HADA
Humber Aggregate Dredging Association

Marine Aggregate Regional Environmental Assessment of the Humber and Outer Wash Region

Volume II: Chapters 7 – 12

May 2012

ERM

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Hanson HEIDELBERGCEMENTGroup
Tarmac
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HUMBER AGGREGATE DREDGING ASSOCIATION

MARINE AGGREGATE REGIONAL ENVIRONMENTAL ASSESSMENT OF THE HUMBER AND OUTER WASH REGION

May 2012

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ACRONYMS

A

AA	Appropriate Assessment
ABP	Associated British Ports
ABPmer	ABP Marine Environmental Research Ltd
ADZ	Active Dredge Zone
AEZ	Archaeological Exclusion Zone
AIS	Automatic Identification System
AMAP	Area of Maritime Archaeological Potential
ANOVA	Analysis of Variance
AONB	Area of Outstanding Natural Beauty
AoS	Areas of Search
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (United Nations)

B

BAT	Best Available Technique
BAP	Biodiversity Action Plan
BGS	British Geological Survey
BMAPA	British Marine Aggregate Producers Association
BODC	British Oceanographic Data Centre
BWEA	British Wind Energy Association

C

CA	Cruising Association
CBD	Convention on Biological Diversity
Cefas	Centre for the Environment, Fisheries and Aquatic Sciences
CFP	Common Fisheries Policy
CIS	Coastal Impact Study
CITES	Convention on International Trade in Endangered Species
CRoW Act	Countryside and Rights of Way Act
cSAC	Candidate Special Area of Conservation

D

dB	decibel
DECC	Department of Energy and Climate Change
Defra	Department for Environment, Food and Rural Affairs
DHI	Danish Hydraulic Institute
dSAC	draft SAC
DTI	Department of Trade and Industry
DW	Deep Water
DWT	Deadweight Tonnage

E

EA	Environment Agency
EC	European Community
EEZ	Exclusive Economic Zone
EH	English Heritage
EIA	Environmental Impact Assessment
EMS	Electronic Monitoring System
ENG	Environmental Network Guidance
EPS	European Protected Species
EQO	Ecological Quality Objectives
ERM	Environmental Resources Management
ERYC	East Riding of Yorkshire Council
ES	Environmental Statement
ESAS	European Seabird At Sea
EUNIS	European Nature Information System

F

FEPA	Food and Environment Protection Act
FOCI	Features of Conservation Importance
F15EZ	Future 15 Year Extraction Zones

G

GHG	Greenhouse Gas
GIS	Geographical Information System
GVA	Gross Value Added

H

HADA	Humber Aggregate Dredging Association
HAML	Hanson Aggregates Marine Ltd
HAT	Highest Astronomical Tide
HCFIG	Holderness Coast Fishing Industry Group
HECAG	Humber Estuary Coastal Authorities Group
HER	Historic Environment Records

HGOWF	Humber Gateway Offshore Windfarm

I

ICES	International Council for the Exploration of the Sea
IFCA	Inshore Fisheries and Conservation Authorities
IMO	International Maritime Organisation
IROPI	Imperative Reasons of Overriding Public Interest
IUCN	International Union for Conservation of Nature

J

JAMP	Joint Assessments and Monitoring Programme
JNCC	Joint Nature and Conservation Committee

K

KIS	Kingfisher Information Service

L

LNR	Local Nature Reserve

M

MAIB	Marine Accident Investigation Branch
MALSF	Marine Aggregates Levy Sustainability Fund
MAREA	Marine Aggregate Regional Environmental Assessment
MarLIN	Marine Life Information Network
MCAA	Marine and Coastal Access Act
MEPF	Marine Environment Protection Fund
MERMAN	Marine Environment Monitoring and Assessment National Database
MESH	Mapping European Seabed Habitats
MHWS	Mean High Water Springs
MIRO	Mineral Industry Research Organisation
MLWS	Mean Low Water Springs
MMCG	Marine Mammal Criteria Group
MMO	Marine Management Organisation
MNA	Marine Natural Area
MoD	Ministry of Defence
MPA	Marine Protected Area
MPS	Marine Policy Statement
MSC	Marine Stewardship Council
MZI	Maximum Zone of Influence

N

NBN	National Biodiversity Network
NE	Natural England
NEIFCA	North Eastern Inshore Fishery & Conservation Authority
NELC	North East Lincolnshire Council
NERC	Natural Environment Research Council
NESFC	North Eastern Sea Fisheries Committee
NMMDS	Non-Metric Multi-Dimensional Scaling
nm	Nautical Mile
NNDC	North Norfolk District Council
NNR	National Nature Reserve
NRHE	National Record of the Historic Environment
NTS	National Transmission System

O

ODN	Ordnance Datum Newlyn
ODPM	Office of the Deputy Prime Minister
OSPAR	Oslo and Paris Commission for the protection of the marine environment of the North East Atlantic (1992)

P

PEL	Probable Effect Level
PEXA	Practice and Exercise Areas
PIZ	Primary Impact Zone
PSA	Particle Size Analysis
PMSL	Precision Marine Survey Ltd
PRIMER	Plymouth Routines In Multivariate Ecological Research
pSPA	Potential Special Protection Areas

R

RAF	Royal Air Force
RAG	Regulatory Advisors Group
REA	Regional Environmental Assessment
REC	Regional Environmental Characterisation
rMCZ	Recommended Marine Conservation Zone
RMNC	Review of Marine Nature Conservation
rRA	Recommended Reference Area
Ro-Ro	Roll-on Roll-off

RSPB	Royal Society for the Protection of Birds
RYA	Royal Yachting Association

S

SAC	Special Area of Conservation
SAP	Species Action Plan
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCOS	Special Committee on Seals
SIZ	Secondary Impact Zone
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SMP	Shoreline Management Plan
SMRU	Sea Mammal Research Unit
SNSSTS	Southern North Sea Sediment Transport Study
SOCC	Species of Conservation Concern
SSB	Spawning Stock Biomass
SSSI	Site of Special Scientific Interest

T

TAC	Total Allowable Catch
TCE	The Crown Estate
TEL	Threshold Effect Level
TMD	Tarmac Marine Dredging Ltd
TSS	Traffic Separation Schemes
TOS	Traffic Organisational Service
TSHD	Trailer Suction Hopper Dredger

U

UKHO	UK Hydrographic Office
USAF	US Air Force

V

VMS	Vessel Monitoring System
VTS	Vessel Traffic Services

W

WCA	Wildlife and Countryside Act
WFD	Water Framework Directive
WWTC	Wildfowl and Wetlands Trust Consulting
WMROWF	Westermost Rough Offshore Wind Farm

GLOSSARY

Abiotic	Refers to non-living objects, substances or processes e.g. climate
Abundance	The number of individuals of a particular species or group.
Accretion	The accumulation of sediment in a specific depositional environment
Adaptability	The ability of the receptor to avoid adverse impacts that would otherwise arise from a particular effect of dredging
Advection	Horizontal movement.
Aggregate	A mixture of sand, gravel, crushed rock or other bulk minerals used in construction and civil engineering.
ALSF (MALSF)	The Aggregates Levy Sustainability Fund (ALSF) is a scheme developed that uses some of money generated by the Aggregates Levy to reduce the environmental impacts of the extraction of aggregates, both on land and from the sea, and to deliver benefits to areas subject to these impacts.
All-in	A marine aggregate cargo that has been loaded without onboard processing (i.e. no screening conducted).
Alluvial deposits	Sediment deposited by flowing water, as in a river bed, flood plain or delta.
Amphidrome	A point within a tidal system where the tidal range is almost zero.
Amphipods	(Phylum Arthropoda, Class Malacostraca, Order Amphipoda) are small, shrimp-like crustaceans recognised by their laterally compressed bodies, lack of a carapace, and numerous, differently modified legs.
Anthropogenic	Derived from, caused by or relating to humans.
Anadromous	Organisms that live in marine waters but migrate to freshwater to breed
Appendicularians	(Phylum Chordata) or larvaceans are solitary, free swimming tunicates. They are filter feeders, live in the pelagic zone. Planktonic organisms 1 cm in length.
Application Area	An area within which a marine aggregate producer has identified commercially viable aggregate resources, has secured an exclusive option with the mineral owner (normally The Crown Estate) and for which a permission to dredge is being sought.
Archaeological Exclusion Zone	A defined zone within a dredging licence area where dredging is not permitted to protect archaeological features such as wrecks.
Archaeological Exclusion Zone	A defined zone within a dredging licence where extraction is prohibited to protect archaeological features- including wrecks.
Automatic Identification System	A system used to track a ship's location.
Backshore	The area of a beach extending from the limit of high water to the extreme inland limit of the beach.
Bathymetry	The depth and topography of the seabed, usually measured from the sea surface.
Beach Replenishment/ Nourishment / Recharge	The process of placing new sediment onto beaches to replace sediment lost through erosion.
Beach toe	The distance to the first break in slope of the submerged beach.
Bedform	A depositional feature on the bed of a river or other body of flowing water that is formed by the movement of bed material due to the flow. The shape of the surface of a bed of granular sediment, produced by the flow of air or water over the sediment.
Bedload	Particles of sand, gravel, or soil carried by the natural flow of a tidal stream or current either on or immediately above the seabed.
Bedrock	The substrate beneath a marine aggregate deposit.
Bed Shear Stress	A measure of the collective force of waves and currents exerted on the seabed.
Benthic	The ecological zone at the lowest level of the water column including the surface layer of sediment, and also refers to bottom-dwelling organisms.
Berne Convention	The Convention of the Conservation of European Wildlife and Natural Habitats 1979. The aims of the convention were to ensure conservation and protection of wild plant and animal species and their natural habitats.
Bioaccumulation	The accumulation of substances, such as contaminants, in an organism at a higher concentration than in the surrounding environment.
Biodiversity Action Plan	The UK Biodiversity Action Plan is the Government's response to the Convention on Biodiversity 1992. It describes the UK's biological resources and commits to preparing a detailed plan on the protection of these resources.
Biogenic Reef	A reef produced by biological processes and composed predominantly of living organisms.
Biotope	This report refers to biotopes as a description of the benthic marine habitats as defined by JNCC's Marine Nature Conservation Review (MNCR).
Birds Directive	The Directive (79/409/EEC) provides a framework for the conservation and management of, and human interactions with, wild birds in Europe.
Bivalves	(Phylum Mollusca, Class Bivalvia) are organisms characterised by having two hard outer shells and they usually live in the intertidal and subtidal coastal zone. They include oysters and mussels.
Biogenic reef	Reef structures formed by animals such as blue mussel. Biogenic reefs generally support higher biodiversity than the surrounding seabed.
Bolders Bank Formation	A stiff clay-rich glacial till of late Devensian (Weichselian) age in the southern North Sea.
Boreal Waters	Subarctic waters of the northern hemisphere.
Botney Cut Formation	Stiff to soft muddy glacio-marine sediments of late Devensian (Weichselian) age infilling sub-glacial valleys and depressions cut into the Bolders Bank Formation.
Bottom dwelling	Organisms that live on or close to the sea bed.

Broadband noise	A broadband noise level is a measurement of noise over a wide (or broad) frequency range. This is in contrast to a frequency band noise level (for example an octave band noise level) which is a measurement of noise centred on a narrow band of frequencies.
Bycatch	Part of a catch of a fishing unit taken incidentally in addition to the target species towards which fishing effort is directed. It typically includes fish but may also include seabirds and marine mammals. Some or all of it may be returned to the sea as discards, usually dead or dying.
Carapace	A dorsal section of the exoskeleton or shell in a number of animal groups, including arthropods such as crustaceans and arachnids.
Catadromous	Organisms that live in freshwater but migrate to marine waters to breed.
Cephalopods	(Phylum Mollusca) Organisms with bilateral symmetry, a prominent head and tentacles. The Class includes the octopus, squid and cuttlefish.
Cetaceans	(Phylum Chordata, Class Mammalia). The Class includes species of dolphin and whale.
Common Fisheries Policy	The fisheries policy for the European Union.
Circalittoral	The subzone of the rocky sublittoral (see below) that is below the infralittoral and is dominated by animals.
Cladocera	(Phylum Arthropoda, Class Branchiopoda) are small free-swimming crustaceans found most commonly in freshwater habitats, with few species in marine environments.
Clupeids	Clupeids are fish of the herring and mackerel family.
Crustacean	(Phylum Arthropoda, Sub-phylum Crustacea) are organisms characterised by having a hard outer shell and jointed appendages and usually live in the water and breathe through gills. They include lobsters, crabs, shrimps, and barnacles.
Ctenophores	(Phylum Cnidaria, Sub-phylum Ctenophora) commonly known as comb jellies, they have distinctive cilia that they use to swim.
Cumulative Impact	Term used in this MAREA to describe impacts that arise from multiple marine aggregate extraction activities within a region.
Deep	A bathymetric feature that is deeper (i.e. in deeper water) than the surrounding seabed.
Demersal	The part of the water column that is near to the seabed and the benthos. Demersal fish are those that spend the majority of their lifecycle on or near to the seabed.
Density Plume	A flow of water and sediment created by a dredger's overflow and screening returns that travels rapidly back to the seabed by virtue of its higher density compared with the surrounding seawater.
Detritus	Non-living particulate organic material, usually consisting of faecal matter and dead organisms.
Diatoms	Are unicellular organisms of the Kingdom Protista characterised by a silica shell. They exist singly or can form colonies and are found in marine and freshwater environments.
Diversity	An ecological term used to describe species richness in terms of the range or variety of species inhabiting an area.
Downdrift	In the direction of the net longshore transport.
Draghead	Equipment on the end of a dredge pipe that is in contact with the seabed during dredging.
Dredge Pipe	Equipment used to convey dredged material from the seabed to the dredging vessel.
Ebb Current	Movement of a tidal current away from shore.
Ebb tide	The receding or outgoing tide. Tide passing from high to low.
Ebb tide delta	An accretionary deposit of sand found on the seaward side of an inlet and usually formed by tidal currents.
EC Habitats Directive	(92/43/EEC) European Directive on the conservation of natural habitats and of wild flora and fauna. The aim of the directive is to promote the maintenance of biodiversity by requiring member states to take measures to maintain natural habitats.
Echinoderms	(Phylum Echinodermata) are invertebrate marine organisms usually characterised by a five-fold symmetry. Examples include: sea urchins and starfish.
Ecosystem services	The benefits people obtain from ecosystems, including provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.
Effect	A change to the baseline conditions that occurs as a result of development activity. The result of an effect interacting with one or more receptors will be the impact.
Elasmobranchs	(Phylum Chordata, Class Chondrichthyes) Cartilaginous fishes, including sharks, rays and skates.
Electronic Monitoring System	The 'black box' monitoring system on board a dredger that records the vessels position and activity to ensure that dredging is only undertaken within permitted zones.
Epibenthic	Living on or near the surface of the seabed.
Epibenthos / epifauna	The flora and fauna living on the seabed.
Estuaries	A partly enclosed body of water that has one or more rivers flowing into it and is connected to the open sea.
Euphausiids	(Phylum Arthropoda, Subphylum Crustacea, Class Malacostraca) are also known as Krill and are a group of shrimp-like pelagic marine invertebrates found in cold waters. They play an important part in marine food chains for whales, seabirds, herring, and gadoid species.
Exclusion Zone	An area around a defined seabed feature within which dredging is not permitted in order to prevent disturbance.
Fetch	The horizontal distance over which wave-generating winds blow.
Flood current	Movement of a tidal current towards shore.
Flood tide	The advancing or incoming tide. Tide passing from low to high.
Fluvial	Produced by the action of a river or stream.
Gadoid	Fish of the cod and hake family.

Gastropods	(Phylum Mollusca) are a class of Mollusca. The shell is an asymmetrical spiral and is carried when crawling and feeding on the extended foot. Gastropods can be found in benthic and pelagic marine environments as well as in freshwater and on land.
Geogenic Reef	Consists of stony or bedrock reef such as cobble reef structures. This habitat supports different plants and animals than the surrounding seabed.
Glacial	Recurrent cold stage of the Quaternary Period (c.2Ma – present) characterized by a global increase in ice volume, falling sea level and, in mid-latitudes, by ice sheet growth and periglaciation.
Glacial till	Poorly sorted, commonly structureless mix of clay, silt, sand and gravel deposited by a glacier or ice sheet without the action of water.
Hamon Grab	Seabed sediment sampling apparatus used to acquire small, undisturbed volume samples capable of being analysed to describe both the nature of seabed sediment particles and the organisms that live within and attached to the surface of the seabed.
Haul out sites	Hauling out is the behaviour, especially associated with pinnipeds (seals), of temporarily leaving the water between foraging activity for sites on land or ice. Haul out sites can be used for mating, giving birth, predator evasion, social activity and rest.
High Water Mark	The highest reach of the water at high tide.
Highest Astronomical Tide	The highest tide level that can be expected to occur under average meteorological conditions and under any combination of astronomical conditions.
Hopper	Hold of an aggregate dredger where seawater and sediment are pumped during loading operations.
Humber Aggregate Dredging Association (HADA)	The Association of marine aggregate extraction companies with interests in the Humber Region.
Hydrodynamic	Of, relating to, or operated by the force of liquid in motion.
Impact	A change (which can be positive or negative) in the existing baseline for a given receptor that occurs as a consequence of an activity associated with dredging in the MAREA study area.
In-Combination Impact	The total impacts of all industrial sectors operating within the same region in the context of natural variability or trends.
Infauna	Benthic organisms that live within the seabed sediments.
Infralittoral	A subzone of the sublittoral (see below) in which upward-facing rocks are dominated by algae, typically kelps.
Interglacial	Warm stage of the Quaternary Period (c.2Ma – present) separating glacial stages, characterized globally by relatively high sea level, low ice volume and, in mid-latitudes, by temperate climate
Intertidal	The area of a seashore that is covered at high tide and uncovered at low tide.
Isobath	Line, usually relating to the seabed, of equal water depth, equivalent to terrestrial contours.
IUCN Red Data List Species	This list is the most comprehensive objective global approach for evaluating the conservation status of plants and animal species.
Keystone species	A species that plays a critical role in maintaining the structure of an ecological community and whose impact on the community is greater than would be expected based on its relative abundance or biomass.
Lagoon	A body of shallow salt or brackish water that is separated from deeper sea water by a shallow or exposed barrier beach, sand bank or coral reef.
Lincshore	A beach renourishment scheme involving the relocation of sand from the seabed to the coast in order to maintain of a 23 km section of the Lincolnshire coastline between Mablethorpe and Skegness.
Littoral drift	Materials moved by waves and currents of the coastal zones. Also known as longshore drift and longshore transport.
Local Nature Reserve	Places designated by Natural England with wildlife or geological features that are of special interest locally.
Lowest Astronomical Tide	The lowest tide level that can be expected to occur under average meteorological conditions and under any combination of astronomical conditions.
Macrobenthic	Marine invertebrates measuring at least 1mm in size that live within the seabed sediments.
Marine Conservation Zone	Sites designated to protect certain marine habitats and species within English territorial waters.
Marine Licence	Statutory document issued by the Marine Management Organisation in English waters which permits, with conditions, marine aggregate dredging from prescribed areas of seabed
Marine transgression/ regression	Transgression: an advance of the sea to cover land due to a rise in the sea level relative to the land. Regression: the withdrawal of water from parts of a land surface due to a fall in sea level relative to the land.
Marl	A calcareous mudstone.
Maximum Future Extraction Scenario	The maximum potential development scenario for HADA.
Mean significant wave height	The average wave height (trough to crest) of the highest one-third of the waves in the wave spectrum.
Mollusc	(Phylum Mollusca) Unsegmented, soft-bodied animals characterised by a muscular foot (the surface on which they crawl) and a calcareous shells secreted by the mantle.
Monitoring	The process by which the actual impacts of dredging are investigated and assessed through acquisition of empirical data from within and surrounding a licence area, by means of a variety of survey techniques and methodologies.
Mysids	(Phylum Arthropda, Subphylum Crustacea, Class Malacostraca) are small shrimp-like organisms and can be found in marine and freshwater environments. The carapace is not fused with the last four thoracic segments but covers them loosely.
National Nature Reserve	Places designated by Natural England with wildlife or geological features that are of special interest nationally.
Nationally	Through UK BAP, criteria have been developed for the

Important Marine Feature	designation of sea areas containing marine landscapes, species and habitats.
Neap tide	The lowest tide in a 14 day tidal cycle.
Negative Impact	Impact results in an adverse change from the baseline conditions.
Olfactorial feeders	Organisms that use olfactory (sense of smell) cues to find food.
Overfalls	Areas of 'rough ground' In the nearshore zone which form shoaling areas over which waves break. These irregular shaped features are typically relict accumulations of till and sand and gravel, left behind by the retreating ice during the last period of glaciation.
Overspill/ Overflow	The discharge of water and associated suspended sediment that occurs through spillways at the top of a dredger's hold.
Peat	Organic rich sediment formed mainly of slightly decomposed or undecomposed plant matter that originally accumulated in a waterlogged terrestrial environment.
Pelagic	The part of the water column in the open sea that is not closely associated with the seabed.
Periglacial	A terrestrial environment where the action of freezing and thawing is or was the dominant surface process, commonly found immediately beyond present day or Pleistocene ice sheets or glaciers
Pinnipeds	(Class Mammalia, Suborder Pinnipedia) Marine carnivorous mammals including walruses and seals.
Plankton	Small micro-organisms that float or drift in great numbers in the water column.
Plume	Sediment that has been resuspended in the water column after disturbance
Polychaetes	(Phylum Annelida, Class Polychaeta) are truly segmented worms, mostly marine, and are characterised by extensions of each segment with numerous bristles projecting from them.
Porewater	The water contained within pores or spaces in soil or rock.
Positive Impact	Impact results in an improvement to the baseline conditions.
Post fledgling/ moult	The period after a bird's first flight when they shed their first feathers and moult into their adult coats.
Production Agreement	The legal and commercial agreement whereby the mineral owner (The Crown Estate) gives permission to a dredging company to extract aggregate from a prescribed area of seabed.
Promontory	A high ridge of land or rock jutting out into a body of water; a headland.
Qualifying interest Feature	The features (usually habitats or species) that a protected (SSSI, MCZ, SPA, SAC or Ramsar site) has been designated to protect.
Ramsar sites	Wetlands of international importance designated under the Ramsar Convention 1971.
Receptor	Any ecological or other feature that is sensitive to, or has the potential to be affected by, an activity.
Recoverability	A measure of a receptor's ability to return to a state close to that which existed before the effect caused a change
Regional Environmental Assessment	A process by which the potential cumulative and in-combination effects of regional marine aggregate extraction proposals are investigated
Regional Environmental Characterisation	A survey undertaken to broadly describe the nature of seabed habitats and associated species that exist within a region.
Relict	A feature created by processes, and under physical conditions, that no longer exist.
Resource	An asset that meets the needs and wants of humans, in this case the extracted sand and gravel
Reverse Screening (scalping)	The process where coarser sediment, such as pebbles or cobbles, is rejected to load a cargo of pure sand.
Saltmarsh	Community found in the upper part of the intertidal zone of estuaries where salt tolerant plants grow between the high spring tide and the mid tide level.
Sand ribbon	Thin trail of mobile sand on the seabed aligned in the direction of the prevailing tidal currents and which can be detected from geophysical survey images.
Sand streak	Trail of mobile sand on the seabed aligned in the direction of the prevailing tidal currents and which can be detected from geophysical survey images.
Sandbank	Sandbanks and linear sand ridges are defined as all elongate coastal to shelf sand bodies that form bathymetric highs on the seafloor and are characterised by a closed bathymetric contour.
Sandflat	A sandy tidal flat barren of vegetation.
Sandwaves	Sub-aqueous dunes formed on a bed of sand or gravel under the action of water flow (+1m high).
Sand ripple	A small sand wave, a few centimetres high, formed on a bed of sand under the action of water flow.
Schedule 1 of the Wildlife and Countryside Act 1981.	Schedule 1 provides a list of birds which are protected either all year round or in the close season
Screening	A means to process the water/sediment mixture while loading marine sand and gravel in order to influence the sand and gravel mix retained in the hold.
Sediment sink	Physical processes in the coastal zone lead to the eventual deposition of sediment in new locations, or sinks. These can be low energy zones, such as harbours, tidal lagoons and offshore deep water, or natural barriers, such as headlands, breakwaters and jetties.
Sediment starvation	The prevention of sediment movement to a particular area.
Sediment transport	The process, driven by hydrodynamic forces (waves and tides), that mobilises and transports sediment particles.
Sediment transport pathway	The pathway of sediment as it moves from a source to a 'sink'.
Sedimentation	The settling of solid particles from fluids.
Semi-diurnal tide	Two tidal cycles in one day (two high tides and two low tides).
Sessile	An organism that is fixed in one place or immobile.
Shear stress	A measure of the collective force of waves and currents exerted on the seabed.

Siphon	Tube connected to the anterior end of a bivalve or gastropod mollusc through which water is conducted into the gill cavity.
Site of Special Scientific Interest	Sites of Special Scientific Interest (SSSIs) give legal protection to the best sites for wildlife and geology in the UK. In England, Sites are designated by Natural England under the Wildlife and Countryside Act 1981, amended by the Countryside and Rights of Way Act 2000.
Smolts	Part of the life cycle of salmon when they move from a freshwater to marine environment.
Spawning Stock Biomass	The total weight of fish in a stock that are old enough to spawn.
Special Area of Conservation	Sites designated under Article 3 of the EC Habitats Directive requiring the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended).
Special Protection Area	Sites designated under Article 4 of the EC Birds Directive to protect rare and vulnerable birds (listed in Annex I of the Directive) and for regularly occurring migratory species.
Species Action Plan	See Biodiversity Action Plan.
Species of Conservation Concern	Lists the JNCC developed criteria for identifying species that are of conservation concern. The Red list consists of species of high conservation concern and the Amber list consists of species of medium conservation concern.
Spillway	The structure used to control release of overflows during dredging.
Spring tide	The highest tide in a 14 day tidal cycle.
Storm surge	Water that is pushed to shore as a result of an offshore rise of water associated with a low pressure weather system, high winds and high waves.
Strand	General description of a wide intertidal area usually composed of sand.
Sublittoral	Zone exposed to air only at its upper limit by the lowest spring tides.
Subtidal	The benthic ocean environment below low tide that is always covered by water.
Swarte Bank Formation	Glacial sediments of Anglian (Elsterian) age in the southern North Sea
Teleosts	Fish with bony skeleton such as cod rather than cartilaginous fish such as skates and rays.
The Crown Estate	The Crown Estate is a diverse property business which owns most of the seabed out to the 12 mile limit and the non-energy mineral rights out to the UK shelf boundary.
Tidal amplitude	The magnitude of the difference between low and high tides.
Tidal cycle	The daily occurrence of two complete high tides and two low tides. A full tidal cycle takes 24 hours and 52 minutes.
Tidal excursion	The net horizontal distance over which a water particle moves during one tidal cycle of flood and ebb.
Tidal mixing fronts	Are sharp horizontal gradients of density created by turbulent mixing generated by tidal currents over shallow topography.
Tidal range	The vertical difference between the high tide and succeeding low tide.
Tidal residuals	Asymmetry between the peak flood and ebb tidal currents resulting in a net (residual) current vector.
Tidal surge	Water that is pushed to shore as a result of an offshore rise of water associated with a low pressure weather system, high winds and high waves.
Tolerance	The extent to which the receptor (at a regional scale) is adversely affected by a particular effect of dredging.
Trailing Suction Hopper Dredger	A dredger designed to remove sediment from the seabed through hydraulic suction whilst moving, and retain the dredged sediment onboard.
Turbidity	The measure of the degree to which water loses transparency due to the presence of suspended particles.
Vibrocore	Equipment designed to acquire a 10cm diameter core sample through the seabed for the purposes of determining the thickness of aggregate resource deposits.
Winnowing	Loss of fine particles from the sediment over time leading to a gradual increase in average particle size over time.
Zooplankton	A type of plankton found in all ocean zones, particularly the pelagic and littoral zones. They form a key component of the marine food web. They include copepods.

7 PHYSICAL EFFECTS OF DREDGING

7.1 INTRODUCTION

As explained in Chapter 3, 13 key 'effects of dredging' have been identified and agreed with stakeholders as the effects to be considered in all five MAREAs that are being conducted for key regions around the UK coast. The purpose of this chapter is to provide a discussion around the 10 effects that are physical in nature, to explain how each potential physical effect has been assessed and to clarify how each effect has been quantitatively or semi-quantitatively represented for use in the subsequent chapters of this Humber and Outer Wash MAREA.

As explained in Chapter 3, benthic communities, fish ecology and seabed features are examples of potential receptors that may be impacted by these effects. Any significant impacts to these receptors may then have knock-on impacts to other receptors e.g. marine mammals may be affected by changes to the distribution of fish. As a result the following three effects are also considered as part of the impact assessment in addition to the 10 physical effects: changes to benthic community composition; changes to distribution of fish; and changes to seabed features. It should be noted that these effects are not discussed in this chapter but rather are considered in Chapters 8, 9 and 10.

The first six of the physical effects of dredging discussed in this chapter are 'primary' (immediate) effects, while the last four are 'secondary' in nature.

1.	Presence of the Vessel	Section 7.3.1
2.	Removal of Sediment	Section 7.3.2
3.	Fine Sediment Plume	Section 7.3.3
4.	Sand Deposition (Formation of Bedforms)	Section 7.3.4
5.	Changes to Sediment Particle Size	Section 7.3.4
6.	Underwater Noise	Section 7.3.7
7.	Changes to Wave Height	Section 7.4.2
8.	Changes to Tidal Currents	Section 7.4.3
9.	Changes to Sediment Transport Rates	Section 7.4.4
10.	Loss of Access	Section 7.3.1

In addition to describing these 10 key effects in detail, the chapter presents additional discussions around some further physical effects of dredging. Although they have not been deemed to comprise one of the 'key' effects of dredging to be considered in the MAREA, information on these effects is provided in this chapter and is drawn on within the impact assessment chapters as appropriate (e.g. the effect of contaminants on water quality).

A number of potential effects of dredging have also been discussed in this chapter that have ultimately been shown to be not significant and hence are not considered key effects of dredging or considered further in the MAREA. Examples of the effects that are discussed but are deemed not significant and are not taken further are emissions to atmosphere from dredge vessels (Section 7.3.1), the potential for turbidity increases as a result of the passage of the draghead (Section 7.3.2) and mobilisation of contaminants (Section 7.3.6).

Figure 7.1 presents a conceptualisation of some of the 10 physical effects of dredging that are discussed throughout this chapter. It is important to note that the potential effects of dredging discussed here are not necessarily considered to represent impacts. They represent changes in the ambient conditions that may or may not be translated into impacts as a result of their interaction with the environment. The extent to which these effects comprise an impact to particular receptors is considered further in Chapters 8 to 10. For further discussion on the difference between effects and impacts please refer back to Chapter 3.

7.2 SOURCES OF INFORMATION

This Chapter is based on a number of specialist studies that have been undertaken for the MAREA as well as other information sources, such as various studies by MALSF and scientific and industry reports, which have been referenced throughout. The main sources of information used in this Chapter are:

- ABPmer (2011) Humber MAREA – Physical Processes Study: Baseline Characterisation. Report R.1820.
- ABPmer (2011) Humber MAREA - Physical Processes Study: Assessment of Dredging Effects. Report R.1825.
- ABPmer (2011) Humber MAREA - Physical Processes Study: Assessment of Sediment Plumes. Report R.1841.
- HR Wallingford (2011) Plume Dispersion Arising from Aggregate Dredging by Large Trailer Suction Hopper Dredgers. Report EX 6437. Release 3.0.
- Tillin, H. M., Houghton, A. J., Saunders, J. E. & Hull, S. C. (2011) Direct and Indirect Impacts of Marine Aggregate Dredging. Marine ALSF Science Monograph Series No. 1. MEPF 10/P144. (Edited by R. C. Newell & J. Measures).
- Navigation Impacts Review – Humber and Greater Wash Dredging Areas (Technical Note). Anatec Limited (2011).
- MIRO (2004) Seabed characterisation and the effects of marine aggregate dredging. Prepared by Andrews Survey.

7.3 PRIMARY EFFECTS

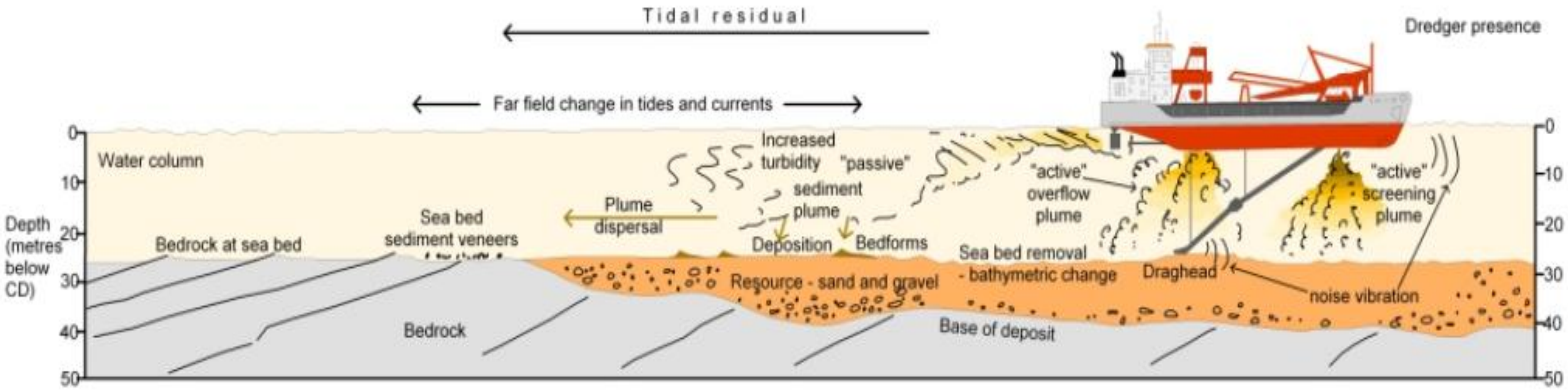
The changes brought about by the primary effects of dredging are likely to be greatest in the immediate vicinity of the dredger. The primary effects of the dredging process relate to:

- the presence of the dredging vessel, which could lead to increase in emissions and potential collision with other vessels;
- physical removal of seabed by passage of the draghead, which modifies the bathymetry and increases turbidity;
- the generation of a sediment plume from the overflow and screening processes;
- mobilisation of contaminants potentially contained within the sediment and porewater; and
- underwater noise generated by the vessel and by material entering the draghead and pipe.

Each of these potential primary effects is discussed in sections 7.3.1 to 7.3.7.

Dredger Pumping Seawater Prior to Dredging

Figure 7.1 Conceptualisation of Aggregate Dredging and its Physical Effects on the Marine Environment



Note that arrows denote directions, not extents

7.3.1 Vessel Presence

The presence of the dredging vessel has two potential effects that are discussed in this section. These are the potential for collisions and the emissions released by dredge vessels.

Collisions

The high traffic density of predominantly commercial vessels in the study area introduces the increased risk of collisions taking place given the increased number of dredging vessel movements. Ship-to-ship collisions are mainly caused by manoeuvring or navigational failures, including equipment and communication failures, and in some cases human error.

The principal concern associated with an increase in the number of dredging vessels in the region is the obstruction caused by slow-moving dredgers to other vessels in the area. The likelihood of collision depends on the following:

- The expected frequency that vessels fail initially to identify that the dredger is a slow-moving vessel and to assess correctly its course and speed and subsequently collide (generally bow to stern).
- The probability that the dredger fails to observe vessels bearing down and does not move out of the way before collision occurs.

The main factors influencing collision risk are:

- ship densities;
- speeds;
- courses;
- types and sizes; and
- visibility conditions for the area.

A navigational assessment of the Humber and Outer Wash region was carried out to assess the navigational risks of future dredging activities in the MAREA study area based on baseline shipping data and the maximum extraction tonnages provided by HADA members.

The navigational assessment was based on a modelling study designed to illustrate where existing shipping congestion is highest and therefore where new or increased dredging activity could lead to an increased risk of collisions. Full details on the modelling study are available in Appendix H. The Humber Estuary and Outer Wash is characterised by relatively high levels of commercial shipping, of which baseline dredger activity associated with HADA member companies represents approximately 0.7% of the total ship movements within the MAREA study area annually. Using the maximum annual future extraction scenario, the dredging activity will be double the baseline, however, in overall traffic terms dredging activity will still represent a low proportion of approximately 2%. This additional dredger traffic will mainly be using existing, established routes to/from the dredge areas. In terms of collision risk for the study area, the future extraction scenario risk was in the order of 1 major collision within the study area in 4.4 years, compared to 1 in 4.54 years for the current conditions, which is an increase of approximately 3.1% and broadly reflects the additional traffic and likely increase in encounters.

Emissions and Discharges

Liquid discharges comprise bilge waters, cooling waters and treated domestic waste water (sewage) and will be discharged in accordance with MARPOL requirements. Solid waste is collected onboard as part of standard waste management practices and transferred to an appropriate licensed facility when the vessel reaches port.

Marine aggregate dredging contributes to emissions of greenhouse gases through shipping and indirectly through downstream production activities (ALSF, 2010). Emissions from shipping have been under scrutiny since the early 90s (ALSF, 2010) and more recently the sector has been scrutinised for emitting a contribution to overall maritime greenhouse gas (GHG) emissions, mainly carbon dioxide (CO_2). Between 65 and 75% of the total fuel used during a dredging cycle is used for transit of the dredging vessels between licence area and wharf. However, as marine aggregates can be supplied close to where they are needed, the need for land-based transport is reduced, which also reduces related greenhouse gas emissions.

The British Marine Aggregate Producers Association (BMAPA) has used industry data to calculate CO_2 emissions from dredgers based on their fuel usage and landed sand and gravel tonnage (BMAPA, 2010a). It is estimated that in 2009 2.54 kg of fuel was used by the average dredger per tonne of marine sand and gravel landed, which is the equivalent of 8.09 kg of CO_2 per tonne landed. Based on the maximum extraction scenario and provisional figures for 2010 that indicate the UK released approximately 492 million tonnes of CO_2 to the atmosphere (DECC, 2011), this equates to approximately 52 million tonnes of CO_2 emitted to air over 15 years or 0.7% of the UK's annual CO_2 emissions.

The dredging vessels are therefore considered no different to other vessels operating in international waters and this issue has not been taken forward into the regional impact assessment.

Potential Effect 1: Presence of the Vessel. This effect is represented quantitatively for the MAREA assessment by two GIS layers: (1) the extent of the 'Future 15 year extraction zones' which represent the extent over which dredge vessels may be present at some time over the 15 year period of the MAREA and (2) the 'future shipping density' extent which has been modelled as part of the shipping and navigation

7.3.2 Removal of Sediment

Seabed Deepening

Removal of sediment occurs through passage of the draghead over the seabed. Dragheads vary in size depending on the type of dredger and those fitted to UK marine aggregate dredgers are typically between 1 and 4 m wide (BMAPA, 2010b). The depth of sediment removed by a passage of the draghead will vary depending on the compaction of the seabed sediments and the power of the dredge pump, but typically a 30 to 50 cm layer of sediment will be removed in a single pass (BMAPA, 2010b) (Tillin *et al.,* 2011). Repeated passage of the draghead across the same area can lower the seabed by several metres, if the deposits are thick enough.

For the dredging activities considered in this MAREA, seabed deepening will be confined to a future 15 year extraction zone, which generally corresponds to a smaller footprint than the full production licence areas and application areas.

The removal of marine aggregate can cause changes in seabed sediment character, including changes in particle size distribution, which can potentially affect the rate of ecological recovery. Also, the resulting bathymetry changes can lead to 'indirect' or 'secondary' effects, such as changes to the existing hydrodynamic and sediment regimes (as discussed in Section 7.4 below). (1)

Research has shown that physical recovery of the seabed can occur in areas that have been dredged. For example natural seabed restoration may take place in areas where currents winnow sands, leaving residual coarser sediment. In less dynamic environments and particularly when dredging relict deposits (for example sediments laid down during periods of lower sea levels), as in parts of the Humber region, the resultant seabed deepening may be permanent as the processes that shaped the original deposit are no longer operating (Tillin *et al.*, 2011). Research in Area 106 has shown that although a deepened seabed will remain, within two years dredge furrows become insignificant features and within four years seabed roughness recovers so that it is similar to the undredged seabed (MIRO, 2004).

(1) Changes to the seabed topography could also potentially lead to 'destabilisation' effects in relation to certain features that may be found on or within the seabed, such as subsea cables or archaeological resources. This could occur if such resources or features are located in very close proximity to the area of sediment removal. This 'destabilisation' effect has been scoped out of this assessment in relation to impacts to subsea cables, because the 500 m exclusion zone associated with them rules out the possibility of any such interaction. The archaeology assessment conducted for this MAREA has, however, considered the potential for a 'destabilisation' effect (referring to this effect as 'bathymetric change'). The archaeology assessment notes that this effect derives directly from substrate removal and therefore the effects of 'substrate removal' and 'bathymetric change' are discussed in close association in that assessment.

Figure 7.2 compares the 'present day' bathymetry, in which seabed levels in existing dredging areas have been established using the latest survey of those areas, with a baseline 'pre-dredged' bathymetry, in which the seabed levels in each existing or relinquished dredging area represent the situation before any dredging was started. As a full record of bathymetry data is not available for the pre-dredged scenario some assumptions for the pre-present have been made. In some areas the pre-dredged bathymetry has been estimated based on where dredging has occurred and the extracted tonnage, the depth changes were then estimated as an average depth change across the areas that were subjected to dredging. The change in bathymetry presented in Figure 7.2 is largely due to aggregate extraction but, in some cases, small changes are observed in parts of the licence area where no dredging has taken place. This is either a result of natural bed level variations or is due to the interpolation of widely spaced measurements. Past dredging has taken shallow layers (0.5-2 m) of the available resource across wide areas of some licence areas, as shown in electronic monitoring system (EMS) data in Figure 7.3. These data show the intensity of dredging during each of the past 12 years and that dredging is a progressive activity across an area. Data are only provided for the last 12 years; however, dredging also occurred prior to 1998.

Figure 7.4 shows the difference between the 'present day' and 'post-dredged' bathymetry, illustrating the predicted further bed lowering until 2030. The extraction plans were provided by each of the HADA member companies for their licence areas and are based on the operating company's understanding of resource availability. Since the completion of the ABPmer studies the future 15 year extraction zone has been further refined in Area 441, making it smaller than the area initially modelled. The extents of the Area 441 deepening shown in Figure 7.4 show a worst case extraction scenario based on an original larger footprint. Given that this footprint encompasses the 15 year extraction zone, the modelling has not been revised in the MAREA.

Anomalies as a result of the widely spaced seabed depth measurements also occur in Figure 7.4, as can be seen by bathymetry changes outside the future 15 year extraction zones; however, these will not affect the performance of the numerical model. For further detail around the functioning of the model see Appendix E.

Planned future dredging as shown in Figure 7.4, in contrast to past dredging (Figure 7.2), will target more precisely the resource at a particular site. For this reason, proposed future dredging will be deeper where possible, while other parts of some licence areas will remain undredged. This variation is reflected in the future 15 year extraction zone extents in both the production licences and new application areas. This is in line with the Marine Minerals Guidance Note 1 (MMG1), which considers minimising the impacts of dredging activities by working within discrete subareas.

Figure 7.2 Difference plot of pre dredged to present day bathymetry

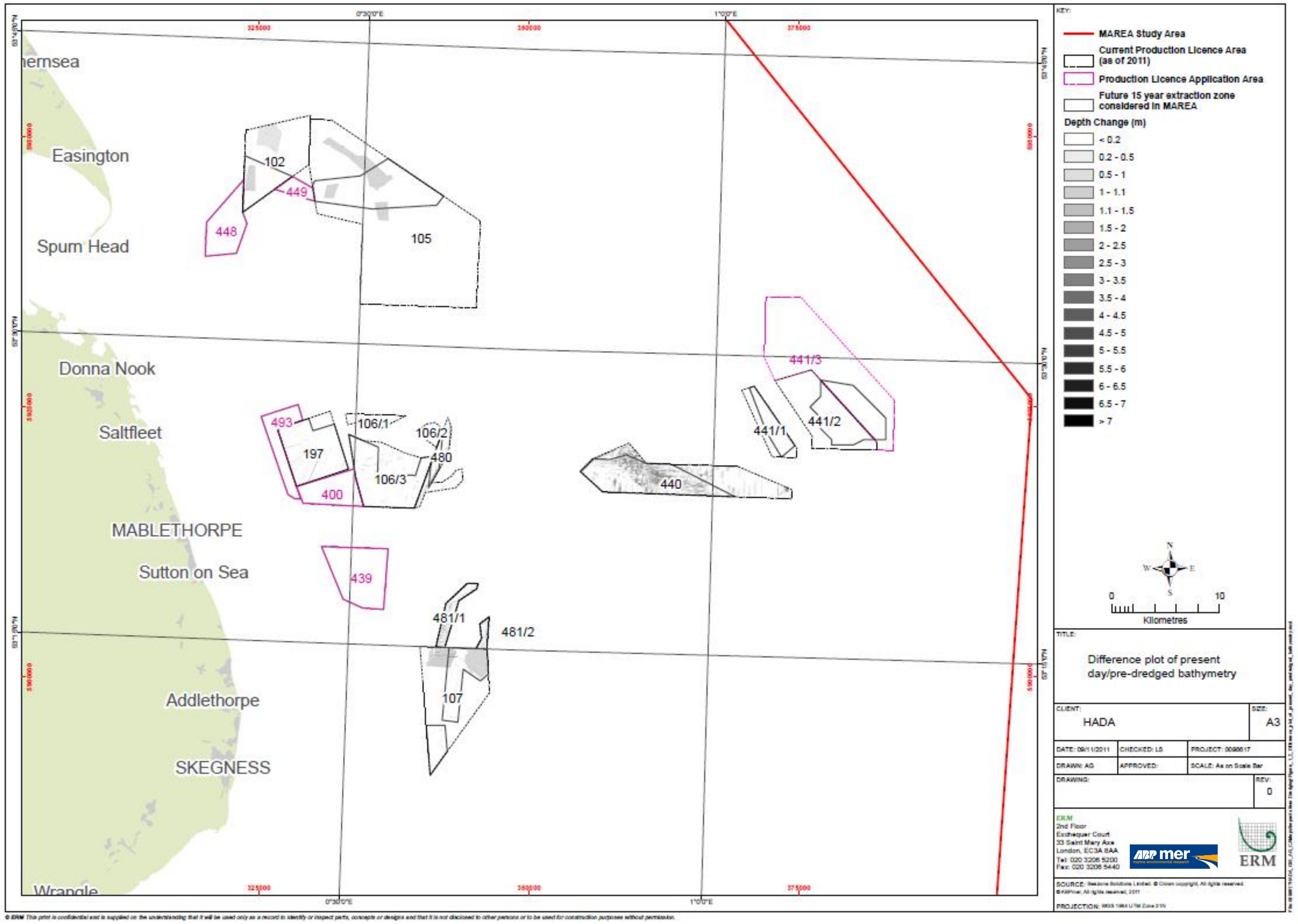


Figure 7.3 Dredging Intensity in MAREA Study Area 1998-2010

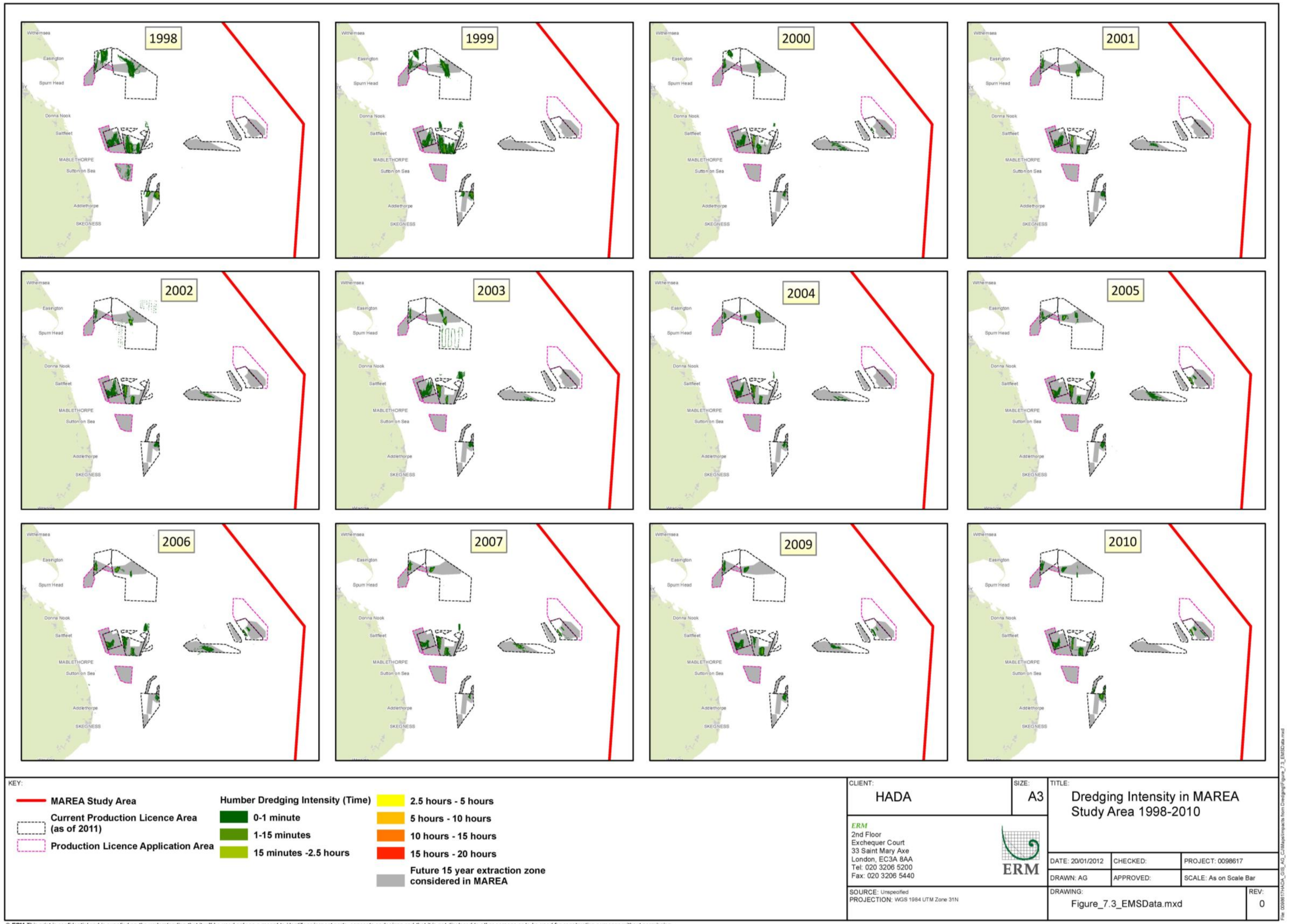
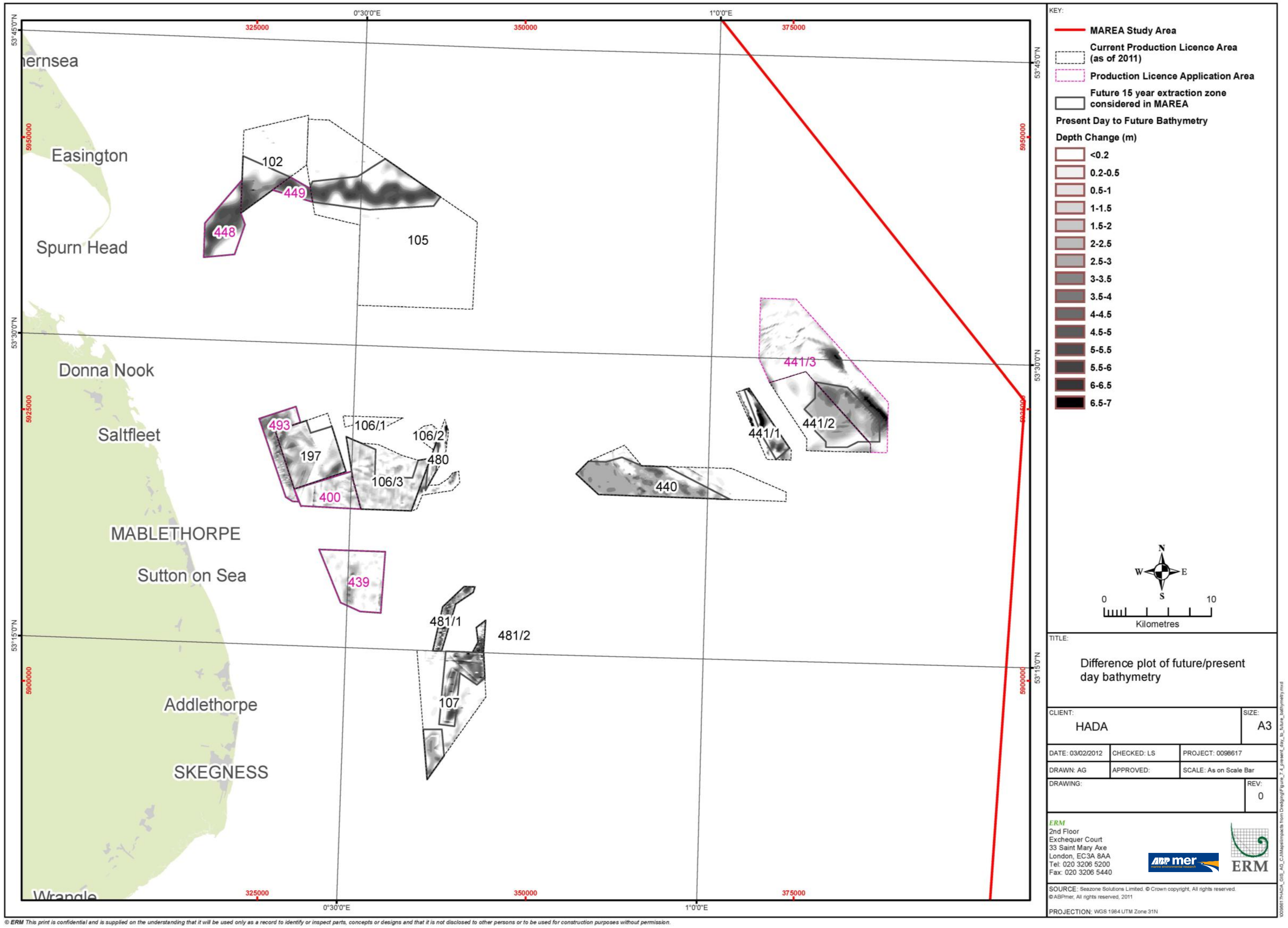


Figure 7.4 Difference plot of present day to future bathymetry



Increased Turbidity

Marine aggregate extraction in the UK is carried out by Trailer Suction Hopper Dredgers (TSHDs). This type of vessel operates by lowering the dredge gear (draghead and dredge pipe) to the seabed and drawing water and sediment into the hopper using powerful suction pumps (BMAPA, 2010b). Normally, the vessel will operate whilst moving at slow speed (typically around 1 knot) but some vessels are also capable of anchoring and dredging whilst stationary.

The passage of the draghead along the seabed disturbs fine sediment and forces some into suspension. Measurements of plumes generated by the movement of the draghead have shown that the volume of sediment introduced into the water column is barely detectable, in the order of 1% of the material introduced by the overflow and screening processes (Hitchcock *et al.*, 1998) (John *et al.*, 2000) and the effect is extremely localised. This effect is therefore not considered separately from the plumes created by the overflow spillways and screening.

Potential Effect 2: Removal of Sediment: This effect is represented quantitatively based on the extent of the 'Future 15 year extraction zones' which represent the maximum extent over which sediment may be removed over the 15 year period of the MAREA.

7.3.3 Sediment Plumes

Information in this section has predominantly originated from the plume modelling studies and associated report conducted specifically for the MAREA by ABPmer. The full Plume Studies Report is presented in Appendix F. Other sources of information are referenced where appropriate.

Inputs of Sediment to the Water column

During aggregate dredging operations sediment is dispersed into the water column via three main processes:

- seabed disturbance by the draghead;
- overflow from the spillways; and
- rejection of sediment back to the seabed through screening.

During dredging water is pumped at high velocity from the seabed and seabed sediment is entrained into the flow, passing through the dredge pipe and being retained in the hopper of the dredger. To allow the vessel to land a full cargo of sand and gravel seawater is displaced and returned to the sea via overflow spillways (BMAPA, 2010b). Some sediment is entrained in the overflow and returned to sea, which forms a plume in the sea consisting of fine sediments (typically fine sands and silts). Fine suspended sediment is dispersed horizontally and vertically as a plume by tidal flows and wave action and will be advected by tidal currents. Advection and dispersion continue until sediment concentrations are reduced to near background levels. Where aggregate resource deposits are of suitable quality (for example when the sand to gravel ratio in the dredging area meets the operational requirements) a cargo can be loaded without onboard processing; this is known as 'as-dredged' or 'all in' (BMAPA, 2010b). In the case of an all in cargo the losses of sediment and seawater are entirely via the overflow spillways on the side of the vessel. However, if the operational requirements dictate and the dredger is suitably equipped, the vessel can partly sort the dredged sediment while loading operations are underway through a process called screening, which influences the final composition of the cargo.

During screening the sediment and water mix is passed over a steel mesh or plastic mat screen before entering the hopper (BMAPA, 2010b). A proportion of the water and finer sediment falls through the screens and is returned to sea via the reject chutes or through the keel, while the coarser sediment is retained. Depending on the screen mesh size used, the mixture of rejected sediment and seawater typically contains coarser sand and usually has a greater density and velocity on entering the water surface than the overflow mixture. As a result it descends rapidly to the seabed as a dynamic plume. When screening for gravel (undersize screening) there is usually a significant proportion of fine sand (and a smaller proportion of silt) released back to the water column that can potentially be transported by tidal currents and waves outside of the dredging area.

'Scalping' or 'reverse screening' occurs when coarser sediment, such as pebbles or cobbles, is rejected to load a cargo of pure sand. Sediment rejected during reverse screening will fall directly back to the seabed and will not be transported out of the dredging area.

The processes affecting the plume are strongly influenced by the composition of the marine aggregate resource targeted for dredging. The turbulent overflow water contains proportionally higher volumes of clay, silt and fine-grained sand, whilst screening of undersize material commonly results in the rejection of sediments up to about 5 mm diameter. The majority of fines are ejected in the overflow discharge; the additional discharge of fines from the screening process is small in comparison (Hitchcock *et al.*, 1998). Together, these effects of dredging create a turbid plume of suspended fine-grained sediment.

Overview of Plume Dispersion

The sediment from the overflow spillways and screening initially forms a plume, of which there are two types (phases) of dispersion: dynamic and passive. It should be noted that the majority of plumes which are seen usually result from the passive phase of the plume as sediment in the dynamic phase descends more quickly towards the bed, where it can be moved by the local flow regime.

The dynamic phase relates to the initial rapid descent of sediment from the dredger to the bed as a result of the sediment/water mixture being of higher density than the surrounding water, where it joins the material resuspended from the draghead disturbance. As the sediment descends, a proportion of the finer sediment is stripped from the plume into the surrounding water column and advected away from the dredging area by currents as a passive plume. The remainder of the sediment reaches the bed, in which some of the sediment (mainly larger fractions) will settle, some will be resuspended upon impact, whilst the rest will spread radially across the seabed as a dense plume (i.e. high suspended sediment concentration, which may be in the order of hundreds to thousands of mg l-1). The overall extent of the plume is predominantly controlled by tidal currents, the presence of a bed slope and the character of the bed. Resuspension of the sediment may also take place if the forces exerted by tidal currents and waves are sufficient. The zone of impact typically resulting from a dynamic plume is relatively small, usually affecting an area less than 100 to 200 m from the dredger. The size of the impact zone is largely dependent on the initial density and momentum of the sediment/water mixture entering the water column as a result of the dredging activity, the water depth, the current velocities and the speed of the dredger.

The passive phase is secondary to the dynamic phase and is controlled more by the hydrodynamic process of advection due to the magnitude and direction of current velocities, where the sediment will remain suspended within the water column until the velocities become low enough for the sediment particles to settle out, and by the nature of the sediment released into the water column. The settling velocities of particles within a passive plume are sufficiently low for them to remain in suspension for a considerable period of time; however, the sediment concentrations within the plume are much lower than those found in the dynamic phase. In comparison with the dynamic phase, the distance of impact typically resulting from a passive plume can exceed several kilometres. Suspended sediment concentrations within the passive plume can be in the order of hundreds of mg l-1 in the vicinity of the dredger, much lower than those in a dynamic plume, reducing to tens of mg l-1 with distance from the dredger before becoming indiscernible from natural background concentrations.

Modelling Approach and Inputs

A study was undertaken by ABPmer to identify the potential footprints relating to the dispersion of fine sediment plumes (passive phase) as a result of future dredging in the study area for the modelled case. The potential footprints of sedimentation were also modelled. The results of the modelling are used to assess the potential effects on environmental receptors. For full details see Appendix F.

The purpose of modelling sediment plumes is to define a footprint within which concentrations of suspended sediment in the plume can be estimated. In reality there are a number of variables that may affect the dispersion of the plume. The dredger (the source of the discharge) could move in variable directions in relation to the direction of movement in the receiving water, which also varies according to the diurnal tides and cycle of springs and neaps. However, for the purposes of modelling, the number of variables is reduced by fixing the location of the dredger. This scenario does not include any dispersion of the plume due to the dredger moving, therefore the modelled concentrations within the plume may be higher than the actual concentrations that would be experienced in the water column, and therefore the modelled scenarios represent a worst case with regard to the overspill plume dispersion.

Modelling of the plumes is based on the overflow operation as it is likely to give rise to the maximum extent of effect of the plume in the water column due to the greater volume of fine sediment discharged, as described above. In support of this approach results from a monitoring study in Area 473 in the East Channel Region have shown that for the all-in load measured suspended sediment concentrations were generally higher than for the screened load and that the higher concentrations were experienced closer to the vessel in the all-in load than for the screened load (HR Wallingford, 2011a). Therefore the modelled scenario can be expected to produce the larger plume with higher concentrations. However, the thickness of sedimentation on the bed will be less in the modelled scenario than for the screening process, although for screening the rate of descent through the water column is faster and the grain size is generally larger indicating the majority of this higher sedimentation will occur within the licensed area where the bed will have already been directly affected by the dredging activity.

Modelling also took into consideration the dredger overflow release rate and the loading time. In order to define realistic modelling input parameters a review of previous reports and monitoring studies was undertaken. A summary of the findings of the previous reports and monitoring studies is presented in Table 7.1. The results presented in Table 7.1 indicate that sediment plumes created through aggregate dredging that have been measured generally disperse much more rapidly to the bed than predicted. Although for different sites, comparison between the greatest measured (monitored) plume extent (3.1 km) and the smallest predicted extent (9 km) would indicate that the predictions are overestimating the extent of effect by approximately three times for suspended sediment concentrations within the plume to reach background (natural) variability. However, it is not always clear whether the measured plume is considered as a depth-averaged concentration, near bed concentration or any other level and different thresholds are used to define the plume extents in different studies and at different locations.

Table 7.1 Summary of Predicted and Measured Plume Data in the Literature

Site	Screening / All-in	Water depth (m)	Current speed (m s^{-1})	Fine sediment loss rate (kg s^{-1})	Dredger pumping rate (m^3 s^{-1})	Plume excursion (km)*
Summary of Modelled Plume Dispersion Assessments Undertaken for Dredging Licence Applications within the Study Area						
Area 439	Screening	10-12	0.75-0.9	33	-	12
Area 106 East (480)	All-in	<20	0.8-0.9	8.3	-	10
Area 481	Screening	20-30	1-1.5	38	-	9
Area 481	All-in	20-30	1-1.5	60	-	9
Summary of Measured Plume Data in the Literature						
Eastern English Channel (Arco Axe)	All-in	45	<2.0	-	2.0	3.1
Eastern English Channel (Arco Axe)	Screening (for gravel)	45	<2.0	-	2.0	2.4
Owers Bank (City of Rochester)	Screening (for gravel)	18	0.25	-	1.25	0.3
Owers Bank (Arco Severn)	All-in	18	0.25	-	1.25	0.55
Owers Bank Geopotes XIV	All-in	18	0.25	-	unknown	>1.0**
North Nab (Area 122/3) (City of Chichester)	All-in	18-25	0.8-1.1	-	unknown	>0.8***
Hastings Shingle Bank	All-in	25-30	0.5	-	1.7	1.5
Area 107/Race Bank	unknown	15-20	<1.0	-	2.0	2.5

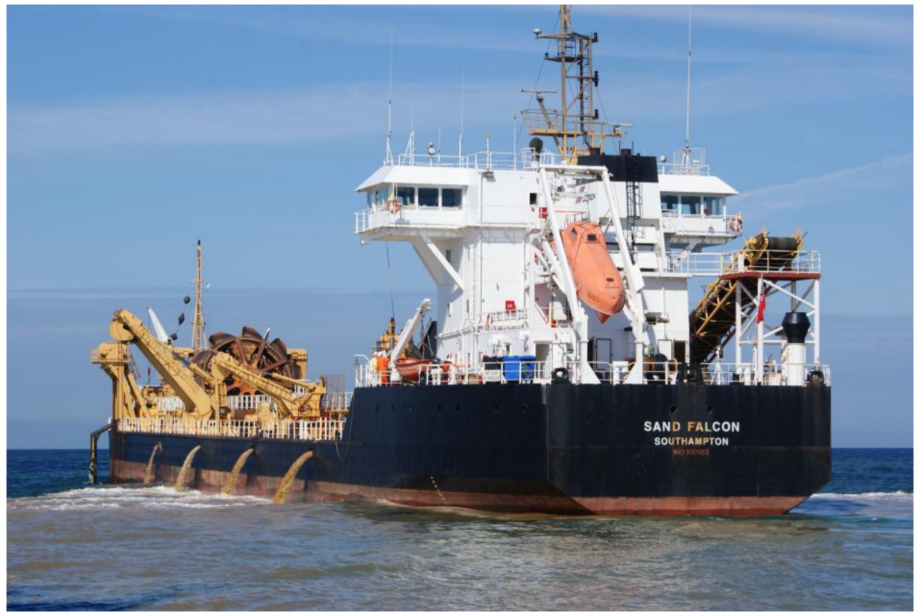
* The excursions were not necessarily measured to the same suspended sediment concentration threshold.
**The exact value of the plume was not recorded, but it was greater than 1.0 km.
*** The total plume excursion was not measured due to obstructions; however, the excursion was greater than 0.8 km.

Close-up Photograph of dredged Sediment being Pumped into the Hopper

Recovery of the Dredge Pipe from the Seabed After Dredging

The modelled case, as presented in Appendix F, places a stationary dredger at the corner extremities of the current production licence areas and licence application areas, which would represent a very conservative scenario in terms of plume footprints. However, for the purposes of the MAREA and to represent a realistic worst case scenario, the modelling results have been interpreted and moved from their original positions to the corners of the nearest future 15 year extraction zone, where relevant. Footprints for certain concentrations have then been drawn. This approach illustrates the likely extent of plumes that may occur due to dredging of the future 15 year extraction zones. It is considered a valid approach for the purposes of the regional scale MAREA, and subsequent EIAs, as similar plume extents can be expected to occur for any locations between the modelled plumes as the hydrodynamics, and therefore plume extents, do not vary significantly across each of the different clusters of licence areas across the MAREA area (see Appendix F).

Dredger Loading Aggregates showing Plume forming from Spillway Overflow



The modelling of the marine aggregate dredging also provides an understanding of suspended sediment transport, its fate, deposition and remobilisation potential over the estimated duration of each dredge and over a spring-neap cycle. Two scenarios were modelled:

- Initial depth-averaged concentrations through the water column and near bed (i.e. within 1 m of the seabed) plumes – Dredging was continuously operated for 4 hours at fixed locations (i.e. a stationary dredger) while materials were released 2 hours ahead of peak flood current or peak ebb current respectively. The model was run for 5 hours in total to obtain the maximum plume extents induced by both flood flow and ebb flow.
- Longer-term depth-averaged and near bed plumes over a spring-neap cycle – Sediment was input for 4 hours at a fixed location with a 36 hour interval reflecting an average dredger cycle time to 'land' the cargo over 15 days (a spring-neap cycle), and then for an additional 6 days without further input. The total of 21 days allows all sediment in suspension to either fall to the sea floor or reach a concentration deemed indistinguishable from background concentrations. Account was also taken of further dispersion by the local hydrodynamic regime, set against the complete range of tidal amplitudes.

As described below, the initial plume has been used as the basis of the impact assessment, with the longer term plume providing further context. See the Longer Term Plume below for further explanation.

Natural Background Suspended Sediment Concentrations

The licence areas can be divided into cluster areas, which are used for the purposes of discussion and can be seen in Figure 7.5. For Clusters A and D the 'normal' background suspended sediment concentration through the water column is likely to be 5-10 mg l^{-1} in the summer increasing to 10- 20 mg l^{-1} in the winter. Under storm conditions the measured data suggest suspended sediment concentrations are likely to increase to around 50 mg l^{-1}, for both summer and winter conditions. For Clusters B and C, closer inshore to the Lincolnshire Coast, the monitoring indicates that suspended sediment concentrations will be higher. 'Normal' summer concentrations would be expected to be in the range of 15-25 mg l^{-1}, increasing to 50-100 mg l^{-1} during winter (in which suspended sediment concentrations will be more variable). Furthermore, storm activity can increase the background suspended sediment concentrations in these areas to be in excess of 150 mg l^{-1} during and immediately after the event.

Fine Sediment Plume Footprints

<u>The Initial Plume</u>

Figures 7. 5 and 7.6 present the initial plume footprints for concentrations of 2 mg l^{-1}, 20 mg l^{-1}, 50 mg l^{-1} and 100 mg l^{-1} above background for both depth-averaged and near bed concentrations. These are the footprints that have been used in the MAREA impact assessments for each receptor under consideration.

The plumes shown in Figure 7.5 and 7.6 represent the maximum concentration modelled over the five hour modelling period, however, the actual concentration varies in both time and distance from the source. Time-series plots can be used to give an indication of how the plume concentration varies in time and space, giving an idea of the movement of the plume. The information presented in the plume 'footprint' plots therefore needs to be considered in association with the time series plots. Time series plots for Clusters A to D show that the model results were very similar in the four cluster areas in terms of the patterns of sediment concentration development and decay, reflecting the local flow regime. Figure 7.7 shows the location of and the individual time-series of suspended sediment concentration for a location within Cluster A (depth-averaged and near bed) for flood and ebb sediment releases, where transect Location 3 is the release point. For time series plots for Clusters B to D see Appendix F.

The plume in Cluster A shows that maximum concentrations do not occur at the release location. This indicates that the released sediment falls relatively quickly to the bed at the point of release and the settled material is then remobilised and adds to the amount of sediment that is still falling through the water column, giving maximum concentrations down flow of the release point (Locations A2 and A4). Further away from the release point still (e.g. A5) maximum concentrations at this point are experienced for a relatively short period of time. For example, in Figure 7.7 the maximum exposure concentration near the bed on the flood tide at location A5 is nearly 30 mg l^{-1} for only a few minutes, however, for two hours from the commencement of dredging (hours 0-2) the concentration at this location is zero and for the next two hours (hours 2-4) the maximum concentration it is less than 10 mg l^{-1}. The time series plots also show that near bed sediment concentrations are higher than the depth-averaged concentration at all times.

Figure 7.5 shows that the plumes are predominantly directed by flood and ebb currents along the tidal axis from each specific sediment release location. During the flood stage, the plume clouds travel towards the south, whilst the ebb tide advects the plume northwards. The results also indicate that higher suspended sediment concentrations are predicted to occur nearer to the bed than through the remainder of the water column, which is also observed in the monitoring studies. Similar plume extents can be expected to occur for any locations between the modelled plumes for a single dredger at any one moment in time. A concentration of 2 mg l^{-1} above natural levels (background) has been used as a threshold concentration below which sediment concentrations are not considered to have a significant environment effect as they will be well within the natural variability of background conditions and at the limits of accurate calibration of monitoring equipment. The footprint of effect at this threshold is considered to be a maximum case representation of the fine sediment plume. Depth averaged concentrations of up to 20 mg l^{-1} may occur up to approximately 1.5 km from the edge of some licence areas; higher concentrations occur only within the licence areas. Seabed concentrations of more than 100 mgl^{-1} may extend up to approximately 1.8 km from some licences, while concentrations of 50 mg l^{-1} and 20 mg l^{-1} extend up to approximately 2.5 km and 3 km in some areas respectively.

It is important to note that footprints shown in Figure 7.5 and 7.6 represent the total envelope of the plume throughout the 15 year dredging period; they do not represent the footprint of the plume itself at any one point in time or for one load. Consequently they are useful for identifying static receptors that may be exposed to the seabed concentrations in the turbid plume from dredging operations at some point in the future but do not indicate the proportion of habitat for mobile receptors that will be affected at any one time. Figure 7.8 and 7.9 provide a 'real time' context to Figure 7.5 and 7.6 as they show a typical plume for seabed and depth averaged concentrations within each cluster (sediments released 2 hours ahead of peak flood current or peak ebb current respectively). At any given point the plumes cover a relatively small area and areas of the plume at any time with concentration increases of over 50 mg l^{-1} cover a smaller area still.

Plume Contours

To summarise from the perspective of marine receptors, the initial plume modelling results have been used to visualise an envelope represented as suspended solids concentration contour plots which are depth averaged and at the seabed.

- For mobile receptors in the water column, the depth averaged concentrations indicate maximum levels of exposure above background as spatially referenced contours that a receptor might be exposed to at some point over the fifteen year period of dredging. The actual exposure level for any single dredging operation will be a function of proximity to the dredger and time. The effect may be repeated each time a dredger visits the dredging zone. As water column receptors are mobile the contour plots represent a worst case potential exposure above and beyond the modelled cases.

- For seabed receptors, similar considerations apply. However, with the exception of bottom feeding fish and seabirds, the majority of seabed receptors can be considered to have little or no mobility. The predicted levels of exposure are therefore closer to the likely levels that will be experienced (allowing for the modelling approaches adopted). For these receptors factors such as proximity to dredging and duration of exposure become important considerations in the assessment of biological effects to be presented in the Chapter 9 of the MAREA.

