEMENT: No evidence has been found to justify concerns that sediment type has changed to a more mobile sediment type as a result of dredging activity. Overall the direct effects of fine sand dispersion are considered to be ***Not Significant*** to fishing gear across both sub-regions.

The cumulative impact on the commercial and recreational fishing sector due to cumulative fine sand dispersion at the regional scale is considered to be ***Not Significant***.

UNCERTAINTY: The modelled data provide a high level of certainty in the spatial scale of fine sand dispersion footprints and recent surveys (both geophysical and benthic) provide an overview of sediment type across the region, therefore uncertainty is considered low.

There is moderate uncertainty for ecological impacts. For herring that spawn directly onto a gravel seabed the precautionary approach has been taken to allow for the uncertainties regarding spatial overlap between the effects and receptor. As described in Chapter 21, it is worthy of note that although Coull *et al*. (1998) identify a defined band for herring spawning grounds, new data from Defra do not provide any qualification of this. It is also worth noting that other studies within the region indicate that the presence of suitable habitat is wider, but uncertainties still arise over use.

25.3 CONCLUSIONS

The Anglian offshore region involves a range of different fishing methods targeting a range of target species. There has been a significant decline in the fishing sector over the past thirty years, with fishermen managing quotas, fish and licensing restrictions against declining fish stocks. Landings have decreased, as have the number of fishing vessels operating from the region's ports (Plumb, 2009). Although aggregate dredging is considered by many fishermen to have contributed to this decline, a recent study has concluded that long term trends are dominated by factors that also govern trends observed across the wider North Sea (Kenny *et al*., 2010).

The receptors across the region can be split into four categories based on vessel range and gear type, namely the inshore, middle ground and offshore fleet; and recreational fishing. It is considered that the offshore fleet is the least sensitive to any potential impacts from aggregate extraction in the region, given their range is extensive and use of the areas that overlap with aggregate dredging footprints are opportunistic in nature.

Both the inshore and middle ground fleets employ small vessels that rely on regional ports. They are therefore more sensitive to any potential impacts.

The potential for impact on the recreational fishing sector has proven more difficult to assess given the lack of any published information or available official data for the region.

25.3.1 Yarmouth sub-regional impacts

The sub-regional cumulative impact assessment for the Yarmouth sub region is assessed overall as being ***Not Significant***. Exceptions are for the impacts of vessel displacement on long lining and potting for the inshore and middle ground fleets. For these, displacement would result in smaller vessels having to extend their range further offshore in line with preferred areas. Potential impacts for these gear types are considered to be of ***Minor Significance*** for the Yarmouth sub-region.

25.3.2 Southwold sub-regional impacts

The sub-regional cumulative impact assessment for the Southwold sub region is assessed overall as being ***Not Significant***. Exceptions arise for vessel displacement for trawling and potting activity, for the inshore and middle ground fleets, both of which are assessed as being of ***Minor Significance***.

25.3.3 Regional impacts

Initially the effects of seabed removal, vessel displacement, suspended sediment and fine sand dispersion were screened in for assessment. However, based on the regional cumulative impact assessment, all effects were considered to be ***Not Significant*** for all gear types across all fleets at a regional scale.

Commercial and recreational fishing and aggregate dredging have co-existed in the region for decades. The aggregate companies that operate within the region have a long history of good communication with the fishing sector providing a forum for all issues to be discussed and addressed.

Over the last thirty years, the fishing sector has experienced an overall decline and despite some representatives from the fishing sector attributing this to dredging, it is considered that the long term trends are intrinsically linked with those governing the wider North Sea. Recent ALSF reports (Kenny *et al.,* 2010 and Vanstaen *et al.,* 2010) confirm this view and highlight only anecdotal evidence of the impact of aggregate extraction on the displacement of fishing activities. Studies in the Eastern English Channel, where the introduction of aggregate extraction provided an opportunity to compare fishing patterns before and after aggregate activity concluded that there was no evidence of any reduction of activity found. Where locally reduced activity was observed, this was considered minor compared to the larger variations in the wider area (Vanstaen *et al*., 2010). Studies found no evidence that dredging had displaced the main areas of fishing activity and that both trends in dredging and fishing effort off the east coast have to a large extent been similar since the mid 1980s.

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Table 25:2 **CUMULATIVE IMPACT ASSESSMENT FOR COMMERCIAL FISHERIES, SUB-REGION YARMOUTH**

EFFECT	SENSITIVE RECEPTOR			
	Inshore Fleet	*Middle ground fleet*	*Offshore fleet*	*Recreational fishing*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** Medium, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Interaction with most westerly licences Limited overlap with trawling (most sensitive gear type to direct impacts). Greatest overlap with Herring spawning ground overlaps with westerly licences (potential ecological impact – *see Chapter 21*) Uncertainties in validity of data are acknowledged given majority of vessels under 10 m	**T:** High, **A:** Medium; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap with trawling (most sensitive gear type to direct impacts) Uncertainties in validity of data are acknowledged given majority of vessels under 10 m	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap **NB:** No official statistics to confirm spatial extent so high uncertainties in assessment for receptor as a whole
	Not significant**	**Not significant****	**Not significant****	**Not significant***
VESSEL PRESENCE *(Effect magnitude = Low)*	**T:** Low, **A:** Low; **R:** Medium **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting, however any displacement may impact on all sectors **NB:** Small vessels sensitive to displacement from traditional grounds and any displacement would require greater range. Industry standard ensure good communication channels are established across region	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting , displacement would require greater range Mitigation in place with good communication channels available across region	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet Least sensitive fleet for displacement for all gear types	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap, dredger presence is temporary and does not overlap with any known sites targeted by recreational or charter fishermen
	Minor Significance**	**Minor Significance****	**Not significant****	**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting, displacement would require greater range	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap
	Not significant**	**Not significant****	**Not significant****	**Not significant***
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High (*all fleets*) **T:** Medium, **A:** Medium; **R:** Medium (*potting activity*) **Value:** Commercial fleet **Spatial overlap:** Likely overlap with effects and receptor some overlap with potting activity which is considered to be more sensitive than other activities given presence of pots on seabed for period of time. **NB:** Potential ecological impact on herring spawning – *see Chapter 21*	**T:** High, **A:** High; **R:** High (*all fleets*) **T:** Medium, **A:** Medium; **R:** Medium (*potting activity*) **Value:** Commercial fleet **Spatial overlap:** Some overlap with potting activity, VMS data indicates low level of activity with focus further south and north around Cromer. **NB:** Potential ecological impact on herring spawning – *see Chapter 21*, which will have a secondary impact on drift netting fleet which target this species but mitigation in place to ensure availability of suitable habitat for herring spawning activity post dredging.	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap
	Not significant**	**Not significant****	**Not significant****	**Not significant***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▩ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

Table 25:3 CUMULATIVE IMPACT ASSESSMENT FOR COMMERCIAL FISHERIES, SUB-REGION SOUTHWOLD

EFFECT	SENSITIVE RECEPTOR			
	Inshore Fleet	*Middle ground fleet*	*Offshore fleet*	*Recreational fishing*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** Medium, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Overlap with trawling (most sensitive gear type to direct impacts), main focus appears to be inshore of licence areas but overlap will occur. Inshore fleet tend to operate within 8nm of the coast, generally inshore of Southwold block.	**T:** High, **A:** Medium; **R:** High **Value:** Commercial fleet **Spatial overlap:** overlap with trawling, VMS and surveillance data suggests main activity is inshore but overlap likely.	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap **NB:** No official statistics to confirm spatial extent so high uncertainties in assessment for receptor as a whole
	Not significant**	**Not significant****	**Not significant****	**Not significant***
VESSEL PRESENCE *(Effect magnitude = Low)*	**T:** Low, **A:** Low; **R:** Medium **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with trawling and potting but any displacement would impact on the inshore fleet as whole as small vessels sensitive to displacement from traditional grounds. Given the presence of only two licence areas within the sub region and temporary nature of the effect, significance rating is precautionary only given sensitive nature of inshore fleet that have a limited range, therefore limited adaptability. **NB:** Good communication channels available across region	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Commercial fleet Spatial overlap: Greatest overlap with trawling, potting Displacement would require greater range. Given the presence of only two licence areas within the sub region and temporary nature of the effect, significance rating is precautionary only. **NB:** Good communication channels exist across region	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet Least sensitive fleet for displacement for all gear types	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap, dredger presence is temporary and does not overlap with any known sites targeted by recreational or charter fishermen.
	Minor Significance**	**Minor Significance****	**Not significant****	**Not significant***
SUSPENDED PLUME *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Greatest overlap with long lining and potting	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap
	Not significant**	**Not significant****	**Not significant****	**Not significant***
FINE SAND DISPERSION *(Effect magnitude = Low)*	**T:** High, **A:** High; **R:** High (*all fleets*) **T:** Medium, **A:** Medium; **R:** Medium (*potting activity*) **Value:** Commercial fleet **Spatial overlap:** Large overlap with potting activity, Inshore fleet tend to operate within 8nm of the coast, generally inshore of Southwold block.	**T:** High, **A:** High; **R:** High (*all fleets*) **T:** Medium, **A:** Medium; **R:** Medium (*potting activity*) **Value:** Commercial fleet **Spatial overlap:** Large overlap with potting activity, in particular the preferred grounds as identified through consultation	**T:** High, **A:** High; **R:** High **Value:** Commercial fleet **Spatial overlap:** Limited overlap and extensive range of fleet	**T:** High, **A:** High; **R:** High **Value:** Social and economic value to region **Spatial overlap:** Limited known overlap
	Not significant**	**Not significant****	**Not significant****	**Not significant***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

26. IMPACT ASSESSMENT: NAVIGATION AND SHIPPING

26.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

A requirement for assessing potential cumulative impacts of aggregate extraction on navigation and shipping is to understand the risks posed by future dredger presence and the potential effects of vessel displacement within the MAREA region. To determine the potential impacts of aggregate extraction activities on navigation and shipping activities it is necessary to:

- Review the necessary literature and commissioned study for the MAREA (see MARICO Marine, 2011, Appendix F) to support the source-pathway-receptor relationship (see Chapter 4) between navigation and the dredging activities described;
- Establish the extent of shipping densities based on MARICO Marine's Automatic Information System (AIS) vessel traffic survey within the MAREA region (see Chapter 15 and Appendix F);
- Identify navigation features that may be particularly sensitive to potential increases in dredging activity; and
- Determine where there are potential present and future interactions between the physical effects of marine aggregate extraction and navigation and shipping activities.

Baseline data on the nature and spatial extent of the MAREA region navigation and shipping activities (Chapter 15) provided the following knowledge basis upon which the assessment was made:

- Shipping density and dredger movements based on AIS information of commercial vessels greater than 300 gross tonnes over a 14 day period in each of the Yarmouth and Southwold sub-regions;
- An overview of satellite and patrol sightings data of fishing activity within the MAREA region from 2005 - 2010;
- Recreational sailing data obtained from the Royal Yachting Association (RYA) and Cruising Association (CA) atlases and consultation with these groups; and
- Navigational features.

26.1.1 Screening effect-receptor interactions

The effects of dredging activities on navigation and shipping within the MAREA region were identified following a screening process.

Step 1 of the impact methodology (see Chapter 3) used the source-pathway-receptor model (Chapter 5) to identify pathways between the physical effects of dredging and navigation and shipping. This initial screening opportunity identified the effects for inclusion in Step 3 of the impact methodology. Following this approach, vessel displacement was identified as the only effect with potential to impact on shipping and navigation. Vessel displacement is an effect of dredger presence, although in the case of this navigation and shipping impact assessment, dredger presence is also considered as an effect as it poses a collision risk to other vessels and navigational features. In summary, the following effect(s) and receptors were screened in/out of the assessment.

Effects screened in:

- Dredger presence and vessel displacement.

Effects screened out:

- Seabed removal;
- Noise and vibration;
- Suspended sediment plume;
- Fine sand dispersion;
- Bathymetric changes;
- Waves;
- Tidal currents; and
- Sediment flux.

Navigation and Shipping receptors screened in:

- Merchant and passenger vessels;
- Commercial fishing vessels;
- Recreation and sailing vessels; and
- Navigational features;

26.1.2 Potential impacts to navigation and shipping

The likely impacts on the navigation and shipping of future dredging activity are centred on displacement of shipping traffic and collision risks and hazards (i.e. associated risks to people, property and business, pollution of the environment, and emergency disposal of cargo) and can be broadly described as follows:

- Potential for collision or contact between aggregate dredgers and other vessels (merchant, commercial fisheries, recreational and passenger) during routine extraction operations;
- Potential for collision between aggregate dredger collision and navigational features during routine extraction operations;
- Other potential hazards associated with dredger grounding, foundering, vessel fire, loss of power, machinery failure, and encounters with unexploded ordnance; and
- Displacement of other vessels due to the presence of aggregate dredgers.

26.2 CUMULATIVE IMPACT ASSESSMENT

It is considered more appropriate to assess the cumulative impacts of dredging activity on navigation and shipping using a regional approach than that typically undertaken by a site-specific EIA. Vessel density is more meaningful when examined from a regional perspective. Large-scale patterns in the spatial distribution of merchant traffic and fishing vessel activity, for example, provide a better indication of receptor 'sensitivity'.

It was also considered appropriate to adopt an approach for this assessment that is based on risk. Consequently, it was undertaken slightly differently to other impact assessments reported on in this MAREA (with the exception of archaeology). On this basis, an increase in dredger presence is likely to increase the risk of collision with navigational features, and other commercial and/or recreational vessels. Consequently, cumulative impacts cannot be directly assessed solely on the basis of receptor 'sensitivity' as defined specifically for all other receptors in this study. Instead, a separate navigation and shipping risk assessment was developed by MARICO Marine (2011; see Appendix F) to support understanding of 'sensitivity'.

Based on a combination of vessel density, ship traffic analyses and risk assessment results, navigation and shipping 'sensitivity' was assigned to determine impact significance in-line with the overall MAREA assessment. The spatial interaction between navigation and shipping receptor 'sensitivity' and individual aggregate licence areas was mapped in GIS (see **Figure 26:1**).

Section 26.2.1 describes the potential impacts of dredger presence and vessel displacement, along with an evaluation of receptor sensitivity for each sub-region. Impact significance is discussed and assigned for regional and sub-regional levels.

26.2.1 Dredger presence and vessel displacement

The presence of dredging vessels has the potential to increase the risk of hazards such as collision or contact with other vessels. Dredger presence also has an influence on vessel density as other vessels may be displaced when avoiding dredgers during operation in licence areas. This could increase the number of potential encounters with other vessels in localised areas of the Anglian Offshore MAREA region, where vessel densities are already greatest.

The Anglian Offshore MAREA region has a relatively moderate shipping density compared with the UK as a whole with the highest densities transecting the Yarmouth sub-region in a north-south and northwest-southeast direction. In addition to ferries, cargo ships, tankers, and fishing vessels operate routinely in and around licence areas across the Anglian Offshore MAREA region (MARICO Marine, 2011).

The MARICO Marine (2011) navigation risk assessment applied a Formal Safety Assessment (FSA) approach to determine risk as a function of the frequency (likelihood) and consequence of particular hazards. Potential hazards associated with dredger operations e.g. dredging in the Anglian Offshore MAREA region and different accident types e.g. collision, contact, fire, etc. involving people, vessels and navigation features were identified by MARICO Marine and a panel of relevant stakeholders (MARICO Marine, 2011). Risk matrices are included in the MARICO Marine (2011) risk assessment in Appendix F, scoring risk for 'most likely' and 'worst credible' scenarios against categories of risk, ranging from 'negligible', 'low', 'as low as reasonably practical', 'significant' or 'high'.

The highest risk hazards identified by MARICO Marine (2011) with the potential to occur during aggregate extraction activities were classified under 'as low risk

		SENSITIVE RECEPTOR				
Sub-region	**Effect**	**Navigational features**	**Merchant and passenger vessels**	**Commercial fishing vessels**	**Recreational and sailing vessels**	**Screening Assessment**
Yarmouth	Seabed removal					● The only effect of aggregate extraction which could potentially impact Navigation and Shipping within the Yarmouth sub-region is dredger presence and vessel displacement*. All other effects have been screened out and not considered further for impact assessment.
	Dredger presence and Vessel displacement*	✔	✔	✔	✔	
	Noise and vibration					
	Suspended plume					
	Fine sand dispersion					
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					
Southwold	Seabed removal					● The only effect of aggregate extraction which could potentially impact Navigation and Shipping within the Southwold sub-region is dredger presence and vessel displacement*. All other effects have been screened out and not considered further for impact assessment.
	Dredger presence and Vessel displacement*	✔	✔	✔	✔	
	Noise and vibration					
	Suspended plume					
	Fine sand dispersion					
	Bathymetry changes					
	Sediment flux					
	Tidal currents					
	Waves					

**Vessel displacement is an effect of dredger presence. In the case of the navigation and shipping impact assessment, dredger presence is also considered as an effect in its own right as it poses a hazard risk to other vessels and navigation features.*

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 26:1 Sub-regional screening assessment. The only effect which potentially impacts shipping and navigation is dredger presence and vessel displacement

as reasonably practical'. A collision between two dredgers was considered the highest risk hazard, as dredgers do on occasion dredge the same licence area concurrently. A significant cause of the risk would be during turning at the end of a dredge run, where it is possible that one vessel could turn into another vessel engaged in dredging. Collisions between dredgers and ferries and tankers were also considered 'as low risk as reasonably practical', while collisions with other vessel types were classed as 'low risk'.

Despite the potentially significant consequences to people and property, the likelihood of all hazards occurring is low and consequently, all hazards were found to be 'negligible' risk, 'low' risk or 'as low risk as reasonably practical' for the Anglian Offshore MAREA region. Owing to the limited navigational features in the region, the more significant risks tend to involve the dredgers and other vessels.

Further to the potential hazards and risks associated with dredger presence, the effect of vessel displacement also has the potential to impact navigation and shipping in the Anglian Offshore MAREA region. In the situation where vessels manoeuvre to pass or avoid a dredger, local vessel distributions may be affected. In areas where vessel density is already high, this can indirectly increase the risk of a collision or other hazards occurring between vessels in the vicinity. It should be noted that all vessel types operating in the Anglian Offshore MAREA region have some effect of vessel displacement.

Mitigation and risk controls are employed by vessels classed under the standards of The International Convention for the Safety of Life at Sea (SOLAS), including aggregate dredgers to reduce risk of a collision, grounding and contact. The main measures are:

- IMO International Regulations for Preventing Collisions at Sea;
- IMO International Convention on Standards of Training, Certification and Watch keeping for Seafarers;
- Technology such as RADAR, AIS, Electronic Charting and Information System, and VHF broadcasts; and
- Vessel Design.