Figure 7.5 Initial Plume (Seabed) Footprints at 2, 20, 50, and 100 mg l^{-1}

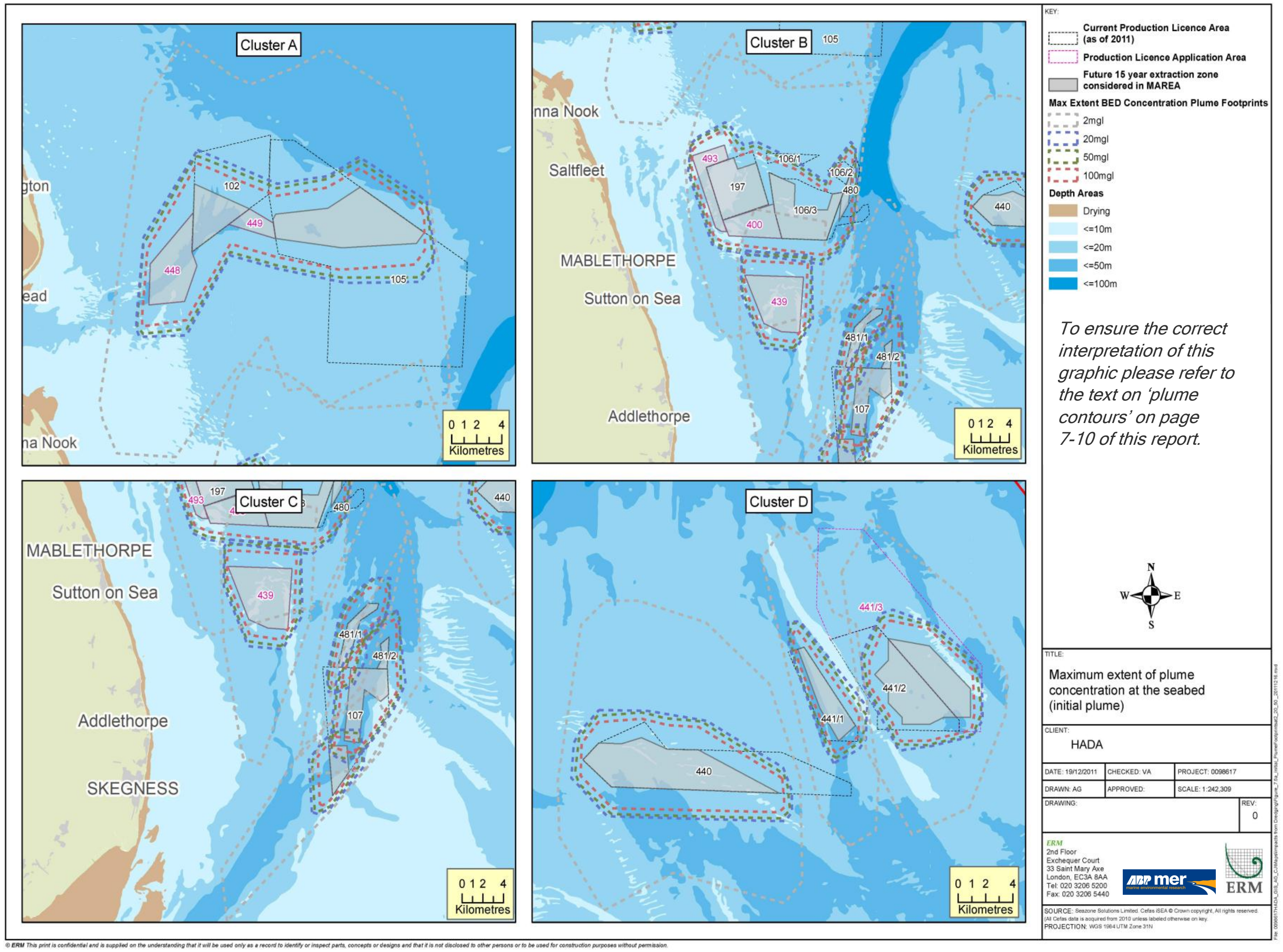


Figure 7.6 Initial Plume (Depth Averaged) Footprints at 2 and 20 mg l[1]

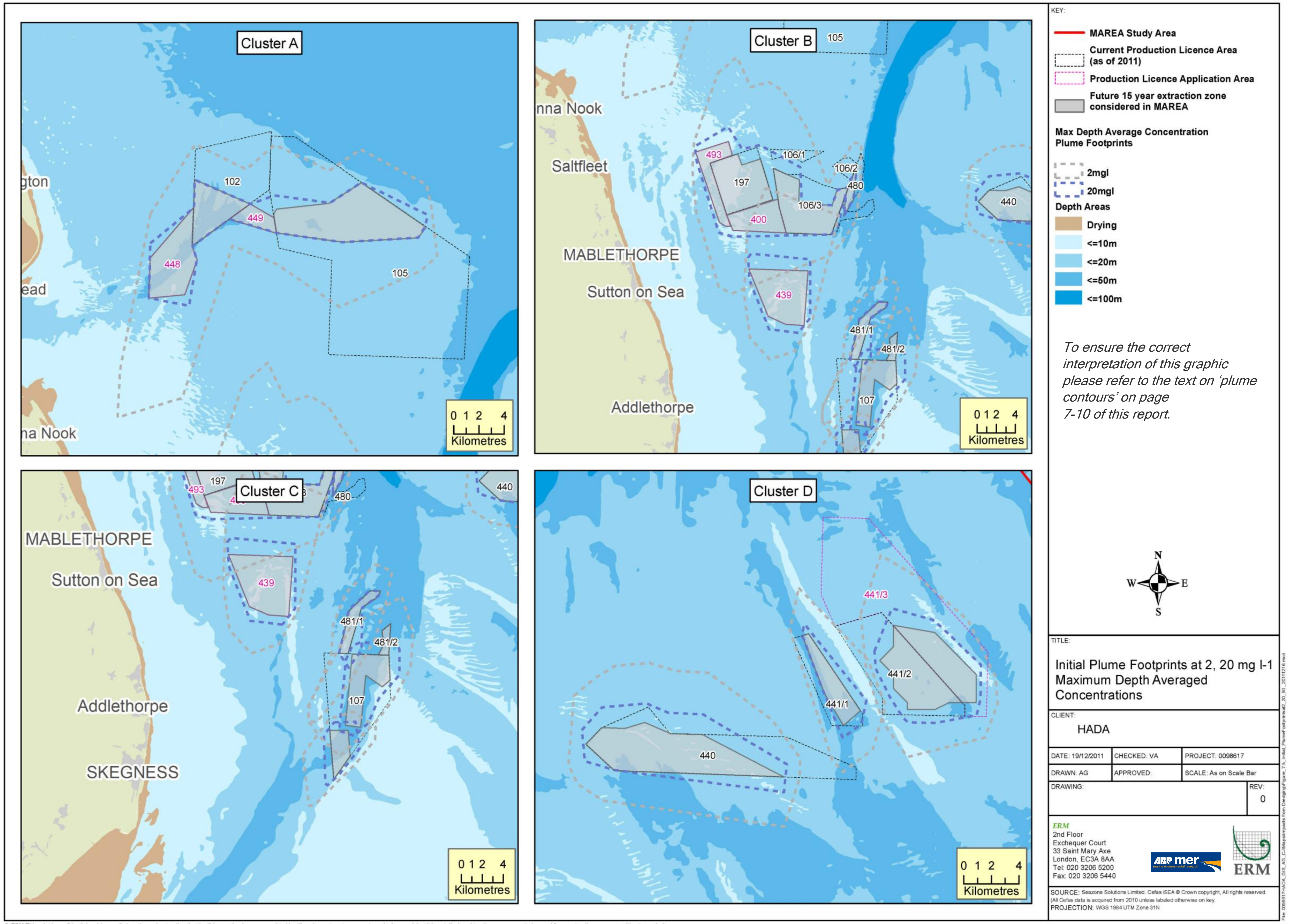


Figure 7.7 Time-series of Concentration on Ebb and Flood Tides at Cluster A

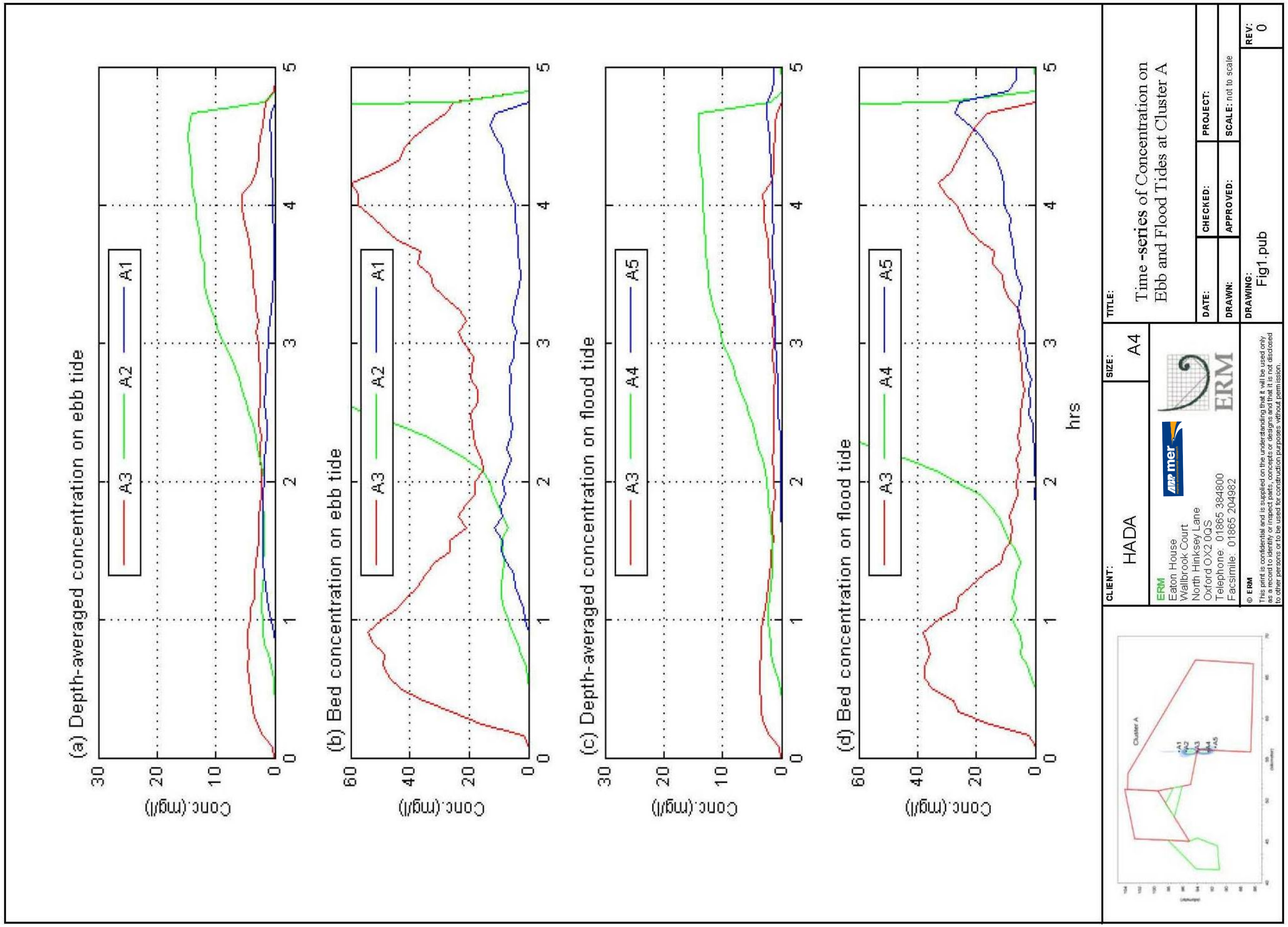


Figure 7.8 Maximum Extent of Depth Averaged Plume Concentrations (initial plume)

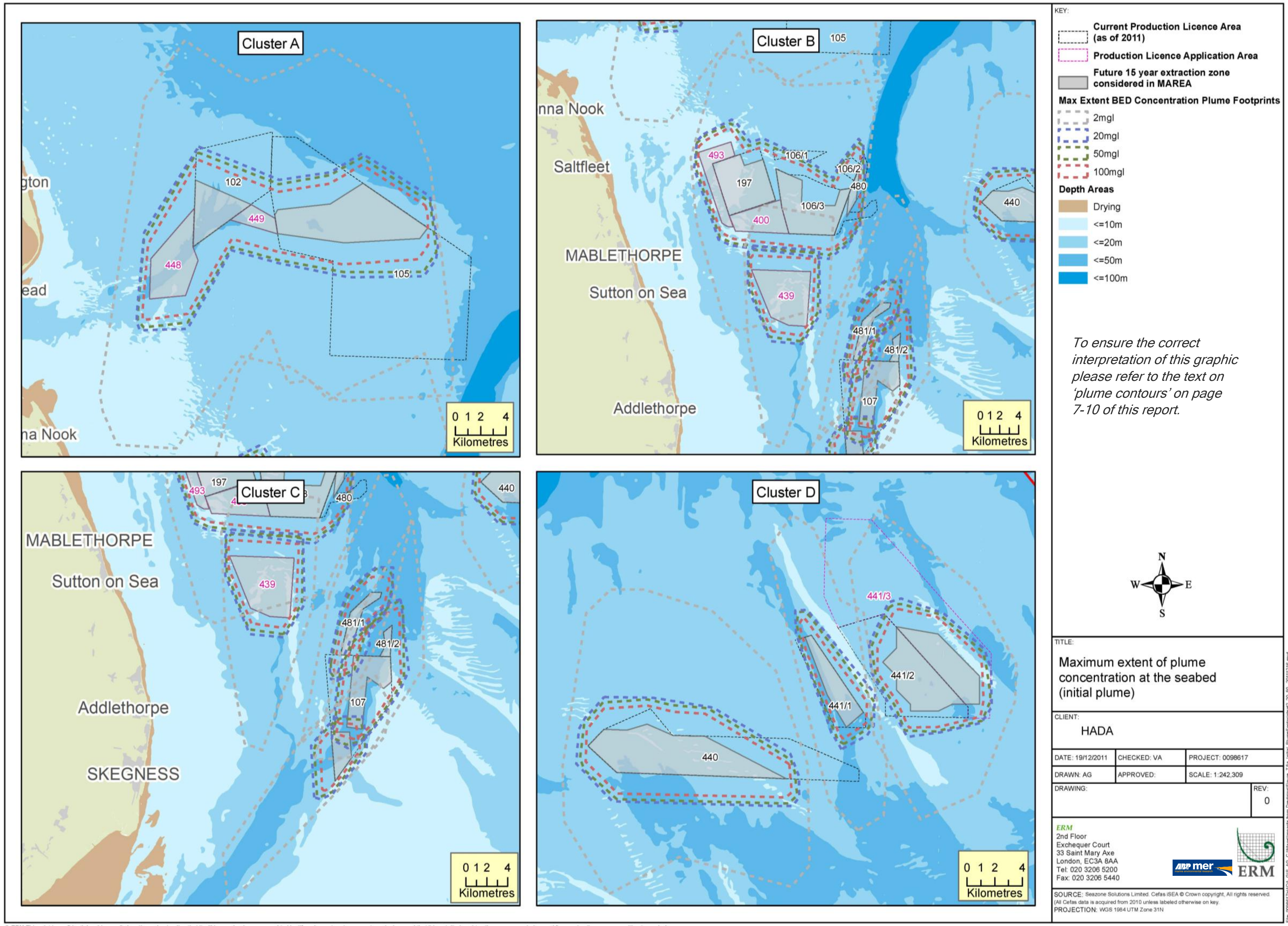
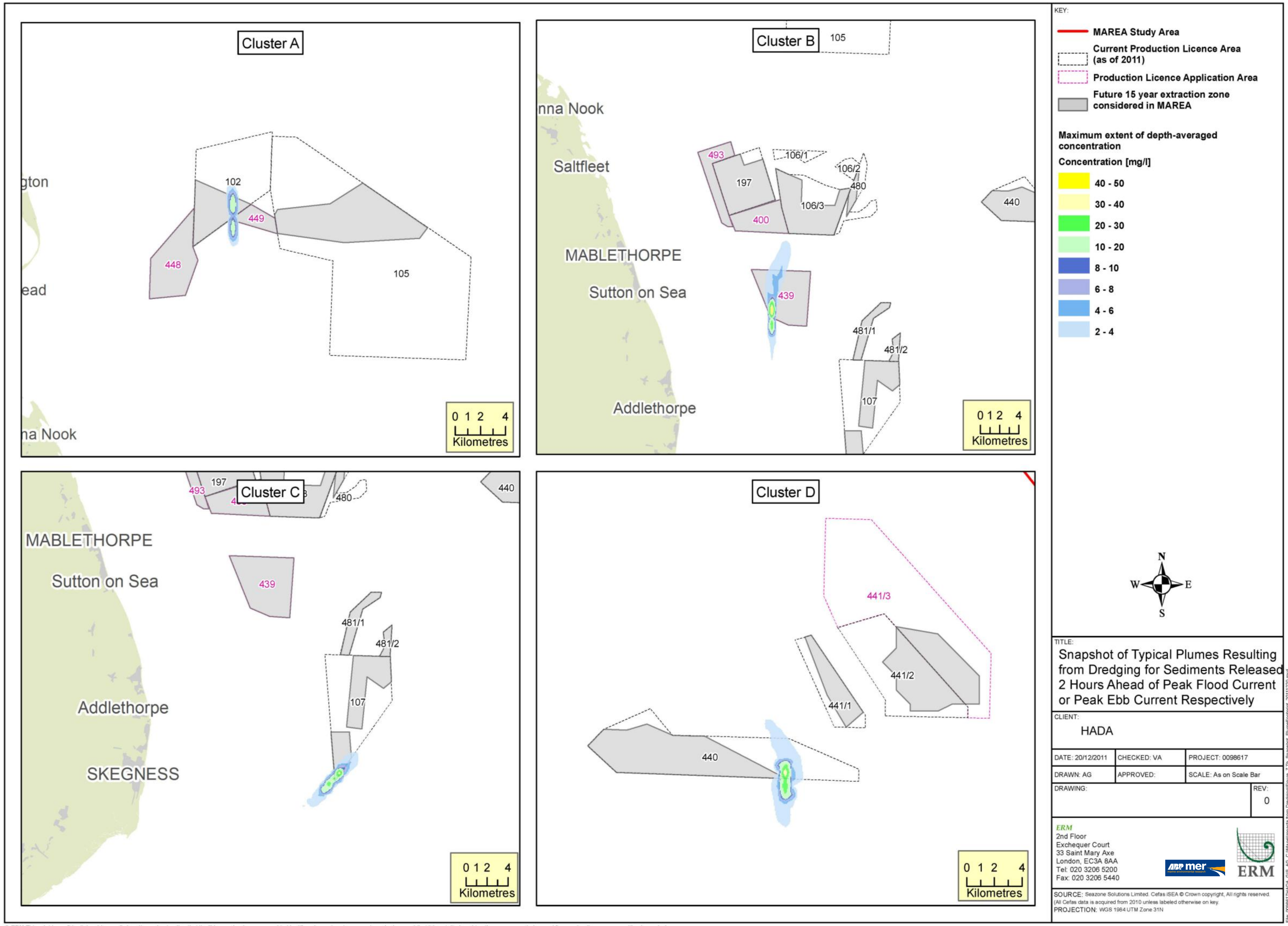


Figure 7.9 Snapshot of Typical Dredging Plumes Resulting from for Sediments Released 2 Hours Ahead of Peak Flood Current or Peak Ebb Current Respectively (depth averaged plume)



Longer-term Plume

The longer-term plume represents a scenario whereby dredging operations take place repeatedly at intervals throughout a spring-neap cycle from a fixed dredging location (i.e. a stationary dredger). Although this scenario would not actually occur it is used in an attempt to understand whether the effects on suspended solids concentrations from repeated dredging could be accumulative.

Based on the model results for the initial plume a dredger was positioned at one location within each cluster that represented the maximum plume likely to occur for the modelled case. The longer-term plume results are not the basis for the MAREA assessment chapters as the overall cluster footprint would not be realistic, however, the results are used qualitatively within the assessment chapters to provide further context for the extent to which the increase in seabed concentrations could be sustained for longer periods and reach higher levels, particularly at locations outside of the dredge zones.

View of a Fine Sediment Plume from Dredging Vessel whilst Loading

Figure 7.10 shows the footprint of maximum suspended sediment concentrations (to a minimum of 2 mg l^{-1}) that may occur over the modelled period (i.e. 21 days) for the scenario modelled i.e. depth-averaged and near bed concentrations above background for one location within each cluster where the maximum footprint occurred for the initial plume. Actual modelled concentrations vary from near zero to a maximum diurnally as well as through the neap spring cycle. Time series plots for Clusters A to D generally show similar patterns but with varying magnitude of effect, which is related to the difference in the flow regime at the different locations. The time series plots for Cluster A are presented in Figure 7.11; time series plots for Clusters B to D are presented in Appendix F. Location A3 on Figure 7.11 shows the overflow release location for Cluster A.

Dredge Vessel Hopper whilst Loading Aggregates

Figure 7.11 shows that net sediment transport away from the overflow discharge locations occurs predominantly on spring tides, with the majority of accretion during neap tides, where also larger concentrations are evident in the water column (up to 5 times the level during springs) due to the slower dispersal in the weaker neap flows.

Sediment remobilisation occurs during the spring tides and creates wider long-term dispersion of the sediment that originates from the aggregate dredging overflow discharges. Figure 7.11 also indicates that increased concentrations decay to background within about four spring tides (rising range) from the last dredge discharge. During this latter period all sediment that was deposited at the site was remobilised. Background concentrations in other clusters may be reached after 14 tides following cessation of the dredge inputs. Elevated suspended sediment concentrations are therefore unlikely to be distinguishable from background levels within a full spring-neap cycle following cessation of dredging.

Comparison of Figure 7.10 with the plume extents shown on Figure 7.5 indicates the effects of the differing tidal conditions and the remobilisation and onward transport of the sediment over a spring-neap cycle. The figures indicate that the sediments spread more compared with the model results for the initial plume for single flood and ebb tides. In Clusters C and D, the footprint extents of increased suspended sediment concentrations are well aligned with their tidal axis, whereas in Cluster A and B there is a weaker linearity with their tidal axis. In general the maximum extents of effects are to the south of the dredge location except for the simulation from Cluster B in Licence Area 106/3 due to the local hydrodynamics. The maximum concentrations near the bed range from around 1100 mg l^{-1} to 1700 mg l^{-1}, whilst concentrations in the water column (depth-averaged) are between 65 mg l^{-1} and 140 mg l^{-1}. In both cases this range is 2-3 times higher than for the initial plume values.

This indicates that regular dredging at one location through a neap spring cycle will have a longer-term effect of increasing maximum concentrations around the dredge location, as subsequent overflow loads will add to the sediment already introduced in the system over previous dredging cycles. This scenario is considered to be an absolute worst case that would rarely occur.

View of Aggregates in the Hopper of a Dredging Vessel

Figure 7.10 Longer-term Plume Extent and Concentrations above Background (Selected examples; plume illustrated on corner of one licence area per cluster for illustrative purposes)

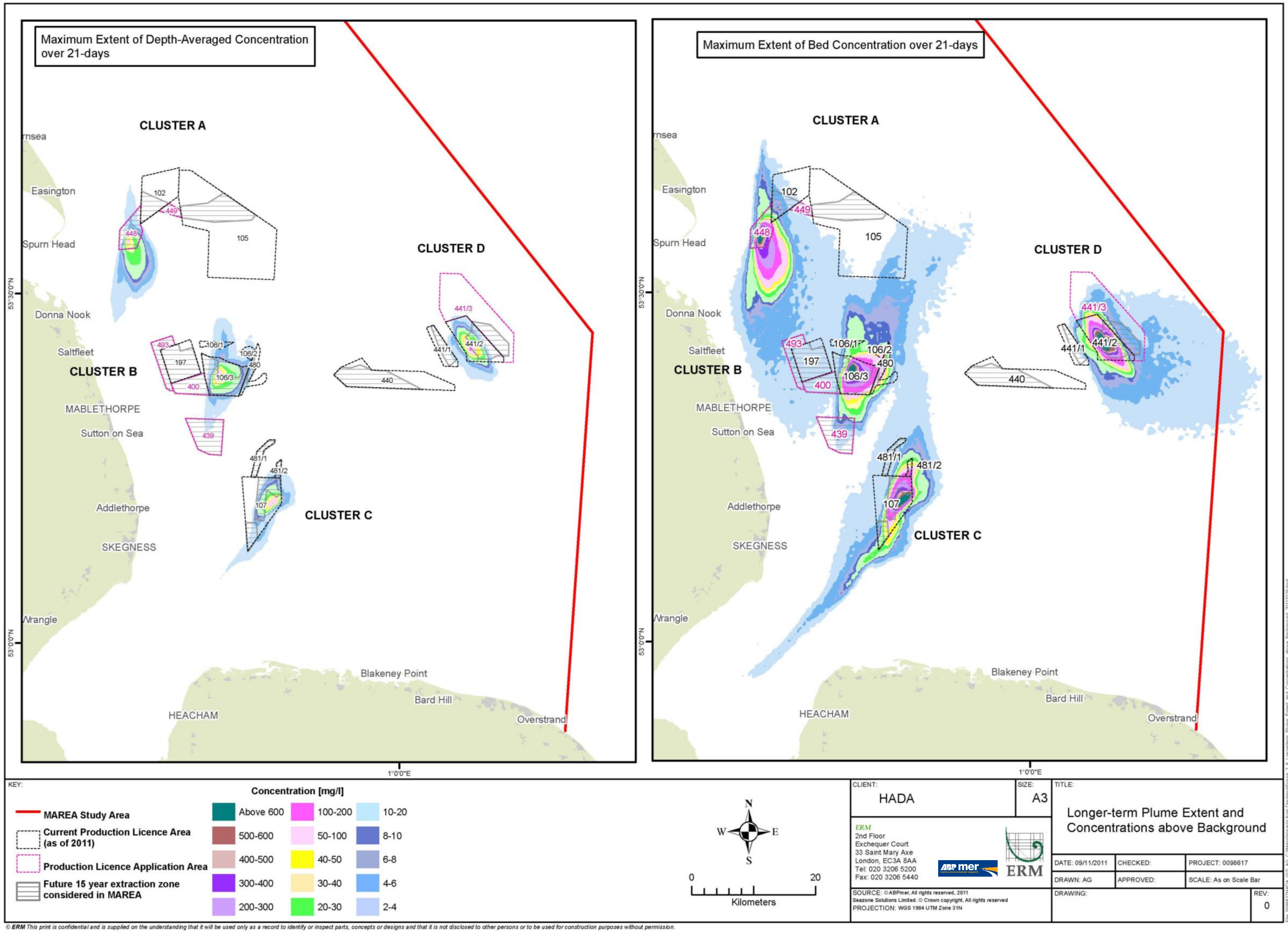
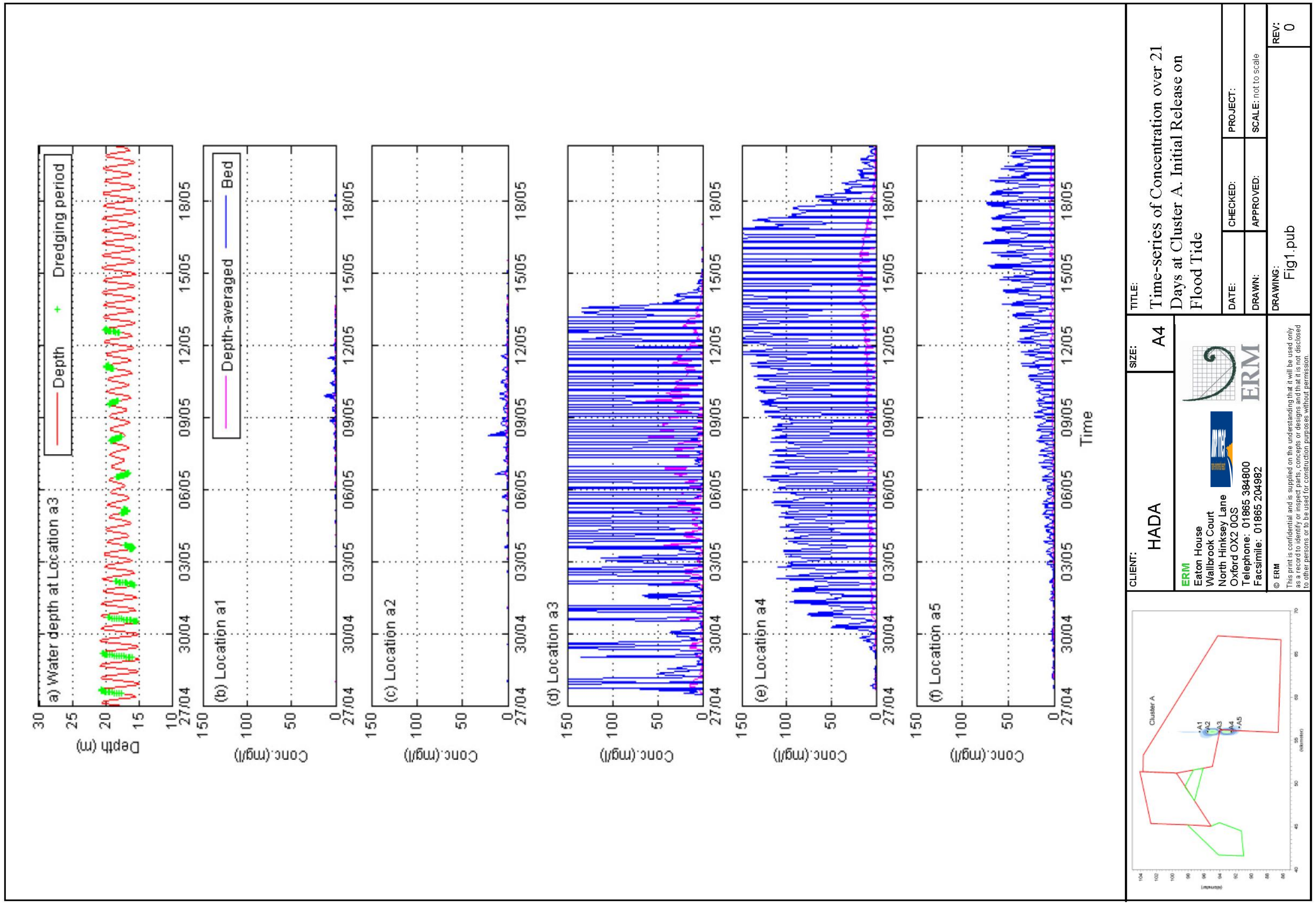


Figure 7.11 Time-series of Concentration Over 21-days at Cluster A -Initial Release on Flood Tide



Seabed Deposition from the Fine Sediment Plume

Modelling studies have been conducted to estimate the seabed deposition that may occur due to the sediment plume settling onto the bed for both the initial plume and the longer-term plume scenarios, as described above. Figure 7.12 presents the sedimentation that may occur due to the initial plume settling onto the bed. As with the plume modelling outputs the modelling results have been interpreted and moved from their original position to the corners of the nearest future 15 year extraction zone, where relevant, to represent a realistic maximum case scenario for the purposes of the MAREA. The model results as shown in Figure 7.12a indicate that the maximum sedimentation from a single dredge load (not taking account of any potential remobilisation) is approximately 0.3 mm in the immediate vicinity of the dredger. Maximum extents of sedimentation away from the release location are up to about 3 km, although from a single load the amount of sediment deposited will be negligible at this distance (i.e. 0.02 mm or the equivalent of a single silt grain). As seabed sedimentation from the fine plume is negligible at any one location from any one dredging operation it has not been taken forward into the assessment. Sand deposition is described below in Changes to Bedforms and Particle Size Distribution.

As with the longer-term plume assessment above the longer-term plume sedimentation results are also not the basis for the MAREA assessment chapters as the overall cluster footprint would not be realistic. For the longer-term plume the maximum distance of sediment transport is increased compared with the initial plume results, indicating that the flows around the site are sufficient to remobilise and transport the sediment derived from the fine sediment plume, therefore causing bedload dispersion. This suggests that although screened cargos do not generally create larger initial plumes than those from the dredger overflows, they may have a greater longer-term aggregative effect as there is potential for a greater mass of sediment on the surface of the bed to be available for remobilisation. Figure 7.12b shows that the most significant sediment deposition remaining after the 21 day scenario of the longer term plume occurs immediately adjacent to the dredge locations. The recorded maximum depositions are up to 1.8 mm (within Cluster D), arising from the total overflow of 11 loads. As with the initial plume the deposition thickness in large areas remains negligible at less than 0.02 mm.

Figure 7.13 presents the time series analysis for sedimentation from the fine sediment plume at Custer A over the 21 day period. Figure 7.11 and Figure 7.13 show that net sediment transport away from the overflow discharge locations occurs predominantly on spring tides, with the majority of accretion during neap tides, where also larger concentrations are evident in the water column (up to 5 times the level during springs) due to the slower dispersal in the weaker neap flows. Sediment remobilisation occurs during the spring tides and creates wider long-term dispersion of the sediment that originates from the aggregate dredging overflow discharges. Also, there is little or no movement of sediment northwards.

Figure 7.12 Extent and Depth of Sedimentation from the Initial and Longer-term Plumes

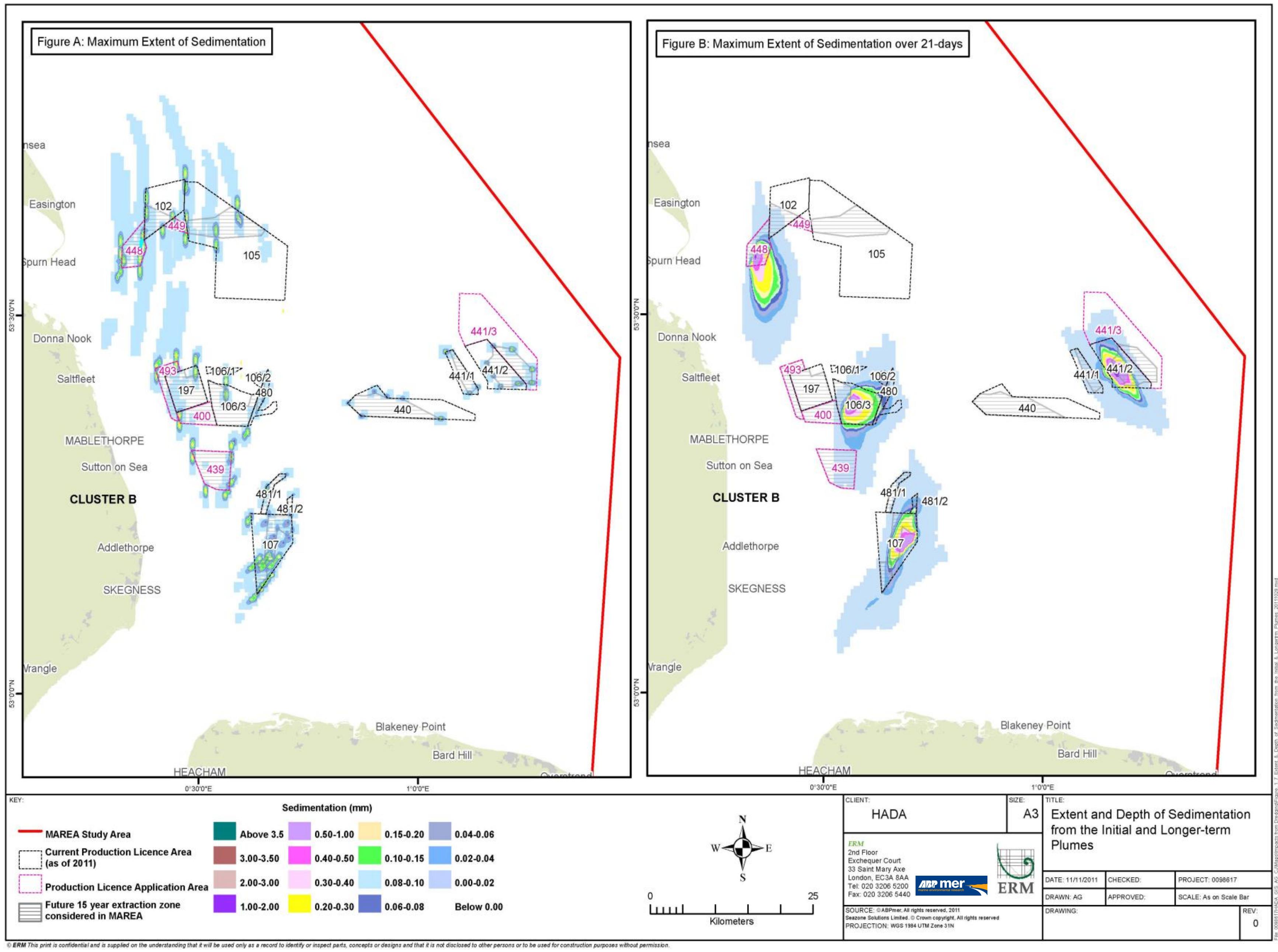
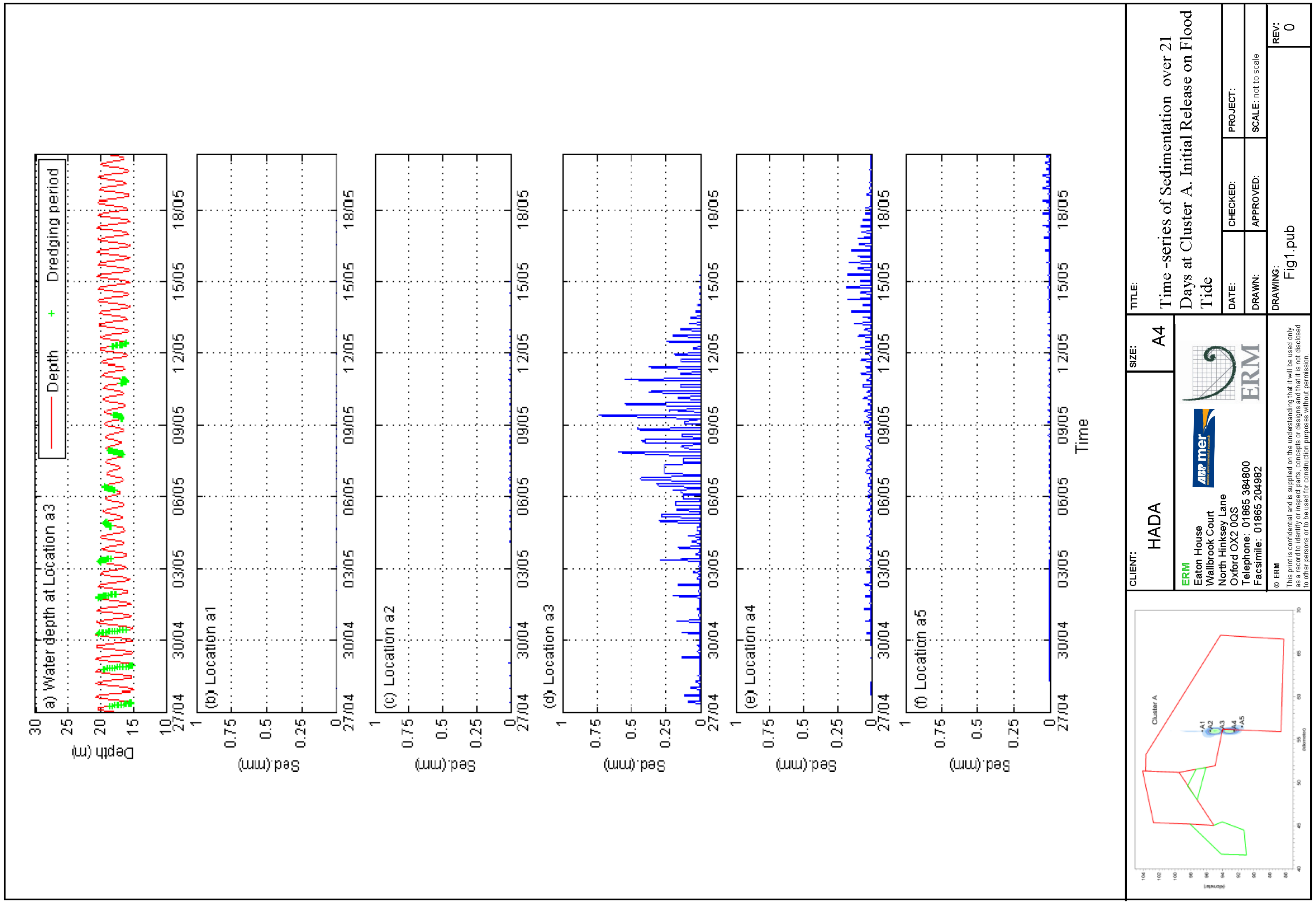


Figure 7.13 Time-series of Sedimentation Over 21-day at Cluster A -Initial Release on Flood Tide



Potential Effect 3: Fine Sediment Plume: This effect is represented quantitatively based on the modelled and interpreted extent of the footprints for the 100, 50 and 20 mg l-1 sediment plume concentration layers as appropriate for the sensitivity of the particular receptor being considered for either seabed, or depth averaged plumes, depending on the receptor under consideration.

7.3.4 Changes to Bedforms and Particle Size Distribution

A described above, sedimentation from the fine sediment plume (passive phase) is limited and temporary and is therefore unlikely to contribute significantly towards changes in bedforms and sediment particle size distribution in the MAREA study area. However, screening, which in general introduces a larger mass of sediment into the water column than the overflow (dynamic phase), was not considered during the modelling. Sand deposition from screening has been associated with deposition of well-sorted fine sands, and their subsequent transport away from dredging areas, which can affect local bedforms and sediment particle size distribution (Newell *et al.*, 2002, and MIRO, 2004).

In general, sand from screening will descend to the seabed relatively rapidly given the larger grain size compared to sediment released in the overspill. Much of this screening sedimentation will occur within the licence area and at most a few hundred metres from the dredger (MIRO, 2004); this sedimentation may be outside the licence area if dredging occurs close to the licence boundary. Following deposition, the sands could be either remobilised and redistributed by the tidal flow or could remain on the seabed close to the dredging area. The volume of sand available for transport is much less than that deposited as some of the finer grains will be mixed in with larger particles and trapped in the void spaces between them, thus being prevented from moving on the seabed. Bed shear stress calculated for specific points across the MAREA study area (see Section 7.4.4) indicates that coarse sands will be remobilised for at least part of the diurnal tidal cycle, however, the tides will not immediately redistribute all of the sand grain sizes that may be deposited on the seabed. Therefore, some sand will temporarily accumulate in and around the licence area.

Monitoring studies have assessed the accumulation of sediment and changes in sediment composition on the bed substrate away from the location of dredging as a result of aggregate dredging (see Appendix E). The results indicate that the extent of effect on the seabed is most likely controlled more by the local flow speeds than the depth or amount of sediment rejected. The monitoring studies have generally only identified an observed change in character of the bed surface; they have not evaluated the significance or thickness of the changes identified. Area 222 (in the Thames region) has identified changes at 4 km and 2.5 km distance from the licence area boundary for changes in particle size distribution and dispersion of sediments forming bedforms respectively. More recently a regional monitoring initiative in the East Channel region compared the predictions of the East Channel REA with field observations (EMU, 2011). The conceptual model used in the East Channel REA predicted that a 10 to 25 cm thick continuous sand sheet would be deposited up to 200 m outside the dredging area (based on water depths of approximately 40-50 m and known particle settling rates) (East Channel Association, 2002). A bedform field of ripples and streaks would form for approximately 1 km down tide followed by a more dispersed zone (from approximately 1 km), both of which were predicted to form predominantly in the direction of net sediment transport and tidal residual flow. However, the monitoring of Licence Area 473 (within the East Channel study area) has shown that there has been no development of significant bedforms over the survey period, although a change in seabed sediment characteristics in the vicinity of the Licence Area seems to have taken place between 2005 and September 2008 (EMU, 2011). The main changes detected from side scan sonar, grab and camera data were the development of sand streak features and an increase in the number of sites where sand patches and ripples sand existed on the seabed. This represents the rapid return of sand from the screening and overflow processes to the seabed, where a continual fining of the surface substrate occurs. A tracer study in the same area suggested that the finest sediment grain size fractions travelled up to 1.5 km, whilst the larger fractions were observed infrequently beyond 100 m from the injection site (EMU, 2009b).

For the purposes of this MAREA, uniform envelopes of 4 km and 2.5 km from the licence area boundary have been assumed to represent potential changes in particle size distribution and potential dispersion of sediments that could form bedforms respectively. This is based on measurements taken in Area 222 (in the Thames region) as they represent the largest changes identified in the literature that differentiates between changes to bedforms and changes to sediment particle size distribution. However, this is to be considered to be a very conservative approach as any actual changes are unlikely to be uniform around the licence area and given recent monitoring (EMU, 2011) are unlikely to form significant bedforms over the region. Any actual changes are likely to be smaller in extent in some directions around the licence and the extent of effect will partially depend on:

- The net sediment transport direction: Bedforms will form predominantly in the direction of the net sediment transport and will not affect a zone around the complete licence boundary to the maximum predicted extent. Based on the analysis of bedform asymmetry as an indicator of net transport direction, offshore transport to the west of Silver Pit is typically southerly, whereas further offshore there is evidence of a net northerly transport pathway through the Race Bank/North Ridge/Dudgeon Shoal area. Superimposed upon this regime are complex local transport pathways, particularly around seabed features.

- Presence of naturally occurring bedforms: Locally active bedforms will commonly mask any bedforms that may be the result of dredging, and the presence of mobile fine sand will mask any transport of fine sand from dredging.

- The extent to which screening (if any) occurs: Literature data (ABPmer, 2011) suggest that in areas where screening does not occur, changes to the seabed may be far smaller than where screening does occur. For example, studies on Area 106, which has previously been subjected to dredging without screening have shown the impact 'footprint' of dredging on the sediment composition was assessed to be symmetrical and extended for less than 450 m to the north of the dredge area in one study and up to 250 m to the north and south of the zone of 'High Intensity' plume deposition in another study.

- Actual dredging area and tonnage: The scenario above considers dredging will occur within the entire 15 year future extraction zones, however, in practice this is highly unlikely to occur on all sites and so any changes to the seabed may be reduced in extent.

In addition, the water depths in the MAREA study area are less than those in the Thames region indicating sand may settle faster to the seabed and therefore closer to the licence area boundary, which reduces the zone where a continuous sand sheet may form. Therefore, given the above, the 4 km and 2.5 km envelopes around a licence area that enclose potential changes in particle size distribution and dispersing sediments can be considered conservative and this interpretation has been taken into consideration in the impact assessment chapters.

Potential Effect 4: Sand Deposition (Formation of Bedforms): This effect is represented quantitatively by a GIS layer indicating a 2.5 km boundary around the 15 year extraction zones where dredging may occur at any point in the 15 year MAREA period. However, it is noted that this is a conservative estimate based on previous studies in the Thames region and the impact assessments take this into consideration, where relevant.

Potential Effect 5: Changes to Sediment Particle Size: This effect is represented quantitatively by a GIS layer indicating a 4 km boundary around the 15 year extraction zones where dredging may occur at any point in the 15 year MAREA period. However, it is noted that this is a conservative estimate based on previous studies in the Thames region and the impact assessments take this into consideration, where relevant.

7.3.5 Additional Contextual Discussion on Plumes

Plumes from a Larger Dredger

Dredging for aggregate in the UK usually takes place with vessels of 1,000-5,000 m^3 capacity. However, aggregate take is occasionally obtained using larger dredgers of 10,000-20,000 m^3 capacity (HR Wallingford, 2011b), particularly for 'one off' contract fill, reclamation or beach replenishment projects. A study has been conducted into the nature of plumes generated by a specific large dredger compared to the plumes from more typically sized UK aggregate dredgers (HR Wallingford, 2011b).

The study demonstrated that the use of larger dredgers results in a higher instantaneous rate of release of fine sediment from the overflow pipe but a lower overall loss of silt and fine sand into the surrounding waters and onto the bed. Larger dredgers also take considerably more aggregate in one load and therefore require fewer loads to remove the same volume as a typical UK dredger. The higher rate of discharge of sediment from the overflow of the larger dredger causes most of the sediment to descend to the seabed as a dynamic plume, which reduces the amount of sediment immediately released into the water column down to levels similar to typical UK dredgers. This suggests that when dredging for aggregate in areas with a low proportion of fine sediment, the effects of the sediment plume from the larger dredger are comparable to the effects from a typical UK dredger, and in terms of total loss of fine sediment overboard, the effects from a larger dredger may be less than a typical UK dredger.

Potential for Additive Effects from Plumes

The potential for additive effects was investigated using a simulation of two trailer suction dredgers working in the same area, one behind the other and 200 m apart from each other. The scenario involved two dredgers travelling back and forth (twice) along a 2 km stretch of the inshore edge of Area 448 and two dredgers doing the same along the inshore edge of Area 102 at a speed of 1 knot (0.51 m s^{-1}). Dredging was continuously operated for four hours while sediments were released two hours ahead of peak flood current or peak ebb current respectively. The model was run for five hours in total to obtain the maximum plume extents for both the flood and ebb phase of the tide.

The footprints of suspended sediment concentration above background for the flood and ebb inputs combined are shown in Figure 7.14 for depth-averaged concentrations and for the near bed. The maximum extent of sedimentation from this scenario is presented in Figure 7.15. Comparing the outputs from this moving dredger scenario with the stationary modelling (Figure 7.5 and Figure 7.12) shows no substantive differences, with the plume controlled by the major axis of the tidal current ellipse. The maximum extents to the 2 mg l^{-1} contour were similar in the flood and ebb direction and similar in extent to the maxima modelled for the initial plume analysis. Depth of sedimentation also showed little difference with the initial plume analysis. It is likely, however, that the temporal nature of the plume will be different and the development and decay of sediment concentrations depend not only upon their positions in the area, but also upon tidal flow states when the initial sediments were released.

Figure 7.14 Potential for Additive Effects from the Sediment Plume

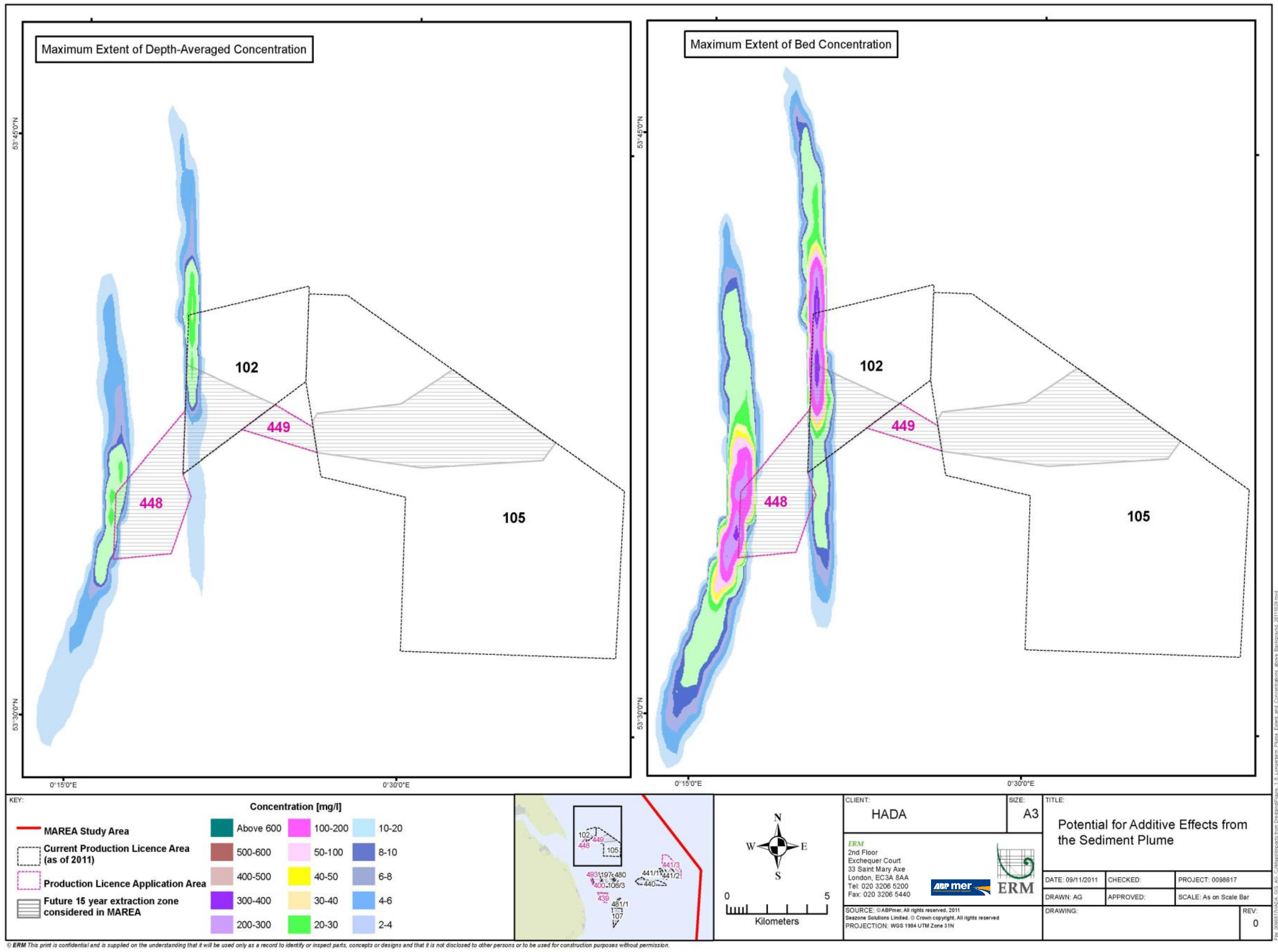
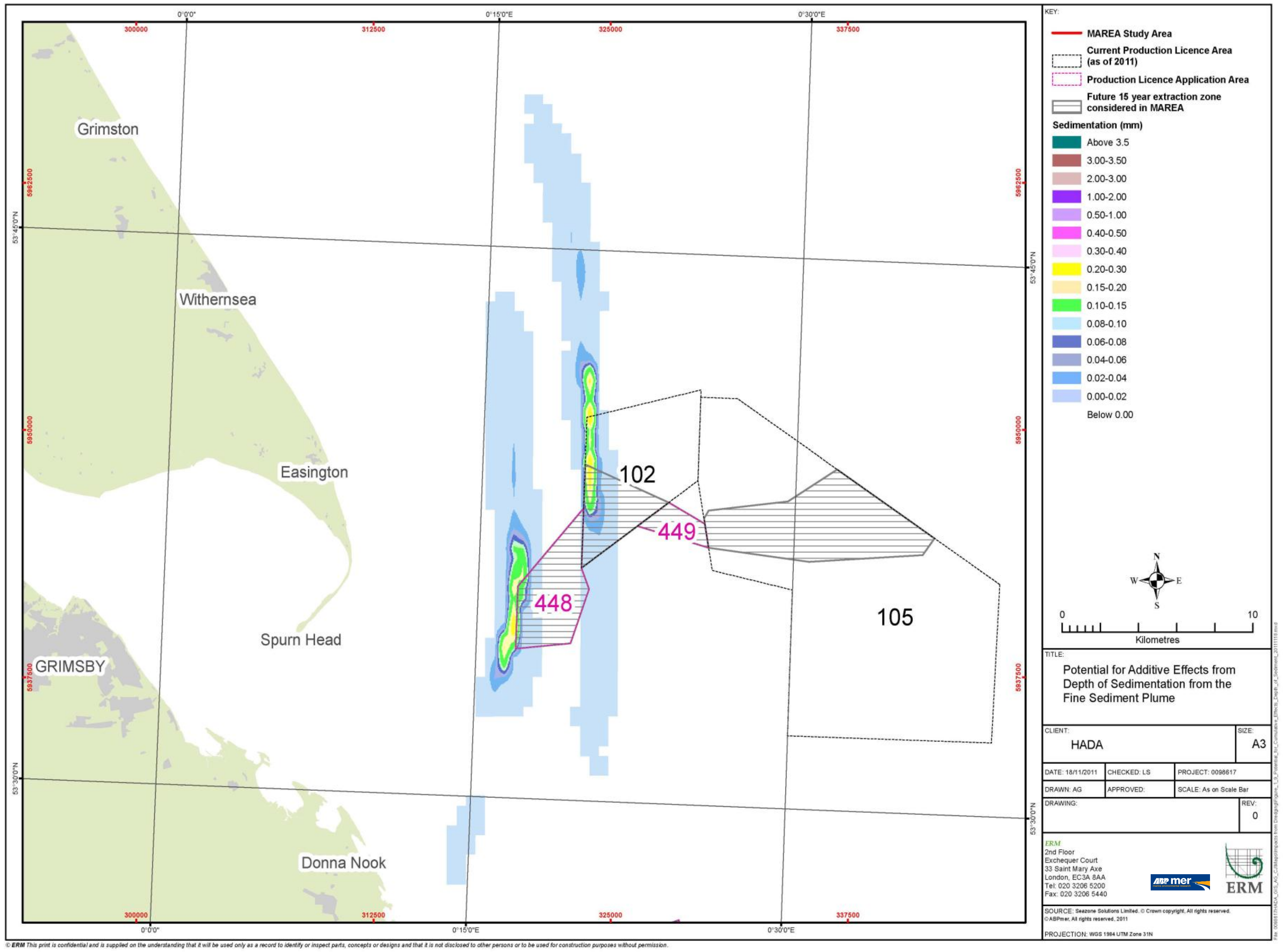


Figure 7.15 Potential for Additive Effects from Depth of Sedimentation from the Fine Sediment Plume



In addition, the potential for additive effects can also occur where two or more of the licence areas are in close proximity to one another so that there is the possibility that plumes from dredgers in two adjacent areas might interact. The zones where two plumes could potentially interact are shown in Figure 7.5, where the footprints for the 2, 20, 50 or 100 mg l^{-1} concentrations overlap with the plumes from a different licence area (for example plumes from Areas 439 and 106). Where licence areas adjoin it is reasonably assumed that there is the potential for plume interaction and this is not shown. However, where licences do not adjoin but are adjacent, the zone in which plume interaction may occur is presented.

Whilst the potential for additive plume effects exists, it is unlikely to occur often as the likelihood of two dredgers working in those parts of adjacent areas such that their plumes interact with each other will be low. For plumes that interact, a larger plume with similar concentrations to those of the separate plumes will be formed as the two bodies of water mix. Peak concentrations would not be exceeded in areas where the plume footprints overlap, but instead they would be experienced slightly more frequently. The footprints identified in Figure 7.5 are a maximum based on the maximum tonnage scenario provided by HADA members and consequently the extent of any additive effect in practice will be smaller than shown.

7.3.6 Mobilisation of Contaminants

Dredging can mobilise contaminants into the water column, such as metals and hydrocarbons that were previously contained within the porewater or adsorbed onto sediment particles. Contaminants released from sediment during dredging can potentially affect marine organisms through direct toxic effects to the organism and through bioaccumulation. It is generally expected that release of contaminants could be expected in sediments with a history of direct contamination, that are close to sources of contamination (e.g. fluvial inputs) and that have high concentrations of fine particles. However, there is no such history of direct contamination of the sediments to be dredged, there are no dumping grounds in the immediate vicinity of any licence area, the licences are some distance from fluvial inputs (also discussed below) and the licences have a low fine particle content in the target materials. The glacial geological origin of the aggregate deposits off the Humber means that modern contaminants will not be present within them. Recently deposited fine material coexisting with the deposits could have the potential to contain some contamination. However, as shown in Figure 4.18 only very low proportions of silt occur within the licence areas and so significant contamination is not expected. In addition samples taken from four coastal stations in the MAREA area generally show hydrocarbon and metal concentrations to be below the Canadian Probable Effect Level (PEL) i.e. the level above which adverse effects are expected to occur frequently. Hydrocarbon and metal concentrations are lowest in The Wash and highest near Grimsby. Concentrations further offshore are generally lower than in the coastal zone and estuaries (Franklin & Jones 1995).

7.3.7 Noise

Potential Effects on Sensitive Receptors

Underwater noise and vibrations from aggregate dredging activities have the potential to adversely impact upon marine mammals and fish in the MAREA study area. Marine mammals and fish have been shown to be affected by anthropogenic underwater noise sources, which at high levels can cause temporary and permanent hearing damage (Turnpenny *et al.*, 1994, Engås *et al.*, 2002, Slotte *et al.,* 2004, Richardson *et al.,* 1995) or behavioural changes.

The effects of dredging noise on marine species depend on the following factors.

- the level and frequency of ambient noise that already exists in the area;
- the noise source;
- noise attenuation due to propagation through the water; and
- the sensitivity of the marine animals to noise and their behavioural responses.

These factors are discussed in more detail in the following sections.

Existing Ambient Noise Levels

Ambient underwater noise in the marine environment comprises a variety of both natural and anthropogenic noise sources. Natural noise sources include wind and wave action, precipitation and the calls of marine life, whereas anthropogenic noise sources include shipping activities (including the movement and activities of fishing vessels, recreational, and military craft) and the construction of offshore developments (such as offshore wind farm structures). Further details on the ambient noise levels in the Humber and Outer Wash study area can be found in the physical baseline chapter (Chapter 4). In order for underwater noise from dredging activities to potentially have an impact upon marine receptors, the noise from dredging must be above the existing noise levels and within their range of hearing sensitivity. For mobile receptors, the species also have to be present and in range.

The Noise Source

A recent study into underwater noise arising from marine aggregate dredging operations published by the Marine Aggregate Levy Sustainability Fund (Robinson *et al.,* 2011) is considered the most recent and comprehensive investigation into underwater noise as an effect of aggregate dredging in UK waters. The study reported source levels from seven UK TSHD in different operational modes, the highest being the Sand Harrier for which a source noise level of 190 dB re 1µPa (rms) was calculated at 1 m from the source during full dredging mode. Although none of the measurements taken were recorded within the MAREA study area, they have been adapted to then make them suitable for EIA studies in other areas. The vessels included in the study are considered to be representative of those used within the Humber and Outer Wash offshore area.

The MALSF study found that marine aggregate dredging vessels in transit contribute shipping noise to the marine environment from their engines (including propellers) and mechanical parts in the same way as all diesel engine vessels. Dredging itself creates variable frequency noise sources from its operational modes, including the motion of the draghead on the seabed, the suction pumps and the flow of aggregates through the pipe work into the hopper. Some seabed vibration occurs during dredging activities but there are few data available on the extent of this or on the ambient seabed vibrations (Robinson *et al.*, 2011).

The findings showed that dredging vessels produce noise below 500 Hz, a level similar to that produced by merchant vessels travelling at modest speed. The aggregate extraction process produces higher frequency broadband noise above 1 kHz. The noise produced is dependent on the dredged sediment type, with coarser sediments producing higher noise levels. Noise produced by marine aggregate dredging is continuous for between 2 and 6 hours per cargo depending on the vessel capacity.

HAM 312 Trailing Suction Hopper Dredging Vessel

Source: Shutterstock.com

Variations in noise source levels and frequencies were identified during the different operational modes. For example, the level of high frequency broadband noise above 1 kHz was recorded to be greater when the draghead was down on the seabed but not pumping compared to when it was raised and pumping water, and that high frequency received levels were greater still during aggregate pumping. Whilst the pump itself contributes to noise levels above 1 kHz, the passing of aggregates through the pipe is also a major contributor to this bandwidth.

Lower frequencies below 550 Hz did not show this variation, indicating that the noise from the engine and propulsion systems remain relatively unchanged during different operational modes. During full dredging operations, frequencies peak between 1 kHz and 100 kHz, with substantial reductions in noise levels at frequencies greater than 100 kHz.

Noise attenuation and the hearing sensitivity of marine species determine the significance of elevated noise levels due to aggregate dredging and these factors are considered below.

Noise Attenuation Due to Propagation through the Water

Underwater noise attenuates (decreases) with distance away from the source and attenuation in deep water is typically greater than in shallow water.

Source propagation models can be used to estimate the distances over which sound may travel, taking account for the interaction of sound waves with the seabed, the sea surface, and the absorption properties of the water. However, the hearing sensitivity of marine species remains the one of the most important factors in determining the significance of underwater noise impacts produced by aggregate dredging. Marine fauna use sound for a variety of functions and behavioural interactions, including to find prey and to communicate with one another. Different species have differing levels of frequency band sensitivity and they make and receive sound using different types of physiology. As a result, marine life displays varying behavioural responses to noise sources.

Physical Effects and Behavioural Responses to Noise

Effects of dredging noise are assessed in this MAREA in terms of any potential physical effects and/or behavioural responses to relevant species. The hearing sensitivities of particular species are discussed in more detail in Sections 9.3 and 9.4.

Potential Effect 6: Underwater Noise: The assessment of the underwater noise effect of dredging is conducted semi-quantitatively due to the many uncertainties related to this topic that make it inappropriate to attempt to develop quantitative GIS layers. The assessments therefore consider the biology of the species under assessment including discussion around likely levels of audibility and levels of responsiveness within the context of ambient noise and habituation.

7.4 SECONDARY EFFECTS

Dredging activity could potentially result in a number of secondary effects due to the alteration of seabed morphology. This section determines the extent to which aggregate dredging carried out in the Humber and Outer Wash study area has affected the natural hydrodynamic and sedimentary regimes and what further changes may occur in response to future dredging activities. The following effects of dredging are considered:

- Changes to the waves.
- Changes to tidal flows.
- Changes to sediment transport as a result of changes to the waves and tidal flows.
- Loss of access to a particular area for other marine users as a result of presence of the dredging vessel.

Each of these potential secondary effects is discussed in sections Section 7.4.2 to 7.4.3.

Buoy in a Strong Tidal Flow

Source: Shutterstock

7.4.1 Approach to Modelling

In order to be able to determine the effects of past and future aggregate dredging on the hydrodynamic and sedimentary regime detailed representations of the pre- and post-dredging bathymetry were developed. Bathymetric data from the licence areas was supplied by the HADA members and regional bathymetric data was supplied by the digital UK Hydrographic Office (UKHO), from Seazone Solutions Ltd. The three bathymetries representing three dredging scenarios are:

- Pre-dredging, which provides a representation of bed levels across the licence areas prior to any aggregate extraction.
- Present day, in which the bed levels within the licence areas reflect the dredging that has been carried out to date.
- Future dredging, which shows the total bed level changes over a 15 year licence period, based on each company's maximum proposed dredging plans.

The two-dimensional software package MIKE 21 has been used to determine the extent and magnitude of changes to the tidal flow and waves as a result of aggregate dredging. The modelling system was developed by the Danish Hydraulic Institute (DHI) Water & Environment group for complex applications within oceanographic, coastal and estuarine environments. It is comprised of various modules enabling the simultaneous modelling of water levels, currents and waves. Two modules of the MIKE 21 FM (Flexible Mesh) model were applied to resolve the key physical processes: the hydrodynamic module MIKE21 HD (Hydrodynamic) that simulates water level variation and two dimensional flows and the MIKE SW (Spectral Wave) model to represent both wave generation and transformation in the Humber and Outer Wash region. The models were calibrated and validated using measured water level, flow and wave data obtained from BODC and Cefas. Wave analysis was carried out using data obtained from the Met Office to determine the 1:200 year and 10:1 year wave conditions to be used in the study. Figure 7.16 presents the flexible mesh used by the model.

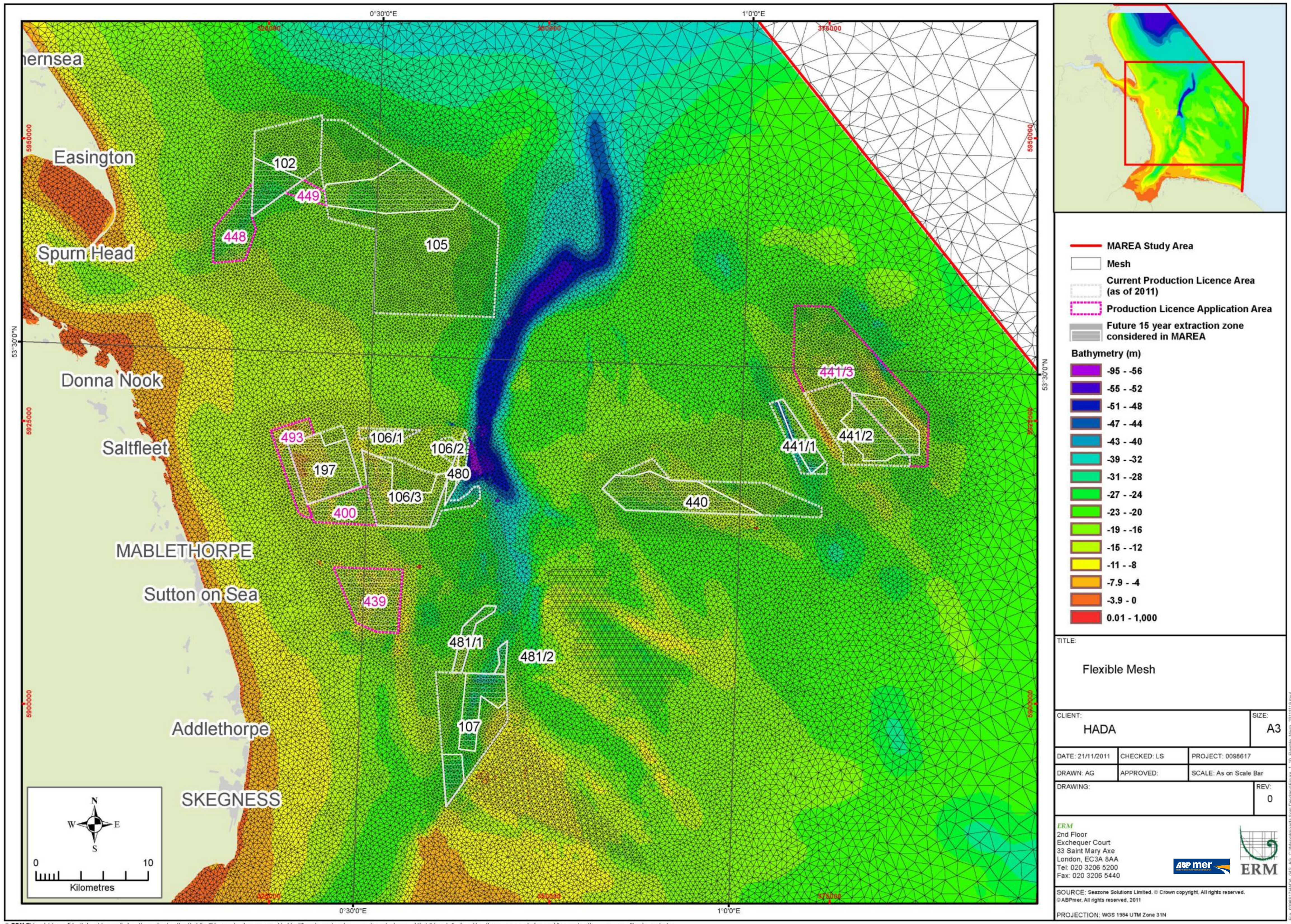
Difference plots were created by comparing the predicted wave height for the pre-dredging and present day bathymetries and for the present day and future bathymetries, and calculating the difference. The differences are shown in terms of both percentage change and absolute change in wave height / tidal flow. For the percentage changes any changes smaller than 2% (either + or -) are not presented in the results as they are within the accuracy of the model and should be regarded as not significantly different from zero. For the absolute values, changes of less than 0.1 m wave height and 0.02 m s-1 flow speed are considered in this study to be within the confidence limits of the chosen model and are not shown as a difference. It is important to note, however, that in some cases a change of 2% or greater might be less than 0.1 m in absolute terms and vice versa, which would result in a change in one figure but not in the other. This does not reflect an error in the model or presentation but is simply a function of the original size of the wave or flow speed. The difference plots showing percentage change are considered to be the primary source of information with the absolute changes included to provide a context for the changes.

The predicted changes predominantly arise through interactions with the dredging areas and decrease in magnitude with increasing distance from the dredging area. A number of figures (primarily those showing percentage changes) also show small, isolated differences that are not connected to the dredging areas. These occur in areas either where the bathymetry is complex, over large intertidal areas or where wave heights are typically very small. These predicted changes have been carefully evaluated in the context of the natural environment and physical processes and are judged to be artefacts of the model calculations rather than real changes caused by the proposed dredging. This is particularly the case for changes within the Humber where the complex intertidal bathymetry in the estuary is not represented accurately and where all estuarine processes are not included in the model. For these reasons the predicted changes to waves in the lee of Spurn Head should be disregarded. This is also the case for the more minor changes predicted in The Wash and at Donna Nook.

Sandflats at Donna Nook at Dawn

Source: Shutterstock.com

Figure 7.16 Flexible Mesh



7.4.2 Changes to the Behaviour of Waves

Potential Effects on Sensitive Receptors

Aggregate dredging causes a localised lowering of the seabed (as described in Section 7.3.2 which has the potential to alter the way that waves propagate across the area. In deep water (>30 m) modification to the waves is likely to be relatively minor, except in the immediate vicinity of the dredging area. These localised changes may only be of concern if there are interest features such as sandbanks or other seabed features, wrecks or submarine cables located near to the site. However, in shallow water (<30 m), changes to the waves may be both larger and more widespread so that waves at the coast might potentially be affected. The majority of dredged depressions will be permanent (i.e. they will not infill) due to aggregate extraction taking place in areas of limited sediment flux, therefore any changes to the behaviour of waves in the region are also likely to be long lasting.

Summary of Methodology for Predicting Changes to Wave Behaviour

For the previous MAREAs, and for this study, a 1:200 year return period was deemed to represent an appropriate worst case, particularly since this is also the return period commonly used in the design of coastal defences. A more commonly occurring wave scenario of 10:1 year was also selected to demonstrate the effect of dredging on the morphology of the study area. More common wave heights can have a greater effect than rare extreme waves on the long term shallow seabed and coastal evolution. The input conditions for the 10 in 1 year and 1 in 200 year wave conditions are presented in Table 7.2.

Table 7.2 Wave Input Statistics

Direction	Parameter	10:1 year	1:200 year
North	Significant wave height (m)	4.26	6.30
	Peak wave period (s)	9.40	11.5
	Wind speed (m s^{-1})	16.0	22.0
Northeast	Significant wave height (m)	3.24	7.62
	Peak wave period (s)	8.20	13.2
	Wind speed (m s^{-1})	12.0	25
East	Significant wave height (m)	3.14	5.65
	Peak wave period (s)	8.10	10.2
	Wind speed (m s^{-1})	13.0	21.5
Southeast	Significant wave height (m)	3.00	5.54
	Peak wave period (s)	7.60	10.2
	Wind speed (m s^{-1})	13.5	21.0

The 1:200 year return period wave was derived for each of the directional sectors presented in Table 7.2. The MIKE spectral wave (SW) model was then used to simulate these waves at both high and low water on a spring tide for the three dredging scenarios: pre-dredging, present day and future. All outputs show the reduction in height as the waves move into shallow water, as demonstrated by Figure 7.17, which shows wave height and direction at MHWS for 1 in 200 year northeast wave with the present day bathymetry. Figure 7.17 shows that close inshore, wave heights are reduced as a result of interaction with the bed and eventual breaking. In addition to the general offshore-onshore reduction in wave height, more localised changes occur as the waves travel over sandbanks or other seabed features. The most obvious effects occur around Triton Knoll, Dudgeon Shoal and Race Bank, although the changes to wave conditions are localised and wave heights commonly increase again inshore of the features. The inshore banks such as Inner Dowsing do not appear to provide a large degree of shelter to the coast and the 1:200 year wave height along much of the study area coastline would be between 3 m and 4 m.

Predicted Changes to Wave Heights

<u>Effects of Past Dredging on Extreme Waves</u>

Figure 7.18 shows the predicted changes to waves from the northeast between the pre-dredging and present day scenarios at MLWS. These show that changes above 2% are restricted to Area 440 and do not exceed 3%. No changes were evident at MHWS. The greater increase in wave height calculated for low water is due to the greater relative increase in water depth from dredging in proportion to overall depth at low tide. Waves from all other directions showed similar results (see Appendix E for full details and difference plots); in all cases the predicted increases in wave height are less than 5% or 0.3 m and are either contained within the licence areas themselves or extend only a few hundred metres beyond. Cumulative effects of past dredging carried out in the MAREA study area are concluded not to have produced a measurable effect upon extreme waves at the coast or over the majority of the study area.

<u>Effects of Future Dredging on Extreme Waves</u>

The total seabed lowering applied in the future scenario represents aggregate dredging that could take place by 2030 based on the availability of resource and the maximum extraction proposals of the HADA members. For reasons set out in the Industry Statement, it is likely that the volumes removed during the licence periods will be substantially less and the future dredging scenario modelled accordingly not only represents the maximum cumulative case but also the maximum case for each licence area. It is therefore safe to assume that if the actual extraction is less than the maximum proposed then changes to the wave climate will be either the same or less than those predicted in the present study.

The predicted differences in 1:200 year waves from the northeast at MHWS are presented in Figure 7.19. This shows that over much of the study area changes to the wave height are less than 2% or ± 0.1 m and no changes greater than this threshold are predicted within 1 km of the coast. In general any changes to the wave height are confined within the dredging areas, with the exception of Areas 493 and 448. Over much of Area 448 and some 6 km to the southwest, wave heights are predicted to decrease by around 3% or up to 0.2 m. This change in wave height is very small and does not extend either to the coast or over any key sedimentary features. Contrary to the decrease of wave height observed in the lee of other dredge areas, there is an apparent increase in wave height of up to 15% in the lee of Area 493, located 11 km off the Lincolnshire coast, in a post-dredge scenario. The largest changes are confined to within a few hundred metres of the licence area but increases of 10% down to 3% (decreasing with distance from the dredging area) extend to almost 1 km from the coast. The relatively shallow pre-dredge water depth within Area 493 (as indicated by the presence of an overfall) at present causes energy to be dissipated. The wave height is hence reduced in the lee of Area 493. Lowering of the seabed by aggregate dredging can reduce the energy dissipation that occurs as waves travel over and in the lee of Area 493. This results in an increase of the wave energy toward the coast. However, the beach profile at Mablethorpe, presented in the baseline characterisation (see inset 6 in Figure 4.10), shows a large bathymetric feature 1 km from the shore, which will provide shelter from wave action. This feature, referred to as the Mablethorpe Bank, plays an important role in dissipating nearshore wave energy (see Figure 7.19). The proposed dredging in this area is not predicted to affect wave heights at the coast, which is the primary concern when considering extreme waves at high water.

Changes to the 1:200 year north-easterly waves at MLWS are also presented in Figure 7.19. Over much of the study area there is little difference between 1 in 200 year waves at MLWS and MHWS. Minor increases are predicted for MLWS to the south of the offshore dredging areas but these changes are localised. The predicted decreases in wave height in and around Area 448 are reduced compared to the MHWS results. The largest changes are predicted for Area 493, where wave heights are predicted to increase by more than 25% compared to the present day within the dredging area and although changes of this magnitude are highly localised, increases of up to 10% or 0.3 m are predicted to extend to occur within 2 km of the coast. These changes are produced as a result of the large increase in water depth in Area 493 relative to the pre-dredge water depth. However, as in the case with the MHWS modelling, the increase in wave energy is subsequently effectively dissipated as it approaches the Mablethorpe Bank.

Waves from all other directions for the 1:200 year wave showed similar results in that differences are typically confined to the dredging areas or their immediate vicinity. The exception is a small stretch of the Lincolnshire frontage, however, in absolute terms this equates to an increase of less than 0.1 m and is not therefore likely to produce an adverse effect at the coast (see Section 7.2 in Appendix E for full details).

The 1:200 year wave condition is by definition extremely rare and the expected duration of such an event would be very short (e.g. a few hours). It is also highly unlikely that such a rare event would coincide with a very low tide level as severe storms in the Southern North Sea are more often accompanied by surges, which typically raise water levels above normal tidal height (although negative surges, which considerably lower the water level, also occur). Based on the modelling results, which predicted smaller changes at MHWS than at MLWS due to the proportionally greater water depth at high water, a combined extreme wave and surge event would most likely moderate the effects of dredging inshore from Area 493. In addition, the infrequent occurrence and short duration of the 1:200 year event suggests that any effects on the morphology or sediment transport would be short lived. If considered over the return interval period of 200 years the potential effects on large seabed features are considered minor compared to longer-term natural variability.

Based on the results of the numerical modelling it is considered that cumulatively, the proposed future dredging within the MAREA study area will not affect waves at the coast. In the context of impacts on coastal erosion and defences, the combination of extreme waves and high water levels did not produce measurable changes within 500 m of the coast.