Hazards and risks posed by the effect of dredger presence and the subsequent effect of vessel displacement have the greatest impact potential in areas were vessel traffic is greatest and where key "pinch points" in vessel traffic lanes occur. The highest densities of ship traffic identified in the Anglian Offshore MAREA region are moderate, but distinctive lanes of traffic were seen to exceed 100 to 150 or more ships per 500 x 500 m grid cell during the course of a 14 day AIS traffic survey (MARICO Marine, 2011). This is equivalent to 7 to 12 ships per day. Although navigation risks associated with dredging are considered by MARICO Marine (2011) to be low, and appropriate mitigation and risk measures are employed by dredgers and other vessels, a precautionary approach has been taken to the cumulative impact assessment. The lanes of denser shipping in the Anglian Offshore MAREA region are considered to be of moderate sensitivity to dredger presence and vessel displacement. The spatial interaction between navigation and shipping receptor 'sensitivity' and individual aggregate licence areas is mapped in **Figure 26:1**.

Yarmouth sub-region: The dredging areas in this sub-region are located where shipping traffic lanes are densest, crossing the sub-region from north-south and from northwest-southeast. Dense traffic also occurs at the entrance to the ports of Great Yarmouth and Lowestoft, to and from which dredgers also transit. ***Moderate Sensitivity*** is assigned to this sub-region.

Southwold sub-region: As a whole, this sub-region is located in an area of low shipping density. Consequently, the Navigation and Shipping receptors in this sub-region are considered ***Low Sensitivity***.

SIGNIFICANCE STATEMENT: Relatively dense shipping traffic occurs in the Yarmouth sub-region. However, the effects of dredger presence and vessel displacement are localised and effect-receptor interactions will be relatively infrequent. Further, standard mitigation and risk management practices mean the cumulative impacts on Navigation and Shipping in this sub-region are considered to be of ***Minor Significance***.

Given the low shipping densities in the Southwold sub-region, the cumulative impacts on Navigation and Shipping in this sub-region are considered to be ***Not Significant***.

The cumulative impact of dredger presence and vessel displacement on Navigation and Shipping at the regional scale is considered to be of ***Minor Significance***.

26.3 CONCLUSIONS

From a regional perspective, the Anglian Offshore MAREA region is characterised by relatively moderate shipping densities, comprising cargo vessels, tankers, ferries, fishing vessels and dredgers operating in the region or en route along the coast, to the region's ports of Great Yarmouth and Lowestoft, and to the near continent.

The aggregate extraction areas within the Yarmouth sub-region are typically located within or adjacent to moderate shipping densities, primarily due to the shipping lanes which pass north-south and northeast-southwest (MARICO Marine, 2011). The Southwold sub-region is located in an area of significantly lower shipping densities located away from the main shipping lanes.

The MARICO Marine (2011) navigation risk analysis demonstrates that potential hazards posed by dredger presence in the Anglian Offshore MAREA region are low risk. Vessel displacement is also considered relative to ship density, although standard mitigation and risk management practices minimise potential cumulative impacts on Navigation and Shipping.

The assigned impact significance rankings show dredger presence and vessel displacement to be of ***Minor Significance*** in the Yarmouth sub-region and ***Not Significant*** in the Southwold sub-region. As a result, regional significance is considered to be of ***Minor Significance***.

Based on the traffic levels and risks in the Anglian Offshore MAREA region, the cumulative impact from future dredging is considered to be largely similar to current traffic levels and collision risk. Moreover, any new dredge areas will be marked on charts and are in close proximity to existing licence areas.

A number of aggregate extraction areas within the Yarmouth sub-region coincided with the densest lanes of shipping traffic, deemed to be of moderate sensitivity. These areas were:

- 212;
- 228;
- 240;
- 242;
- 251;
- 254;
- 296;
- 319; and
- 401/2.

REFERENCE

MARICO Marine (2011). AODA Navigation Risk Assessment in support of a Regional Environmental Assessment. Report No. 10UK718, March 2011.

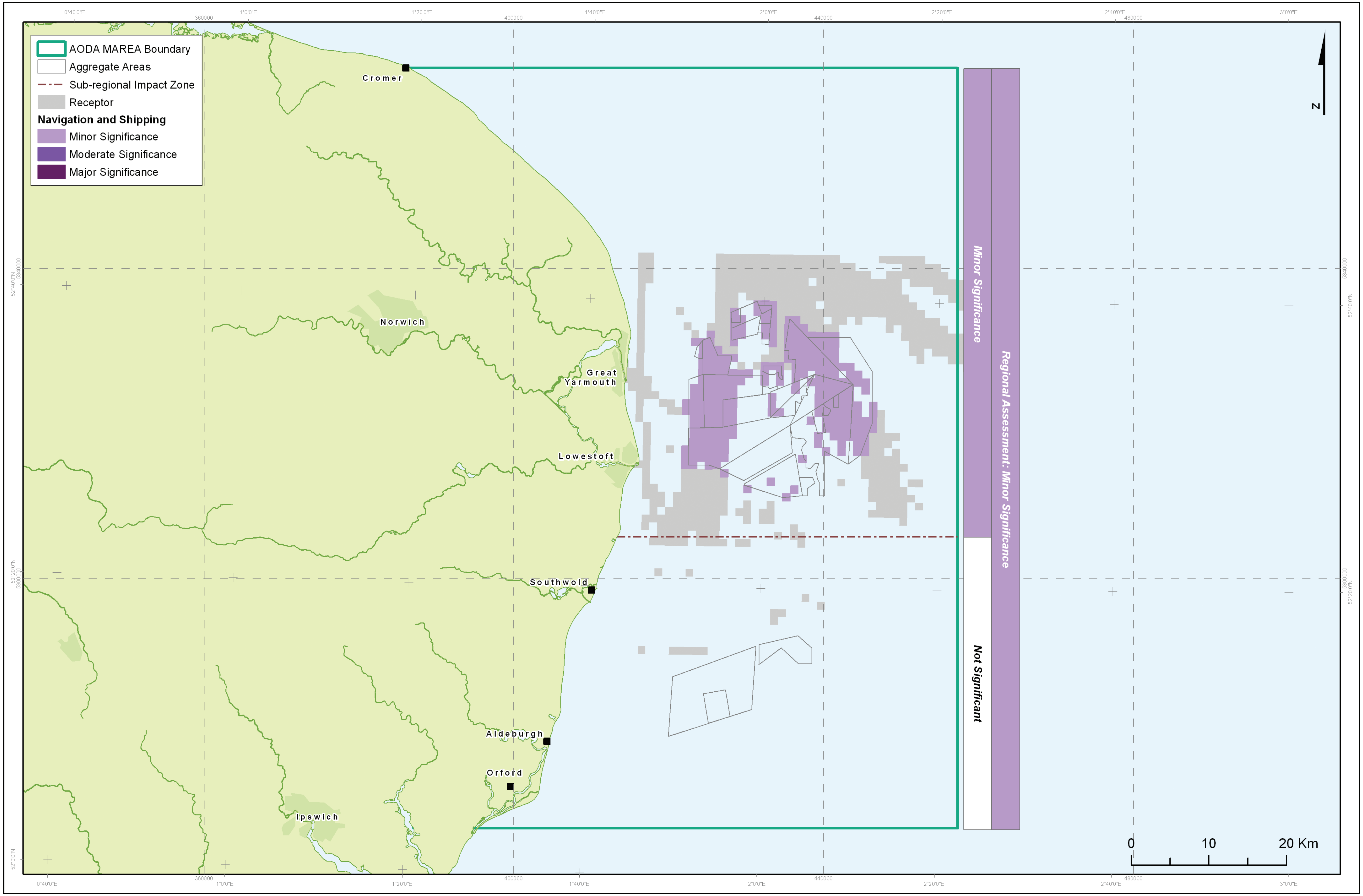

Figure 26:1 Impact significance (sub-regional and regional) of dredger presence and vessel displacement on navigation and other shipping in the Anglian Offshore MAREA region during aggregate extraction activities

27. IMPACT ASSESSMENT: INFRASTRUCTURE AND OTHER MARINE USERS

27.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

Assessing the potential cumulative regional and sub-regional impacts of aggregate extraction on the infrastructure and other marine users in the Anglian offshore MAREA region, requires knowledge of the types of infrastructure and key activities occurring within the region (see Baseline Chapter 16). The locations and spatial extent of a variety of infrastructure and areas utilised for recreational activities within the MAREA region were mapped using data obtained directly from operators, supply companies, research organisations, and existing literature. The importance and sensitivity of infrastructure and activities were identified and instances of existing and potential future conflicts between these receptors and dredging activities were determined.

Much of the region's infrastructure is well established, documented and spatially defined. Infrastructure is concentrated close to the coast and throughout the region. The following key sensitive receptors were identified in the baseline:

- Oil and gas infrastructure such as exploration wells and land based oil fields and refineries;
- Renewable energy (offshore wind farm)and associated infrastructure licensed under Round 1;
- Cables and pipelines, including active and out-of-service telecommunication cables, pipelines and waste water outflows;
- Open and closed dredge spoil disposal sites, military disposal sites and historical disposal sites used for the dispersion of liquid industrial waste;
- Major commercial ports, harbours, marinas and associated maintained channels;
- Recreational sailing activities and facilities such as RYA sailing areas, racing areas, cruising routes, marinas, clubs and training centres;
- Diving activities based around popular recreational dive sites and Seasearch sites;
- Coastal tourism and recreation based on coastal bathers, visitors and sightseers;
- Coastal defences; and
- Potential developments known to be in the planning system, including port and harbour developments, channel dredge projects and Round 3 zones for offshore wind energy.

Coastal tourism is largely unaffected by aggregate extraction activities given aggregate sites are remote from bathing beaches and the coastline, use existing commercial wharves and have no permanent visual presence. Other recreational activities in the region are predominantly sailing, diving and recreational angling. As is the case throughout UK waters, these activities can occur across the MAREA region throughout the year.

Baseline information and data on the occurrence, nature and spatial extent of infrastructure and activities provided the following knowledge base, upon which the assessment was made:

- The locations and extents of different types of infrastructure in the vicinity of each individual licence area in the MAREA region;
- The current operational status of individual infrastructure; and
- The spatial distribution of other marine users.

The potential impacts of aggregate extraction on commercial and recreational fishing are addressed in Impact Chapter 25, *Commercial and Recreational Fisheries*, while the potential impacts of dredger presence on navigational aspects and sailing activities have been assessed collectively in Chapter 26.

27.2 SCREENING EFFECT-RECEPTOR INTERACTIONS

Using the effect-receptor model presented in the 'Effects Chapter', the following effects of aggregate dredging on infrastructure and other marine user receptors have been identified and either screened in or out of the assessment:

Effects screened in:

The following effects may have a potential impact on the infrastructure and other marine users and interact with some of the receptors:

- Seabed removal;
- Vessel displacement ;
- Noise and vibration;
- Suspended sediment plume;
- Waves;
- Tidal currents; and
- Sediment flux.

Effects screened out:

- Bathymetry; and
- Fine sand dispersion.

Changes to bathymetry and fine sand dispersion were considered to have no direct or indirect effects on infrastructure and other marine user receptors and are therefore not considered further in this impact assessment.

Infrastructure receptors screened in:

- Cables and pipelines;
- Offshore renewables;
- Disposal sites;
- Ports, harbours and maintained channels;
- Diving activities;
- Coastal tourism; and
- Coastal defence.

Infrastructure receptors screened out:

- Oil and gas; and
- Recreational sailing (although the potential impacts of vessel displacement are discussed in Chapter 26).

27.3 POTENTIAL IMPACTS TO INFRASTRUCTURE AND OTHER MARINE USERS

The likely impacts on infrastructure and other marine users from the effects of aggregate extraction can be broadly described as:

- Potential scour and damage to marine infrastructure, including both submarine (e.g. cables and pipelines) and land-based infrastructure (e.g. seawalls and harbours);
- Scour, re-suspension and transport of pollutants and disposed sediments from marine disposal sites; and
- Safety of recreational marine/coastal users (e.g. sailing activities, bathers and divers).

A summary of the effect-receptor interactions which are considered for impact assessment is presented in **Table 27:1**.

27.4 CUMULATIVE IMPACT ASSESSMENT

Infrastructure and other marine user receptors within the MAREA region form an important component of the UK's supply of energy, imports, defence, marine developments and recreational activities. As such, it is necessary to evaluate how any of these key interests may be impacted by present and future aggregate extraction activities.

The following sections present the results of the cumulative impact assessment of the effects of aggregate extraction and include a description of potential impacts on infrastructure/marine user receptors for the region and each sub-region.

27.4.1 Seabed removal

Seabed removal has the potential to impact on fixed seabed infrastructure only where overlap with licence areas occurs. Seabed removal only has a direct subsea effect; therefore no direct interaction with surface activity will arise. Within the region, overlap with seabed receptors occurs within the Yarmouth sub-region with an open disposal site; and within the Southwold sub-region for cables.

Seabed removal has the potential to impact seabed infrastructure e.g. submarine cables, which have the potential to be expensive to repair and can damage dredge gear and cause disruption to international telecommunications (United Kingdom Cable Protection Committee (UKCPC), 2010).

Sub-region	Effect	SENSITIVE RECEPTORS									Screening Assessment
		Oil & Gas	Cables & Pipeline	Disposal Sites	Ports, harbours & maintained channels	Recreational sailing activities & facilities	Diving activities	Coastal tourism and recreation	Coastal defence	Renewable Energy	
Yarmouth	Seabed removal	✗	✗	✔			✗		✗	✗	● Effects from aggregate extraction which can potentially impact infrastructure/other marine users are seabed removal, vessel displacement (discussed in detail in Chapter 26), noise and vibration, suspended sediment plume, sediment flux, tidal currents and waves. ● Receptors which may potentially be impacted by dredging effects are disposal sites, diving activities, recreational sailing, cables and pipelines and renewable energy
	Vessel displacement				✗	✔*	✔			✗	
	Noise and vibration						✔			✗	
	Suspended plume			✔			✔			✗	
	Fine sand dispersion										
	Bathymetry changes										
	Sediment flux	✗	✗	✔	✗		✗	✗	✗	✔	
	Tidal currents	✗	✗	✔	✗			✗	✗	✔	
	Waves	✗	✔	✔	✗			✗	✗	✔	
Southwold	Seabed removal	✗	✔	✗	✗	✗	✗			✗	● Effects from aggregate extraction which can potentially impact infrastructure/other marine users are seabed removal, vessel displacement (discussed in detail in Chapter 26), noise and vibration, suspended sediment plume, sediment flux, tidal currents and waves. ● Receptors which may potentially be impacted by dredging effects are cables and pipelines and renewable energy.
	Vessel displacement				✗	✗*	✗			✗	
	Noise and vibration						✗			✗	
	Suspended plume			✗			✗			✗	
	Fine sand dispersion										
	Bathymetry changes										
	Sediment flux	✗	✗	✗	✗		✗	✗	✗	✔	
	Tidal currents	✗	✔	✗	✗		✗	✗	✗	✔	
	Waves	✗	✔	✗	✗		✗	✗	✗	✔	

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Assessed under Navigation, Chapter 26

Table 27:1 Screening assessment matrix for sub-regions

Seabed removal may also interact with channel maintenance if both activities occur simultaneously over the same area. Current data, however, show no overlap between the maintained channels for either Great Yarmouth or Lowestoft ports and aggregate licence areas.

The siting of seabed infrastructure and maintained channels are licensed activities for which an Environmental Impact Assessment (EIA) is required. Where fixed infrastructure exists, mitigation measures such as exclusion zones will be implemented prior to aggregate licensing. These receptors are also often marked on navigation charts, and impacts from seabed removal are unlikely if shipping/navigation rules and exclusion zones are adhered to.

SIGNIFICANCE STATEMENT: Infrastructure has a **low tolerance**, **low adaptabilit**y and **low recoverability** to the effects of seabed removal. However, the locations and spatial extents of marine infrastructure identified above are clearly defined and marked, and exclusion zones around such infrastructure are implemented. Individual impact significance is provided in **Tables 27:2** and **27:3**.

The potential impact from seabed removal on infrastructure for both sub-regions, and at a regional scale is considered to be ***Not Significant***.

UNCERTAINTY: The locations and spatial extents of marine infrastructure are clearly defined, and the areas of future seabed removal are well known. Uncertainty regarding this assessment is therefore considered to be ***Low***.

Future EIAs should ensure any future developments are considered, in particular in relation to Round 3 offshore wind farm cable routes and/or any changes to maintenance or capital dredge channels.

27.4.2 Vessel Displacement

The presence of a dredging vessel is unlikely to have any impact on existing seabed infrastructure. The possibility of a heavily laden vessel colliding with seabed infrastructure in shallow water was considered as part of this assessment but there is no coincidence of seabed infrastructure and licence areas in shallow waters within the MAREA region.

Dredger presence has the potential, however, to displace other vessels - be they commercial vessels or sailing/pleasure craft. A number of cruising routes identified for recreational use transect the Yarmouth sub-region. These tend to be of light or medium usage and are not fixed, with recreational craft being highly adaptable to changes in route. The effect of vessel displacement is assessed in Chapter 26 Impact Assessment: Navigation and Shipping and is not considered further in this chapter.

The presence of a dredger may impact recreational diving activities, requiring temporary avoidance by divers of sites that would otherwise be visited. There are dive sites within the region; however known sites are located away from the current licence areas with the majority located within inshore waters north of the licence areas in the Yarmouth sub-region. No dive sites have been identified that overlap with licence areas. No dive sites have been identified in the Southwold sub-region.

SIGNIFICANCE STATEMENT: Diving activities are considered to have **high adaptability**, **high tolerance**, and **high recoverability** to vessel displacement. They are therefore considered to have a **Low Sensitivity** to this effect for both the sub-regions and at the region scale. Individual impact significance is provided in **Tables 27:2** and **27:3**.

Given the lack of overlap between known dive sites and aggregate licences and the low intensity usage for pleasure craft, the temporary nature of any exclusion, the available mitigation measures; and the anecdotal evidence that suggests dredging activities do not affect divers or sailors, the impact of vessel displacement at a sub-regional and regional level is considered to be ***Not Significant***.

UNCERTAINTY: There are no data available which detail the frequency of dives on sites located within the region, however known dive sites are located away from the current licence areas. The effect of vessel displacement on diving is is assessed as being of ***Low*** uncertainty.

27.4.3 Noise and vibration

Robinson *et al.* (2011) undertook a study of a number of UK dredger vessels to determine relative noise levels and concluded that source levels at frequencies below 500 Hz are generally in line with those expected from a cargo ship travelling at modest speed (between 8 and 16 knots). Levels above 1 kHz showed elevated levels of broadband noise generated by the aggregate dredging process itself, with coarse gravel generating higher noise levels than sand. When placed in context, dredgers are basically 'noisy ships' but substantially quieter in terms of acoustic energy output than other sources such as seismic arrays and marine piling.

The results from the study showed noise spectral density level as a function of frequency in units of dB re 1 μPa2/Hz. For the East coast region, given the target resource is primarily sand, the ambient noise levels were lower than for other regions surveyed (South coast and EEC). Other environmental factors (e.g. water depth, currents, bathymetry and substrate) can all affect sound attenuation and influence the distance over which noise propagates, before it is considered insignificant relative to background noise (Richardson ***et al.***, 1995).

Noise effects will be generated by vessels transiting to and from the site and from dredgers in full operation. Transit is considered to be no different to any merchant vessel transiting the region from the ports of Great Yarmouth and Lowestoft and through the region. Consequently, noise effects are only perceived to be significant when the dredger is in operation on site. Noise and vibration from dredging activities have no impact on marine infrastructure, sailing activities or onshore activities, but do have the potential to impact on divers in close proximity to the dredger.

It has been shown that the hearing threshold of the human ear is less sensitive in water than in air (Parvin *et al.*, 1994) and is thus able to tolerate a higher level of underwater noise (Health & Safety Executive, 2009). Furthermore, divers produce a high level of breathing noise generated by gas flow through the regulator demand valve and so self-generated breathing noise is a major contributor to divers' noise exposure. As a consequence, the total noise dose received by divers can potentially be very high (Health and Safety Executive, 2009). While the significance of noise exposure levels from dredging will be site-specific, it is assumed for this assessment that the most significant impacts of noise will be reduced beyond 500 m of the dredger. Beyond this distance, noise levels may be detectable but are likely to be close to background levels and relatively insignificant in relation to other nearby sources of shipping noise.

Data derived from Seasearch and regional consultation indicated a very low intensity of diving activity with little or no overlap with the licence areas of either sub area and it is therefore unlikely that diving and dredging activities will overlap.

SIGNIFICANCE STATEMENT: Diving activities are considered to have **high adaptability**, **high tolerance**, and **high recoverability** to noise and vibration generated by dredging vessels and divers/diving activities are therefore considered to have **Low Sensitivity** to this effect. The impact of noise and vibration due to dredging activities for the Yarmouth sub-region is considered to be Not Significant. No dive sites have been identified in the Southwold sub-region. The impact of noise and vibration on diving activities at a regional scale is also considered to be ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27:3**.

UNCERTAINTY: Scientific evidence regarding underwater noise and diving activities is well established, and therefore uncertainty is considered ***Low***. Uncertainties do arise regarding any informal use of the region for diving but there is reasonable confidence, given the low visibility within the region, to assign significance.

27.4.4 Suspended sediment plumes

Suspended sediment concentrations and the possible settling of fine sediment from sediment plumes do not have any known implications for marine infrastructure, however it may have effects on other marine activities and users.

Disposal Sites

Where plumes from aggregate dredging occur in the vicinity of operational dredge spoil disposal sites, there is the potential for interaction between aggregate-derived plumes and plumes from the disposal. The likelihood of this interaction having an impact is small, but the relationship between suspended sediment plumes and the plumes generated from disposal sites has not been modelled or documented. In the absence of absolute certainty, all overlaps between the disposal sites and plumes of any concentration are considered.

A number of disposal sites are present within the region. It is considered that only sites classified as open, or open but not currently in use, are likely to be impacted. Direct overlap with licence areas occurs for the open site HU175, within Licence Area 401/2 in the Yarmouth sub-region. HU175 is used to dispose of unwanted dredge material when the aggregate is contaminated with excess fine sediment. In addition, two sites (HU150 and HU160) are located inshore.

SIGNIFICANCE STATEMENT: Although suspended sediment plumes may potentially affect the concentration and dispersion of plumes from disposal activities, disposal sites/activities are considered to have **high adaptability**, **high tolerance**, and **high recoverability** to suspended sediment plumes, and are therefore considered to have ***Low*** sensitivity to this effect.

Suspended sediment concentrations as high as 800 mg/l have been measured at disposal sites (Partrac, 2006). Maximum modelled increases in sediment plumes are unlikely to affect existing, elevated background suspended sediment concentrations at disposal sites. The impact of suspended plumes at sites that have naturally high SSCs is considered ***Not Significant*** within both sub-regions and at the regional scale.

UNCERTAINTY: It is known that disposal sites have unusually high background suspended sediment concentrations, since fine sediments are often deposited at these locations. Plumes from dredging activities have much lower concentrations and occur only intermittently. Therefore uncertainty regarding the impact of suspended sediment plumes on disposal sites is considered ***Low***.

Diving

In addition to the effect of sediment plumes on disposal areas, an increase in suspended sediments may also reduce visibility, site desirability and safety for recreational and commercial divers, although the increase in sediment concentrations required to have an impact is not known.

SIGNIFICANCE STATEMENT: Divers/diving activities are considered to have **high adaptability**, **medium tolerance** and **high recoverability** to suspended sediment plumes, and are therefore considered to have ***Low*** sensitivity to this effect. Diving activity is limited to the Yarmouth sub-region and has little or no overlap with current licence areas. Given the naturally high levels of suspended sediment that exist and the temporary nature of any additional plume generated by aggregate extraction, the impact of suspended sediment plumes at a sub-regional and regional scale is considered to be ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27:3**.

UNCERTAINTY: Since the suspended sediment plume (concentrations and footprints) has been modelled uncertainty is considered ***Low***. Uncertainties do arise regarding any informal use of the region for diving but there is reasonable confidence, given the low visibility within the region, to assign significance.

27.4.5 Tidal currents and sediment flux

These effects are inextricably linked and were considered for the same potential impacts. However, the rates of change of each are not directly proportional. Sediment flux is a function of tidal current speeds and sediment grain size; therefore the footprints of both effects are not identical, and not all receptors may be impacted by both effects.

For purposes of this assessment, only increased tidal current speeds and sediment flux were considered. Decreases in these effects were considered beneficial and therefore not assessed for impacts.

A reduction in tidal current speeds/sediment flux may have beneficial effects on marine infrastructure via deposition of materials, thus making them less susceptible to high energy forces (e.g. storms).

The main potential impact of significant changes in peak tidal current speeds and sediment flux within the region are on disposal sites, current and/or future renewable energy installations which may be subject to scour or deposition of existing or introduced material.

There are no direct overlaps of changes in sediment flux with renewable energy receptors within either of the MAREA sub-zones. A small potential increase in sediment flux of 500-1000 kg/m/tide occurs in the vicinity of the Scroby Sands wind farm site but does not overlap with the boundaries of this site. Applying a precautionary approach, however, this is included within the assessment.

There are no overlaps of increases in tidal current with identified renewable energy developments in either sub-zone. There is a small overlap of increased peak spring tidal current (5-10 % increase), from Licence Area 430 with the boundary of the East Anglia Round 3 zone. However this is approximately 18 km distant from the known boundary of the first East Anglia One development. The level of overlap between increases in tidal current and the wider zone available for development is very small, being less than 1% of the total zone.

SIGNIFICANCE STATEMENT: Disposal sites are considered to have **low** adaptability to small changes in tidal currents/sediment flux, however they have **high** tolerance. They are considered to have **low** sensitivity to these effects. The impact on these receptors at a regional and sub-regional level is considered ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27:3**.

Renewable energy installations are considered to have **low** adaptability to small changes in tidal currents/sediment flux, however they have **high** tolerance. They are considered to have **low** sensitivity to these effects. The impact on these receptors at a regional and sub-regional level is considered ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27.3**.

UNCERTAINTY: While the precise location and layout of potential installations within the East Anglian Round 3 zone is currently unknown, the overall boundaries of the zone are well defined. The modelled boundaries are well defined and there are no overlaps between the effects and known site for the East Anglia One development. The uncertainty in this assessment is therefore considered to be ***Low***.

27.4.6 Waves

An increase or decrease in wave energy (and orbital velocities) over the long-term has the potential to increase/decrease turbulence in the lee of marine infrastructure such as cables, pipelines and outflows (Whitehouse, 1998; Sumer and Fredsoe, 2002) and may cause localised scour, the undermining of seabed structures or the exposure of buried cables to external stresses. The recommended burial depths for marine cables range from approximately 0.9 to 1.5 m, although cables laid prior to the 1990s may have been buried at shallower depths of 0.6 m (Allan, 1998). The design of seabed structures will vary, but some variability in hydrodynamic processes and safety factors will have been considered in their design and small changes in the wave climate affecting them are not likely to be significant. Where obvious interactions occur, these may be assessed at site-specific EIA level.

Waves, whether occurring as a single storm or as a change in the long-term magnitude of frequent wave conditions, are the primary driver of cross-shore sediment transport (Komar, 1998). An increase in waves (and peak tidal currents) near the coast may exacerbate the seaward movement of sediment, resulting in increased coastal erosion. The seaward limit beyond which shoaling storm waves cease to have a significant effect on sediment transport/shore profile change is determined by a 'depth of closure' (DoC) (Hallermeier, 1979). This is dependent upon the incident wave height, wave period, and sediment size and density. Dredging occurring seaward of the DoC is unlikely to have an effect, while dredging operations occurring within the depth of closure should be assessed more closely at EIA level. A more active wave climate can also result in the damaging or overtopping of coastal defences while a less active nearshore wave climate can result in sediment accretion and preservation of beaches and coastal defences.

For the purpose of this assessment only wave height increases are considered as a potential impact.

Cables and pipelines/disposal sites

There is an overlap between the footprint of a 2-5 % increase in the 200 year significant wave height with the positions of active cables within both the Yarmouth and Southwold sub-regions.

In addition both increases of 2-5 % and decreases of 2-5 % in the 200 year significant wave height are modelled to occur in the immediate vicinity of the HU175 disposal site in the Yarmouth sub-region, although there is no direct overlap of these changes with the disposal site. Assuming the precautionary approach, however, it is included in assessment. There is no overlap of changing wave heights with any other disposal sites.

It is acknowledged that marine disposal sites are commonly located in places of relatively deep water, where small changes in hydrodynamic conditions are unlikely to affect the integrity of disposed material (HR Wallingford 2011, Appendix A).

SIGNIFICANCE STATEMENT: Marine cables, which are specifically built to withstand high-storm conditions, are considered to have **high adaptability**, **high tolerance**, and **high recoverability** to a small increase in wave heights; therefore they are considered to have low sensitivity to this effect. The impact of a small increase in 200 year wave heights (< 5 %) at a regional and sub-regional level is considered ***Not Significant*** for marine cables.

Disposal sites are considered to have high adaptability, tolerance and recoverability to the a maximum 5 % increase in the 200 year significant wave heights and are therefore considered to have a low sensitivity to this effect. The impact of wave height changes on disposal sites, at a sub-regional and regional scale is considered ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27:3**.

UNCERTAINTY: Wave height modelling was conducted using a state-of-the-art programme that has been field validated and is widely accepted by the scientific/engineering/modelling community. The location of cables and disposal sites is well known. Uncertainty in this assessment is therefore considered ***Low***.

Renewable Energy

There are no direct overlaps of changes in wave height with renewable energy receptors within the Yarmouth sub-zone. Small potential increases in the 200 year significant wave height on 2-5 % occur close to the boundaries of the Scroby Sands Round 1 site and the East Anglia Round 3 site. Applying a precautionary approach, however, these are included within the assessment.

Within the Southwold sub-region there are small overlaps of both 2-5 % increases and 2-5 % decreases in the 200 year significant wave height from Licence Area 430, with the boundary of the East Anglia Round 3 zone. However these are approximately 18 km distant from the known boundary of the first East Anglia One development. The level of overlap between increases in tidal current and the wider zone available for development is very small, being less than 1% of the total zone.

SIGNIFICANCE STATEMENT: Renewable energy installations are considered to have a **high** tolerance of small changes in significant wave height. They are therefore considered to have a low sensitivity to these effects. The impact on these receptors at a regional and sub-regional level is considered ***Not Significant***. Individual impact significance is provided in **Tables 27:2** and **27:3**.

UNCERTAINTY: While the precise location and layout of potential future installations within the East Anglian Round 3 zone is currently unknown, the overall boundaries of the zone and the Scroby Sands development are well defined. The modelled effects are well defined and the uncertainty in the assessment is considered ***Low***.

27.2 CONCLUSIONS

Although the MAREA region is comprised of potentially numerous marine infrastructure/marine user effect-receptor interactions, it can be concluded that none of the effects from aggregate extraction will have any significant impact on any of the receptors.

It would be prudent to examine any site-specific interactions of aggregate licence areas in close proximity to (both open and closed) disposal sites at EIA level. The location of proposed wind turbines for future developments of the East Anglia One zone should also be assessed carefully, principally to avoid any potential ship to ship collisions.

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Table 27:2 **SUB-REGION YARMOUTH – CUMULATIVE IMPACT ASSESSMENT**

EFFECT	SENSITIVE RECEPTOR								
	Oil and Gas	*Cables and pipelines*	*Disposal sites*	*Ports, harbours and maintained channels*	*Recreational sailing activities and facilities*	*Diving activities*	*Coastal tourism and recreation*	*Coastal defence*	*Renewable energy*
SEABED REMOVAL *(Effect magnitude = Medium)*			**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for marine infrastructure, coastal defence and coastal management. **Spatial overlap:** Some overlap exists with known/licenced disposal sites principal applied for cumulative effects						
			Not significant* **						
VESSEL DISPLACEMENT *(Effect magnitude = Low)*					■ See chapter 26	**T:** High, **A:** High; **R:** High **Value:** Socio-economic value for regional tourism and leisure sector **Spatial overlap:** No overlap with known sites, low intensity usage of pleasure craft so unlikely for casual use.			
						Not significant* **			
NOISE AND VIBRATION *(Effect magnitude = Low)*						**T:** High, **A:** High; **R:** High **Value:** Socio-economic value for regional tourism and leisure sector **Spatial overlap:** no overlap with known sites.			
						Not significant* **			
SUSPENDED PLUME *(Effect magnitude = Low)*			**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for marine infrastructure, coastal defence and coastal management. **Spatial overlap:** Some overlap exists with known/licenced disposal sites			**T:** High, **A:** High; **R:** High **Value:** Socio-economic value for regional tourism and leisure sector **Spatial overlap:** no overlap with known sites.			
			Not significant* **			**Not significant*** **			
SEDIMENT FLUX *(Effect magnitude = Medium)*			**T:** High, **A:** Low; **R:** High **Value:** Socio-economic importance for marine infrastructure, coastal defence and coastal management. **Spatial overlap:** Some overlap exists with known/licenced disposal sites						**T:** High, **A:** Low; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined although uncertainty noted for actual location of turbines
			Not significant* **						**Not significant*** **
TIDAL CURRENTS *(Effect magnitude = Medium)*			**T:** High, **A:** Low; **R:** High **Value:** Socio-economic importance for marine infrastructure, coastal defence and coastal management. **Spatial overlap:** Some overlap exists with known/licenced disposal sites						**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined
			Not significant* **						**Not significant*** **
WAVES *(Effect magnitude = Low)*		**T:** High, **A:** High; **R:** High **Value:** Socio-economic value to water, energy and communications sector when in active use. **Spatial overlap:** overlap with the positions of active cables.	**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for marine infrastructure, coastal defence and coastal management. **Spatial overlap:** No overlap of changing wave heights with any disposal site, of note that both increases of 2-5% and decreases of 2-5% in the 200 year significant wave height modelled to occur in vicinity of HU175 site but no overlap of changes with the disposal site.						**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined
		Not significant* **	**Not significant*** **						**Not significant*** **

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant ▨ Minor significance ▨ Moderate significance ■ Major significance **Uncertainty:** *High **Moderate *** Low

Summary of cumulative impact assessments for sub-region Yarmouth. Grey shading denotes effect and/or receptor screened out of assessment

Table 27:3 SUB-REGION SOUTHWOLD – CUMULATIVE IMPACT ASSESSMENT

EFFECT	SENSITIVE RECEPTOR								
	Oil and Gas	*Cables and pipelines*	*Disposal sites*	*Ports, harbours and maintained channels*	*Recreational sailing activities and facilities*	*Diving activities*	*Coastal tourism and recreation*	*Coastal defence*	*Renewable energy*
SEABED REMOVAL *(Effect magnitude = Medium)*		**T:** Low, **A:** Low; **R:** Low **Value:** Socio-economic importance to water, energy and communications sector when in active use. **Spatial overlap:** direct overlap with Area 496. **NB:** Locations clearly defined and in practice exclusion zones agreed with operators will mitigate any impacts. **Not significant*****							
VESSEL DISPLACEMENT *(Effect magnitude = Low)*					■ See chapter 26				
NOISE AND VIBRATION *(Effect magnitude = Low)*									
SUSPENDED PLUME *(Effect magnitude = Low)*									
SEDIMENT FLUX *(Effect magnitude = Medium)*									**T:** High, **A:** Low; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined although uncertainty noted for actual location of turbines in Round 3 sites **Not significant*****
TIDAL CURRENTS *(Effect magnitude = Medium)*		**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance to water, energy and communications sector when in active use. **Spatial overlap:** overlap with the positions of active cables. **Not significant*****							**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined **Not significant*****
WAVES *(Effect magnitude = Low)*		**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance to water, energy and communications sector when in active use. **Spatial overlap:** overlap with the positions of active cables. **Not significant*****							**T:** High, **A:** High; **R:** High **Value:** Socio-economic importance for energy sector **Spatial overlap:** no overlap with Zones defined **Not significant*****

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant 🟪 Minor significance 🟪 Moderate significance 🟪 Major significance **Uncertainty:** *High **Moderate *** Low

Summary of cumulative impact assessments for sub-region Southwold. Grey shading denotes effect and/or receptor screened out of assessment

28. IMPACT ASSESSMENT: ARCHAEOLOGY

28.1 BASIS FOR CUMULATIVE IMPACT ASSESSMENT

In order to assess the potential cumulative and in-combination impacts of aggregate extraction on the archaeological record a regional understanding of that record is necessary (see Baseline Chapter 17). The archaeological baseline report for the Anglian Offshore MAREA Region therefore provided:

- A review of known archaeological sites and materials; and
- An assessment of the potential for currently unknown and unrecorded archaeological sites and material in the region.