Figure 7.17 Wave Height and Direction for the Present Day Bathymetry at MHWS for a 1 in 200 year Northeast Wave

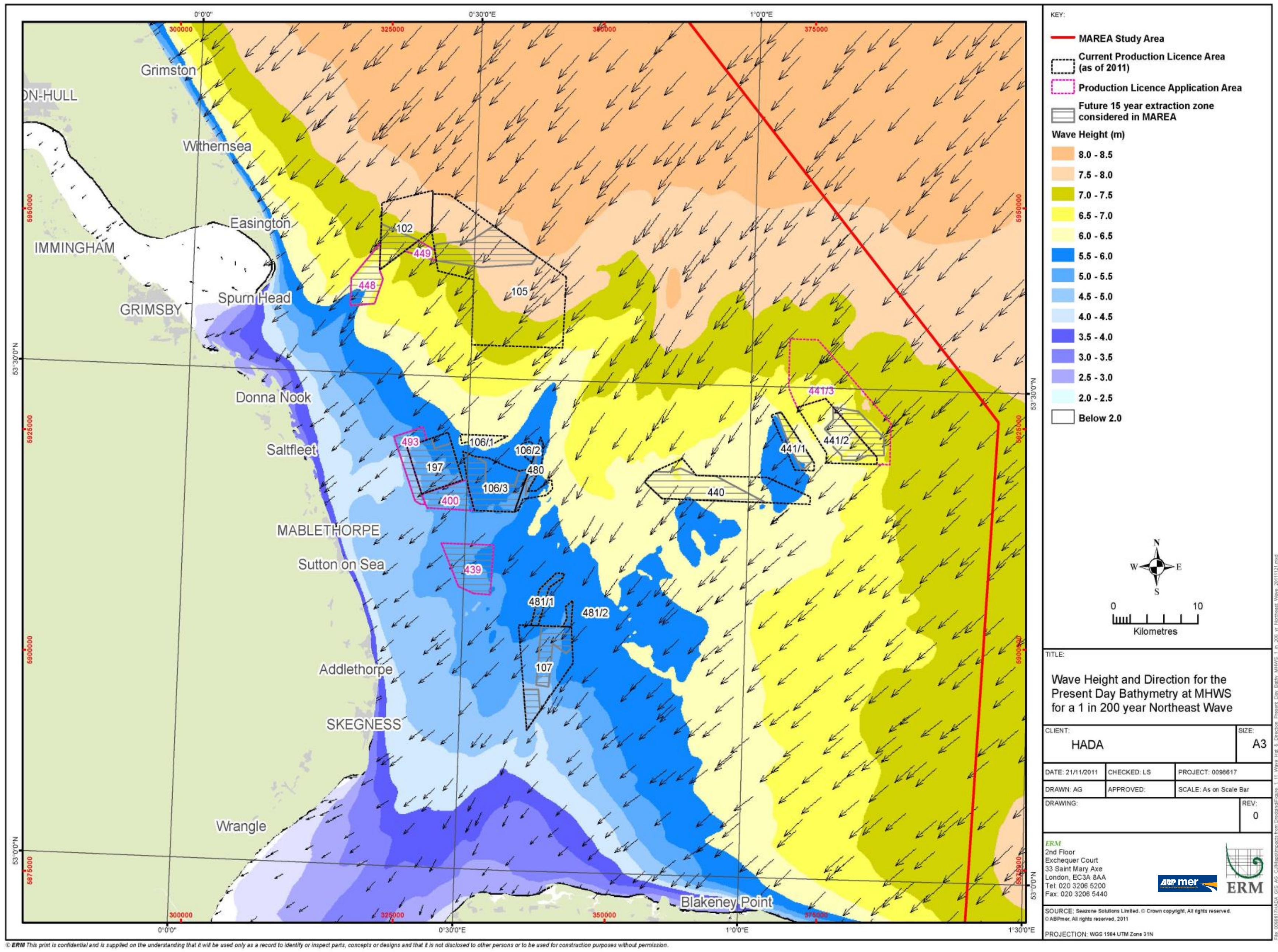


Figure 7.18 Past Changes in Wave Height for a 1 in 200 year North-easterly Wave at MHWS and MLWS

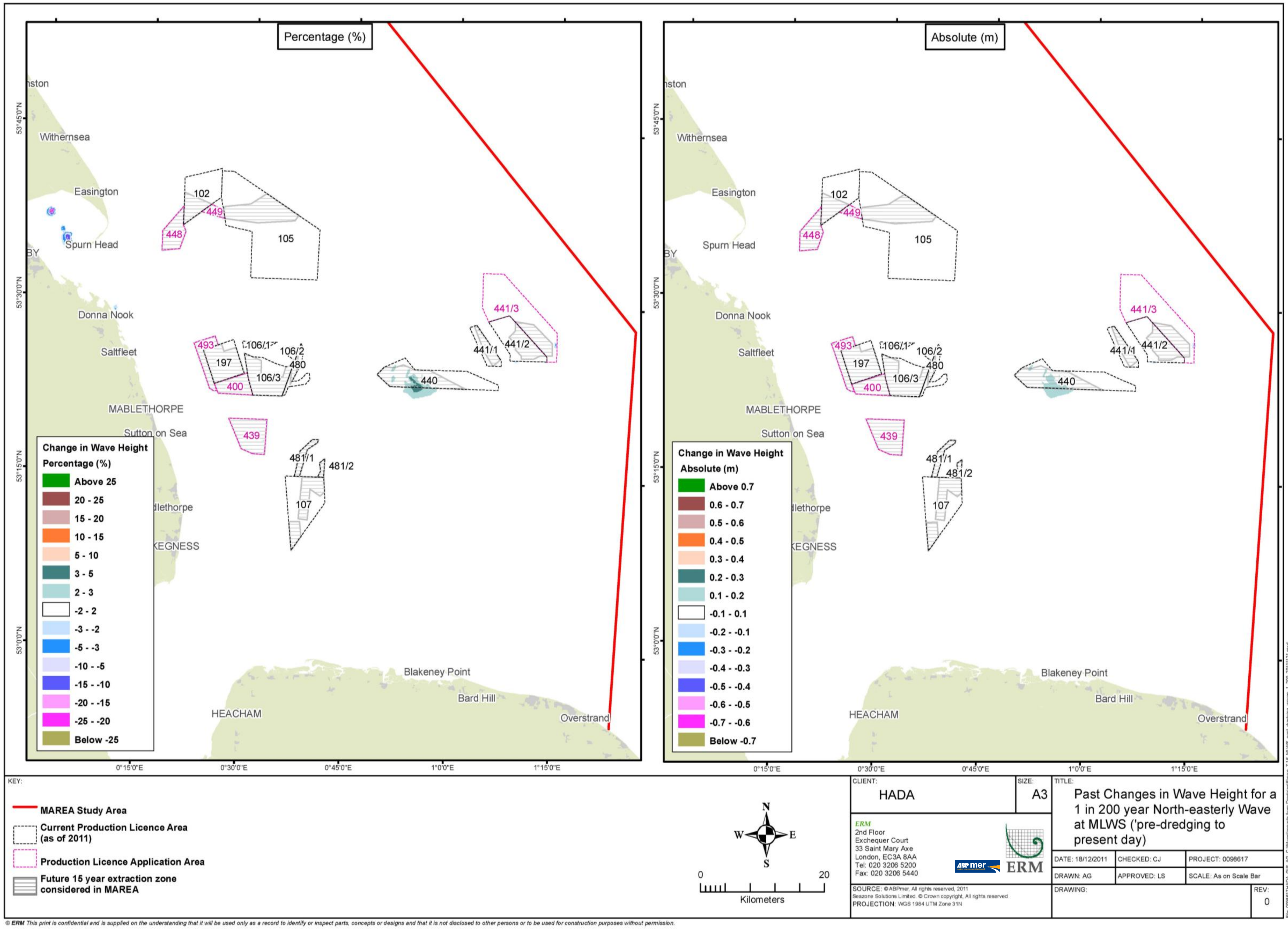
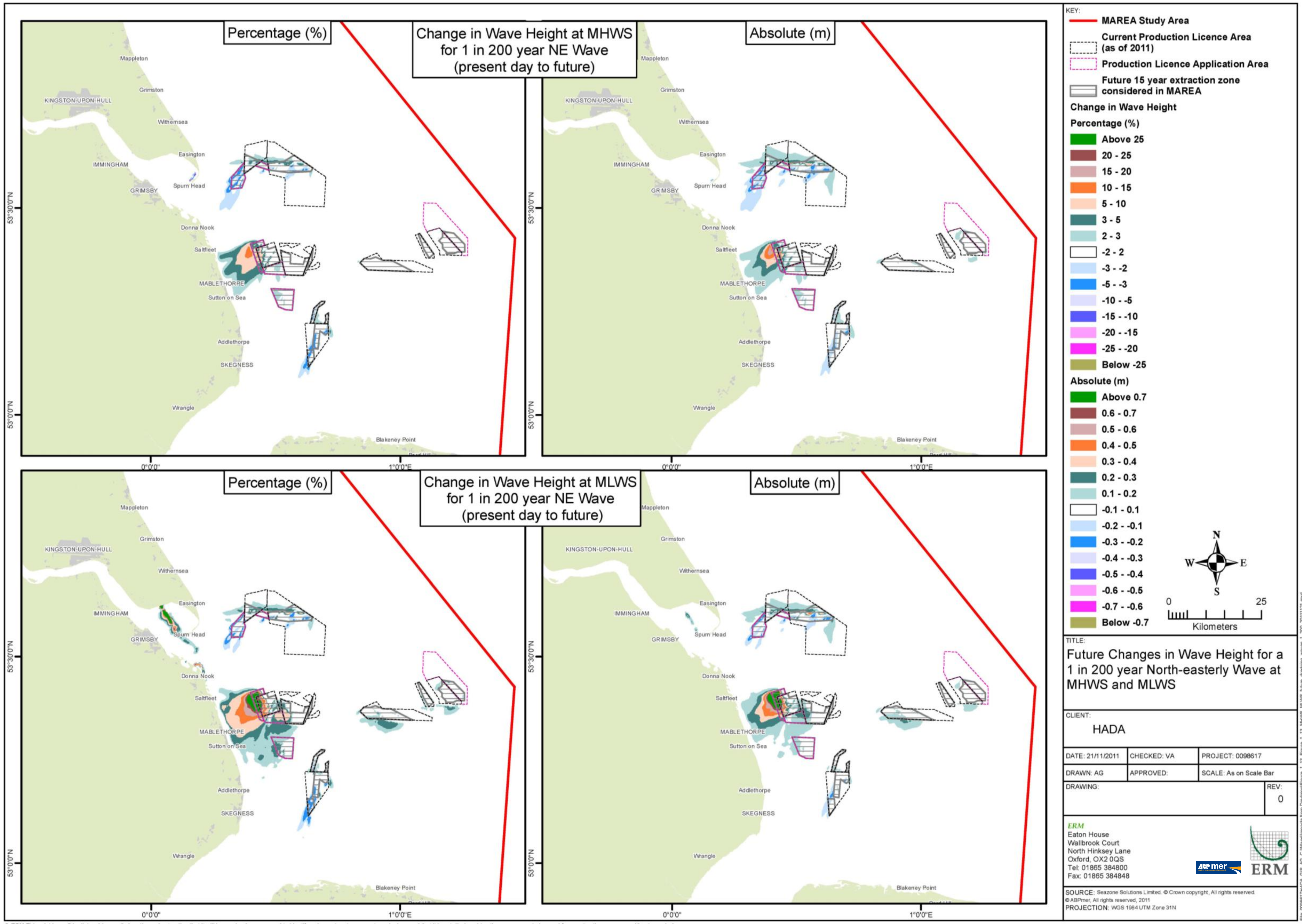


Figure 7.19 Future Changes in Wave Height for a 1 in 200 year North-easterly Wave at MHWS and MLWS



Effects of Dredging on 'Morphological' Waves

Long-term seabed and coastal evolution is driven by moderate, frequently occurring events rather than the very extreme and relatively short duration conditions described above. Therefore the effects of aggregate dredging on smaller, more frequent waves have been considered to establish whether and where changes to seabed features may occur. The 10:1 year annual return period means that a wave of this size would be expected to occur up to ten times per year; it therefore represents a wave that may affect the morphology of the seabed. The northeast incident wave angle was selected for this assessment as this produced the largest effects for the 1:200 year modelling. The 10:1 year wave was simulated at MHWS and MLWS from this direction only for each of the three dredging scenarios: pre-dredging, present day and future. As demonstrated by Figure 7.20 10 in 1 year wave heights are much smaller than for the 1:200 year wave and the more regular height contours indicate a lower degree of interaction with the offshore seabed and sandbank features. Along the coast, 10:1 year wave heights are typically between 1.5 and 2.5 m.

Effects of Past Dredging on 'Morphological' Waves

Throughout the entire study area, no changes in excess of the ±2% threshold were predicted at either MHWS or MLWS for the 10:1 year waves. Consequently it is concluded that past dredging in the Humber Region is highly unlikely to have had a measurable effect on seabed morphology or wave driven sediment transport.

Effects of Future Dredging on 'Morphological' Waves

The predicted changes to the 10:1 year north-easterly waves in response to the proposed future aggregate extraction are presented in Figure 7.21. At MHWS the only changes that exceed the ±2% threshold are those resulting from dredging in Area 493 and very minor, localised changes in Area 105 and at the southern tip of Area 448. The predicted changes at MHWS from Area 493 extend over 8 km inshore from the dredging area with increases in wave height of up to 3% extending to the coast. However, in absolute terms such changes to wave height at the coast fall within the computational accuracy of the model. As described previously the predicted changes are greater at low water than at high water due to the proportionally greater increase in total water depth. In this case, wave height increases of 15% were predicted to extend almost 2 km from the Area 493, whilst a 5% increase was predicted to extend to the coast albeit over only a very small section of the frontage. In absolute terms the predicted changes in wave height close to the coast are less than 0.1 m, which is within the computational accuracy of the model.

Figure 7.20 Wave Height and Direction for the Present Day Bathymetry at MHWS for a 10 in 1 year Northeast Wave

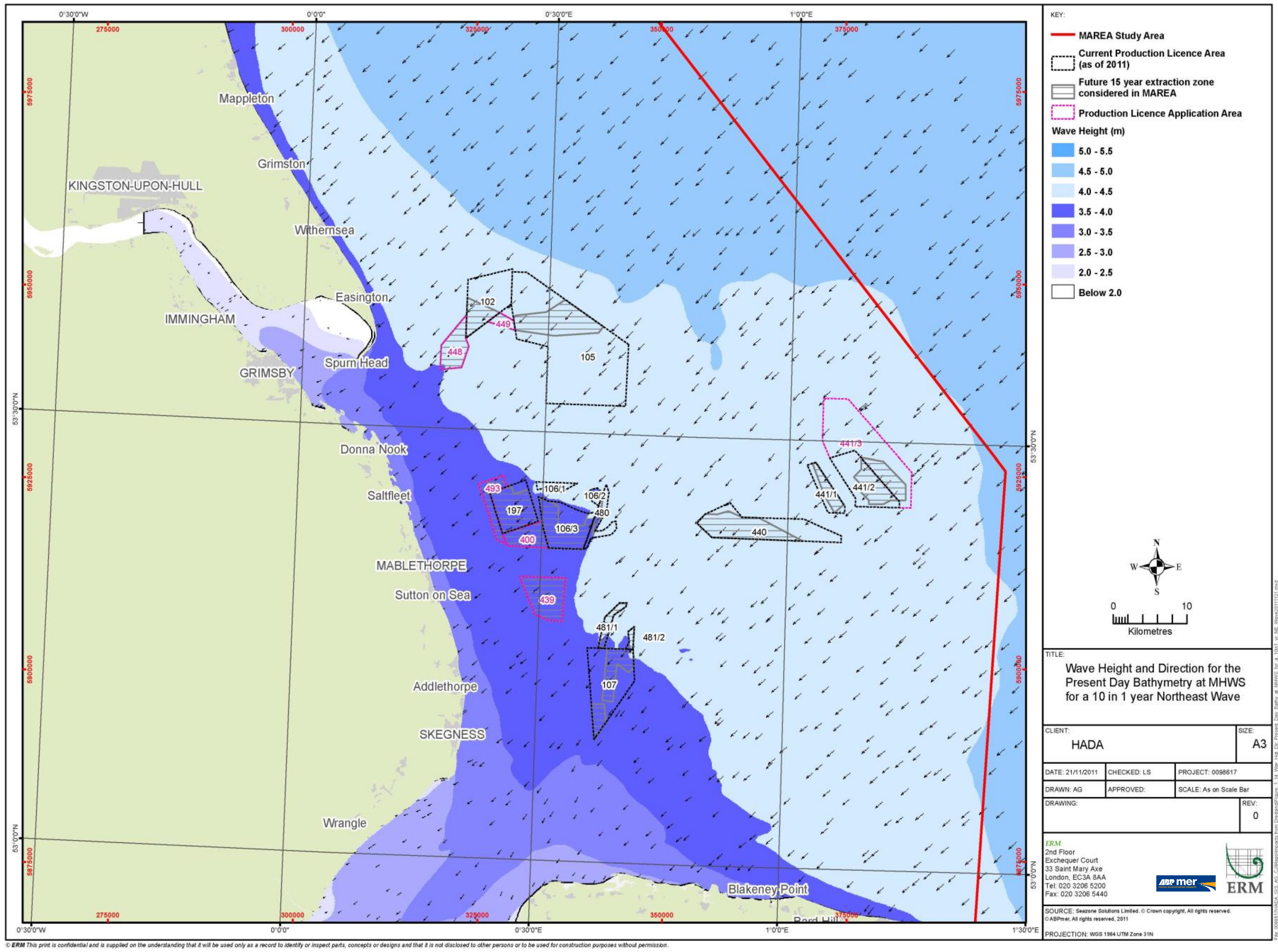
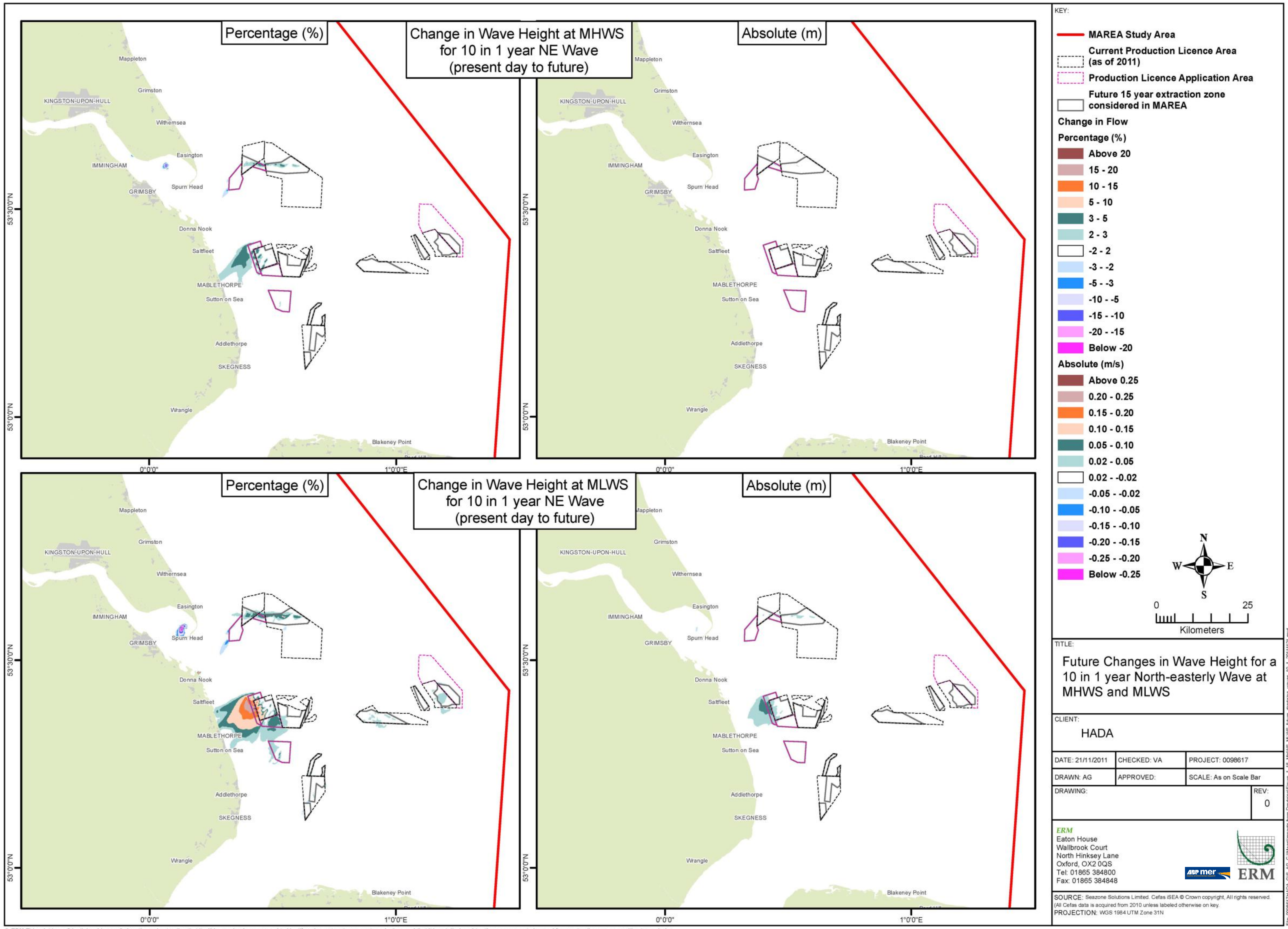


Figure 7.21 Future Changes in Wave Height for a 10 in 1 year North-easterly Wave at MHWS and MLWS



Sensitivity Tests

As global warming occurs, mean sea level increases as sea water expands and as fresh water is released from melting ice masses. An increase in the frequency and intensity of severe storm events is also possible in a warming climate. UK Government guidance requires that all plans and projects should consider the possibility of such an increase in storminess and should carry out sensitivity tests to ensure that the proposed developments remain sustainable in the light of such changes. For these sensitivity tests the 1:200 year north-easterly waves were increased in line with recent guidance (UKCP09).

The primary purpose of these sensitivity tests was to determine whether there would be any changes in wave conditions at the coast. Therefore results at MHWS were calculated. The level for MHWS has been increased to reflect sea level rise of 4 mm per year. As with the previous results, difference plots to demonstrate the change in wave height between present day and future dredging were produced. Two scenarios were considered: climate change scenario 1 = +5% and climate change scenario 2 = +10%. For climate change scenario 1 the predicted changes to the 1:200 year waves are similar in extent and magnitude to the future condition without climate change. This is most likely due to the increased water levels, which moderate the effects of the increased wave height. For climate change scenario 2 the changes are more widespread although the magnitude of change is similar to the original future dredging scenario.

Even with the larger waves and higher water levels as discussed in the sensitivity tests the proposed dredging does not affect wave heights at the coast within the study area.

Potential Effect 7: Changes to Wave Height: This effect is represented quantitatively by GIS layers representing the model outputs from the ABPmer study into physical effects. Layers are provided for both the 'Change in wave height at MLWS for 1 in 200yr NE wave (Future - Present)' and the 'Change in wave height at MLWS for 10 in 1 year NE wave (Future – Present)' scenarios. The 1 in 200 year wave represents a worst case; however, 10 in 1 year wave is a more commonly occurring wave. Both percentage and absolute changes are considered.

7.4.3 Changes to Tidal Currents/Local Circulation

Potential Effects on Sensitive Receptors

Tidal currents arise from the spatial differences in vertical water movements associated with the progression of the tidal wave. Tidal currents move in a rotational pattern and constrictions imposed on these currents by a shoaling seabed accelerate the flow, so that tidal currents are generally stronger close to the shore than in the open sea. In shallow water, large volumes of sediment may potentially be transported by tidal currents alone, or more commonly, by a combination of currents and waves. The change in bathymetry caused by aggregate extraction could potentially alter the magnitude and direction of tidal currents, both in the vicinity of the dredging area and further afield. Any such modification of the tidal currents may lead to a change in the rate and pattern of sediment transport, which could for example affect the integrity of reef features and their associated flora and fauna. Research into the effects of aggregate dredging on physical processes carried out over many years has demonstrated that changes in tidal currents are typically very minor and localised. The depth changes associated with the majority of existing dredging operations are modest in relation to the pre-dredge water depth and therefore have little or no effect on current speeds. Numerical modelling studies have shown that tidal currents are generally reduced at either end of the dredged depressions, with modest increases in current speed along the edges.

Boats Navigating the Humber in a Strong Tidal Flow

Summary of Methodology for Predicting Changes to Tidal Flows

Tidal flow modelling results show an instantaneous snapshot of the current speeds and direction within the study area. Outputs from the flow model were obtained for peak flood and peak ebb on both spring and neap tides. The current speeds and directions for flood and ebb on the spring tide simulations for present day bathymetry are shown in Figure 7.22, which produced greater effects than the neap tide simulations. The peak flood and ebb flows presented in Figure 7.22 are similar to the dredging scenarios for the past and future bathymetries. The figures show that the peak flood tidal currents flow in a southerly direction both along the Holderness and Lincolnshire coastlines and further offshore. Flows into The Wash are south-easterly and the tidal currents flow from east to west along the North Norfolk Coast. Peak ebb currents flow north-eastwards out of The Wash, eastwards along the North Norfolk coast and northwards over the remainder of the study area. A series of difference plots have been created for pre-dredging to present day and present to future to demonstrate the differences.

Predicted Changes to Tidal Flows

Effects of Past Dredging on Tidal Flows

The differences between pre-dredging and present day tidal currents for peak flood and peak ebb are presented in Figure 7.23, which shows that with the exception of some very localised flow modifications of less than 0.1 m s-1 in Area 105, Area 440 and Area 481/1 the predicted changes to flow speeds are below the ± 0.02 m s-1 threshold.

It is therefore concluded that cumulatively past aggregate dredging has not affected nearshore tidal currents or altered sediment transport within the Humber Region.

Effects of Future Dredging on Tidal Flows

The comparisons of peak flow speeds for the present day and future dredging scenario are presented in Figure 7.24, which shows that over the dredged areas themselves, peak tidal currents are predicted to decrease as a result of the increased water depths. Flow speeds are predicted to decrease by between 2 and 20%, which in absolute terms is less than 0.2 m s^{-1} and for the most part less than 0.1 m s^{-1}. The size of the change appears to be directly related to the amount of seabed lowering with the largest changes corresponding to the deepest dredged depressions such as in Areas 105, 449 and 440. It is important to remember that the future dredging scenario represents the maximum potential extraction over the whole licence period and that whilst depth limits may be reached in some locations, the amount of seabed lowering over all the dredging areas together will likely be considerably less.

Numerical modelling studies have demonstrated that flow speeds increase along the edges on both sides (Tillin *et al*,, 2011) of the dredged area simultaneously with a reduction in flows within. The tidal current modelling shows that outside of the dredged areas, flows to the north and south are predicted to increase by up to 15%as a result of the larger tidal discharge through the deepened areas. The increased discharge entering and leaving the dredging areas causes current speeds to accelerate over the adjacent un-dredged areas. Increases in current speed of >5% are typically confined to within a few hundred metres of the dredging areas, with the exception of Area 493 where increases in peak flow speeds of 10% are predicted to extend for more than 1 km to the north on both the flood and the ebb tide. However, in absolute terms this represents a difference of less than 0.1 m s^{-1} compared to the present day.

To the east and west of the dredging areas peak tidal currents are predicted to decrease on both the flood and ebb tide. In all cases the reduction in flow speed is less than 10% and typically changes of more than 5% are confined to within a few hundred metres of the licence area boundary. At all locations the absolute magnitude of change to tidal current speed is less than 0.1 m s^{-1}. The proposed dredging in Areas 493, 448, 439 and 107 cause current speeds to decrease over several kilometres to the east or west of the licence areas, although actual flow speeds are not predicted to change by more than 0.02 m s^{-1} within 1 km of the coast. Further widespread reductions in peak flood and ebb flow speed are predicted to the east of Area 107, although these are typically less than 5% lower than present day values.

The proposed future dredging is predicted to affect tidal current speeds along the Spurn Peninsula and along a short section of the Lincolnshire coastline. In terms of absolute current speed, however, the difference between the present day and future dredging scenarios is less than 0.02 m s^{-1} within 1 km of the coast, which equates to a change of around 3%. Tidal flows are subject to a degree of natural variability and peak current speeds may vary by a few percent on two days when the same tidal range occurs. As a result changes of less than ±2% are not presented. However, even a 5% change is unlikely to affect sediment mobility and induce changes to seabed features when the actual flow speeds change by less than 0.05 m s-1, as is the case over much of the seabed between the dredging areas and the coast.

It is concluded that the proposed future dredging would not change the flow regime sufficiently to cause an adverse effect on the coast or designated seabed features.

Changes to Tidal Flow Direction

In addition to the change in peak flow speed, changes in the tidal current direction have also been predicted. Past dredging has not affected tidal current direction. Future dredging may cause a maximum change in direction within the dredging areas of approximately 12º and outside the dredging areas of approximately 10º, as shown in Figure 7.25. For the most part changes of >4º are confined to within a few hundred metres of the dredging areas.

Potential Effect 8: Changes to Tidal Currents: This effect is represented quantitatively by GIS layers representing the model outputs from the ABPmer study into physical effects. Layers are provided for both the 'Change in peak flood flow speed on spring tide (future minus present) and the "Change in peak ebb flow speed on spring tide (future minus present)" scenarios. Both percentage and absolute changes are considered.

Figure 7.22 Peak Flood and Ebb on Spring Tide Present Bathymetry

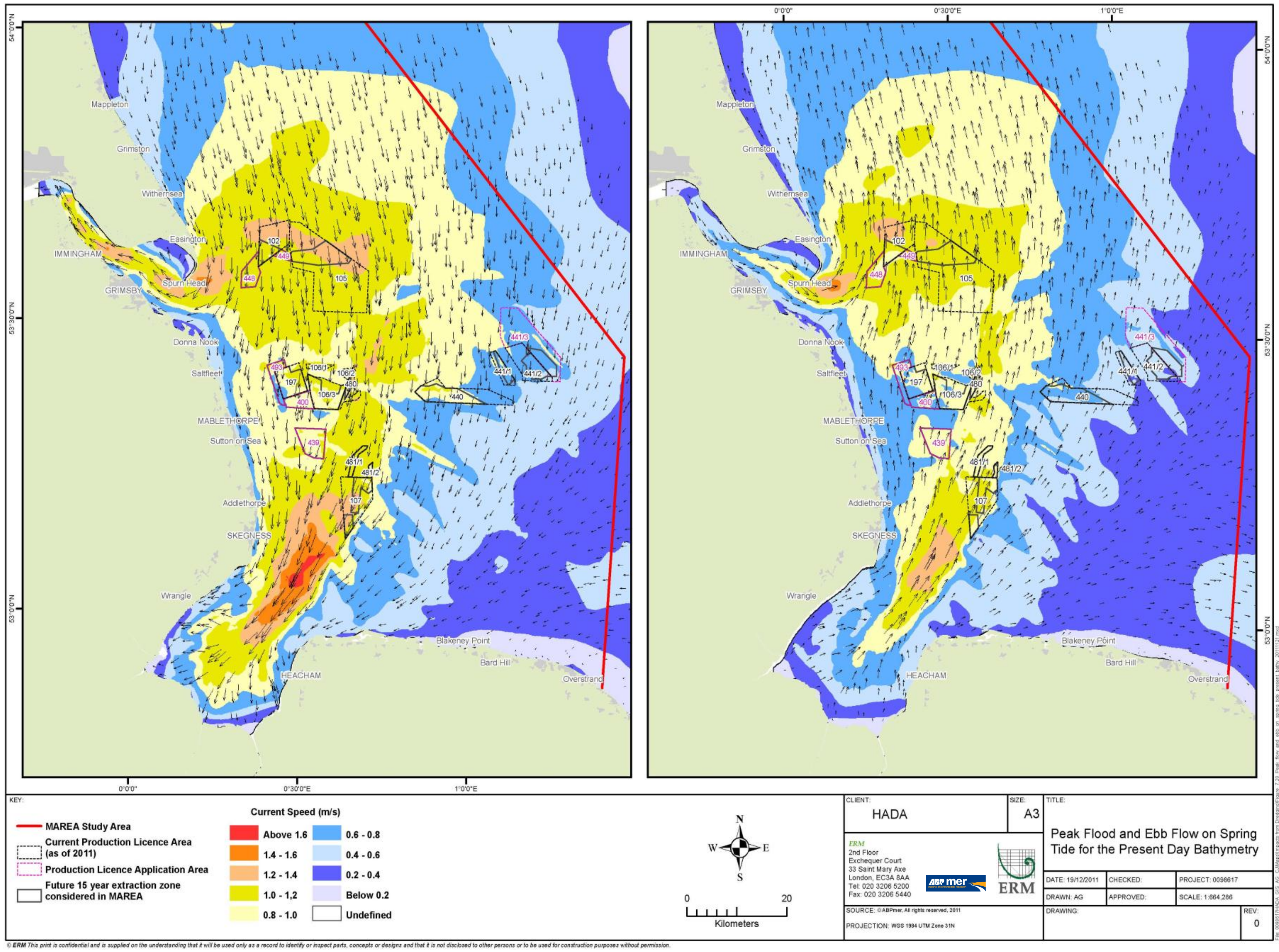


Figure 7.23 Past Changes in Peak Flood and Ebb Tidal Flows

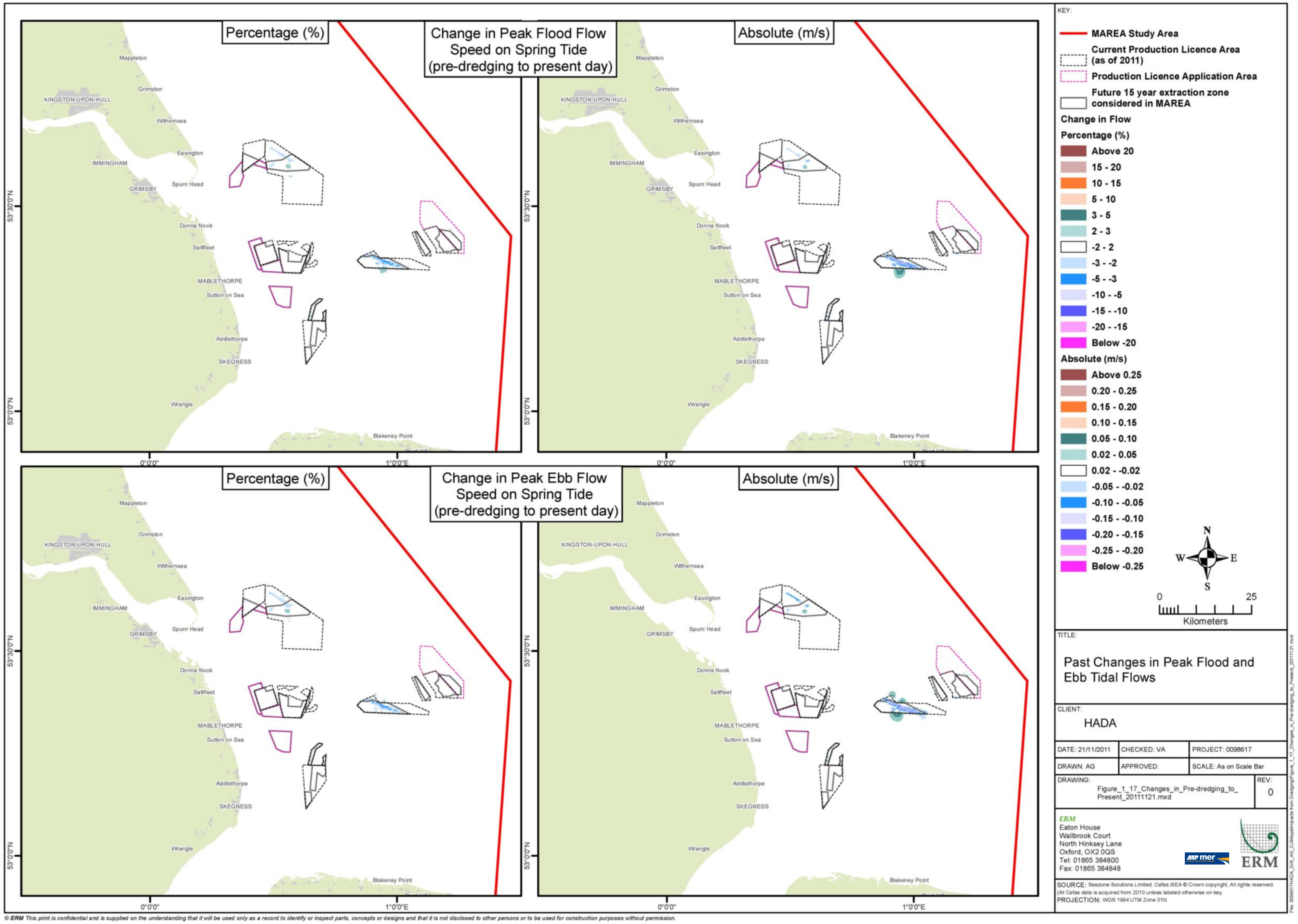


Figure 7.24 Future Changes in Peak Flood and Ebb Tidal Flows

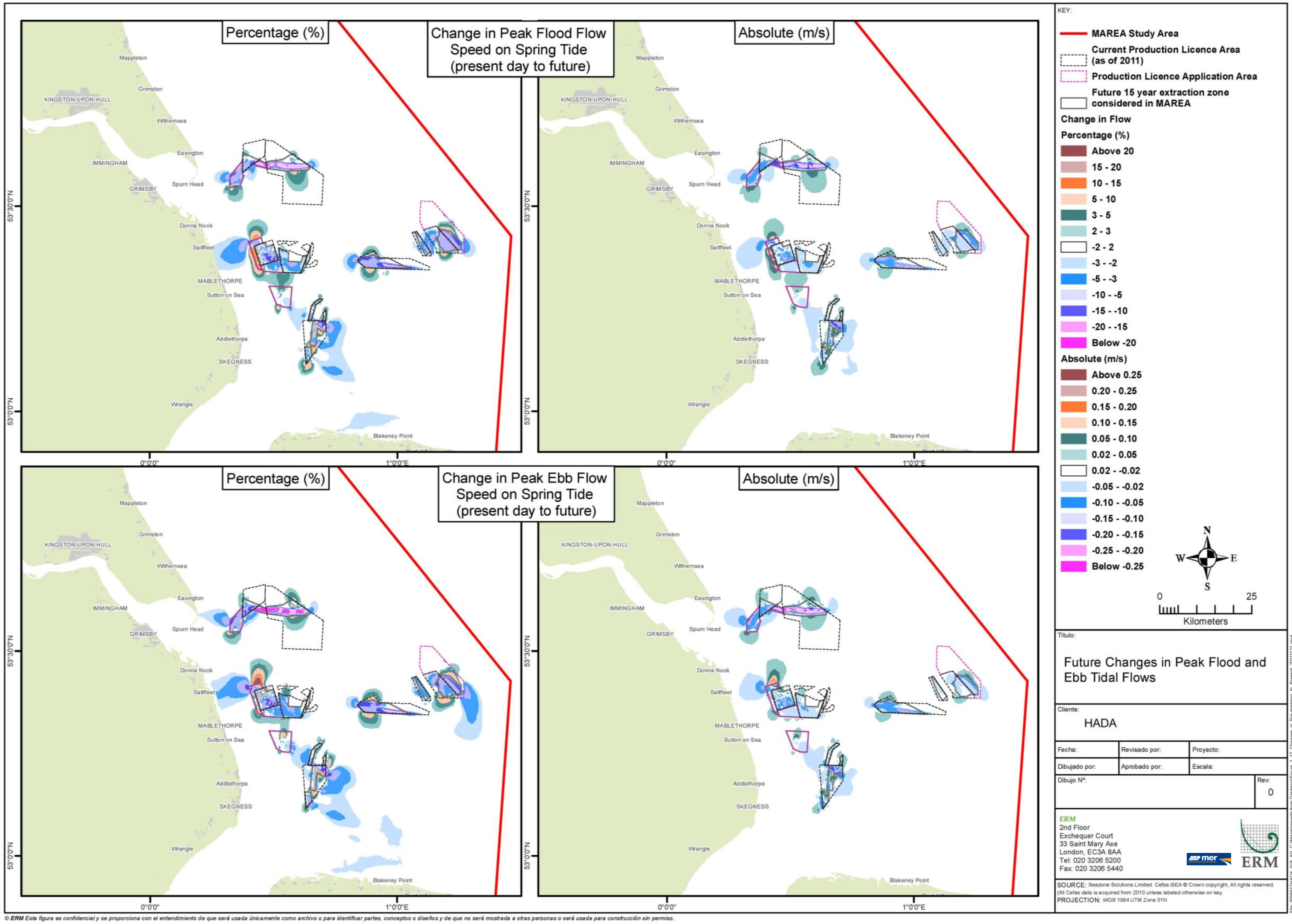
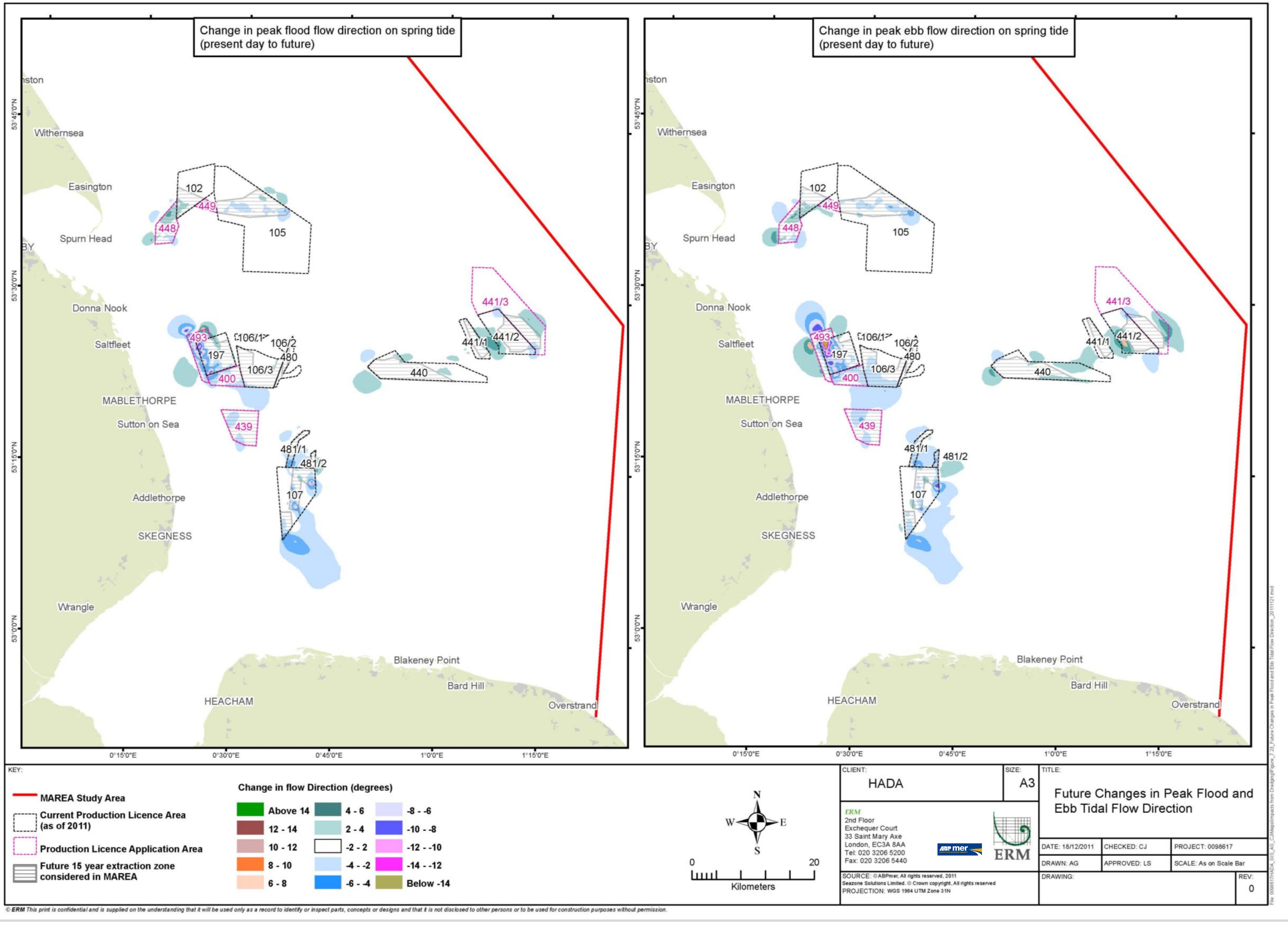


Figure 7.25 Future Changes in Peak Flood and Ebb Tidal Flow Direction



7.4.4 Changes in Sediment Transport

Potential Effects on Sensitive Receptors

Changes in tidal currents and waves as a result of aggregate dredging have the potential to alter sediment transport rates and pathways both within the dredging areas and further afield. The extent and magnitude of sediment transport depends on a number of factors including the sediment type and morphology of the seabed, water depth and the natural variability in waves and tidal currents. The coastline along the study area is considered sensitive to changes in sediment supply; see Chapter 4 for further details. Furthermore, Natural England has raised concerns about potential changes to sediment transport around sandbanks.

Summary of Methodology for Predicting Changes to Sediment Transport

Having assessed the effects of past and future dredging on tidal currents and waves, it is necessary to further interpret these changes within the context of seabed morphology and sediment transport. This has been done by determining the effects of dredging on seabed mobility due to waves and tidal currents in isolation as well as the potential changes to total sediment mobility arising from the bed shear stress exerted by waves and currents combined.

As discussed in Sections 7.4.2 and 7.4.3 the numerical modelling results showed that past dredging in the Humber Region has not resulted in large or widespread changes to either tidal flows or waves. Consequently, previous dredging would not have affected the morphology or sediment transport within the study area and the effects of past dredging are not considered further.

For MAREAs in other localities numerical modelling was used to predict changes to current induced sediment transport. However, modelling of this nature is subject to considerable uncertainty due to the large variations in tidal range and grain size that cannot be accurately represented within a regional scale study. In order to provide a simplified but more realistic picture of the potential changes to sediment movement as a result of aggregate dredging in the present study a desk based empirical approach was applied. This involves calculating the shear stress at the seabed; shear stress is the force on sediments from water moving due to waves and/or tidal currents. Results for waves or tidal currents in isolation are presented at key locations within the study area alongside calculated theoretical sediment mobility thresholds for the different size fractions within the grain size distribution at each site.

In addition bed shear stress due to a 10:1 year wave from the northeast combined with peak flood tidal currents has been calculated. These conditions combine to produce a worst case set of circumstances, however, the probability of this wave condition coinciding with peak current speeds is small and so the combined shear stress will be commonly less than predicted. The extent of changes to the combined shear stress was determined using the wave and flow models run for the present day and future dredging scenarios. The outputs were then subject to further analysis based upon standard empirical techniques (Soulsby, 1997) to demonstrate the spatial extent of changes. A range of sediment sizes from medium to very coarse-grained sand were considered independently as the model does not allow the representation of variable, poorly sorted seabed sediments. Different grain-size fractions are considered as the sediment size affects bed roughness, which is a key factor in the calculation of bed shear stress.

Figure 7.26 shows changes in bed shear stress for very coarse sand due to the proposed future dredging. The extent of changes is largest for this sediment size; other results are presented in Appendix E. It should be noted that these figures present changes to bed shear stress and not sediment mobility. For all sediment sizes, changes to the combined bed shear stress (both positive and negative) are confined to within the licence areas and their immediate vicinities. The most widespread effects are predicted to occur inshore of Areas 197 and 493, although the magnitude of these changes is relatively small. Changes in bed shear stress outside all of the licence areas range from -0.5 to +0.5 Nm-2, which is less than 10% of present day values (except for along the boundary of Area 493 where increases of up to 20% may occur).

This approach enables sediment mobilisation events to be identified and demonstrated the extent to which dredging induced changes in waves and/or tidal currents affect sediment mobility and hence the potential for sediment transport. Spatial variation in residual flow and residual sediment displacement (i.e. the net advective pathway) is calculated as the net displacement of water, but only when current speeds are above the threshold for sediment mobility. This measure can then be used for a qualitative comparison between the different dredging scenarios. These methods will not provide an indication of changes in sediment transport rates but will demonstrate where changes to the hydrodynamic regime are likely to have an effect on sediment movements in and around the dredging areas.

Predicted Changes to Sediment Transport

The predicted changes to tidal currents and/or waves from future dredging are for the most part confined within the dredging areas and their immediate vicinity. Therefore it is not necessary to consider changes to sediment transport and seabed morphology over the entire study area. Instead this assessment will focus on those areas for which large or widespread changes in waves and/or tidal currents were predicted. The key areas to be considered are:

- Zone 1: Inshore from Area 493 to the Lincolnshire coast;
- Zone 2: Inshore from Area 440 to Spurn Peninsula;
- Zone 3: Inshore from Area 440 to the north Lincolnshire coast; and
- Zone 4: Inshore from Area 107 to the north Norfolk coast.

For waves and tidal currents in isolation a theoretical grain size distribution has been assumed for each of the locations identified in Figure 7.27 (The points shown on Figure 7.27 are representative of the method used to look at bed mobility and shear stress from the licences to the coast and have been presented for illustration purposes. The actual points may vary from those shown in Figure 7.27 to allow the greatest changes in bed shear stress to be examined). This information was then used with current data from the model to calculate bed shear stress over a typical spring tide at each of the locations (Points A-E) on Figure 7.27. The variability of bed shear stress at these locations has been plotted as graphs, which also show the force from waves or tidal currents required to mobilise the different grain size fractions (i.e. the critical bed shear stress) found on the bed at this location.

The wave induced bed shear stress for the present and future dredging scenarios has been calculated along transects as shown in Figure 7.27. Graphs have been produced for 10:1 year waves at low water. As with the tidal current plots the graphs also show the critical bed shear stress required to move the different sediment size fractions that are found on the bed at these locations.

The effect of proposed future dredging on combined sediment mobility has also been investigated. Due to the inherent complexities of representing non-linear processes, it has been necessary to make a number of simplifications and assumptions. It has been assumed that the 10:1 year wave condition occurs throughout the tidal cycle, which results in an over estimation of the total bed shear stress as waves are episodic and would not occur continuously in this way. Waves were found to exert the least and greatest influence on bed shear stress at high water and low water respectively and so wave heights at low water and high water have been used as the representative wave conditions and have both been applied throughout the tidal cycle.

Whilst this does not provide a realistic representation of wave behaviour through a whole tidal cycle it ensures that the minimum and maximum bed shear stress values are captured and that the actual bed shear stress at any time will be between these values. Data have been extracted from the numerical model at three locations (b, d, and f) on each of the transects (1 - 4) shown in Figure 7.27. These locations were chosen to represent the combined bed shear stress within the licence areas and to demonstrate the extent of any changes closer inshore.

Figure 7.26 Changes to Combined Bed Shear Stress - Very Coarse Sand

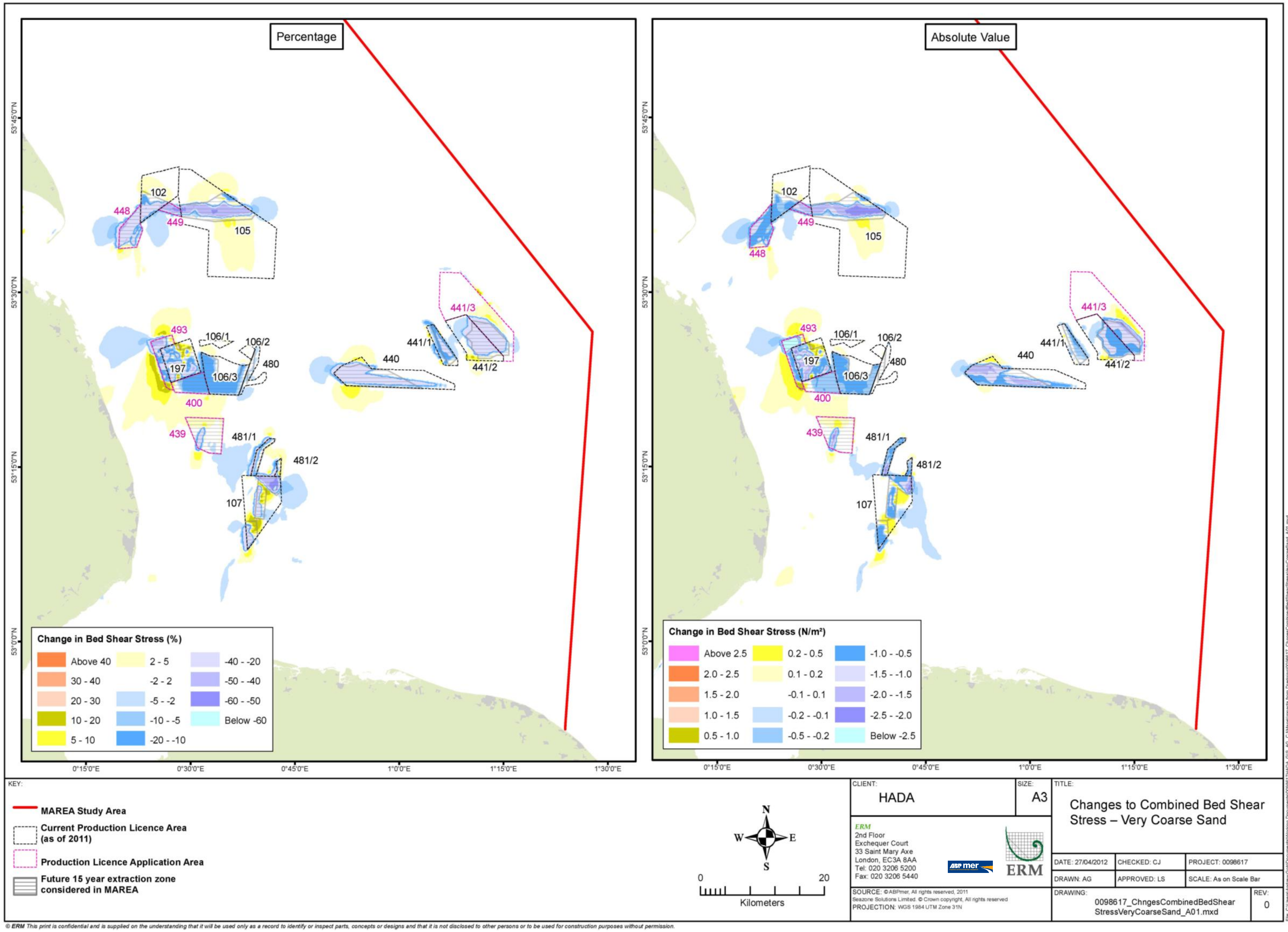
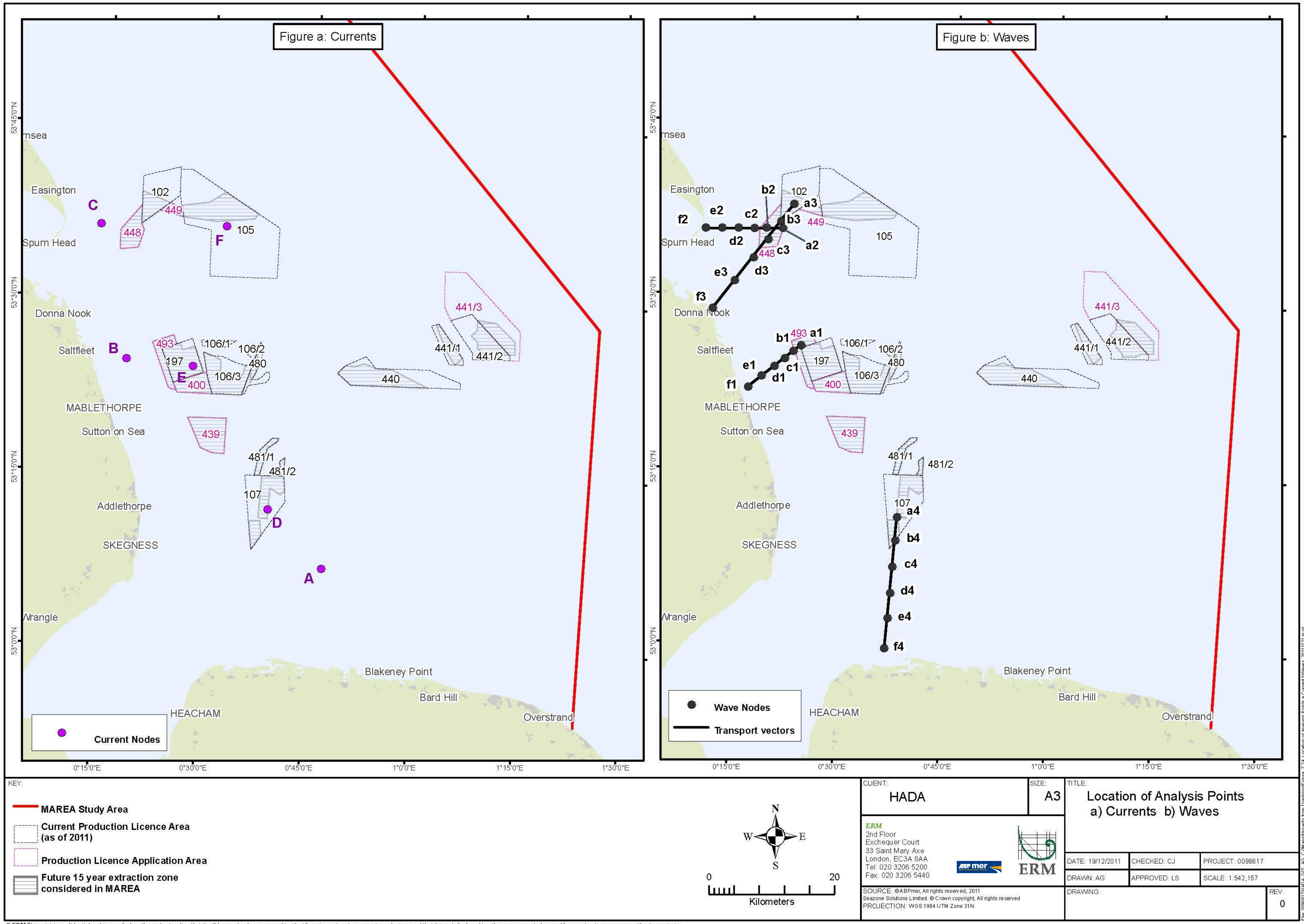


Figure 7.27 Location of Analysis Points a) Currents b) Waves



Zone 1

This zone has been selected on the basis that the proposed future dredging in Areas 493 and 197 produced the largest and most widespread changes to both tidal currents and waves. The main reason for these changes is that the present day bathymetry within Application Area 493 is relatively shallow and has been shown to dissipate waves (e.g. Figure 7.17). The proposed future dredging would lower bed levels by up to 6 m, which represents a proportionally large increase in total water depth.

Figure 7.28 indicates that during spring tides fine sand is mobile most of the time whilst coarse sand is mobilised during periods of peak flow speed. The two graphs are similar, which demonstrates that the predicted changes to tidal currents do not greatly affect the bed shear stress and consequently bed shear stress inshore from the dredging areas.

Figure 7.29 shows that within Area 197 bed shear stress for the future dredging scenario is predicted to decrease in comparison with the present day scenario. This would result in a slight reduction in the mobility of very coarse sand but as this size fraction is only currently mobile during peak flood and peak ebb, this change is unlikely to have a significant effect on sediment transport. Additionally, the bed shear stress has been calculated for a specific location, for which a reduction in flow speed was predicted. Elsewhere in the immediate vicinity, both increases and decreases in current speed were predicted and as such any changes in sediment transport are likely to be highly localised. Given that sediment supply to the Lincolnshire coast is predominantly from longshore transport from the Holderness Cliffs (see Figure 4.19) and that changes in sediment transport are likely to be highly localised, changes in bed shear stress and therefore tide induced bedload transport due to dredging are unlikely to affect sediment transport pathways and therefore supply of sediment to the Lincolnshire coast.

Figure 7.28 Spring Tidal Current Bed Shear Stress Variability Point B (Present and Future)

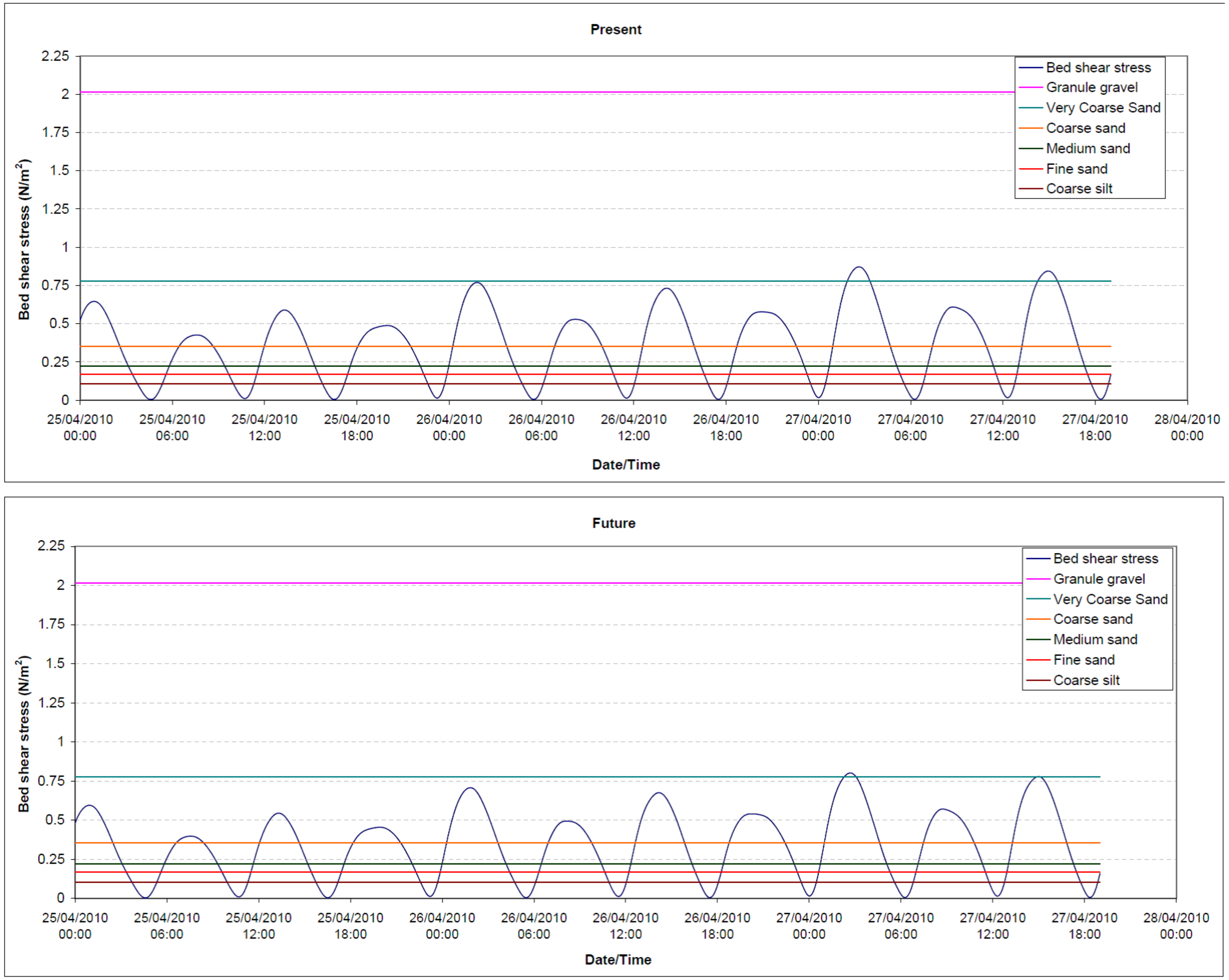
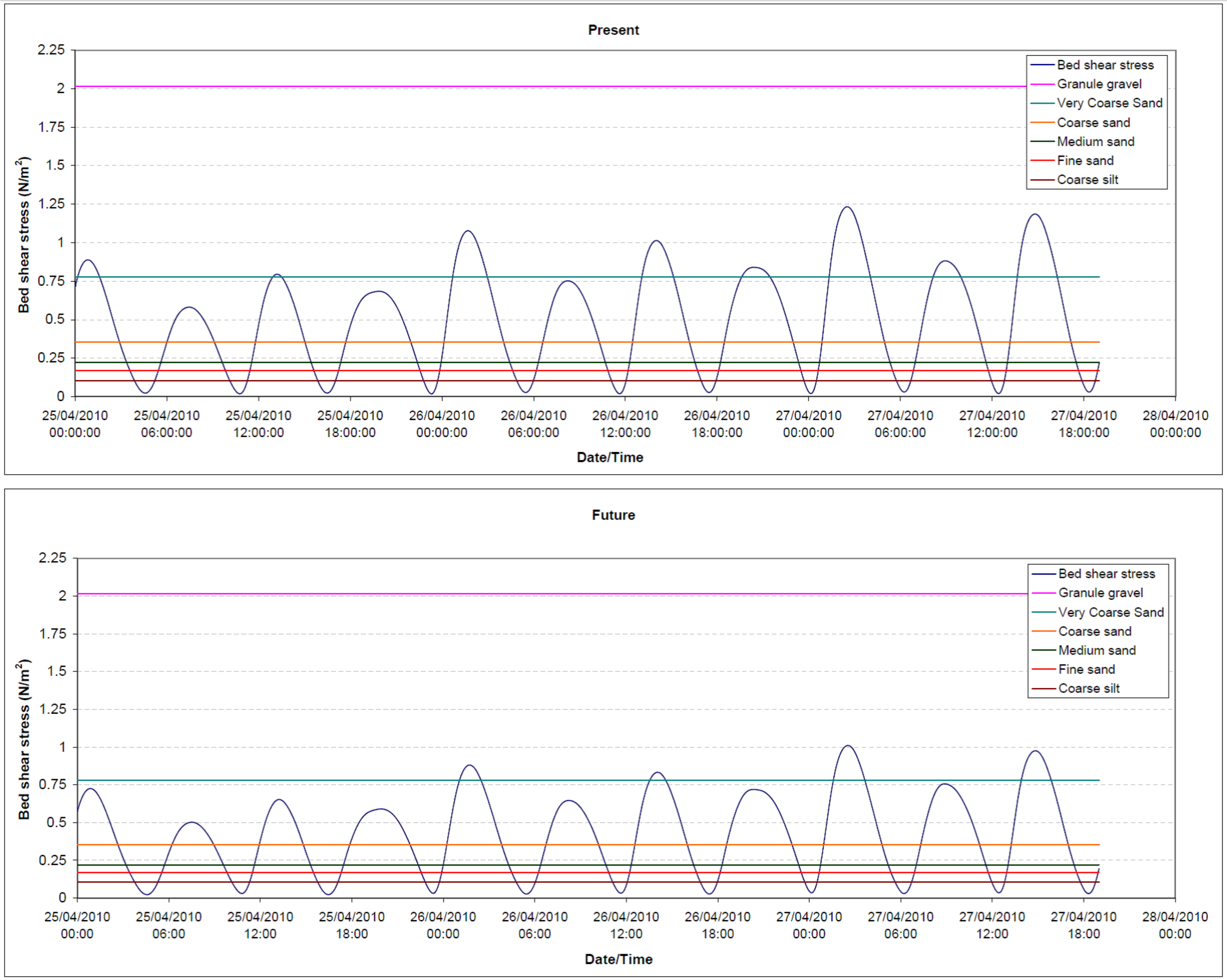


Figure 7.29 Spring Tidal Current Bed Shear Stress Variability Point E (Present and Future)



The wave induced bed shear stress for the present and future dredging scenarios between dredging Area 493 and the Lincolnshire coast, as shown in Figure 7.27, are shown in Figure 7.30. These plots show that over the dredging areas themselves, (Points a1 and b1) the bed shear stress for the future dredging scenario is reduced compared to present day values at low water. This is due to the increased water depth at the site combined with relatively small waves. Further inshore the future bed shear stress is increased slightly compared to present day values, although this does not result in significant change in bed mobility and will therefore not affect sediment supply to the coast

Southerly View on a Lincolnshire Beach showing Wooden Stakes and Used Christmas Trees Serving as Coastal Defences against Longshore Drift

Source: ERM

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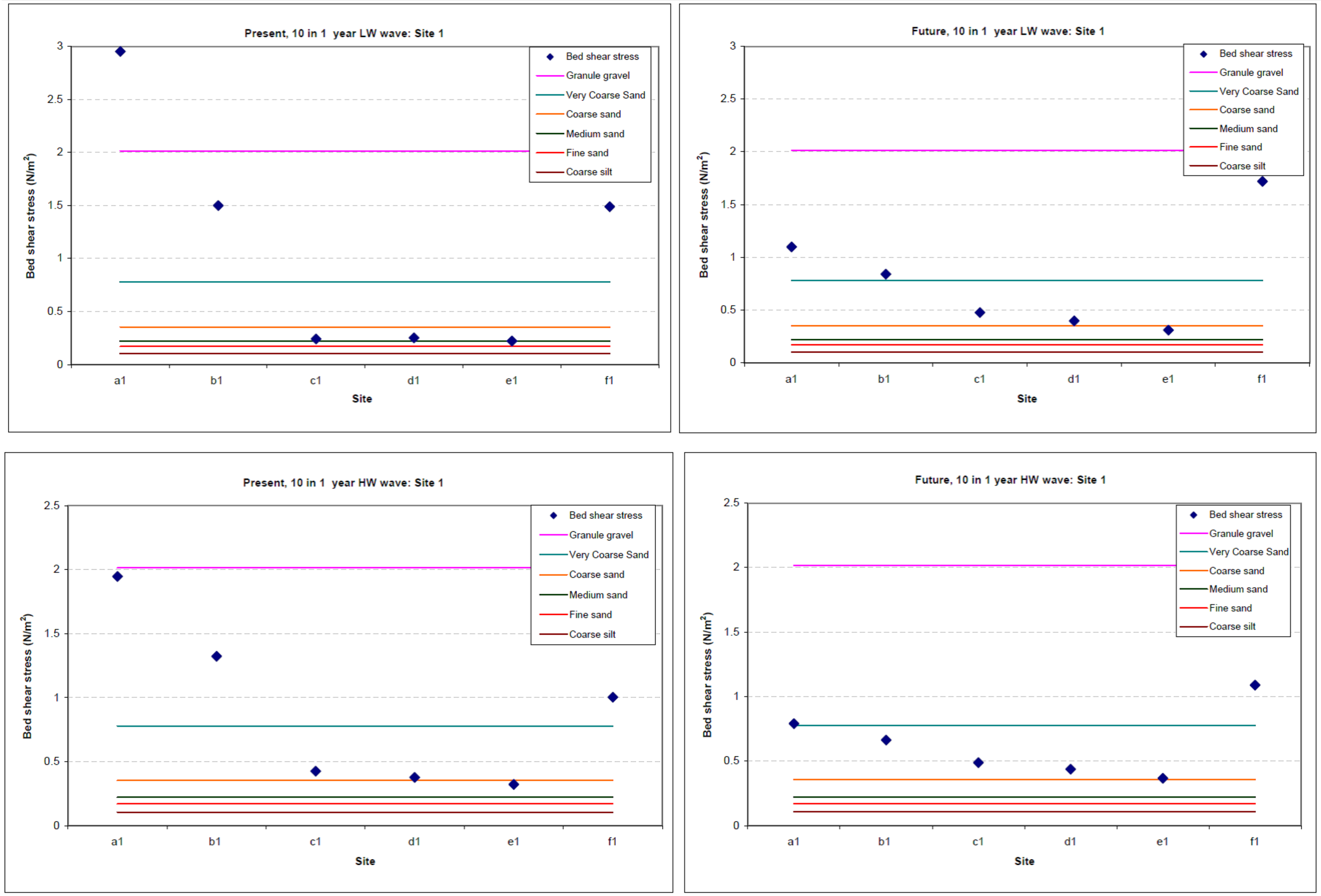
Figure 7.30 Wave Induced Bed Shear Stress - Zone 1 (Present and Future)

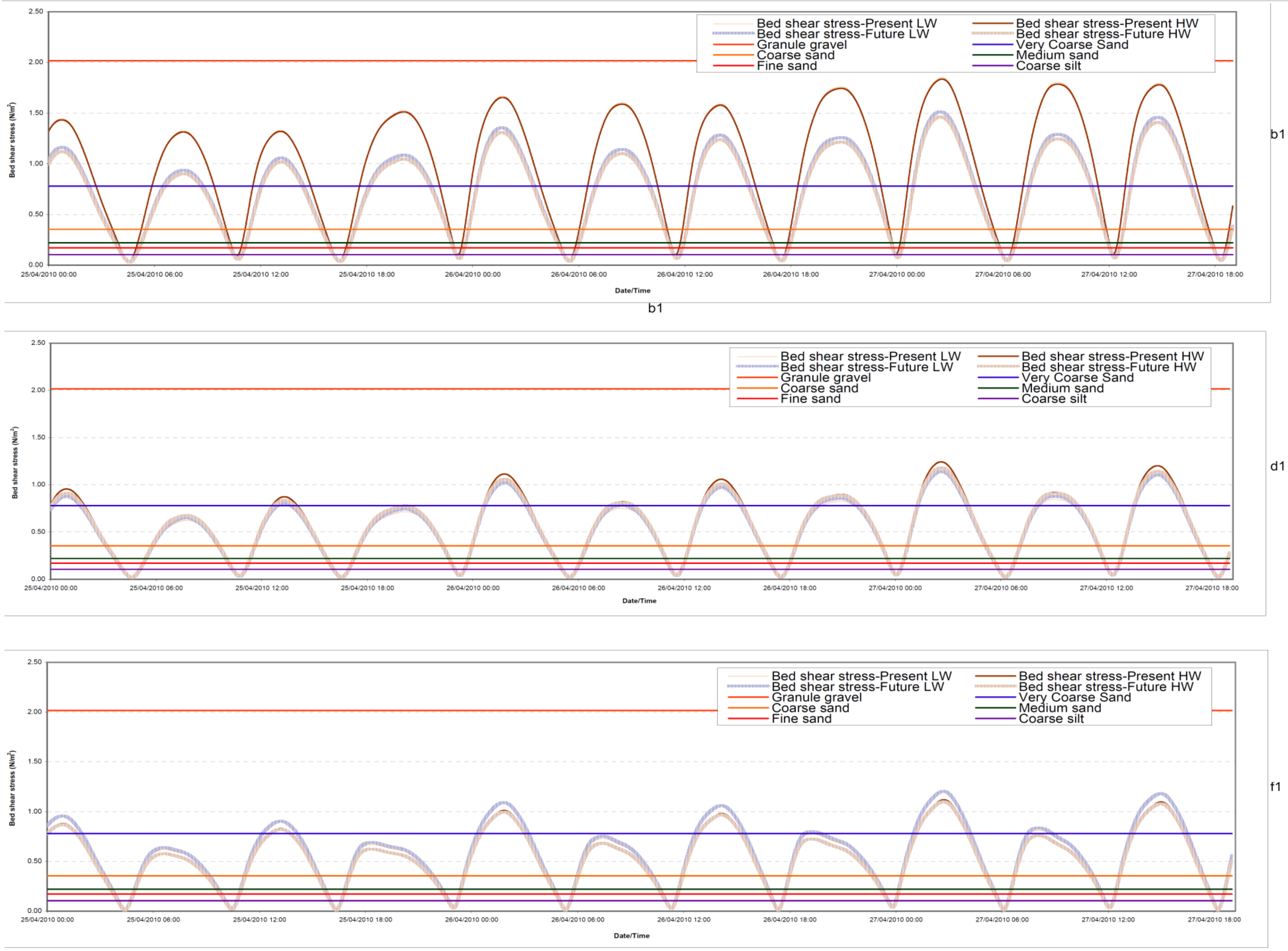


The cumulative effects of dredging on combined wave and current induced seabed mobility are also limited to within the licence area boundaries and do not extend to the coast. Figure 7.31 shows that the total peak bed shear stress is reduced by up to 0.5 Nm^{-2} (i.e. the difference between the present and future scenario), which at location b1 (the boundary of the licence area) represents only a slight reduction in the mobility of very coarse sand (in terms of the percentage of the tidal cycle for which this size fraction is mobile). However, given that at this location very coarse sand is predicted to be mobilised during at least half the tidal cycle during both the baseline and post dredging scenarios the reduction in combined bed shear stress is unlikely to result in a measurable change to sediment transport processes. The mobility of other sediment size fractions is unaffected by the proposed dredging. Inshore from the licence area there is virtually no change in total bed shear stress and hence sediment mobility between the present and future scenarios. The assessment of combined sediment mobility is conservative in that it assumes a 10:1 year wave event continued throughout a spring tidal cycle. Therefore it is concluded that the proposed dredging would not affect the contemporary sediment transport regime either within the licence areas or closer inshore.

Small Sand Waves on a Lincolnshire Beach

Source: Shutterstock.com

Figure 7.31 Combined Wave and Tidal Current Induced Bed Shear Stress - Zone 1



Note: Bed shear stress - Present LW and Bed shear stress - Present HW are virtually on top of each other at location b1. Bed shear stress - Future LW and Bed shear stress - Future HW are virtually on top of each other at location b1. At locations d1 and f1 Bed shear stress - Present LW and Bed shear stress - Future LW are virtually on top of each other. At locations d1 and f1 Bed shear stress - Present HW and Bed shear stress - Future HW are virtually on top of each other

It is considered that the proposed future dredging in the licence areas off the Lincolnshire coast, and particularly area 493, will not produce a measurable or permanent change in sediment mobility or seabed morphology in the inshore areas or at the coast.

Zone 2

Zone 2 has been selected on the basis of the potential impact of changes to waves and currents inshore from New Sand Hole on the sediment transport pathway between Holderness and Lincolnshire.

There is very little difference in the current induced bed shear stress for the future dredging scenario compared to the present day case at Point C. This indicates that the proposed future dredging in the licence areas off the Spurn Peninsula will not produce a measurable or permanent change in current induced sediment transport.

The bed shear stress within Area 105 is relatively large compared to other locations so that the mobility threshold for gravel is exceeded at certain times during spring tides. Point F corresponds to a location inside the dredging area, for which increases in flow speed were predicted and this is reflected in the bed shear stress calculations, which also show a slight increase compared to present day values (Figure 7.32). As the differences in bed shear stress between the future and present day scenario are small, it is unlikely there will be a residual effect on sediment transport in this area.

The wave induced bed shear stress for the present and future dredging scenarios has been calculated along a transect between dredging Area 448 and the Spurn Peninsula as shown in Figure 7.27. Figure 7.33 shows that over the dredging areas themselves, the bed shear stress for the future dredging scenario is reduced compared to present day values. This is due to the increased water depth at the site combined with relatively small waves. Further inshore there is no apparent difference between the present day and future dredging scenarios.