Baseline information on the nature and spatial distribution of archaeological sites and materials, integrated with geotechnical and geophysical datasets combined into the following knowledge base, upon which the impact assessment was made:

- The distribution of known maritime and aviation archaeology sites and material within the MAREA region;
- Evidence for the existence of, and indicative distribution of, recorded shipping and aircraft casualties;
- An indication of the potential for currently unknown maritime and aviation archaeology sites and material to be present virtually anywhere in the MAREA region; and
- Evidence of the high potential for submerged prehistoric archaeological sites and materials in the MAREA region.

The baseline highlighted the specific sensitivities of archaeological receptors, which are central to assessing the impacts of aggregate dredging on the archaeological record. These are discussed (where appropriate) later in this chapter.

28.1.1 Screening assessment

A screening of effects identified those most likely to impact the archaeological record, allowing better targeting of the archaeological assessment. The initial conceptualisation of the effect-receptor interactions (see source-pathway-receptor model presented in Chapter 4, and Step 1 of the Impact methodology, Chapter 3) identified direct and indirect pathways between the physical effects of dredging and the archaeological record.

A further screening opportunity, undertaken in Step 3 of the impact assessment (see Chapter 3), involved overlaying the effects of future aggregate extraction on the archaeological record in GIS. Where overlap between archaeological receptors and effects occurred, receptors and effects were either screened in or out (**Table 28:1**). Based on this analysis, it was determined that potential impacts to receptors were all within individual licence areas and so all receptors and effects were screened in. The following effects and receptors were screened in for the cumulative impact assessment:

Direct effect (screened in):

- Seabed removal - direct effect on archaeological receptors where the sediments in which they lie are removed or disturbed by dredging.

Indirect effects (screened in):

- Bathymetric changes – the lowering of the seabed across licence areas may affect archaeological receptors beyond the dredging footprint by exposing previously buried material through erosion, making it vulnerable to physical, chemical or biological attack, degradation and loss.
- Sediment flux - as a proxy for seabed erosion/deposition and including the effects of suspended sediment plume and fine sand dispersion, sediment flux has the potential to be either positive or negative for archaeological receptors. Where it results in the burial of sites through sediment deposition it is likely to be positive, but net sediment loss or erosion may expose previously buried archaeological material.

Indirect effects (screened out):

- Dredger presence;
- Noise and vibration; and
- Tidal currents.

Archaeological receptors (screened in):

The baseline identified the following key sensitive receptors within each of the three broad archaeological themes it described. No archaeological receptors were screened-out of the assessment:

- Prehistoric Archaeology - Pleistocene fluvial gravels; estuarine alluvium; peat; and isolated prehistoric finds;
- Maritime Archaeology - known, charted shipwrecks; recorded, uncharted maritime casualties; unknown, uncharted shipwrecks; and isolated maritime finds; and
- Aviation Archaeology - known, charted aircraft wrecks; recorded aircraft losses; and isolated aircraft finds.

28.1.2 Potential impacts to archaeology

The likely impacts on the archaeological record of the effects identified above can be broadly described as follows:

- Damage to and dispersal of *in situ* material, resulting in the disturbance of relationships between structures, artefacts and their surroundings or contexts;
- Loss of artefacts in the volume of aggregate;
- Destabilisation of archaeological sites and deposits through the removal of overlying or adjacent sediments, prompting exposure and leading to instability, erosion or corrosion and decay; and
- Burial of archaeological sites and deposits due to re-deposited sediment, potentially protecting and promoting the favourable preservation of sites.

28.2 CUMULATIVE IMPACT ASSESSMENT

The following sections describe in detail the potential impacts of future dredging effects on the archaeological record, based on the three archaeological themes.

There is a high degree of uncertainty about the presence of archaeological material and it can thus only be assessed using the precautionary principle. For this reason, overall uncertainty in the assessment for archaeology is considered ***High*** for all receptors.

28.2.1 Seabed removal

Archaeological receptors are finite and non-renewable, and each site is unique. The removal of seabed will have a direct impact on these receptors within areas subject to aggregate dredging. The physical process of extracting aggregate will impact any archaeological material that lies within the sediments affected, or that comes into contact with the draghead.

Seabed removal: Prehistoric archaeology

Primary and secondary context prehistoric archaeological material will occur within sediments subject to removal during aggregate extraction (Wenban-Smith, 2002), and is unlikely to be identified prior to or during extraction activities. There is precedent from within the MAREA region (Area 240) (Wessex Archaeology, 2009) for the identification of individual items of prehistoric material during the post-dredge aggregate processing, and these finds have an intrinsic value as indicators of the presence of such material in or on the seabed.

In situ archaeological deposits and finds relating to the submerged prehistory in the MAREA region must be regarded to be of potential national and international importance in understanding the prehistory of the UK, and Europe's earliest human populations.

When assessing submerged prehistoric archaeological potential and impacts in the context of aggregate dredging it is more meaningful to describe the archaeological record in terms of the deposit types in which the archaeological material may be found, rather than according to archaeological periods. For the purposes of this assessment, therefore, submerged prehistoric archaeological receptors have been linked to seabed deposits and broadly categorised as Pleistocene fluvial gravels, estuarine alluvium and peat, with an additional category of isolated prehistoric finds.

Pleistocene fluvial gravels: Pleistocene fluvial gravels, which are the primary target of aggregate dredging, comprise sands and gravels likely to represent river terraces from periods of lowered sea level. Based on finds of Palaeolithic artefacts within material dredged from Area 240 (Wessex Archaeology, 2009) within the MAREA Region these gravels have the potential to contain Palaeolithic archaeological material.

Archaeological material in Pleistocene fluvial gravels is likely to be in both primary and derived, or secondary, contexts. Recent discoveries have shown that even secondary context material has the potential to provide valuable information on patterns of human land use and demography in a field of study which is still little understood and constantly developing.

		SENSITIVE RECEPTORS											
Sub-region	**Effect**	**Pleistocene fluvial gravels**	**Estuarine alluvium**	**Peat**	**Isolated prehistoric finds**	**Known chartered shipwrecks**	**Recorded uncharted maritime casualties**	**Unknown, uncharted shipwrecks**	**Isolated maritime finds**	**Known charted aircraft wrecks**	**Recorded aircraft losses**	**Isolated aircraft finds**	**Screening Assessment**
Yarmouth	Seabed removal	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	● Vessel displacement, and noise and vibration are considered to have no potential impact on archaeological receptors so are screened out and not considered further for Impact Assessment. ● Suspended plume and fine sand dispersion are considered as part of sediment flux, so are screened out as specific, individual effects. ● The likely changes to tidal currents and waves are considered too small to have an impact on archaeological receptors and are screened out for Impact Assessment.
	Vessel displacement												
	Noise and vibration												
	Suspended plume												
	Fine sand dispersion												
	Bathymetry changes	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
	Sediment flux	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
	Tidal currents												
	Waves												
Southwold	Seabed removal	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	● Vessel displacement, and noise and vibration are considered to have no potential impact on archaeological receptors so are screened out and not considered further for Impact Assessment. ● Suspended plume and fine sand dispersion are considered as part of sediment flux, so are screened out as specific, individual effects. ● The likely changes to tidal currents and waves are considered too small to have an impact on archaeological receptors and are screened out for Impact Assessment.
	Vessel displacement												
	Noise and vibration												
	Suspended plume												
	Fine sand dispersion												
	Bathymetry changes	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
	Sediment flux	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
	Tidal currents												
	Waves												

	Screened out: No effect-receptor pathway
✗	Screened out: No overlap of effect-receptor footprints
✔	Screened in: Effect-receptor interaction – take forward to impact assessment

Table 28:1 Screening assessment matrix for sub-regions

Pleistocene fluvial gravels should thus be regarded as a ***high value*** receptor. They are **unable to adapt to, tolerate or recover** from the effects of seabed removal, resulting in a permanent change to the receptor. Due to its non-renewable and finite nature, and as the primary target of aggregate extraction, the receptor is thus ***highly sensitive*** to the effects of seabed removal.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels, across both **sub-regions**, are considered to be of ***High Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels due to cumulative seabed removal at the **regional** scale are also considered to be of ***High Significance***.

Estuarine alluvium: Estuarine alluvium, which can overlie the Pleistocene gravel, is of particular archaeological interest because it appears to relate to the inundation during the Holocene marine transgression of the prehistoric river systems which crossed the southern North Sea. The fluvial processes of the Holocene resulted in the deposition of alluvial sediments within the MAREA region, some of which will have sealed and buried deposits or landscape features in which *in situ* Late Devensian and early Holocene archaeological material may be present. Estuarine alluvia may thus contain both archaeological material and palaeo-environmental data.

Estuarine alluvium should thus be regarded as a ***high value*** receptor which will be **unable to adapt to, tolerate or recover** from the effects of seabed removal, resulting in a permanent change to the receptor. However, alluvial deposits are not targeted by the marine aggregate industry, therefore spatial overlap with effect and receptor is considered to be limited.

SIGNIFICANCE STATEMENT: For aggregate deposits not targeted for dredging the potential overall cumulative impacts on the archaeological record potentially contained within estuarine alluvium, across both **sub-regions**, are considered to be ***Not Significant***.

However, if accidentally impacted this receptor is considered to be of ***High Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within estuarine alluvium due to cumulative seabed removal at the regional scale are also considered to be ***Not Significant*** (*non-targeted*) or ***High Significance*** (*accidentally impacted*).

Peat: Fluvial processes during the Late Devensian and Holocene resulted in the formation of peat deposits. These deposits contain data that can help reconstruct past environments and provide a greater understanding of the geomorphology of the coastline during these periods. Peats may also contain *in situ* archaeological material and palaeo-environmental data.

Peat deposits should thus be regarded as a ***high value*** receptor. Peat deposits will be **unable to adapt to, tolerate or recover** from the effects of seabed removal, resulting in a permanent change to the receptor. Peat deposits are not targeted by the marine aggregate industry, therefore spatial overlap with effect and receptor is considered to be limited.

SIGNIFICANCE STATEMENT: For aggregate deposits not targeted for dredging the potential overall cumulative impacts on the archaeological record potentially contained within peat deposits, across both **sub-regions**, are considered to be ***Not Significant***.

However, if accidentally impacted this receptor is considered to be of ***High Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the palaeo-environmental and archaeological record potentially contained within peat deposits due to cumulative seabed removal at the **regional** scale are also considered to be ***Not Significant*** (*non-targeted*) or ***High Significance*** (*accidentally impacted*).

Isolated prehistoric finds: Fluvial activity and a series of marine transgressions and regressions have shaped the sediments of the MAREA region. These processes will also have resulted in the disturbance, movement and re-distribution of prehistoric artefacts and assemblages from their primary contexts.

There is thus a high potential for isolated prehistoric archaeological finds within the areas of dredging impact and across the MAREA region as a whole.

However, whilst this potential exists, it is not possible to quantify or predict the volume or distribution of such artefacts. While impacts from aggregate extraction are inevitable, the precise overlap with the location and distribution of this receptor is unknown.

Isolated prehistoric finds may be encountered in either primary or secondary context. As mentioned already, even derived archaeological material has the potential to provide valuable information and isolated prehistoric finds should thus be regarded as ***high value*** receptors. Isolated prehistoric finds will be unable to adapt to, tolerate or recover from the effects of seabed removal resulting in a permanent change to the receptor. This receptor is thus ***highly sensitive*** to the effects of seabed removal.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated prehistoric finds, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated prehistoric finds due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

Seabed removal: Maritime archaeology

Maritime archaeology sites and materials in and on the seabed may also be directly impacted by seabed removal through disturbance, removal or dispersal by the draghead. Pre-dredge identification and exclusion of such sites and material from dredging activities are likely to largely mitigate the effects of seabed removal on maritime archaeology. As with prehistoric archaeology, low-profile or ephemeral sites (which may be older wrecks, and therefore of potentially greater archaeological significance), or isolated maritime archaeological material may not be identified prior to dredging, and will be directly affected by seabed removal. These potential impacts are described in further detail below.

Known wrecks are generally widely spread across the MAREA region, with a high degree of overlap with many licence areas, particularly in the Yarmouth sub-region. For operational and archaeological reasons these sites will be avoided during aggregate extraction, and the interaction of the identified effects with this receptor within licence areas is thus likely to be limited. Recorded losses are also widespread across the MAREA region and unknown wrecks should be expected, although there is substantial uncertainty as to their overlap with licence areas, due to imprecise positional data for these sites. Where such sites are subsequently located, however, they too are likely to be avoided for operational reasons, and effect interaction is likely to be minimal.

It is unlikely that there will be appreciable aggregate extraction-related effects on wreck sites beyond the immediate footprint of extraction activities or just beyond. There is, however, likely to be a high degree of effect overlap with isolated maritime finds, which by nature are small and difficult to locate and avoid.

The value assigned to a maritime archaeological site is to a large degree site specific. A wreck may have historical importance at a local, national or international level as a result of its association with a historical event or figure. Wartime losses, or vessels whose sinking was associated with major loss of life, may have a level of importance directly associated with that loss of life. Wrecks which are key to or representative of specific periods of maritime development may also be regarded as important. A wreck may have a level of archaeological importance based on the rarity of its representation within the maritime archaeological record and/or its cargo. The differing levels of importance assigned to wrecks are not necessarily dictated by age.

Known, charted wreck sites: The 813 known or charted shipwrecks and seabed obstructions in the MAREA region are fairly evenly dispersed across the area, although there are higher densities of sites between Caister-on-Sea and Southwold and within 10 km of the coast, and in the approaches to Lowestoft and Great Yarmouth.

A total of 75 are located within the boundaries of current aggregate licence, licence application and prospecting areas.

These sites have been charted, mainly by the UKHO, and their positions on the seabed are relatively secure. The potential for interaction between this receptor and aggregate extraction impacts is thus easy to predict and document.

It is important to remember that the record of charted wrecks and obstructions is biased towards large iron or steel wrecks dating from within the last 150 years, due to the higher potential for structures of ferrous material to be identified on the seabed through geophysical survey.

The relative potential importance of the various periods into which the known, charted wrecks within the MAREA region fall has been discussed already. The archaeological potential and value of the known wrecks in the MAREA region will, therefore, vary from wreck to wreck. Due to this variability at a regional scale known, charted wreck sites must be regarded as a ***high value*** receptor. Where seabed removal results in a direct impact, this receptor will be unable to adapt to, tolerate or recover from the effects, resulting in a permanent change.

However, the distribution of this receptor is fairly accurately known and the marine aggregate industry avoids seabed structures and obstructions such as wrecks, so potential for spatial overlap of effect and receptor is limited.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known, charted wreck sites, across both **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on known, charted wreck sites due to cumulative seabed removal at the **regional** scale are also considered to be of ***Minor Significance***.

Recorded, uncharted maritime casualties: A total of 2998 shipping losses are recorded by the NRHE within the MAREA region. Of these 48 are located within the boundaries of current aggregate licence, licence application and prospecting areas.

Although recorded losses are more representative, and have a greater time depth than known or charted wrecks they are, nevertheless, also biased by being limited to only that proportion of historical maritime casualties whose loss was recorded.

The NRHE records of shipping casualties are drawn from documentary sources and descriptions and, as a result, there are generally not accurate positions for these wrecks. Instead, the NRHE has assigned recorded losses fairly arbitrary positions on the seabed, based on descriptions of their loss. While it is thus unlikely that these sites are located at the co-ordinates assigned them they should be expected to survive in some form within the MAREA region. Similarly, the potential exists for the remains of shipping casualties listed at locations outside licence, application and prospecting areas to be present within these potential areas of impact.

The large number of recorded losses and the lack of accurate positional data mean that this receptor must be regarded with a degree of uncertainty.

As with known wrecks, the archaeological potential and value of the recorded shipping casualties in the MAREA region will vary from wreck to wreck, and this receptor must be regarded as a high ***value receptor***. Where seabed removal results in a direct impact, this receptor will be unable to adapt to, tolerate or recover from the effects, resulting in a permanent change. In terms of the spatial overlap, there is a high degree of uncertainty associated with the location of this receptor, therefore the receptor is considered highly sensitive to the effects of seabed removal.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded, uncharted maritime casualties, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on recorded, uncharted maritime casualties due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

Unknown, uncharted wreck sites: Unknown and uncharted wreck sites are those for which there is no record of loss or position, but whose existence is inferred or likely on the basis of the maritime history of the MAREA region. It is thus not possible to quantify the extent of unknown and uncharted sites within the impact areas or the MAREA region.

The MAREA region contains a number of Areas of Maritime Archaeological Potential (AMAPs) in which a high potential for ship loss coincides with a high potential for the preservation of archaeological materials (Merrit *et al.*, 2007). However, the conditions favourable for the preservation of archaeological shipwreck material are predominantly provided by finer-grained sediments, rather than by the coarse gravel deposits targeted by the aggregate industry, and only those licence areas in the extreme north of the Yarmouth sub-region overlap the Southern North Sea sandbanks AMAP proposed by Merrit *et al.* (2007).

The biases in the records of both charted wrecks and documented shipping casualties towards vessels lost from the mid-18th century onwards have already been discussed, as has the potential for the presence within the MAREA region of unknown watercraft and vessels dating from the Mesolithic. A significant proportion of unknown, uncharted wreck sites will pre-date the consistent keeping of casualty records and on that basis (i.e. their age and rarity) unknown, uncharted wrecks as a group can be considered to be of special archaeological interest and should be regarded as a ***high value*** receptor.

Where seabed removal results in a direct impact the remains of unknown, uncharted wrecks will be unable to adapt to, tolerate or recover from the effects, resulting in a permanent change.

In addition there is a lack of certainty as to their numbers and location, and the consequent potential for them to be impacted by aggregate dredging.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on unknown, uncharted wreck sites, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on unknown, uncharted wreck sites due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

Isolated maritime finds: Maritime sites comprise not only wrecks of vessels, but also debris which is associated with maritime activities. This can include artefacts which were accidentally lost, material deliberately thrown overboard from a vessel, or the debris fields of shipwrecks.

While there is the potential for isolated maritime finds within the MAREA region as a whole, it is not possible to quantify the volume or distribution of such artefacts. However, the number of known wrecks and documented losses and the inferred potential for unknown and uncharted wreck sites suggest a high potential for such finds to be present on the seabed.

Isolated maritime finds are isolated or derived artefacts which are generally likely to be of limited archaeological importance. However, the occurrence of a number of seemingly isolated artefacts within a particular area can indicate historical shipping routes or maritime battlegrounds, for example, or may suggest the presence of a hitherto unknown wreck site. On this basis, isolated maritime finds are regarded as a ***moderate value*** receptor.