Figure 7.32 Spring Tidal Current Bed Shear Stress Variability Point F (Present and Future)

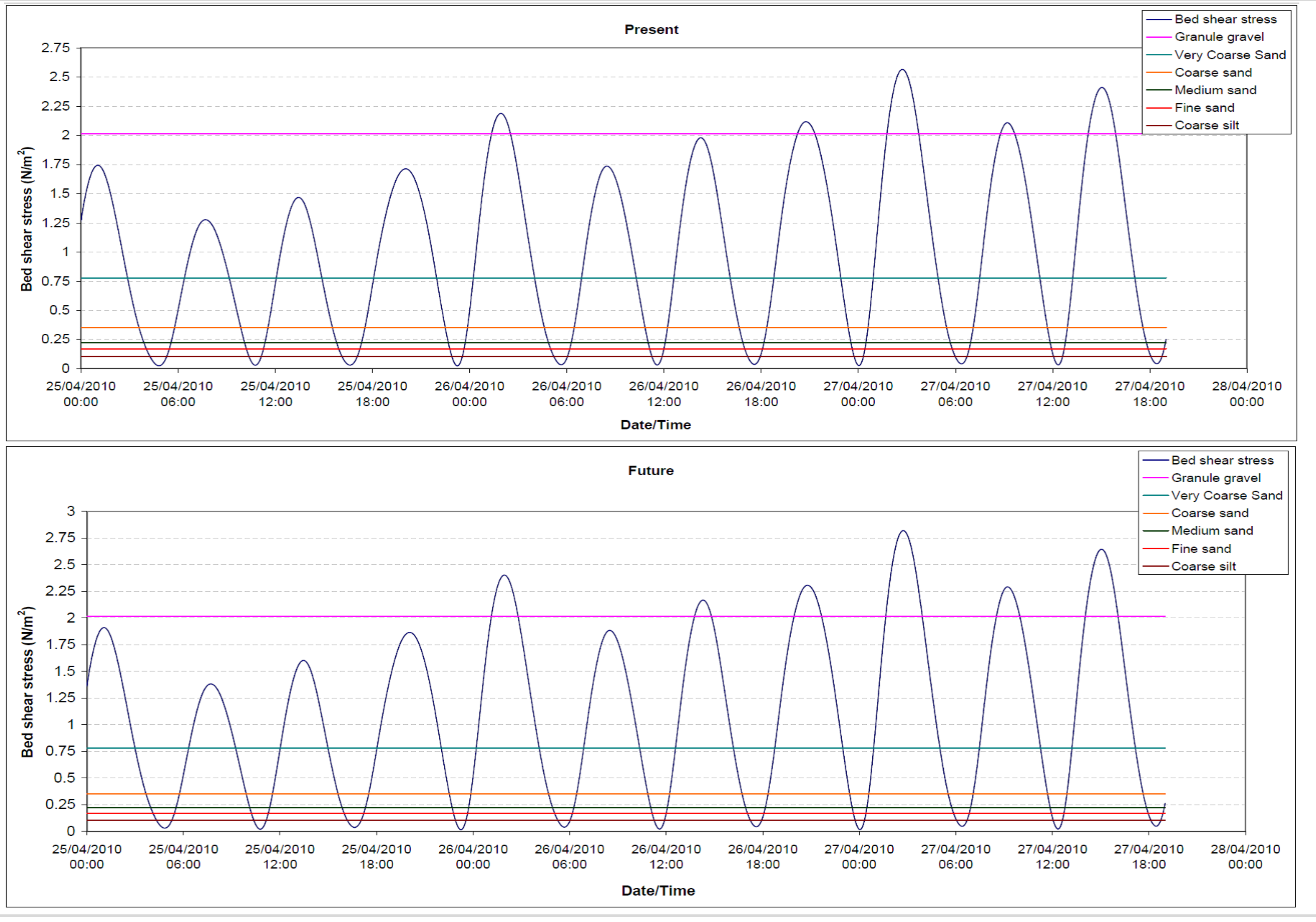
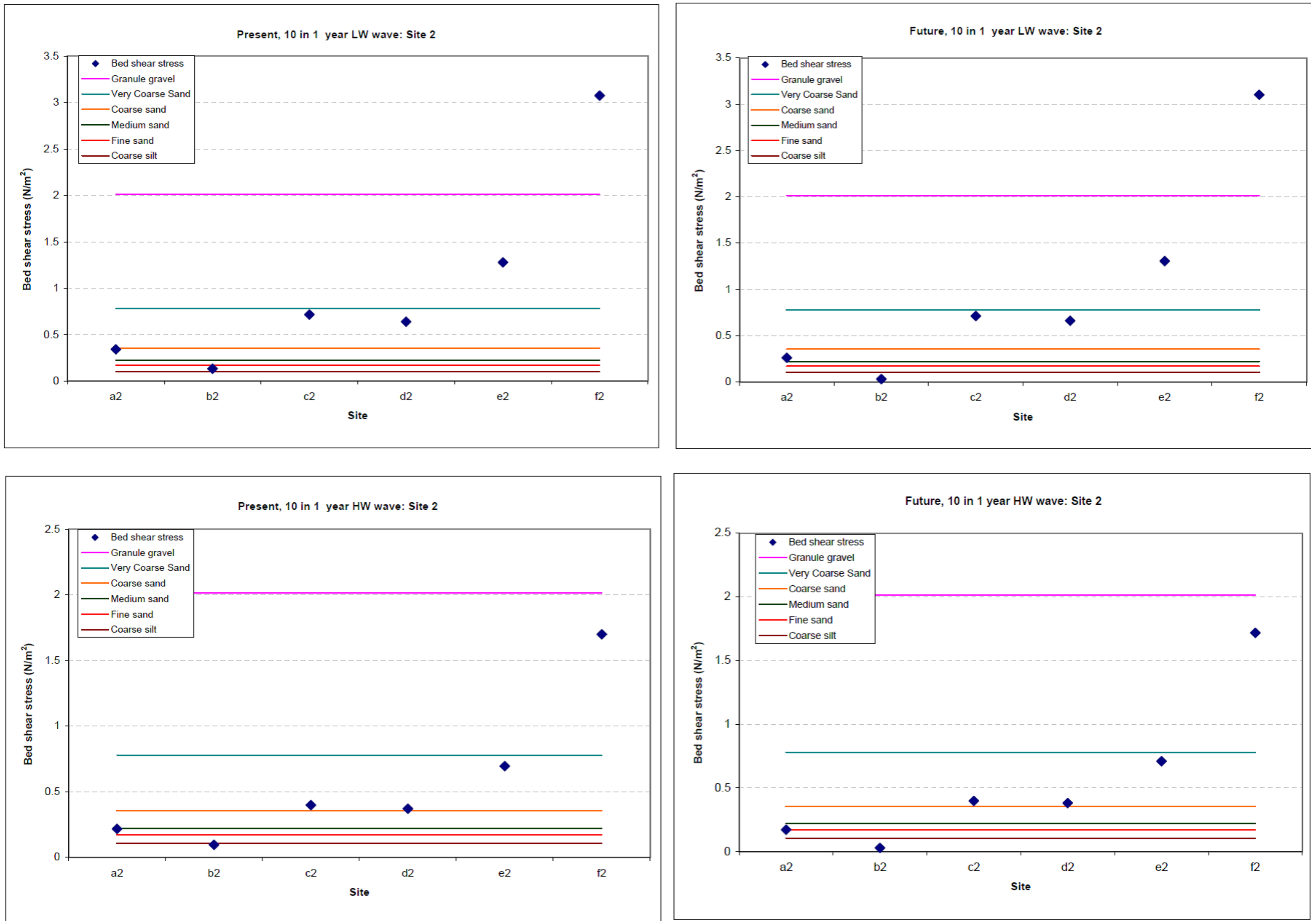


Figure 7.33 Wave induced bed shear stress - Zone 2 (Present and Future)



The cumulative effects of dredging on combined wave and current induced seabed mobility inshore from Area 448 to the Spurn Peninsular is not expected to change as a result of the proposed future dredging. The results of the bed shear stress calculations show a similar pattern of change to Zone 1 with a reduction in total bed shear stress within the licence area (locations b2 and b3) and little or no change further inshore. The assessment of combined sediment mobility is conservative in that it assumes a 10:1 year wave event continued throughout a spring tidal cycle. Therefore it is concluded that the proposed dredging would not affect the contemporary sediment transport regime either within the licence areas or closer inshore.

It is considered that proposed future dredging in the licence areas off the Spurn Peninsula will not produce a measurable or permanent change in sediment mobility inshore. This suggests that the sediment transport pathway between Holderness and the Lincolnshire coast will not be affected by the proposed dredging.

Zone 3

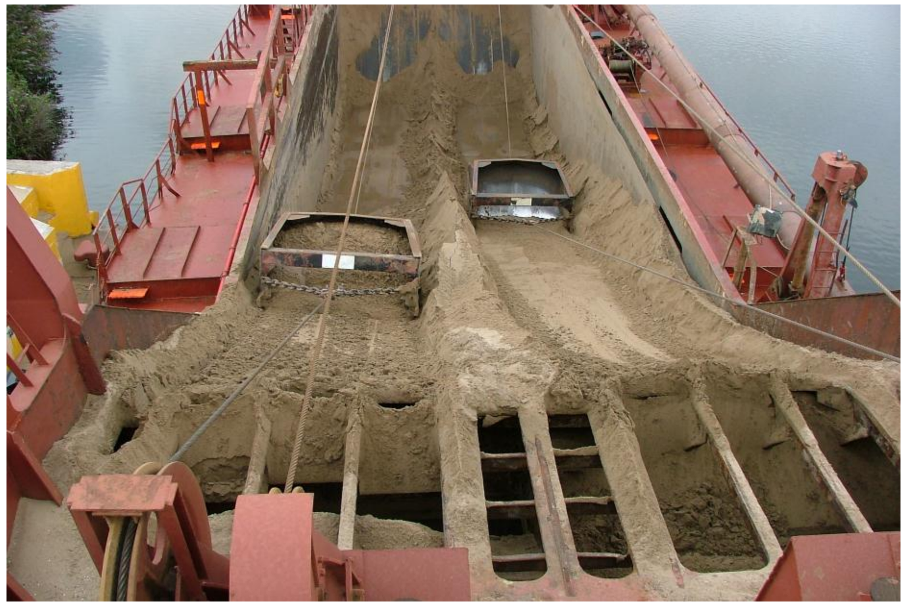
Zone 3 has been selected on the basis of the small but widespread changes in wave height within and inshore from Area 448. No changes to the tidal currents were predicted in the modelling and therefore the changes to current induced bed shear stress and sediment mobility have not been assessed in this instance.

Wave induced bed shear stress for the present and future dredging scenarios has been calculated between Area 448 and the Spurn Peninsula, as shown in Figure 7.27. Within the dredging areas the bed shear stress is typically low due to the larger water depths at the site (>20 m for the present day scenario) and the bed shear stress for the future dredging scenario is slightly reduced compared to present day values at both low and high water. Further inshore there is no apparent difference between the present day and future dredging scenarios.

Similar to Zone 2, the cumulative effects of dredging on combined wave and current induced seabed mobility inshore from Area 448 to the Lincolnshire coast is not expected to change as a result of the proposed future dredging. The results of the bed shear stress calculations show a similar pattern of change to Zone 1 with a reduction in total bed shear stress within the licence area (locations b2 and b3) and little or no change further inshore. The assessment of combined sediment mobility is conservative in that it assumes a 10:1 year wave event continued throughout a spring tidal cycle. Therefore it is concluded that the proposed dredging would not affect the contemporary sediment transport regime either within the licence areas or closer inshore.

It is considered that proposed future dredging in the licence areas off the Spurn Peninsula will not produce a measurable or permanent change in sediment mobility inshore. This suggests that the sediment supply to the Lincolnshire coast will be unaffected by the proposed dredging.

Dredger Discharging Using Bucket Scrapers



Zone 4

Zone 4 has been selected on the basis of predicted tidal current changes across Docking Shoal and Burnham Flats and the potential impact pathway between Burnham Flats and the North Norfolk Coast.

Current induced bed shear stress at Points A and D on Figure 7.27 is typically low in comparison to other areas, although coarse sand would still be mobile during much of the spring tide. There is virtually no difference in the current induced bed shear stress for the future dredging scenario compared to the present day case at Point A.

The present day bed shear stress within Area 107 (Point D) is sufficient to mobilise very coarse sands during peak flow conditions. For the future dredging scenario, peak flow speeds and consequently bed shear stress are predicted to decrease compared to the present day. The reduced bed shear stress could affect the mobility of very coarse sands at certain times but overall the general seabed mobility and sediment transport will be unaffected by the proposed dredging.

Wave induced bed shear stress for the present and future dredging scenarios has been calculated between dredging Area 107 and the North Norfolk Coast, as shown in Figure 7.27. Over the dredging areas the bed shear stress is typically very low due to the large water depth compared to the wave height. There is no difference between the future dredging scenario and the present day at either high or low water. Further inshore the water depths are very shallow but as the waves are also very small as a result of energy dissipation across Burnham flats the resultant bed shear stress is also fairly low. There is no apparent difference between the present day and future dredging scenarios.

The cumulative effect of dredging on combined wave and current induced seabed mobility inshore from Area 107 to the North Norfolk Coast is not predicted to be affected by the proposed dredging.

The total bed shear stress within Area 107 is predicted to decrease compared to the baseline and at certain times during the spring tidal cycle coarse sand would no longer be mobilised. However, within Area 107 areas of both increase and decrease in bed shear stress will occur. The threshold of motion for coarse sand within the areas of greatest reduction in bed shear stress is still frequently exceeded in the post dredge scenario (as well as being exceeded naturally in areas of no change or exceeded more frequently where there are areas of increased bed shear stress) and dredging would therefore not significantly affect sediment transport through this area. Closer inshore, the total bed shear stress and hence sediment mobility are not predicted to change relative to baseline values. The assessment of combined sediment mobility is conservative in that it assumes a 10:1 year wave event continued throughout a spring tidal cycle. Therefore it is concluded that the proposed dredging would not affect the contemporary sediment transport regime either within the licence areas or closer inshore.

It is considered that the proposed dredging in Area 107 will produce no measurable or permanent change in sediment mobility inshore. The Burnham Flats, Docking Shoal sandbanks and sediment supply to the North Norfolk coast from offshore will not be affected by the proposed future dredging.

Potential Effect 9: Changes to Sediment Transport Rates Due to the uncertainties associated with modelling of this effect potential changes to sediment transport have been considered based on a desk based empirical approach. The assessment concluded that changes in sediment transport the change relative to the baseline are considered negligible and there will be no spatial interaction with any receptors. Consequently the impact assessments which follow do not consider the direct interaction of this effect with any receptors.

Changes in Sediment Transport Pathways

In addition to changes in sediment transport rates, changes to key sediment transport pathways to the coast and seabed features within the study area are also considered. Offshore linkages with the nearshore environment and key sediment transport pathways (sources, pathways and sinks) in the region have been characterised in Chapter 4 and Appendix E. Figure 7.34 presents sediment transport pathways and seabed features in the MAREA study area.

Offshore linkage profiles suggest that there is no direct impact pathway between the dredging areas and the Holderness coast, the Lincolnshire coast or the north Norfolk coast (see Chapter 4). Nearshore seabed features (such as Trusthorpe and Saltfleet Overfalls) between the licence areas and the coast would also therefore be unaffected as direct sediment transport pathways between the licence areas and the coast do not exist. In addition there will be no changes to the sediment transport pathways along the coast due to the sediment transport pathway directions and relative locations of the licence areas and sediment sources and sinks (see Figure 7.34).

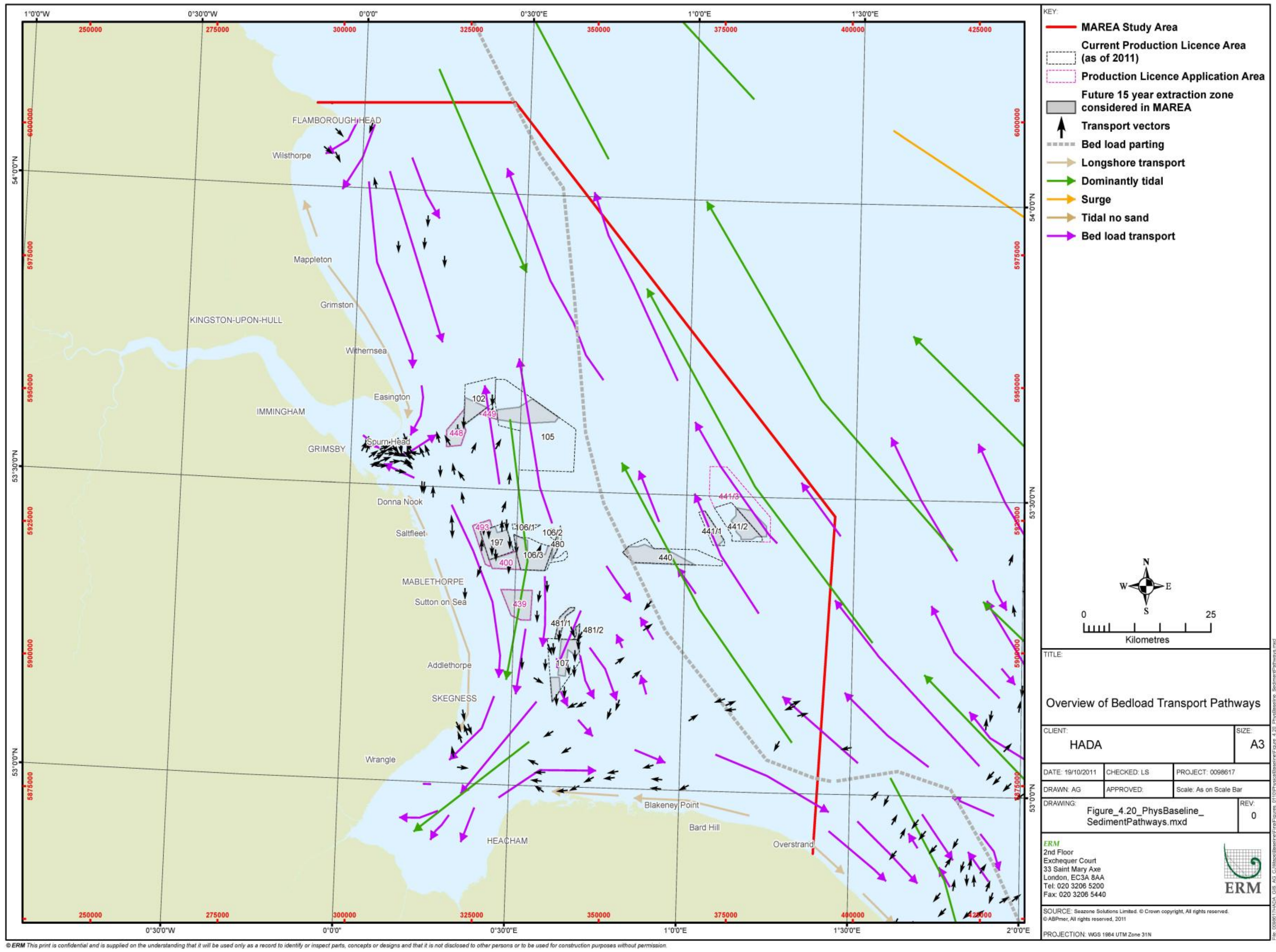
Considering the broad sediment transport pathways presented in Figure 7.34 Docking Shoal could be affected if sediment transport pathways across Areas 107 and 481 are altered. However, modelling studies conducted for the Docking Shoal Windfarm ES (Centrica, 2008) combined with morphological evidence suggests sediment transport across Docking Shoal is more complex than presented in broad scale studies. In addition sources of sediment to the North Norfolk coast are not well understood (North Norfolk SMP5 Final Plan Appendix C Baseline Processes, 2010), although Docking Shoal is thought to be a source of sediment to the North Norfolk coast during high magnitude, low frequency events (such as storms) (North Norfolk SMP5 Final Plan Appendix C Baseline Processes, 2010) and there is conflicting evidence on movement of sediment around the North Norfolk coast. Considering that there will be no predicted changes in sediment mobility across the region outside the licence areas or across Docking Shoal and limited localised changes to bed shear stress within the licence areas (both positive and negative) overall the sediment transport pathways are unlikely to be affected. Sediment supply to the shoals of North Norfolk is therefore unlikely to be significantly affected.

7.4.5 Loss of Access

When the dredger is active a part of the marine environment will be unavailable to other marine users, resulting in a temporary loss of access. For the purposes of this MAREA, this potential effect is represented by the extent of the 'future 15 year MAREA extraction zones' which illustrate the areas where dredge vessels may be present over the 15 year MAREA period, however, at any one time the area with temporary loss of access will only be around the dredging vessel.

Potential Effect 10: Loss of Access: This effect is represented quantitatively based on spatial interactions between the receptor and GIS layers representing the interaction of receptors with the 'Future 15 year extraction zones' which represent the maximum areas where dredge vessels may be present at any time over the 15 year MAREA period (actual loss of access will be the area where the dredger is working only).

Figure 7.34 Sediment Transport Pathways



7.4.6 Representation of Effects Of Dredging as GIS Layers

This section has provided a detailed discussion on the various effects of dredging. As explained in Chapter 3 and as further elaborated upon in this chapter, each of these effects has each been modelled or semi-quantitatively described so as to form the basis of assessment for the rest of the MAREA.

Wherever possible each effect has been represented by one or more GIS layers, which can then be overlaid with baseline features to inform the degree of interaction of each effect with each of the receptors under consideration.

Throughout this chapter an indication has been given at the end of each key section on the 10 key effects of dredging and how each effect of dredging has been quantitatively or semi-quantitatively represented in GIS format, or how each physical effect has been semi-quantitatively described, to inform the impact assessments provided in Chapters 8, 9 and 10 of this MAREA. These are summarised again below in Box 7.1.

Dredger Loading Aggregates showing Spillways and Loading Tower

Box 7.1 Summary of Quantitative or Semi-Quantitative Representation of each Potential Effect of Dredging for the purposes of the MAREA

Potential Effect 1: Presence of the Vessel. This effect is represented quantitatively by two GIS layers: (1) the extent of the 'Future 15 year extraction zones' which represent the extent over which dredge vessels may be present at some time over the 15 year period of the MAREA and (2) the 'future shipping density' extent which has been modelled as part of the shipping and navigation assessment.

Potential Effect 2: Removal of Sediment: This effect is represented quantitatively based on the extent of the 'Future 15 year extraction zones' which represent the maximum extent over which sediment may be removed over the 15 year period of the MAREA.

Potential Effect 3: Fine Sediment Plume: This effect is represented quantitatively based on the modelled and interpreted extent of the footprints for the 100, 50 and 20 mg l-1 sediment plume concentration layers as appropriate for the sensitivity of the particular receptor being considered for either seabed, or depth averaged plumes, depending on the receptor under consideration.

Potential Effect 4: Sand Deposition (Formation of Bedforms): This effect is represented quantitatively by a GIS layer indicating a 2.5 km boundary around the 15 year extraction zones where dredging may occur at any point in the 15 year MAREA period. However, it is noted that this is a conservative estimate based on previous studies in the Thames region and the impact assessments take this into consideration, where relevant.

Potential Effect 5: Changes to Sediment Particle Size: This effect is represented quantitatively by a GIS layer indicating a 4 km boundary around the 15 year extraction zones where dredging may occur at any point in the 15 year MAREA period. However, it is noted that this is a conservative estimate based on previous studies in the Thames region and the impact assessments take this into consideration, where relevant.

Potential Effect 6: Underwater Noise: The assessment of the underwater noise effect of dredging is conducted semi-quantitatively due to the many uncertainties related to this topic that make it inappropriate to attempt to develop qualitative GIS layers. The assessments therefore consider the biology of the species under assessment including discussion around likely zones of audibility, zones of responsiveness, and zones of masking within the context of ambient noise and habituation.

Potential Effect 7: Changes to Wave Height: This effect is represented quantitatively by GIS layers representing the model outputs from the ABPmer study into physical effects. Layers are provided for both the 'Change in wave height at MLWS for 1 in 200yr NE wave (Future - Present)' and the 'Change in wave height at MLWS for 10 in 1 year NE wave (Future – Present)' scenarios. The 1 in 200 year wave represents a worst case; however, 10 in 1 year wave is a more commonly occurring wave. Both percentage and absolute changes are considered.

Potential Effect 8: Changes to Tidal Currents: This effect is represented quantitatively by GIS layers representing the model outputs from the ABPmer study into physical effects. Layers are provided for both the 'Change in peak flood flow speed on spring tide (future minus present) and the "Change in peak ebb flow speed on spring tide (future minus present)" scenarios. Both percentage and absolute changes are considered.

Potential Effect 9: Changes to Sediment Transport Rates: Due to the uncertainties associated with modelling of this effect potential changes to sediment transport have been considered based on a desk based empirical approach. The assessment concluded that changes in sediment transport the change relative to the baseline are considered negligible and there will be no spatial interaction with any receptors. Consequently the impact assessments which follow do not consider the direct interaction of this effect with any receptors.

Potential Effect 10: Loss of Access: This effect is represented quantitatively based on spatial interactions between the receptor and GIS layers representing the interaction of receptors with the 'Future 15 year extraction zones' which represent the maximum areas where dredge vessels may be present at any time over the 15 year MAREA period (actual loss of access will be the area where the dredger is working only).

7.5 MAGNITUDE OF EFFECTS

The effects of dredging have been modelled or semi-quantitatively considered as part of a number of specialist studies that have been undertaken for the MAREA. These studies have predicted the spatial extent of each effect. In most cases a number of different thresholds or concentrations of the effect have been identified to help establish the degree of change from baseline conditions.

This is important because it is often the case that the spatial extent of the effect is inversely correlated with the amount of change from baseline conditions and using a single contour showing return to background concentrations may not always provide sufficient information for the impact assessment.

Other effects that do not involve predictive modelling, such as the occupancy of vessels on licence areas and the areas of seabed lowering are based directly on the predictions of the aggregate companies that operate each licence.

This information on spatial extents is used, together with the frequency and duration of the effect, plus the amount of change from baseline conditions (It should be noted that the 'change relative to the baseline' is taken to mean the change relative to the regional baseline conditions for the parameter in question, which is not just based on the baseline effects of dredging but incorporates all natural and anthropogenic influences) to classify the overall magnitude of the effect. Table 7.3 below shows the overall magnitude categories that have been determined for each of the effects of dredging. These magnitudes are taken forward into the impact assessment sections in Chapters 8-10. The magnitudes of potential changes to seabed features, to fish distribution and to the benthic community are presented at the end of each of these respective sections (see Chapter 8 for sandbanks and other seabed features and Chapter 9 for fish and benthic ecology impacts and predicted magnitude of these three effects)

Table 7.3 Magnitude Categories for the Physical Effects of Dredging

Physical Effects	Extent of Effect	Duration of effect	Frequency of effect	Change relative to baseline [1]	Magnitude
Presence of the vessel	Site Specific	Temporary	Routine	Low	Small
Removal of sediment	Site Specific	Long term	Routine	High	Medium-Large
Fine sediment plume/elevated turbidity above background 2-20 mg l^{-1} (depth averaged)	Sub Regional	Temporary	Routine	Low	Small - Medium
20-50 mg l^{-1} plume (depth averaged)	Local	Temporary	Routine	Low	Small-Medium
50-100 mg l^{-1} plume (depth averaged)	Local	Temporary	Routine	Medium	Medium
> 100mg l^{-1} plume (depth averaged)	Site Specific	Temporary	Routine	Medium	Medium
Fine sediment plume/elevated turbidity above background 2-20 mg l^{-1} (near bed)	Sub Regional	Temporary	Routine	Negligible	Small-Medium
20-50 mg l^{-1} plume (near bed)	Local	Temporary	Routine	Low	Small-Medium
50-100 mg l^{-1} plume (near bed)	Local	Temporary	Routine	Medium	Medium
>100mg l^{-1} plume (near bed)	Site Specific	Temporary	Routine	Medium	Medium
Sand deposition (formation of bedforms)	Local	Short term	Routine	Low	Small
Changes to sediment particle size	Local	Short term	Routine	Low	Small
Changes to 1 in 200 year wave heights - >5% change	Local	Long term	Rare	Low	Small-Medium
Changes to 1 in 200 year wave heights - 2-5% change	Sub Regional	Long term	Rare	Low	Small-Medium
Changes to 10 in 1 year wave heights >5% change	Site Specific	Long term	Occasional	Medium	Small-Medium
Changes to 10 in 1 year wave heights 2-5% change	Local	Long term	Occasional	Low	Small-Medium
Changes to tidal currents - 10-20% change	Site Specific	Long term	Routine	Medium	Medium
Changes to tidal currents 2-10% change	Local	Long term	Routine	Low	Medium
Changes to sediment transport	Local	Long term	Routine	Negligible	N/A [2]
Underwater noise - 'Level 6' behavioural response - marine mammals [3]	Local	Temporary	Routine	Low-Medium	Small - Medium
Underwater noise - behavioural response - fish	Local	Temporary	Routine	Low-Medium	Small - Medium
Loss of access	Site Specific	Temporary	Routine	Low	Small

1 It should be noted that the 'change relative to the baseline' is taken to mean the change relative to the regional baseline conditions for the parameter in question, which is not just based on the baseline effects of dredging but incorporates all natural and anthropogenic influences.
2 Based on the approach described in Section 7.4.4 to assessing changes in sediment transport the change relative to the baseline is considered negligible. Therefore it follows that the magnitude of impact does not apply as there will be no spatial interaction with any receptors.
3 Level 6 behavioural response as per Southall *et al.*, 2009 corresponding to: Minor or moderate individual and/or group avoidance of sound source; Brief or minor separation of females and dependent offspring; Aggressive behaviour related to noise exposure (e.g., tail/flipper slapping, fluke display, jaw clapping/gnashing teeth, abrupt directed movement, bubble clouds); Extended cessation or modification of vocal behaviour; Visible startle response; or Brief cessation of reproductive behaviour

7.6 SUMMARY

This chapter summarises a number of studies into the effects of aggregate dredging in the Humber and Outer Wash MAREA study area on the physical environment. Primary effects investigated include the risk of vessel collision and loss of access, the generation of a fine sediment plume and noise generated by the dredging operation. Secondary effects, which occur as a result of changes to bed morphology, include changes in wave conditions, changes in tidal currents and changes to sediment transport.

Wharf Grab Moving Sand

The potential effects of dredging as discussed in this chapter do not necessarily represent significant impacts. The effects investigated represent changes in the baseline conditions that may or may not be translated into significant impacts as a result of their interaction with the environment. Impacts will be considered further in Chapters 8 to 10.

In summary:

- Proposed future dredging activity will be potentially double the existing baseline activity, although will still only represent a low proportion of approximately 2% of all vessel traffic. Collision risk will increase by 3.1% from 1 major collision in 4.54 years to 1 collision in 4.4 years.

- The maximum extents of the plumes outside the extremities of the dredged areas were derived both for the distribution of the depth-averaged concentrations in the water column and near bed, in both the flood and ebb directions. Maximum distances to the 10 mg l^{-1} threshold were generally out to 3.5-4 km near to the bed and 1.5-2 km in the water column. At the 2 mg l^{-1} threshold, which is considered to be not discernible from the background variability, distances range from 3.5-9 km and 8.5-16 km near to the bed.

- Maximum sedimentation at any time from within the dredge plumes was 0.3mm from a single aggregate load.

- Uniform envelopes of 4 km and 2.5 km from the licence area boundary have been assumed to represent potential changes in particle size distribution and potential dispersion of sediments that could form bedforms respectively. However, this is to be considered to be a very conservative approach as any actual changes are unlikely to be uniform around the licence area and given recent monitoring are unlikely to form significant bedforms over the region.

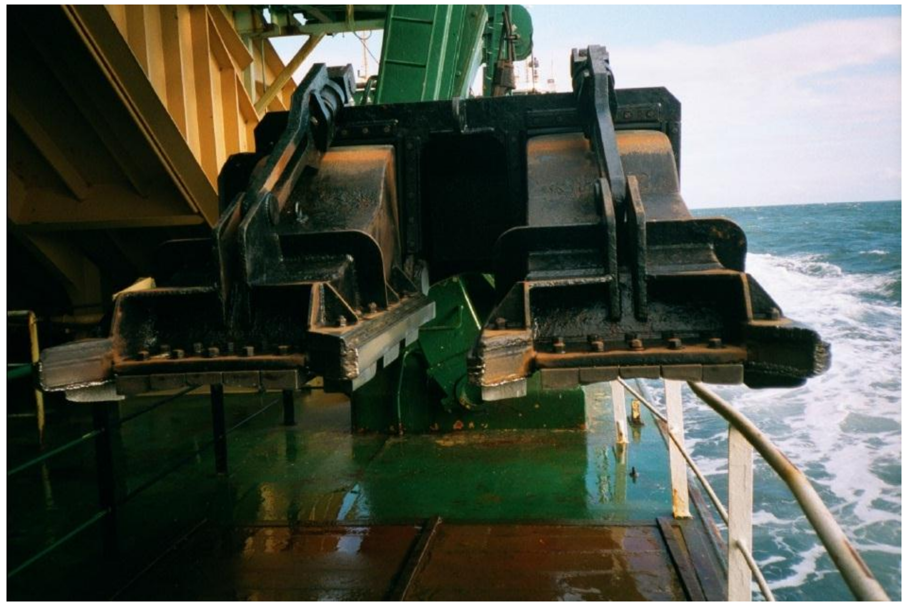
- Cumulative effects of past dredging carried out in the study area have not produced a measurable effect upon waves at the coast or over the majority of the study area. The proposed future dredging will not affect waves at the coast, although wave heights are predicted to increase by more than 25% within Area 493 and increases up to 10% or 0.3 m are predicted to extend to within 2 km of the coast at MLWS.

- Cumulatively past aggregate dredging has not affected nearshore tidal currents or altered sediment transport within the study area. The proposed future dredging is predicted to affect tidal current speeds along the Spurn Peninsula and along a short section of the Lincolnshire coastline. However, the difference between the present day and future dredging scenarios is less than 3% (or 0.02 m s^{-1}) within 1 km of the coast, which is unlikely to be significant in terms of sediment mobility and changes to seabed features.

- The proposed future aggregate dredging will not affect wave or current induced sediment mobility anywhere outside the dredging areas themselves. Therefore it is extremely unlikely that dredging will affect the existing sediment transport processes within the Humber Region.

Each of the key effects of dredging has been modelled or semi-quantitatively described so as to form the basis of assessment for the rest of the MAREA. Wherever possible each effect has been represented by one or more GIS layers, which can then be overlaid with baseline features to inform the degree of interaction of each effect with each of the receptors under consideration.

Close-up Photograph of a Draghead



Source: Shutterstock.com

Geopotes 15 Trailing Suction Hopper Dredger

8 THE PHYSICAL ENVIRONMENT - ASSESSMENT OF REGIONAL IMPACTS

8.1 INTRODUCTION

This Chapter describes the potential regional impacts on the physical environment as a result of future marine aggregate extraction activities in the Humber and Outer Wash MAREA study area.

The topics covered in this Chapter include:

- impacts to seabed features (Section 8.2);
- impacts to the coast (Section 8.3); and
- impacts to water quality (Section 8.4).

In all cases, the potential impacts as a result of the 'effects of dredging' discussion in Chapter 7 are considered.

8.2 IMPACTS TO SEABED FEATURES

8.2.1 Introduction

The seabed features considered within this assessment are the banks and shoals (including sandbanks) and overfalls within the MAREA study area. These seabed features are subject to potential changes due to alterations which may arise to the wave, tide and sedimentary regime as a result of dredging activities.

Sandbanks are important in marine sediment systems as they trap large amounts of sand for long periods of time and are thought to reduce the energy of waves and storm surges. They also provide important habitats for benthic fauna and benthic species in turn provide food for the species that prey on them. The formation and maintenance of sandbanks requires an input of suitably sized sediment material and currents strong enough to induce bedload movement (Dyer, K. et al,1999). Consequently sandbanks may be particularly sensitive to changes in these parameters. Other seabed features may also dissipate the energy of waves and storm surges and provide important habitats and feeding grounds.

For the purpose of this impact assessment the impacts considered are only those with regard to the physical structure of the seabed features and the physical processes that maintain them and their natural dynamics. Impacts to the associated benthos are considered in Section 9.2, impacts to sandbanks when regarded as protected areas and their conservation objectives are considered in Section 9.6 and any impacts to infrastructure which may be associated with these seabed features are considered in Section 10.3.

Seabed features have an important physical role in the marine environment, however, in the context of the 'value' definitions used in the MAREA (see Chapter 3) they are regarded as being of neutral value, i.e. they are not rated on the low, medium, high scale. The individual assessments of impacts to benthic ecology protected areas and to infrastructure discuss value in a specific context where appropriate.

8.2.2 Identification of Potential Impacts to Seabed Features

Table 8.1 shows the predicted effects of dredging with reference to whether or not they have the potential to impact seabed features. As explained in Section 8.1.1 above, only those impacts that have the potential to affect the physical structure or processes that govern their formation and dynamics are considered.

Table 8.1 Matrix of Potential Impacts of Dredging on Seabed Features

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to seabed features
Seabed features as physical structures	■	✓	×	✓	✓	✓	×	×	■	■	■	■	N/A

■	Not affected
×	No Interaction
✓	Potential interaction

The fine sediment plume created by dredging activity has been assessed as having no interaction with seabed features as it refers to the sediment while in suspension in the water column. Sediment settling out of the water column onto seabed features is considered below in the section concerning changes to sediment particle size distribution.

Changes to sediment transport rates have been assessed as having no significant interaction with seabed features as, although some changes to waves and / or tidal flows (which can affect sediment transport rates) may occur, the changes are not large enough to significantly alter sediment mobility outside of the licence areas. Sediment transport direction is also predicted not to change over the majority of the MAREA study area, although some small changes may occur within the licence areas. Similarly sediment transport pathways are not expected to be affected. See Chapter 7 for more information.

Tidal currents can impact the physical structure of seabed features by altering the sediment transport rates to and from the features. However, changes to tidal flows do not necessarily translate directly into changes in sediment movement and as shown in Chapter 7 sediment transport or sediment transport pathways are not predicted to be affected by the changes in tidal currents. Seabed features in the MAREA study area will therefore not be affected by changes in tidal currents and this has not been considered further.

8.2.3 Removal of Sediment

Removal of sediment from seabed features changes the bathymetry and can affect waves and tidal currents. If sediment from nearshore features is removed changes at the coast may occur. In regard to seabed feature distribution within the Humber MAREA study area, no features within approximately 10 km of the shore will be directly affected by sediment removal. However, Protector Overfalls and Inner Dowsing Overfalls lie within Areas 197 and 439 respectively, another unnamed overfalls lies partially within Area 400 and Area 440 and 441 overlap with features further offshore. Area 440 overlaps with approximately 36% of Triton Knoll and Area 441/3 overlaps with approximately 18% of an unnamed offshore bank (see Figure 8.1). In addition the northern edge of Docking Shoal may be subject to extraction from Area 481.

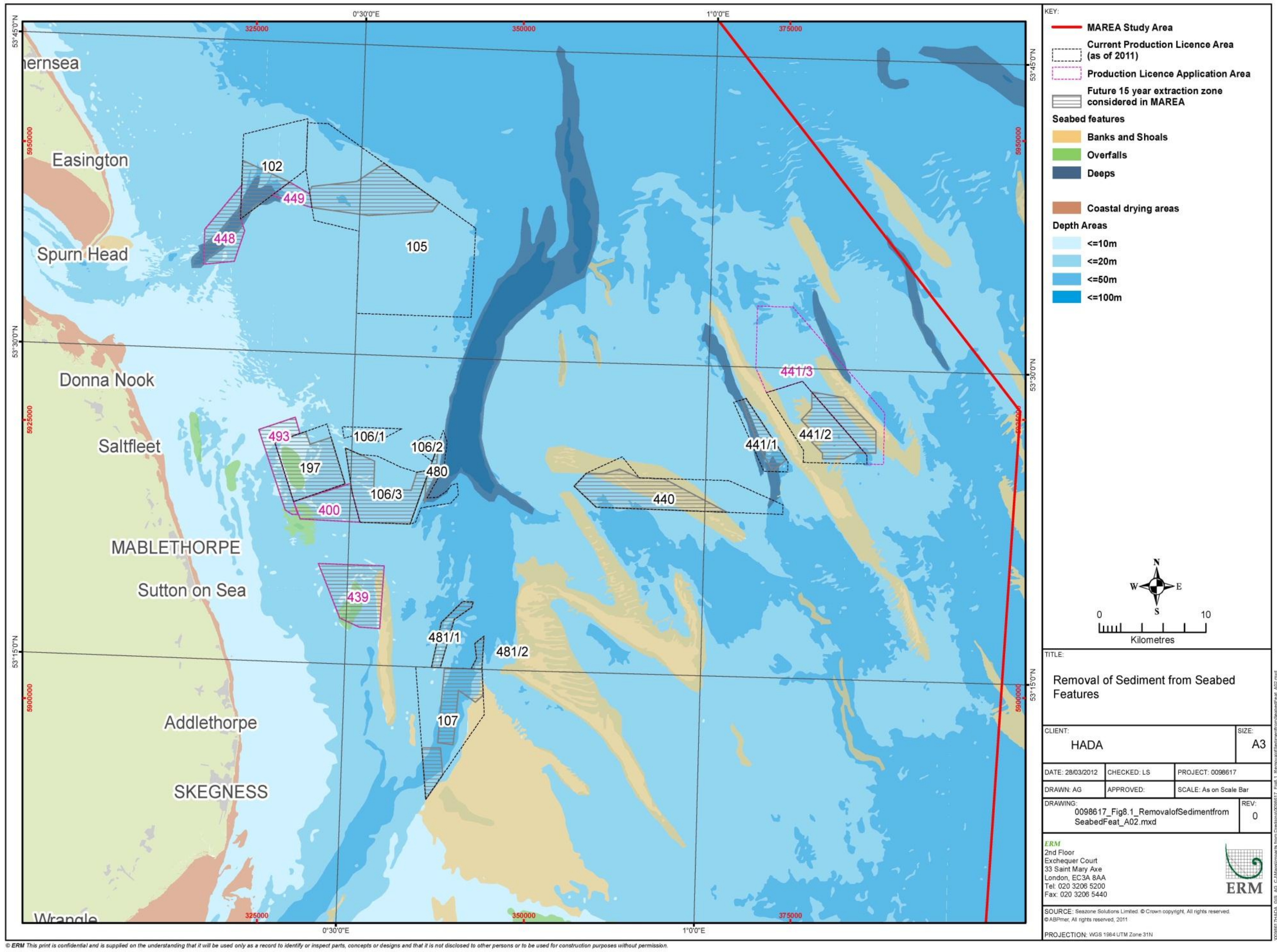
The overfalls off the Lincolnshire coast consist of mounds of sand, gravel and glacial till. The seabed of the overfalls within Areas 197, 439 and 400 will be lowered by up to 6 m in places, including all of Protector Overfalls, 86% of Inner Dowsing Overfalls and 23% of the overfalls that extend into Area 400. (1) Triton Knoll is formed of gravelly sand, overlying Bolders Bank tills, with fine to medium sand at the crest. Up to 3 m depth of sediment may be removed from some parts of the future 15 year MAREA extraction zone of Area 440 (which has previously been dredged) and 4 m depth of sediment may be removed from 441/3 in the areas where these extraction zones overlap with the seabed features. However, these are maximum depths of removal for some areas only and in reality much of the depth changes will be considerably less. Removal of sediment from seabed features as a result of dredging activity is assessed as being a small magnitude effect for the seabed features based on the site specific changes, the low level of change relative to the baseline, the routine occurrence and long term duration of effect. The exception is the overfalls along the Lincolnshire coast, which should be considered in more detail at the EIA stage.

Seabed features are considered to have a high level of tolerance to sediment removal as they are generally naturally subjected to changes, especially following episodic storm events. Seabed features are assessed as having high adaptability to progressive sediment removal spread over 15 years due to their high mobility and regular geomorphological changes, which may make it difficult to determine which regional scale changes are natural and which are caused as a result of dredging activity. Recoverability of seabed features is not applicable due to their highly dynamic nature. Taking into consideration tolerance and adaptability the sensitivity of the seabed features to sediment removal is low.

As described above approximately 36% of Triton Knoll, 18% of the unnamed offshore bank, 23% of the bank within Area 400, 86% of Inner Dowsing Overfalls and all of Protector Overfalls may be directly affected by sediment removal. This is approximately 5% of all the seabed features in the MAREA study area. It can therefore be assumed that only a small degree of interaction between seabed features and sediment removal may occur at a regional scale.

Based on these assessments of the small magnitude of the effect, the low value and sensitivity of seabed features as physical structures and the small degree of interaction between the receptor and the effect, the impact of sediment removal on seabed features is assessed as being of minor significance at the regional scale. However, impacts to the overfalls along the Lincolnshire coast at a local scale may be of greater significance and should be considered in more detail at the EIA stage.

Figure 8.1 Removal of Sediment from Seabed Features



(1) These percentages represent the seabed area and not necessarily the full volume of the feature.

8.2.4 Sand Deposition

Sand deposition can result from the overspill and screening processes during dredging. Coarse sand deposition will be mostly contained within the dredged area up to tens of metres away from the source as this sand settles quickly out of the water column. Finer sand may be deposited further afield and lead to alterations to seabed bedforms up to 2.5 km from the boundary of the licence area (see Chapter 7).

It is expected that only a very localised, thin and discontinuous veneer of sand may be deposited as far as 2.5 km from the licence area boundary and this sediment would be subject to regular reworking by waves and tidal currents and so would quickly disperse, merging with the naturally occurring sands found commonly in the region. It can therefore be considered that the seabed features contained wholly or partly within the licence areas or those that are in close proximity to the licence areas (i.e. <2.5 km) may potentially be affected. Sand deposition on seabed features as a result of dredging activity is assessed as being a small magnitude effect based on the low level of change relative to the baseline and it being localised in extent, routine in terms of frequency of occurrence but short-term in duration.

Seabed features are considered to have a high level of tolerance to sand deposition as they are naturally subjected to sand deposition following episodic storm events, and given the fact that there may only be a small change at the local scale if a large quantity of coarse sand is deposited on or near the feature. Seabed features are assessed as having high adaptability to sand deposition due to their high mobility and regular geomorphological changes, which may make it difficult to determine which regional scale changes are natural and which are caused as a result of dredging activity. Recoverability of seabed features is not applicable due to their highly dynamic nature. Taking into consideration their tolerance and adaptability the sensitivity of the seabed features to sand deposition is low.

Sand deposition may interact with seabed features which overlap with or are within 2.5 km of Areas 107, 197, 440, 441/1, 441/2 and 441/3, 481/2, 493 (although much of the Protector and Inner Dowsing Overfalls will be directly removed by dredging – see Section 8.2.3). The assumption of 2.5 km is considered a very conservative estimate of the effects that may occur and in reality the extent of effect is likely to be much less, especially considering the net direction of tidal flows. In addition it should be borne in mind that a dredger will only produce a plume of sediment covering a small area at any one time and the proportion of this settling on to seabed features is likely to be smaller still. It can therefore be assumed that only a small degree of interaction between seabed features and sand deposition may occur.

Based on these assessments of the small magnitude of the effect and the small degree of interaction between the receptor and the effect, the impact of sand deposition on seabed features is assessed to be not significant at the regional scale.

8.2.5 Changes to Sediment Particle Size

This section considers the changes in sediment particle size with respect to the physical structure of seabed features. The sediment particles in the fine sediment plume will settle out of the water column over time, and may deposit on to seabed features; however, as described in Chapter 7, sedimentation from the fine sediment plume is minimal and is not considered in this assessment.

The majority of the sand from the overspill and screening will settle inside the licence area, although changes in sediment particle size distribution may occur up to 4 km from the licence area. As described further in Chapter 7 this footprint has been arrived at from an interpretation of a scenario whereby dredging occurs continuously throughout the dredging areas up to the licence area boundary while in reality a dredger in the MAREA area will only produce a plume covering a small area (see Figure 7.8 and 7.9 in Chapter 7) at any time. Taking this into account the proportion of sediment settling on to seabed features and potentially altering sediment particle size composition is likely to be smaller still than the 4 km footprint used here as a conservative estimate.

The seabed in the MAREA study area is generally rough and some of the finer grains will be mixed with larger particles and trapped in the void spaces between them. If this occurs on a feature such as a sandbank it may alter its sediment composition. Given the conservative nature of the 4 km footprint and the net direction of tidal flows it is likely only Triton Knoll, Outer Dousing Shoal, the northern part of Dudgeon Shoals and Docking Shoal and an additional unnamed bank further offshore may be affected from sand dispersion from Areas 107, 440 and 441/1, 441/2, 441/3. The overfalls along the Lincolnshire coast, that will be affected directly by dredging may also be affected by changes to sediment particle size distribution. Other seabed features within 4 km of the licence boundary are unlikely to be affected given the net direction of tidal flows.

The extent of effect of changes in sediment particle size distribution is considered local. Based on the current location of seabed features, the impact will be localised, and the finer sediments that settle will temporarily change the sediment composition in the top few centimetres of sediment. The duration of effect is considered short-term as the sediment will be continually re-worked and redistributed naturally. The frequency of effect is routine and it is expected to represent a low level of change relative to the existing conditions. Overall, the potential for changes in sediment particle size distribution on seabed features has been assessed as being a small magnitude effect.

Seabed features can be considered to have a high level of tolerance and adaptability to changes in sediment particle size distribution at the regional scale, as there will be minimal or no detectable changes to the dynamism of the seabed features in general. This is especially noteworthy considering the natural reworking of the sediment by storms, which have been shown to alter sediment particle size distribution on seabed features such as sandbanks (Houthuys, R. *et al.*, 1994). As discussed above, recoverability of seabed features is not applicable. Taking into consideration tolerance, adaptability and value, the sensitivity of the seabed features to changes in sediment particle size distribution is low.

Close-up Photograph of Sand in the Hopper of a Dredging Vessel

Although a proportion of the seabed features in the MAREA study area are within this 4 km boundary and may be affected by changes in sediment particle size distribution, as explained above, the actual effect is likely to be much smaller since the assumption of a potential 4 km footprint is conservative and the actual area affected at any period over the MAREA lifetime will be significantly smaller. It can therefore be assumed that only a small degree of interaction between seabed features and changes in sediment particle size distribution may occur with the features in their current locations.

Based on the assessment of the small magnitude of the effect, the low sensitivity of seabed features and the small degree of interaction between receptor and effect, the significance of impact of changes in sediment particle size distribution on the physical structure of seabed features is assessed to be not significant at the regional scale.

8.2.6 Changes to Wave Heights

This section considers the potential for impacts to the physical presence and structure of seabed features as a result of changes in wave height. Waves can affect seabed features by changing the amount of sediment transported across them and altering sediment transport pathways. The 10 in 1 year wave has been shown not to produce a measurable or permanent change in sediment mobility or seabed morphology across the MAREA study area (see Chapter 7) and has not been included in this assessment. Waves from storms, however, are known to rework the sediments and can affect seabed features such as sandbanks (Houthuys *et al.,* 1994). Therefore this assessment is based on modelling of the propagation of waves that are only expected to occur on average once every 200 years; this is the same wave condition that is typically used in modelling related to the design of coastal defences.

This impact assessment presents predicted percentage changes in wave height (greater than ± 2%) from areas of planned future dredging and assesses the impact this may have on seabed features in the MAREA area. Figure 8.2 presents potential seabed features and wave height change interactions for 1 in 200 year waves from the northeast at MLWS (i.e. the worst case incident direction).

Very localised areas of Triton Knoll, Outer Dousing Shoal and Dudgeon Shoals may experience increases in extreme waves of up to 5%, which in absolute terms is the equivalent of 10-20 cm. Docking Shoal may experience very localised increases in wave height at its northern point by 5% (10-20 cm) and decreases at its western point of 5%, however, in absolute terms this is less than the 10 cm change limit set in the model. Trusthorpe Overfalls may experience increases in wave height of up to 10% (20-30 cm), the overfalls to the north may experience increases in wave height of 15 % (30-40 cm) and Saltfleet Overfalls may experience increases in wave height of up to 5% (20 cm over part of the overfalls). In addition, Protector, Inner Dowsing and unnamed Overfalls may also experience changes within and in the lee of the licence areas, although these overfalls will also be actively dredged.

The magnitude of this effect on seabed features is considered small given the very localised effect on the features (Changes to 1 in 200 year wave heights of 2-5% are considered a small to medium magnitude effect at the regional scale across the whole MAREA study area, however, the magnitude of effect on seabed features at the regional scale is small given only the very localised extent of potentially impacted features.), the low change relative to the baseline, the rare occurrence and long term duration of effect. The exception is the overfalls along the Lincolnshire coast, which should be considered in more detail at the EIA stage.

As the potential effects of the predicted wave height changes on the seabed features would be comparatively small compared to the alteration of the features by natural processes, it is unlikely any impacts would be seen at a regional scale. Seabed feature adaptability and tolerance is therefore assessed as high. As discussed above, recoverability of seabed features is not applicable. Taking into consideration tolerance and adaptability, the sensitivity of the seabed features to changes in wave height is low.

Overall it is considered that only a small degree of interaction between seabed features and changes in wave height may occur at the regional scale with the features in their current location. However, as seabed features have the potential to move the area of interaction may vary over 15 years.

Overall based on the small or medium magnitude of the impact, low value and sensitivity of the receptor as physical structures and small or high degree of regional interaction between the receptor and the effect, the impact of changes in extreme wave height is assessed to be of minor significance at the regional scale. However, impacts to the overfalls along the Lincolnshire coast at a local scale may be of greater significance and should be considered in more detail at the EIA stage.

A Sandy Beach on the Lincolnshire Coast showing Coastal Wave Action

Source: ABPmer

8.2.7 Summary of Impacts

Cumulative effects of dredging on seabed features may occur in two ways. Firstly, two dredging areas in close proximity to each other create a potential for the effects to overlap and impact the same area of the feature. However, the assessment above has taken this into consideration where relevant (i.e. the potential for sand deposition and changes to sediment particle size distribution). The second way is that multiple effects (i.e. two or more from: removal of sediment, sand deposition, changes to sediment particle size, changes to wave height) may occur over the same area of a seabed feature. However, given the limited extent of potential impacts to the seabed features this is unlikely to be significant.

Table 8.2 summarises the significance of the cumulative impacts of dredging on seabed features as physical structures at the regional scale.

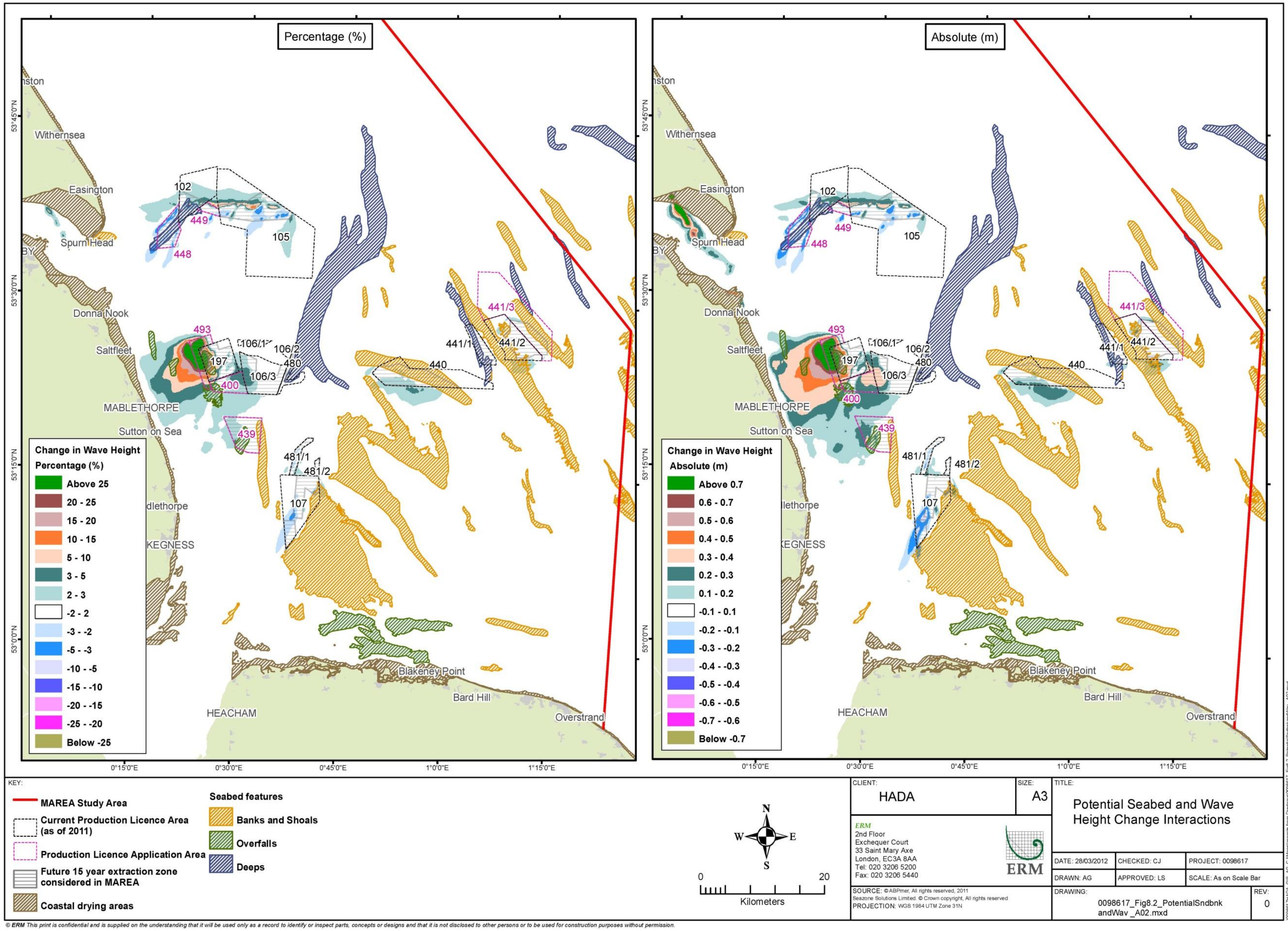
Table 8.2 Regional Significance of Impacts to Seabed Features from Dredging in the Humber and Outer Wash Area

Effect of Dredging	Seabed features as physical structures	
Removal of sediment	Minor significance	
Sand deposition	Not significant	
Changes to sediment particle size	Not significant	
Changes to wave height	Not significant - as no changes in sediment transport rate from the 10 in 1 year wave.	Extreme wave conditions - Minor significance
Changes to tidal currents	Not significant - as no changes in sediment transport rate from changes to tidal currents	

Regional impacts to seabed features from the effects of changes to wave heights and changes to sediment transport rates associated with dredging are predicted to be not significant at the regional scale. Impacts to the overfalls along the Lincolnshire coast should be considered in more detail at the EIA stage as follows.

EIAs for Areas 440 and 441/3 will need to consider impacts from sediment removal from seabed features on a site-specific basis given their location over Triton Knoll and another unnamed offshore bank respectively. EIAs for Areas 197, 400, 439 and 493 will need to consider impacts from sediment removal from seabed features and EIAs for Areas 197 and 493 will need to consider impacts from changes in wave height on seabed features.

Figure 8.2 Potential Seabed Feature and Wave Height Change Interactions



8.3 IMPACTS TO THE COASTLINE

8.3.1 Introduction

Within the context of the present assessment, the coastline refers to the high water mark as this was used during the modelling. However the foreshore environment from mean low water spring to mean high water spring is also considered. The coastline not only provides a variety of habitats for a diverse range of organisms but it also can act as a natural flood defence and a local amenity. The coastline in many parts of the study area is dynamic and shifts in position and morphology due to the collective action of waves, tidal currents and sediment transport. Any changes to these processes have the potential to impact this dynamic equilibrium and therefore shift the relative position of the coastline over longer timescales, possibly at the expense of valuable land or intertidal habitat.

For the purpose of this impact assessment the impacts considered refer to the physical processes that naturally affect the dynamic equilibrium of the coastline, and not its role in providing intertidal habitats or for coastal defence. As such, in the context of the 'value' definitions used in the MAREA (see Chapter 3) the coastline is regarded as being of neutral value, i.e. it is not rated on the low, medium, high scale.

Example of a Groyne in the Intertidal Zone on the Holderness Coast

Source: ABPmer

8.3.2 Identification of Potential Impacts to the Coastline

Table 8.3 shows the predicted effects of dredging with reference to whether or not they have the potential to impact the coastline. Only impacts that have the potential to affect the physical structure of the coastline are considered.

Sand deposition has been assessed as having no potential interaction with the coastline as it predominantly occurs within the licence areas and may change bedforms up to 2.5 km from licence area boundaries (although the actual footprint of potential impact is likely to be less). The licence areas are all more than 10 km from the coast therefore an interaction between the coast and sand deposition will not occur.

Changes to sediment particle size due to dredging has been assessed as having no interaction with the coastline as changes may occur up to a 4 km from the licence area boundary (although the actual footprint of interaction is likely to be less). As the licence areas are all more than 10 km from the coast there is no interaction between the coast and changes to sediment particle size.

Table 8.3 Matrix of Potential Impacts of Dredging on the Coastline

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Coastline as a physical structure	■	■	■	×	×	×	✓	×	■	■	■	■	×

■	Not affected
×	No interaction
✓	Potential interaction

Waves can affect the coast by changing the amount of sediment transported to and along it and by altering sediment transport pathways. The 10 in 1 year wave has been shown not to produce a measurable or permanent change in sediment mobility or seabed morphology across the MAREA study area (see Chapter 7) and has not been considered further.

Waves from storms, however, may affect the coast (i.e. the 1 in 200 year extreme wave scenario). Figure 8.2 presents wave height change interactions for 1 in 200 year waves from the northeast at MLWS (i.e. the worst case incident direction) together with the location of the coast, including the coastal drying areas. Increases of up to 3% are shown to occur within a kilometre of Lincolnshire coastline and increases of up to 5% occur within 1.5 km of the coastline, which is the equivalent of up to a 20 cm wave height increase.

These changes of up to 3% and 5% occur within 400 m and 700 m of the coastal drying areas respectively. As described in Chapter 7 the lowering of the seabed by aggregate dredging has reduced the energy dissipation that occurs as waves travel over and in the lee of Area 493, where the Protector Overfalls were situated in the pre-dredge scenario. However, Mablethorpe Bank, located approximately 1 km off the Lincolnshire coast (as presented in the baseline characterisation - see inset 6 in Figure 4.10) is located well outside the dredging areas and continues to provide shelter from wave action as it dissipates nearshore wave energy.

Considering this feature and the modelling results the proposed dredging in this area is not predicted to affect wave heights at the coast. Changes to extreme wave heights have therefore been assessed as having no interaction with the coastline at the regional scale as although some small changes may occur near the Lincolnshire Coast, the modelled changes are not expected to extend as far as the coast. However, given the sensitivity of the coastline in this region this effect should be considered in more detail at the EIA stage for Areas 197 and 493.

Changes to sediment transport have been assessed as having no interaction with the coastline as changes in bed shear stress do not exceed the critical bed shear stress required to move larger sediment size fractions. In addition, regional sediment transport pathways do not move from the offshore region to the nearshore but instead the majority of sediment is transported along the coast from nearby sediment sources (such as cliffs) (see Figure 4.19). Therefore no changes to sediment transport are predicted at the coast.

Changes to seabed features, including sandbanks, may affect the coast through:

- removal of seabed features within the licence areas causing increased wave height towards the coast;

- changes in wave height compromising the ability of seabed features between the licences and the coast to dissipate wave energy; and

- changes to the sediment transport pathways through the seabed features to the coast.

Potential changes to sediment transport pathways are discussed in Chapter 7 and it is expected no measureable changes will occur. Changes to seabed features, including sandbanks, have been assessed in the seabed features impact assessment above (Section 8.2). Only changes to the overfalls along the Lincolnshire coast have been assessed as being significant due to sediment removal (those overfalls within the licence areas) and changes to significant wave height (those overfalls between the licences and the coast). However, wave height changes are not predicted to extend to or affect the coast, even though there will be potential changes to the seabed features. Therefore no interaction between changes to seabed features and the coast is predicted. However, given the sensitivity of the coastline in this region this effect should be considered in more detail at the EIA stage for Areas 197 and 493.

8.3.3 Changes to Tidal Currents

Modelling studies have predicted that there may be a reduction in peak flood tidal flow on a spring tide of up to -3% between Saltfleet and Mablethorpe along the Lincolnshire coastline as a result of the depth changes in Area 493 (see Figure 7.24). However, this change is less than 0.02 ms-1 within 1 km of the coastline (within the limits of the model and natural variation), which is unlikely to be significant in terms of sediment mobility and changes to seabed features. Therefore, although a small interaction occurs it is not predicted to affect the coast and has not been assessed further. No other interactions with the coastline are predicted for peak flood or peak ebb flow on a spring tide.

8.3.4 Summary of Impacts

The coastal impact studies have predicted that there will be no changes at the coastline, even using maximum dredging tonnages and footprints. However, given the sensitivity of the of Lincolnshire coastline it is recommended that impacts to the coast from Areas 197 and 493 are examined in further detail at the EIA stage.

Sandy Beach and Dunes on the Lincolnshire Coast

Source: ABPmer

North Norfolk Coastline

Source: ABPmer

Shingle Beach and Sandy Cliffs on the North Norfolk Coast

Source: ABPmer

Eroding Cliffs on the Holderness Coast

Source: ABPmer

8.4 IMPACTS TO WATER QUALITY

8.4.1 Introduction

Suspended sediment, nutrient and dissolved oxygen levels can be used as indicators of water quality. Water quality in the Humber and Outer Wash MAREA study area is described in Section 4.7.

Water quality is important at both local and regional scales. It can directly affect marine organisms as well as affecting the distribution of fish populations, which in turn may indirectly impact other species in the wider region such as birds and marine mammals. A relatively small volume of water is affected by dredging operations at any one time compared with the whole MAREA area and the offshore locations of the licence areas are not covered by the Bathing Waters Directive. Although water quality is an important characteristic of the physical environment in the context of the 'value' definitions used in the MAREA (see Chapter 3) it is regarded as being of neutral value, i.e. it is not rated on the low, medium, high scale.

Sand Falcon Trailing Suction Hopper Dredger Loading Sand showing Overflow from Spillways and Associated Plume of Fine Particles

8.4.2 Identification of Potential Impacts to Water Quality

Table 8.4 shows which of the predicted effects of dredging has the potential to impact on water quality.

Table 8.4 Matrix of Potential Impacts of Dredging on Water Quality

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to sandbanks
Water Quality	■	■	✓	■	■	✓	✓	■	■	■	■	■	■

■	Not affected
×	No interaction
✓	Potential interaction

8.4.3 Fine Sediment Plume

The fine sediment plume has the potential to impact water quality by:

- releasing nutrients from organic material and contaminants (e.g. metals and hydrocarbons); and
- increasing turbidity (the amount of suspended sediment in the water column).

A change in nutrient concentration could either improve or reduce water quality depending on the quantity of nutrients released; a relatively small increase in nutrients could boost primary production, while a large increase in nutrients and organic matter has the potential to reduce oxygen concentrations. Metals and hydrocarbons released from the sediment and associated porewater can reduce water quality, which may potentially impact marine organisms. However, the proportion of silt in the material dredged in the MAREA area is low and given that contaminant concentrations near the coast in the MAREA study area are generally below the Probable Effect Level (PEL) (see Chapter 4) it is likely that only low levels of nutrients and contaminants may be released during dredging. In addition, organic material and contaminants are commonly associated with or preferentially concentrated on fine sediments (mud and silt), which are not targeted during dredging. Therefore nutrients and contaminants are not considered to affect water quality due to dredging and have not been considered further.

View of a Fine Sediment Plume from an Active Dredging Vessel

Increased turbidity can result in changes in fish distribution and community composition as well as reducing light penetration, which affects primary production. The presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a small to medium magnitude effect for 20 mg l^{-1} plumes and a medium magnitude effect for plumes of 50 mg l^{-1} and 100 mg l^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20 mg l^{-1} and 50 mg l^{-1} plume) or site specific (for the 100 mg l^{-1}) and regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 20 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 mg l^{-1} and 100 mg l^{-1} plumes.

The water column is assessed as having high adaptability and tolerance to turbidity as the Humber and Outer Wash is regularly subjected to natural turbidity increases of a few tens of mg l^{-1} above background concentrations, which can be in excess of 150 mg l^{-1} during and immediately after a storm event. Water quality recoverability is assessed as high as turbidity increases will only be experienced while dredging occurs or up to the extent of one tidal cycle and only in the streamline of the dredger. Taking into consideration tolerance, adaptability and recoverability, the sensitivity of the water column to increased turbidity is low.

Close-up of Sand in the Discharge Conveyor of a Dredging Vessel

Increased turbidity for the depth averaged plume will predominantly occur inside the licence areas, although increases of up to 20 mg l^{-1} above background levels may be experienced within 1.5 km of the licence area boundary in some areas. Increased turbidity for the seabed plume may, however, cause increases of 20 mg l^{-1} above background levels up to 3 km from the licence area boundary in some areas on some occasions. However, these are extreme predictions from the modelled scenario of dredging occurring continuously throughout the dredging areas up to the licence area boundary when in reality, dredging will generally be focused in one particular zone and in most cases be carried out by one vessel. Therefore at any given time the 20 mg l^{-1} above background plumes associated with dredging will be temporary events and will cover a relatively small area, and concentration increases of over 100 mg l^{-1} above background associated with the plumes will cover a smaller area still. The degree of interaction between water quality and the elevated turbidity associated with the sediment plume is therefore considered to be small.

Based on these assessments of the small-medium magnitude of the effect, the low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of increased turbidity on water quality is assessed to be not significant at the regional scale.

8.4.4 Changes to Wave Heights

Increased wave height may result in sediment resuspension, which increases turbidity and may release nutrients, metals and hydrocarbons stored in the sediment. Changes in wave height are unlikely to produce greater effects than the fine sediment plume from dredging, due to the much smaller quantity of sediment that can be resuspended by waves compared to the quantity of material discharged from the dredging vessel. This indicates that the impact of changes to wave height on water quality will be less than the impact of the sediment plume; therefore the impact of changes in wave height on water quality is also assessed as not significant.

8.4.5 Changes to Tidal Currents

Changes in tidal currents may affect water quality in the same ways as described above for the fine sediment plume. Changes in tidal currents are unlikely to produce greater effects than the fine sediment plume from dredging due to the much smaller quantity of sediment that can be resuspended by tidal currents compared to the quantity of material discharged from the dredging vessel. This indicates that the impact of changes to tidal currents on water quality will be less than the impact of the sediment plume; therefore the impact of changes in tidal currents on water quality is also assessed as not significant.

View of a Dredger Loading Sand in the Hopper

8.4.6 Summary of Impacts

Table 8.2 summarises the significance of the cumulative impacts of dredging on water quality at the regional scale.

Table 8.5 Regional Significance of Impacts to Water Quality

Effect of Dredging	Water Quality
Fine sediment plume/elevated turbidity	Not Significant
Changes to wave height	Not Significant
Changes to tidal currents	Not Significant

Impacts to water quality from dredging are predicted to be not significant. No action is required to study the potential impacts further at the licence specific EIA stage other than adopting normal good working practice.

HAM 316 in Steaming through Turbid Waters

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9 THE BIOLOGICAL ENVIRONMENT - ASSESSMENT OF REGIONAL IMPACTS

9.1 INTRODUCTION

This section describes the potential regional impacts on the offshore biological environment as a result of future marine aggregate extraction activities in the Humber and Outer Wash region.

The topics covered in this section include:

- impacts to benthic ecology (Section 9.2);
- impacts to fish ecology (Section 9.3);
- impacts to marine mammals (Section 9.4);and
- impacts to designated sites (Section 9.5).

In all cases, the potential impacts as a result of the effects of dredging discussion in Chapter 7 are considered.

9.2 POTENTIAL IMPACTS TO BENTHIC ECOLOGY

9.2.1 Introduction

In the Humber and Outer Wash region a combination of inputs of fine sediments from coastal erosion and resuspension of seabed material by waves and storm surges results in a relatively high turbidity environment. Turbidity tends to decrease with distance from shore but bedload transport, among other factors, increases turbidity near the seabed. The study area is also subject to considerable anthropogenic activity including commercial fishing and aggregate dredging (see Section 6.3 for details).

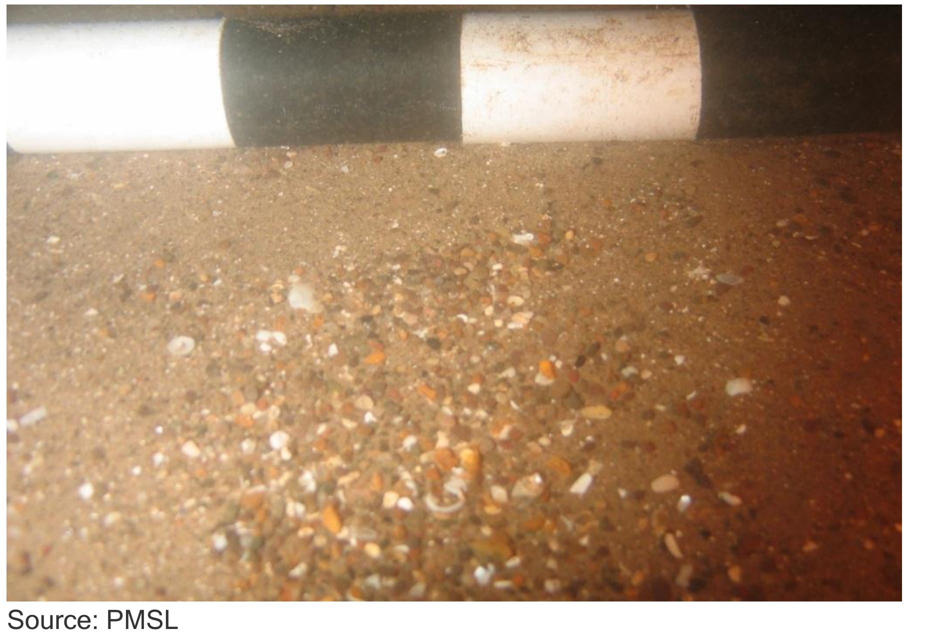
The benthic ecology baseline section (see Section 5.2) has identified those aspects of the benthic ecology of the study area which could potentially be impacted as a result of marine aggregate extraction and presented them within the following three groups that are discussed further here:

- Biotopes (see Section 9.2.4);
- Protected Species and Habitats (see Section 9.2.5); and
- Commercial Species (see Section 9.2.6).

9.2.2 The Value of Benthic Ecology Features in the Study Area

As presented in Section 5.2, the benthic communities within the study area have been grouped together by their biotope code. This means that impacts to sensitive benthic communities can be assessed by determining the potential impacts to sensitive biotopes.

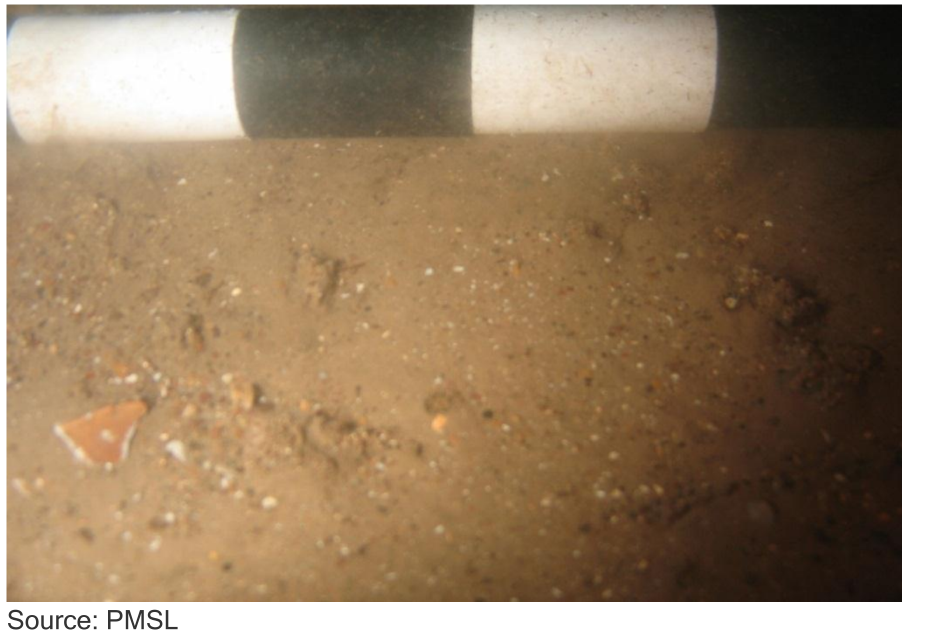
Photograph of Poorly Sorted Mixed Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals



Source: PMSL

It is recognised that there are inconsistencies in the biotope classification system, where appropriate characterising species are discussed as a proxy for the sensitivity of the biotope or where, in order to ensure a precautionary approach, all biotopes within a biotope complex are assessed. Of specific relevance in this regard are the biotopes 'semi-permanent tube-building amphipods and polychaetes in sublittoral sand', SS.SSa.IFiSa.TbAmPo, and *'Neopentadactyla mixta* in circalittoral shell gravel or coarse sand', SS.SCS.CCS.Nmix. The former was present on a far wider range of sediment types than would typically be expected and the latter is included as part of the biotope complex SS.SCS.CCS, despite not having been recorded in the region, to provide a precautionary assessment of sensitivity.

Photograph of Fine Grained Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals



Source: PMSL

Benthic communities are a major link in the food chain and provide an important ecosystem function. The filter feeders remove sediments and organic material from the water column, effectively cleaning the water in the process. Organic matter that is not used within the water column is deposited on the seabed and remineralised by the deposit feeders into nutrients which are put back into the water column. This is particularly important for maintaining the high primary production rates of estuaries and coastal waters.

The values of the individual biotopes which have been identified in the study area are discussed below in Table 9.1.

In addition to identifying the value of biotopes in the study area, value has also been assigned to the protected habitats and species, and commercial species, which are also considered in this chapter.

- Protected habitats and species have been assigned a high value for their rarity and/or conservation status.

- Commercial species are assigned a high value due to their importance as a source of income for the commercial shellfish fishing industry within the region.

Table 9.1 Biotope Values

Biotope	Value	Reason
SS.SCS.ICS.HeloMsim	Medium	This biotope is commonly found both inshore along the east coast of the UK and in the Southern Bight of the North Sea and off the Belgian coast. This biotope supports an important meiofaunal population as well as macrofaunal population.
SS.SCS.ICS.Glap	Low	This biotope is quite widespread and may occur in a variety of coarser sediments. In many cases e.g. along the East Yorkshire coast this biotope is found in shallow inshore areas facing directly into the prevailing wind and subject to considerable wave action.
SS.SCS.ICS.SLan	Low-Medium	This biotope is found in a wide range of habitats off all mainland UK coasts. It may be more accurate to define SS.SCS.ICS.SLan as an epibiotic biotope which overlays a variety of infaunal biotopes. Species included within this biotope include: crabs which are scavengers and predators of molluscs and annelids; gobies and flatfish which frequent the biotope to feed upon polychaetes; small crustaceans; cumaceans and small crabs.
SS.SCS.CCS.PomB	Low-Medium	This biotope is found on exposed open coasts as well as at the entrance to marine inlets. The MarLIN and JNCC distribution maps indicate scattered records around much of the UK. Starfish and hermit crabs are generalist predators within this biotope.
SS.SCS.CCS.MedLumVen	Medium	This biotope and variants of it make up a significant proportion of the offshore North Sea and Irish Sea benthos and is found patchily around the British coast. SS.SCS.CCS.MedLumVen may be quite variable over time and in fact may be closer to a biotope complex in which a number of biotopes or sub-biotopes may yet be defined. This biotope supports bivalves which are predated by boring gastropods and flatfish. Whelk and fish feed on the echinoid *Spatangus purpureus* and starfish feed on bivalves within this biotope.
SS.SCS.CCS.Pkef	Low	This biotope is found along open coasts in depths of 10 to 30 m, and in shallower offshore areas. This biotope has been reported in the North Sea along the Norfolk/Lincolnshire coast located in and around marine aggregate dredging areas. This biotope is an impoverished variant of SS.SCS.CCS.MedLumVen.
SS.SSa.IFiSa.IMoSa	Low	This biotope is found in shallow water, often formed into dunes, on exposed or tide-swept coasts. In England, SS.SSa.IFiSa.IMoSa has been recorded from various locations on the east coast (including Spurn Head and The Wash), the Sussex coast, Start Point (Devon), the Bristol Channel and Morecambe Bay as well as more sparse records in Scottish and Irish waters. As this biotope is sparsely populated it supports predators that are primarily scavengers.
SS.SSa.IFiSa.NcirBat	Low-Medium	This biotope is present in the shallow sublittoral to depths of 30 m at wave and tide exposed locations around Britain and Ireland. This biotope is common in UK waters. Shrimps, crabs, starfish and sandeels may be locally abundant, whilst juvenile gadoids, adult and juvenile flatfish all predate in this biotope.
SS.SSa.iFiSa.TbAmPo	Medium	This biotope is common in lagoons on Shetland and Orkney. The MarLIN and JNCC distribution maps show that this biotope has been found in this area before. The biotope has historically been assigned to samples in this region but does not fit with the expected sediment type in the MNCR biotope description. It is expected that the polychaetes in this community in particular would be predated by benthic fish, particularly flatfish as for SS.SCS.ICS.SLan and SS.SCS.ICS.Glap.
SS.SSa.IMuSa.FfabMag	Medium	This biotope is recorded from the Shetland Islands, Orkney Islands, SE Scotland, NE England, the Isles of Scilly, Bristol Channel and Cardigan Bay. Demersal fish, nemertean worms, echinoderms and crabs all predate on species within this biotope.
SS.SSa.CFiSa.ApriBatPo	Low-Medium	This biotope is found in the central and northern North Sea (JNCC, 2012a). It is expected that the polychaetes in this community in particular would be predated by benthic fish. However, this community is common in the North Sea.
SS.SSa.CMuSa.AalbNuc	Low	This biotope is found throughout the North Sea including within Danish waters and the German Bight as well as on all UK coasts (ref)(JNCC, 2012b). The benthic species within this community are prey items for starfish and demersal fish. This biotope provides a food source for high trophic levels, but is very common.
SS.SBR.PoR.SspiMx	High	This biotope is widespread around the British Isles. It has the potential to support Annex I defined habitat: *Sabellaria spinulosa* biogenic reef.
SS.SCS.CCS.Blan	Medium	This biotope has been described from a limited number of records and as such may need revising when further data become available. This biotope may be an epibiotic overlay of the biotope SS.SCS.ICS.MoeVen or SS.SCS.CCS.MedLumVen. A precautionary value of Medium has been applied.
SS.SCS.CCS.Nmix	Medium	This biotope is primarily found on the west coast of the UK and around the Irish coasts. From the JNCC distribution map it does not appear to have been found within the study area before the review of the survey data was conducted for this MAREA (JNCC 2012c).
SS.SSa.IFiSa.ScupHyd	Medium	This biotope is recorded mostly around the south and west coasts of England, Wales and the east coast of Ireland (JNCC, 2012d). It has also been recorded in Morecambe Bay in the west of the UK and off the coast of Wales. Two records have been recorded in Scotland and SS.SSa.IFiSa.ScupHyd has also been found on the north coast of Northern Ireland and at several locations along the east and south west coasts of Ireland. Crabs, starfish and sea slugs are likely to prey on the species within this benthic community. This biotope does not appear to be common within the study area but is common around other parts of the UK coast.