The adaptability and tolerance of isolated maritime finds to seabed removal is ***low***. This assessment is based on the scattered and ephemeral nature of this receptor and the limited effect the impacts of aggregate dredging will thus have on it.

If the receptor is adversely affected by seabed removal, it will be unable to recover, resulting in permanent change. As such the measure of the receptor's ability to return to its pre-impact state is **zero**. It is thus suggested that isolated maritime finds be regarded as a receptor of ***moderate sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated maritime finds, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated maritime finds due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

Seabed removal: Aviation archaeology

Aviation archaeology sites and materials in and on the seabed are directly impacted by seabed removal as previously described for maritime archaeology. The following sections describe potential impacts in more detail.

Like maritime archaeology, there is the potential for a high degree of overlap between known and recorded aircraft losses and aggregate extraction activities. As with maritime archaeology, however, within licence areas this overlap will be largely mitigated through the avoidance of sites where they are known or once they are identified, and their exclusion from extraction activities.

Appreciable effect overlap on aircraft wrecks beyond the immediate footprint of extraction activities is unlikely. There is, however, likely to be a high degree of effect overlap with isolated aviation finds, which by nature are small and difficult to locate and avoid.

The importance of aircraft crash sites has been discussed above. They not only have significance for remembrance and commemoration, but also have an implicit heritage value as historic artefacts, providing information on the aircraft itself and also the circumstances of its use and loss (English Heritage, 2002). All aircraft crash sites are also automatically protected by law.

Known, charted aircraft crash sites: There are three (3) SeaZone records of aircraft crash sites in the MAREA region, two of which are military aircraft protected by the Protection of Military Remains Act. These wrecks are considered to be **high value** receptors. None of the known aircraft wrecks are, however, located within the boundaries of a licence, application or prospecting area, therefore there is no potential for spatial overlap based on current data.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known, charted aircraft crash sites, across both **sub-regions**, are considered to be ***Not Significant***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on known, charted aircraft crash sites due to cumulative seabed removal at the **regional** scale are also considered to be of ***Not Significant***.

Recorded aircraft losses: Records of aircraft losses at sea in the UK, listed in NRHE Named Locations and in the records of WWII Air/Sea Rescue Operations, are extensive. There are 58 NRHE records within the MAREA region which refer to aircraft losses and World War II records show that a substantial number of Air/Sea Rescue Operations took place within the region. The latter must be used with caution having been extracted from contemporary maps which are sometimes ambiguous and unclear (Wessex Archaeology, 2008). All but one of the NRHE casualties date to World War II, and they include 17 German, 38 British and three aircraft whose origin is not recorded.

The location and distribution across the MAREA region of the physical remains of recorded aircraft losses is poorly understood and are not tied to known positions. They can, however, be expected to survive in some form within the MAREA region. Similarly, the potential exists for the remains of aircraft losses listed in Named Locations located outside licence, application and prospecting areas to be present within these potential areas of impact.

Aircraft crash sites are likely to be of special archaeological interest, and will be automatically protected by the Protection of Military Remains Act 1986 should they be located. Consequently, at a regional scale recorded aircraft losses must be considered as a ***high value*** receptor.

Where seabed removal results in a direct impact the remains of recorded aircraft losses would be unable to tolerate the effects, resulting in a permanent change in the receptor. Although the positions of these sites are not known, the relatively short span of time since they were deposited on the seabed suggests that wreckage should be expected to survive in some form within the MAREA region. The uncertainty regarding their precise location is noted and a precautionary approach taken to mitigate this.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded aircraft losses, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on recorded aircraft losses due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

Isolated aircraft finds: Isolated finds related to aviation activity may be present within the MAREA region. Most aircraft came to be on the seabed as a result of in-flight accident or enemy action. The remains of aircraft that exploded in mid-air or hit the water at speed are likely to be represented by fragmented and widely dispersed wreckage and artefacts, rather than a coherent aircraft wreck.

It is not possible to quantify the volume or distribution of such artefacts across the MAREA region but the number of recorded aircraft losses suggests a high potential for such material to be present in or on the seabed.

Isolated aircraft finds will consist of aircraft-related artefacts which may be of limited archaeological importance as isolated objects. However, the occurrence of a number of seemingly isolated artefacts within a particular area may suggest historical flight paths and can give insights into patterns of aviation across the MAREA region. Alternatively, they may indicate the presence of a recorded but uncharted aircraft crash site. On this basis, isolated aircraft finds are regarded as a ***moderate value*** receptor.

The adaptability and tolerance of isolated aircraft finds to seabed removal is **low**. This assessment is based on the scattered and ephemeral nature of this receptor and the limited effect the impacts of aggregate dredging will thus have on it, but also considering where overlap does occur, the receptor will be unable to recover, resulting in permanent change.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated aircraft finds, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated aircraft finds due to cumulative seabed removal at the **regional** scale are also considered to be of ***Moderate Significance***.

28.3 BATHYMETRIC CHANGES

Bathymetric changes (i.e. the lowering of the seabed) resulting from or precipitated by aggregate dredging are likely to be largely restricted to within the boundaries of individual licence areas. There is unlikely to be any overlap of this effect between licence areas, within sub-regions, or across the MAREA region as a whole.

Changes to bathymetry, as a secondary effect caused primarily by seabed removal, have the potential to impact archaeological receptors both within licence areas and sub-regionally, or beyond the boundaries of licence areas (see Section 28.1.3).

Bed lowering has the potential to modify the upstream current and flow regime, causing seabed scour and erosion (see 28.8 below). This can expose previously buried archaeological material through erosion, making it vulnerable to physical, chemical or biological attack, degradation and loss (Dix *et al*., 2007).

Bathymetric changes: Prehistoric archaeology

Many of the likely impacts resulting from changes in bathymetry as a result of future extraction activities are strongly associated with seabed removal.

Pleistocene Fluvial Gravels:

Pleistocene fluvial gravels are unable to adapt to, tolerate or recover from bathymetric changes, resulting in a permanent change to the receptor. Due to its non-renewable and finite nature, and as the primary target of aggregate extraction, the receptor is thus ***highly sensitive***. Pleistocene fluvial gravels should also be regarded as a ***high value*** receptor.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels, across both **sub-regions**, are considered to be of ***Moderate Significance***. Individual impact significance for this receptor is provided in **Table 28:2**. The cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Moderate Significance***.

Estuarine alluvium:

Estuarine alluvium deposits are unable to adapt to, tolerate or recover from bathymetric changes, resulting in a permanent change to the receptor. Due to its non-renewable and finite nature the receptor is ***highly sensitive***.

SIGNIFICANCE STATEMENT: Because this receptor will not be targeted by aggregate extraction, therefore potential for spatial overlap is limited. The potential overall cumulative impacts on the archaeological record potentially contained within estuarine alluvium, across both **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within estuarine alluvium due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Minor Significance***.

Peat:

Peat deposits have some potential to be impacted by downstream changes to bathymetry and are regarded as a receptor of **moderate sensitivity** to these effects, but should be regarded as a ***high value*** receptor.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within peat deposits, across both **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within peat deposits due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Minor Significance***.

Isolated Prehistoric Finds:

With regards to the downstream effects of changes to bathymetry, isolated prehistoric finds are likely to be unaffected and are thus regarded as a receptor of ***moderate sensitivity*** to these effects.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record represented by isolated prehistoric finds, across both **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the isolated prehistoric finds due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Minor Significance***.

Bathymetric changes: Maritime archaeology

As previously stated, the likely impacts resulting from changes in bathymetry as a result of future extraction activities are strongly associated with seabed removal.

Known, Charted Shipwrecks:

Known charted wrecks should be regarded as a ***high value*** receptor. They are unable to adapt to, tolerate or recover from the effects of bathymetric changes, resulting in a permanent change to the receptor. Due to its non-renewable and finite nature, the receptor is thus ***highly sensitive*** to the effects of bathymetric changes. Known wrecks are well documented and actively avoided by the industry with exclusion zones implemented therefore the potential for direct spatial overlap is low, it is also considered that wrecks will be unaffected by any downstream changes to bathymetry.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known charted wrecks, across all three **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on known charted wrecks due to cumulative bathymetric changes at the regional scale are also considered to be of ***Minor Significance***.

Recorded, Uncharted Maritime Casualties:

With regard to the effects of downstream changes to bathymetry, the remains of shipping casualties are likely to be unaffected. The receptor is considered be of ***low sensitivity*** but of ***high value***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded, uncharted maritime casualties, across both **sub-regions**, are considered to be of ***Minor Significance***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on recorded, uncharted maritime casualties due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Minor Significance***.

Unknown, Uncharted Shipwrecks:

With regard to the effects of downstream changes to bathymetry, unknown, uncharted shipwrecks are unable to adapt to, tolerate or recover from the effects of bathymetric changes, resulting in a permanent change to the receptor due to its non-renewable and finite nature.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on unknown, uncharted shipwrecks, across both **sub-regions**, are considered to be of ***Moderate Significance***. individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on unknown, uncharted shipwrecks due to cumulative bathymetric changes at the **regional** scale are also considered to be of ***Moderate Significance***.

Isolated Maritime Finds:

The receptor is considered to be of low sensitivity to the effects of bathymetric changes, however, given the scattered nature of the receptor there is an assumption of presence across both sub regions so the potential for spatial overlap is high.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts isolated maritime finds, across both **sub-regions**, are considered to be of ***Moderate Significance***. individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on impacts isolated maritime finds due to cumulative bathymetric changes at the **regional** scale are also considered to be of **Moderate Significance**.

Bathymetric changes: Aviation archaeology

The likely impacts resulting from changes in bathymetry as a result of future extraction activities are strongly associated with seabed removal.

Known, Charted Aircraft Crash Sites:

With regard to the effects of downstream changes to bathymetry, known aircraft crash sites are likely to be unaffected and are regarded as a receptor of ***low sensitivity but high value. There are no recorded sites recorded within any of the licence areas within the region***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known aircraft crash sites, across both **sub-regions**, are considered to be ***Not Significant***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts known aircraft crash sites due to cumulative bathymetric changes at the **regional** scale are also considered to be ***Not Significant***.

Recorded Aircraft Losses:

With regard to the effects of downstream changes to bathymetry, the remainsof recorded aircraft losses are likely to be unaffected and are regarded as areceptor of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded aircraft losses, across both **sub-regions**, are considered to be of ***Minor Significance***. individual impact significance for this receptor is provided in **Table 28:2**. The cumulative impacts on recorded aircraft losses due to cumulative seabed removal at the **regional** scale are also considered to be of ***Minor Significance***.

Isolated Aircraft Finds:

The receptor is considered to be of low sensitivity to the effects of bathymetric changes, however, given the scattered nature of the receptor there is an assumption of presence across both sub regions so the potential for spatial overlap is high.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts, isolated aircraft finds, across both **sub-regions**, are considered to be of ***Moderate Significance***. individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated aircraft finds due to cumulative bathymetric changes at the **regional** scale are also considered to be of **Moderate Significance**.

28.4 SEDIMENT FLUX

Sediment flux, which is a proxy for seabed erosion or deposition, may have an effect beyond the boundaries of licence areas, and thus has the potential to overlap at a sub-regional level. The impact of this effect on archaeological receptors may be negative, where it causes erosion, or positive, where it results in net sediment gain or accretion.

Dix *et al*. (2007) have collated the results of a number of studies which have investigated the total downstream distance travelled by dredge plumes, and the distance of fallout of the main body of such material. The findings suggest average maximum downstream transport of less than 3 km, with the bulk of sediment settling within an average of 450 m of the dredger. Most suspended sediment generated by aggregate dredging is thus likely to be redeposited within the boundaries of aggregate licence areas, with finer material being transported in the region of 3-5 km beyond licence areas.

Where it is accompanied by net loss of sediment, resulting in the exposure of previously buried archaeological material and making it vulnerable to physical, chemical or biological attack, degradation and loss (Dix *et al*., 2007), the effects of sediment flux will be negative. Where it results in net sediment gain and site burial, sediment flux is likely to be positive for the longer-term preservation of affected archaeological sites.

Sediment flux: Prehistoric archaeology

Pleistocene Fluvial Gravels:

Pleistocene fluvial gravels are likely to be unaffected by sediment flux and are thus regarded as a receptor of ***low sensitivity*** to these effects.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels, across both **sub-regions**, are considered to be ***Not Significant***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within Pleistocene fluvial gravels due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant***.

Estuarine Alluvium:

Alluvial deposits have some potential to be impacted by sediment flux and are regarded as a receptor of ***moderate sensitivity*** to these effects.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within alluvial deposits, across both **sub-regions**, are considered ***Not Significant*** for deposition, although of ***Moderate Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within alluvial deposits due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Moderate Significance*** for erosion.

Peat:

Peat deposits have some potential to be impacted by effects of sediment flux and are regarded as a receptor of ***moderate sensitivity*** to these effects.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on the archaeological record potentially contained within peat deposits, across both **sub-regions**, are considered ***Not Significant*** for deposition, although of ***Moderate Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on the archaeological record potentially contained within peat deposits due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Moderate Significance*** for erosion.

Isolated Prehistoric Finds:

With regards to the effects of sediment flux, isolated prehistoric finds are unlikely to be affected, and are thus regarded as a receptor of ***low sensitivity*** to these effects.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated prehistoric finds, across both **sub-regions**, are considered to be ***Not***

Significant for deposition, although of ***Minor Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated prehistoric finds due to cumulative sediment flux at the regional scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

Sediment flux: Maritime archaeology

Known, Charted Shipwrecks:

With regard to the effects of downstream changes to sediment flux, known charted wrecks are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known charted wrecks, across both **sub-regions**, are considered to be ***Not Significant***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on known charted wrecks due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant***.

Recorded, Uncharted Maritime Casualties:

With regard to the effects of downstream changes to sediment flux, the remains of recorded shipping casualties are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded, uncharted maritime casualties, across both **sub-regions**, are considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on recorded, uncharted maritime casualties due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

Uncharted Shipwrecks:

With regard to the effects of downstream changes to sediment flux, uncharted shipwrecks are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on uncharted shipwrecks, across both **sub-regions**, are considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion. Impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on uncharted shipwrecks due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

Isolated Maritime Finds:

With regard to the effects of downstream changes to sediment flux, isolated maritime finds are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated maritime finds are considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated maritime finds to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

Sediment flux: Aviation archaeology

Known, Charted Aircraft Crash Sites:

With regard to the effects of downstream changes to sediment flux, known aircraft crash sites are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on known aircraft crash sites, across both **sub-regions**, are considered to be ***Not Significant***. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on known aircraft crash sites due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant***.

Recorded Aircraft Losses:

With regard to the effects of downstream changes to sediment flux, the remains of recorded aircraft losses are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on recorded aircraft losses, across both **sub-regions,** are considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on recorded aircraft losses due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

Isolated Aircraft Finds:

With regard to the effects of downstream changes to sediment flux, isolated aircraft finds are unlikely to be negatively affected. There is also the potential that these sites may be positively affected by burial through net sediment gain. This receptor is thus regarded as being of ***low sensitivity***.

SIGNIFICANCE STATEMENT: The potential overall cumulative impacts on isolated aircraft finds, across both **sub-regions**, are considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion. Individual impact significance for this receptor is provided in **Table 28:2**.

The cumulative impacts on isolated aircraft finds due to cumulative sediment flux at the **regional** scale are also considered to be ***Not Significant*** for deposition, although of ***Minor Significance*** for erosion.

28.5 CONCLUSIONS

In summary, therefore, while the effects of aggregate dredging on the archaeological receptors will be experienced mainly within or close to licence areas, the cumulative impact of these effects on the non-renewable archaeological record will be a permanent and non-reversible change to the archaeological baseline of the MAREA region.

The archaeological record is widely scattered across the MAREA region, and there is marked variability in our knowledge and understanding of its extent, distribution, value and importance. All archaeological receptors are, however, immobile, non-renewable and finite in nature and any adverse impacts on the archaeological baseline by aggregate dredging will be permanent and irreversible.

Of the effects associated with aggregate dredging, three have been assessed to be applicable to the archaeological receptors.

Seabed removal, as the primary, direct effect of aggregate dredging will have a permanent effect on any archaeological sites or materials it impacts. Known sites and materials can be excluded from the effects of seabed removal through the implementation of exclusion zones. The currently unknown elements of the archaeological record, the existence of which can be predicted on the basis of historical research, are however, more susceptible to the effects of seabed removal, and appropriate mitigation measures must be put in place, as an outcome of future EIAs, to ensure that sites or material are not negatively affected by aggregate dredging.

Changes to bathymetry, as a result of aggregate dredging (as was the case with seabed removal) will affect the immediate dredging footprint and, potentially, a limited area beyond it. It is unlikely that this effect will be felt much beyond the individual licence area boundaries. Changes to seabed bathymetry have the potential to modify the upstream current and flow regime, causing seabed scour and negative sediment flux. This can expose previously buried archaeological material through erosion, making it vulnerable to physical, chemical or biological attack, degradation and loss.

Sediment flux or transport may have either a negative or positive effect on archaeological receptors. Where it is accompanied by net loss of sediment, it can result in the exposure of previously buried archaeological material, making it vulnerable to degradation and loss. Where it results in net sediment gain and site burial, sediment flux is likely to be positive for the longer-term preservation of archaeological sites.

The results of this regional assessment highlight the need to include archaeology in any future licence area-specific Environmental Impact Assessments carried out for aggregate dredging.

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Table 28:2

SUMMARY OF CUMULATIVE IMPACT ASSESSMENT RESULTS FOR YARMOUTH / SOUTHWOLD SUB-REGIONS

EFFECT	SENSITIVE RECEPTOR										
	Prehistoric Archaeology				*Maritime Archaeology*				*Aviation Archaeology*		
	Pleistocene fluvial gravels	*Estuarine alluvium*	*Peat*	*Isolated prehistoric finds*	*Known, charted shipwrecks*	*Recorded, uncharted maritime casualties*	*Unknown, uncharted shipwrecks*	*Isolated maritime finds*	*Known, charted aircraft wrecks*	*Recorded aircraft losses*	*Isolated aircraft finds*
SEABED REMOVAL *(Effect magnitude = Medium)*	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions but not targeted.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions but not targeted.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** Of the 813 known or charted shipwrecks, only 75 are located within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** receptor position largely unknown, 48 shipping losses are recorded within current or future licence areas.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** A number of AMAPs exist within the MAREA region (Merrit *et al.*, 2007), however conditions favorable for preservation (fine sand) is not targeted by dredging activity.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value, although isolated or derived artefacts generally likely to be of limited archaeological potential. **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value and protected features under Protection of Military Remains Act 1986. **Spatial overlap:** no sites fall within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value and protected under Protection of Military Remains Act 1986 (where known). **Spatial overlap:** Fifty-eight recorded aircraft loses in the MAREA region, although position is largely unknown.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and hertiage value. **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.
	High significance*	**Not significant***	**Not significant***	**Moderate significance***	**Minor significance*****	**Moderate significance****	**Moderate significance***	**Moderate significance***	**Not significant*****	**Moderate significance****	**Moderate significance***
		High significance*	**High significance***								
BATHYMETRY CHANGES *(Effect magnitude = Medium)*	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions, but not targeted.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions but not targeted.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions, but likely to be widely scattered.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** Of the 813 known or charted shipwrecks, only 75 are located within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value. **Spatial overlap:** receptor position largely unknown, 48 shipping losses are recorded within current or future licence areas.	**T:** Low, **A:** Low; **R:** Low **Value:** Cultural and heritage value. **Spatial overlap:** A number of AMAPs exist within the MAREA region (Merrit *et al.*, 2007), however conditions favorable for preservation (fine sand) is not targeted by dredging activity.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value, although isolated or derived artefacts generally likely to be of limited archaeological potential. **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value and protected features under Protection of Military Remains Act 1986. **Spatial overlap:** no sites fall within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value and protected under Protection of Military Remains Act 1986 (where known). **Spatial overlap:** Fifty-eight recorded aircraft loses in the MAREA region, although position is largely unknown.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.
	Moderate significance*	**Minor significance***	**Minor significance***	**Minor significance***	**Minor significance*****	**Minor significance****	**Moderate significance***	**Moderate significance***	**Not significant*****	**Minor significance****	**Moderate significance***
SEDIMENT FLUX *(Effect magnitude = Medium)*	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across both sub-regions, but not targeted.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions but not targeted.	**T:** Medium, **A:** Medium; **R:** Medium **Value:** Cultural and heritage value. **Spatial overlap:** Assumption of presence across both sub-regions, but likely to be widely scattered.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value. **Spatial overlap:** Of the 813 known or charted shipwrecks, only 75 are located within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value **Spatial overlap:** Receptor position largely unknown, 48 shipping losses recorded within current or future licence areas.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value **Spatial overlap:** A number of AMAPs exist within the MAREA region (Merritt *et al.*, 2007) however conditions favourable for preservation (fine sand) are not targeted by dredging activity.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value, although isolated or derived artefacts generally likely to be of limited archaeological potential **Spatial overlap:** Assumption of presence across both sub-regions but likely to be widely scattered.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value and protected features under Protection of Military Remains Act 1986 **Spatial overlap:** No sites fall within current or future licence areas, known sites are actively excluded where they fall within licence areas.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value and protected features under Protection of Military Remains Act 1986 (where known) **Spatial overlap:** Fifty-eight recorded aircraft loses in the MAREA region, although position is largely unknown.	**T:** High, **A:** High; **R:** High **Value:** Cultural and heritage value **Spatial overlap:** Assumption of presence across two sub-regions, but likely to be widely scattered.
	Not significant for deposition*	**Not significant for deposition***	**Not significant for deposition***	**Not significant for deposition***	**Not significant for deposition*****	**Not significant for deposition****	**Not significant for deposition***	**Not significant for deposition***	**Not significant for deposition*****	**Not significant for deposition****	**Not significant for deposition***
	Not significant for erosion*	**Moderate significance for erosion***	**Moderate significance for erosion***	**Minor significance for erosion***	**Not significant for erosion*****	**Minor significance for erosion****	**Minor significance for erosion***	**Minor significance for erosion***	**Not significant for erosion*****	**Minor significance for erosion****	**Minor significance for erosion***

As defined in Chapter 3: **T:** Tolerance; **A:** Adaptability; **R:** Recoverability.

☐ Not significant 🟪 Minor significance 🟪 Moderate significance 🟪 Major significance

Uncertainty: *High **Moderate *** Low

29. IN-COMBINATION IMPACT ASSESSMENT

29.1 INTRODUCTION

This chapter presents the findings for the in-combination assessment for the Anglian Offshore MAREA. This assessment is conducted at a sub-regional level and captures all industrial sectors operating in the region that interact or potentially interact with the effects generated by aggregate extraction activities (see Chapter 3 for methodology).

The approach has been designed to identify the potential for interactions with other activities on the physical, biological, human and historical environment, but it was not considered appropriate at a regional scale to assess the scale of any potential impacts. Where activities have no definitive boundaries (i.e. non fixed structures) then the spatial extent has been derived from the best available information, however, consideration should be given at EIA stage to the matrix to identify those activities that are likely to have an in-combination effect.

Particular attention has been given to any effects that occur in-combination with other activities that may impact on the integrity of European sites within the region. It is noted that a more detailed assessment will be required at EIA stage in line with the Dredging Regulations to ensure the integrity of European sites are not adversely affected either alone or in-combination with other activities.

29.2 METHODOLOGY

The definition of in-combination that has been adopted for the purposes of this MAREA is provided below:

> *'The total effects of all industrial sectors operating within the same region in the context of natural variability or trends'.*

The assessment takes a spatial approach. The matrix in **Table 29:1** summarises other uses of the region and is used as a high level screening exercise to identify the potential for in-combination impacts with the effects of aggregate extraction across the region.

The effects included are those previously identified in the Impact Assessment Methodology chapter (Chapter 3). A brief narrative is then provided in **Tables 29:2** and **29:3** explaining the nature of the interactions with other activities and the receptors screened in for further assessment at the EIA stage.

This assessment has only considered activities that are currently operating or are in planning. However, consideration has been given to activities such as offshore wind farm development where likely effects are well documented but site specific data at this stage are unavailable. **Figure 29:1** provides a spatial overview of all activities where these represent hard constraints. It was considered that the spatial fisheries data contained too many uncertainties and given the dynamic and opportunistic nature of the sector in the region, it was not considered appropriate to plot this receptor.

29.3 SCREENING

Activities screened in from the baseline assessment are listed below:

- Commercial and recreational fisheries – widespread throughout the region;
- Shipping – widespread throughout the region with spatial extent linked directly to shipping density plots;
- Ports and navigation – which incorporates all supporting infrastructure, in particular maintenance and capital dredge channels and anchorages;
- Renewable energy - Round 1 (assessment undertaken on the use of monopiles, future EIA should take note of any changes in technology and design of structures)
- Cables and pipelines – both out of service and active routes;
- Disposal sites;
- Tourism and recreational activities – including sailing, diving and other watersports;
- Coastal defences – widespread along the coastline;
- Military areas – exclusion zones for firing and practice ranges, and military disposal sites; and
- Oil and gas, including pipelines.

	OTHER USERS OF THE SEA									
Potential effects similar to dredging by other users of the Sea	**Commercial Fishing**	**Recreational Fishing**	**Shipping**	**Ports & Navigation**	**Renewable Energy**	**Cables & Pipelines***	**Military Areas**	**Recreation & Tourism**	**Oil and Gas**	**Disposal Sites**
Seabed removal (e.g. occurrence of seabed furrows, changes in topography)	🟢			🔵	🔵	🔵			🔵	
Vessel displacement (e.g. reduced access to areas)	🟣	🟣	🟣	🟣	🟣		🟣	🔵	🔵	🔵
Noise and vibration (e.g. sound pressure changes)	🔵	🔵	🔵	🔵	🟣	🟢	🔵	🔵	🔵	
Suspended sediments (e.g. plume/elevated turbidity, deposition)	🔵			🔵	🟣	🔵			🔵	🟣
Fine sand dispersion (e.g. changes in seabed bedforms)	🔵			🔵	🔵	🔵			🔵	🔵
Bathymetry	🔵			🔵	🔵				🔵	🔵
Waves				🔵	🟣				🟢	
Tides				🔵	🟣				🟢	
Sediment flux (e.g. proxy for sediment erosion and accretion)				🔵	🟣				🟢	🔵

*Includes cable and pipeline laying and maintenance.

🔵 **Low potential:** Activity listed is considered to have a low potential to create a similar effect to that produced by marine aggregate extraction, therefore having insignificant in-combination effects.

🟢 **Medium potential:** Activity listed is considered to have a medium potential to create a similar effect to that produced by marine aggregate extraction, however the potential for in-combination effects is still considered to be unlikely.

🟣 **High potential:** Activity listed is considered to have a high potential to create a similar effects to that produced by marine aggregate extraction, unless appropriate monitoring and mitigation requirements are established.

Table 29:1 Summary of in-combination interactions.

In addition to these existing uses, the following development is in the planning system and has been considered for its potential to interact with aggregate extraction:

- Round 3 offshore wind farm development Zone 5 (East Anglia).

The following tables provide a summary of the likely interactions identified in **Table 29:1**. The tables also provide an indication of which receptors are sensitive to change and should be assessed further at the EIA stage. This assessment has been undertaken on the basis that in-combination effects may arise where aggregate extraction alone (cumulative impacts of aggregate extraction) has not been assessed as having a significant impact, but in-combination with other

YARMOUTH SUB-REGION

Potential Dredging Effects	Spatial overlap with effects similar to dredging	Receptors screened in that are potentially affected by in-combination impacts
Seabed removal (e.g. occurrence of seabed furrows, changes in topography)	• Commercial Fishing (gear types that interact with the seabed) • Ports and Navigation • Renewable Energy • Cables and Pipelines • Oil and Gas	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation); • Infrastructure and Other Marine Users (Disposal sites); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).
Vessel displacement (e.g. reduced access to areas)	• Commercial Fishing • Recreational Fishing • Shipping • Ports and Navigation • Renewable Energy • Recreation and Tourism • Oil and Gas • Disposal Sites	• Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation); • Navigation and Shipping (Navigational features, Merchant and passenger vessels, Commercial fishing vessels, Recreational and sailing vessels); • Infrastructure and Other Marine Users (Diving activities).
Noise and vibration (e.g. sound pressure changes)	• Commercial Fishing • Recreational Fishing • Shipping • Ports and Navigation • Renewable Energy • Cables and Pipelines • Recreation and Tourism • Disposal Site	• Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Infrastructure and Other Marine Users (Diving activities).
Suspended sediments (e.g. plume/elevated turbidity, deposition)	• Commercial Fishing • Ports and Navigation • Renewable Energy • Cables and Pipelines • Oil and Gas • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation); • Infrastructure and Other Marine Users (Disposal sites, diving activities).
Fine sand dispersion (e.g. changes in seabed bedforms)	• Commercial Fishing • Ports and Navigation • Renewable Energy • Cables and Pipelines • Oil and Gas • Disposal Site	• Coastline and Inshore Sandbanks (Inshore Sandbanks) • Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, grebes and mergansers; Others); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation).
Bathymetry	• Commercial fishing • Ports and Navigation • Renewable Energy • Oil and Gas • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).
Waves	• Ports and Navigation • Renewable Energy • Oil and Gas	• Coastline and Inshore Sandbanks (Inshore Sandbanks); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Infrastructure and Other Marine Users (Cables and pipelines, Disposal sites, Renewable energy).
Tides	• Ports and Navigation • Renewable Energy • Oil and Gas	•Infrastructure and Other Marine Users (Disposal sites, Renewable energy).
Sediment flux (e.g. proxy for sediment erosion and accretion)	• Ports and Navigation • Renewable Energy • Oil and Gas • Disposal Site	• Coastline and Inshore Sandbanks (Inshore Sandbanks); • Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA; Haisborough, Hammond and Winterton cSAC); • Infrastructure and Other Marine Users (Disposal sites, Renewable energy); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).

Table 29:2 Receptors potentially affected by in-combination effects within the Yarmouth sub-region

projects has the potential to have a significant effect. Therefore all receptors screened in for assessment, regardless of significance from aggregate extraction, have been included.

SOUTHWOLD SUB-REGION

Potential Dredging Effects	Spatial overlap with effects similar to dredging	Receptors screened in that are potentially affected by in-combination impacts
Seabed removal (e.g. occurrence of seabed furrows, changes in topography)	• Commercial Fishing (gear types that interact with the seabed) • Renewable Energy • Cables and Pipelines	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Infralittoral fine sand, *Sabellaria spinulosa* on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation); • Infrastructure and Other Marine Users (Cables and Pipelines); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).
Vessel displacement (e.g. reduced access to areas)	• Commercial Fishing • Recreational Fishing • Shipping • Ports and Navigation • Recreation and Tourism • Disposal Site	• Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation); • Navigation and Shipping (Navigational features, Merchant and passenger vessels, Commercial fishing vessels, Recreational and sailing vessels). .
Noise and vibration (e.g. sound pressure changes)	• Commercial Fishing • Recreational Fishing • Shipping • Ports and Navigation • Renewable Energy • Cables and Pipelines • Recreation and Tourism • Disposal Site	• Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA).
Suspended sediments (e.g. plume/elevated turbidity, deposition)	• Commercial Fishing • Renewable Energy • Cables and Pipelines • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Infralittoral fine sand, Sabellaria spinulosa on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Marine Mammals and Turtles (Harbour porpoise, Short beaked common dolphin, Bottlenose dolphin, Common seal, Grey seal); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation).
Fine sand dispersion (e.g. changes in seabed bedforms)	• Commercial Fishing • Renewable Energy • Cables and Pipelines • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, Sabellaria spinulosa on stable circalittoral mixed sediment); • Fish and Shellfish Ecology (Adult stock – fish and shellfish, Spawning – pelagic fish, Spawning – demersal fish, Nursery – all fish and Migratory species); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Commercial and Recreational Fishing (Inshore fleet, Middle ground fleet, Offshore fleet, Recreation).
Bathymetry	• Commercial Fishing • Renewable Energy • Oil and Gas • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, Sabellaria spinulosa on stable circalittoral mixed sediment); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).
Waves	• Renewable Energy	• Nature Conservation (Outer Thames pSPA); • Infrastructure and Other Marine Users (Cables and Pipelines, Renewable energy).
Tides	• Renewable Energy	• Infrastructure and Other Marine Users (Cables and Pipelines, Renewable energy).
Sediment flux (e.g. proxy for sediment erosion and accretion)	• Renewable Energy • Disposal Site	• Benthic Ecology (Circalittoral coarse sediment, Infralittoral coarse sediment, Circalittoral muddy sand, Infralittoral fine sand, Sabellaria spinulosa on stable circalittoral mixed sediment); • Ornithology (Gulls, Terns, Auks, Seaducks; Divers, Grebes and Mergansers; Others); • Nature Conservation (Outer Thames pSPA); • Infrastructure and Other Marine Users (Renewable energy); • Archaeology (Pleistocene fluvial gravels; Estuarine alluvium; Peat; Isolated prehistoric finds; Known, charted shipwrecks; Recorded, uncharted maritime casualties; Unknown, uncharted shipwrecks; Isolated maritime finds; Known, charted aircraft wrecks; Recorded aircraft losses; Isolated aircraft finds).

Table 29:3 Receptors potentially affected by in-combination effects within the Yarmouth sub-region

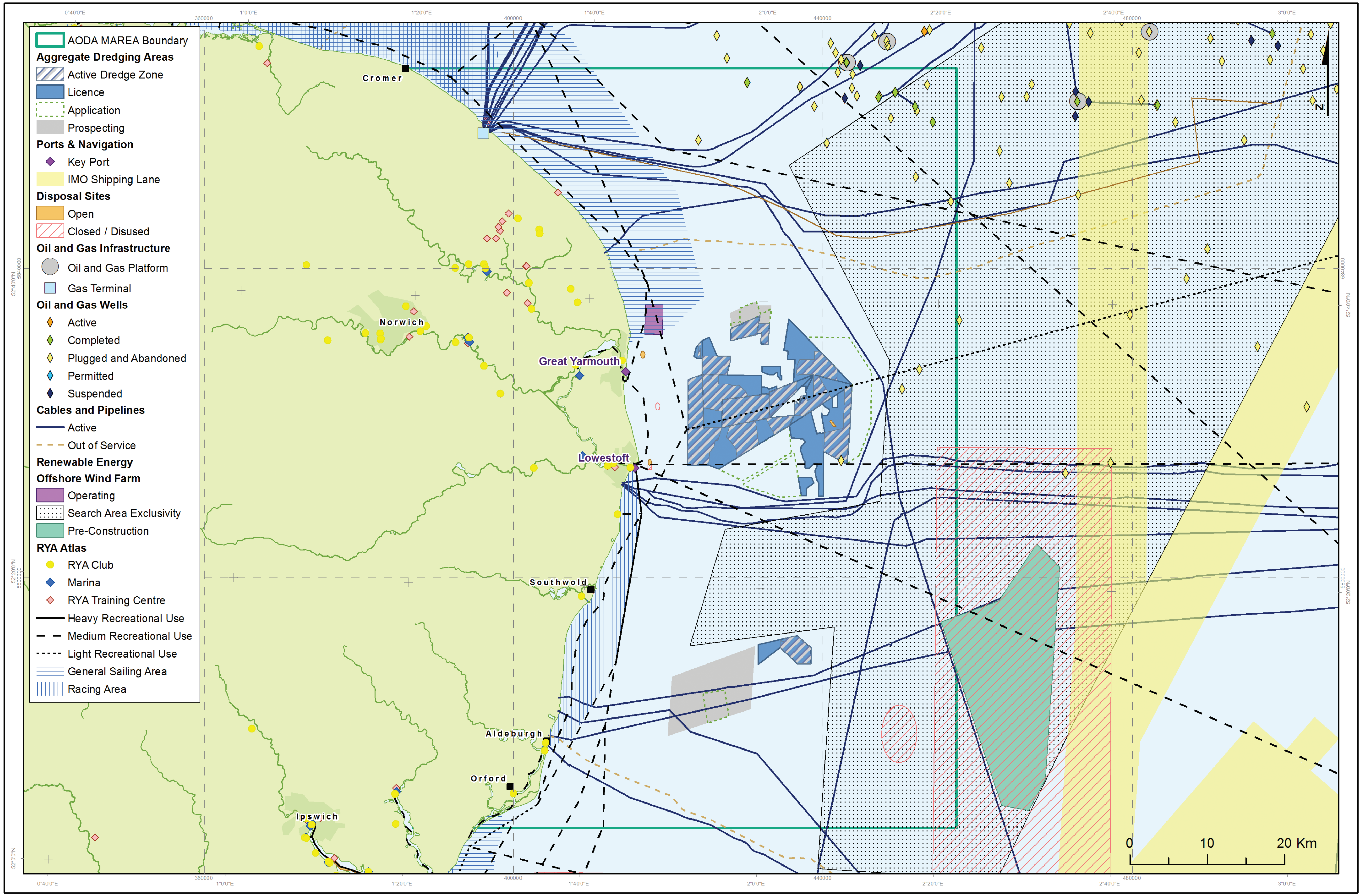

Figure 29:1 In combination activities within the AODA region

30. FINAL SUMMARY AND CONCLUSIONS

30.1 INTRODUCTION

Land-based sources of sands and gravels along the Anglian region, whilst defined, are constrained and declining. Therefore, over the past 40 years marine sands and gravels have been an important source of aggregates for the Anglian region and are of particularly high quality. As a result of this, the supply of marine aggregates forms an important contribution to fulfilling local and national demand.