9.2.3 Identification of Potential Impacts on Benthic Ecology

Introduction

Table 9.2 illustrates which of the predicted effects of dredging have the potential to impact sensitive biotopes, protected habitats and species, and commercial benthic species. Potential interactions have been determined by overlaying the distribution of the community, species or habitat in question with the footprint of the dredging effect wherever possible.

Only communities that are found within the future 15 year MAREA extraction zones have been identified as being affected by removal of sediment since sediment removal will be constrained to these areas.

Dredger Discharging Sand Using A Bucket Wheel

Table 9.2 Matrix of Potential Interactions between Benthic Receptors and the Effects of Dredging

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to seabed features
Biotopes													
SS.SCS.ICS.HeloMsim	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SCS.ICS.Glap	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SCS.ICS.SLan	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SCS.CCS.PomB	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SCS.CCS.MedLumVen	■	×	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SCS.CCS.Pkef	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SSa.IFiSa.IMoSa	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SSa.IFiSa.NcirBat	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SSa.iFiSa.TbAmPo	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SSa.IMuSa.FfabMag	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SSa.CFiSa.ApriBatPo	■	×	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SSa.CMuSa.AalbNuc	■	×	✓	×	×	■	×	×	■	■	■	■	×
SS.SBR.PoR.SspiMx	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	✓
SS.SCS.CCS.Blan	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SCS.CCS.Nrrix	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	×
SS.SSa.IFiSa.ScupHyd	■	×	×	×	✓	■	×	×	■	■	■	■	×
Protected Species and Habitats													
Ross worm (*Sabellaria spinulosa*) individuals and reef	■	✓	✓	■	✓	■	✓	×	■	■	■	■	■
Honeycomb worm (*Sabellaria alveolata)* and reef	■	✓	✓	■	✓	■	✓	×	■	■	■	■	■
Blue mussel reef (*Mytilus edulis*)	■	×	■	✓	✓	■	×	×	■	■	■	■	■
Horse mussel (*Modiolus modiolus*)	■	✓	■	✓	✓	■	✓	×	■	■	■	■	■
European edible sea urchin (*Echinus esculentus*)	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	■
The amphipod *Leptocheirus hirsutimanus*	■	✓	✓	✓	✓	■	✓	×	■	■	■	■	■
Edwardsiidae	■	✓	×	×	×	■	×	×	■	■	■	■	■
Commercial Species													
European lobster (*Hommarus gammarus*)	■	✓	■	✓	■	■	■	×	■	■	■	■	■
Brown crab (*Cancer pagarus*)	■	✓	■	✓	■	■	■	×	■	■	■	■	■
Pink Shrimp *(Pandalus montagui*) and Brown Shrimp (*Crangon crangon*)	■	✓	■	✓	✓	■	■	×	■	■	■	■	■
Cockles (Cerastoderma edule)	■	×	■	×	×	■	■	×	■	■	■	■	■
Mussels (*Mytilus edulis*)	■	×	■	✓	✓	■	■	×	■	■	■	■	■
Whelks (*Buccinum undatum*)	■	×	■	×	×	■	■	×	■	■	■	■	■
Velvet crab (*Necora puber*)	■	×	■	×	■	■	■	×	■	■	■	■	■

Not affected	■
No interaction	×
Potential interaction	✓

Determination of Sensitivity of Receptors

For each dredging effect, the sensitivity of the receptor to the effect has been determined. As described in Chapter 3, the overall sensitivity of each receptor (in this case, biotope, species or habitat) is determined based on the tolerance, adaptability and recoverability of the receptor to the effect. The following sources have been used in arriving at the assignment of particular sensitivities to these receptors.

- The ranking of sensitivity of different biotopes to the effects of dredging has primarily been taken from a report on biotope sensitivities prepared by the MarLIN. The full report, which includes factsheets for each biotope, is provided in Appendix J. This study has provided sensitivity rankings for each biotope under consideration, based on the concepts of 'intolerance' (the susceptibility of a species population to damage, or death, from an external factor, assessed relative to change in a specific factor) and 'recoverability' (the ability of a habitat, community, or individual (or individual colony) of species to redress damage sustained as a result of an external factor). The criteria applied for these two concepts are presented in the report in Appendix J. It should be noted that the concept of 'adaptability' which is applied in this MAREA is incorporated in this study into the concept of 'intolerance'. However, within the impact assessment in this section the term 'tolerance' is used in line with the MAREA methodology.

- To supplement the data in this report a range of useful information is also available for the benthic environment on the Marine Life Information Network (MarLIN) website. The site provides quality assured information on many species present around the coasts of Britain and Ireland. Where MarLIN has provided information on the species of relevance for this assessment, the information has been drawn upon. For species that have not been assessed by MarLIN, a comparison has been made to species which were functionally similar and the sensitivity of the receptor in this assessment was inferred based on this comparison.

- For the assessment of the sensitivity of the benthic communities supported within protected habitats, information has also been taken from Natural England site selection and conservation objectives document for the SACs in the area, from the Environmental Network Guidance (ENG) (Natural England and JNCC, 2010) and other published sources.

9.2.4 Potential Impacts to Biotopes

Introduction

Biotopes are used within this assessment to assess the significance of dredging at a regional scale on the different benthic communities that are known to exist within the study area. Biotopes were assigned to different areas using characteristic species of that community (see Section 5.2). As described in Section 5.2 the sensitivity of the characterising species of a biotope was assessed by MarLIN. The full report of this assessment is provided within Appendix J.

For this assessment the extrapolated biotope map was overlaid with the spatial footprint of each effect to determine the degree of interaction. For effects that were not mapped in GIS, expert judgement was used to assess the degree of interaction. Table 9.3 provides an assessment of the cumulative impact significance for each biotope with each effect of dredging. The assessment uses a combination of biotope value, degree of interaction, magnitude of the effect and the tolerance and recoverability of the biotope to the effect to determine the overall cumulative impact significance.

It is important to recognise that use of the biotope classification system occasionally requires allocation of a 'best fit' biotope code. This is specifically important in the assessment of the biotope 'semi-permanent tube-building amphipods and polychaetes in sublittoral sand', SS.SSa.IFiSa.TbAmPo. Of the 50 grab sample stations assigned to this biotope code none of them reflect the 'typical' community composition or the sediment composition associated with the biotope code. This is likely to reflect inconsistencies in the biotope classification system, with the key characterising species (*Corophium crassicorne* a synonym of *Crassicorophium crassicorne*) having a 'best fit' with this biotope alone.

The frequent occurrence of the characterising community in association with a wider than expected range of substrata including coarse sand and gravel is likely to indicate that the community is less sensitive to key effects of dredging such as changes in sediment particle size and tidal currents than the typical biotope which is associated with fine sand to muddy sand. For the purpose of this assessment the 'typical biotope' is assessed to provide a precautionary assessment, with caveats provided on relevant effects.

For an extrapolated biotope map of the study area please see Figure 5.10 in Section 5.2.

Magnitude of Effects

Removal of Sediment

Dredging typically occurs in 2-3 metre wide 'strips' within lanes or 'Active Dredge Zones' that are up to 200 m wide. Benthic species will generally be removed from the dredging strips but are expected to recolonise the area once dredging activities have ceased, as a result of recruitment from nearby undisturbed areas. Removal of sediment is assessed to be of medium-large magnitude as the effect is long term, routine and is a high level change relative to the baseline but is site specific.

View of Sand Loading into the Hopper of a Dredger

Recovery of a Draghead from the Seabed after Dredging showing Hopper Full of Sand

Fine Sediment Plume

The fine sediment plume will cause a local increase in suspended sediments. This may clog respiratory organs or the feeding apparatus of filter and suspension feeders, decrease the sorting efficiency of suspension feeders and decrease the hunting efficiency of visual predators. An increase in turbidity may also result in localised and short-term avoidance reactions of mobile benthic species.

The effect of the seabed fine sediment plume at 2-20 mg l^{-1} has been assessed to have a sub-regional extent, be temporary in duration, have a routine frequency and cause a low change relative to the baseline resulting in a small - medium magnitude effect.

The effect of the seabed fine sediment plume at 20-50 mg l^{-1} has been assessed to have a local extent, be temporary in duration, have a routine frequency and cause a low change relative to the baseline resulting in a small - medium magnitude effect.

The effect of the seabed fine sediment plume at 50-100 mg l^{-1} has been assessed to have a local extent, be temporary in duration, have a routine frequency and cause a medium change relative to the baseline resulting in a medium magnitude effect.

The effect of the seabed fine sediment plume at >100 mg l^{-1} has been assessed to have a site specific extent, be temporary in duration, have a routine frequency and cause a medium change relative to the baseline resulting in a medium magnitude effect.

Sand Deposition

Benthic species are often dependent upon a particular sediment or substrate type on which to live. The plume caused by screening will cause medium and fine sands to be deposited on the seabed mainly within the future 15 year MAREA extraction zone. This may result in deposition of up to 25 cm of sand per dredge but in a very localised area (see Chapter 7) in which sediment removal effects will already have occurred.

Further away from the source of the plume, and predominantly in the direction of net sediment transport, bedforms of sand waves and ripples may form. Bedforms are dynamic and a proportion of the bedforms will move with every tide. Moving away from the source of the plume these bedforms will have more patchy coverage and will decrease in volume. For the purpose of the MAREA, a very conservative estimate of the total footprint of these bedforms has been used. A footprint of up to 2.5 km from the boundary of each future 15 year dredge area has been used to indicate the furthest extent to which patches of bedforms may form as a result of sand dispersion, although 2.5 km is considered to be a very conservative estimate. Recent monitoring has shown that there has been no development of significant bedforms over the monitoring period. For further information on this effect see Chapter 7.

Benthic species within this footprint may be smothered by sand deposition. Species can be partially smothered causing increased survival effort or completely smothered resulting in death. Some species have demonstrated a good ability to escape smothering by burrowing to the surface, or to tolerate smothering for several weeks, whereas for other species smothering will quickly result in death. Further information on the effects of smothering on benthic species can be found in Last *et al* (2010) who studied the survival of six different benthic species to smothering in laboratory conditions with mixed results.

The effect of sand deposition has been assessed to be local in extent, have a short term effect, have a routine frequency and cause a low change relative to the baseline resulting in a small magnitude.

Changes to Sediment Particle Size

A change in the sediment particle size of an area may alter the types of benthic communities that are able to survive within that area. Some benthic communities are more dependent upon a narrow range of sediment particle sizes than others. The potential sensitivity of different biotopes to a change in sediment particle size as a result of dredging has been assessed by MarLIN and the report is provided within Appendix J. This assessment assessed a change in the Folk classification of the sediment for a duration of six months, two and 10 years.

An extremely conservative estimate of changes in sediment particle size up to 4 km from the future 15 year MAREA extraction zones has been used for this assessment. This is the maximum distance at which changes in particle size distribution may be observed. Relatively coarse sand may be moved around as bedload on most tides. It is expected that previous sediment conditions would re-establish within a relatively short timeframe within the dynamic environment of the Humber and Outer Wash region. For further information on this effect see Chapter 7.

A change in sediment particle size has been assessed to be local in extent, short term, routine and to cause a low change relative to the baseline resulting in a small magnitude effect.

Changes to Tidal Currents

Deepening of the seabed in areas of dredging can cause changes in tidal current flows. An increase in tidal flow will mobilise progressively larger sediment particle sizes. A small increase may be beneficial to tube-building species but an increase in sediment particle concentrations in the water column may clog respiratory and feeding organs as well as increasing scour by sand particles. A decrease in tidal flow may decrease the amount of food in the water column that is available to benthic species as well as decreasing the availability of tube-building materials. The change in tidal currents is considered to be long term and routine but a low change to the baseline and local in extent, resulting in a medium magnitude effect.

Changes to Seabed Features

Changes to seabed features may affect the benthic communities that are supported by the feature. These effects have been assessed above and consist of sediment removal, sand deposition and changes to sediment particle size.

Photograph of Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals

Source: PMSL

Table 9.3 below presents a summary of information provided in Annex J regarding the assessment of impacts to biotopes with regard to their sensitivity to the effects of dredging. It should be noted that it is important to read this table in conjunction with Annex J as the sensitivity rankings are assigned with regard to various criteria that are not fully described here. Certain biotopes are assigned a sensitivity range for example, that can be fully understood with reference to the detailed information presented in Annex J.

Table 9.3 Cumulative Impact Assessment of Dredging Effects on Biotopes

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim Medium Value	SS.SCS.ICS.Glap Low Value	SS.SCS.ICS.SLan Low-Medium Value	SS.SCS.CCS.PomB Low-Medium Value	SS.SCS.CCS.MedLumVen Medium Value	SS.SCS.CCS.Pkef Low Value	SS.SSa.IFiSa.IMoSa Low Value	SS.SSa.IFiSa.NcirBat Low-Medium Value	SS.SSa.iFiSa.TbAmPo Medium Value
Removal of sediment - Medium-Large Magnitude (see Chapter 7)	4.4% of biotope within the MAREA 0.2 km^2 of 5.2 km^2	18.0% of biotope within the MAREA 14.6 km^2 of 81.5 km^2	18.0% of biotope within the MAREA 5.7 km^2 of 31.6 km^2	10.9% of biotope within the MAREA 30.6 km^2 of 281.5 km^2	No Interaction	23.0% of biotope within the MAREA 11.0 km^2 of 47.0 km^2	5.4% of biotope within the MAREA 2.7 km^2 of 50.0 km^2	3.0% of biotope within the MAREA 7.4 km^2 of 246.6 km^2	2.2% of biotope within the MAREA 4.5 km^2 of 203.4 km^2
	• Found in areas of high physical disturbance • During storms the uppermost layer of sand may be removed • Loss and/or displacement of individuals • Medium tolerance.	• Found in areas of high physical disturbance • During storms the uppermost layer of sand may be removed • Loss and/or displacement of individuals • Medium tolerance.	• Characteristic species are predominantly infaunal and tube-forming epifauna and would be removed from substratum • Low tolerance.	• Dominated by permanently attached epifauna • Loss and/or displacement • Low tolerance.	• Dredged furrows would remove entire infauna and sessile epifauna simultaneously • Low tolerance.	• Characterising species are tubicolous polychaetes with limited mobility found on or near the surface. • Loss and/or displacement • Medium tolerance.	• Found in areas of high physical disturbance • During storms the uppermost layer of sand may be removed • Loss and/or displacement of individuals • Medium tolerance.	• Found in areas of high physical disturbance • During storms the uppermost layer of sand may be removed • Loss and/or displacement of individuals • Medium tolerance.	• Most species are infaunal • Loss and/or displacement • Low tolerance.
	High Recoverability	High Recoverability	High Recoverability	Very High Recoverability	Medium Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability
	Low Sensitivity	Low Sensitivity	Medium Sensitivity	Low Sensitivity	Medium Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Medium Sensitivity
	Minor Significance	Minor Significance	Minor-Moderate Significance	Minor Significance	No Interaction	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Fine sediment plume/ elevated turbidity - Small-Medium Magnitude (see Chapter 7)	17.3% of biotope within the MAREA 0.9 km^2 of 5.2 km^2	31.4% of biotope within the MAREA 25.6 km^2 of 81.5 km^2	20.8% of biotope within the MAREA 6.6 km^2 of 31.6 km^2	27.6% of biotope within the MAREA 77.6 km^2 of 281.5 km^2	1.9% of biotope within the MAREA 0.7 km^2 of 35.0 km^2	47.6% of biotope within the MAREA 22.6 km^2 of 47.0 km^2	14.3% of biotope within the MAREA 7.1 km^2 of 50.0 km^2	5.0% of biotope within the MAREA 12.4 km^2 of 246.6 km^2	8.7% of biotope within the MAREA 17.6 km^2 of 203.4 km^2
	• Elevated concentrations of sediment normal • Infaunal therefore protected from scour • Tolerant.	• Elevated concentrations of sediment normal • Infaunal therefore protected from scour • Tolerant.	• Filter feeders will likely benefit • Biotope can occur in estuarine conditions where it is likely to experience v. high sediment loads • Tolerant.	• Recorded in areas of high sediment load and in areas where sediment is likely to settle • May temporarily stop feeding • High tolerance.	• Could clog feeding apparatus • In the short term species are likely tolerant • High tolerance.	• Require sand grains to construct tubes • May clog feeding apparatus • Tolerant.	• Elevated concentrations of sediment normal • Infaunal therefore protected from scour • Tolerant.	• Elevated concentrations of sediment normal • Infaunal therefore protected from scour • Tolerant.	• May affect suspension feeding species by clogging • Growth would quickly return when suspended sediment returns to normal • High tolerance.
	Not Relevant	Not Relevant	Not Relevant	Immediate Recovery	Very High Recoverability	Not Relevant	Not Relevant	Not Relevant	Immediate Recoverability

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim	SS.SCS.ICS.Glap	SS.SCS.ICS.SLan	SS.SCS.CCS.PomB	SS.SCS.CCS.MedLumVen	SS.SCS.CCS.Pkef	SS.SSa.IFiSa.IMoSa	SS.SSa.IFiSa.NcirBat	SS.SSa.iFiSa.TbAmPo
	Medium Value	Low Value	Low-Medium Value	Low-Medium Value	Medium Value	Low Value	Low Value	Low-Medium Value	Medium Value
	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive	Very Low Sensitivity	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive
	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
Sand deposition [a] - Small Magnitude (see Chapter 7)	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Small degree of interaction	Large degree of interaction	Large degree of interaction	Small degree of interaction	Small degree of interaction
	• Suspension and re-deposition 'normal environment' for biotope • Thick sediment may smother some epibenthic species • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition.	• Suspension and re-deposition 'normal environment' for biotope • Intermediate intolerance • Sediment likely to re-suspended and redistributed • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition.	• Sudden increase likely to smother sand worm • Epifauna unable to escape smothering, shallow burrowers likely to escape • High energy environments therefore sediment likely to be removed quickly • Low - Medium tolerance.	• Epifauna likely to be intolerant of smothering • Occurs in high energy environment of sediment likely to removed quickly • Low tolerance.	• Smothering will result in temporary cessation of feeding and respiration • Sessile epifauna unable to relocate following smothering • Medium-High tolerance.	• Suspension and re-deposition 'normal' for biotope • May interrupt feeding • Tolerant to low levels of sand deposition • Medium tolerance of high sand deposition.	• Suspension and re-deposition 'normal environment' for biotope • Occur in areas of sand • Although infauna may be lost there are no characteristic species to define loss of the biotope • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition.	• Suspension and re-deposition 'normal environment' for biotope • Occur in areas of sand • Although infauna may be lost there are no characteristic species to define loss of the biotope • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition.	• 5cm would prevent suspension feeding • Infauna would be able to return to preferred depth • Energetic costs to species required to relocate • Medium tolerance.
	High Recoverability	High Recoverability	High Recoverability	Very High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High-Very High Recoverability
	Not Sensitive-Low Sensitivity	Not Sensitive-Low Sensitivity	Low - Medium Sensitivity	Low Sensitivity	Low Sensitivity	Not Sensitive-Low Sensitivity	Not Sensitive-Low Sensitivity	Not Sensitive-Low Sensitivity	Low Sensitivity
	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Changes to sediment particle size [a] - Small Magnitude (see Chapter 7)	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Large degree of interaction	Large degree of interaction	Medium degree of interaction	Medium degree of interaction
	• Biotopes tolerant to a range of sediment sizes • Storms may change sediment anyway • Tolerant to changes in sediment type.	• Biotopes tolerant to a range of sediment sizes • Storms may change sediment anyway • Tolerant to changes in sediment type.	• A 6 month change will reduce the abundance of particular species, especially Lanice conchilega. • Although species will survive, long term change in sediment will change species composition and therefore biotope will be lost • Low-Medium tolerance.	• Fining of sediment will reduce availability of suitable habitat • Likely to result in loss or replacement • Low-Medium tolerance.	• Change in sediment likely to form unfavourable conditions • May change food availability • Low-High tolerance.	• Can also be found on non-gravelly areas • Tolerant	• Biotopes tolerant to a range of sediment sizes • Storms may change sediment anyway • Tolerant to changes in sediment type.	• Biotopes tolerant to a range of sediment sizes • Storms may change sediment anyway • Tolerant to changes in sediment type.	• 6 month change likely to result in reduced abundance • Longer term change will change community and cause loss of biotope • Low-High tolerance.

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim	SS.SCS.ICS.Glap	SS.SCS.ICS.SLan	SS.SCS.CCS.PomB	SS.SCS.CCS.MedLumVen	SS.SCS.CCS.Pkef	SS.SSa.IFiSa.IMoSa	SS.SSa.IFiSa.NcirBat	SS.SSa.iFiSa.Tb AmPo
	Medium Value	Low Value	Low-Medium Value	Low-Medium Value	Medium Value	Low Value	Low Value	Low-Medium Value	Medium Value
	Not Relevant	Not Relevant	High Recoverability	Medium-Very High Recoverability	Medium-Very High Recoverability	Not Relevant	Not Relevant	Not Relevant	Low-Very High Recoverability
	Not Sensitive	Not Sensitive	Low - Medium Sensitivity	Low-Medium Sensitivity	Very Low - Medium Sensitivity	Not Sensitive	Not Sensitive	Not Sensitive	Very Low-High Sensitivity
	Not Significant	Not Significant	Minor Significance	Minor Significance	Minor Significance	Not Significant	Not Significant	Not Significant	Minor-Moderate Significance
Changes to tidal currents - Medium Magnitude (see Chapter 7)	0.1% of biotope within the MAREA 0.01 km^2 of 5.2 km^2	1.9% of biotope within the MAREA 1.6 km^2 of 81.5 km^2	18.2% of biotope within the MAREA (0.6%of the biotope interaction with an increase in tidal currents & 17.6% of the biotope with a decrease in tidal currents) 5.8 km^2 of 31.6 km^2	1.0% of biotope within the MAREA 2.8 km^2 of 281.5 km^2	8.3% of biotope within the MAREA 2.9 km^2 of 35.0 km^2	6.3% of biotope within the MAREA 3.0 km^2 of 47.4 km^2	1.2% of biotope within the MAREA 0.6 km^2 of 50.0 km^2	3.1% of biotope within the MAREA 7.5 km^2 of 246.6 km^2	0.6% of biotope within the MAREA 1.2 km^2 of 203.4 km^2
	• A decrease in tidal currents may enhance the survival of more sedentary forms of polychaete and large deposit feeders may move in. • However, characteristic species are likely to remain • Medium tolerance.	• Disturbed but has narrowest preference range for flow • Medium tolerance	• Change in flow rate likely to result loss of biotope by changing the sediment composition • Low tolerance.	• In exposed areas may be significant • Strengthening or weakening of flow may encourage colonisation of more suitable biotopes • Low tolerance.	• An increase in tidal currents is likely to change the community to one dominated by suspension feeders • A decrease in tidal currents may cause clogging of feeding and respiration structures of venerid bivalves. • Low tolerance.	• Strong current may break up soft mucous tubes exposing fauna • Low tolerance.	• An increase in tidal currents may result in an impoverished community. • Medium tolerance.	• Preference for weak to very weak flow • An increase in tidal currents is likely to result is the loss of characterising species • Polychaetes are less likely to be affected. • Medium tolerance.	• Change of flow would change sediment characteristics in which the biotope occurs, therefore shifting the community and losing the biotope • Low tolerance
	High Recoverability	High Recoverability	High Recoverability	Very High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability
	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Low Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity
	Not Significant	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Not Significant
Changes to sediment transport rates [b] - Negligible (see Chapter 7)	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
	• Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Medium tolerance to changes in tidal currents.	• Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Medium tolerance to changes in tidal currents.	• Low - Medium tolerance to sand deposition • Low tolerance to changes in tidal currents.	• Low tolerance to sand deposition • Low tolerance to changes in tidal currents.	• Medium-High tolerance to sand deposition • Low tolerance to changes in tidal currents.	• Tolerant to low levels of sand deposition • Medium tolerance of high sand deposition. • Low tolerance to changes in tidal currents.	• Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Medium tolerance to changes in tidal currents.	• Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Medium tolerance to changes in tidal currents.	• Medium tolerance to sand deposition • Low tolerance to changes in tidal currents.
	High Recoverability	High Recoverability	High Recoverability	Very High	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High-Very High Recoverability

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim	SS.SCS.ICS.Glap	SS.SCS.ICS.SLan	SS.SCS.CCS.PomB	SS.SCS.CCS.MedLumVen	SS.SCS.CCS.Pkef	SS.SSa.IFiSa.IMoSa	SS.SSa.IFiSa.NcirBat	SS.SSa.iFiSa.TbAmPo
	Medium Value	Low Value	Low-Medium Value	Low-Medium Value	Medium Value	Low Value	Low Value	Low-Medium Value	Medium Value
	Low Sensitivity	Low Sensitivity	Medium Sensitivity	Medium Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Medium Sensitivity
	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features [b c] - Small Magnitude (see Chapter 7)	No Interaction	19.6% of biotope within the MAREA 16.0 km^2 of 81.5 km^2	No Interaction	4.4% of biotope within the MAREA 12.3 km^2 of 281.5 km^2	No Interaction	No Interaction	25.7% of biotope within the MAREA 12.8 km^2 of 50.0 km^2	18.2% of biotope within the MAREA 44.9 km^2 of 246.6 km^2	0.3% of biotope within the MAREA 0.6 km^2 of 203.4 km^2
	• Medium tolerance to sediment removal • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Tolerant to changes in sediment type.	• Medium tolerance to sediment removal • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Tolerant to changes in sediment type.	• Low tolerance of sediment removal • Low - Medium tolerance to sand deposition • Low-Medium tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • Low tolerance to sand deposition • Low-Medium tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • Medium-High tolerance to sand deposition • Low-High tolerance to changes in sediment particle size.	• Medium tolerance to sediment removal • Tolerant to low levels of sand deposition • Medium tolerance of high sand deposition. • Tolerant to changes in sediment type.	• Medium tolerance to sediment removal • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Tolerant to changes in sediment type.	• Medium tolerance to sediment removal • Tolerant of low levels of sand deposition • Medium tolerance of high sand deposition • Tolerant to changes in sediment type.	• Low tolerance to sediment removal • Medium tolerance to sand deposition • Low-High tolerance to change in sediment type
	High Recoverability.	High Recoverability.	High Recoverability.	Very High Recoverability (Medium-Very High for Changes to Sediment Particle Size).	High Recoverability (Medium-Very High for Changes to Sediment Particle Size).	High Recoverability.	High Recoverability.	High Recoverability	High-Very High Recoverability (Low-Very High for Changes to Sediment Particle Size)
	Low Sensitivity	Low Sensitivity	Medium Sensitivity	Medium Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity
	No Interaction	Not Significant	No Interaction	Minor Significance	No Interaction	No Interaction	Not Significant	Minor Significance	Not Significant

a The effects of sand deposition and changes to sediment particle size cannot be clearly defined geospatially and therefore the exact percentage of overlap with biotopes cannot be calculated. Instead, expert judgement has been applied to determine the likely degree of interaction scored using the ranking of Small, Medium and Large degree of interaction.
b This effect was not considered within the biotope sensitivity report. However, for *Changes to Sediment Transport Rates* a change in sediment transport may increase scour and accretion/ deposition.
The effects of scour are considering within the *Change in Tidal Currents* effect and the effects of accretion primarily result in smothering which is considered within the *Sand Deposition*. *Changes to Seabed Features* may affect the benthic communities that are supported by the sand bank feature. This change may have the following effects which have already been considered within this table: *Sediment Removal*, *Sand Deposition* and *Changes to Sediment Particle Size*.
c The changes to seabed features effect does not include changes to overfalls as the characterising biotopes of overfalls have already been assessed separately under the individual effects of dredging.

Receptor	Sensitive Receptor SS.SSa.IMuSa.FfabMag	SS.SSa.CFiSa.ApriBatPo	SS.SSa.CMuSa.AalbNuc	SS.SBR.PoR.SspiMx	SS.SCS.CCS.Blan (SS.SCS.CCS Complex)	SS.SCS.CCS.Nrrix (SS.SCS.CCS Complex)	SS.SSa.IFiSa.ScupHyd (SS.SSa.IFiSa Complex)
	Medium Value	Low-Medium Value	Low-Medium Value	High Value	Medium Value	Medium-High Value	Medium Value
Removal of sediment - Medium-large Magnitude (see Chapter 7)	9.9% of biotope within the MAREA 14.4 km^2 of 146.6 km^2	No Interaction	No Interaction	3.2% of biotope within the MAREA 40.6 km^2 of 1274.9 km^2	0.3% of biotope within the MAREA 0.2 km^2 of 84.9 km^2	0.3% of biotope within the MAREA 0.2 km^2 of 84.9 km^2	No Interaction
	• Most species infauna, furrows will remove entire populations • Epifauna may be able to escape • Low tolerance	• Furrows would remove entire populations of infauna and sessile epifauna • Low tolerance	• Most species infauna, furrows will remove entire populations • Low tolerance	• Loss and/or displacement • Reefs particularly affected by dredging • Low tolerance	• Infauna will be removed with substratum • Mobile epifauna may be able to avoid pressure • Low tolerance	• Most species infauna, and are likely to be highly intolerant of substratum loss • Low tolerance	• Removal of substratum will result in removal of large proportion of sessile organisms • Low tolerance
	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability
	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity
	Minor Significance	No Interaction	No Interaction	Moderate Significance	Not Significant	Not Significant	No Interaction
Fine sediment plume/ elevated turbidity - Small-Medium Magnitude (see Chapter 7)	27.5% of biotope within the MAREA 40.4 km^2 of 146.9 km^2	26.1% of biotope within the MAREA 0.6 km^2 of 2.1 km^2	No Interaction	12.0% of biotope within the MAREA 153.5 km^2 of 1274.9 km^2	14.5% of biotope within the MAREA 12.3 km^2 of 84.9 km^2	14.5% of biotope within the MAREA 12.3 km^2 of 84.9 km^2	No Interaction
	• Risk of clogging feeding apparatus • May lead to cessation of feeding or increased food supply • High Tolerance	• Better food supply for filter feeders switching between deposit and suspension • Increased suspended sediment has potential to affect feeding, however, unlikely to cause mortality • High tolerance	• No mortality of suspension feeders likely • Potential to enhance food supply for deposit feeders • High tolerance	• Found in highly turbid areas • Could facilitate tube construction • Could clog feeding apparatus in the short term • High tolerance	• Suspension feeders likely to benefit from food availability • May become clogged with excessive sediment • Infauna unlikely to be perturbed • High tolerance	• Most are burrowing infauna and not affected by an increase in suspended sediment. • Some suspension feeders may benefit if the suspended material contains a significant proportion of organic matter. • High tolerance	• Biotope tolerant to periodic submergence • May temporarily stop feeding but is unlikely to result in loss of individuals • High tolerance
	Immediate Recovery	Medium Recoverability	High Recoverability	Medium Recoverability	Very High Recoverability	High Recoverability	Very High Recoverability
	Not Sensitive	Not Sensitive	Not Sensitive	Not Sensitive	Very Low Sensitivity	Low Sensitivity	Very Low Sensitivity
	Not Significant	Not Significant	Not Significant	Not Significant	Minor Significance	Minor Significance	No Interaction
Sand deposition [a] - Small Magnitude (see Chapter 7)	Medium degree of interaction	Medium degree of interaction	No Interaction	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	No Interaction
	• Majority of the species are infaunal • Shallow burrowing siphonate suspension feeders are typically able to escape smothering • Medium tolerance	• Infauna species able to escape smothering • Unlikely to cause mortality • High tolerance to high levels of sand deposition in the immediate vicinity of the dredger • Tolerant of low levels of sand deposition up to 2.5 km from the dredger in the direction of net sediment transport	• Likely tolerant of temporary smothering • High tolerance	• Smothering unlikely to affect biotope for long • Some epifauna may be lost but reef or crust will likely remain • High tolerance to low levels of sand deposition • Medium tolerance to high levels of sand deposition	• Sudden increase likely to smother sand worm • Epifauna unable to escape smothering, shallow burrowers likely to escape • High energy environments therefore sediment likely removed quickly • Medium - High tolerance	• Neopentadactyla mixta spend much of the winter buried up to 60 cm in aerobic sediment. Lanice conchilega builds tubes that rise several centimetres above the sediment surface and can adapt to increased sedimentation by increasing its tube height. • High tolerance of low levels of sand deposition • Medium tolerance of high levels of sand deposition.	• Characteristic of areas subject to scour and siltation and most species are tolerant of periodic smothering • Smothering by ≥5 cm may result in loss of small hydroid colonies • Medium-High tolerance

Receptor	Sensitive Receptor						
	SS.SSa.IMuSa.FfabMag	SS.SSa.CFiSa.ApriBatPo	SS.SSa.CMuSa.AalbNuc	SS.SBR.PoR.SspiMx	SS.SCS.CCS.Blan (SS.SCS.CCS Complex)	SS.SCS.CCS.Nrrix (SS.SCS.CCS Complex)	SS.SSa.IFiSa.ScupHyd (SS.SSa.IFiSa Complex)
	Medium Value	Low-Medium Value	Low-Medium Value	High Value	Medium Value	Medium-High Value	Medium Value
	High Recoverability	Very High Recoverability	Very High Recoverability	High-Very High Recoverability	High Recoverability	High Recoverability	High-Very High Recoverability
	Low Sensitivity	Not Sensitive/ Very Low Sensitivity	Very Low Sensitivity	Very Low - Low Sensitivity	Low Sensitivity	Low Sensitivity	Very Low-Low Sensitivity
	Minor Significance	Not Significant	No Interaction	Minor Significance	Minor Significance	Minor Significance	No Interaction
Changes to sediment particle size [a] - Small Magnitude (see Chapter 7)	Large degree of interaction	Medium degree of interaction	No Interaction	Medium degree of interaction	Medium degree of interaction	Medium degree of interaction	Large degree of interaction
	• Characteristic of muddy sands • Change in sediment type in the long term would replace this biotope with another community • Shorter term change may temporarily reduce the abundance of some species • Low-High tolerance	• Change in sediment type could result in unsuitability for burrowing deposit feeders • 6 month change will probably result in reduce abundance of some species temporarily • Low - High Tolerance	• Change in sediment type could result in unsuitability for burrowing deposit feeders • 6 month change will probably result in reduce abundance of some species temporarily • Low - High Tolerance	• Not characteristic of one sediment type • Change unlikely to be detrimental • Tolerant of changes in sediment particle size	• Short term change will result in loss of abundance of some characteristic species • Longer term change will result in loss of biotope • Low-High tolerance	• An increase in the mud component to the sediment is likely to block interstices, reduce aeration and result in a drop in the abundance of Neopentadactyla mixta. • A change of only six months may result in a loss of abundance in characterising species. • Longer term changes would result in a loss of the biotope. • Low - Medium Tolerance	• Biotope associated with varied sediment type • A change in sediment for 6 months will likely reduce abundance of attached epifauna • Long term change likely to change community and cause loss of biotope • Low-Medium tolerance
	Medium-Very High Recoverability	Low-Very High Recoverability (High Recoverability)	Low-Very High Recoverability (High Recoverability)	Not Relevant	Medium-Very High Recoverability	Low-High Recoverability (Medium Recoverability)	Low-High Recoverability
	Very Low - Medium Sensitivity	Very Low - High Sensitivity (Medium Sensitivity)	Very Low - High Sensitivity (Medium Sensitivity)	Not Sensitive	Very Low - Medium Sensitivity	Low-High Sensitivity	Low-High Sensitivity
	Minor Significance	Minor Significance	No Interaction	Not Significant	Minor Significance	Minor Significance	Minor Significance
Changes to tidal currents - Medium Magnitude (see Chapter 7)	9.2% of biotope within the MAREA 13.4 km^2 of 146.9 km^2	26.1% of biotope within the MAREA (all from an increase of 2-10% in tidal flow) 0.6 km^2 of 2.1 km^2	No Interaction	0.6% of biotope within the MAREA 8.0 km^2 of 1274.9 km^2	0.9% of biotope within the MAREA 0.8 km^2 of 84.9 km^2	0.9% of biotope within the MAREA 0.8 km^2 of 84.9 km^2	No Interaction
	• Likely to result in increased deposition of fine particles which would alter sediment characteristics • Deposit feeders may dominate over suspension feeders which would alter the structure of the community • Low tolerance.	• Likely to undergo a shift in composition • Community likely to lost and replaced by another • Low tolerance.	• Likely to undergo a shift in composition • Community likely to lost and replaced by another • Low tolerance.	• Strong flow could break tubes and redistributed exposing species to increase predation • Low tolerance.	• Increased flow would winnow away finer particles • Lower flow would increase deposition of finer particles • Either change over the long term will result in loss of biotope • Low tolerance.	• An increase from 'moderately strong' to 'very strong' water flow may interfere with feeding and change sediment characteristics. • Decreased water flow rate would increase deposition of finer deposits which would change the sediment composition and loss of the biotope. • Low tolerance.	• Water movement essential for hydroids • Strong movement may increase drag and scour • Decrease flow will result in increased siltation, however this biotope is characteristic of areas subject to periodic siltation • Medium tolerance.
	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability	High Recoverability
	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity	Low Sensitivity
	Minor Significance	Moderate Significance	No Interaction	Not Significant	Not Significant	Not Significant	No Interaction

Receptor	Sensitive Receptor						
	SS.SSa.IMuSa.FfabMag	SS.SSa.CFiSa.ApriBatPo	SS.SSa.CMuSa.AalbNuc	SS.SBR.PoR.SspiMx	SS.SCS.CCS.Blan (SS.SCS.CCS Complex)	SS.SCS.CCS.Nrrix (SS.SCS.CCS Complex)	SS.SSa.IFiSa.ScupHyd (SS.SSa.IFiSa Complex)
	Medium Value	Low-Medium Value	Low-Medium Value	High Value	Medium Value	Medium-High Value	Medium Value
Changes to sediment transport rates [b] - Negligible (see Chapter 7)	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
	• Medium tolerance to sand deposition • Low tolerance to changes in tidal currents.	• High tolerance to low levels of sand deposition. • Low tolerance to changes in tidal currents.	• High tolerance to sand deposition. • Low tolerance to changes in tidal currents.	• High tolerance to low levels of sand deposition • Medium tolerance to high levels of sand deposition • Low tolerance of changes in tidal currents.	• Medium - High tolerance to sand deposition • Low tolerance to changes in tidal currents.	• High tolerance of low levels of sand deposition • Medium tolerance of high levels of sand deposition. • Low tolerance to changes in tidal currents.	• Medium-High tolerance to sand deposition. • Medium tolerance to changes in tidal currents.
	High Recoverability	High-Very High Recoverability	High-Very High Recoverability	High-Very High Recoverability	High Recoverability	High Recoverability	High-Very High Recoverability
	Medium Sensitivity	Low Sensitivity	Low Sensitivity	Low Sensitivity	Medium Sensitivity	Low Sensitivity	Low Sensitivity
	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features [b c] - Small Magnitude (see Chapter 7)	16.9% 24.8 km^2 of 146.6 km^2	53.6% 1.1 km^2 of 2.1 km^2	No Interaction	0.4% 5.2 km^2 of 1274.9 km^2	No Interaction	No Interaction	No Interaction
	• Low tolerance of sediment removal • Medium tolerance to sand deposition • Low-High tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • High-Very High tolerance of sand deposition. • Low-High tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • High tolerance of sand deposition • Low-High tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • High tolerance to low levels of sand deposition • Medium tolerance to high levels of sand deposition • Tolerant of changes in sediment particle size.	• Low tolerance to sediment removal • Medium - High tolerance to sand deposition • Low-High tolerance to changes in sediment particle size	• Low tolerance to sediment removal • High tolerance of low levels of sand deposition • Medium tolerance of high levels of sand deposition. • Low- Medium tolerance to changes in sediment particle size.	• Low tolerance to sediment removal • Medium-High tolerance to sand deposition • Low-Medium tolerance to changes in sediment particle size.
	High Recoverability (Medium-Very High for Sediment Particle Size)	High Recoverability (Low-Very High for Sediment Particle Size)	High-Very High Recoverability (Low-Very High for Sediment Particle Size)	High - Very High Recoverability	High Recoverability (Medium-Very High for Sediment Particle Size)	High Recoverability (Low-High Recoverability for Sediment Particle Size)	High-Very High (Low-High Recoverability for Sediment Particle Size)
	Medium Sensitivity	Medium Sensitivity	Low Sensitivity	Low Sensitivity	Medium Sensitivity	Medium Sensitivity	Medium Sensitivity
	Minor Significance	Minor Significance	No Interaction	Not Significant	No Interaction	No Interaction	No Interaction

a The effects of sand deposition and changes to sediment particle size cannot be clearly defined geospatially and therefore the exact percentage of overlap with biotopes cannot be calculated. Instead, expert judgement has been applied to determine the likely degree of interaction scored using the ranking of Small, Medium and Large degree of interaction.

b This effect was not considered within the biotope sensitivity report. However, for *Changes to Sediment Transport Rates* a change in sediment transport may increase scour and accretion/ deposition. The effects of scour are considering within the *Change in Tidal Currents* effect and the effects of accretion primarily result in smothering which is considered within the *Sand Deposition*.

Changes to seabed features may affect the benthic communities that are supported by a sand bank feature. This change may have the following effects which have already been considered within this table: *Sediment Removal*, *Sand Deposition* and *Changes to Sediment Particle Size*.

c The changes to seabed features effect does not include changes to overfalls as the characterising biotopes of overfalls have already been assessed separately under the individual effects of dredging.

Conclusion

There were four interactions between the effects of dredging and biotopes that were assessed to be of moderate significance. All the other interactions were assessed to be of minor significance, not significant or for there to be no interaction. The four moderate significance interactions were for removal of sediment to the SS.SCS.ICS.SLan and SS.SBR.PoR.SspiMx biotope communities; changes to sediment particle size to the SS.SSa.iFiSa.TbAmPo (minor-moderate significance); and changes to tidal currents to the SS.SSa.CFiSa.ApriBatPo biotope community. These are precautionary assessments as many of the effects will not have the same magnitude uniformly across their footprint of effect. For example, changes to sediment particle size will be greatest near the zone of active dredging and will decrease moving away from the active dredging zone.

Biotope communities are known to be difficult to assign to areas of seabed as discussed in Section 5.2. As such, it is important that biotope codes are reassigned to survey data at the site specific level where required by the regulators as part of an EIA.

9.2.5 Protected Species and Habitats

Introduction

Protected habitats such as sandbanks support benthic communities that can be described using biotope codes. These habitats are therefore not assessed here as the benthic fauna they support have been assessed in *Section 9.2.4* above.

Removal of Sediment

Dredging typically occurs in 2-3 metre wide 'strips' with varying distances between dredged strips. Benthic species will generally be removed from the dredging strips but are expected to recolonise the area once dredging activities have ceased following recruitment from nearby undisturbed areas. However, the species discussed in this section are often protected for their rarity, fragility or low recoverability rates. Removal of sediment is assessed to be of medium-large magnitude as the effect is long term, routine and is a high level change relative to the baseline but is site specific.

Ross Worm

This section assesses the potential impact to the population of individual Ross worms as well as to *Sabellaria spinulosa* reef formations. Individual *Sabellaria spinulosa* worms are assessed by MarLIN to have a medium sensitivity to sediment removal based on a low tolerance but a high recoverability assessment (Jackson and Hiscock, 2008). The sensitivity of the population of individual worms for this assessment is therefore considered to be medium. Aggregations of worms in the form of a reef are rarer than the individual worms. The effects of dredging on *Sabellaria spinulosa* reef is expected to be greater as reef formations have not been observed to recover as quickly as individual worm populations (up to three year and within several months respectively (Pearce, *et al.*, 2007)). As such, *Sabellaria spinulosa* reef is assessed to be of high sensitivity to sediment removal.

There are no grab stations within the future 15 year MAREA extraction zones where 300 individual worms or more were recorded. 328 stations were recorded with 1-299 individual worms out of a total of 753 stations. As the majority of individual worms were found in the centre of the MAREA study area, and primarily in association with the edges of Silver Pit, the degree of interaction between individual worms and the effect of sediment removal is considered to be medium.

Based on these assessments of the medium-large magnitude of the effect, the high value and medium sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of individual *Sabellaria spinulosa* worms is assessed to be of moderate significance at the regional scale. There is an area of 'high reefiness' that overlaps with 0.12 km^2 of the future 15 year MAREA extraction zone of Area 106/3 and 0.04 km^2 of Area 481/2 (see Figure 9.1). This could lead to mortality of individual worms and loss of reef. The degree of interaction between potential reef and the effect of sediment removal is considered to be small.

A recent report from Net Gain (2011) presents data that suggest that *S. spinulosa* reef may be present in patches throughout the east of Area 107 and all of Area 481/2 (west of Recommended Marine Conservation Zone (rMCZ) NG 4) as well as within Area 106/3 and Area 480 (south west of rMCZ NG 6). However, some of the data are from surveys conducted in 1994 (Holt, 1994). *S. spinulosa* reefs are dynamic and even without anthropogenic disturbance the reef may no longer be present within these areas. These areas have not been deemed to be valuable enough to be protected within a MCZ. A ministerial statement (Defra, 2011b) suggests that as a result of a number of recognised gaps and limitations in the scientific evidence base supporting the MCZ recommendations Defra are commissioning significant additional work to support MCZ designation. This will include an in depth review of the evidence base for all the regional projects' site recommendations and committing additional resources to carrying out seabed and habitat monitoring. Given this, and that the modelling of 'high reefiness' is based upon a large consolidated dataset of benthic survey data, the information presented within the Net Gain report has not been used to add to this assessment.

Based on these assessments of the medium-large magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on *Sabellaria spinulosa* reef is assessed to be of moderate significance at the regional scale. However, in reality, surveys conducted either at the EIA stage or at the pre-dredge stage will identify whether these reefs exist. If reefs are found, their extents will be mapped and an appropriate exclusion zone established in consultation with Natural England and/or the JNCC. Areas 106/3 and 481/2 will need to ensure they have adequately surveyed the area as part of the pre-dredge survey to determine whether reef exists before dredging continues under a renewed licence.

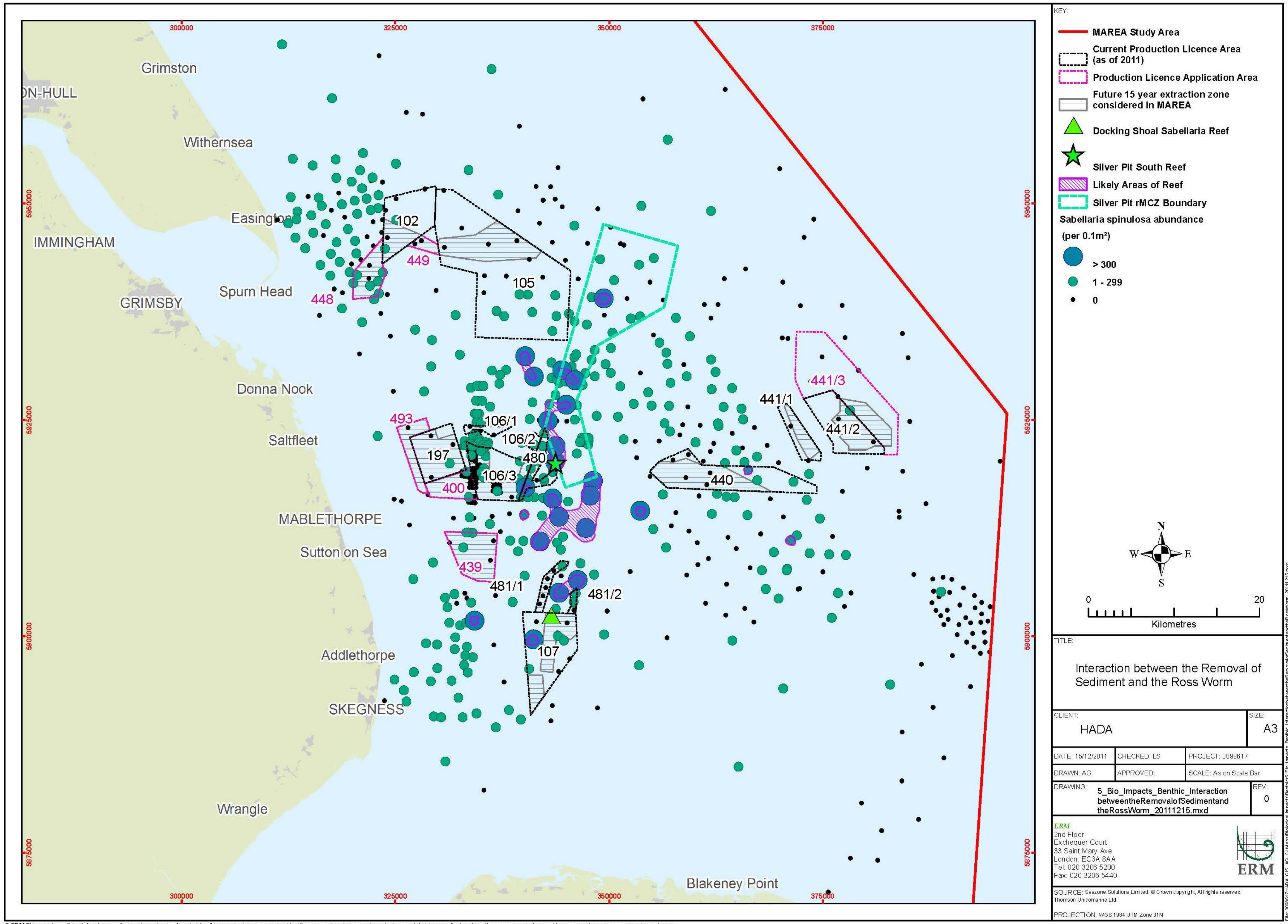
There are two known reefs within the Inner Dowsing, Race Bank and North Ridge SAC: the Silver Pit South reef and the Docking Shoal reef. An assessment of the interactions between dredging and the SAC is provided within Section 9.6. The Docking Shoal reef is located within Area 107 and may therefore be subjected to direct impacts including removal of sediment. If dredging were to occur over the location of the reef then the integrity of the reef would be compromised. The degree of interaction with the effect is assessed to be large.

Based on these assessments of the medium-large magnitude of the effect, the high value and high sensitivity of the receptor and the large degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the known Docking Shoal *Sabellaria spinulosa* reef is assessed to be of high significance. However, as stated above, prior to dredging within Area 107, a survey will be conducted to determine the presence, location and distribution of the reef and an appropriate exclusion zone will be established in consultation with Natural England.

Photograph of Poorly Sorted Gravelly Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals and a Red Anemone

Source: PMSL

Figure 9.1 Interaction between the Removal of Sediment and the Ross Worm

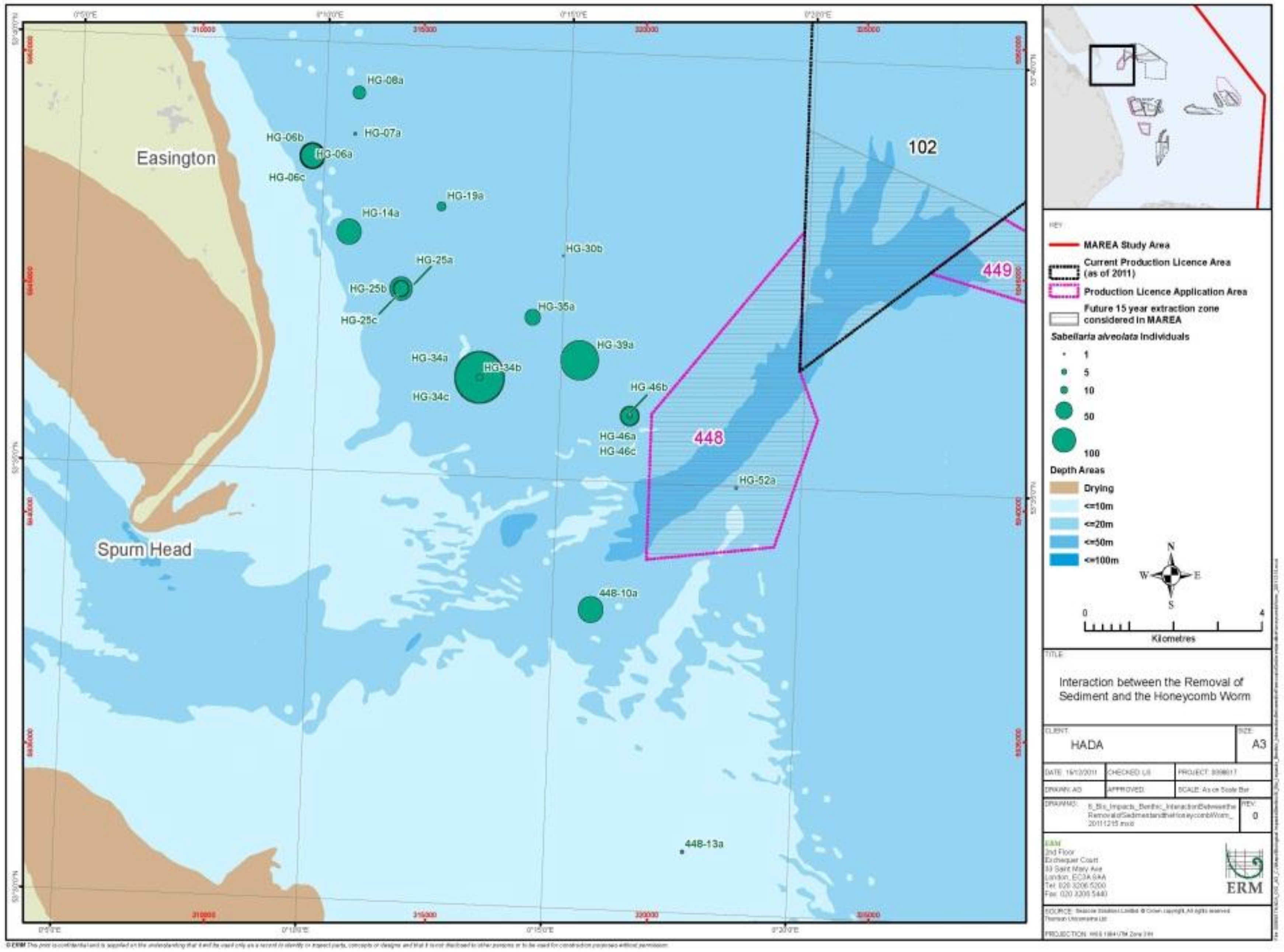


Honeycomb Worm

Individual honeycomb (*Sabellaria alveolata*) worms are assessed by MarLIN to have a medium sensitivity to sediment removal based on a low tolerance and a medium recoverability assessment (Jackson, 2008). The population of individual worms for this assessment is therefore considered to be of medium sensitivity. Like the Ross worm, honeycomb worms may also form biogenic reefs although there were no recorded findings of sufficient density to indicate the presence of reef. Two individual worms were found at a single grab station, which was within Area 448. All of the other findings of honeycomb worm from the consolidated dataset were from stations closer to the coast. This indicates that the honeycomb worm is near the edge of its depth preference and is not likely to be found any deeper; research also suggests this species is not normally found below the upper infralittoral (Jackson, 2008). There is a very small degree of interaction between the effect and the receptor (Figure 9.2).

Based on these assessments of the medium-large magnitude of the effect, the high value and medium sensitivity of the receptor but noting the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of individual honeycomb worms is assessed to be not significant at the regional scale.

Figure 9.2 Interaction between the Removal of Sediment and the Honeycomb Worm



Horse Mussel

The horse mussel, *Modiolus modiolus*, has been assessed by MarLIN (Tyler-Walters, 2007) to have a low tolerance and low recoverability to sediment removal resulting in an overall high sensitivity.

The exact distribution of horse mussel populations within the Humber and Outer Wash MAREA study area is unknown. They are found in partially buried in soft sediments, on coarse grounds or attached to hard substrata in water depths of up to approximately 280 m deep (Tyler-Walters, 2007). This indicates that horse mussels could be found within any of the licence areas. However, this species is rare and was only found in 19 of the 1,013 benthic survey samples primarily from stations within the western central area of the MAREA study area. Based on these survey results the potential degree of interaction between horse mussel and sediment removal is anticipated to be very small.

Based on these assessments of the medium-large magnitude of the effect, the high value and high sensitivity of the receptor but noting the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the horse mussel population is assessed to be of minor significance at the regional scale.

European Edible Sea Urchin

The European sea urchin, *Echinus esculentus*, has been assessed by MarLIN (Tyler-Walters, 2008a) to have a low tolerance to sediment removal as they are slow moving and are unlikely to avoid the passage of the draghead but have high recoverability as they have high fecundity. Consequently they are given an overall assessment of medium sensitivity.

This species was only found in one sample from the REC benthic survey but in general terms the species is considered to be widespread and is not considered to be in decline (see Section 5.2). The survey data suggest that there is only a small population of this species within the MAREA study area and so a small degree of interaction is predicted with the effect.

Based on these assessments of the medium-large magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of European sea urchin is assessed to be of minor significance at the regional scale.

Photograph of Poorly Sorted Gravelly Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals and Sea Urchin

Source: PMSL

The Amphipod *Leptocheirus hirsutimanus*

The distribution of this species within the study area is not known. However, a scientific study on the impacts of dredging on benthos found that *Leptocheirus hirsutimanus* was found within and in the vicinity of aggregate extraction sites, and was in fact more abundant in the vicinity of active trailer dredging (Boyd, *et al.*, 2003). The authors postulate that it may be responding positively to some feature of the disturbance associated with extraction activity. As a result, impacts to this species are not assessed further.

Edwardsiidae

MarLIN has not assessed the sensitivity of any marine Edwardsiidae species. However, this genus of sea anemones lives in tubes in the sand and it is expected that removal of sediment will result in the loss of this sessile species from with the future 15 year MAREA extraction zones. Reproduction involves a planktonic stage which may repopulate affected areas. A low level of tolerance with a recoverability level of medium has been assigned giving an overall sensitivity level of high.

The anemone Edwardsiidae was found in five sample sites from the REC and other licence area specific surveys and was primarily found close to the coast therefore the degree of interaction is assessed to be small.

Based on these assessments of the medium-large magnitude of the effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of Edwardsiidae is assessed to be of minor significance at the regional scale.

Fine Sediment Plume/Elevated Turbidity

For a description of the effect that the sediment plume may have on benthic species please see Section 9.2.4.

Ross Worm

Individual *Sabellaria spinulosa* worms are assessed by MarLIN to be tolerant to increases in suspended sediment and turbidity (Jackson and Hiscock, 2008). Last *et al* (2010) found higher tube growth was achieved under high suspended particle matter (SPM) concentrations when compared to low or no SPM conditions. As such, the potential effect of increased suspended sediment as a result of the fine sediment plume has been assessed to be not significant for both individual worms and *S. spinulosa* reefs.

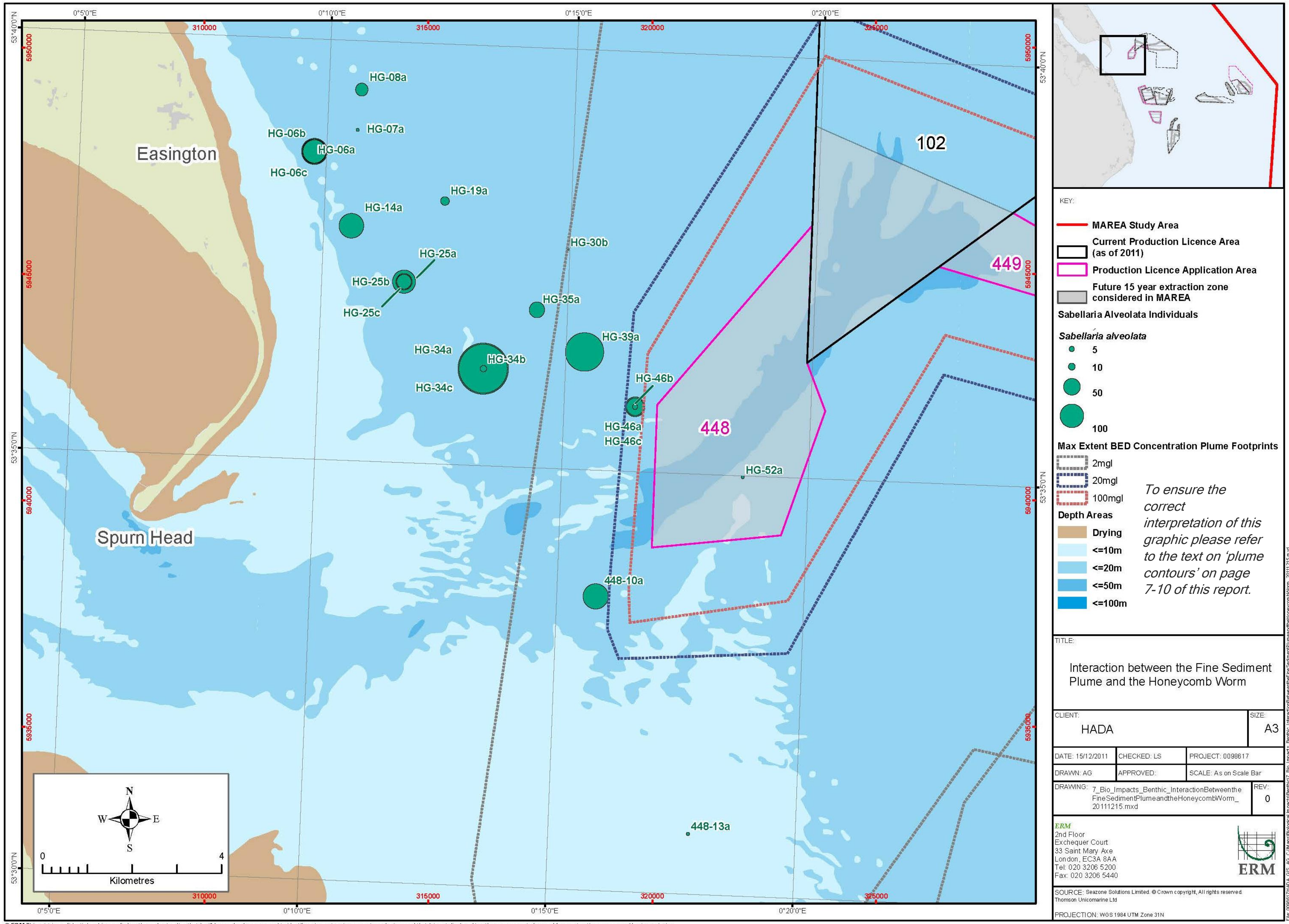
Honeycomb worm

The honeycomb worm, *Sabellaria alveolata*, has been assessed by MarLIN (Jackson, 2008) to have a high tolerance (as suspended sediments are required for tube building) and very high recoverability to an increase in suspended sediments giving an overall sensitivity of very low.

Two individual worms were found at a single grab station, which was within Area 448. It is unlikely that there are reef formations within the study area. Only one sample of honeycomb worm was found from within the >100 $mg.l^{-1}$ seabed sediment plume footprint which was taken from within Area 448 (HG-52a). Three replicates samples containing honeycomb worms (HG-46a, HG-46b and HG-46c) were found within the 20-100 $m.g^{-1}$ sediment footprint. The rest of the honeycomb worm samples were found closer to the coast. There is a very small degree of interaction between the effect and the receptor (Figure 9.3).

Based on these assessments of the medium magnitude of the effect, the high value and very low sensitivity of the receptor and noting the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of individual honeycomb worms is assessed to be not significant at the regional scale.

Figure 9.3 Interaction between the Fine Sediment Plume and the Honeycomb Worm



European Edible Sea Urchin

The European sea urchin, *Echinus esculentus*, has been assessed by MarLIN (Tyler-Walters, 2008a) to have a high tolerance as previous research (Comely and Ansell, 1988) and (Morre, 1977)) indicates they are unaffected by turbid conditions and very high recoverability to increased suspended sediments with an overall sensitivity of very low. This species was only found in one sample from the REC benthic survey. This species is considered to be widespread but is not in decline (see Section 5.2). It seems likely that there is only a small population of this species within the MAREA study area and so a small degree of interaction is predicted with the effect.

Based on these assessments of the medium magnitude of the effect, the high value but very low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on the population of European sea urchin is assessed to be not significant at the regional scale.

Sand Deposition

The plume caused by screening will cause medium and fine sands to be deposited on the seabed mainly within the future 15 year MAREA extraction zone. This deposition of primarily sand components of the sediment will mostly be deposited within the future 15 year MAREA extraction zones. This may result in deposition of up to 25 cm of sand per dredge but in a very localised area (see Chapter 7).

Further away from the source of the plume, and predominantly in the direction of net sediment transport, bedforms of sand waves and ripples may form. Bedforms are dynamic and a proportion of the bedforms will move with every tide. Moving away from the source of the plume these bedforms will have more patchy distribution and will decrease in volume. For the purpose of the MAREA, a very conservative estimate of the total footprint of these bedforms has been used. A footprint of up to 2.5 km from the boundary of each future 15 year dredge area has been used to indicate the furthest extent to which patches of bedforms may form as a result of sand dispersion, although 2.5 km is considered to be a very conservative estimate. For further information on this effect see Chapter 7.

Benthic species within this footprint may be smothered by sand deposition. They can be partially smothered causing increased survival effort or completely smothered resulting in death. Some species have demonstrated a good ability to escape smothering by burrowing to the surface, or to tolerate smothering for several weeks, whereas for other species smothering will quickly result in death. Further information on the effects of smothering on benthic species can be found in Last *et al* (2010) who studied the survival of six different benthic species including the blue mussel, *Mytilus edulis*, to smothering in laboratory conditions with mixed results. This study found that blue mussel was relatively tolerant of short term (≤ 32 day) burial events, with less than 15% mortality of all buried specimens.

The effect of sand deposition has been assessed to be local in extent, have a short term effect, have a routine frequency and cause a low change relative to the baseline resulting in a small magnitude effect.

Blue Mussel Beds

The common or blue mussel, *Mytilus edulis*, can form dense beds which qualify as Annex I biogenic reefs (see Section 5.2). There are two areas where blue mussel beds may be present within the MAREA study area: on the western slopes of Silver Pit and within the Cromer Shoals chalk bed area. These two areas are within recommended Marine Conservation Zones (MCZ): NG2 Cromer Shoals Chalk Bed and NG6 Silver Pit (Section 5.6).

Sand deposition may occur up to 2.5 km from the future 15 year MAREA extraction zones. Part of NG6 Silver Pit MCZ is within 2.5 km of the future 15 year dredge Area 480. This is a small amount of the MCZ and constitutes a small degree of interaction. There is no interaction between this effect and NG2 Cromer Shoals Chalk Bed MCZ.

Individual mussels have been assessed by MarLIN (Tyler-Walters, 2008b) to have a medium tolerance, high recoverability and therefore an overall sensitivity of low to smothering as a result of sand deposition as, whilst blue mussels are apparently sedentary, they are able to move some distance to resurface when buried by sand. However a proportion of individuals may not be able to surface. Recovery may occur rapidly through good annual recruitment.

Based on these assessments of the small magnitude of the effect, the high value but low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of smothering on potential mussel beds within NG6 Silver Pit is assessed to be not significant at the regional scale.

Horse Mussel

The effect of sand deposition has been assessed to be local in extent, to have a short term effect, a routine frequency and to cause a low change relative to the baseline resulting in a small magnitude.

The horse mussel, *Modiolus modiolus*, has been assessed by MarLIN (Tyler-Walters, 2007) to have a medium tolerance and low recoverability to smothering resulting in an overall high sensitivity. This is based on statements by Holt *et al*, (1998) that biogenic reef formation involves the build-up of faecal mud, suggesting that adults can move up through the accreting mud to maintain their relative position within the growing mound. However, there are no studies of the accretion rates that horse mussel beds can tolerate. Recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years resulting in an assessment of low recoverability.

The exact distribution of horse mussel populations within the Humber and Outer Wash study area is unknown. They are found partially buried in soft sediments, on coarse grounds or attached to hard substrata in water depths of up to approximately 280 m deep (Tyler-Walters, 2007). This indicates that horse mussels could be found within any of the licence areas. However, this species is not common within this region and was only found in 19 of the 1,013 benthic survey samples primarily from stations within the western central area of the MAREA study area. Based on these survey results the degree of interaction is predicted to be very small.

Based on these assessments of the small magnitude of the effect, the high value and high sensitivity of the receptor but noting the very small degree of interaction between the receptor and the effect, the cumulative impact of smothering on the population of horse mussels is assessed to be of minor significance at the regional scale.

Changes to Sediment Particle Size

An extremely conservative estimate of changes in sediment particle size up to 4 km from the future 15 year MAREA extraction zones has been used for this assessment. This is the maximum distance at which changes in particle size distribution may be observed. However, it must be noted that recent monitoring has shown that there has been no development of significant bedforms over the monitoring period (see Chapter 7). The nature of change within this footprint has not been determined. A change in sediment particle size has been assessed to be local in extent, short term, routine and cause a low change relative to the baseline resulting in a small magnitude.

Ross Worm

The Ross worm, *S. spinulosa*, requires particles of a certain size to build its tubes (usually sand or shell fragments). If the particle sizes change to become unfavourable for tube building it will put a strain on survival of the worm. Based on this, the Ross worm has been assessed to have a medium tolerance and high recoverability to changes in particle size giving a medium sensitivity.

There are areas of 'high reefiness' within the 4 km footprint of a potential change in sediment particle size (see Section 5.2 for discussion on this term). The degree of interaction between potential reef (including the Docking Shoal reef) and the effect of a change in sediment particle size is considered to be medium.

Based on these assessments of the small magnitude of the effect, noting that this is a very conservative estimate, the high value and medium sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of changes in sediment particle size on the potential *Sabellaria spinulosa* reef is assessed to be of minor significance at the regional scale.

There are no other areas of >300 individual worms per grab (0.1 m^2) so the interaction with individual worms is not expected to be much greater than for potential areas of reef. The effect at the regional scale on individual Ross worms is therefore expected to be similar to the effect on potential reef areas.

Honeycomb Worm

Like the Ross worm, the honeycomb worm *S. alveolata*, requires particles of a certain size to build its tubes (usually sand or shell fragments). If the particle sizes change to become unfavourable for tube building it will put a strain on survival of the worm. Based on this, the honeycomb worm has been assessed to have a medium tolerance and high recoverability to changes in particle size giving a medium sensitivity.

Eleven samples from seven benthic survey stations are within the 4 km footprint of a potential change in sediment particle size [(1)]. The rest of the honeycomb worm samples were found closer to the coast. As the majority of benthic survey data used for this assessment has come from aggregate dredging projects, there have not been many samples taken closer to shore. It is expected that a larger population of honeycomb worm exists closer to shore than is apparent from the limited survey results from this area. There is a small degree of interaction between the effect and the individual honeycomb worms. No evidence of *S. alveolata* reefs was detected.

Based on these assessments of the small magnitude of the effect, noting that this is a very conservative estimate, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes in sediment particle size on the population of individual honeycomb worms is assessed to be not significant at the regional scale.

Blue Mussel Beds

As stated above, MarLIN (Tyler-Walters 2008b) does not assess the influence of changes in sediment particle size on different species. However, within the assessment of an increase in water flow rate the following statement was made:

> "*Mytilus edulis can attach and grow on a variety of substrata in a variety of water flow regimes, and an intolerance of low has been reported.*"

(1) These were samples HG-30b, HG-34a, HG-34b, HG-34c, HG-35a, HG-39a, HG-46a, HG-46b, HG-46c, HG-52a and 448-10a.

Photograph of Poorly Sorted Seabed within the MAREA Study Area showing Scale Bar with 10 cm Interval and Examples of Mussel and Anemone

Source:PMSL

Mussels are found from the high intertidal to the shallow subtidal, on rocky shores of open coasts attached to the rock surface and in crevices, and on rocks and piers in sheltered harbours and estuaries. Overall, they have been assessed to have low sensitivity to a change in sediment particle size.

A change in sediment particle size may occur up to 4 km from the future 15 year MAREA extraction zones. Approximately 19.9 km^2 of NG6 Silver Pit MCZ is within 4 km of the future 15 year dredge Area 480. This is approximately 11.8% of the MCZ and is a small degree of interaction.

Based on these assessments of the small magnitude of the effect, the high value but low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of a change in sediment particle sizes on potential mussel beds within NG6 Silver Pit is assessed to be not significant at the regional scale.

Horse Mussel

The exact distribution of horse mussel populations within the Humber and Outer Wash MAREA study area is unknown. They are found partially buried in soft sediments, on coarse grounds or attached to hard substrata in water depths of up to approximately 280 m deep (Tyler-Walters, 2007b). As they are found on a variety of substrate types they are expected to have a low sensitivity to a change in sediment particle size.

Horse mussels could be found within any of the licence areas. However, this species is not common within this region and was only found in 19 of the 1,013 benthic survey samples primarily from stations within the western central area of the MAREA study area. Based on these survey results the degree of interaction is small.

Based on these assessments of the small magnitude of the effect, the high value but low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of a change in sediment particle size on the population of horse mussels is assessed to be Not Significant at the regional scale.

European Edible Sea Urchin

The European sea urchin, *Echinus esculentus*, is found on rocky substrata from the sublittoral to depths of 100 m or more (Tyler-Walters, 2008a). If the rocky areas where this species is found are covered with thick deposits of sand this species is unlikely to be able to remain within the area. As such, this species has been assessed to have a low tolerance but high recoverability to the effect of a change in sediment particle size giving an overall sensitivity of medium.

The European sea urchin was only found in one sample from the REC benthic survey. This species is considered to be widespread but is not in decline (see Section 5.2). It seems likely that there is only a small population of this species within the MAREA study area and so a small degree of interaction is predicted with the effect.

Based on these assessments of the small magnitude of the effect, the high value and medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of smothering on the population of European urchin is assessed to be of minor significance at the regional scale.

Changes to Tidal Currents

Deepening of the seabed in areas of dredging can cause change in tidal current flows. An increase in tidal flow will mobilise larger sediment particle sizes. A small increase may be beneficial to tube-building species but an increase in sediment particle concentrations in the water column may clog respiratory and feeding organs as well as increasing scour by sand particles. A decrease in tidal flow may decrease the amount of food in the water column that is available to benthic species as well as decreasing the availability of tube-building materials. A change in tidal currents is considered to be long term and routine but a low change to the baseline and local in extent resulting in a medium magnitude effect.

Ross Worm

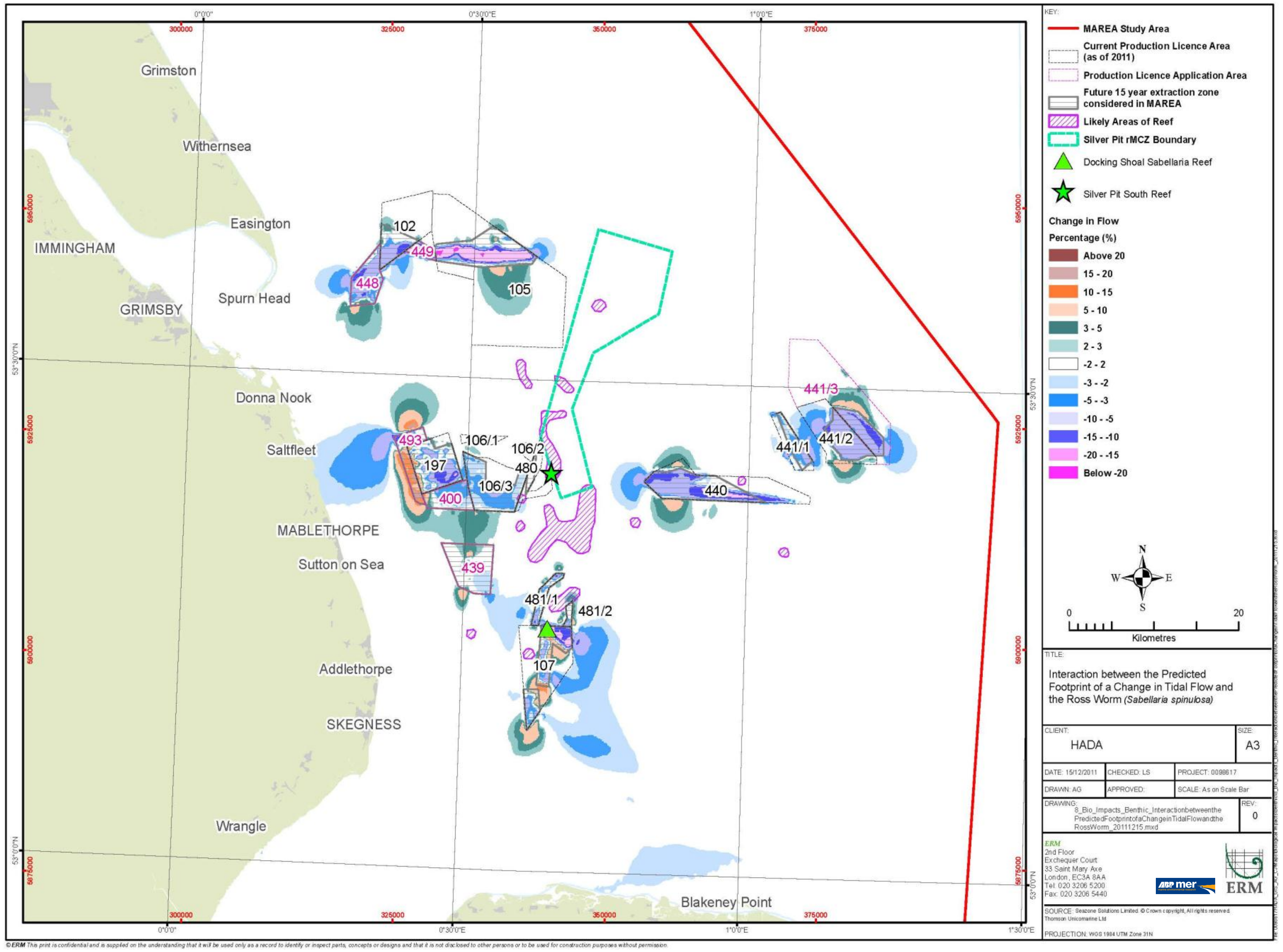
The Ross worm has been assessed by MarLIN (Jackson and Hiscock, 2008) to have a medium tolerance and high recoverability to an increase or decrease in water flow rate giving an overall sensitivity of low as this species occurs in areas with high water flow so an increase in rate is likely to have little effect on attached individuals. However, the Ross worm typically inhabits cobbles and pebbles that are likely to become mobile if water flow rate is increased and therefore result in scour and mortality of a proportion of individuals. A decrease in water flow may reduce the availability of suspended particles, hindering growth and repair and feeding. High levels of recruitment mean that recovery could be quite rapid.