To ensure this demand is met, AODA commissioned this MAREA to research, analyse and support future aggregate dredging off the Anglian coast; to facilitate new licences for recently discovered aggregate resources, and to re-license existing areas, where viable aggregate resource remains within the boundaries of licences that are due to expire.

More specifically, AODA intends to use the MAREA to inform regulators and their advisors about potential cumulative and in-combination regional impacts of proposed future dredging, as well as providing individual operators with important background information for site-specific EIAs.

For the purpose of this regional assessment, licences and applications were grouped into two distinct sub-regions (Yarmouth and Southwold blocks). This reflected the arrangement of dredging areas and their isolation from each other in terms of their cumulative and in-combination effects and allows monitoring plans to be developed according to the nature and scale of the receptors impacted. It should be noted however that a precautionary approach was taken for mobile species (marine mammals and birds). A regional approach to the assessment was taken to account for the mobile nature of the receptor and a presence across the entire region was assumed.

30.2 FUTURE DREDGING ACTIVITIES

The MAREA takes a precautionary approach to the assessment of cumulative and in-combination impacts in order to clearly define sensitivities. An annual aggregate extraction of 11.75 Mt p.a. over a 15 year period is assumed to be the 'maximum development scenario' (i.e. the maximum level permitted by individual consents), although in practice annual offtake is likely to be significantly less than this. The precautionary approach also assumes that all renewals, applications and development of prospecting licences within the MAREA region will be permitted and dredged concurrently.

It is important to note that all modelled outputs and assessments have been undertaken assuming this worst case scenario, future EIAs should take note of any licence areas that are relinquished to ensure consideration is given to the likelihood of reduced impacts.

In the event that all existing licences, applications and prospecting licences operate to the maximum level permitted by their individual consents, projected future extraction levels within the MAREA region would increase fourfold on current levels (please refer to industry statement for the context of this projected future extraction).

The AODA companies currently dredge 14 marine aggregate licence areas within the MAREA region. The industry minimises the dredged area within its permissions and consequently dredging does not take place evenly across the dredging permission areas. Marine aggregate extraction only occurs in Active Dredge Zones which, in line with Government guidance (MMG1; ODPM, 2002), typically comprise a small proportion of the licensed area.

The permitted area for dredging has changed year on year. Some older dredging areas have been reduced in size, several new permissions have been granted, and periodically licence areas are surrendered. Between 1998 and 2007, the area of seabed licensed has decreased by approximately 141 km^2, with the greatest changes occurring within 12 nm of the coast (TCE, 2008).

There are currently two prospecting areas and four application areas in the MAREA region at various stages of the permitting process. It is possible for a permission to be denied if the impacts associated with the application are considered to be environmentally unacceptable by the regulators and their advisors.

30.3 MEETING PROJECT OBJECTIVES

To date, no legislative framework exists for the MAREA process. Regional assessments are guided by the Regulatory Advisory Group (RAG) and supported by The Crown Estate and industry. The processed involved a scoping study (Phase 1), which was undertaken to focus consultation on the potential cumulative and in-combination impacts within the region, and review methodologies for undertaking a full-scale MAREA (Phase 2) before commission.

RAG posed a fundamental question to aid the decision making process undertaken by regulators charged with managing offshore aggregate extraction activities: "Should existing dredging continue and new areas be dredged within the MAREA regions? (i.e. are the current levels of dredging activity environmentally acceptable and if so, can they be increased without causing significant environmental impact?)" The aims and objectives of this MAREA have been developed to answer this fundamental question.

The industry recognised at an early stage that in order to address the questions above, it would be necessary to carry out a MAREA to consider cumulative and in-combination effects. This includes interactions with other marine aggregate extraction sites and other marine uses and users operating in the region.

The Anglian MAREA has focused on the following objectives of the RAG guidance:

- Development of an evidence-based assessments of the distribution and importance of regional and sub-regional resources (living and non-living) and the potential impacts from the proposed activities on these resources;
- Collection and interpretation of substantial baseline data to support site-specific EIAs within the relevant MAREA region;
- Identification of site-specific issues that individual EIAs need to address; and
- Development of a robust assessment of cumulative and in-combination impacts at the regional and sub-regional level.

Two objectives set out in the RAG guidance have not been focused on to the same degree as those above as they were not considered practicable for this assessment:

- The MAREA has not focused on providing recommendations for monitoring or research and development (R&D). It is considered that monitoring and R&D can be best addressed once the MAREA findings have been considered and once the proposed development scenarios have been finalised at the EIA stage.
- Similarly, different development scenarios have not been considered because the maximum development scenario has appraised the maximum tonnage proposed to be extracted from the region, reflecting the cumulative total of all potential site specific EIA proposals.

Based on the MAREA impact assessment, it has been demonstrated that current and future projected levels of dredging activity at the regional and sub-regional scale will pose only minor impact significance to a small number of sensitive receptors. For this reason, it is considered that future dredging activities are likely to be well within environmentally acceptable parameters.

The following sections provide justification for this conclusion.

30.4 DEVELOPING THE IMPACT ASSESSMENT

Currently, there is no recognised industry standard for conducting cumulative and/or in-combination impact assessments for regional level assessments. This MAREA represents one of the first studies to introduce a systematic and auditable approach designed around the need to capture evidence to support decisions on impact significance (see Chapter 3).

Central to this assessment has been the standardisation of terminology with other MAREA studies, including the MAREA currently being undertaken for the Thames region. The main terms include 'magnitude of effect' and 'sensitivity of receptor', which includes consideration of receptor 'value'. MAREA terminology has been developed specifically for regional and sub-regional cumulative and in-combination impacts, and as such differs slightly from EIA terminology, and in some cases those defined by BMAPA/The Crown Estate. Some discrepancies do exist, for example the use of the term 'spatial overlap' in this MAREA as opposed to 'interaction' for the Thames MAREA.

The MAREA assessment is not designed to replace individual EIAs and the assessment of impact significance can only support decisions about cumulative and in-combination impacts if being applied specifically to EIA. The MAREA is distinct from EIA and other large scale assessments such as SEA because it is a non-statutory planning tool; it assigns impact significance at a different scale, and it does not address mitigation measures as this remains inherent to EIA.

The process for undertaking a MAREA is defined, yet the assessment of regional cumulative and in-combination impacts still remains poorly understood, despite legislative requirements from various EC Directives (e.g. since 85/337/EEC) to promote cumulative assessments. RAG guidance was developed to help steer MAREA studies and provide recommendations rather than statutory requirements.

A wide range of cumulative and in-combination impact methods have been considered as part of this MAREA, and a commonly occurring feature is their reliance on professional judgement and best-practice. The reliance on professional judgement requires an evidence-based approach that must be auditable when evaluating potential changes to baseline conditions. Here, the evidence-based approach takes account of data and information from the scientific and grey literature, and includes a wide range of different analytical methods to describe and interpret this evidence.

Cumulative and in-combination impacts involve complex interactions with equally complex data requirements and limitations - both at spatial and temporal scales. For this reason, the range of different analytical methods used included conceptualisation, consultation, matrices, categorical, historical, statistical analysis, GIS, numerical modelling, field data and observations. Applying these multiple methods was beneficial because it augmented qualitative and quantitative data to address these complexities.

Assessing cumulative and in-combination impacts is a complex process and so the final results are often equally complex. MAREA is intended to simplify this and ensure its interpretation is straightforward to enable regulators and stakeholders to understand the findings (Freeman, 2010).

The effectiveness of the MAREA assessment is largely due to comprehensive modelling (see Section 30.5) of potential effects and the use of GIS to map both effects and receptors. GIS was used to perform important functions, namely screening-out receptors not interacting with effects; and calculating the spatial extent of a receptor potentially impacted by an effect, relative to the total area of receptor across the region and sub-region. Understanding the spatial extent or value of the receptor was an important decision making parameter in assigning impact significance. Because this function was effective, a method for mapping the spatial extent of impacts considered to be significant was developed. Here, an impact matrix that combined magnitude, sensitivity and value was used (see Chapter 3). The advantage was an alternative perspective on understanding the nature or scale of the impact to that conventionally left to a description in the text.

Importantly, the impact assessment was not conducted in isolation to the rest of the MAREA process. Data and information gathered during the initial scoping phase, stakeholder consultation and baseline data acquisition were used to inform the assessment at various stages.

30.5 CONCEPTUALISING AND MODELLING EFFECTS

- A key component of the assessment process was conceptualising the dredging process in order to understand how the physical effects of dredging potentially alter sensitive receptors. Pathways of exposure linking physical effects to their source (e.g. drag head, overspill, vessel presence etc.) and to potentially sensitive receptors were identified (see Chapter 5). This was a critical step in assessing cumulative impacts as it builds a conceptual picture of the effect-receptor relationship and was part of the systematic approach to the assessment.

- This type of analysis formed the foundation on which the assessment was based. It is also advantageous because it aids understanding from the assessor, regulator and stakeholder perspective; helped develop assumptions to support the assessment; it provided the basis for receptor selection; and it identified areas where uncertainty in the data existed.

- A third generation 'state of the art' spectral wave transformation model for coastal studies known as SWAN (Simulating Waves in the Nearshore) was used to assess potential changes to wave heights due to aggregate extraction (see Chapter 6). The advantage of this model over others was that it is freely available; it is widely accepted by scientific and regulatory bodies and it has been tested rigorously with real empirical case studies. Additionally, TELEMAC and Sandflow numerical models were used to assess changes to peak tidal currents and sediment flux, respectively. All of the models were calibrated and validated with field data.

- Importantly, the modelling exercise allowed AODA the opportunity to assess potential changes to coastal and marine environments and subsequently modify proposed plans where the effects were considered to be unacceptable. This is especially important with regards to coastal areas and locations with important and sensitive receptors.

30.6 CUMULATIVE IMPACT FINDINGS

The MAREA cumulative impact assessment has identified receptors that are potentially impacted by aggregate extraction. Current and future projected levels of dredging activity at the regional and sub-regional scale were considered to be within environmentally acceptable parameters (see Section 30.3). The following sections take account of these impacts.

30.6.1 Potential Impacts to the coastline and inshore banks

The MAREA coastline and inshore banks were assessed based on an understanding of the regional and sub-regional characteristics of these receptors within the MAREA region. It was important to understand how these receptors may be impacted by changing hydrodynamic conditions.

Understanding potential future change in the coastline and inshore banks as a result of cumulative aggregate extraction activities is an issue that requires careful consideration, especially in light of climate change. The SWAN model predicts changes in wave heights across the region as a result of aggregate extraction using various scenarios. The TELEMAC and SANDFLOW models were used to predict changes in peak tidal current speeds and sediment flux across the region. It was also important to examine potential changes attributed to fine sand dispersion. For this purpose, a desk based assessment using worst case scenarios, coupled with tidal current data was undertaken.

In the Southwold sub-region it was concluded that proposed future marine aggregate extraction will have no impact on the Anglian MAREA region coastline or inshore banks, since none of the effects are predicted to overlap with these receptors, even assuming worst case scenarios.

In the Yarmouth sub-region it was concluded that the proposed marine aggregate extraction will have no impact on the coastline since no overlap was predicted. However, there are some small, localised areas of overlap between the inshore banks and the effects of fine sand dispersion, sediment flux (attributed to changes in peak tidal current speeds) and increases in wave heights. Since, the inshore banks play an important role in sheltering the coast from storms, and as a precautionary principle, the impact of these effects is considered to be of ***Minor Significance***.

On a regional scale, the modelling results show that there is no overlap of cumulative effects from aggregate extraction with any coastal for either Yarmouth or Southwold sub-regions. All effects of aggregate extraction on the coast are therefore assessed as being ***Not Significant*** from a regional perspective. Although some minor overlap is predicted for inshore banks and waves, flux and fine sand dispersion for the Yarmouth sub-region, from a regional perspective, the impact is considered to be ***Not Significant***.

30.6.2 Potential Impacts to benthic ecology

Species sensitivity and consideration of the spatial extent of biotopes within the MAREA region have been a critical component in this assessment. The total area of overarching habitats was used to determine how common they were within the region and to provide an indicative value for percentage loss due to future cumulative impacts from dredging activities.

The MAREA region supports a low diversity of biotopes, with sublittoral unstable coarse sediments (SS.SCS) and its sub-divisions dominating the region. These are of national conservation importance, both as BAP and MCZ habitats. The relatively widespread *Sabellaria spinulosa* biotope designated within the region is afforded international protection under the Habitats Directive (92/43/EEC) only when reef is present.

The overall sub-regional cumulative impact assessment for the Yarmouth and Southwold sub-region is ***Not Significant*** for the sublittoral coarse sediment and sublittoral sand biotopes and complexes. These biotopes are considered generally adaptable to disturbance given their widespread occurrence (JNCC, 2011) and the natural mobility of sediments within the regions' high-energy environment.

In the Yarmouth sub-region, the highly protected *S. spinulosa* biotope **SS.SBR.PoR.SspiMx** is significantly impacted by seabed removal, suspended sediment plume, fine sand dispersion and sediment flux, however Last *et al*. (2011) suggests that the impacts may not be entirely detrimental. All potential impacts are considered of ***Minor Significance***.

In the Southwold sub-region there is also an overlap between the effect envelopes for seabed removal, suspended sediment plume, fine sand dispersion and sediment flux and the *S. spinulosa* biotope. Again the potential impacts are considered of ***Minor Significance*** for the sub-region.

On a regional scale, the overall cumulative impact significance on biotopes as a result of future dredging activities is ***Not Significant***. This is largely because most of the biotopes fall under the overarching habitat type sublittoral coarse sediments. These are considered generally adaptable to change given their wide distribution throughout the UK and their adaptation to the naturally disturbed conditions within the region.

30.6.3 Potential Impacts to fish and shellfish ecology

The MAREA region supports suitable habitats and feeding grounds for maintaining adult stocks of several fish and shellfish species and also critical habitats required for their survival and long term success. However, in the majority of cases where overlap of spawning and nursery grounds occur with aggregate licences, the availability of suitable grounds is widespread both within the region and beyond.

The sub-regional cumulative impact assessment for both the Yarmouth and Southwold sub-regions is overall ***Not Significant***. The sub-regions support spawning and nursery grounds for a number of species but where overlap occurs, the availability of alternative ground is widespread. The exception being for herring in the Yarmouth sub-region which is considered of ***Minor Significance*** as the species has a specific habitat preference and a high level of uncertainty surrounds the presence and use of available habitat.

On a regional scale, the overall cumulative impact significance on fish and shellfish populations as a result of future dredging activities is ***Not Significant***. Although the region supports a number of commercially and ecologically important species and spawning and nursery grounds, in most cases where overlap with any licence areas or effects footprints occurs, the extent of alternative habitat is considered widespread across the region and in many cases beyond. However a precautionary assessment of ***Minor Significance*** is assigned to herring within the Yarmouth sub-region as detailed above.

30.6.4 Potential Impacts to marine mammals and turtles

It is acknowledged that sightings data are generally opportunistic and little systematic data are available for the region as a whole, uncertainty in the data is high for marine mammals with regard to their presence and use of the region. There is no indication that the region provides critical habitats or prey to support any species of marine mammal or turtle. Many species are considered to be in transit to other suitable feeding and breeding grounds outside the region, the exception being common and grey seals, which are considered to be resident year round (JNCC, 1995; NNNS, 2009).

At both the MAREA sub-regional and regional scales, the overall cumulative impact significance as a result of future dredging activities is considered ***Not Significant***. Given the mobile nature of the species, the assessment has been taken at a regional scale taking an assumption that where sightings have occurred, these species are present throughout the region as a whole. Marine mammal diversity is generally low off eastern England and all species appear to be less common than in the wider North Sea.

Marine mammals are mobile species that can avoid areas of active dredging and resulting effects from seabed removal, vessel displacement, noise and vibration and suspended sediment plumes and are able to return to the area once dredging has ceased. Moreover, their feeding habits and behaviour suggest they are unlikely to be reliant upon resources within dredging areas and are highly adaptable to changes in physical conditions.

Scroby Sands is the only haul-out site for the common seal within the MAREA region and supports 3.1% of the regional total (JNCC, 1995). However, common seals are inshore foragers and prey species are common throughout the MAREA area and wider region.

Sightings of marine turtles are believed to represent animals at the extreme limits of their range and the recorded leatherback turtle stranding is almost certainly a result of migratory movements.

30.6.5 Potential Impacts to ornithology

The coastline and waters of the MAREA region support suitable habitats and feeding grounds for maintaining breeding, wintering and migratory bird populations of international, national and local importance. In particular, gulls, terns, divers, grebes and mergansers, auks and other birds all have the potential to be impacted by future cumulative extraction effects. Initially, the effects of seabed removal, noise and vibration, suspended sediment plume, fine sand dispersion, bathymetry changes and sediment flux were considered to have potential impact on these birds. However, based on the regional cumulative impact assessment, the majority of species and habitats are unlikely to be significantly impacted. Given the mobile nature of all species, the assessment has been taken at a regional scale taking an assumption that where sightings have occurred, all species are present throughout the region as a whole

The sub-regional cumulative impact assessment for bird receptors in the Yarmouth and Southwold sub-regions is overall ***Not Significant***. The exceptions to this are seabed removal and noise and vibration (disturbance) and suspended sediment which were assessed to be of ***Minor Significance*** in relation of seaducks, red throated divers and terns, due to their restricted foraging range coincident with a number of licence areas. In addition the impacts on auks from suspended sediment were considered of ***Minor Significance***.

At the regional scale, the overall cumulative impact significance on bird populations as a result of future dredging activities is assessed as ***Not Significant***. This is because the majority of seabirds that occur in the MAREA region are generally adaptable to change given their wide feeding preferences and presence throughout the region. Noteworthy is the presence of the internationally and nationally important species protected by SPAs in the region, in particular the red throated diver which is protected by the Outer Thames SPA which overlaps directly with licence areas in both sub-regions, but also of note is the presence of designated tern species.

30.6.6 Potential Impacts to nature conservation

The MAREA region supports a large number of statutory and non-statutory designations at a local, national and international level. However, a large number of these are restricted to the coastal zone, with only a small number having a marine component. Direct impacts from aggregate extraction which are restricted to the licence area footprint are only predicted where overlap between licence areas and designated sites occur. This is limited to the Outer Thames SPA and the Haisborough, Hammond and Winterton SAC. However, a number of licence areas fall within foraging range of designated species from SPA sites within and beyond the region.

Potential direct impacts on nature conservation sites within the Yarmouth sub-regions are limited to the Outer Thames SPA and Haisborough, Hammond and Winterton SAC. This is due to the potential impacts of seabed removal and vibration and suspended sediment on the qualifying feature for the red throated diver, and for seabed removal, suspended sediment, fine sand dispersion and sediment flux for reef sub features. For these effects the impact significance for the Yarmouth and Southwold sub-regions is assessed as being of ***Minor Significance***.

At the regional scale, the overall significance of the cumulative impact upon nature conservation sites, features and sub-features as a result of future dredging activities is, in general, considered ***Not Significant***.

The majority of sandbanks that comprise the qualifying features of the Haisborough, Hammond and Winterton SAC lie to the north of the MAREA region. There is an overlap between effects envelopes and the Newarp and Middle Cross Sands sandbanks, but these effects were considered to be negligible and therefore ***Not Significant***.

30.6.7 Potential Impacts to commercial and recreational fisheries

The MAREA region includes a range of different fishing methods targeting a range of fish species. The receptors can be split into four categories based on vessel range and gear type, namely the inshore, middle ground and offshore fleet and recreational fishing. Both the inshore and middle ground fleets employ small vessels that rely on regional ports and are therefore more sensitive to potential impacts. The potential impact on the offshore fleet is considered the least sensitive, given their extensive range and use of areas that overlap with aggregate dredging footprints are opportunistic in nature. The potential for impact on the recreational fleet has proven more difficult to assess given the lack of any published information or available official data for the region.

The sub-regional cumulative impact assessment for both the Yarmouth and Southwold sub-region is assessed overall as being ***Not Significant***. Exceptions are for the impacts of vessel displacement on long lining and potting for the inshore and middle ground fleets, where the potential impacts for these gear types are considered to be of ***Minor Significance***.

Based on the regional cumulative impact assessment, all impacts were considered to be ***Not Significant*** for all gear types across all fleets at a regional scale. Commercial and recreational fishing and aggregate dredging have co-existed in the region for decades. Studies have found no evidence that dredging activity has displaced the main areas of fishing activity and trends in dredging and fishing effort off the east coast have to a large extent been similar since the mid-1980s (Kenny *et al*., 2010; Vanstaen *et al*., 2010).

30.6.8 Potential Impacts to navigation

The MAREA region is characterised by relatively moderate shipping densities, comprising cargo vessels, tankers, ferries, fishing vessels and dredgers operating in the region or en route to the region's ports of Great Yarmouth or Lowestoft and to the near continent.

The aggregate areas within the Yarmouth sub-region are typically located within or adjacent to moderate shipping densities, primarily due to shipping lanes which pass north-south and northeast-southwest (MARICO Marine, 2011). The Southwold sub-region is located in an area of significantly lower shipping densities located away from the main shipping lanes.

The assigned impact significance show dredger presence and vessel displacement to be of ***Minor Significance*** in the Yarmouth sub-region and ***Not Significant*** in the Southwold sub-region. As a result the regional input is considered to be of ***Minor Significance***.

Based on the traffic levels and risks in the MAREA region, the cumulative impact from future dredging is considered to be largely similar to current traffic levels and collision risk. Moreover, any new dredge areas will be marked on charts and are in close proximity to existing licence areas.

30.6.9 Potential Impacts to infrastructure and other marine users

Much of the MAREA region's infrastructure is well established, documented and spatially defined. The assessment considers oil and gas infrastructure such as exploration wells, renewable energy and associated infrastructure licensed under Round 1, cables and pipelines including active and out-of-service telecommunication cables, pipelines and waste water outflows, open and closed dredge spoil disposal sites, recreational sailing activities and facilities, diving activities, coastal tourism and recreation, coastal defences and potential developments known to be in the planning system (including port and harbour developments, channel dredge projects and Round 3 zones for offshore wind energy).

Coastal tourism is largely unaffected by aggregate extraction activities given the remote location of aggregate sites from bathing beaches and the coastline; use of existing wharves and have no permanent visual presence. Other recreational activities in the MAREA region are predominantly sailing, diving and recreational angling. As is the case throughout UK waters, these activities can occur across the MAREA region throughout the year.

Although the MAREA region is comprised of potentially numerous marine infrastructure and marine user effect-receptor interactions, it can be concluded that the impacts from aggregate extraction on any of the receptors will be ***Not Significant***.

30.6.10 Potential Impacts to archaeology

The archaeological record is widely scattered across the MAREA region, and there is marked variability in knowledge and understanding of its extent, distribution, value and importance. All archaeological receptors are, however, immobile, non-renewable and finite in nature and any adverse impacts on the archaeological baseline will be permanent and irreversible.

Seabed removal as the primary, direct effect of aggregate dredging will have a permanent effect on any archaeological sites or materials it impacts. Known sites can be excluded from the effects of seabed removal through the implementation of exclusion zones. The unknown elements, the existence of which can be predicted on the basis of historical research, are more susceptible to the effects of seabed removal and appropriate mitigation measures must be put in place to ensure that sites or material are not negatively impacted by dredging.

Changes to bathymetry will affect the immediate dredging footprint and, potentially, a limited area beyond it. It is unlikely that this effect will be felt much beyond individual licence area boundaries. Changes to seabed bathymetry have the potential to modify the upstream current and flow regime causing seabed scour and sediment flux. This can expose previously buried archaeological material through erosion, making it vulnerable to physical, chemical or biological attack, degradation and loss.

Sediment flux or transport may have either a negative or positive effect on archaeological receptors. Where it is accompanied by a net loss of sediment, it can result in the exposure of previously buried archaeological material. Where it results in net sediment gain and site burial, sediment flux is likely to be positive for the longer term preservation of archaeological sites.

30.7 CUMULATIVE MAPPING OF MULTIPLE IMPACTS

Mapping the combined cumulative impacts for multiple effects was deliberately not assigned an impact significance category. The potential interactions between multiple effects was considered too complex and the interpretation too subjective to be meaningful. However, it was considered appropriate to map the extent of multiple effects that were consider to have potentially significance impacts, where the total number of overlapping impacts was counted to produce a 'heat map' of multiple cumulative impacts (**Figure 30:1**). This is achieved using a weighted grid in GIS to calculate the number and spatial extent of multiple effects.

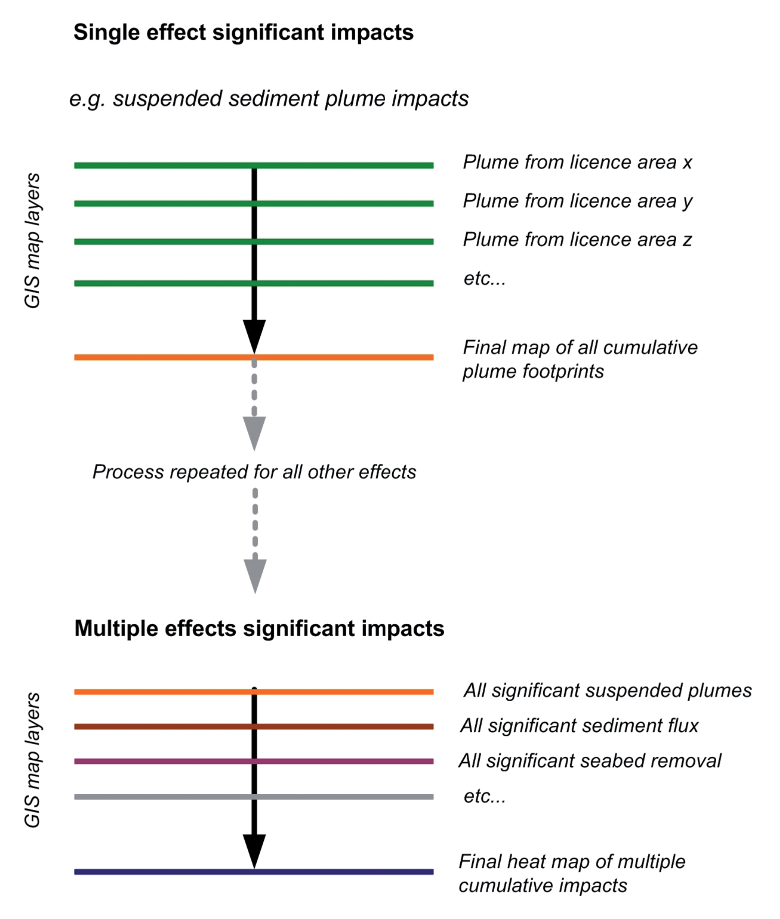

Figure 30:1 Conceptual illustration showing how GIS is used to map cumulative impacts for single and multiple impacts

Figure 30:2 shows that multiple effects, which are considered to have potentially significant impacts, typically occur in close proximity to the Licence Areas. It can also be seen that while cumulative effects occur within sub-regions, there is no overlap between multiple effects from adjacent sub-regions

30.8 NEXT STEPS

Next steps are:

- Consideration of comments. Although the MAREA will not be updated following circulation, comments received will be considered at the EIA/site specific consultation stage;
- Consideration by individual AODA members of the environmental aspects of their dredging proposals. Based on the results of the MAREA, individual companies may alter their proposals;
- Development of site specific EIA to incorporate and develop REA findings. Based on the findings of this MAREA assessment **Tables 30:1** and **30:2** provide a summary of the recommendations for further assessment at EIA. These are captured according to sub-region and licence area; and
- Consideration of appropriate scale and scope of mitigation and monitoring for inclusion within consultation stages of EIA.

It is recommended that the AODA companies continue to work together to develop a regional approach to managing dredging activity once licence renewals are forthcoming in the coming years. This includes regional monitoring where possible, that is beneficial and desirable to both operators and industry regulators. At the time of writing, the Industry has already begun dialogue with The Crown Estate on this topic and an industry charter setting out a commitment by each company to do the following, has been drafted:

- Monitor, mitigate and manage environmental impacts and operational activity on a regional basis;
- Develop generic monitoring, mitigation and management plans for regions based on MAREA's and other studies;
- Work together with all the other aggregate companies in the region in a constructive, flexible and timely basis to deliver plans to agreed timescales;
- Align existing permissions with regional monitoring plans over time;
- Co-operate in the planning, procurement, management and reporting of regional monitoring activities;
- Engage with the regulator and their advisors at a regional scale;
- Be transparent by making all relevant dredging and monitoring data publicly available through regular reporting;
- Share costs, effort and responsibility in a proportionate way in developing the concept in each region; and
- Work with The Crown Estate to deliver plans.

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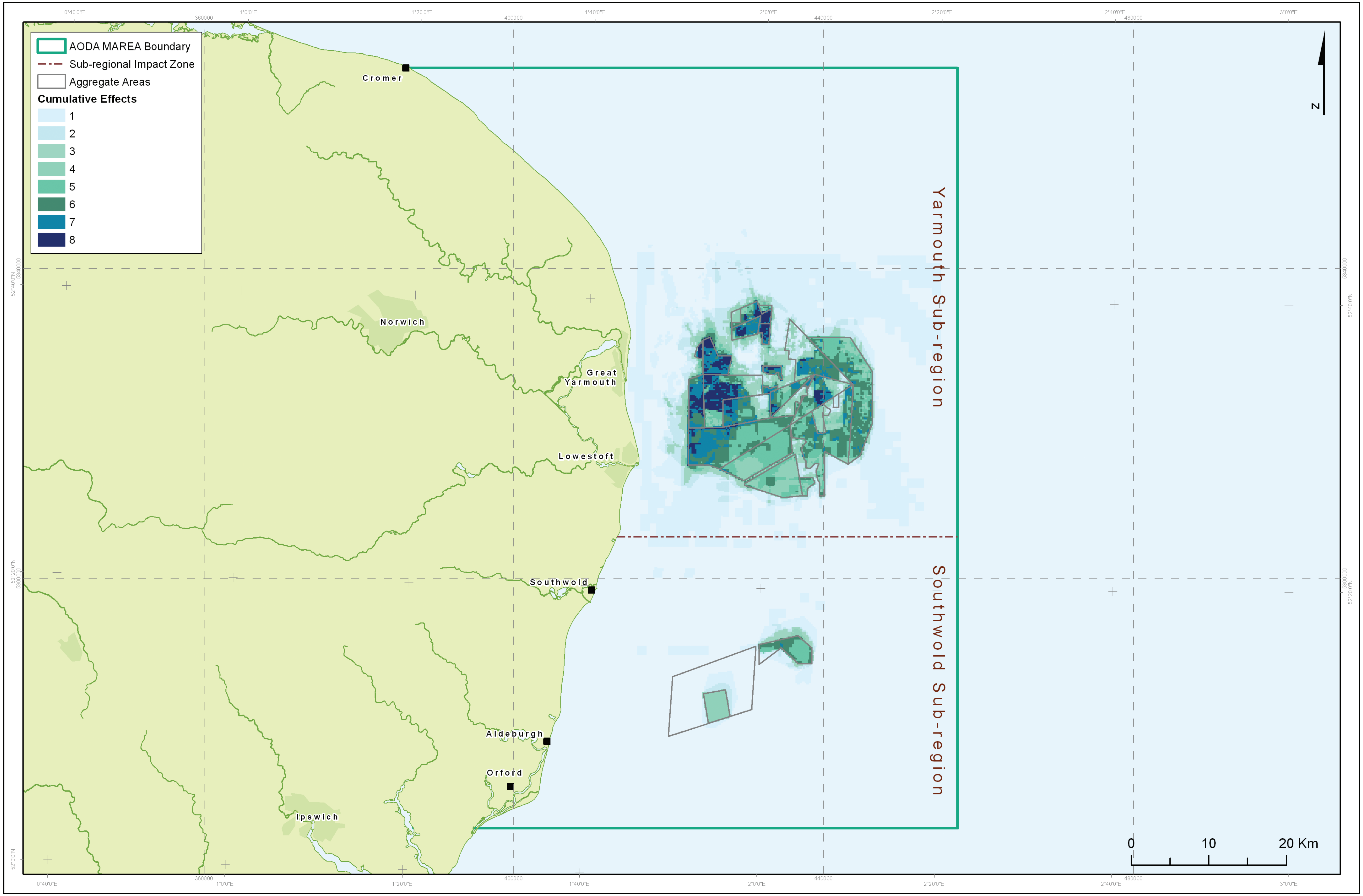

Figure 30:2 Multiple effects of dredging within the MAREA region. Note: the majority of overlapping effects are concentrated within the aggregate areas.

Sub-region	Receptor to be assessed at site specific EIA												Specific ecommendations
	Licence Area	Coastline	Inshore Banks	Benthic Ecology	Fish and Shellfish	Marine Mammals & Turtles	Ornithology	Nature Conservation	Commercial & Recreational Fisheries	Navigation	Infrastructure	Archaeology	
Yarmouth	251	No	Yes	Yes	Herring potential*	No	Yes	No	Yes	No	No	Yes	● Inshore banks: site specific assessments at EIA level for waves, flux and fine sand dispersion are recommended for aggregate areas located adjacent to any inshore banks. ● Benthic ecology: site specific assessments at EIA level based on local habitat distributions, significant local features and dredging patters will be required for all licences within the sub-region; ● Commercial and recreational fisheries: site specific assessments utilising up to date fisheries statistics data for the relevant ICES squares should be made at EIA level for all licences; ● Archaeology: site specific assessments of geophysical and geotechnical data, newly discovered artefacts and new wreck information should be made at EIA level for all licences; ● Herring spawning: assessment of the suitability of available habitat for herring spawning* should be undertaken for all licence areas*; ● Ornithology: consideration should be given to use of area by seaducks, red throated diver, auks and terns for all licence areas; ● Future developments: Consideration of any future developments, in particular in relation to Round 3 offshore wind farm cable routes should be undertaken for all licence areas; ● Nature conservation: Consideration should be given to identification of potential reef features where overlap occurs with the Haisborough, Hammond and Winterton SAC**
	319	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	360	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	430	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	202	No	Yes	Yes	Yes	No	Yes	Yes**	Yes	No	No	Yes	
	212	No	No	Yes	Yes	No	Yes	Yes **	Yes	No	No	Yes	
	240	No	Yes	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	328 a,b,c	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	242	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	361	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	401/2	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	254	No	Yes	Yes	Yes	No	Yes	Yes**	Yes	No	No	Yes	
	296	No	No	Yes	Yes	No	Yes	Yes**	Yes	No	No	Yes	
	228	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	494	No	No	Yes	Yes	No	Yes	Yes**	Yes	No	No	Yes	
	454	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	495A	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	
	495	No	No	Yes	Yes	No	Yes	No	Yes	No	No	Yes	

Table 30:1 Requirements for receptor analysis at site specific EIA level and specific recommendations for the Yarmouth sub-region.

Sub-region	Receptor to be assessed at site specific EIA											Site specific Recommendations
	Licence Area	Coastline	Inshore Banks	Benthic Ecology	Fish and Shellfish	Marine Mammals & Turtles	Ornithology	Nature Conservation	Commercial & Recreational Fisheries	Navigation	Infrastructure	Archaeology	
Southwold	430	No	No	Yes	Yes*	No	Yes	No	Yes	No	No	Yes	● Benthic ecology: site specific assessments at EIA level based on local habitat distributions, significant local features and dredging patterns will be required for all licences within the sub-region; ● Commercial and recreational fisheries: site specific assessments utilising up to date fisheries statistics data for the relevant ICES squares should be made at EIA level for all licences; ● Archaeology: site specific assessments of geophysical and geotechnical data, newly discovered artefacts and new wreck information should be made at EIA level for all licences; ● Herring spawning: assessment of the suitability of available habitat for herring spawning* should be undertaken for all licence areas; ● Ornithology: consideration should be given to use of area by seaducks, red throated diver, auks and terns for all licence areas; ● Future developments: Consideration of any future developments, in particular in relation to Round 3 offshore wind farm cable routes should be undertaken for all licence areas.
	496	No	No	Yes	Yes*	No	Yes	No	Yes	No	No	Yes	

Table 30:2 Requirements for receptor analysis at site specific EIA level and specific recommendations for the Southwold sub-region