Approximately 1% of the high reefiness area overlaps with a predicted 2-3% decrease in peak flood flow speed on spring tides. This is a decrease of approximately 0.02-0.05 $m.s^{-1}$. Approximately 0.9% of the high reefiness area overlaps with a predicted 3-5% increase in peak flood flow speed on spring tides. This is an increase of approximately 0.02-0.05 $m.s^{-1}$. Both of these changes have a very small degree of interaction with the receptor (Figure 9.4).

Based on these assessments of the medium magnitude of the effect, noting that this is a very conservative estimate, the high value but low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to tidal currents on potential *Sabellaria spinulosa* reef areas is assessed to be not significant at the regional scale.

There are no other areas of >300 individuals worms so the interaction with individual worms is not expected to be much greater than for potential areas of reef. The effect at the regional scale on individual Ross worms is therefore expected to be similar to the effect on potential reef areas.

Figure 9.4 Interaction between the Predicted Footprint of a Change in Tidal Flow and the Ross Worm



Honeycomb Worm

The honeycomb worm, *Sabellaria alveolata*, has been assessed by MarLIN (Jackson, 2008) to have a medium tolerance and high recoverability to an increase in water flow rate giving an overall sensitivity of low. It is worth noting that this species inhabits areas with high water flow so an increase in rate is likely to have little effect. A decrease in water flow may reduce the availability of suspended particles, hindering growth and repair and feeding. Variability in recruitment (dependent on suitable environmental conditions) means that recovery could take a few years.

Two individual worms were found at a single grab station, which was within Area 448. All of the other findings of honeycomb worm from the consolidated dataset were from stations closer to the coast. This indicates that the honeycomb worms that were found near the licence areas are near the edge of this species' depth preference; the species is not likely to be found any deeper and research suggests this species is not normally found below the upper infralittoral (Jackson, 2008). It is unlikely that there are reef formations within the study area.

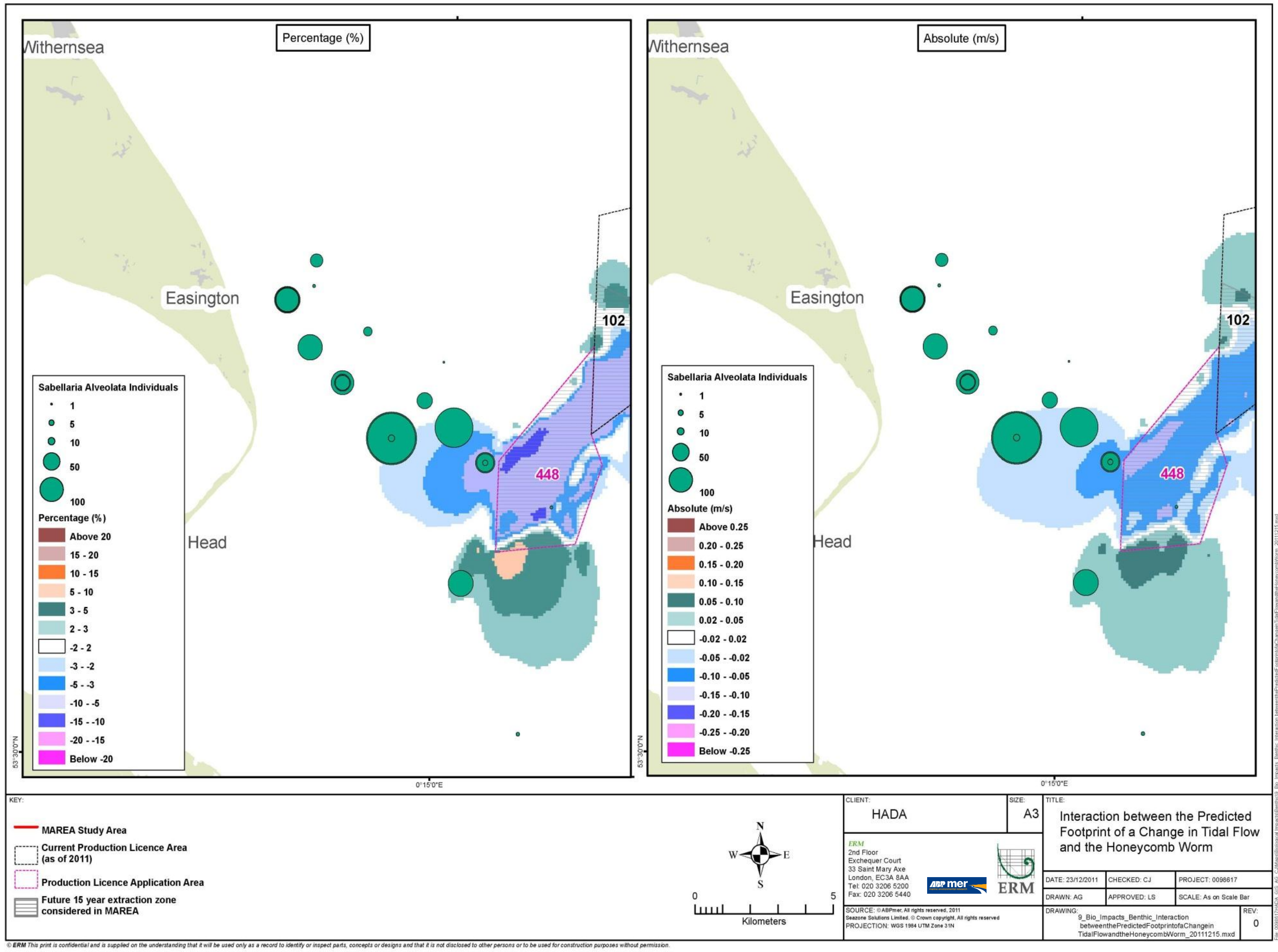
Sabellaria alveolata was found in sample HG-52 which is within the modelled decrease in tidal current of 5-10% with an absolute decrease of 0.02-0.05 $m.s^{-1}$. *S. alveolata* was also found at three replicate stations (HG-46a, HG-46b and HG-46c) which are within the modelled decrease in tidal current of 5-10% with an absolute decrease of 0.05-0.10 $m.s^{-1}$. Sample HG-39a is within the modelled footprint of a 2-3% decrease in tidal current with an absolute decrease of 0.02-0.05 $m.s^{-1}$. Three replicate stations (HG-34a, HG-34b and HG-34c) were not within the percentage change footprint but were within the footprint of an absolute decrease of 0.02-0.05 $m.s^{-1}$.

Sample 448-10a was within the footprint of a 2-3% increase in tidal flow with an absolute change of 0.02-0.05 $m.s^{-1}$.

There is a small degree of interaction between both the increase and decrease in tidal flow and the receptor (Figure 9.5).

Based on these assessments of the medium magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of a change in tidal flow rate on the population of individual honeycomb worms is assessed to be not significant at the regional scale.

Figure 9.5 Interaction between the Predicted Footprint of a Change in Tidal Flow and the Honeycomb Worm



Horse Mussel

The horse mussel, *Modiolus modiolus*, has been assessed by MarLIN (Tyler-Walters, 2007) to have a medium tolerance and low recoverability to an increase or decrease in tidal current flow resulting in an overall sensitivity of high. Horse mussel populations are found in areas of weak to strong tidal streams and are, therefore, probably tolerant of changes in water flow within this range. However, Comely (1978) suggested that areas exposed to strong currents required an increase in byssus [1] production, at energetic cost, and resulted in lower growth rates. Populations in strong tidal streams may be more intolerant of an increase in water flow. A decrease in water flow rate may reduce the supply of organic particulates and phytoplankton on which the horse mussel feeds. Recruitment is sporadic, highly variable and some areas receive little or no recruitment for several years.

The exact distribution of horse mussel populations within the Humber and Outer Wash study area is unknown. They are found partially buried in soft sediments, on coarse grounds or attached to hard substrata in water depths of up to approximately 280 m deep (Tyler-Walters, 2007). This indicates that horse mussels could be found within any of the licence areas. However, this species is rare and was only found in 19 of the 1,013 benthic survey samples primarily from stations within the western central area of the MAREA study area. Based on these survey results the degree of interaction is small.

Based on these assessments of the medium magnitude of the effect, the high value and high sensitivity of the receptor but noting the small degree of interaction between the receptor and the effect, the cumulative impact of a change in tidal currents on the population of horse mussels is assessed to be of minor significance at the regional scale.

European Edible Sea Urchin

The European sea urchin, *Echinus esculentus*, has been assessed by MarLIN (Tyler-Walters, 2008a) to have a high tolerance and very high recoverability to an increase in water flow rate with an overall sensitivity of very low. Whilst the European sea urchin can be displaced by strong wave and current action they only feed normally when in 'good' water flow (Boolootlan, 1966). Sea urchins are adapted to being washed to deeper water by wave action (Lewis and Nicholas, 1979). Therefore, whilst increased water flow may remove the population from the affected area the individuals would probably not be killed in the process and could recolonise the area if returned to pre-impact condition.

The European sea urchin was only found in one sample from the REC benthic survey. This species is considered to be widespread but is not in decline (see Section 5.2). It seems likely that there is only a small population of this species within the MAREA study area and so a small degree of interaction is predicted with the effect.

(1) Byssus threads are fibres that mussels use to attach to hard substrates.

Based on these assessments of the medium magnitude of the effect, the high value but very low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of a change in tidal currents on the population of European urchin is assessed to be not significant at the regional scale.

9.2.6 Commercial Species

Removal of Sediment

Dredging typically occurs in 2-3 metre wide 'strips' within lanes or 'Active Dredge Zones' that are up to 200 m wide. Crabs and lobsters are expected to recolonise the affected areas once dredging activities have ceased following recruitment from nearby undisturbed areas. Removal of sediment is assessed to be of medium-large magnitude as the effect is long term, routine and is a high level change relative to the baseline but is site specific.

Brown Crab and European Lobster

The brown crab (*Cancer pagurus*) and the European lobster (*Hommarus gammarus*) are fished in several areas within the study area including within some of the future 15 year MAREA extraction zones including Area 105, 197, 106/3 and 107 (see Figure 6.20).

Brown crabs have been assessed by MarLIN to have a medium sensitivity to sediment removal based on a medium tolerance and medium recoverability (Neal and Wilson, 2008). Some crabs are expected to be able to avoid the passage of the draghead although it is likely there will be some mortality of a few individuals. The European lobster has not been subject to a sensitivity assessment from MarLIN. However, it is a mobile species like the brown crab and it is expected to have a similar if slightly slower rate of recovery (brown crabs have a high fecundity with approximately 0.25-3 million eggs per spawning (Neal and Wilson, 2008) whereas female European lobsters carry approximately 4,000-40,000 eggs per spawning (Agnalt, 2008)). As such, both the brown crab and European lobster are considered to have a medium sensitivity to sediment removal.

Female brown crabs carry eggs under their abdomen for six to nine months after copulation (Thompson *et al.*, 1995). During this time the 'berried' females do not feed and remain in pits dug in the sediment or under rocks. Therefore berried females are considered to have a low tolerance to sediment removal and an overall sensitivity of high.

Sediment removal will interact with approximately 44.9 km^2 of the shellfish (brown crab and European lobster) fishing grounds. These interactions will occur in the following future 15 year MAREA extraction zones:

- Area 105 - 15.5 km^2;
- Area 197 - 2 km^2;
- Area 106/3 - 5.2 km^2 and 0.2 km^2; and
- all of Area 107- 6.2 km^2 + 15.8 km^2.

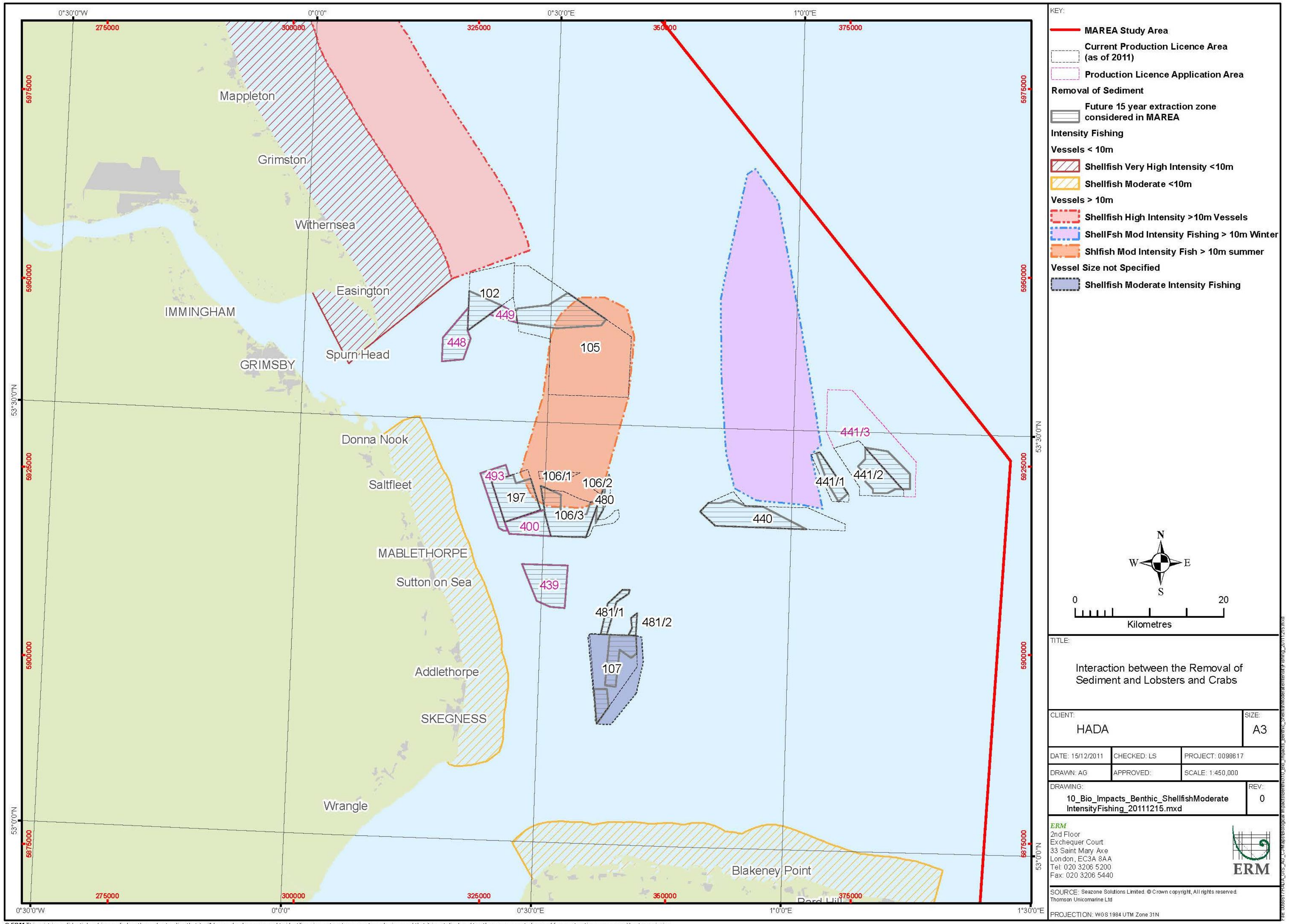
Photograph of Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals and Small Brown Crab

Source: PMSL

None of the <10 m vessel shellfish fishing ground areas will be affected by removal of sediment. The total shellfish fishing area is 2,560 km^2 therefore the effect of sediment removal will interact with approximately 1.8% of the total shellfish fishing grounds within the MAREA study area. This is a small degree of interaction between the effect and the receptor (Figure 9.6).

Based on these assessments of the medium-large magnitude of the effect, the high value and medium sensitivity of the receptor but noting the small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on brown crab and European lobster is assessed to be minor at the regional scale. Berried female brown crabs are more sensitive to sediment removal as they are more sedentary. The cumulative impact of sediment removal on berried female brown crabs is assessed to be of moderate significance at the regional scale.

Figure 9.6 Interaction between the Removal of Sediment and Lobsters and Crabs



Pink Shrimp and Brown Shrimp

Brown shrimp (*Crangon crangon*) are primarily targeted along the coast but are also fished as far offshore as Area 441/1. The high intensity fishing area interacts with the whole of Licence Area 107 and therefore both of the future 15 year MAREA extraction zones within it (15.7 km^2 and 6.2 km^2) and part of Area 481/2 (0.5 km^2). The medium intensity fishing area overlaps with the following future 15 year MAREA extraction zones:

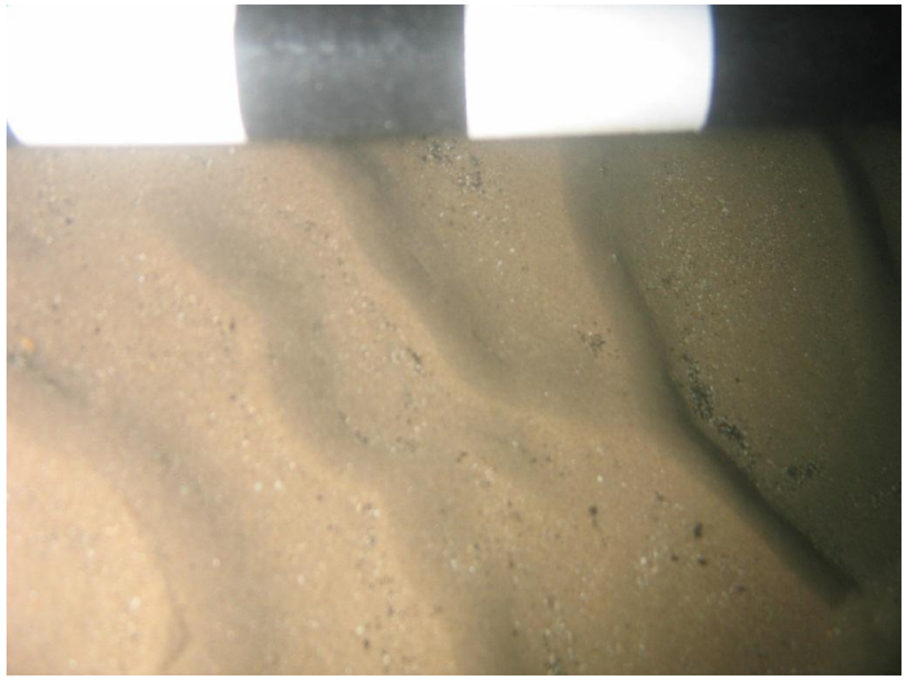
- Area 493 - 12.2 km^2;
- Area 197 - 26.2 km^2;
- Area 400 - 14.3 km^2;
- Area 106/3 - 26.3 km^2;
- Area 480 - 2.4 km^2;
- Area 439 - 26.3 km^2;
- Area 481/1 - 6.1 km^2;
- Area 481/2 - 1.4 km^2;
- Area 440 - 31.3 km^2; and
- Area 441/1- 4.7 km^2.

The low intensity fishing area interacts with 7 km^2 of the future 15 year extraction zones of Area 448, all of Area 102 (11.7 km^2), all of Area 449 (4.2 km^2) and all of Area 105 (33.7 km^2).

The interaction between the PIZ and all of the brown shrimp fishing areas is therefore approximately 230.2 km^2. The total shellfish fishing area is 3,529.4 km^2 so the effect will interact with approximately 6.5% of the total brown shrimp fishing area. This is a small degree of interaction, however, this is for all fishing intensity levels and only approximately 0.64% of the high intensity fishing area (total of 22.56 km^2) will have an interaction with this effect which is a very small degree of interaction.

The locations where pink shrimp (*Pandalus montagui*) are targeted by fishing have not been clearly defined but for the purposes of this assessment are thought to be within the same areas that brown shrimp are targeted. However, it should be noted that in general, brown shrimp are thought to live in shallow waters (0-20 m deep but up to 130 m) on sand or muddy sand (FAO, 2012a) whereas pink shrimp are found in deeper waters (20-1,330 m deep) on clay and mud substrates (FAO, 2012b).

Photograph of Sand Ripples on Well Sorted Fine Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals



Source: PMSL

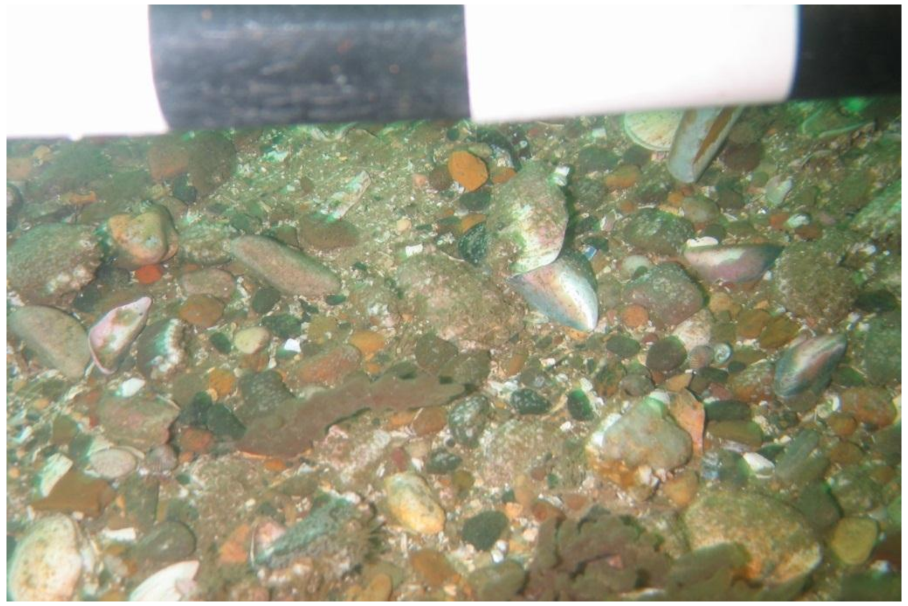
Brown shrimp have been assessed by MarLIN (Neal, 2008) to have a low tolerance to sediment removal as this species buries itself to ambush prey and avoid predation. However, this is combined with a very high recoverability giving an overall sensitivity to sediment removal of low. Removal of the sediment will result in direct mortality of some individuals and may result in increased predation of individuals displaced by dredging activities. The very high recoverability assessment is based on the brown shrimp being a common food item for a wide range of species including crustacea, fish, birds and mammals and therefore at the population level is already adapted to constant high mortality (Neal, 2008). The brown shrimp has rapid growth, early maturity, high fecundity and a prolonged reproductive season, all of which allow populations to recover from mass mortalities very quickly (Neal, 2008). Pink shrimp do not bury themselves (Warren, 1973) and so may have a greater ability to avoid the passage of the draghead, however, as a precautionary approach this species is also assessed to have a low sensitivity to sediment removal.

Based on these assessments of the medium-large magnitude of the effect, the high value and low sensitivity of the receptor but noting the very small degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on brown and pink shrimp is assessed to be of minor significance at the regional scale.

Photograph of Poorly Sorted Fine Sandy Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals and Algae

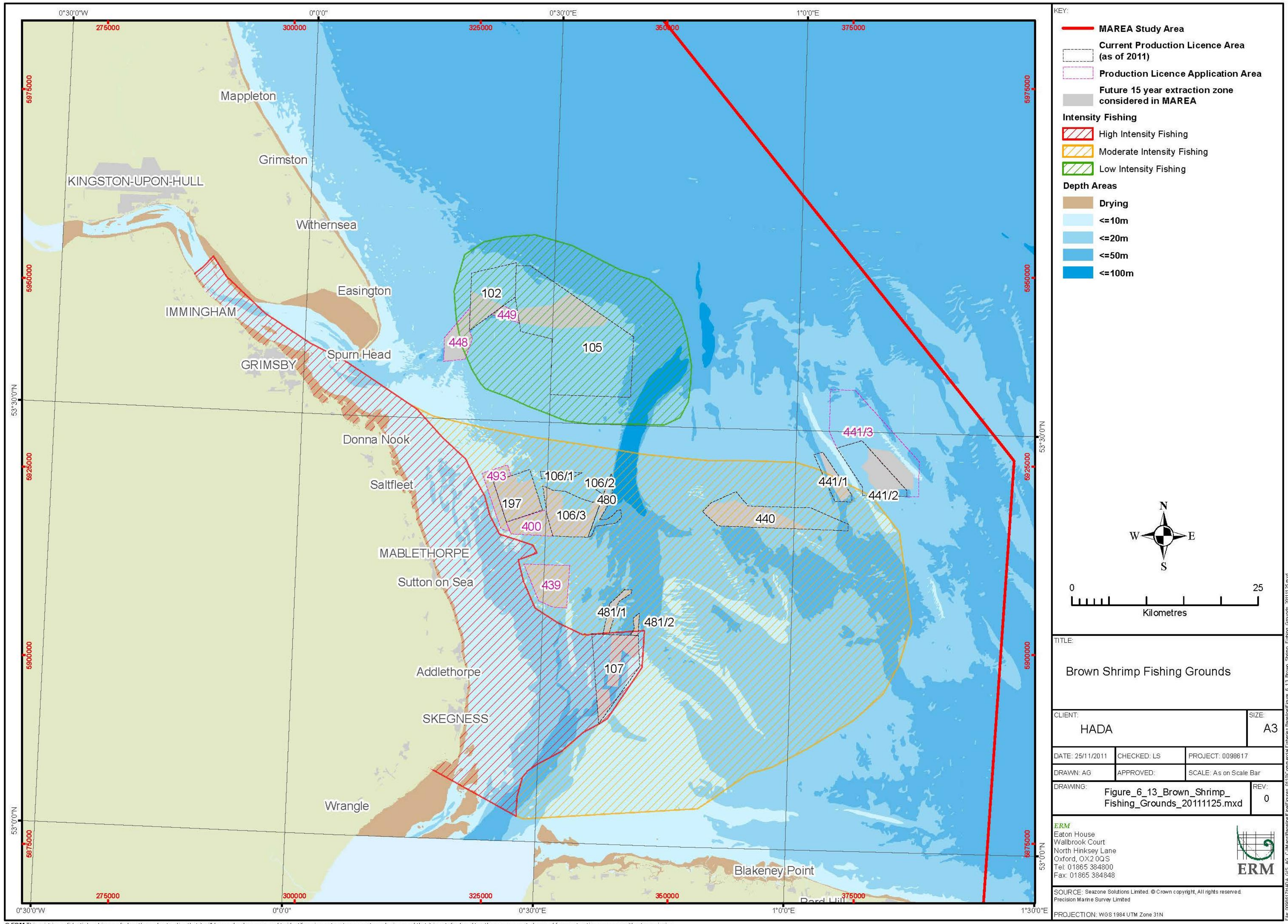
Source: PMSL

Photograph of Poorly Sorted Gravelly Seabed within the MAREA Study Area showing Scale Bar with 10 cm Intervals and Shell Debris



Source: PMSL

Figure 9.7 Interaction between the Removal of Sediment and Brown Shrimp Fishing Grounds



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Sand Deposition

For a description of the effect that sand deposition may have on benthic species please see Section 9.2.4. The effect of sand deposition has been assessed to be local in extent, have a short term effect, have a routine frequency and cause a low change relative to the baseline resulting in a small magnitude.

Brown Crab and European Lobster

The brown crab (*Cancer pagurus*) and the European lobster (*Hommarus gammarus*) are understood to be fished in several areas within the study area including within some of the future 15 year MAREA extraction zones including Area 105, 197, 106/3 and 107 (see Figure 6.20).

Brown crabs have been assessed by MarLIN to have a very low sensitivity to sand deposition based on a high tolerance and very high recoverability (Neal and Wilson 2008). Crabs have been observed to escape burial under silt and migrate away from the area (Neal and Wilson, 2008). The deposition of sand may be more difficult to escape from but for any crabs that happen to be in the path of the dredger, the majority are expected to be able to escape smothering by sand deposition although it is possible that there may be some mortality of a few individuals.

The European lobster has not been subject to a sensitivity assessment by MarLIN. However, it is a mobile species like the brown crab and it is expected to have a similar if slightly slower rate of recovery (brown crabs have a high fecundity with approximately 0.25-3 million eggs per spawning (Neal and Wilson, 2008) whereas female European lobsters carry approximately 4,000-40,000 eggs per spawning (Agnalt, 2008). As such, both the brown crab and European lobster are considered to have a very low sensitivity to sand deposition.

Approximately 198.3 km^2 of shellfish (brown crab and European lobster) fishing grounds lies within 2.5 km of the future 15 year MAREA extraction zones. Approximately 7.75% of the total shellfish (brown crab and European lobster) fishing ground area may be affected by sand deposition. None of the <10 m shellfish fishing ground areas will be affected by sand deposition. This is a medium degree of interaction between the effect and the receptor (Figure 9.7).

Based on these assessments of the small magnitude of the effect, the high value and very low sensitivity of the receptor and the medium degree of interaction between the receptor and the effect, the cumulative impact of sand deposition on brown crab and European lobster is assessed to be of minor significance at the regional scale.

Pink Shrimp and Brown Shrimp

Brown shrimp have been assessed by MarLIN (Neal, 2008) to have a medium tolerance to smothering as a result of sand deposition with a very high recoverability giving an overall sensitivity to sand deposition of low. Pink shrimp do not bury themselves (Warren, 1973) and so may be less able to escape from sediment if they are smothered. As such, this species has been given an overall sensitivity of medium.

Brown shrimp (*Crangon crangon*) are primarily targeted along the coast but are also fished far offshore as Area 441/1. Approximately 837 km^2 of the brown shrimp fishing area is within 2.5 km of the future 15 year MAREA extraction zones. This is approximately 23.7% of the total brown shrimp fishing area. This is a medium degree of interaction between the effect and the receptor. The degree of interaction between this effect and the pink shrimp is expected to be similar.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of brown shrimp, particularly noting their ability to burrow and therefore escape smothering, and the medium degree of interaction between brown shrimp and the effect, the cumulative impact of sand deposition on brown shrimp is assessed to be Not Significant at the regional scale. As pink shrimp are potentially more sensitive to smothering than brown shrimp, the effect of sand deposition on pink shrimp is assessed to be of minor significance at the regional level.

Mussels

Mussels have been assessed by MarLIN (Warren, 1973) (Tyler-Walters, 2008b) to have a medium tolerance to smothering as a result of sand deposition with a high recoverability giving an overall sensitivity of low to sand deposition. This is based on evidence to suggest that mussels are able to move upwards through accumulated sediment but that a proportion will succumb. Whilst the effect of smothering may cause mortality of a few individuals, it will decrease the fitness of all individuals exposed as more energy will be required to clear their siphons. This may have an effect on the ability of these individuals to spawn.

Approximately 29 km^2 of the seed mussel area is within 2.5 km of Areas 439, 493, 197 and 400. This is approximately 17.8% of the seed mussel area within the Humber and Outer Wash region and is therefore a small degree of interaction with the effect.

Approximately 37.5 km^2 of the mussel dredge area is within 2.5 km of the future 15 year MAREA extraction zones. This is approximately 10.4% of the mussel dredge area within the MAREA study area and is a small degree of interaction with the effect.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the seed mussel area and the effect, the cumulative impact of sand deposition on seed mussels is assessed to be minor at the regional scale. Given the small degree of interaction between sand deposition and the mussel dredge areas, the effect on mussels in these areas is assessed to be Not Significant at the regional level.

Changes to Sediment Particle Size

For a description of the effect that sediment particle size may have on benthic species please see Section 9.2.4. The effect of changes in sediment particle size has been assessed to be local in extent, have a short term effect, have a routine frequency and cause a low change relative to the baseline resulting in a small magnitude.

Pink Shrimp and Brown Shrimp

MarLIN (Neal, 2008) does not assess changes in sediment particle size to different species. Brown shrimp have been observed to show a preference for grain sizes between 125 and 710 µm although they are found on sandy and muddy ground. Studies on the effect of particle size on the burying ability of brown shrimp found that the depth of burial varied with grain size (Pinn and Ansell, 1993). Brown shrimp are expected to have a high tolerance and high recoverability to changes in sediment particle size and have therefore been assessed to have a low sensitivity to changes in sediment particle size. Pink shrimp do not bury themselves and are therefore not expected to be as dependent on sediment type. As such, the effect of changes to sediment particle size and pink shrimp is assessed to be not significant.

Brown shrimp (*Crangon crangon*) are primarily targeted along the coast but are also fished as far offshore as Area 441/1. Approximately 1,210 km^2 of the total brown shrimp fishing area is within 4 km of the future 15 year MAREA extraction zones. This means that approximately 34% of the shrimp fishing area may be affected by a change in sediment particle size and is a medium degree of interaction.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of brown shrimp, and the medium degree of interaction between brown shrimp and the effect, the cumulative impact of a change in sediment particle size on brown shrimp is assessed to be of minor significance at the regional scale.

Mussels

As stated above, MarLIN (Tyler-Walters, 2008b) does not assess changes in sediment particle size to different species. However, within the assessment of an increase in water flow rate the following statement was made:

> "*Mytilus edulis can attach and grow on a variety of substrata in a variety of water flow regimes, and an intolerance of low has been reported.*"

Mussels are found from the high intertidal to the shallow subtidal, on rocky shores of open coasts attached to the rock surface and in crevices, and on rocks and piers in sheltered harbours and estuaries. Overall, they have been assessed to have low sensitivity to a change in sediment particle size.

Approximately 56 km^2 of the mussel seed area is within 4 km of the future 15 year MAREA extraction zones. This is approximately 32% of the total mussel seed area and is a medium degree of interaction.

Approximately 90 km^2 of the mussel dredge area is within 4 km of the future 15 year MAREA extraction zones. This is approximately 25% of the total mussel seed area and is a medium degree of interaction.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of mussels, and the medium degree of interaction between both the mussel seeding area and the mussel dredging area and the effect, the cumulative impact of a change in sediment particle size on mussels is assessed to be of minor significance at the regional scale.

9.2.7 Summary of Impacts

Table 9.4 Summary of Impacts to Impacts to Biotopes (1 of 2)

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim	SS.SCS.ICS.Glap	SS.SCS.ICS.SLan	SS.SCS.CCS.PomB	SS.SCS.CCS.MedLumVen	SS.SCS.CCS.Pkef	SS.SSa.IFiSa.IMoSa	SS.SSa.IFiSa.NcirBat	SS.SSa.iFiSa.TbAmPo
Removal of Sediment	Minor Significance	Minor Significance	Minor-Moderate Significance	Minor Significance	No Interaction	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Fine sediment plume/ elevated turbidity	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
Sand deposition	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Changes to sediment particle size	Not Significant	Not Significant	Minor Significance	Minor Significance	Minor Significance	Not Significant	Not Significant	Not Significant	Minor-Moderate Significance
Changes to tidal currents	Not Significant	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Not Significant
Changes to sediment transport rates	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features	No Interaction	Not Significant	No Interaction	Minor Significance	No Interaction	No Interaction	Not Significant	Minor Significance	Not Significant

Table 9.5 Summary of Impacts to Impacts to Biotopes (2of 2)

Receptor	SS.SSa.IMuSa.FfabMag	SS.SSa.CFiSa.ApriBatPo	SS.SSa.CMuSa.AalbNuc	Sensitive Receptor SS.SBR.PoR.SspiMx	SS.SCS.CCS.Blan (SS.SCS.CCS Complex)	SS.SCS.CCS.Nrrix (SS.SCS.CCS Complex)	SS.SSa.IFiSa.ScupHyd (SS.SSa.IFiSa Complex)
Removal of sediment	Minor Significance	No Interaction	No Interaction	Moderate Significance	Not Significant	Not Significant	No Interaction
Fine sediment plume/ elevated turbidity	Not Significant	Not Significant	Not Significant	Not Significant	Minor Significance	Minor Significance	No Interaction
Sand deposition	Minor Significance	Not Significant	No Interaction	Minor Significance	Minor Significance	Minor Significance	No Interaction
Changes to sediment particle size	Minor Significance	Minor Significance	No Interaction	Not Significant	Minor Significance	Minor Significance	Minor Significance
Changes to tidal currents	Minor Significance	Moderate Significance	No Interaction	Not Significant	Not Significant	Not Significant	No Interaction
Changes to sediment transport rates	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features	Minor Significance	Minor Significance	No Interaction	Not Significant	No Interaction	No Interaction	No Interaction

Table 9.6 Summary of Impacts to Protected Species and Habitats and Commercial Species

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to seabed features
Protected Species and Habitats													
Ross worm (Sabellaria spinulosa) individuals and reef		Moderate/ High significance	Not significant		Minor significance		Not significant	No Interaction					
Honeycomb worm (Sabellaria alveolata) and reef		Not significant	Not significant		Not significant		Not significant	No Interaction					
Blue mussel reef (Mytilus edulis)		No Interaction		Not significant	Not significant		No Interaction	No Interaction					
Horse mussel (Modiolus modiolus)		Minor significance		Minor significance	Not significant		Minor significance	No Interaction					
European edible sea urchin (*Echinus esculentus*)		Minor significance	Not Significant	Not significant	Minor significance		Not significant	No Interaction					
The amphipod Leptocheirus hirsutimanus		Not significant	Not Significant	Not significant	Not significant		Not significant	No Interaction					
Edwardsiidae		Minor significance	No Interaction	No Interaction	No Interaction		No Interaction	No Interaction					
Commercial Species													
European lobster		Minor significance		Minor significance				No Interaction					
Brown crab		Minor/ Moderate significance *		Minor significance				No Interaction					
Pink Shrimp and Brown Shrimp		Minor significance		Not significant / Minor significance	Minor significance			No Interaction					
Cockles		No Interaction		No Interaction	No Interaction			No Interaction					
Mussels		No Interaction		Not significant	Minor significance			No Interaction					
Whelks		No Interaction		No Interaction	No Interaction			No Interaction					
Velvet crab		No Interaction		No Interaction				No Interaction					

* The medium significance rating is for berried female brown crabs.

9.2.8 Interactions to be Carried Forward to the EIA Stage

The following provides information on which dredge areas will need to assess particular effects at the EIA stage.

Biotopes

Each licence specific EIA will need to re-assess the existing survey data to determine which biotopes are likely to be present within the survey area. The following interactions between dredging effects and the biotopes within the licence area will need to be considered as part of the EIA.

	Presence of vessel	Removal of Sediment	Fine sediment plume/ elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave height	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Benthic community composition	Change to distribution of fish	Changes to seabed features
SS.SCS.ICS.HeloMsim	✗	✓	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
SS.SCS.ICS.Glap	✗	✓	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗	✗
SS.SCS.ICS.SLan	✗	✓	✗	✓	✓	✗	✓	✗	✗	✗	✗	✗	✗
SS.SCS.CCS.PomB	✗	✓	✗	✓	✓	✗	✓	✗	✗	✗	✗	✗	✓
SS.SCS.CCS.MedLumVen	✗	✗	✗	✓	✓	✗	✓	✗	✗	✗	✗	✗	✗
SS.SCS.CCS.Pkef	✗	✓	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗	✗
SS.SSa.IFiSa.IMoSa	✗	✓	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗	✗
SS.SSa.IFiSa.NcirBat	✗	✓	✗	✓	✗	✗	✓	✗	✗	✗	✗	✗	✓
SS.SSa.iFiSa.TbAmPo	✗	✓	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
SS.SSa.IMuSa.FfabMag	✗	✓	✗	✓	✓	✗	✓	✗	✗	✗	✗	✗	✓
SS.SSa.CFiSa.ApriBatPo	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗	✗	✗	✓
SS.SSa.CMuSa.AalbNuc	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
SS.SBR.PoR.SspiMx	✗	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗	✗
SS.SCS.CCS.Blan	✗	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
SS.SCS.CCS.Nrrix	✗	✗	✗	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
SS.SSa.IFiSa.ScupHyd	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗	✗	✗	✗

Consideration required at the EIA stage	✓
Does not need to be considered	✗

Protected Species and Habitats

	Removal of sediment	Fine sediment plume/ elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to tidal currents	hanges to seabed features
Area 441/1						
Ross worm (*Sabellaria spinulosa*)	✗	✗	✗	✗	✗	✗
Honeycomb worm (*Sabellaria alveolata)*	✗	✗	✗	✗	✗	✗
Blue mussel reef (*Mytilus edulis*)	✗	✗	✗	✗	✗	✗
Horse mussel (*Modiolus modiolus*)	✓	✗	✓	✗	✓	✗
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	✗
The amphipod *Leptocheirus hirsutimanus*	✗	✗	✗	✗	✗	✗
Edwardsiidae	✓	✗	✗	✗	✗	✗
Area 441/2						
Ross worm (*Sabellaria spinulosa*)	✗	✗	✗	✗	✗	✗
Honeycomb worm (*Sabellaria alveolata)*	✗	✗	✗	✗	✗	✗
Blue mussel reef (*Mytilus edulis*)	✗	✗	✗	✗	✗	✗
Horse mussel (*Modiolus modiolus*)	✓	✗	✓	✗	✓	✗
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	✗
The amphipod *Leptocheirus hirsutimanus*	✗	✗	✗	✗	✗	✗
Edwardsiidae	✓	✗	✗	✗	✗	✗
Area 441/3						
Ross worm (*Sabellaria spinulosa*)	✗	✗	✗	✗	✗	✗
Honeycomb worm (*Sabellaria alveolata)*	✗	✗	✗	✗	✗	✗
Blue mussel reef (*Mytilus edulis*)	✗	✗	✗	✗	✗	✗
Horse mussel (*Modiolus modiolus*)	✓	✗	✓	✗	✓	✗
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	✗
The amphipod *Leptocheirus hirsutimanus*	✗	✗	✗	✗	✗	✗
Edwardsiidae	✓	✗	✗	✗	✗	✗
Area 400						
Ross worm (*Sabellaria spinulosa*)	✗	✗	✗	✗	✗	✗
Honeycomb worm (*Sabellaria alveolata)*	✗	✗	✗	✗	✗	✗
Blue mussel reef (*Mytilus edulis*)	✗	✗	✗	✗	✗	✗
Horse mussel (*Modiolus modiolus*)	✓	✗	✓	✗	✓	✗
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	✗
The amphipod *Leptocheirus hirsutimanus*	✗	✗	✗	✗	✗	✗
Edwardsiidae	✓	✗	✗	✗	✗	✗
Area 439						
Ross worm (*Sabellaria spinulosa*)	✗	✗	✗	✓	✗	✗
Honeycomb worm (*Sabellaria alveolata)*	✗	✗	✗	✗	✗	✗
Blue mussel reef (*Mytilus edulis*)	✗	✗	✗	✗	✗	✗

	Removal of sediment	Fine sediment plume/ elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to tidal currents	hanges to seabed features
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 440						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 481/2						
Ross worm (*Sabellaria spinulosa*)	✓	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 493						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 106/3						
Ross worm (*Sabellaria spinulosa*)	✓	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 480						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	✓	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 102						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	✓	×	×	✓	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 105						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 107						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 448						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	✓	✓	×	×	✓	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 449						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 481/1						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 197						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×

Consideration required at the EIA stage	✓
Does not need to be considered	×

Commercially Important Species

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 441/1						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 441/2						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	×	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 441/3						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	×	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 400						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 439						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 440						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 481/2						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 493						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 106/3						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 480						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 102						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 105						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 107						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 448						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 449						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 481/1						
European lobster	×	×	✓	×	×	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 197						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×

Bed of Mussels (Mytilus edulis)

Source: Shutterstock.com

Photograph of Cockles (Cerastoderma edule)

Source: Shutterstock.com

Whelk (Buccinum undatum)

Source: Shutterstock.com

9.3 Potential Impacts to Fish Ecology

9.3.1 Introduction

As discussed in Section 5.3 the fish that will be considered in this impact assessment are:

Protected species:

- Atlantic salmon (*Salmo salar*);
- sea trout (*Salmo trutta*);
- allis shad (*Alosa alosa*);
- twaite shad (*Alosa fallax*);
- eel (*Anguilla anguilla*);
- sea lamprey (*Petromyzon marinus*);
- river lamprey (*Lampetra fluviatilis*);
- smelt (*Omerus eperlanus*);
- short snouted seahorse (*Hippocampus hippocampus*); and
- spiny seahorse (*Hippocampus guttulatus*).

Demersal species:

- cod (*Gadus morhua*);
- bass (*Dicentrarchus labrax*);
- sole (*Solea solea*);
- haddock (*melanogrammus aeglefinus*)
- grey gurnard (*Eutrigla gurnardus*)
- gobiidae (*Pomatoschistus micropsi*)
- snake pipe fish (*Entelurus aequoreus*)
- lesser weaver (*Echiichthys vipera*)
- red mullet (*Mullus barbatus*)
- bib (*Trispterus luscusi)*
- pogge (*Agonus cataphractus*)
- dragonet (*Callionymus lyra*)
- plaice (*Pleuronectes platessa*)
- lemon sole (*Microstomus kitt*)
- dab (*Limanda limanda*)
- brill (*Scophthalmus rhombus*)
- greater sandeel (*Hyperoplus lanceolatus*)
- lesser sandeel (*Ammodytes marinus*); and
- whiting (*Merlangius merlangus*):

Pelagic species:

- mackerel (*Scomber scombrus*)
- Atlantic horse mackerel (*Trachurus trachurus*)
- herring (*Clupea harengus*); and
- sprat (*Sprattus sprattus*).

Elasmobranch species:

- thornback ray (*Raja clavata*);
- spurdog (*Squalidae*);
- smooth hound (*Mustelus asterias*);
- tope (*Galeorhinus galeus*);
- lesser spotted dogfish (*Scyliorhinus canicula*);
- spotted ray (*Raja montagui*);
- tope (*Galeorhinus galeus*).

These species are considered to be important within the MAREA study area for reasons including their protection status, commercial value, regional ecological sensitivities (spawning and nursery grounds and migration routes), ecosystem value and in some cases the local (Humber and Outer Wash) population comprising a significant proportion of the national population (see Section 5.3 for more details).

Due to their protection status, all protected species that were identified as being present within the study area have been initially taken forward into this impact assessment, despite the fact that many of them are not abundant and are only likely to be present in coastal areas. These factors have been taken into account in the discussions of potential impacts to each species which follow.

It is important to consider the values of each species when discussing the significance of potential impacts to resources. A brief explanation of the value of each receptor species can be found below. Throughout the remainder of this section certain fish species are grouped and discussed together in relation to their comparable sensitivities to the effects of dredging.

Salmon

Salmon are protected under the *Berne Convention* and the *EC Habitats Directive*; they are also a UK BAP species. There is, however, a low abundance within the study area and the study area is not therefore considered to be of regional importance for this species. Salmon have consequently been assigned a low value.

Sea Trout

Sea trout is a UK BAP species. Sea trout are abundant within the study area, particularly within coastal areas and are of moderate commercial importance in this region. Sea trout are therefore assigned a medium value.

Allis Shad

Allis shad are protected under the *EC Habitats Directive*, *The Wildlife and Countryside Act* and the *Berne Convention*. Allis shad is also a UK BAP species. Allis shad may move through the coastal zones of the study area before spawning, however the MAREA study area is not of regional importance in the context of broader UK distribution of this species. Allis shad currently have no commercial value within the study area; however they have historically been of commercial importance in the area. Allis shad are therefore assigned a low - medium value.

Twaite Shad

Twaite shad are protected under the *EC Habitats Directive* and the *Berne Convention*. Twaite shad is also a UK BAP species. Twaite shad may move through the coastal zones of the study area between October and December; however the MAREA study area population is not regionally important in the context of the wider UK distribution of this species. Despite having historically been an important species they currently have no commercial value within the study area. Twaite shad are therefore assigned a low - medium value.

Eel

Eel are classified under the IUCN Red List of Endangered Species as critically endangered and are also a UK BAP species. There is a high probability of a significant population within the Humber area, focused in coastal locations; however they are not a major commercial fishery in this region. Eel are therefore assigned a medium value.

Sea Lamprey

Sea lampreys are protected under the *Berne Convention* and *EC Habitats Directive*; Sea lampreys are also a UK BAP species. There is evidence that sea lampreys may be present in small numbers in coastal areas within the study area. Sea lampreys are not a significant commercial fishery. Sea lampreys have therefore been assigned a low value.

River Lamprey

River lampreys are protected under the *Berne Convention* and *EC Habitats Directive* and are also a UK BAP species. There is evidence that river lampreys may be present in small numbers in inshore areas within the study area. There is no significant commercial fishery around this species. River lampreys have therefore been assigned a low value.

Smelt

Smelt is a UK BAP species. Smelt undertake seasonal migrations through coastal areas within the study area; therefore this area represents an important ecological pathway for smelt. However, they are of no commercial importance in the area. Smelt have therefore been assigned a medium value.

Smelt (Omerus eperlanus)

Source: shutterstock.com

Seahorse

Both species of seahorses are protected under the *Wildlife and Countryside Act*. There is a small possibility of individuals being found in coastal locations in the southern part of the study area. Seahorses are found throughout the UK and the MAREA study area is not an important habitat for them. They are of no commercial importance. Seahorses have therefore been assigned a low value.

Cod

Cod is a Nationally Important Marine Feature (NIMF) and a UK BAP species; it is also listed as vulnerable on the IUCN red list of endangered species. Cod is of commercial importance in the study area. Cod have therefore been assigned a high value.

Bass

Bass form a significant proportion of the inshore commercial fishery within the study area. There is also a known spawning ground in the area. Bass are therefore assigned a high value.

Whiting

Whiting is a NIMF as well as a UK BAP species. They are of commercial importance to the area, contributing significantly to overall landings. Whiting are therefore assigned a high value.

Haddock

Haddock are found in limited numbers in the study area and are of limited commercial value, only being targeted by a small number of recreational anglers. Haddock have therefore been assigned a low value.

Grey Gurnard

Grey Gurnard are moderately widespread throughout the study area; however the population within the area is not of national significance. Grey gurnard have therefore been assigned a low value.

Gobiidae

Gobiidae are abundant within the area, notably in inshore areas, however the Humber population is not of national significance. No protected species of gobiidae are present within the study area. Gobiidae have therefore been assigned a low value.

Snake Pipefish

Snake pipefish, although present within the study area, do not have a population of national significance. Snake pipefish have therefore been assigned a low value.

Red Mullet

Red mullet is found in low numbers in the area and is not of commercial importance in this area. Red mullet have therefore been assigned a low value.

Bib

Bib are found in low numbers in the area and are not of commercial importance. Bib have therefore been assigned a low value.

Pogge

Pogge are found in low numbers in the area and are not of commercial importance. Pogge has therefore been assigned a low value.

Dragonet

Dragonet are found in low numbers in the area and are not of commercial importance. Dragonet have therefore been assigned a low value.

Plaice

Plaice is a NIMF and a UK BAP species. Although there is a population in the Humber region it is no longer of commercial importance. Plaice have therefore been assigned a low - medium value.

Plaice (Pleuronectes platessa)

Source: Shutterstock.com

Lemon Sole

Lemon sole are not found in large numbers in the study area and are no longer of commercial importance. Lemon sole have therefore been assigned a low value.

Dab

Dab are found in low numbers in the area and are not of commercial importance. Dab have therefore been assigned a low value.

Brill

Brill are found in low numbers in the study area; however they are a high value commercial species. Due to their low abundance they are no longer targeted by fishing activity but can be taken as by-catch. Brill have therefore been assigned a low value.

Brill (Scophthalmus rhombus)

Source: Shutterstock.com

Sole

Sole is a UK BAP species. It is also one of the most important commercial species targeted in the area and the Humber is a particularly important spawning ground for the species. Sole are therefore assigned a high value.

Mackerel

Mackerel is a UK BAP species. They are expected to occur seasonally within the study area, however there is no commercial fishery. Mackerel have therefore been assigned a low value.

Sandeel

Sandeels are found throughout the area. Although there is no commercial fishery, they play an important role in the ecosystem as a prey source for many marine mammals and birds, as well as larger fish. They are the main food source of kittiwakes which are on the Amber List of Species of Conservation Concern and which form part of the qualifying feature of the Flamborough Head and Bempton Cliffs SPA (*see* Section 5.6). Sandeel are therefore assigned a medium value.

Atlantic puffin eating Sandeels

Source: Shutterstock.com

Herring

Herring is a UK BAP species. There is an important overwintering ground for herring within the Humber Estuary and associated coastal areas and there is also a small local fishery. There is evidence of extensive spawning grounds in this area (Coull *et al.,* 1998), however more recent observations have shown a shift in the spawning grounds to outside the study area (Nigel Proctor, 2011). Herring spawning grounds are very site specific and due to the apparent disparity in predicted and observed spawning grounds a precautionary approach is taken here; therefore herring is assigned a high value.

Sprat

There are important overwintering grounds for sprat within the Humber estuary and associated coastal areas. There is also a moderate commercial fishery within the study area. Sprat provide an important prey source to other fish species, marine mammals and seabirds in the region (ICES, 2011a), and are therefore assigned a medium value.

Atlantic Horse Mackerel

Atlantic horse mackerel is a UK BAP species. There is a small population in the study area but it is not of commercial importance. Atlantic horse mackerel have therefore been assigned a low value.

Thornback Ray

Thornback ray are targeted as part of a large coastal commercial fishery. There is also an important spawning ground with the study area. Thornback rays are therefore assigned a medium - high value.

Thornback Ray (Raja clavata)

Source: Shutterstock.com

Spurdog

Spurdog are listed as vulnerable on the IUCN red list and is a UK BAP species. However, there is only a small population in the study area. Spurdog have therefore been assigned a medium value.

Smoothound

Smoothound are not common within the study are and there is no commercial fishery. Smoothound have therefore been assigned a low value.

Starry Smoothound

Starry smoothound are not common within the study area and there is no commercial fishery. Starry smoothound have therefore been assigned a low value.

Spotted Ray

Spotted ray are not common within the study area and there is no commercial fishery. Spotted ray have therefore been assigned a low value.

Tope

Tope have a limited population with the study areas and there is no commercial fishery. Tope have therefore been assigned a low value.

Lesser Spotted Dogfish

Lesser spotted dogfish are of no local commercial value and although they are present within the area, the population is not significant in a national context. Lesser spotted dogfish are therefore assigned a low value.

Lesser Spotted Dogfish (Scyliorhinus canicula)

Source: Shutterstock.com

9.3.2 Identification of Potential Impacts to Fish Ecology

Table 9.7 details the predicted impacts of dredging with reference to whether or not they have the potential to impact these fish species. This section focuses on the impacts on fish primarily from an ecological standpoint. For further detail on the impacts to commercial fisheries please refer to Section 10.2.

Impacts from sediment plume, sand deposition, changes to tidal currents, underwater noise, benthic community composition and changes to distribution of fish have also been scoped out as not relevant for tope in this context due to the lack of known nursery grounds, spawning grounds and known interaction with activities relating to aggregate extraction.

Table 9.7 Matrix of Potential Impacts to Fish Ecology

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to seabed features
Salmon	■	■	✓	■	■	■	■	■	✓	■	✓	✓	■
Sea Trout	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Allis Shad	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Twaite Shad	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Eel	■	■	✓	■	■	■	■	■	✓	■	✓	■	■
Sea Lamprey	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
River Lamprey	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Smelt	■	■	✓	■	■	■	■	■	✓	■	✓	✓	■
Seahorse	■	■	✓	■	■	■	■	■	✓	■	✓	■	■
Cod	■	✓	✓	✓	■	■	■	■	✓	■	✓	✓	■
Bass	■	✓	✓	✓	■	■	■	■	✓	■	✓	✓	■
Whiting	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Sole	■	✓	✓	✓	✓	■	■	■	✓	■	✓	■	✓
Haddock	■	✓	✓	✓	■	■	■	■	✓	■	■	✓	■
Grey Gurnard	■	✓	✓	■	■	■	■	■	✓	■	✓	✓	■
Gobiidae	■	✓	✓	✓	■	■	■	■	✓	■	✓	■	■
Snake Pipefish	■	■	✓	✓	■	■	■	■	✓	■	■	■	■
Red Mullet	■	✓	✓	✓	■	■	■	■	✓	■	✓	■	■
Bib	■	✓	✓	✓	■	■	■	■	✓	■	✓	✓	■
Pogge	■	✓	✓	■	■	■	■	■	✓	■	✓	■	■
Dragonet	■	✓	✓	■	■	■	■	■	✓	■	✓	■	■
Plaice	■	✓	✓	✓	✓	■	✓	■	✓	■	✓	■	✓
Lemon Sole	■	✓	✓	✓	✓	■	■	■	✓	■	✓	■	✓
Dab	■	✓	✓	✓	✓	■	■	■	✓	■	✓	■	✓
Brill	■	✓	✓	✓	✓	■	■	■	✓	■	■	✓	✓
Sandeel (both genus)	■	✓	✓	✓	✓	■	■	■	✓	■	✓	■	✓
Herring	■	✓	✓	✓	✓	■	✓	■	✓	■	✓	■	■
Sprat	■	■	✓	■	■	■	■	■	✓	■	✓	■	■
Mackerel	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Atlantic Horse Mackerel	■	■	✓	■	■	■	■	■	✓	■	■	✓	■
Smoothound	■	■	✓	■	■	■	■	■	✓	■	✓	✓	■
Spurdog	■	■	✓	■	■	■	■	■	✓	■	✓	✓	■
Starry Smoothound	■	■	✓	■	■	■	■	■	✓	■	✓	✓	■
Tope	x	x	x	x	■	■	x	■	x	■	x	x	■
Spotted Ray	■	✓	✓	✓	■	■	■	■	✓	■	✓	✓	■
Lesser Spotted Dogfish	■	✓	✓	✓	■	■	✓	■	✓	■	✓	✓	■
Thornback Ray	■	✓	✓	✓	■	■	✓	■	✓	■	✓	✓	✓

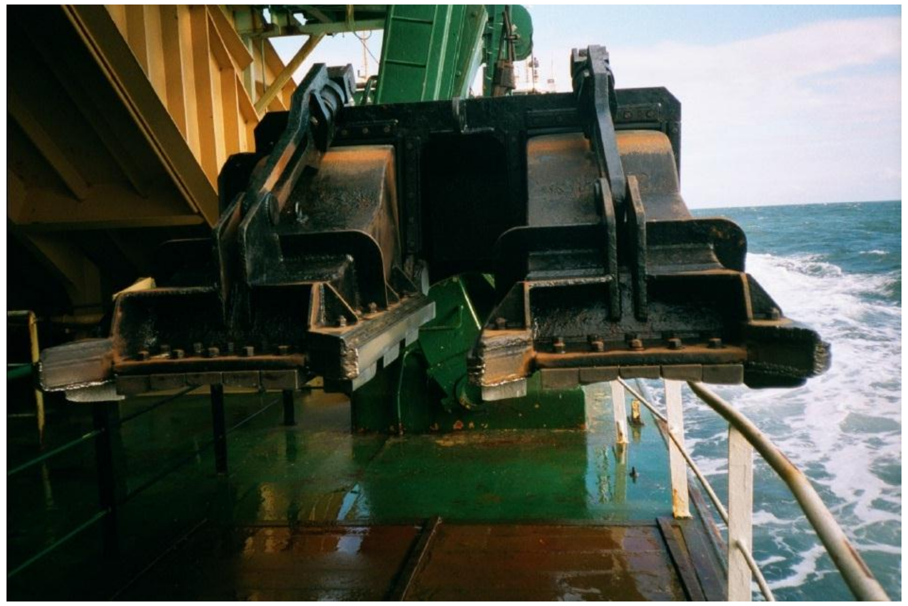
Not affected	■
no interaction	x
potential interaction	✓

9.3.3 Removal of Sediment

Magnitude of Effect

The removal of sediment by dredging is considered to be site specific in extent but long term in duration, regularly occurring (routine) and to constitute a high change relative to baseline levels. As such it is assessed as being a medium - large magnitude effect.

Close-up Photograph of a Draghead



Source: Shutterstock.com

Cod, Bass, Haddock, Gobiidae, Grey Gurnard, Red Mullet, Dragonet, Plaice, Lemon Sole, Dab, Brill and Sole

Cod, bass, haddock, gobiidae, grey gurnard, red mullet, dragonet, plaice, lemon sole, dab, brill and sole are all assessed as having a medium level of tolerance and adaptability to removal of sediment via dredging. A change in their distribution may occur as they move away from dredging activity; however, following the cessation of dredging these species will rapidly return to any areas they have moved away from (Tillin *et al.*, 2011) as they have a high level of substrate fidelity (ICES,2012). They are therefore assessed as having a high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to sediment removal from dredging is considered to be low - medium.

As these species are present across the wider North Sea area (Fishbase,2011), the aggregate dredging licence areas only represent a small proportion of the overall habitat of these species. As a result the degree of interaction of these species with the removal of sediment is assessed to be small - medium.

Based on these assessments of the high value of each of these species, the medium - large magnitude of the effect, but noting the low - medium sensitivity of the receptors and the small - medium degree of interaction between the receptors and the effect, the cumulative impact of sediment removal on these fish is considered to be not significant at a regional scale.

Sandeel (both *Ammodytidae* and *Hyperoplus*)

Sandeel spend a significant part of their lifecycle burrowed into sandy sediments leading to potential losses of individuals that cannot avoid the draghead (Tillin *et al.*, 2011) and therefore has low tolerance to this effect. A local change in their distribution may also occur among those not immediately impacted; however, following the cessation of dredging these species will rapidly return to any areas they have moved from (Van der Kooij et al., 2008) and at the population level tolerance is high. Recruitment to the population is generally rapid so Sandeel are assessed as having a high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to sediment removal from dredging is considered to be low - medium.

The dredge areas only represent a small proportion of the overall habitat for sandeel. As a result the degree of interaction of these species with the removal of sediment is assessed to be small - medium.

Based on these assessments of the medium - large magnitude of the effect, the low - medium sensitivity of the receptor and the small - medium degree of interaction between the receptor and the effect, and noting the medium value of the species, the cumulative impact of sediment removal on sandeel is considered to be not significant at a regional scale.

Herring

Herring has a low tolerance and adaptability to the removal of sediment as eggs are deposited directly onto the sediment and their removal via dredging may result in reduced recruitment to the population. Herring spawning areas are limited by the availability of the gravel sized sediment that is needed for their eggs to attach on to (ICES, 2009a). Therefore removal of sediment of this specific particle size could affect spawning grounds (Nichols, 1999). The recoverability of herring is therefore assessed as being medium as any reduced recruitment to the stock is likely to be made up in the years following the cessation of dredging in the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of herring to sediment removal is considered to be high. This recoverability is based on the assumption that sediment type will still be suitable for herring spawning following cessation of dredging.

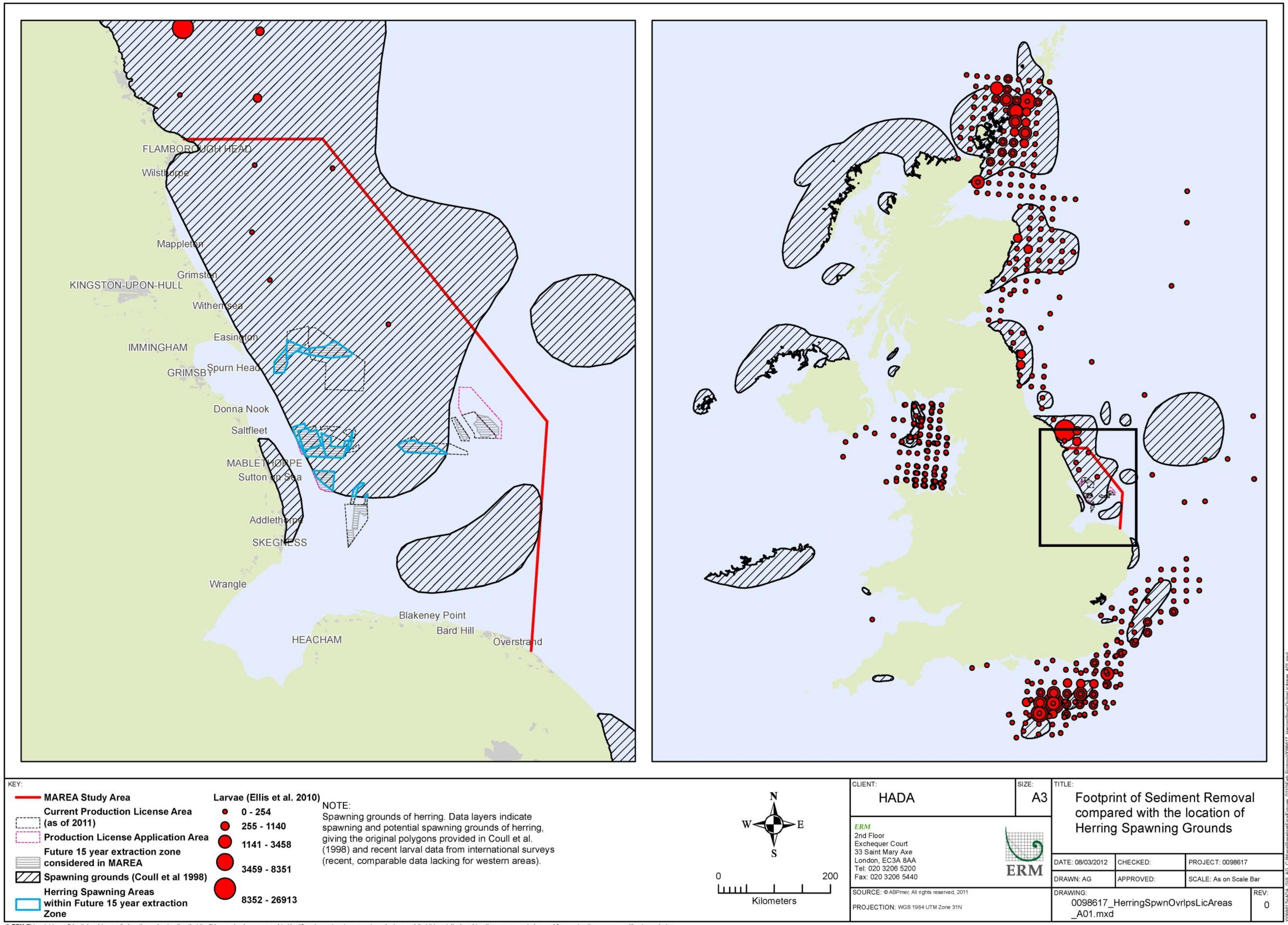
The documented overlap between spawning grounds for herring with the future 15 year extraction zones is shown in Figure 9.8. The MAREA study area overlaps with 4.6% of the predicted herring spawning ground in the UK, however, within the study area, the future 15 year extraction zones overlap with only 0.16% of the herring spawning grounds shown in Figure 9.8. Further to this, recent observations have shown a shift in the spawning grounds to outside the study area and this overlap is likely to be an overestimate (Nigel Proctor, 2011). Herring spawn over a wide area with in the North Sea (Coull et al., 1998) and as such it can be seen that the sections of potential spawning ground that overlap with the extraction zones are very small. It can also be seen that the more recent data showing larval abundance show smaller amounts of larvae being found within the study area than to the north and east of the area (Ellis et al., 2010). Therefore, when taking these data sources into consideration the degree of interaction of herring spawning grounds with the removal of sediment is assessed as being small.

Herring (Clupea harengus)

Source: Shutterstock.com

Based on these assessments of the medium - large magnitude of effects, the high value and high sensitivity of the receptor, the small potential degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on herring is considered to be of minor significance at the regional scale.

Figure 9.8 Footprint of Sediment Removal compared with the location of Herring Spawning Grounds



Thornback Ray, Spotted Ray and Lesser Spotted Dogfish

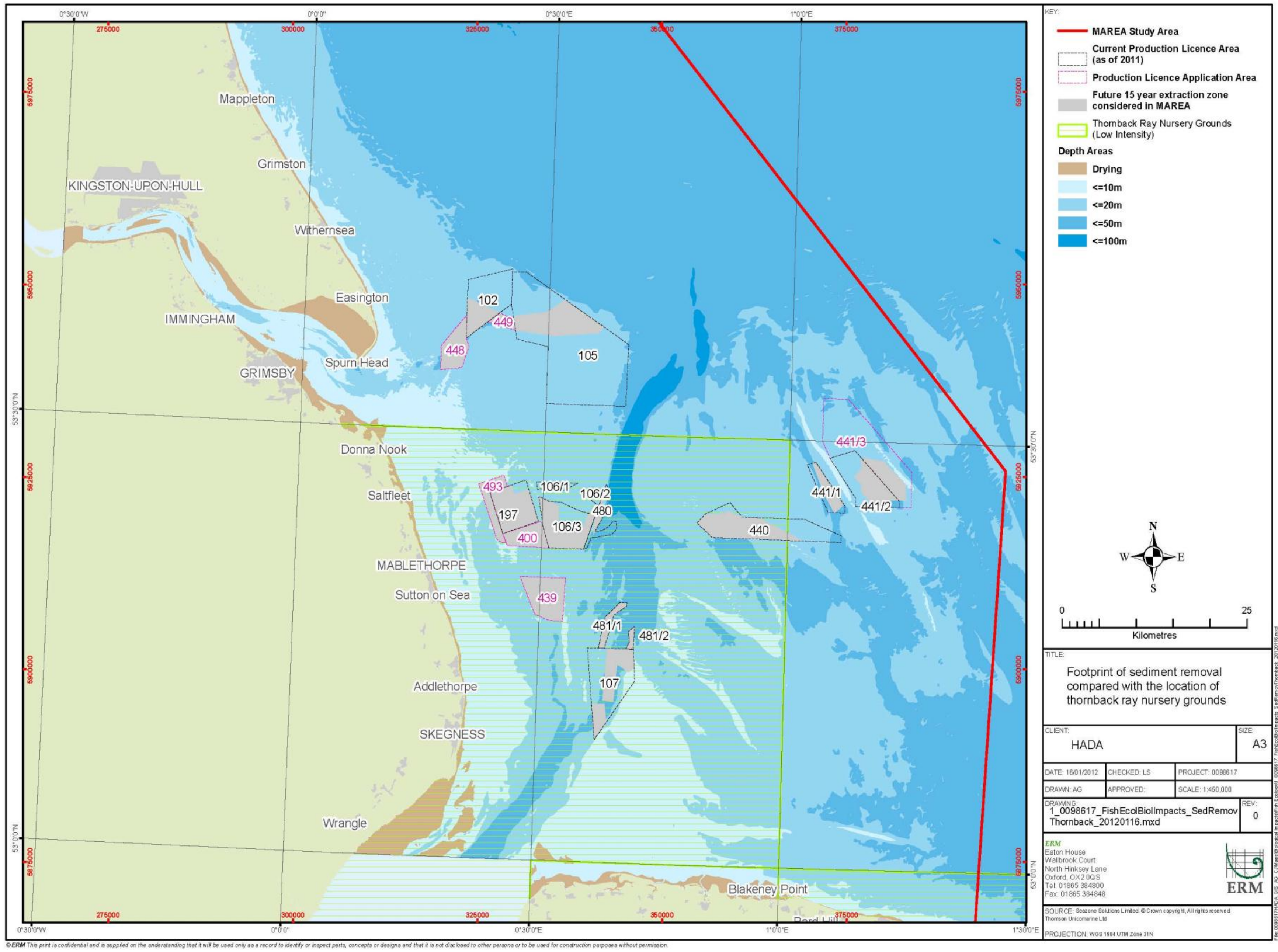
Thornback ray, spotted ray and lesser spotted dogfish have a low tolerance and adaptability to the removal of sediment as they all produce egg cases that are deposited directly onto the sediment and their removal via dredging may result in reduced recruitment to the population. The recoverability is therefore assessed as being medium as any reduced recruitment to the stock is likely to be made up in the years following the cessation of dredging (this is within the medium term of <10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of thornback ray, spotted ray and lesser spotted dogfish to sediment removal is considered to be high.

Thornback ray spawning grounds are not accurately known although it is thought that they widely overlap with nursery grounds (Ellis et al., 2010), that occur within the central inshore zone of the study area. This overlaps with future 15 year extraction zones 481/ 1/ 481/2, 107, 440, 197 106 1/2/3, 480, and Application Areas 493, 400 and 439 (Figure 9.9). As such the degree of interaction of thornback ray with the removal of sediment is assessed as being medium.

Lesser spotted dogfish are known to spawn in a wide area throughout the North Sea and English Channel, therefore the overlap between spawning grounds and the future 15 year extraction zones will be small (Ivory and Nolan, 2004). As such, the degree of interaction between lesser spotted dog fish and spotted ray spawning grounds with the removal of sediment if assessed as being small.

Based on these assessments of the small - large magnitude of effects, the high value and high sensitivity of the receptor, but the low - medium degree of interaction between the receptor and the effect, the cumulative impact of sediment removal on thornback ray, spotted ray and lesser spotted dog fish is considered to be of minor significance at the regional scale.

Figure 9.9 Footprint of Sediment Removal Compared with the Location of Thornback Ray Nursery Grounds



9.3.4 Fine Sediment Plume / Elevated Turbidity

The predicted effects from elevated suspended sediment levels for the areas affected by the >100 mgl^{-1} zone and 100 - 50 mgl^{-1} zones have been assessed as being of medium magnitude for both depth averaged and near bed plumes. The 50 – 20 mgl^{-1} zone and 20 – 2mgl^{-1} zone have been assessed as being of small-medium magnitude due to their relatively low concentration and/or relatively small area of effect.

The effect of the sediment plume is temporary and the assessment of magnitude is based on the fact that the plume is local (for the 20 - 50 mgl^{-1} and 50 - 100 mgl^{-1} plumes) or site specific (for the >100 mgl^{-1} plume) and regularly occurring (routine). The baseline suspended sediment concentrations experienced within the study area vary between 1 – 64 mgl^{-1} in summer months and 2 – 128 mgl^{-1} in winter months. The baseline data suggest that suspended sediment concentrations are higher in estuaries than further offshore. Therefore, these plumes constitute a negligible (for the near bed plume) or low (for the depth averaged plume) change relative to baseline conditions for the 2 - 20 mgl^{-1} zones and 20 – 50 mgl^{-1} zones or a medium change relative to the baseline for the 50 -100 mgl^{-1} and > 100 mgl^{-1} plumes for both near bed and depth averaged plumes.

Salmon, Sea Trout, Sea Lamprey, River Lamprey, Allis Shad and Twaite Shad

It has been noted that salmon, sea trout, sea lamprey, river lamprey, allis shad and twaite shad all undertake migrations up very turbid rivers throughout their lifecycle, and therefore they may be more tolerant as they experience similar conditions at various points in their lifecycle. Consequently these species are considered to have a medium level of tolerance and adaptability to the presence of a sediment plume and the associated increase in turbidity.

These species also have the ability to leave an area that is adversely affected by elevated turbidity and forage elsewhere in a similar habitat as they are highly mobile. Therefore a change in distribution may occur as they avoid, and move away from, areas of high turbidity, but effects on the overall population are unlikely to occur. Following the cessation of dredging these species will rapidly return to any areas they previously avoided. They are therefore assessed as having a high recoverability.

Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to fine sediment plumes is considered to be low - medium.

Sea lamprey, river lamprey, seahorses, salmon, smelt, allis shad, twaite shad and sea trout are not common within the study area and are predominantly distributed inshore. However, there is the possibility that due to the shallow nature of the MAREA study area, these species, with the exception of the seahorse, may cross The Wash further offshore during their migrations, thus interacting with some of the future 15 year extraction zones (Nigel Proctor, 2011).

Based on the assessments of the small - medium magnitude of the effect, the medium – high value and low - medium sensitivity of the receptors and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on these fish species is considered to be not significant at the regional scale.

Cod, Bass, Sprat, Whiting, Haddock, Grey Gurnard, Gobiidae, Snake Pipe Fish, Red Mullet, Bib, Pogge, Dragonet, Lemon Sole, Mackerel, Atlantic Horse Mackerel, Smoothound, Starry Smoothound, Spotted Ray, Lesser Spotted Dogfish and Thornback Ray

Cod, bass, sprat, whiting, haddock, grey gurnard, gobiidae, snake pipe fish, red mullet, bib, pogge, dragonet, lemon sole, mackerel, Atlantic horse mackerel, smoothound, starry smoothound, spotted ray, lesser spotted dogfish and thornback rays are all assessed as having a medium level of tolerance and adaptability to the presence of a sediment plume and the associated increase in turbidity; however a change in their distribution may occur as they avoid and move away from areas of high turbidity (Sicira Offshore Energy Ltd, 2006). Following the cessation of dredging, these species will rapidly return to any areas they previously avoided (Wilhelmsson *et al.*, 2006) and are therefore assessed as having high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to fine sediment plumes is considered to be low - medium.

Bass are widely distributed throughout the study area and are highly mobile and therefore the interaction at a point in time between any dredging activity and this species is likely to be very low. Haddock, grey gurnard, gobiidae, snake pipe fish, red mullet, bib, pogge, dragonet, lemon sole, mackerel, Atlantic horse mackerel, smoothound, starry smoothound, spotted ray, lesser spotted dogfish are not widely distributed within the study area and are highly mobile therefore any interaction with active dredge zones is going to minimal. Horse mackerel and mackerel all occupy the pelagic zones preferentially and are therefore outside of the peak area of influence on the seabed. Cod, sprat, whiting and thornback ray are all widely distributed throughout the study area and all have nursery grounds overlapping with some of the future 15 year extraction zones (Figure 9.10). However, these species are highly mobile and as a result individuals would be able to avoid these relatively small impact areas within the wider nursery ground areas.

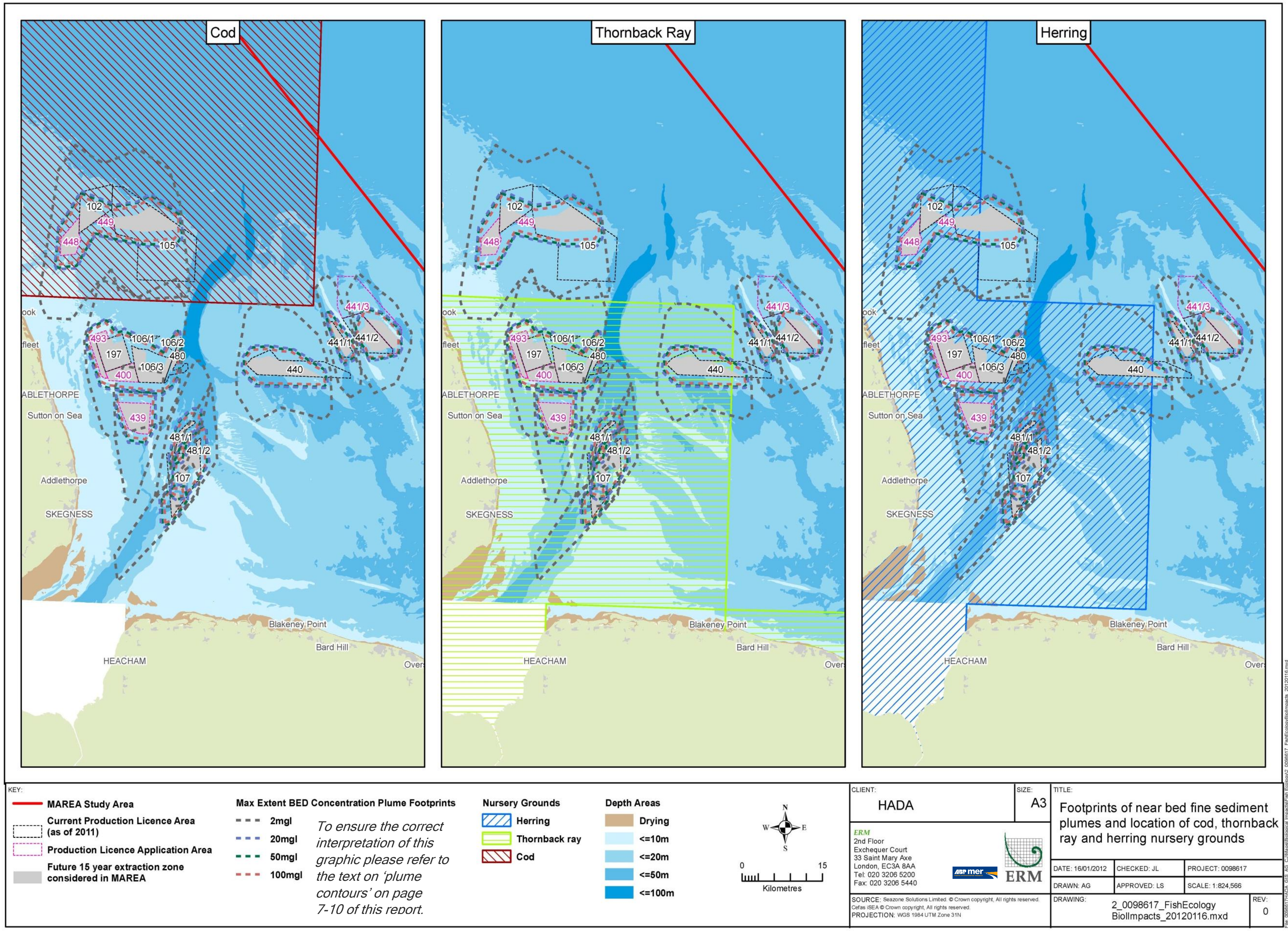
Sea Bass (Dicentrarchus labrax)

Source: Shutterstock.com

Cod, thornback ray and sprat also have spawning grounds in the study area; however these only overlap with the northeast section of the study area and will only overlap with future 15 year extraction zone 105. As a result the degree of interaction of these species with the presence of sediment plumes is assessed as being small.

Based on the assessments of the small - medium magnitude of the effect, the low– high value and low - medium sensitivity of the receptors but noting in particular the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on these fish species is considered to be not significant at the regional scale.

Figure 9.10 Footprints of Near Bed Fine Sediment Plumes (above Background Concentration and 100mg/l) compared with the Location of Cod, Sprat, Whiting and Thornback Ray Nursery Grounds



Sandeel (Ammodytidae and Hyperoplus)

Sandeel are assessed as having a high level of tolerance and adaptability to the presence of sediment plumes as they spend a large part of their life cycle in sandy and often turbid environments. Their recoverability in relation to this effect of dredging is also anticipated to be high as they will be able to return to an area at the end of the dredging period, if they have avoided the area during dredging (Tillin et al., 2011). Based on the consideration of tolerance adaptability and recoverability, the sensitivity of sandeel to fine sediment plumes is considered to be low.

Sandeel are found throughout the study area, however the areas of increased turbidity related to the near bed plume only represent a small proportion of the nursery and spawning grounds, with the densest near bed plumes (>100 mgl^{-1}) only overlapping with small areas of seabed habitat. As a result sandeel will have a small degree of interaction with the presence of sediment plumes associated with dredging.

Based on these assessments of small - medium magnitude of the effect, medium value and low sensitivity of sandeel and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on sandeel is considered to be not significant at the regional scale.

Sole, Plaice, Dab and Brill

Sole, plaice, dab and brill are assessed as having a high level of tolerance and adaptability to the presence of sediment plumes as they naturally live in sandy and often turbid environments. Their recoverability in relation to this effect of dredging is also anticipated to be high as they will be able to return to an area at the end of the dredging period, if they have avoided the area during dredging. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to fine sediment plumes is considered to be low.

Sole are widely distributed throughout the study area and have both large-scale spawning and nursery grounds within the study area. However the areas of increased turbidity related to the near bed plume only represent a small proportion of the nursery and spawning grounds, with the densest near bed plumes (>100 mgl^{-1}) only overlapping with small areas of spawning grounds. Plaice, dab and brill do not have large populations within the study area and there are no defined spawning or nursery grounds documented here. As a result, these species will have a small degree of interaction with the presence of sediment plumes associated with dredging.

Based on these assessments of small - medium magnitude of the effect, high value and low sensitivity and the small degree of interaction between the receptors and the effect, the cumulative impact of sediment plumes on sole, plaice, dab and brill is considered to be not significant at the regional scale.

Dab (Limanda limanda)

Source: Shutterstock.com

Herring

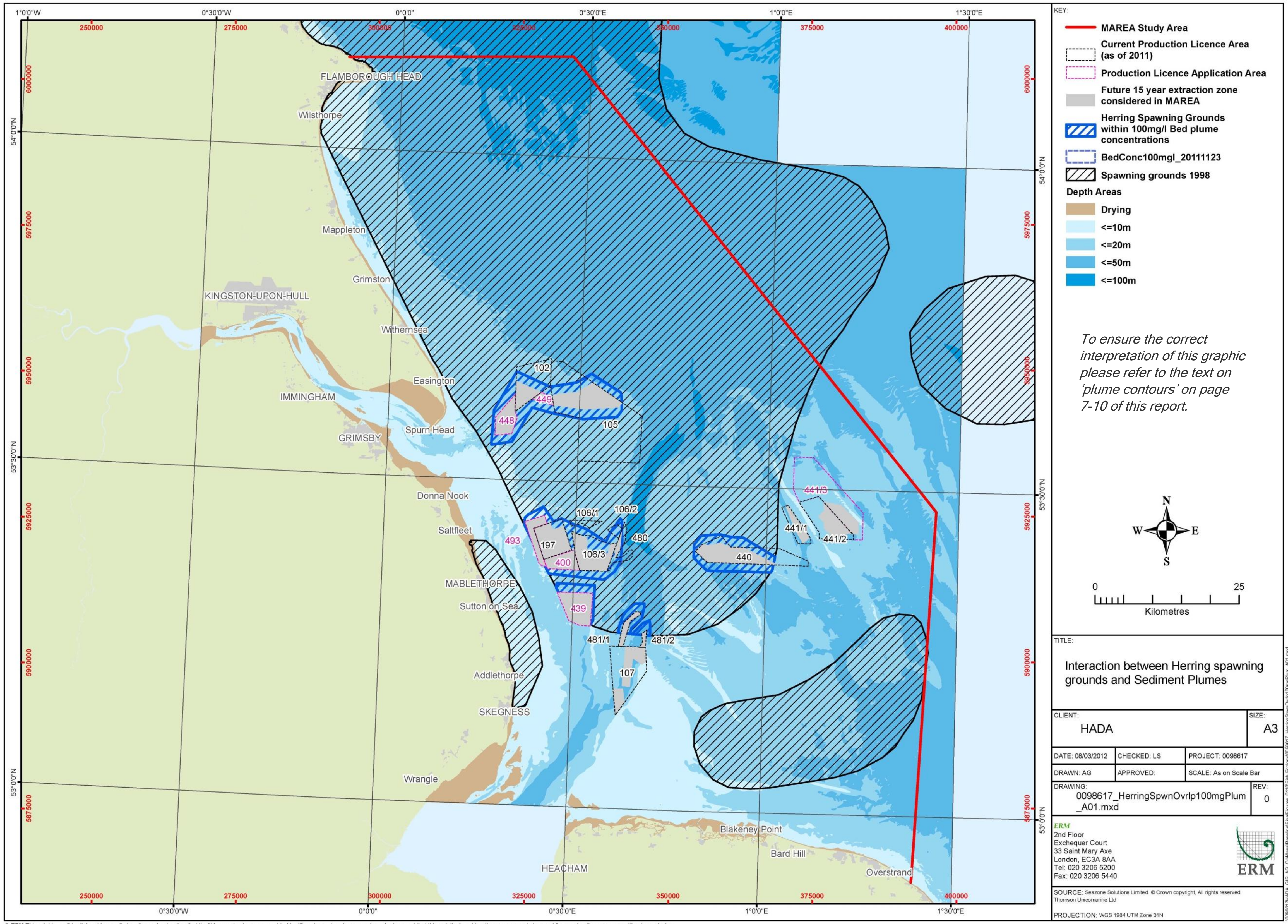
Herring have a low tolerance and adaptability to the presence of fine sediment (near bed) plumes as herring eggs are laid directly onto the seabed and need clear, well oxygenated water to survive. An increase in turbidity in the water column can therefore have a detrimental effect on spawning grounds. The recoverability of herring stock as a result of impacts to spawning grounds is likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of spawning herring to fine sediment plumes is considered to be high.

There is documented overlap between spawning grounds for herring and sediment plumes associated with the future 15 year extraction zones (Coull *et al.*, 1998) and (ICES, 2009a) as shown in Figure 9.11. However, more recent observations have shown a shift in the spawning grounds to outside the study area (Nigel Proctor, 2011). As such, when taking these data sources into consideration the degree of interaction of herring spawning grounds with sediment plumes is assessed as being small.

Based on these assessments of the small - medium magnitude of effect, the high value and high sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment plumes on herring is considered to be minor at the regional scale.

Sand Falcon Trailing Suction Hopper Dredger Loading Sand showing Overflow from Spillways and Associated Plume of Fine Particles

Figure 9.11 Sediment Plume Interactions with the Location of Herring Spawning Grounds



9.3.5 Sand Deposition

Magnitude of Effect

The deposition of sand onto the seabed (i.e. the formation of bedforms) as a result of dredging operations is assessed as being a small magnitude effect, based on it being a localised and short term effect that will be routine in occurrence, and constituting a low level change relative to the baseline.

Cod, Brill, Gobiidae, Snake Pipe Fish, Red Mullet, Bib and Bass

Cod, brill, gobiidae, snake pipe fish, red mullet, bib and bass are assessed as having a medium level of tolerance and adaptability to deposition of sand on the seabed; a change in their distribution may occur as they avoid and move away from areas where this occurs. When dredging has finished, these species will rapidly return to any areas they previously avoided and are therefore assessed as having a high recoverability (Wilhelmsson et al., 2006). Based on the tolerance, adaptability and recoverability the sensitivity of these species to sand deposition is assessed as being low - medium.

Cod, gobiidae and bass are widely distributed throughout the study area and cod has extensive nursery and spawning grounds in the area (Figure 9.10). However, the areas within which dredging and the deposition of sand onto the seabed will take place constitute a very small amount of this overall habitat. Brill, snake pipe fish, red mullet and bib are not as common within the study area and have no documented spawning or nursery ground in the area. As a result the degree of interaction of these species with the effects of sand deposition is assessed as being small.

Based on these assessments of low – medium sensitivity, small magnitude and a small degree of interaction between the receptor and the effect the cumulative impact of sand deposition on these fish species is considered to be not significant at a regional scale.

Sandeel (*Ammodytidae* and *Hyperoplus*)

Sandeel burrow into sand during parts of their lifecycle and in response to events such as naturally high turbidity as driven by storms for example. They are therefore assessed as having high tolerance, adaptability and recoverability to the effects of sand deposition.

Although sandeel are widely distributed in the study area the degree of interaction with sand deposition is small.

Based on the assessment of a small magnitude effect, a low sensitivity and medium value receptor and a small degree of interaction the effects of sand deposition on sandeel are assessed as not significant.

Herring

Herring has a low tolerance and adaptability to sand deposition as eggs are deposited directly onto the sediment and they therefore risk being smothered; this may result in reduced recruitment to the population. The recoverability of herring is therefore assessed as being medium as any reduced recruitment to the stock is likely to be made up in the years following the cessation of dredging in the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of herring to sand deposition is considered to be high.

There is documented overlap between spawning and nursery areas for herring with the future 15 year extraction zones and therefore areas of predicted sand deposition. However, more recent observations have shown a shift in the spawning grounds to outside the study area (Nigel Proctor, 2011). As such, when taking these data sources into consideration the degree of interaction of herring spawning grounds with sand deposition is assessed as being small.

Based on these assessments of the medium - large magnitude of effects, the high value and high sensitivity of the receptor, and the medium degree of interaction between the receptor and the effect, the cumulative impact of sediment deposition on herring is considered to be minor at the regional scale.

Thornback Ray, Lesser Spotted Dogfish, and Spotted Ray

Thornback ray, lesser spotted dogfish and spotted ray have a medium tolerance and adaptability to sediment deposition as their egg cases are deposited directly onto the sediment and burial via sediment deposition may result in reduced recruitment to the populations. However, these egg cases are much sturdier than herring eggs and survival is therefore more likely. Recoverability of thornback rays and lesser spotted dogfish are therefore assessed as being medium as any reduced recruitment to the stock is likely to be made up in the years following the cessation of dredging in the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of thornback ray, lesser spotted dogfish, spotted ray and tope to sediment deposition is considered to be low - medium.

Thornback ray spawning grounds are not accurately known although it is thought that they widely overlap with nursery grounds (Ellis *et al.*, 2010), of which there is one present in central inshore areas of the study area. This overlaps with future 15 year extraction zones of Areas 481, 439, 493, 400, 197, 106, 107, 480 and 440. As such the degree of interaction of thornback ray with the sediment deposition is assessed as being medium.

Lesser spotted dogfish are known to spawn in a wide area throughout the North Sea and English Channel, therefore the overlap between spawning grounds and the future 15 year extraction zones will be low (Ivory and Nolan, 2004). As such, the degree of interaction between lesser spotted dog fish spawning grounds with the removal of sediment is assessed as being small.

Based on these assessments of the medium - large magnitude of effects, the high value and medium sensitivity of the receptor, and the small degree of interaction between the receptor and the effect, the cumulative impact of sediment deposition on thornback ray, lesser spotted dogfish and spotted ray is considered to be of minor significance at the regional scale.

Sole, Lemon Sole, Dab and Plaice

Sole, lemon sole, dab and plaice are assessed as having a high level of tolerance and adaptability to sand deposition as they naturally live in sandy and often turbid environments. Their recoverability in relation to this effect of dredging is also high as they will recover rapidly at the end of the dredging period if they are adversely impacted in any way. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to sand deposition is considered to be low.

Sole are widely distributed throughout the study area and have both large scale spawning and nursery grounds within the study area. However the areas of sand deposition only overlap with small areas of nursery and spawning grounds in relation to the wider area. Lemon sole, dab and plaice are not as common and have no spawning or nursery grounds within the study area. As a result these species will have a small degree of interaction with sand deposition associated with dredging.

Based on these assessments of small - medium magnitude of the effect, medium - high value and low sensitivity of sole to this effect, and the small degree of interaction between the receptor and the effect, the cumulative impact of sand deposition on sole, lemon sole, dab and plaice is considered to be not significant at the regional scale.

9.3.6 Changes to Sediment Particle Size

Magnitude of Effect

Any changes to sediment particle size as a result of dredging activity will be localised, short term in duration and will represent a low level of change relative to the baseline. However, they will be routine in occurrence. Particle size change therefore is assessed as being a small magnitude effect.

Sole, Plaice, Lemon Sole, Dab and Brill

Sole, plaice, lemon sole, dab and brill are assessed as having a medium level of tolerance and adaptability to changes in particle size as they predominantly prefer sandy substrates as habitats, and as a result may move away from an area if the particle size changes significantly and is no longer suitable (Tillin *et al.*, 2011) . However following the cessation of dredging, they will rapidly return to any areas from which they have been displaced (Newell *et al*., 1998) and are therefore assessed as having a high recoverability. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of sole, plaice, lemon sole, dab and brill to changes in particle size in favour of a slightly sandier seabed is considered to be low.

Sole are widely distributed throughout the study area. However the area within which dredging activities occur and where changes to particle sizes may take place only constitutes a very small amount of this available habitat. Plaice, lemon sole, dab and brill are not as common in the area and will therefore not overlap with active dredge zones regularly. As a result, the degree of interaction of these species with the effect of changes to sediment particle size is assessed as being small.

Based on this assessment of the small magnitude of the effect, the medium – high value and the low - medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the regional cumulative impact of changes to sediment particle size on sole, plaice, lemon sole, dab and brill is considered to be not significant at a regional scale.

Sandeel (*Ammodytidae* and *Hyperoplus*)

Studies by Holland *et al* .,(2005) show that 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 (Holland *et al.,* 2005). 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. Sandeel are therefore assessed as having a medium - high tolerability and a medium degree of adaptability to changes in sediment particle size as some changes may be negative while others may be favourable. Their recoverability in regard to the effect is assessed as high. Sandeel sensitivity to sediment particle size changes is therefore assessed as low – medium.

Sandeel are widely distributed throughout the study area. However the area within which dredging activities occur and where changes to particle sizes may take place only constitutes a very small amount of this available habitat. As a result the degree of interaction of sandeel with the effect of changes to sediment particle size is assessed as being small.

Based on this assessment of the small magnitude of the effect, the medium value and the low - medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to sediment particle size on sandeel is considered to be not significant at a regional scale.

Herring

Herring spawning areas are limited by the availability of the gravel sized sediment that is needed for their eggs to attach (Nichols, 1999). Spawning typically occurs on coarse gravel (0.5 – 5cm) to stone (8 - 15cm) substrates, and often on the crest of a ridge rather than in the hollow (ICES, 2011b). This specificity therefore means that herring are assessed as having a low tolerance and adaptability to the changes to particle size. The recoverability of herring is assessed as being medium as any reduced recruitment to the herring stock as a result of displacement from spawning grounds is likely to recover within the medium term (<10 years). This recoverability is based on a return to baseline conditions after cessation on dredging. Based on consideration of tolerance, adaptability and recoverability, the sensitivity of herring species to changes to sediment particle size is considered to be medium.

There is documented overlap between spawning and nursery areas for herring with the future 15 year extraction zones (Coull *et al*., 1998). However, more recent observations have shown a shift in the spawning grounds to outside the study area (Nigel Proctor, 2011). As such, when taking these data sources into consideration the degree of interaction of herring spawning grounds with changes to particle size is assessed as being small.

Based on these assessments of small magnitude of the effect, the high value and the medium sensitivity of the receptor, and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to sediment particle size on herring is considered to be minor at the regional scale.

9.3.7 Changes to Tidal Currents

A 10 – 20% change to tidal currents as a result of dredging operations is a medium magnitude effect, based on the fact that it is site specific in extent, regularly occurring (routine), long term in duration and a medium level of change relative to the baseline. A 2 – 10% change in tidal currents is a localised effect and is a low level of change relative to the baseline. However, it is long-term in duration and regularly occurring (routine). It is therefore also assessed as being a medium magnitude effect.

Herring

Herring lay their eggs directly onto the seabed. These eggs survive best in well oxygenated environments with good water flow over the eggs. As a result, significant reductions to tidal currents could impact upon survival of eggs through reduced water flow; as a result recruitment into the species population could be impacted. Herring therefore has a medium tolerance and adaptability to changes in tidal currents as this may result in a shift in spawning grounds to other less suitable areas. Their recoverability is assessed as being medium as any impaired levels of recruitment are likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of herring to changes in tidal currents is considered to be medium.

There is documented overlap between spawning and nursery areas for herring with the future 15 year extraction zones (Ellis *et al*., 2010). However, more recent observations have shown a shift in the spawning grounds to outside the study area (Nigel Proctor, 2011). As such, when taking these data sources into consideration the degree of interaction of herring spawning grounds with changes to tidal current is assessed as being small. Based on these assessments of the medium magnitude of effects, the medium to high value and medium sensitivity of the receptors, but the small degree of interaction between the receptors and the effects, the cumulative impact of changes to tidal currents on herring is considered to be minor at the regional scale.

Thornback Ray and Lesser Spotted Dogfish

Thornback ray and lesser spotted dogfish lay their egg cases directly on the seabed. However, these are robust structures with leathery cases protecting the eggs and the sediment type that they settle on will not significantly impact their survival. Nonetheless, the risk of beaching of these egg cases as a result of an increase in tidal currents may have an adverse impact on recruitment to the population. These species are assessed as having a high tolerance and adaptability to changes in tidal currents. Their recoverability is assessed as being high to medium as any impaired levels of recruitment are likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of thornback ray and lesser spotted dogfish to changes in tidal currents is considered to be low.

Thornback ray spawning grounds are not accurately known although it is thought that they widely overlap with nursery grounds (Ellis *et al*.,2010), of which one is found in the central inshore areas of the study area. This overlaps with future 15 year extraction zones 481, 439, 493, 400, 197, 106, 107, 480 and 440. As such the degree of interaction of thornback ray with changes to tidal currents is assessed as being small - medium. Lesser spotted dogfish are not as common within the area therefore the degree of interaction is assessed as being small.

Based on these assessments of the medium magnitude of effects, the medium to high value and low sensitivity of the receptors, but the small degree of interaction between the receptors and the effects, the cumulative impact of changes to tidal currents on thornback ray and lesser spotted dogfish is considered to be not significant at the regional scale.

Plaice

Plaice make use of the tidal stream for transport during the seasonal migrations between spawning and feeding grounds. Adults move downstream in the winter and will stay on the bottom whilst the tide flows in the opposite direction and will then utilise the opposite tidal current in the spring (Metcalfe and Arnold, 1997). Plaice are assessed as having a high tolerance and adaptability to changes in tidal currents as they will retain the ability to stay out of the disadvantageous tidal currents. Their recoverability is assessed as being high - medium as any impaired levels of recruitment through delayed access to spawning grounds are likely to recover within the medium term (<10 years). Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of plaice to changes in tidal currents is considered to be low.

Plaice are not a common species within the study area and there are limited documented spawning grounds. As such the degree of interaction of plaice with changes to tidal currents is assessed as being small.

Based on these assessments of the medium magnitude of effects, the medium to low value and low sensitivity of the receptors, but the small degree of interaction between the receptors and the effects, the cumulative impact of changes to tidal currents on plaice is considered to be not significant at the regional scale.

9.3.8 Underwater Noise

Underwater noise and vibrations from maritime activities have the potential to adversely impact marine mammals and fish. They have been shown to produce strong behavioural responses, often avoidance mechanisms, from a variety of fish species (CEDA, 2011). Fish hear a narrow band of sound and sensitivity is higher at lower frequencies. Those with swim bladders are the most sensitive as the swim bladder acts as an internal amplifier. There is therefore variation between species as to their sensitivity to underwater noise. Although there is a lack of data and information available on the impacts of noise directly from aggregate dredging, there is more available from windfarm studies, which has therefore been used within this assessment where appropriate.

Some fish, such as sole, thornback ray, and bass are hearing generalists (Lovell et al., 2005) and as such are relatively insensitive to noise as their hearing ability is thought to be poor. Others, such as herring are able to detect sound pressure and as such have a high sensitivity. It is unlikely that underwater noise from dredging can cause injury (Gots *et al.*, 2009), however, other less direct impacts can occur such as the additional noise masking biologically important sounds, temporary loss of normal hearing capacity and impacts on the stress levels and immune system of the organism (Popper and Hastings, 2009a) as well as behavioural reactions such as avoidance. These may potentially cause abandonment of the most favourable spawning, nursery or feeding grounds, negatively impacting the population (Robinson *et al.*, 2011).

Magnitude of Effect

Underwater noise levels at all frequencies attenuate with distance from the source as described in Chapter 7. As a result, the change relative to baseline varies with distance as the noise levels decrease relative to ambient noise. Therefore, in this assessment it is necessary to describe the change relative to baseline as a range, from low to medium where a medium change is experienced close to the source and a low change is experienced with distance from it. The extent of the effect is considered to be local because the noise attenuates with distance from the source such that a behavioural response may not be exhibited on a regional scale. The effect occurs for a temporary duration and at a routine frequency during active dredging, which results in an overall magnitude range of low to medium.

Impact Significance

Hearing Generalists

Sea lamprey, river lamprey, allis shad, twaite shad, salmon, smelt, sea trout, eel, sole, thornback ray, haddock, mackerel, dab, plaice (Nedwell *et al.*, 2004) and bass are hearing generalists (Nedwell et al., 2007) and (Lovell *et al.*, 2005) and as such are relatively insensitive to noise as their hearing ability is thought to be poor. Cod, despite having a swim bladder, are also considered to be a hearing generalist as they have no specialised structures connecting the swim bladder with the inner ear (Gill and Bartlett, 2010). It has been shown in previous studies that although noise will cause fish to move away from the source, they will re populate the area once the noise has stopped (Sicira Offshore Energy Lyd, 2006). As a result of the limited sensitivity to noise of these species, only minor, short term changes to their distribution are expected. Sole, thornback ray, haddock, mackerel, dab, plaice and bass are widespread throughout the study area and therefore any change to their distribution as a result of noise is unlikely to be detectable on a regional level (Mueller-Blenkle *et al.*, 2010) .

There has been limited assessment of the effect of underwater noise on elasmobranchs (Thomsen *et al.*, 2006) (in this study, smoothound, starry smoothound, spurdog, tope, spotted ray, lesser dogfish and thornback ray). It has been hypothesised that their lack of swim bladder and cartilaginous skeleton makes them less susceptible to underwater noise than teleosts (Popper and Hastings, 2009b). Additional research would be necessary to confirm the impact of underwater noise on elasmobranchs (Myrberg, 2001).

These species are assessed as having a high tolerance since they are relatively insensitive to noise and a high adaptability to underwater noise due to their ability to move away from the area of impact. Their recoverability is assessed as being high, as once dredging has ceased they are likely to return to the areas that they were displaced from. Based on this consideration of tolerance, adaptability and recoverability the sensitivity of these species to underwater noise is considered to be low.

Hearing Specialists

Whiting and sandeel are found throughout the study area and are known to be sensitive to underwater noise (Popper and Hastings, 2009). These species have gas filled swim bladders, which can act as an amplifier to noise. The close proximity of the swim bladder to the inner ear in these species, (Hawkins and Johnstone, 1978), makes them very sensitive to sound and they will therefore exhibit strong avoidance behaviour. As a result some distribution changes to these species may be expected to occur as a result of underwater noise including that associated with dredging. However, it has been shown that this displacement is not permanent and fish will repopulate an area rapidly following a cessation of dredging (Thomsen *et al.*, 2006).

Whiting and sandeel have been assessed as having a medium – high tolerance and adaptability. Their recoverability is assessed as high as once dredging has ceased, they are likely to return to the area. Based on this consideration of tolerance, adaptability and recoverability the sensitivity of whiting and sandeel to underwater noise is considered to be medium.

Sprat and herring are hearing specialists and are particularly sensitive to sound. Intensive underwater noise may cause damage to individuals and due to their increased sensitivity, avoidance behaviour may be seen from further away from noise sources that is seen in other species. Therefore the tolerance and adaptability of these species is assessed as medium – low. However, their recoverability is assessed as high as once dredging has ceased they are likely to return to the area. Based on the consideration of adaptability, tolerance and recoverability the sensitivity of sprat and herring to underwater noise is assessed as being medium.

Degree of Interaction

A recent report for MASLF by Robinson *et al.* (2011) determines the level and frequency of underwater noise resulting from aggregate dredging as described in Chapter 7. The highest dipole [(1)] level measured in this study was from the Sand Harrier dredging vessel, for which a maximum noise source level of 181.4 dB re 1µPa^2 m^2 at a frequency of 158.5 Hz was calculated at 1 m from the source during full dredging mode. Other frequencies were recorded propagating from this vessel but at lower levels (Robinson *et al.*, 2011).

There is evidence that fish can potentially suffer physical impacts at levels of 206 dB re 1 µPa (peak) and at accumulated sound exposure level (SEL) of 187 dB re 1 µPa^2 for fish weighing more than 2 g and 183 dB re 1 µPa^2 for

(1) Dipole source levels are commonly used to describe shipping noise. Monopole source levels refer to a direct and omni-directional sound wave source, whilst dipole source levels take account for interference to the direct sound waves from the source that result from the noise reflecting at the interface with the seabed and sea surface. The Robinson et al 2010 report presents the majority of its results as dipole source levels so that they may be understood in the context with data from other commercial vessels (Robinson *et al*, 2010).

fish weighing less than 2 g (California Department of Transportation, 2009). The peak noise criterion of 206 dB re 1 µPa (peak) is not expected to be exceeded at any location based on the noise sources of dredgers and cumulative exposure at this level is also very unlikely due to the mobile nature of fish. This conclusion has also been drawn by Thomsen *et al*. (2011), who have concurred that dredging activity is very unlikely to cause injury to fish.

Marine fish are likely to be able to detect dredging noise over significant distances, and there may be a potential for behavioural effects such as avoidance of dredging zones and physiological damage (Cook and Burton, 2010). CEDA (2009) concluded from an investigation into the hearing abilities of marine fish that the greatest effect is likely to be temporary avoidance of the affected area (Tillin *et al*., 2011) although there is a general consensus that it is very difficult to measure (Popper and Hastings, 2009a). It was concluded that aggregate extraction may cause '*minor and short-term changes*' to the distribution of fish (Tillin *et al*., 2011).

Whilst dredging activities are capable of producing noise that can be detected by fish and may cause temporary avoidance behaviour, in order to understand whether these impacts are significant at a regional level these potential effects must also be considered within the baseline context. The ambient underwater noise baseline (see Chapter 4) describes the varied sources of ambient noise in the study area, the greatest contributor being the widespread shipping that operates constantly in the MAREA study area and wider North Sea. Current fish distribution and fisheries activity in the area suggest that fish are somewhat habituated to the current levels of anthropogenic noise, including current dredging noise.

From this assessment it can be concluded that if noise has an adverse impact on fish in the area it will be behavioural, causing fish to exhibit avoidance behaviour of areas of significant underwater noise. This will lead to a local re-distribution of fish stocks; however, as the dredge zones represent a small proportion of available habitat this movement will not be significant on a regional scale. Due to the mobile nature of these organisms it is assessed that they will all have a high recoverability and will return to areas once dredging has stopped. Therefore, based on these assessments of the small – medium and medium magnitudes of the effect and the high value and high recoverability of the receptor combined with the limited interaction, the cumulative impact of underwater noise on fish ecology is considered to be of minor significance at a regional scale.

9.3.9 Change to Benthic Community Composition

A change to the composition of the benthic community as a result of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence because the majority of dredging occurs along tracks that have been dredged before and therefore the frequency of previously un-dredged seabed (and the associated benthic communities) being affected is low. As a result it is classified as a medium – large magnitude.

Herring, Salmon and Sprat

Herring, salmon and sprat are pelagic species that predominantly feed on small fish and plankton in addition to a small number of benthic organisms. As they do not rely solely on benthic organisms as prey items, they can be considered to have high tolerance, adaptability and recoverability to changes in benthic communities. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to changes in benthic communities is considered to be low.

Salmon have a low abundance throughout the study area and will most commonly be found in the coastal margins and in estuaries. Herring and sprat are widely distributed throughout the study area but are highly mobile. As a result there will be a very small degree of interaction between these species and any changes to benthic communities as a result of dredging within the study area over the 15 year period of the MAREA.

Based on these assessments of the medium – large magnitude of the effect, the high and medium value and low sensitivity of the receptors combined with the very small degree of interaction between the receptor and the effects, the cumulative impact of changes in benthic communities on herring, sprat and salmon is considered to be not significant at the regional scale.

Eel, Smelt, Seahorses, Cod, Sandeel, Bass, Grey Gurnard, Red Mullet, Bib, Smoothound, Starry Smoothound, Spurdog, Lesser Spotted Dogfish, Spotted Ray and Thornback Ray

Eel, smelt, seahorses, cod, sandeel, bass, grey gurnard, red mullet, bib, smoothound, starry smoothound, spurdog, lesser spotted dogfish, spotted ray and thornback ray feed on a variety of prey including plankton, benthic invertebrates and fish. Their tolerance and adaptability to changes in benthic communities is assessed as medium as they depend on some benthic species as a food source but are able to forage over a large area as well as utilise some pelagic food sources. Recoverability is assessed as high as they are generally found throughout the study area (with the exception of seahorses which will generally only be found in the coastal margins) as these species are not limited to foraging in a small area and are capable of preying upon a wide variety of species. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to changes in benthic community composition is considered to be low – medium.

Seahorses, eel and smelt are not common within the study area and are predominantly distributed in the southern half of the study area along the coastal margins. Grey gurnard, red mullet, bib, smoothound, starry smoothound, spurdog, lesser spotted dogfish and spotted ray are found throughout the study area but are not common species. They are therefore unlikely to overlap in distribution with the change in benthic community composition associated with dredging operations. Cod, sandeel, bass, sole and thornback ray are more widely distributed throughout the study area. However, the area within which the dredging activities occur and where changes in benthic communities may take place only constitutes a very small amount of the overall available habitat. As a result the degree of interaction of these species with the effect of changes in benthic communities is small.

Based on these assessments of the medium – large magnitude of effects, the medium – high value and medium – low sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of changes in benthic communities on these species is considered to be not significant at the regional scale.

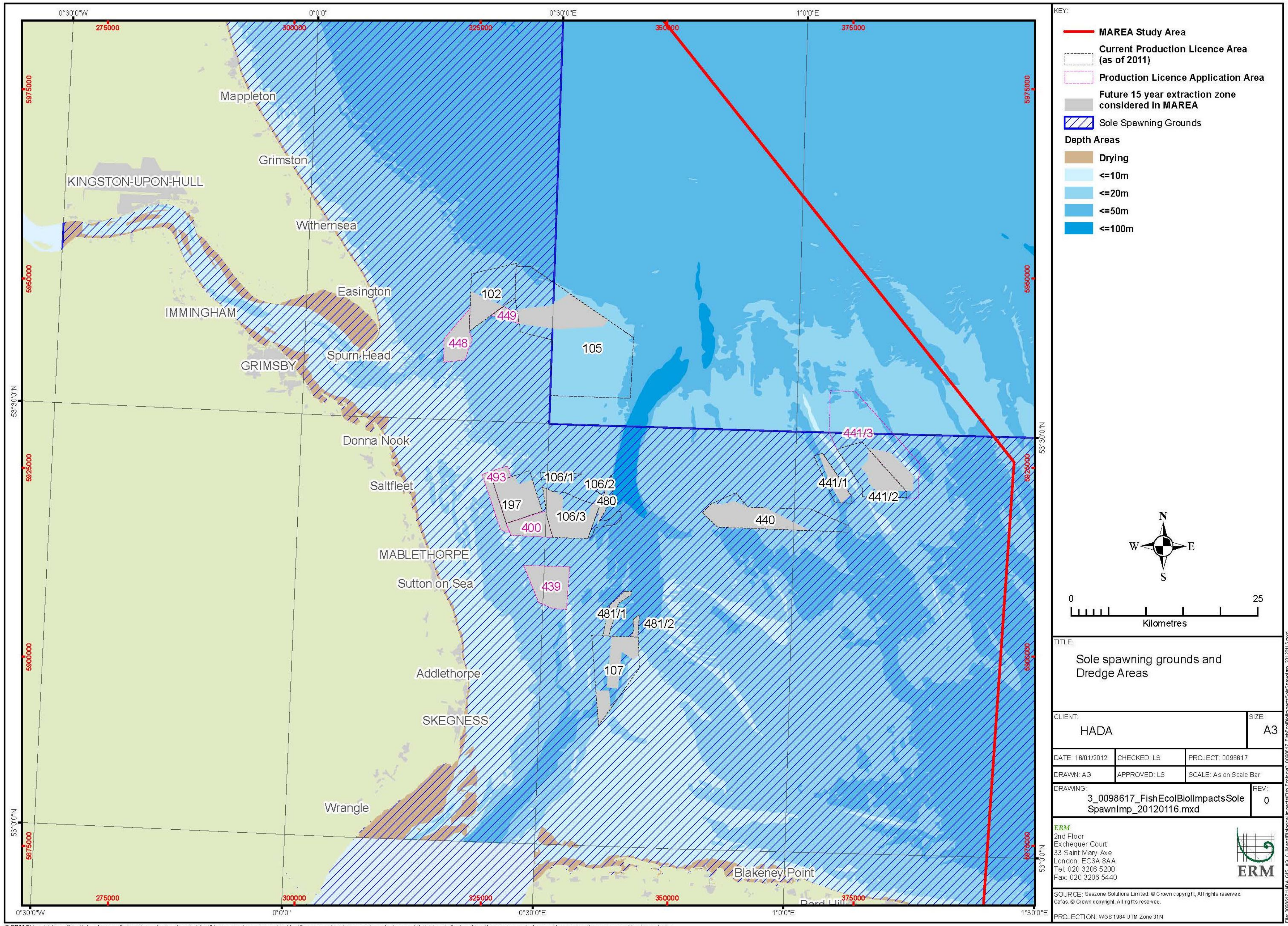
Sole, Pogge, Dragonet, Plaice, Lemon Sole and Dab

Sole, pogge, dragonet, plaice, lemon sole and dab feed primarily on benthic infauna. Their tolerance and adaptability to changes in benthic communities is assessed as low - medium as they rely on these species almost entirely for their food source, however they are all mobile species that are capable of moving foraging areas to a more suitable benthic environment that has not been affected. Recoverability is assessed as high as they are generally found throughout the study area and none of these species are limited to foraging in a small area. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to changes in benthic community composition is considered to be medium.

Sole have extensive spawning and nursery grounds throughout the study area, primarily in the more inshore areas. These areas overlap with all future 15 year extraction zones (figure 9.12). However, the area within which the dredging activities occur and therefore where changes in benthic communities may take place only constitutes a very small amount of the overall available habitat. Pogge, dragonet, plaice, lemon sole and dab are not as common throughout the study area therefore it is unlikely that there will be interaction between these species and areas of changed benthic communities. As a result the degree of interaction of these species with the effect of changes to benthic communities is small.

Based on these assessments of the medium – large magnitude of effects, the medium – high value and medium sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of changes in benthic communities on sole is considered to be minor at the regional scale. The cumulative impact of changes in benthic communities on pogge, dragonet, plaice, lemon sole and dab is considered to be not significant at the regional scale.

Figure 9.12 Sole spawning grounds and Dredge Areas



9.3.10 Change to Distribution of Fish

A change in distribution of fish prey species as a result of dredging operations is a small magnitude effect based on its localised extent, its medium term in duration and transient nature. There is also a low level of change relative to baseline levels but it is regularly occurring (routine). It is noted that any change to fish distribution will be a localised effect and will not impact the whole population due to the mobile nature of the fish species discussed.

Whiting and Mackerel

Whiting and mackerel are widely distributed throughout the study area and feed on small fish such as Norway pout and sprat as well as juveniles of larger species including their own. Juveniles also feed on pelagic zooplankton and copepods. As a result, changes to the distribution of prey species may affect the distribution of whiting and mackerel as they forage. Tolerance, adaptability and recoverability have all been assessed as high due to the large foraging area to which whiting and mackerel have access. Following the cessation of any one dredging event, prey species and therefore whiting and mackerel are likely to return to the area. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of whiting and mackerel to change in fish prey distribution is considered to be low.

Mackerel (Scomber scombrus)

Source: Shutterstock.com

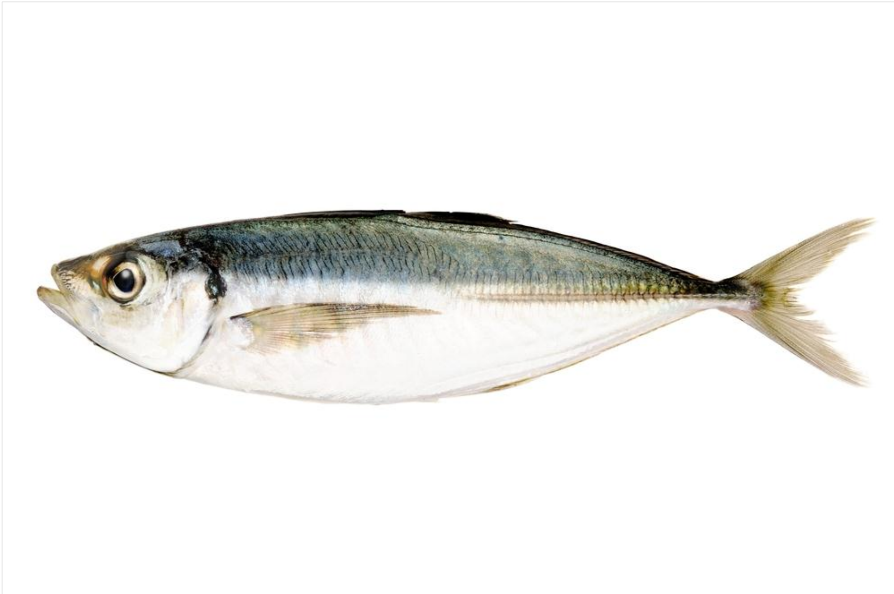
Whiting and mackerel are widely distributed throughout the study area. However, the area within which dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. As a result the degree of interaction of whiting and mackerel with the effect of changes in fish prey distribution is assessed as being small.

Based on these assessments of the small – medium magnitude of the effect, the medium value and low sensitivity of the receptors combined with the small degree of interaction between the receptor and the effect, the cumulative impact of changes in fish prey distribution on whiting and mackerel is considered to be not significant at the regional scale.

Salmon, Sea Trout, Allis Shad, Twaite Shad, Sea Lamprey, River Lamprey, Smelt, Cod, Bass, Atlantic Horse Mackerel, Haddock, Grey Gurnard, Bib, Brill, Smoothound, Spurdog, Starry Smoothound, Lesser Spotted Dogfish, Spotted Ray and Thornback Ray

Salmon, sea trout, allis shad, twaite shad, sea lamprey, river lamprey, smelt, cod, bass, Atlantic horse mackerel, haddock, grey gurnard, bib, brill, smoothound, spurdog, starry smoothound, lesser spotted dogfish, spotted ray, and thornback ray all feed at least partially on other fish species. Therefore a change to the distribution of fish prey species may result in a detectable change to the distribution of these species at a regional scale. However they are assessed as having a medium level of tolerance and adaptability to this effect as a result of their ability to target other species as prey or move to other areas. Recoverability is assessed as high since following the cessation of any one dredging event, prey species are likely to return to the area and attract these predator species back.

Atlantic horse mackerel (Trachurus trachurus)



Source: Shutterstock.com

Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species and the effect of changes in fish distribution is assessed as low - medium.

Salmon (Salmo salar)

Source: Shutterstock.com

Salmon, sea trout, allis shad, twaite shad, sea lamprey, river lamprey and smelt are not common within the study area and are predominately distributed inshore close to the rivers into which they migrate for spawning. Although Atlantic horse mackerel, haddock, grey gurnard, bib, brill, smoothound, spurdog, starry smoothound, lesser spotted dogfish and spotted ray have been documented within the study area they are not common and this is not a dominant habitat for them. The dredged areas and thus areas within which changes to fish distributions may occur is relatively small, and will only result in small changes to fish prey distribution. As a result, the degree of interaction between these species and the effect of changes in prey distribution is assessed as small.

Based on these assessments of the small magnitude of the effect, the medium – high value, the low – medium sensitivity of the receptor and the effect, and the small degree of interaction, the cumulative impact of changes to fish prey distributions on these species is considered to be not significant at the regional scale.

9.3.11 Changes to Seabed Features

Information from the seabed features impact assessment (Section 8.2) suggests that there may be impacts of significance to seabed features, but these will be minor at most. A change to seabed features as a result of dredging operations is a small magnitude effect based on the fact that it is a routine effect that is medium term in duration; however, any changes will be very localised and constitute a low level of change relative to baseline levels (sandbanks are naturally mobile features).

Sandeel

Sandeel show a relatively strong association with sandbanks along with other suitable sandy seabed habitat and therefore changes to seabed features could lead to changes in their general distribution. Sandeel are assessed as having a medium tolerance and adaptability to changes in sandbanks as other suitable habitat is available but their distribution might be changed. Sandeel are assessed as having high recoverability to the effect as sandbanks are dynamic features and other habitat suitable for sandeel will become available in the medium term. Sandeel are therefore assessed as having low - medium sensitivity to changes in seabed features including sandbanks.

Although sandeel are found associated with sandbanks they are also distributed widely across the MAREA study area and are not limited to using sandbanks as their habitat. As a result the degree of interaction of sandeel with changes to sandbanks is assessed as being small.

Based on these assessments of the small magnitude of the effect, the medium value and low - medium sensitivity of the receptor combined with the small degree of interaction between the receptor and the effects, the cumulative impact of changes to seabed features on sandeel is considered to be not significant at the regional scale.

Sole, Plaice, Lemon Sole, Dab, Brill and Thornback Ray

Sole, plaice, lemon sole, dab, brill and thornback ray are commonly found on or along the sides of sandbanks. Changes to sandbanks from effects such as sediment particle size changes, tidal current changes or sand deposition may affect distribution due to a change in their habitat conditions. Therefore tolerance and adaptability to changes to sandbanks have been assessed as medium. Recoverability is assessed as high as sandbanks are naturally dynamic and thus habitat conditions would be subject to natural changes. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of these species to changes to sandbanks is considered to be low-medium. Although these species are found associated with sandbanks they are also distributed throughout the entire MAREA study area and are not limited to using sandbanks as their habitat. As a result the degree of interaction of these species with changes to sandbanks is assessed as being small.

Lemon Sole (Microstomus kitt)

Source: Shutterstock.com

Based on these assessments of the small magnitude of the effect, the medium-high value and low-medium sensitivity of the receptors combined with the small degree of interaction between the receptors and the effects, the cumulative impact of changes to seabed features on these species are considered to be not significant at the regional scale.

Dab (Limanda limanda)

Source: Shutterstock.com

9.3.12 Summary of Impacts

Table 9.8 summarises the significance of the cumulative impacts of dredging on fish ecology at a regional scale.

The impacts to fish ecology that are predicted to be significant are assessed as being Minor - Moderate and are likely to affect at most only a small proportion of the regional population of any one species at any one time.

The following points are noted regarding impacts that may require further consideration at the EIA stage.

- Impacts to herring: all licence areas except for 441/1, 441/2, 441/3 and 107 overlap with the data available indicating herring spawning and nursery grounds, resulting in regional impacts of potentially minor significance for the effects of removal of sediment, fine sediment plume, sand deposition and changes to tidal currents. This issue may require discussion at the EIA stage for the other licence areas.

- Impacts to sole: all licence areas are located within documented sole spawning and nursery grounds and the impacts to sole due to changes in the benthic community composition.

Impacts to thornback ray, lesser spotted dogfish and spotted ray: Thornback ray, lesser spotted dogfish and spotted ray may be impacted by removal of sediment and sand deposition to levels of minor significance. The future 15 year extraction zones of the following licence areas overlap with the spawning grounds of thornback ray: 481, 439, 493, 400, 197, 106, 107, 480 and 440.

Table 9.8 Summary of Impacts to Fish Ecology

Effect of Dredging	Salmon	Sea Trout	Allis Shad	Twaite shad	Eel	Sea Lamprey	River Lamprey	Smelt	Seahorse	Cod	Bass	Whiting	Sole	Haddock	Grey Gurnard	Gobiidae	Snake pipefish	Red mullet	Bib	Pogge	Dragonet	Plaice	Lemon sole	Dab	Brill	Sandeel (both genus)	Herring	Sprat	Mackerel	Atlantic horse mackerel	Smoothound	Spurdog	Starry Smoothound	Tope	Spotted Ray	Lesser spotted dogfish	Thornback ray
Presence of Vessel																																					
Removal of sediment										NS	NS		NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS											
Fine sediment plume	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	NS	N S
Sand deposition										NS	NS		NS	NS		NS	NS	NS	NS			NS	NS	NS	NS	NS											
Changes to sediment particle size													NS									NS	NS	NS	NS	NS											
Changes to wave height																																					
Noise	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS
Changes to tidal currents																						NS														NS	NS
Changes to benthic community composition	NS				NS			NS	NS	NS	NS			NS	NS	NS		NS	NS	NS	NS	NS	NS	NS		NS	NS	NS			NS	NS	NS		NS	NS	NS
Changes to distribution of fish	NS	NS	NS	NS		NS	NS	NS		NS	NS	NS		NS	NS				NS						NS				NS	NS	NS	NS	NS		NS	NS	NS
Changes to seabed features													NS									NS	NS	NS	NS	NS											NS

NS	Not significant
	Minor significance
	No interaction
	Not affected

9.4 POTENTIAL IMPACTS TO MARINE MAMMALS

9.4.1 Introduction

As discussed in Section 5.4, the harbour porpoise, common seal and grey seal are the only species considered to be resident in the MAREA study area. Due to the presence of these species in the MAREA study area they may experience impacts from dredging operations, and will therefore be the focus of this impact assessment. Other species that have been recorded in the area are considered to be rare or occasional visitors to the area and, as such, are excluded from the assessment.

9.4.2 Value of Receptors

Harbour Porpoise

Harbour porpoise are the most abundant cetacean recorded within the study area and although they are known to be wide-ranging, they commonly use the area for breeding and foraging and are understood to be resident in the area. The North Sea population is understood to be stable although some southward shift in distribution has been observed (SCANS II, 2006). The harbour porpoise is an important predator of fish species in the wider ecosystem with a diet that consists of many species known to be widespread in the MAREA study area (Santos and Pierce, 2003).

The species has international conservation status by virtue of its listing in the *Berne Convention*, the *Bonn Convention*, OSPAR, CITES, and under the *'Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas' (ASCOBANS)*. It also receives protection through European and UK legislation in the form of Annexes II and IV of the *EC Habitats Directive* [(1)], Section 74 (repealed in Schedule 12) of the *Countryside and Rights of Way Act 2000*, and Schedule 5 of *the Wildlife and Countryside Act 1981*. There is a UK Species Action Plan for the harbour porpoise, and the species forms part of the local Biodiversity Action Plan for Norfolk (see Section 5.4).

The protection of the harbour porpoise under the Habitats Directive means that the MAREA must consider the amended *Conservation of Habitats and Species Regulations 2010* during the assessment of potential impacts to this species. In particular, the requirement for EIAs to consider the potential for any of the dredging activity to result in deliberate disturbance must be considered. This issue is discussed further in Section 9.4.4.

(1) Under the EC Habitats Directive, Annex I covers habitats, Annex II species requiring designation of special areas of conservation, Annex IV species in need of strict protection, and Annex V species whose taking from the wild can be restricted by European law.

Common and Grey Seal

Common seals and grey seals are also resident within the MAREA study area, using several coastal haul-out sites throughout the year and ranging across the MAREA study area for foraging. The UK supports approximately 40% and 45% of the world population of common and grey seals respectively (Davies *et al*, 2001) and (Hiby *et al*, 1996). The majority of UK grey seals are found in Scottish waters with the English east coast sub-population comprising less than 10% the total numbers. Common seals are more prevalent in the MAREA study area, with the largest colony in the UK found inhabiting the Southern North Sea Marine Natural Area centred on and around The Wash and the sandbanks of the north Norfolk coast. This colony is of international importance and North Sea seals are keystone predator species in the wider ecosystem. Their populations are understood to be stable or slowly increasing despite viral outbreaks and other threats.

Both seal species are listed in the *Bonn* and *Berne Conventions* as well as in Annexes II and V of the *EC Habitats Directive*. In the UK, seals are also protected under the *Conservation of Seals Act, 1970* (see Section 5.4) and the common and grey seal are both included in a grouped local BAP for Lincolnshire. The grey seal is an Annex II qualifying feature of the Humber Estuary SAC, and the common seal is an Annex II qualifying feature of The Wash and North Norfolk Coast SAC.

Seals at Blakeney Point

Source: Shutterstock.com

Common seals and grey seals are found throughout the MAREA study area and may therefore be similarly impacted by the effects of dredging. However, the overall UK grey seal population may be less sensitive to impacts than common seals as they are found in lower numbers within the MAREA study area, suggesting that the MAREA study area is of less importance to this species. On the basis of the available data, a conservative approach is taken and the same impact assessment criteria are applied to both. The following impact assessment therefore discusses 'seals' as a group rather than the individual species.

Summary

The common and grey seal receive conservation status under UK and EU law, but the only European Protected Species that is strictly protected under Annex IV of the *Habitats Directive* and recorded in the study area is the harbour porpoise. In light of the designations for these species and their keystone role in the wider marine ecosystem, all three marine mammal species are considered to be high value receptors.

9.4.3 Identification of Potential Impacts on Marine Mammals

Table 9.9 identifies the predicted effects of dredging with reference to whether or not they have the potential to impact harbour porpoises and seals, with common and grey seals grouped together.

Table 9.9 Matrix of Potential Impacts of Dredging on Marine Mammals

	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to seabed features
Harbour porpoise	✓	■	✓	■	■	■	■	■	✓	■	■	✓	■
Seals	✓	■	✓	■	■	■	■	■	✓	■	✓	✓	✓

Not affected	■
no interaction	×
potential interaction	✓

9.4.4 Harbour Porpoise

Presence of Vessel

When considering the impact of dredging vessel presence on marine mammals, it is important to understand the wider shipping context. The MAREA study area has a higher average shipping density than many marine areas elsewhere in the UK (Chapter 6.5 and Appendix H). For comparison, an average shipping cell of approximately 0.5 square nautical miles in the UK waters has a shipping density in range 50 to 200 ships per year, with top-ranked cells exceeding 600 ships per year. The average shipping cells in the MAREA study area have a range of 130 to 350 ships per year with top-ranked cells exceeding 700 ships per year.

The 28 day shipping survey recorded an average of 150 commercial vessels per day in the MAREA study area, with the majority being cargo vessels and tankers. Within this number, the average number of aggregate dredgers was three vessels per day (see Section 6.5). The day of highest vessel activity recorded 177 vessels in the MAREA study area, whilst the highest number of dredging vessels operating at any one time was five. The breakdown of vessel type found 4% of the commercial shipping activity in the MAREA study area during the 28 day survey to be aggregate dredgers. When compared with all types of shipping activity including fishing and recreational vessels, the percentage of total shipping movements made up by aggregate dredgers decreased to approximately 1.2%.

The maximum future dredging scenario anticipates a three-fold increase in aggregate dredging vessel activity in the study area, which amounts to approximately 2% of all shipping activity assuming no increase in other vessel movements.

The presence of additional dredging vessels is therefore considered to be a small magnitude effect, based on it being site-specific in extent and regularly occurring (routine). It is transient (temporary), and constitutes a low level change relative to the baseline.

Harbour porpoise are timid animals that generally avoid large vessels by diving or swimming away. The species is therefore classified as having a medium tolerance and a high adaptability to vessel presence due to its high level of mobility and avoidance behaviour. Harbour porpoise populations are understood to be stable and to be migrating southwards in the North Sea (SCANS II, 2006), with the implication that the presence of dredging vessels is not affecting their ability to inhabit the area. This species is therefore assessed as having high recoverability to the presence of vessels on a regional scale as harbour porpoise do not currently appear to be deterred from inhabiting an area of dredging activity. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of harbour porpoise to vessel presence is considered to be low.

Harbour porpoises are highly mobile and widely distributed throughout the study area so the entire MAREA study area is considered to be potential harbour porpoise habitat. The future shipping density plots produced by the shipping and navigation study illustrated the extent of future shipping density predicted, highlighting that a significant extent of the study area will be subject to a high (200-1000 ships per year) or very high (>1000 ships per year) level of vessel density based on future dredging scenarios (see Section 6.4 and Appendix H).

Given that the species is highly mobile over a very large area, the likelihood of individual harbour porpoises being in the same locality as a dredging vessel at any one time is low resulting in a low degree of interaction. Acknowledging the high value of the receptor but noting the small magnitude of the effect, the low-medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of dredging vessel presence on the harbour porpoise is considered to be not significant at the regional scale.

Fine Sediment Plume

The presence of suspended sediment plumes during dredging operations that has a concentration above background levels is a small to medium magnitude effect for 2-20 mgl^{-1} and 20 - 50 mgl^{-1} plumes and a medium magnitude effect for plumes of 50 - 100 mgl-1 and >100 mgl-1. This is based on the local extent of the plume (for the 20-50 mgl-1 and 50-100 mgl-1 plume) or site specific extent (for the > 100 mg l -1 plume) and them being regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 2-20 and 20 - 50 mgl^{-1} plumes and a medium change relative to baseline conditions for the 50-100 mgl^{-1} and > 100 mgl^{-1} plumes.

Harbour porpoises are widely distributed throughout the study area so any sediment plume within the MAREA study area may be considered to be within harbour porpoise habitat. Plumes within this habitat have been modelled for the seabed concentration footprints and as depth average for the averaged concentration through the water column. As harbour porpoise commonly feed on benthic and epibenthic species such as sandeel and various crustacea, the bed concentrations are considered to be of greater relevance to harbour porpoise than averaged concentrations and are therefore taken forward for assessment.

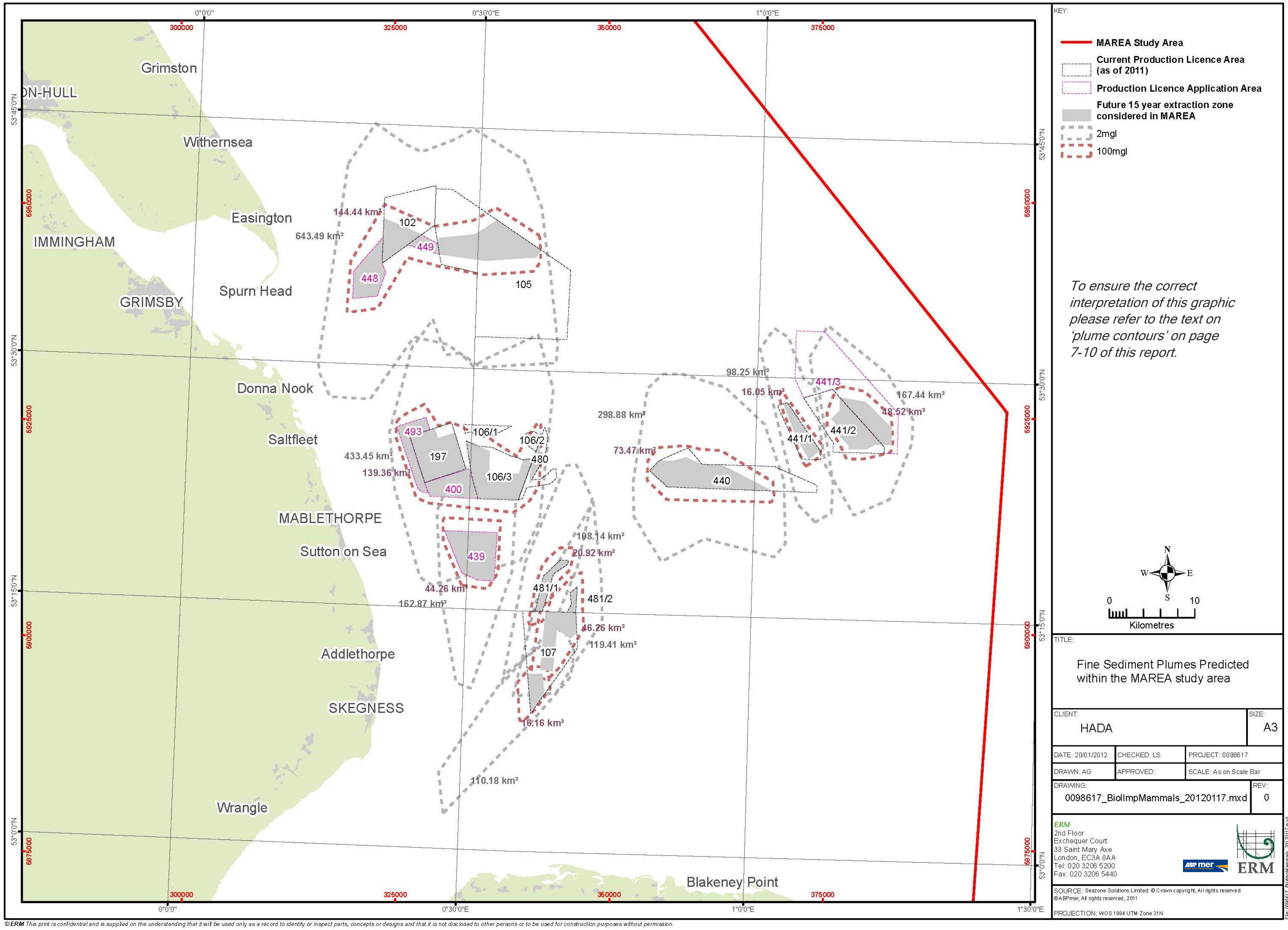
Fine sediment plumes with concentrations above background levels at the seabed are predicted to impact on a total area of approximately 1,584 km^2 at some point over the next 15 years, and plumes with concentrations of 100 mg l^{-1} or higher are predicted to impact on approximately 528 km^2 of the MAREA study area (Figure 9.13).

These figures are based on a worst-case scenario with dredging assumed to take place throughout each licence area at all times, whereas in practice there will be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in a licence area would be much smaller than the modelled plumes in Figure 9.13. As a result the interaction between the receptor and the effect is considered to be low.

Dredging Vessel Loading the Hopper at Sea

Dredging Vessel Unloading onto the Wharf

Figure 9.13 Fine Sediment Plumes Predicted within the MAREA Study Area



Harbour porpoise generally have good vision and whilst they are functionally colour blind (Peich. *et al*., 2011), their eyesight is adapted to low light conditions. Despite this, they are widely understood to use echolocation for navigation, communication and the identification and capture of prey so the presence of a fine sediment plume at the seabed as a result of dredging is not considered to significantly alter their orientation or ability to find food.

Harbour Porpoise (Phocoena phocoena)

Source: Shutterstock.com

The water quality baseline presented in Chapter 4 describes the high levels of suspended sediments entering the North Sea from the Humber Estuary and The Wash. Whilst the precise concentrations vary seasonally and as a result of storm surges and other events, harbour porpoise inhabiting this area are likely to be habituated and well adapted to tolerate conditions of high suspended sediment load. Therefore, the harbour porpoise is considered to have a high tolerance of high suspended sediment loads and therefore of sediment plumes from dredging. It also has a high adaptability as the species is sufficiently mobile to avoid or swim away from areas of elevated turbidity if necessary. There will be no physical harm to harbour porpoises as a result of an aggregate dredge plume and the animal is expected to quickly return to the area once dredging has ceased as it is habituated to naturally fluctuating suspended sediment concentrations in this part of the North Sea. Its recoverability is therefore considered to be high.

Based on the above consideration of tolerance, adaptability, and recoverability, the overall sensitivity of harbour porpoise to fine sediment plumes is low.

Based on these assessments of the small-medium magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of the fine sediment plumes on this species is assessed to be not significant at the regional scale.

Underwater Noise

As harbour porpoise use echolocation for navigation, communication and the identification and capture of prey, underwater noise above the ambient levels to which they are habituated has the potential to impact upon their ability to go about their normal behaviour.

Harbour porpoises are sensitive to a very broad bandwidth of sound and are responsive to underwater noise at frequencies from 100 Hz to 170 kHz. Peak hearing sensitivity occurs over the frequency range from 20 kHz to 150 kHz. At this frequency the harbour porpoise is thought to be capable of hearing narrowband sounds as low as 40 dB re 1 µPa (Kastelein, *et al.,* 2002). They vocalise using clicks and other sounds with a frequency of approximately 2 Hz, and they echolocate with short intense pulses of 110-150 kHz and with source levels of 135-177 dB re 1 µPa at 1m (Richardson, *et al.,* 1995).[(1)]

The recent MASLF report by Robinson *et al.* (2010) determines the level and frequency of underwater noise resulting from aggregate dredging as described in Chapter 7. The highest dipole (Southall *et al*, 2007) level measured in this study was from the Sand Harrier dredging vessel, for which a maximum noise source level of 181.4 dB re 1μPa^2 m^2 at a frequency of 158.5 Hz was calculated at 1 m from the source during full dredging mode. Other frequencies were recorded propagating from this vessel but at lower levels (Robinson *et al*., 2010).

A paper published by Southall *et al.,* (2007) of the Marine Mammal Criteria Group has been increasingly adopted as the best practice assessment method for addressing the impacts of underwater noise on marine mammals. This study identified levels at which extreme noise can cause instantaneous auditory injury to various species and identified lower levels that can cause a variety of behavioural reactions. The criteria published in this work have therefore been used to derive criteria for the assessment of potential noise impacts from the proposed dredging operations on marine mammals in the MAREA study area.

The Southall *et al.* work reviewed data for activities involving multiple noise pulses such as seismic survey noise sources separately from more continuous, non-pulsed noise such as that from dredging vessels. It is important to note that the responses exhibited by marine mammals to pulsed noise sources tend to be more severe or exaggerated than those exhibited to continuous noise or those that are regularly experienced in the environment.

(1) However these units may not be directly comparable.

For example the noise from a slow moving vessel is likely to generate a lesser reaction than a fast moving vessel suddenly entering an area or an explosion.

The criteria in Southall *et al.* (2007) suggest that in order to cause instantaneous injury to cetaceans (including porpoise) resulting in a permanent loss in hearing ability (referred to as permanent threshold shift, PTS), the sound level must exceed 230 decibels (dB) re 1 micropascal (µPa) (peak). Subsequent research has suggested that a precautionary limit might be set for harbour porpoise for pulsed sound from an airgun of approximately 200 dB re 1 µPa peak. This research is based on a single individual animal in captivity and it has not been adopted as an update in a formal manner to the Southall *et al.* database. This threshold also applies to the pulsed sound from an airgun rather than the non-pulsed sound from a dredger. Nevertheless, since harbour porpoise is a high value receptor and a keystone predator species in the marine environment of the North Sea, this precautionary assessment criterion is used in the first part of this assessment.

The maximum measured noise level from an active dredger is below the most conservative threshold level for PTS in harbour porpoise [(2)]. Furthermore, given that harbour porpoise is an intelligent and highly mobile animal, it is unlikely that this species would approach or remain within an area of noise that it found intolerable or that could cause it auditory damage. Therefore, the likelihood of dredging noise causing a PTS to harbour porpoise is considered to be negligible, and is not considered further in this assessment.

The potential for underwater noise from aggregate dredging to impact marine mammals including the harbour porpoise is therefore considered in the second part of this assessment in terms of behaviours that can be exhibited in response to lower noise levels. The relevant criteria from the Southall *et al* .report and additional information of relevance to the MAREA is provided in Box 9.1.

Whilst dredging activities have been shown to be capable of producing underwater noise at and above this precautionary assessment level, the potential for this to impact upon harbour porpoise at a regional level must be considered within the baseline context. The ambient underwater noise baseline (see Chapter 4) describes measured ambient underwater noise data from studies conducted for offshore wind developments. The upper limits of these data are broadly comparable with the precautionary criterion selected for this assessment, with typical baseline levels recorded between approximately 95 and 145 dB re 1µPa (rms). Dredging noise is expected at low frequencies where ambient noise is likely to be highest at coastal sites due to shipping.

(2) Typically peak levels are 6 dB higher than rms.

Box 9.1 Relevant Detail from Southall Report

The US Marine Mammal Criteria Group (MMCG) has attempted to develop criteria (published as Southall *et al.*, 2007) that would help to document the level of behavioural response that can be expected from marine mammals if they are subjected to sound levels that coincides with the frequencies at which they are sensitive to noise. The MMCG's work in this regard involved compiling a database of studies on behavioural responses to sounds, for five different functional categories of cetaceans (low/mid/high frequency cetaceans, and pinnipeds in air/water). The documented responses to certain types of sound have been logged using a unique severity scoring system, which ranks the sound level at which behavioural responses start from zero for 'no response' to nine for 'outright panic, flight, stampede, attack of con-specifics or stranding events'. However, it is recognised that there are not enough data to be able to specify sound levels corresponding to all of the severity rating levels.

A severity rating level of '6' has been taken as the point at which impacts would become 'significant' for the MAREA, which is defined as:

- minor or moderate individual and/or group avoidance of sound source;
- brief or minor separation of females and dependent offspring;
- aggressive behaviour related to noise exposure (e.g. tail/flipper slapping, fluke display, jaw clapping/gnashing of teeth, abrupt directed movement, bubble clouds);
- extended cessation or modification of vocal behaviour;
- visible startle response; and
- brief cessation of reproductive behaviour.

Lower severity ratings are described in similar behavioural terms but with a specification that no avoidance of the noise source occurs. These behavioural response levels are not considered to be of consequence to harbour porpoise at a regional scale and are therefore not considered further in this assessment.

Since there is not always evidence for the sound level at which specific levels of behavioural response are seen, a precautionary approach has been taken by adopting the lowest exposure levels known to result in a Level 6 response. Studies reported on by Southall *et al.* (2007) show that harbour porpoise tend to respond to anthropogenic sounds at low exposure levels (90 to 120 dB re 1 μPa rms) at least for initial exposures. All recorded exposures exceeding 140 dB re 1 μPa rms induced avoidance behaviour in wild harbour porpoises but it was noted by Southall *et al.* (2007) that habituation was noted in some but not all of the studies. It is therefore precautionary to adopt 140 dB re 1 μPa rms as the criterion for Level 6 behavioural responses in this assessment; the extent to which sound levels may lead to behavioural effects on marine mammals is discussed in this section in the broader context of other relevant factors.

The sources of this ambient noise are varied, but the greatest contributor is understood to be the widespread shipping that operates constantly in the MAREA study area and wider North Sea. Robinson *et al* (2010) compared measured noise data from dredging vessels with other comparable merchant vessels including measured data for a large tanker similar to many that operate daily in the MAREA study area. The key findings from this work were that the dredging vessels studied propagate low frequency noise (below 500 Hz) at levels comparable with or less than that produced by merchant vessels travelling at a low speed of 8 knots. Frequencies above 500 Hz are emitted by vessels travelling at higher speeds and by dredging operations. It was found that the higher frequency bandwidths produced by operational dredging tended to be slightly higher than those produced by the merchant vessel travelling at a higher speed of 16 knots (Robinson *et al.*, 2010).

A fundamental difference between these two types of vessel is their operational durations in any given area and therefore their duty cycle [(1)]. Merchant vessels in the MAREA study area are typically steaming through en-route between international ports. Dredging vessels by comparison remain within a licence area, operating for up to eight hours at a time in the case of particularly large dredgers.

Whilst the noise levels produced by aggregate dredging have been assessed as posing no threat of auditory injury to harbour porpoise, there is potential for longer duty cycles to cause prolonged exposures and more subtle cumulative effects than those defined by Southall *et al.*'s Level 6 criterion. To date there has been little research into the influence of duty cycle, ambient noise 'budgets' that an ecosystem can sustain (Southall *et al.*, 2007), or the exposure times that could result in biologically significant behavioural responses (NRC, 2005a).

As noted in the assessment of impacts from vessel presence, the maximum (worst case) planned future dredging scenario over the 15 year MAREA period will represent a three-fold increase in aggregate dredging vessel activity in the study area which would result in an increase in underwater noise. This will consist of an increase in the total amount of dredging noise produced across the region over time. It does not however, equate to a three-fold increase in total noise levels in any one area or at any one time as the increase in dredging vessel activity will not occur simultaneously. The region is already experiencing high levels of shipping activity and ongoing dredging operations and is therefore characterised by a relatively high level of anthropogenic noise. The increase in vessel activity and longer duty cycles are not considered to result in a significant change to overall baseline conditions. The introduction of construction noise from the many planned offshore windfarms is likely to be a more significant contributor.

The presence of underwater noise as an effect of dredging is assessed as being a small to medium magnitude impact according to the following rationale.

Underwater noise levels at all frequencies attenuate with distance from the source as described in Chapter 7. As a result, the change relative to baseline varies with distance as the noise levels decrease in relation to ambient noise. Therefore, in this assessment it is necessary to describe the change relative to baseline as a range, from low to medium where a medium change is experienced close to the source and a low change is experienced with distance from it. The extent of the effect is considered to be local because the Level 6 response may only occur in close proximity to the noise source and the noise attenuates with distance from the source such that a Level 6 response may not be exhibited on a regional scale. The effect occurs for a temporary duration of up to a maximum of eight hours by any one vessel, and at a routine frequency during active dredging.

The distances over which underwater noise propagates are highly dependent on the sound frequency and a number of physical factors as described in Chapter 7. Given that harbour porpoise constantly use sound communication and navigation and that noise produced by aggregate dredging propagates from the source the degree of interaction between the receptor and the effect is considered to be medium.

Although the noise source is well within their audible range, baseline data taken from publications such as the SCANS II study and recent offshore windfarm surveys (see Section 5.4) have shown that there is a widespread distribution of the species across the MAREA study area and that the population is stable (SCANS II, 2006). The SCANS II data even indicate that there has been a southward migration of more northerly populations since 1994, which has occurred within a context of heavy shipping and ongoing dredging activities that produce underwater noise at and above the precautionary assessment criterion. The implication therefore is that harbour porpoise in the MAREA study are able to tolerate and become habituated to the ambient noise levels found there, including that produced by aggregate dredgers and that there is not currently a negative relationship between underwater noise and harbour porpoise population dynamics.

The phenomenon of habituation is widely published (NRC, 2005b) and as a result, harbour porpoise are considered to have a high tolerance to the underwater noise emitted by aggregate dredging vessels. This is expected to remain the same in the context of the future dredging scenario because the projected three-fold increase in dredging vessel activity will not be simultaneous. The cumulative effect of increased dredging frequency and longer duty cycles will result in an incremental increase in total underwater noise in the area, and is considered to be within the range of tolerance of this species.

In assessing these impacts it is important to note that the maximum future dredging scenario is precautionary and to place impacts from dredging within the context of other impacts. It is beyond the scope of the MAREA to assess the total noise contributions of all activities and industries in the region. However, several other sources of noise can be identified, including offshore windfarm development, oil and gas activities, and shipping. Shipping activity is the dominant source of background noise at present, and is likely to increase in line with future economic development. Marine piling activity associated with offshore windfarm construction will be a major source of underwater noise in the region over the coming decades, and is associated with a greater magnitude of impact. Increased dredging activity is therefore

(1) The proportion of time when a noise is present (Southall et al., 2007)

likely to make a relatively minor contribution to future noise levels in the region as compared to other sources.

Harbour porpoise are also considered to have a high adaptability as they are sufficiently mobile to avoid areas of the highest noise level in close proximity to the dredging vessel. Furthermore, the species is widespread in an area of high ambient underwater noise when there is available habitat in other areas of the North Sea that have less shipping traffic and therefore lower levels of ambient underwater noise.

The absence of any apparently negative effects on population dynamics in the noisy marine environment of the North Sea indicates that the recoverability of harbour porpoise is high. Based on consideration of tolerance, adaptability, and recoverability, the sensitivity of harbour porpoise to underwater noise from dredging is considered to be low.

Based on the above assessment, acknowledging the high value of the species in ecological terms but noting the low to medium magnitude of the effect, the low sensitivity of the receptor and the medium degree of interaction between the receptor and the effect the cumulative impact of underwater noise from aggregate dredging on harbour porpoise is considered to be of minor significance at the regional scale.

Changes to Distribution of Fish

Fish distribution is of relevance to the harbour porpoise because of their dependence on fish species as prey. Section 5.4 discusses the key prey species for harbour porpoise as herring, whiting, and sandeel, all of which are assessed in Chapter 9.3. Changes to the distributions of prey species as a result of dredging have the potential to cause a change in the distribution of harbour porpoise at a regional scale. This is particularly relevant as harbour porpoise commonly feed at or near the seabed (Santos and Pierce, 2003) as the prey is often more prevalent and easier to catch than in open water, so there is a potential secondary interaction between the effects of dredging that occur on or near the seabed and harbour porpoise.

A change in the distribution of fish species as a result of dredging operations is a small-medium magnitude impact as it is local in extent, temporary in duration, routine in frequency, and a low change relative to baseline. Given that harbour porpoise are present throughout the MAREA study area, it is likely that this species will interact with any changes in the distribution of their prey fish species. The degree if interaction between the receptor and the effect is therefore considered to be minor.

The diet of harbour porpoise is known to vary seasonally depending on the availability of prey species, and they have also been reported to geographically follow the seasonal distributions of prey species such as sandeel (Santos and Peirce, 2003). It is therefore within the natural behaviour of harbour porpoise to respond to changes in the distribution of fish so the species is therefore considered to have a medium level of tolerance and high level of adaptability to this effect. Section 9.3 considers the recoverability of fish species including those of concern to harbour porpoise. Whiting for example, were assessed as being likely to return quickly to a licence area following the cessation of dredging, with a high level of recoverability. Harbour porpoise are likely to return following the return of prey species so harbour porpoise are assessed as having a high level of recoverability to this effect. Based on this assessment of tolerance, adaptability and recoverability, harbour porpoise therefore have a low sensitivity to changes in the distribution of fish.

Acknowledging the high value of harbour porpoise, but taking into account the low sensitivity of the harbour porpoise species given that the species is able to feed on a range of species and is sufficiently wide-ranging and mobile to pursue fish such as herring that may be displaced by dredging operation, the impact to harbour porpoise as a result of changes in the distribution of fish is assessed as not significant.

Box 9.2 Deliberate Disturbance to European Protected Species

Under Article 12(1)(b) of the amended Habitats Regulations and the new Offshore Marine Regulations 2010, it is an offence to deliberately disturb European Protected Species in such a way that it is likely that there will be a significant effect on:

- the ability of any significant group of animals of that species to survive, breed, or rear or nurture their young; and
- the local distribution or abundance of that species.

The potential for a deliberate disturbance effect needs to be considered at the EIA stage. JNCC has provided useful guidance on this issue (JNCC, 2008) and makes the following statements about the potential for marine aggregate dredging to result in deliberate disturbance to Annex IV species (in this case the harbour porpoise):

"Concerns relating to impacts of this activity on marine EPS refer to those that could potentially arise from the noise generated by large vessels associated with dredging, prey reduction (through removal of benthic prey to fish) and by increased turbidity. In reality, the likelihood of these impacts causing a disturbance offence is very low, since the area affected is small and cetaceans are highly mobile. There are "Guidelines on the impact of aggregate extraction on European marine sites" [also published by the JNCC], *which discuss very briefly potential impacts of dredging activities on marine mammals. …*

…There are no specific good practice guidelines on how to mitigate disturbance of marine EPS during this activity since the potential for impacts and its significance are considered to be low. Mitigation measures associated with this activity are mostly aimed at reducing the impacts on the seabed and associated benthos and the effects of suspended sediment concentrations."

JNCC, 2008. The deliberate disturbance of marine European Protected Species - Guidance for English and Welsh territorial waters and the UK offshore marine area http://jncc.defra.gov.uk/PDF/consultation_epsGuidanceDisturbance_all.pdf

9.4.5 Seals

Presence of Vessel

As previously discussed for harbour porpoise (Section 9.4.4), dredging vessels in the MAREA study area operate within a wider shipping context whereby they account for 4% of the industrial shipping vessels present, or 0.7% of the total vessels including fishing boats and recreational craft. The increase in dredging vessels present as a result of the future dredging scenario will be three-fold, which will account for approximately 2% of all shipping activity in the MAREA study area assuming no increase in any other type of vessel movements.

The presence of additional dredging vessels is therefore considered to be a small magnitude effect, based on it being site-specific in extent and regularly occurring (routine). It is temporary in duration and constitutes a low level change relative to the baseline. Given the small numbers of dredging vessels within a large area of habitat suitable for seals, the degree of interaction between the receptor and the effect is considered to be small.

Despite the previously described high levels of shipping (Section 9.4.4), both common and grey seals are successfully inhabiting and breeding in the MAREA study area throughout the year and The Wash and North Norfolk coast in particular are supporting the largest population of common seals in the UK. Furthermore, seals are inquisitive animals and have been known to approach fishing vessels (EON, 2008), which is not a comparable behaviour with many other species of marine mammal that tend to be more timid.

Grey Seal (Halichoerus grypus)

Source:Shutterstock.com

Seals are therefore classified as having a high tolerance to vessel presence, and a high adaptability as a result of being able to avoid the vessel by moving away. Seals are assessed as having high recoverability as they would return to an area where a vessel has been if they have moved away while it passed.

Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of seals to vessel presence is considered to be low.

The entire MAREA study area is considered to be seal habitat as they are known to forage within ranges that extend beyond the boundaries of the study area (see Section 5.4). As stated in Section 9.4.4, a significant extent of the study area will be subject to a high (200-1000 ships per year) or very high (>1000 ships per year) level of vessel density based on future dredging scenarios, and using existing, established routes to which seals are already likely to be accustomed and habituated to.
Based on these assessments of the small magnitude of the effect, acknowledging the high value of the receptor but noting the low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of dredging vessel presence on seals is considered to be not significant at the regional scale.

Fine Sediment Plume

As previously described for harbour porpoise, the presence of a plume of suspended sediment as a result of dredging, with a concentration above background levels, is a small to medium magnitude effect for 2-20 and 20-50mgl^{-1} plumes and a medium magnitude effect for plumes of 50 - 100 mgl^{-1} and > 100 mgl^{-1}. These assessments of magnitude are based on the fact that the plume is local (for the 20-50 and 50 - 100 mgl^{-1} plume) or site specific (for the > 100 mgl-1 plume) and regularly occurring (routine).

However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 2-20 and 20-50 mg l^{-1} plume and a medium change relative to baseline conditions for the 50 - 100 mgl^{-1} and >100 mgl^{-1} plumes.

Seals generally have a good sense of vision that is well adapted to low light conditions and whilst seals are widely understood to use their eyesight to hunt and capture fish, blind but otherwise healthy individuals have been found at sea, including mothers rearing healthy pups (Renouf, 1983) and (Vancouver Aquarium,2011). There is inconclusive evidence regarding the ability of seal species to echolocate, but the mystacial vibrissae (or whisker follicles) are known to be extremely sensitive and widely used as sense organs for diving in low light (Dehnhardt and Kaminski, 1995), which may account for their well-recorded ability to capture prey in low light and high suspended sediment conditions (Riedman, 1990) and (Hyvarinen, 1989). Like the harbour porpoise, seals in this area are habituated to fluctuations in naturally occurring high levels of suspended solids that occur with storm surges, wave action, and rain events as described in Chapter 4. Therefore, seals are considered to have a high tolerance of sediment plumes.

They have a high adaptability to plumes as they are sufficiently mobile to avoid or swim away from areas of elevated turbidity if necessary. There will be no physical harm to seals as a result of an aggregate dredge plume and the animal is expected to quickly return to the area once dredging has ceased. Its recoverability is therefore assessed to be high. Based on consideration of tolerance, adaptability, and recoverability, the sensitivity of seals to plumes is considered to be low.

As seals are known to forage over wide areas of up to 120 km from their haul-out sites, the entire MAREA study area is considered to be potential seal habitat. For the same reason as for harbour porpoise, sediment plumes at the seabed are considered to be of greater relevance to seals than depth average modelled plumes. Approximately 1,584 km^2 of the study area will be exposed at some time during the course of the 15 year MAREA period to fine sediment plumes with concentrations above background levels at the seabed. Approximately 528 km^2 is predicted to be exposed at some time to concentrations exceeding 100 mgl^{-1} above background.

For any one dredging visit any plumes occurring would be associated with a single dredging vessel within a specific licence area and therefore the extent of exposure to the assessed concentrations would therefore be much smaller than the modelled plumes presented graphically. Given that seals spend considerable lengths of time in close proximity to the coast as they have a diurnal haul-out pattern (Evans, 2001), the likelihood of significant numbers of animals encountering an aggregate dredge plume at any given time is further reduced, and therefore the potential degree of interaction is low.

Based on these assessments of the small-medium magnitude of the effect, the low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, but acknowledging the high value of the receptor and the importance of the region for the populations in the MAREA study area, the cumulative impact of the fine sediment plumes on seals is assessed to be of minor significance at the regional scale.

Underwater Noise

Although research into their ability to echolocate is inconclusive, seals can vocalise sounds in the region of 0.1-16 kHz, and produce clicks between 0.1 and 40 kHz (Richardson *et al.*,1995). Seals are able to hear sound over the frequency range of 100 Hz to approximately 100 kHz, with peak underwater hearing sensitivity occurring over the mid-frequency range of 1 kHz to 40 kHz (Nedwell *et al.*, 2007). The grey seal is thought to be marginally less sensitive to underwater sound than the common seal although there is little evidence to support this (Parvin *et al.*, 2008).

The criteria in Southall *et al* (2007) (as described in Section 9.4.4) suggest that in order to cause instantaneous injury to pinnipeds resulting in a permanent loss in hearing or PTS, the sound level must exceed 218 dB re 1 µPa (peak). This level is not exceeded by the maximum measured source data published by Robinson *et al.* 2010 so the likelihood of dredging noise causing a PTS to seals is considered to be negligible, and is not considered further in this assessment.

A report published for the OSPAR commission Thomsen *et al.* (2009) presents an overview of the sensitivity to noise of marine mammals that are found in UK waters, with a general conclusion that seals are more sensitive to dredging noise than cetaceans as there is a more significant overlap between the emitted frequency spectrum and the bandwidth of hearing for seals. Given that there are stable breeding populations inhabiting the MAREA study area, there are no apparent negative effects on the population dynamics of seal species despite dredging noise being well within their audible range. This is expected to remain the same in the context of the future dredging scenario.

As previously described in detail in Section 9.4.4, underwater noise as an effect of dredging is assessed as being a low to medium magnitude impact based on the extent being local as a result of noise attenuation with distance from the dredging activity, of temporary duration and of routine frequency during active dredging, and constituting a low to medium change relative to baseline in the context of existing ambient underwater noise.

As seals constantly use sound in their normal behaviour and that noise from dredging propagates away from the source such that it will be audible to them, the degree of degree of interaction between the receptor and the effect is considered to be medium. Seals are assessed as having a high tolerance to the underwater noise emitted by aggregate dredging vessels as the species is widespread in an area of high ambient underwater noise when there is available habitat in other areas of the North Sea that have less shipping traffic and therefore lower levels of ambient underwater noise. It is considered to have a high adaptability as they are sufficiently mobile to avoid areas of the highest noise level in close proximity to the dredging vessel.

The stability of seal populations in the relatively noisy marine environment of the MAREA study area indicates that the recoverability of seals is high. Based on consideration of tolerance, adaptability, and recoverability, the sensitivity of seals to underwater noise from dredging is considered to be low.

Based on these assessments of the low to medium magnitude of the effect, the low sensitivity of the receptor, the medium degree of interaction between the receptor and the effect and the high value of the species in ecological terms, the cumulative impact of underwater noise from aggregate dredging on seals is considered to be of minor significance at the regional scale.

Changes to Benthic Community Composition

Change to the composition of benthic communities as a result of dredging operations is considered to be a local effect resulting from the direct removal of sediments, medium-term in duration as it takes time for largely sessile benthic communities to recolonise following the cessation of dredging, and constitutes a medium level change from baseline conditions as there is natural variability in the composition of benthic community compositions (Section 9.2). The effect is considered to be intermittent in occurrence in the existing licence areas as dredging tends to occur along previously dredged tracks so the frequency of un-dredged seabed being impacted occurs only in the minority of cases. This analysis results in a medium-large magnitude effect.

Small pelagic fish species make up the majority of the diet of North Sea seals, but they also eat crustaceans and other benthic species in albeit smaller quantities. Consequently seals are considered to have a high tolerance to local changes to benthic community composition as the species of concern do not represent their core diet. Seals are considered to have a high adaptability due to their high degree of mobility and their ability to find other prey species elsewhere. They also have a high level of recoverability as they will quickly resume their predation of benthic species once they become available. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of seals to changes to benthic community composition is considered to be low.

Several biotopes have been identified within the MAREA study area in which benthic prey species for seals are likely to be found, as follows.

- SS.SCS.ICS.SLan;
- SS.SSa.IFSa.IMSO;
- SS.SSa.IFSa.NcirBat
- SS.SCS.ICS.Glap
- SS.SCS.ICS.HeloMsim;
- SS.SCS.CCS.MedLumVen;
- SS.SSa.CMuSa.AalbNuc; and
- SS.SBR.PoR.SspiMx.

The total area of these habitats in the MAREA study area has been calculated using GIS as 1747 km^2, or 34.4% of the study area demonstrating a wide distribution of these biotopes as potential seal foraging habitat. The total area of these biotopes that will be directly disturbed by the future dredging scenario is calculated to be 71 km^2, which is 4 % of the total suitable biotopes available in the study area. Given the small proportion of the total available biotopes and the degree of regional interaction is considered to be very small.

Based on these assessments of the medium-large magnitude of the effect, the high value but low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to benthic community composition on seals is assessed to be not significant at the regional scale.

Changes to Distribution of Fish

In the same way as for the harbour porpoise, seals also commonly feed on fish at or near the seabed particularly over sand and gravel substrates (SMRU, 2008). Section 5.4 discusses the key prey species for common and grey seals as sandeel, flatfish such as plaice, sole, flounder, and dab, and whitefish such as cod, haddock, whiting, and ling. Small pelagic fish such as herring and sprat are also key prey species, both of which are assessed in Section 9.3. A change to the distribution of prey species as a result of dredging, if on a significant enough scale, has the potential to cause a change in the distribution of seals at a regional scale.

Seal diet composition exhibits temporal and spatial variability depending on prey availability and the process of foraging and searching for prey is within the natural behaviour of these species. Seals are therefore considered to have a medium level of tolerance and adaptability to changes in the distribution of fish.

The rationale applied to harbour porpoise with regard to recoverability may also be applied to seals. Section 9.3 identified a high level of recoverability in fish species including those of concern to seals, with fish quickly returning to disturbed areas following the cessation of dredging. Seals are also likely to return following the return of prey species so seals are assessed as having a high level of recoverability to this effect.

Based on this assessment of tolerance, adaptability and recoverability, seals therefore have a low sensitivity to changes in the distribution of fish. Section 9.3 assesses the removal of sediment and sediment plumes from dredging to cause minor impacts on herring. It also assesses changes in the distribution of benthic communities as causing a minor impact on sole. No other interactions with the identified seal prey species were found to result in an impact of significance at a regional scale. Given that seals are able to feed on a range of species and are sufficiently wide-ranging and mobile to pursue fish such as herring or sole that may be displaced by dredging operations, the impact to seals as a result of changes in the distribution of fish is assessed as not significant.

Herring (Clupea harengus)

Source: Shutterstock.com

Changes to Seabed Features

Changes to seabed features, in particular sandbanks, have the potential to affect seals in two ways; by changing their haul-out habitat on sandbank drying areas and by changing submerged sandbanks that serve as foraging habitat. There are no offshore sandbank drying areas used by seals in the MAREA study area and the coastal haul-out sites are not impacted by dredging operations (Chapter 8) so sandbank drying areas are not considered further in relation to seals.

Information from the seabed features impact assessment (Section 8.2) suggests that there may be impacts of minor or no significance to submerged sandbanks due to the direct removal of sediment. A change to sandbanks as a result of dredging operations is a small magnitude effect based on the fact that it is a routine effect that is medium term in duration. However, any changes are highly localised and constitute a low level of change relative to baseline levels as sandbanks are naturally mobile features (Section 8.2)

Seals are highly adaptable and will re-enter an area rapidly following disturbance by dredging or other activities. Furthermore, as they exhibit wide-ranging foraging behaviour and predate a range of species their ability to find food will not be adversely affected by small changes to submerged sandbank foraging habitats as a result of dredging activities. This is particularly true given that sandbanks in the region exhibit natural variability and change as a result of changing tidal currents and storm events (Section 4.3.3). Seals are therefore considered to have a high level of recoverability to changes to sandbanks. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of seals to a change in to sandbanks as a result of dredging is considered to be low.

The degree of interaction between potential changes to sandbanks and seal distribution is assessed to be very small as any significant changes to sandbanks are most likely to occur within the licence area boundaries, which only overlap with a very small proportion of available offshore sandbank habitat. Only two dredging areas directly remove sediment from sandbanks: Areas 440 and 441/3, and Areas 197, 439, 400, and 441 overlap with overfall features. Some localised reductions to the 1 in 200 year wave height were identified at the adjacent Triton Knoll, as well as at the Dudgeon Shoal and Race Bank sandbanks and the 10 in 1 year waves were modelled to show a low degree of interaction with offshore sandbank features. On a regional scale, these changes are not significant. No changes were modelled to occur at the Docking Shoal sandbanks adjacent next to Area 107, which are likely to be used as foraging areas by seals given their proximity to haul out sites in The Wash and on the North Norfolk coast.

Based on these assumptions of the small magnitude of the effect, the high value and medium sensitivity of the receptor, the small degree of interaction between the receptor and the effect, the cumulative impact of changes to the sandbanks on seals is assessed to be not significant at the regional scale.

Seals as Features of Protected Areas

Both seal species found in the MAREA region are listed as qualifying features for conservation designations in the region. The grey seal is an Annex II qualifying feature of the Humber Estuary SAC, and the common seal is an Annex II qualifying feature of The Wash and North Norfolk Coast SAC. Any impacts on these designations may therefore have an impact on the seals that occupy them. As qualifying features for these sites, any significant impacts on seals from dredging may also interfere with the conservation objectives of these sites.

The only potential impact identified for the Humber Estuary SAC as a result of dredging is altered distribution of fish, and particularly river and sea lamprey. This has been assessed as not significant in Section 9.6. The Wash and North Norfolk Coast SAC may interact with fine sediment plumes and increased turbidity as a result of dredging, but this is also expected to have no significant impact on the site.

Therefore, in both cases there will be no impact on the conservation objectives of the sites in terms of providing habitat to seal species. Impacts to seals from underwater noise and sediment plumes are predicted to be of minor significance for seals on a regional scale across the region and impacts of this level are not sufficient to affect the conservation objectives of these sites.

9.4.6 Summary of Impacts

Table 9.10 summarises the significance of the cumulative impacts of dredging on marine mammals at the regional scale.

Table 9.10 Regional Significance of Impacts to Marine Mammals

Effect of Dredging	Harbour Porpoise	Seals
Presence of the vessel	Not significant	Not significant
Fine sediment plume/elevated turbidity	Not significant	Minor significance
Underwater noise	Minor significance	Minor significance
Change to benthic community composition		Not significant
Change to the distribution of fish	Not significant	Not significant
Changes to seabed features		Not significant

The impacts to marine mammals from dredging are predicted to range from not significant to minor significance. As the species of concern commonly travel and forage alone or in small groups, these impacts are not likely to affect large portions of their regional populations at any one time.

Impacts to marine mammals will be discussed in all the individual EIAs in the context of 'deliberate disturbance' to European Protected Species and measures that may be taken to avoid this. The EIAs for all licence areas will also need to be responsive to any changes that may occur as the Marine Strategy Framework Directive is implemented in the UK with regard to underwater noise.

City of Westminster Trailing Suction Dredger Steaming at Sea

Shingle Ridge at Blakeney Point within The Wash and North Norfolk Coast SAC

Source: ABPmer

9.5 Birds

9.5.1 Introduction

This section presents the assessment of impacts to birds as a result of the proposed dredging operations within the MAREA study area. The discussion of impacts is organised according to the following species or species group, highlighted as being of importance to the study area within the baseline (Section 5.5):

- red-throated divers;
- northern gannets;
- kittiwake;
- gulls;
- terns; and
- auks.

Each of these species or species groups is discussed briefly below.

Red-Throated Diver

Red-throated divers are only present within the MAREA study area during the winter (see Section 5.5) and so this assessment relates to the impacts to the wintering population. The majority of the MAREA study area supports low numbers of divers, with localised concentrations within the Wash and off the North Norfolk Coast. The majority of divers which overwinter off the east coast of England occur in the outer Thames Estuary and off the east coast of East Anglia. Red-Throated Divers are a high value species due to their conservation status. They are listed on the Amber List of Species of Conservation Concern and in Annex I of the *Birds Directive*, and Schedule 1 of the *Wildlife and Countryside Act*.

Northern Gannet

Northern gannets may be found within the study area during all seasons as sub-adult birds may disperse over wide areas and breeding pairs may forage over large distances from breeding colonies. The majority of records came from the summer period although there were also abundant records of gannets during the winter (see Section 5.5) and so the sections below relate to the impacts to both the wintering and summer populations. Gannet number records within the study area are likely to relate to birds from populations which form part of the designated features of Special Protection Areas (SPAs). The MAREA study area provides important foraging habitat for the nationally important breeding colony at Bempton Cliffs. They are also listed on the Amber List of Species of Conservation Concern and they are considered to be bird species of high value as a receptor.

Gannet (Morus bassanus)

Source: Shutterstock.com

Kittiwake

Kittiwakes are found in the study area during both summer and winter, although they are only recorded at high densities during the summer. The majority of the birds recorded during the summer are likely to be associated with the large breeding colony at the Flamborough and Bempton Cliffs SPA and the MAREA study area provides an important foraging are for this internationally important population. Kittiwakes are considered to be a high value receptor as a result. During the winter, kittiwakes disperse over wide areas and are not limited in foraging range. During the winter therefore kittiwakes are considered to be medium value receptors.

Gulls

Gull species were recorded within the study area during both the summer and winter survey periods (see Section 5.5) although the distributions during the summer were greatly restricted. The impacts to both summer and winter populations using the area are discussed here. Although gull numbers in the study area are relatively high, in most cases they represent a small proportion of the regional populations of each species and are considered to be of medium value. Lesser black-backed, great black-backed, black headed, common and Mediterranean gull are all on the Amber List of Species of Conservation Concern. During the breeding season the herring gull breeding population at Flamborough Head and Bempton Cliffs forms part of the qualifying interest feature of the SPA. In addition herring gull is also on the Red List of Species of Conservation Concern and therefore is considered to be of high value.

Terns

Terns were recorded as being present within the study area during the summer surveys only (see Section 5.5) and so this assessment reflects the potential impacts to the summer breeding population. Tern numbers are relatively high within the southern half of the study area, with most birds being associated with populations which form qualifying interest features of coastal SPAs. The study area is therefore considered to be important for providing foraging areas for internationally and nationally important populations of common tern, Sandwich tern and little tern. Consequently, they are considered to be of high value as receptors. All species of tern are listed in *Annex I of the Birds Directive*, in *Schedule 1 of the Wildlife and Countryside Act*. Sandwich, little and Arctic terns are all on the Amber list of Species of Conservation Concern.

A Pair of Little Terns (Sterna albifrons)

Source: Shutterstock.com

Auks

Auks were recorded in high numbers during both the summer and winter surveys but with a more concentrated distribution during the summer breeding season (see Section 5.5). Therefore, this assessment relates to impacts to both the breeding and wintering population. Auks are considered to be of high value as receptors during the breeding season as the majority of the birds present within the study area are likely to originate from the population at Flamborough Head and Bempton Cliffs SPA and be involved in chick rearing with a limited foraging range. The north of the MAREA study area is an important foraging area for these breeding colonies and is therefore important for the regional population of guillemot, razorbill and puffin. During the winter season auks are considered to be medium value as the birds present are not restricted to a particular foraging range and the population within the study area is likely to contain birds from a number of colonies. All species of auks breeding in the UK are also on the Amber List of Species of Conservation Concern.

Common Guillemot (Uria aalge)

Source: ERM

Aerial View of Flamborough SPA on the Holderness Coast

Source: Shutterstock.com

9.5.2 Identification of Potential Impacts to Birds

Table 9.11 highlights the impacts from dredging which may potentially interact with the relevant groups of birds identified within the baseline.

Table 9.11 Matrix of Potential Impacts of Dredging on Birds

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to seabed features
Red-throated diver	✓	■	✓	■	■	■	■	■	■	■	■	✓	×
Northern gannets	✓	■	✓	■	■	■	■	■	■	■	■	✓	×
Kittiwakes	✓	■	✓	■	■	■	■	■	■	■	■	✓	■
Gulls	✓	■	✓	■	■	■	■	■	■	■	■	✓	■
Terns	✓	■	✓	■	■	■	■	■	■	■	■	✓	✓
Auks	✓	■	✓	■	■	■	■	■	■	■	■	✓	✓

Not affected	■
no interaction	×
potential interaction	✓

The effects of dredging most likely to interact with and have the potential to impact bird species within the MAREA study area are presence of the vessel, fine sediment plume/elevated turbidity and changes to the distribution of fish.

Presence of the Vessel

Future shipping density predictions (see Appendix H) incorporate the future tonnage applications and associated numbers of vessel movements for current licence areas and application areas within the study area, based on the regional tonnage scenario (i.e. maximum dredging scenario). However, it is worth noting that the presence of other vessels in the region is far greater than the presence of dredging vessels. The future scenario is predicted to double dredging activity relative to the baseline. However, overall dredging activity will still represent a low proportion (approximately 2%) of total shipping traffic in the Humber and Outer Wash area.

The presence of additional dredging vessels has been identified as a small magnitude effect, due to the site specific, regularly occurring (routine) and transient nature of the impact which represents a low level change relative to the baseline.

Fine Sediment Plume/Elevated Turbidity

The presence of suspended sediment plumes during dredging operations that has a concentration above background levels is a small to medium magnitude effect for 2-20 mgl^{-1} and 20 - 50 mgl^{-1} plumes and a medium magnitude effect for plumes of 50 - 100 mgl^{-1} and >100 mgl^{-1}. This is based on the local extent of the plume (for the 20-50 mgl^{-1} and 50-100 mgl^{-1} plume) or site specific extent (for the > 100 $mg\ l^{-1}$ plume) and them being regularly occurring (routine). However, the effect is temporary and the baseline data suggest that suspended sediment concentrations are higher in estuaries than further offshore. Therefore the plume only constitutes a low change relative to the baseline conditions for the 2-20 and 20 - 50 mgl^{-1} plume and a medium change relative to baseline conditions for the 50-100 mgl^{-1} and > 100 mgl^{-1} plumes.

Changes to Distribution of Fish

A change to the distribution of fish species as a result of dredging operations is a small magnitude effect. This is based on the localised and transient nature of the change and the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

Changes to Seabed Features

Information from the seabed features impact assessment (Section 8.2) has concluded that no nearshore banks will be directly affected by sediment removal. However, two of the future 15 year extraction zones overlap with sandbanks further offshore. Area 440 overlaps with 36 % of Triton Knoll (where up to 3 m depth of sediment may be removed) and Area 441/3 overlaps with 14% of an unnamed offshore bank (where up to 4 m depth of sediment may be removed), although this is a maximum depth in some areas only and in reality much of the depth changes will be less[(1)]. In addition to sandbanks, overfalls are present within the MAREA study area (see Section 8.2). Areas 493, 197, 400 and 439 are located along the Lincolnshire coast and all overlap with overfalls present on the seabed. The seabed in the area characterised by overfalls within Areas 197, 439 and 400 will be lowered by up to 6 m in places, including all of Protector Overfalls, 86% of Inner Dowsing Overfalls and 23% of the overfalls that extend into Area 400[(2)]. Removal of sediment from sandbanks and other seabed features as a result of dredging activity is assessed as being a small magnitude effect based on the site specific changes, the low level of change

(1) These depths have been interpreted from Figure 7.4 in Chapter 7
(2) These percentages represent the seabed area and not necessarily the full volume of the feature.

relative to the baseline, the routine occurrence and long term duration of effect. Overall, the impacts to sandbanks from a physical perspective have been determined to be not significant at a regional scale; however the changes in depth to sandbanks could potentially impact birds which forage around these features so will be considered here where relevant. The magnitude of effect on overfalls along the Lincolnshire coast is expected to be different but will be considered in more detail in site specific EIAs.

The following sections assess the impacts of these potential effects to the species groups present in the MAREA study area.

9.5.3 Red-Throated Diver

Presence of Vessel

Red-throated divers are known to be a shy species which will avoid boats and may maintain a stand-off distance of up to 2 km from vessels (Cook and Burton, 2010), although they have been known to become habituated to vessel movements in some areas.

Red Throated Diver (Gavia Stellata)

Source: Shutterstock.com

Since red-throated divers tend to actively avoid ships (Cook and Burton, 2010) they have been classified as having a low level of tolerance to the presence of vessels, and a low adaptability as they have specific habitat requirements in terms of water depth preferences. They have a medium recoverability however, and are likely to return to favoured feeding areas once vessels have left an area. Their overall sensitivity to the presence of dredging vessels has been classified as high (Cook and Burton, 2010).

The current distribution of red-throated divers shows that they are present at low densities across the MAREA study area and their distribution overlaps within the future 15 year extraction zones 448, 493, 197, 400, 106/3, 480, 439, 481/1, 481/2 and 107; this represent 1.5 % of the study area. In addition divers are largely absent from licences areas in the north and west of the MAREA area (see Figure 5.64. The degree of interaction between red-throated diver and proposed dredging activity is therefore considered to be small.

Based on these assessments of the small magnitude of the effect, the high value and high sensitivity of the receptor, but the small degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on this species is assessed to be of minor significance at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Fine sediment plumes with concentrations above background levels (2 mgl^{-1} depth averaged) are predicted to potentially impact red-throated diver; divers feed predominantly by sight and although they often forage in coastal habitats with elevated levels of suspended sediment, any increase in turbidity may reduce feeding success. Hence they have been assigned a medium level of tolerance to elevated levels of suspended sediment.

They are believed to have a medium level of adaptability as they are a mobile species capable of adapting foraging patterns to take advantage of changing prey distribution, and will follow fish prey if they move away from areas of elevated suspended sediment. The recoverability of red-throated divers to elevated suspended sediment levels is also believed to be medium as they will return to areas with high prey availability once turbidity levels have returned to normal. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of this species to the sediment plume is considered to be medium.

The plumes of this concentration are predicted to cover 11% of the MAREA study area at some point over the next 15 years. The majority of the plumes overlap with suitable foraging habitat of the red-throated diver (less than 30 m water depth); however, this constitutes a small portion of the total foraging habitat available in the Humber and Outer Wash region. The main areas of interaction between suspended sediment plumes and red-throated divers are predicted to be around future 15 year extraction zones 107, 481/1, 481/2, 439, 400, 197, 493, 106/3, 480. The overall interaction is expected to be small.

The assessment of the area impacted is based on the assumption that dredging takes place throughout each future 15 year extraction zone at all times, whereas in practice there will only be a small number of vessels operating within the region at any one time. The plume that would be associated with a single dredging vessel in each extraction zone would therefore be much smaller than the modelled plumes.

Based on these assessments of the medium magnitude of the effect, the high value and medium sensitivity of the receptor, and the small degree of interaction between receptor and effect, the cumulative impact of the fine sediment plumes on this species is assessed to be of minor significance at the regional scale.

Change to Distribution of Fish

Divers are believed to have a medium level of tolerance and adaptability to changes to the distribution of fish as they are a mobile species capable of adapting foraging patterns in line with changing prey distribution. Prey species of divers include herring, sprat, cod, whiting, sandeels, flounder and dab (Pollack and Burton, 2004). The recoverability of red-throated divers to changes to the distribution of fish is also believed to be medium as their foraging strategy will focus on areas with high prey availability and they will follow shoals of fish in response to changes in distribution. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of the species is considered to be medium (Cook and Burton, 2010).

The majority of fish species are widely distributed throughout the study area. The area within which dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected (see Section 9.3). As a result the degree of interaction between the predicted distribution of divers and any changes to the distribution of fish is assessed as being small.

Given the small magnitude of the impact, the high value and medium sensitivity of the red-throated diver, and the small degree of interaction between receptor and effect, the cumulative impact of changes to the distribution of fish is assessed as not significant at the regional scale.

9.5.4 Northern Gannet

Presence of the Vessel

Gannets have a high tolerance to vessel presence, and a high level of adaptability because they are highly mobile species and not limited to a particular habitat types for foraging. Northern gannets are known to forage widely (Cook and Burton, 2010). The recoverability of the northern gannet is expected to be high because they are expected to continue foraging as normal once the dredging vessels leave the area. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of species to presence of the vessel is considered to be low.

In addition, the known locations of gannets during summer and winter show little overlap with the future 15 year extraction zones; measurements of the relative density of northern gannets show that gannets were identified in a small area of future 15 year extraction zones 102, 448 and 440 so the interaction between receptor and effect will be very small.

Taking into consideration the small magnitude of the effect, the high value and low sensitivity of the receptor, and the small degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on this species is assessed to be not significant at the regional scale.

Fine Sediment Plume/Elevated Turbidity

Gannets are visual feeders so any increase in turbidity could have a negative effect on their foraging success. Therefore, gannets have medium tolerance to elevated levels of suspended sediment but are expected to have high adaptability because they are highly mobile and forage over a wide area and will follow fish prey if they move away from areas of elevated suspended sediment. Gannets are assessed to have high recoverability to elevated turbidity as they are expected to forage in those areas once the turbidity has decreased. Taking into account the tolerance, adaptability and recoverability the sensitivity of the northern gannet to elevated turbidity is low.

Information on the location of the gannets in the MAREA study area indicates that they are found in low densities sparsely distributed across the region and are therefore assessed as having a relatively small degree of interaction with the future 15 year extraction zones and their associated plumes.

Based on the medium magnitude of effect, the high value and low sensitivity of the receptor to elevated turbidity, and the limited interaction between receptor and effect the cumulative impact of elevated turbidity on northern gannets is assessed to be not significant. There is expected to be no effect on the breeding population that forms part of the qualifying feature of the Flamborough Head and Bempton Cliffs SPA.

Changes to Distribution of Fish

Northern gannets are expected to have a high tolerance to changes to distribution of fish because they forage over a wide area. This species has high adaptability because their diet consists of a number of prey species including herring, mackerel and sandeel (Cook and Burton, 2010) over a wide area enabling them to vary foraging strategy if one species is affected. Gannets also have high recoverability because they forage over a wide area and will alter their hunting strategy in accordance with fish distributions. In consideration of the tolerance, adaptability and recoverability of northern gannets the sensitivity to changes in the distribution of fish is low.

The majority of fish species are distributed widely across the MAREA study area. The area where dredging activities occur at any one time is relatively small and only small changes to fish distribution are expected. Northern gannets are also found in low densities, sparsely distributed across the region. As a result the degree of interaction between the potential distribution of gannets and any changes to the distribution of fish is assessed as being small.

Based on the consideration of the small magnitude of the effect, the high value of the species and the low sensitivity of the receptor, and small interaction between receptor and effect, the cumulative impact of changes to distribution of fish on northern gannets is assessed to be not significant.

9.5.5 Kittiwake

Presence of the Vessel

During the summer kittiwakes breed on Bempton Cliffs and are known to forage out to beyond 50 km from their nests (Cook and Burton, 2010). Survey data indicate that high densities of kittiwakes are found in the north of the MAREA study area during the summer away from the majority of the future 15 year extraction zones. Kittiwakes were found to overlap with extraction zones 105, 440, 441/1 and as a result the degree of interaction with dredging vessels is expected to be small.

Kittiwakes at Bempton Cliff SPA on the Holderness Coast

Source: Shutterstock.com

Kittiwakes have high tolerance and high adaptability to vessel presence because they are highly mobile and their main foraging range in summer does not overlap with the future 15 year extraction zones. Recoverability is expected to be high because kittiwakes will continue to forage in an area once dredging vessels have left the area. In consideration of the tolerance, adaptability and recoverability of the species, the sensitivity of kittiwakes to vessel presence is low.

Taking into account the small magnitude of the effect, the high value of the receptor, the low sensitivity of the receptor to the effect and the small degree of interaction, the cumulative effect of vessel presence on kittiwakes during the summer is assessed to be not significant.

Bempton Cliff SPA on the Holderness Coast

Source: Shutterstock.com

In the winter, kittiwakes were found to be widespread throughout the MAREA study area and where they overlap with the future 15 year extraction zones they are present in low densities. These individuals are expected to be post-breeding sub adults that are highly mobile and not tied to a particular area. Therefore, kittiwakes have high tolerance and high adaptability. The recoverability of the species is believed to be high because they are expected to return to dredge areas to forage after the vessels have left. Based on the tolerance, adaptability and recoverability, kittiwakes are expected to have low sensitivity to vessel presence during winter.

Taking into account the small magnitude of the effect, the medium value and low sensitivity of the receptor to the effect, and small degree of interaction, the cumulative effect of vessel presence on kittiwakes during the winter is not significant.

Fine Sediment Plume/Elevated Turbidity

Kittiwakes are visual feeders and in the North Sea their diet is dominated by sandeels (Cook and Burton, 2010) and (Bull *et al.*, 2004). As the survey data show, during the summer breeding kittiwakes are restricted in their foraging range due to the location of the breeding colonies in Bempton Cliffs. However, there is little overlap with future 15 year extraction zones and therefore the majority of areas of elevated turbidity (Figure 5.61). The overall interaction between receptor and effect is small.

Kittiwakes have medium tolerance to elevated turbidity as they hunt prey by sight. They have high adaptability because within their foraging range they can easily avoid areas of elevated turbidity and forage in the nearest area of clear water. Kittiwakes have high recoverability because they are expected to return to the foraging areas once the turbidity has reduced. Taking into account their tolerance, adaptability and the recoverability, kittiwakes in summer have a low sensitivity to elevated turbidity (Cook and Burton, 2010).

Taking into account the medium magnitude of the effect, the high value and low sensitivity of the receptor to the effect and small degree of interaction, the cumulative effect of elevated turbidity on kittiwakes is considered to be not significant.

In the winter, kittiwakes are distributed across the study area overlapping with most future 15 year extraction zones but in low densities (Figure 5.68); however, these post-breeding sub adults are highly mobile and are not restricted in their range unlike the summer population. The overall degree of interaction will be small.

In the winter, kittiwakes have high tolerance to the effect of elevated turbidity because the birds are highly mobile and their prey species are widespread across the North Sea. Kittiwakes also have high adaptability to elevated turbidity because although the distribution of individuals is widespread across the study area the density of individuals is low and the birds can avoid areas of elevated turbidity. The recoverability of kittiwakes is high because they are expected to return to forage within an area once the turbidity of the water column decreases. Based upon the tolerance, adaptability and recoverability, kittiwakes have a low sensitivity to elevated turbidity during winter.

In consideration of the medium magnitude of the effect, the high value of the receptor and the low sensitivity of the receptor to the effect and the small interaction, the cumulative effect of elevated turbidity on kittiwakes in winter is not significant.

Changes to Distribution of Fish

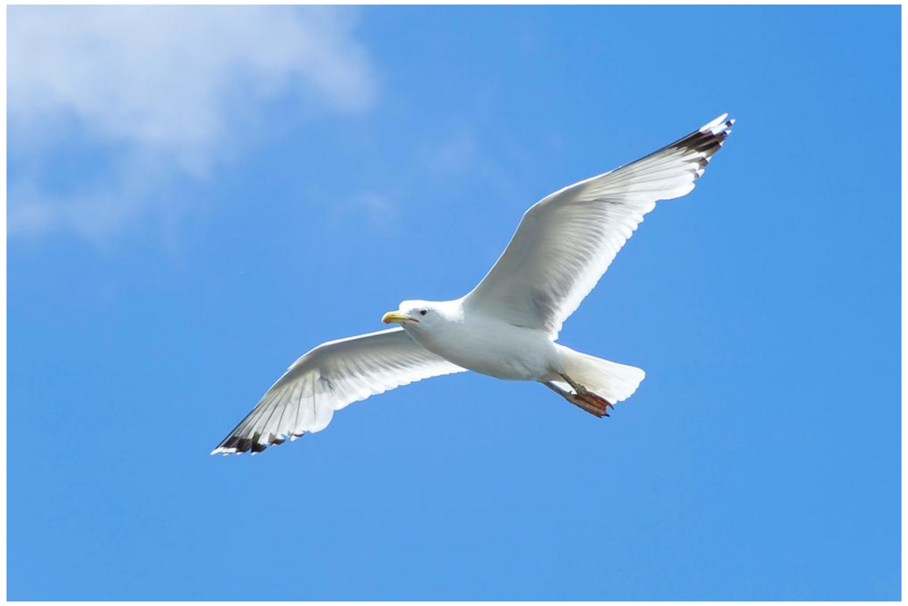
As explained previously, kittiwakes in the North Sea have a limited diet largely consisting of sandeels (Cook and Burton, 2010) and Bull *et al.*, 2004). Section 9.3 assessed the impact to sandeels from dredging activity in the Humber and Outer Wash MAREA study area as not significant. Therefore, there will be no impacts to kittiwakes as a result of changes to fish distribution because sandeel are the predominant prey item for kittiwakes.

9.5.6 Gulls

Presence of the Vessel

During the summer, gulls within the MAREA study area are tied to foraging areas within range of their breeding colonies located along the North Norfolk coast and at Gibraltar Point as well as in The Wash [(1)]. As explained in Section 5.5 these species are expected to be the black-headed gull, lesser black-backed gull, as well as, herring gull and Mediterranean gulls. There is little interaction between gulls and the future 15 year extraction zones (Section 5.5). During the incubation phase of the breeding season there is a dense aggregation of gulls in the centre of the MAREA study area which are expected to be gulls foraging; there is likely to be a small degree of interaction between dredging vessels in transit and the gulls as they travel to their breeding colonies.

Herring Gull (Larus argentatus) in Flight



Source: Shutterstock.com

During summer gulls have a high tolerance to vessel presence because dredging activity brings benthic organisms to the surface providing food on which they can prey (Cook and Burton, 2010). Gulls also have high adaptability because they are highly mobile and although they are tied to breeding colonies and limited in their foraging range there is little overlap with the future 15 year extraction zones. The recoverability of gulls is high because they will return to forage in the future 15 year extraction zones once dredging operations have ceased. Taking into account their tolerance, adaptability and recoverability gulls have low sensitivity to vessel presence.

Taking into account the small magnitude of the effect, the high value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of presence of vessels on gulls during the summer is not significant.

(1) The summer aerial survey data did not cover The Wash but it is known that there are a number of gull breeding colonies located in The Wash and it is expected that gulls will be located in The Wash during the summer.

In the winter gulls are widespread across the MAREA study area with the largest overlap with the future 15 year extraction zones during the first two months of winter (period 1 and period 2); however, the gulls are mainly located between the extraction zones. During late winter (period 3 and period 4) there is very little interaction between gulls and the future 15 year extraction zones. The area within which dredging vessels will be travelling at any one time is relatively small and the main interaction is expected to occur during vessel transit. The overall degree of interaction will be small.

The tolerance of gulls to vessel presence during the winter is high because dredging vessels bring food to the water surface making it easier for gulls to forage. Gulls also have high adaptability because they are highly mobile and do not have a restricted diet. The recoverability of gulls is high because they will return to forage in the future 15 year extraction zones once dredging operations have ceased. Taking into account their tolerance, adaptability and recoverability, gulls have low sensitivity to vessel presence.
Based upon the small magnitude of the effect, the medium value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of presence of vessels on gulls during the winter is not significant.

Fine Sediment Plume/Elevated Turbidity

Gulls are believed to have a high level of tolerance to elevated levels of suspended sediment. As a group they adopt a range of feeding techniques from scavenging to hunting fish from the sea surface and so are not dependent on water clarity for foraging. Gulls have high adaptability because they although they are tied to their breeding colonies during the summer they can easily avoid areas of elevated turbidity and forage in the nearest area of clear water. The recoverability of gulls to elevated suspended sediment levels is also believed to be high as they will return to areas with high prey availability once turbidity has decreased. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of gulls is therefore considered to be low.

During the summer the majority of gulls were located away from the footprint of elevated turbidity around the future 15 year extraction zones so there will be a small degree of interaction with the foraging effort of gulls.

Based upon the medium magnitude of the effect, the high value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of presence of vessels on gulls during the summer is not significant-minor.

During the winter gulls have high tolerance to elevated turbidity because they can adopt a range of feeding techniques from scavenging to hunting fish from the sea surface and so are not dependent on water clarity for foraging. Gulls have high adaptability because they can forage over a wide area and are capable of adapting foraging patterns in line with changing prey distribution. The recoverability of gulls to elevated suspended sediment levels is also believed to be high as they will return to areas with high prey availability once turbidity has decreased. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of gulls in winter is considered to be low.

During the first two months of winter there is overlap between the footprints of the depth averaged plume with concentrations of 2 mg l^{-1} and above with future 15 year extraction zones 107, 481/1, 481/2, 439, 400, 197, 493, 106/3, 480, 448, 102, 449, 440, and 441/1. Gulls are also widespread across the rest of the MAREA study area during these periods. In periods 3 and 4 gulls are densely aggregated in The Wash, the Humber Estuary and close to Flamborough Head. There is a small degree of interaction with gulls and future 15 year extraction zones 448, 102, 449 and 105 but at relatively low densities.

Taking into account the medium magnitude of the effect, the medium value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of presence of vessels on gulls during the summer is not significant.

Changes to the Distribution of Fish

During the summer, gulls present in the MAREA study area are tied to their breeding colonies on the North Norfolk coast, in The Wash and Gibraltar Point. The gulls known to be present in the region forage at distances between 10 km and 75 km [(1)] from their colonies. Gulls feed on a wide range of species including fish, crustaceans, molluscs and terrestrial species.

During the summer gulls have high tolerance to changes to distribution to fish because they have a wide diet and do not rely on fish. The adaptability of gulls is medium because they can change their foraging strategy to focus on other species if fish are not available but gulls are limited in their foraging range due to their breeding colonies. Gulls have high recoverability because they will continue to feed on fish or other prey once the dredging vessels have left the area. Taking into account the tolerance, adaptability and recoverability the overall sensitivity of gulls to changes to the distribution of fish is low.

Section 9.3 assessed the impact to fish as a result of dredging activity to overall be of minor significance. Therefore, the interaction between gulls and changes to the distribution of fish is expected to be small.
Taking into account the small magnitude of the effect, the high value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of changes to the distribution of fish on gulls during the summer is not significant.
During the winter gulls are present across the study area overlapping with most of the future 15 year extraction zones. However, the gulls present in the study area are post breeding sub adults which are highly mobile and can forage over a wide area. Taking into account the assessment of effects on fish ecology was concluded to be of minor significance (see Section 9.3) and the small area that dredging vessels will be working in at any one time the interaction between gulls and changes to the distribution of fish is expected to be small.

In winter gulls are expected to have high tolerance to changes in the distribution to fish during the winter because they have a wide diet. The adaptability of gulls will be high because they are highly mobile and are able to exploit other resources and the recoverability will also be high because they are expected to continue to feed on fish once the dredging vessels have moved on from the dredging area. Taking into account their tolerance, adaptability and recoverability the overall sensitivity of gulls to changes to the distribution of fish is low.

Based upon the small magnitude of the effect, the high value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of presence of vessels on gulls during the winter is not significant.

9.5.7 Terns

Presence of Vessel

Terns tend to avoid shipping lanes (Cook and Burton, 2010) but generally tolerate vessel presence so have therefore been classified as having medium tolerance to presence of the vessel. Terns are expected to have high adaptability because they are able to exploit prey in other areas if a vessel is present. The recoverability of terns is high because they are expected to return to an area once the dredging vessel has left. Given their medium tolerance, high adaptability and recoverability terns have been assessed as having low sensitivity to presence of the vessel.

Terns breed in colonies along the North Norfolk coast and at Gibraltar point and during the incubation phase for their eggs they forage up between 5 and 30 km from their nests (Cook and Burton, 2010). Although the distribution of terns in the summer shown in Figure 9.14 shows that terns are widely distributed these data are a combination of three months during breeding season (period 5, 6, and 7) and it is likely that the wide distribution of terns recorded represent those birds dispersing from breeding colonies during the last month, the post fledging stage. There is overlap between the tern distribution and parts of the future 15 year extraction zones 107, 106/3, 440, 441/1, 481/1 and 481/2 but the main interaction would be with dredging vessels in transit. Therefore, the interaction between the dredging vessels and terns will be small.

Based on these assessments of the small magnitude of the effect, the high value and low sensitivity of the receptor, and the small degree of interaction between receptor and effect, the cumulative impact of the presence of vessels on this species is assessed to be not significant at the regional scale.

Fine Sediment Plume/Elevated Turbidity

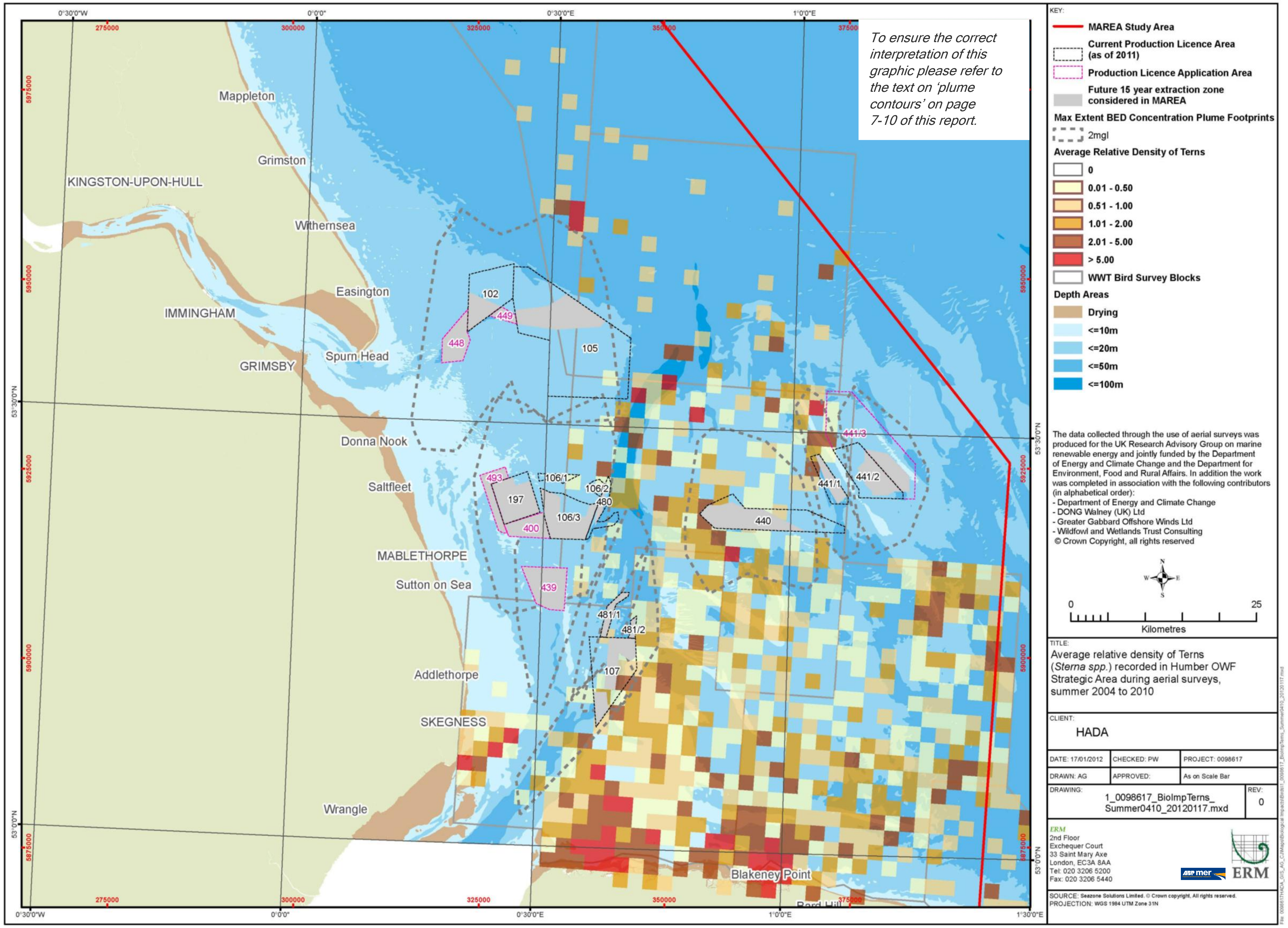
Terns are visual feeders that hover above the water's surface before diving to capture prey and are therefore sensitive to any decreases to water clarity. Therefore, they have been assigned low tolerance to an increase in turbidity. Terns are assessed to have high adaptability because although they are tied to their breeding colonies they can easily forage away from the areas of elevated turbidity generated by dredging vessels. The recoverability of terns is assessed to be high because terns will return to forage in an area once the turbidity has decreased. Taking the tolerance, adaptability and recoverability of terns into account they are assessed as having medium sensitivity to elevated turbidity.

Fine sediment plumes with concentrations above background levels (2 mg l^{-1} depth averaged) at future 15 year extraction zones 107, 106/3, 440, 441/1, 480, 481/1 and 481/2 overlap with terns present in the MAREA study area (Figure 9.14). The area of overlap constitutes a small proportion of the total habitat available for terns during the summer. The degree of interaction between fine sediment plume and terns during the summer is small. Little tern, which breed at a number of sites around the coast of the study area, generally forage within 5 km of breeding colonies (Cook and Burton 2010), with a mean maximum foraging range of 6.94 reported (Birdlife International 2011a). As a result it is likely that foraging breeding little tern will have a very limited interaction with any of the effects of dredging, with depth averaged suspended sediment plumes of >2 mg l^{-1} only extending to within 6 km of the coast offshore of Donna Nook. Sandwich terns are also present in breeding colonies surrounding the Greater Wash and they forage further offshore than little terns. Sandwich terns therefore are potentially more sensitive to elevated turbidity because they are more likely to overlap with the dredging areas.

Taking into account the medium magnitude of the effect, the high value and medium sensitivity of the receptor and small degree of interaction, the cumulative effect of elevated turbidity on common and Sandwich terns is of minor significance. Given the very limited interaction of little tern foraging ranges with suspended sediment plumes, the effect to little tern is predicted to be not significant. Suspended sediment plumes may have an effect on the breeding population of common and Sandwich tern species that form part of the qualifying feature of the North Norfolk Coast SPA.

(1) The Mediterranean gull is known to forage up to 75 km from their breeding colonies.

Figure 9.14 Interaction between distribution of Terns (Sterna) spp. during the summer and elevated sediment plume (2 mg l^{-1})



Changes to the Distribution of Fish

During the breeding season terns forage on small fish such as sandeels and herring, crustaceans and invertebrates found in shallow waters. Section 5.3 describes how sandeels and herring are widespread throughout the region. Terns have medium tolerance to changes in the distribution of fish because fish are one of their main prey items; however, they do have a wide diet and can feed on other prey items if fish were not available. The adaptability of terns is medium because they have a restricted foraging range during the breeding season so could not avoid the effect. The recoverability is expected to be high because terns will continue feeding on fish if they return to the same location once dredging activity has ceased. Taking into account the tolerance, adaptability and recoverability the sensitivity of terns to changes in the distribution of fish is low-medium.

The area within which dredging activity will occur is small and Section 9.3 assessed the effect of dredging on fish to be minor therefore only small changes in fish distribution are expected. The degree of interaction between changes in the distribution of fish and terns is small.

Based on the small magnitude of the effect, the high value and low-medium sensitivity of the receptor, and the small degree of interaction between receptor and effect, the cumulative impact of the changes to the distribution of fish on terns is assessed to be not significant at the regional scale. There is not expected to be any effect on the breeding population that form part of the qualifying features for the North Norfolk SPA.

Changes to Seabed Features

Terns are expected to have high tolerance to changes to sandbanks and overfalls because they forage in a wide range of habitats. They are also expected to have high adaptability because terns are mobile and can react to changes with prey distributions within their foraging range. Terns will return to forage in and around the sandbanks and overfalls once the dredging vessels have left the area and can forage elsewhere if there are changes in prey distribution as a result of changes to sand banks and overfalls therefore they have high recoverability. Taking into account the tolerance, adaptability and recoverability the sensitivity of terns to changes to sandbanks is low.

The sandbanks in the MAREA study area are located in the southeast of the area overlapping with future 15 year extraction zone 440, 441/1, and 441/3. This area overlaps with only a small proportion of the terns present within the study area. Overfalls located along the Lincolnshire coast overlap with future 15 year extraction zones 493, 197, 400 and 439. Terns are expected to forage in the shallow waters surrounding the sandbanks and overfalls; however, while terns are tied to their breeding colonies they are only expected to forage in the sandbanks closest to the Norfolk coast. Therefore, the degree of interaction between terns and changes to sandbanks and overfalls is assessed to be small.

Taking into account the small magnitude of the effect, the high value and low sensitivity of the receptor and small degree of interaction, the cumulative effect of changes to sandbanks and overfalls on terns is not significant.

9.5.8 Auks

The auk species considered in the section are the common guillemot (*Uria aalge*), razorbill (*Alca torda)* and Atlantic puffin (*Fratecula arctica*).

Presence of Vessel

Auks are sensitive to shipping traffic (Cook and Burton) and are expected to avoid dredging vessels so they have low tolerance to vessel presence. The adaptability of auks during the summer is medium because when they are tied to their breeding colonies they have restricted foraging range; however, later in the summer the auks are more mobile and able to forage in other locations. The recoverability of auks is high because they are expected to return to forage once dredging vessels have left the area. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to vessel presence is medium.

Oranje Trailing Suction Hopper Dredger Discharging its Sand Cargo for Beach Renourishment

During the summer breeding auks within the MAREA study area are tied to their breeding colonies at Bempton Cliffs. The auks breeding at Bempton Cliffs are known to forage between 10 km and 30 km from their colonies (see Table 5.19 in Section 5.5) so there will be little interaction with the future 15 year extraction zones (Figure 5.63). During periods 6 and 7 there is increasing overlap with auk distribution and the future 15 year extraction zones. In period 7 auks were found to overlap with parts of future 15 year extraction zones 106/3, 440, 441/1, 480, 481/1, and 481/2. Moulting adults are unable to fly making them particularly sensitive to vessel presence during Period 7 when the main interaction with dredging vessels in transit to and from future 15 year extraction zones will occur. The overall degree of interaction during summer will be small-medium.

Razorbill (Alca torda)

Source: Shutterstock.com

Based upon the small magnitude of the effect, small-medium degree of interaction, the high value and medium sensitivity of the receptor, the cumulative impact of vessel presence on auks during the summer is of minor significance. The breeding population in Period 5 (Incubation) and Period 6 (chick rearing) that forms part of the qualifying feature of the Flamborough Head and Bempton Cliffs SPA will not be affected by the presence of dredging vessels.

Auks are present in the MAREA study area throughout the winter overlapping with all future 15 year extraction zones except 441/2 at progressively lower densities each month. The largest interaction with the future 15 year extraction zones will be during the first two months of winter (Period 1 and Period 2) when auk densities are highest; however, the total area of the aggregate dredging zones is small compared to the foraging range of auks. The overall degree of interaction during winter will be small.

As explained above auks have a low tolerance for vessel presence and a high recoverability as they will return to forage once vessels have left the area. During the winter auks are not restricted in their foraging range and are highly mobile so are therefore expected to have high adaptability. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to vessel presence is low.

In consideration of the small magnitude of the effect, small degree of interaction, the medium value and low sensitivity of the receptor, the cumulative impact of vessel presence on auks during the winter is not significant.

Atlantic puffin (Fratecula arctica)

Source: Shutterstock.com

Fine Sediment Plume/Elevated Turbidity

Auks are a diving species that dive between 25 m and 50 m for prey (cook and Burton, 2010), therefore, it is expected that any increase in turbidity above background levels would impair their hunting ability.

During the summer, particularly during period 7 (post fledgling/moult), there is partial overlap with the 2 mgl^{-1} plume footprint in future 15 year extraction zones 105, 106/3, 107, 439, 440, 441/1, 480, 481/1, 481/2 which constitutes 4.7% of suitable foraging habitat within the MAREA study area. The breeding population in period 5 (incubation) and period 6 (chick rearing) have very little overlap with the footprint of the plumes. The overall interaction between auks and footprint of 2 mgl^{-1} plume is small.

During the summer auks are tied to their breeding colonies and have restricted foraging ranges. Widespread increases in turbidity during this period would reduce their foraging success and potentially impact the survival of their young. Therefore, auks have low tolerance to elevated turbidity. The adaptability of auks is medium because they can hunt in a variety of water depths and are highly mobile although their foraging range is restricted during the summer reducing the area of available habitat. Auks are expected to have high recoverability because they will return to forage in the area once the plume has subsided. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to elevated turbidity is medium.

Based upon the medium magnitude of the effect, small degree of interaction, the high value and medium sensitivity of the receptor, the cumulative impact of elevated turbidity on auks during the summer is of minor significance. The breeding population in Period 5 and Period 6 that form part of the qualifying feature of the Flamborough Head and Bempton Cliffs SPA will not be affected by elevated turbidity.

During the winter, auks were recorded across most of the MAREA study area [(1)] and overlapping with the mgl^{-1} plume footprint in all future 15 year extraction zones except the plume surrounding area 441/2 [(2)]. Given the large area over which auks forage the areas that will be dredged constitute a small proportion of this. The overall interaction during winter is expected to be small.

The auks present in the study area during the winter are highly mobile and are not restricted in their foraging range; therefore, auks have high tolerance to elevated turbidity. The adaptability of auks is high because the forage in a range of habitats and their main prey items are mobile so auks will alter their foraging strategy according to food availability. Auks are expected to have high recoverability because they will return to forage in the area once the plume has subsided. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to elevated turbidity is low.

In consideration of the medium magnitude of the effect, small degree of interaction, the medium value and low sensitivity of the receptor, the cumulative impact of elevated turbidity on auks during the winter is not significant-minor.

Changes to the Distribution of Fish

Auks have a wide diet predominantly comprising fish such as sandeels (Cook and Burton, 2010) but also target whiting, squid and shrimp (Nature Works, 2011).

During the summer, auks have limited foraging ranges so have low tolerance to changes in the distribution of fish. The adaptability of auks is expected to be medium because they do have a relatively wide diet however they have a restricted area within which to hunt. Auks are expected to have high recoverability because they will be able to alter their foraging strategy according to prey location and availability. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to changes in the distribution of fish is medium.

Section 9.3 assessed the impacts to sandeels from dredging activity to be not significant at the regional scale and in addition sandeels are widespread across the Humber and Outer Wash. Therefore, degree of interaction between changes to the distribution of fish and auks is small.

Based upon the small magnitude of the effect, small degree of interaction, the high value and medium sensitivity of the receptor, the cumulative impact of changes to the distribution of fish on auks during the summer is not significant. The breeding population in Period 5 and Period 6 that form part of the qualifying feature of the Flamborough Head and Bempton Cliffs SPA will not be affected by changes to the distribution of fish.

During the winter auks have medium tolerance to changes in the distribution of fish because they have a wide diet but primarily feed on fish. During the winter the auks present in the MAREA study area are highly mobile and can alter their foraging strategy according to the location of prey so have high adaptability and high recoverability. Taking into account the tolerance, adaptability, and recoverability the overall sensitivity of auks to changes in the distribution of fish is low.

In consideration of the small magnitude of the effect, small degree of interaction, the medium value and low sensitivity of the receptor, the cumulative impact of elevated turbidity on auks during the winter is not significant.

Changes to Seabed Features

The sandbanks in the MAREA study area are located in the southeast of the area overlapping with future 15 year extraction zones 440, 441/1, and 441/3. Sandbanks provide a feature that attracts shoaling fish and the shallow waters may be favoured by seabirds for hunting. Overfalls located along the Lincolnshire coast overlap with future 15 year extraction zones 493, 197, 400 and 439. During the summer auks are tied to their breeding colonies in the north of the MAREA study area; in period 7 auks are more mobile and there is some overlap with the sandbanks but no overlap with the overfalls located along the Lincolnshire coast. The overall interaction between sandbanks and auks during the summer is small.

Auks have high tolerance to changes in sandbanks and overfalls because they forage in a range of habitats and are not tied to a particular habitat. The adaptability of auks is high because they are highly mobile and can alter their foraging strategy if changes to sandbanks and overfalls affect prey availability. Auks are expected to have high recoverability because they can forage of wide areas if sandbanks and overfalls are affected. Overall, the sensitivity of auks during summer and winter to changes in sandbanks is low.

(1) Aerial survey data was not available for the entire MAREA study area.
(2) Aerial survey data was not available for the area covering future 15 year extraction zone 441/2.

Based upon the small magnitude of the effect, small degree of interaction, the high value and low sensitivity of the receptor, the cumulative impact of changes to sandbanks on auks during the summer is not significant.

In the winter, during early winter and mid-winter (period 1 and period 2), auks are widespread across the south of the MAREA study area, overlapping with some of the sandbanks present in the area. In period 3 and 4 there is little overlap between auk location and sandbanks. In addition, there is little overlap between the overfalls located along the Lincolnshire coast and distribution of auks in the winter. Overall, the interaction between auks and sandbanks during the winter is small.

Auks have high tolerance to changes in sandbanks and overfalls because they forage in a range of habitats and are not tied to a particular habitat. The adaptability of auks is high because they are highly mobile and can alter their foraging strategy if changes to sandbanks and overfalls affect prey availability. Auks are expected to have high recoverability because they can forage over wide areas if sandbanks are affected. Overall, the sensitivity of auks during winter to changes in sandbanks is low.

Taking into account the small magnitude of the effect, small degree of interaction, the medium value and low sensitivity of the receptor, the cumulative impact of changes to sandbanks on auks during the winter is not significant.

9.5.9 Summary of Impacts

Table 9.12 summarises the significance of cumulative effect of dredging on birds at a regional scale.

Impacts to birds will need to be revisited within the individual EIAs in light of any new data that may become available from other sources and studies, but the conclusions are unlikely to change. The significant impacts listed above will need to be of particular relevance for EIAs for the following licence areas.

- Impacts to Red-throated divers from vessel presence should be assessed at the individual licence level for the following future 15 year extraction zones 448, 493, 197, 400, 106/3, 480, 439, 481/1, 481/2 and 107.
- Impacts to Auks: During moulting period auks are unable to fly. The following future 15 year extraction zones overlap with auk distribution during moulting. 106/3, 440, 441/1, 480, 481/1, and 481/2.

Table 9.12 Summary of Impacts to Birds

	Red-throated Diver	Northern Gannet	Kittiwake Summer	Kittiwake Winter	Gulls Summer	Gulls Winter	Terns	Auks Summer	Auks Winter
Presence of Vessel	Minor significance	Not Significant	Not significant	Not significant	Not significant	Not significant	Not significant	Minor significance	Not significant
Fine Sediment Plume	Minor significance	Not significant	Not significant	Not Significant	Not significant-Minor	Not significant	Not significant - Minor	Minor significance	Not significant-Minor
Changes to the Distribution of Fish	Not significant	Not significant			Not significant	Not significant	Not significant	Not significant	Not significant
Changes to Seabed features							Not significant	Not significant	Not significant

Not affected

9.6 DESIGNATED SITES

9.6.1 Introduction

This section presents the assessment of effects to designated sites as a result of the proposed dredging operations within the Humber and Outer Wash MAREA study area. Within the study area there are a large number of both marine and coastal areas which are designated for their nature conservation importance, as outlined in Section 5.6.

The results of the modelling studies and consideration of physical effects found that there would be no physical effects to the coastline within the study area. A full explanation and interpretation of the results is provided in Chapter 7). In summary, the model outputs do show some areas of small percentage comparative change in wave heights and tidal flows reaching to the coast, however the modelling of absolute changes reveals that these effects are not significant in quantitative terms. As a result, an assessment of physical effects on purely terrestrial and intertidal designated sites is not reported here as there is no potential for impact to these sites. An assessment of changes to sediment transport rates, including a consideration of changes to combined wave and tidal current induced bed shear stress, found that there would be no significant changes across the study area and therefore no impacts from changes to sediment transport rates are considered (see Chapter 7).

The effects are therefore discussed for the following designated sites which have a marine component which overlaps with the modelled and predicted effects of the proposed dredging activity.

- Inner Dowsing and Race Bank candidate Special Area of Conservation (cSAC);
- The Wash and North Norfolk Coast SAC;
- NG 4 Wash Approaches recommended Marine Conservation Zone (rMCZ);
- NG 5 Lincs Belt rMCZ;
- NG 6 Silver Pit rMCZ;
- NG 8 Holderness Inshore rMCZ; and
- NG 9 Holderness Offshore rMCZ.

All designated sites within the study area are considered to be of high importance as a result of their designated and protected status, and as a result of the nationally or internationally important habitats and species for which they have been designated. Therefore all of the qualifying features of the designated sites have been assigned a high Importance/value.

9.6.2 Identification of Potential Impacts to Designated Sites

Table 9.13 highlights where the impacts from dredging may potentially interact with any of these designated sites.

Table 9.13 Matrix of Potential Impacts to Designated Sites

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Change to benthic community composition	Change to distribution of fish	Changes to seabed features
Inner Dowsing and Race Bank cSAC		✓	✓	✓	✓	✓	✓	×	×		✓	×	
The Wash and North Norfolk Coast SAC		×	✓	×	×	×	×	×	×		×	×	
The Humber Estuary SAC		×	×	×	×	×	×	×	×		×	✓	
NG 4 Wash Approach rMCZ		✓	✓	✓	✓	✓	✓	×	×		×	×	
NG 5 - Lincs Belt rMCZ		×	✓	×	×	✓	✓	×	×		×	×	
NG 6 - Silver Pit rMCZ		×	✓	✓	✓	×	×	×	×		×	×	
NG 8 - Holderness Inshore rMCZ		×	×	×	✓	×	✓	×	×		×	×	
NG 9 - Holderness Offshore rMCZ		×	×	×	✓	×	×	×	×		×	×	

Note: The assessment has considered the effects to sandbanks from the other potential impacts listed above where they are an interest feature of a designated site and therefore the potential impact Changes to Seabed Features is not considered separately.

Not affected	
no interaction	×
potential interaction	✓

Where an impact to a qualifying feature of a protected area has been identified, the nature of the impacts to these features is discussed in more detail in the sections that follow.

The assessment of effects to sediment transport has been considered to have no effect within the study area (see Section 7) and so has not been considered here.

When assessing the level of interaction between an effect and a designated site or individual qualifying feature (whichever is the more appropriate) the following criteria have been adopted.

- 1-5% is considered to be a small degree of interaction;
- 6-20% is considered to be a medium degree of interaction; and
- >30% is considered to be a large degree of interaction.

These criteria are specific to the assessment of interactions with designated sites and take account of the limited spatial extent of some features.

The sensitivities of sites' qualifying interest features have been taken from conservation objectives for the sites (in the case of SACs) or from the Final Recommendations Submission report for rMCZs. Where information on the benchmarking used to inform the sensitivities is available (for rMCZs) this has been included in the discussion of the assessment. Additional information on the confidence of the assessment of sensitivities can be found in the individual draft conservation objectives (Natural England, 2009) or from supporting documents for the rMCZ Recommendations Submission Report (DEFRA *et al.*, 2009) and has been summarised for the relevant qualifying interest features considered here in Appendix P.

All of the SPAs within the study area are coastal and no physical impacts to any SPAs are predicted; however impacts to the foraging of bird species which form the qualifying interest features of various SPAs are discussed further under Section 9.5. A summary of the assessment of potential impacts to designated sites qualifying interest feature bird species is presented in Section 9.6.10 below.

Effects to marine mammals which are qualifying interest features of designated sites are considered in Section 9.3 and a summary of the assessment of potential impacts is presented in Section 9.6.10 below.

Effects to migratory fish species which are a qualifying interests feature of The Humber SAC are considered in Section 5.3 and a summary of the assessment of potential impacts is presented in Section 9.6.10 below.

9.6.3 Inner Dowsing and Race Bank cSAC

The Inner Dowsing and Race Bank cSAC has been assigned the following conservation objectives.

- Subject to natural change, maintain or restore the sandbanks which are covered by seawater all the time in favourable condition such that:
    - the natural environmental quality is maintained;
    - the natural environmental processes are maintained;
    - the extent, physical structure, diversity, community structure and typical species representative of low diversity dynamic sand communities are maintained; and
    - the extent physical structure, diversity community structure and typical species representative of moderate diversity stable sand communities are maintained, or restored where deterioration has occurred.
- Subject to natural change maintain or restore *Sabellaria spinulosa* reefs in/to favourable condition, such that:
    - the natural environmental quality is maintained;
    - the natural environmental processes are maintained; and
    - the extent, physical structure, diversity, community structure and typical species representative of Sabellaria spinulosa biogenic reef in the southern North Sea are maintained, or restored where deterioration has occurred.

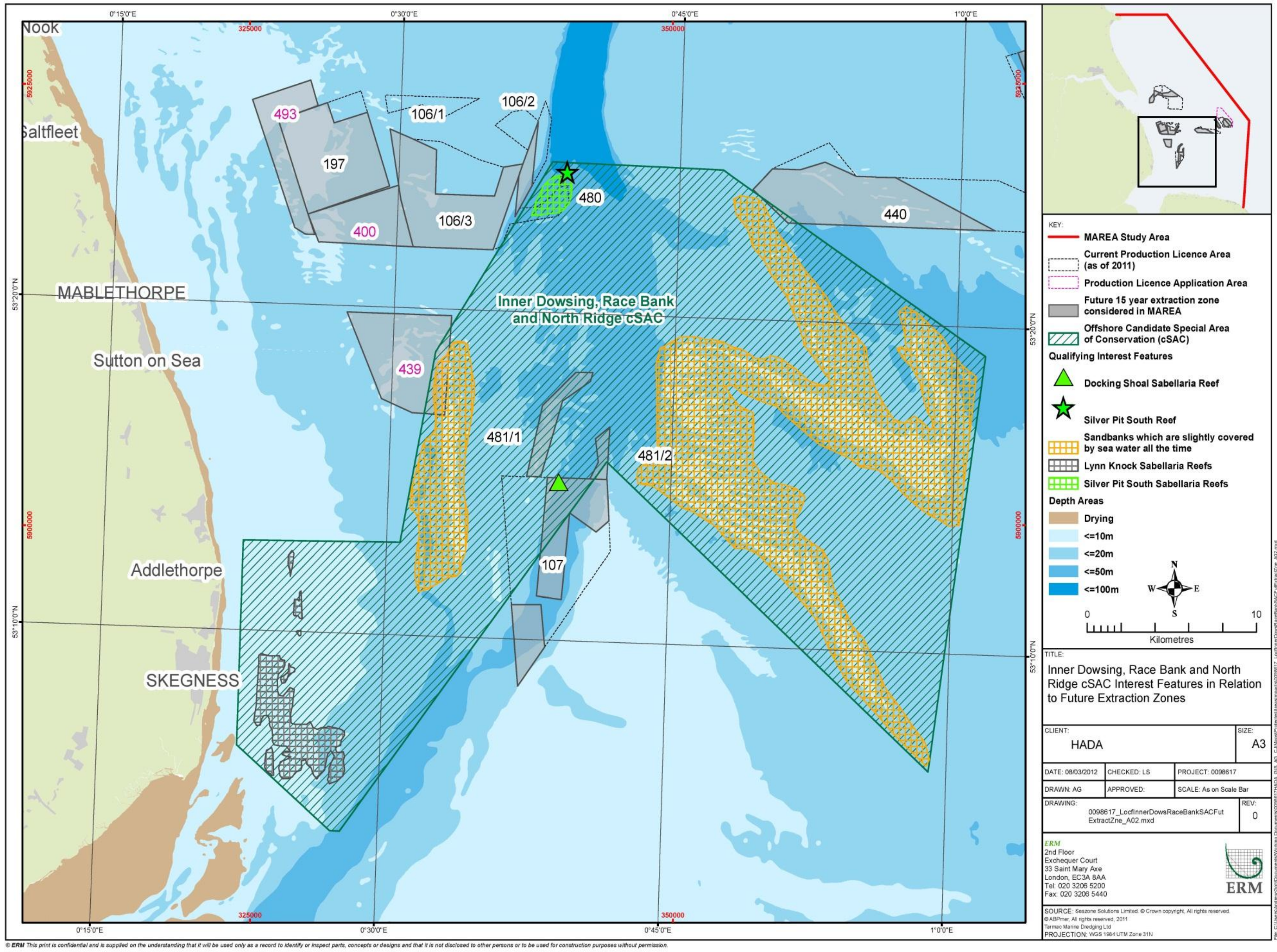
The predicted and modelled effects of dredging in the MAREA study area over the next 15 years, which will interact with the site, are assessed below.

Removal of Sediment

The magnitude of the impact of the removal of sediment across the MAREA study area is assessed as medium-large as the effect is long term, routine and is a high level change relative to the baseline but is site specific.

Removal of sediment from the future 15 year extraction zones in Licence Areas 107, 481/1, 481/2, 440 and Application Area 439 will take place within the SAC boundary as illustrated in Figure 9.15.

Figure 9.15 Location of Inner Dowsing, Race Bank and North Ridge cSAC in Relation to Future Extraction Zones



The NE and JNCC guidance on the conservation objectives and guidance on operations for the Inner Dowsing, Race Bank and North Ridge cSAC provides guidance on the sensitivities of the cSAC interest features to various activities (JNCC/NE, 2009), predominantly drawn from MarLIN's (2001) evaluations of biotope sensitivities. The interest features include both sandbank features and reef features, the sensitivities of which are as follows.

- The sandbank features are assessed as having a medium tolerance and adaptability and a high recoverability and the overall sensitivity to removal of sediment is assessed here as medium [(1)].
- The reef habitat within the cSAC is assessed as having a low tolerance, adaptability and recoverability and therefore an overall high sensitivity to removal of sediment (or of reef structures).

Although they overlap with the cSAC boundary, the extraction zones of Licence Area 481/1 and 481/2 do not overlap with the known extent of qualifying interest feature sandbank or reef habitats within the cSAC and so removal of sediment in these licence areas will not affect the qualifying features of the cSAC. However, other licence areas that fall within the cSAC boundary do have potential interactions with sandbank and reef interest features, as follows (and as indicated on Figure 9.15).

- The extraction zone of Licence Area 107 overlaps entirely with the location of the Docking Shoal *Sabellaria* Reef which results in high level of interaction with the reef feature (see Figure 9.15).
- The potential extraction zone of Application Area 439 overlaps with around 10% of the qualifying sandbank interest feature within this cSAC (Inner Dowsing Overfalls), resulting in a medium level of interaction with the cSAC's sandbank habitat feature (see Figure 9.15).

The effects to the cSAC are predicted to be long term effects which will occur as a matter of routine dredging activity.

Overall there is predicted to be a large degree of interaction between this effect and one of the three reef qualifying features in this cSAC [(2)]. Given the medium to large magnitude of the impact, the high value of the receptor, the high sensitivity of the qualifying reef interest feature habitats found within the cSAC, and the large degree of interaction between the effect and features, the potential impacts from sediment removal on the Inner Dowsing, Race Bank and North Ridge cSAC reef features are assessed to be of major significance. [(3)]

Overall there is predicted to be a medium degree of interaction (10%) between this effect and the sandbank qualifying features in this cSAC. Given the medium to large magnitude of the impact, the high value of the sandbank qualifying feature receptor, the medium sensitivity of the sandbank qualifying interest feature habitats found within the cSAC, and the medium degree of interaction between the effect and features, the potential impacts from sediment removal on the Inner Dowsing, Race Bank and North Ridge cSAC sandbank qualifying features are assessed to be of moderate - major significance. [(4)]

Fine Sediment Plume / Elevated Turbidity

The suspended sediment plume resulting from dredging activities decreases in concentration with distance from dredging activity and with time since dredging has taken place. The modelling of sediment plumes undertaken represents the varying levels of suspended sediment above background concentration using contours of 100 mg l^{-1}, 50 mgl^{-1}, 20 mgl^{-1} and 2 mgl^{-1}.

The predicted effects from these elevated suspended sediment levels for the areas affected by the >100 mgl^{-1} and 100 - 50 mgl^{-1} zones have been assessed as being of medium magnitude. The 50 - 20 mgl^{-1} zones and 20 - 2 mgl^{-1} zones have been assessed as being of small-medium magnitude due to their relatively low concentration and/or relatively small area of effect.

The NE and JNCC guidance on the conservation objectives and guidance on operations for the Inner Dowsing, Race Bank and North Ridge cSAC provide information on the sensitivities of the cSAC interest features to various activities. The sandbank features of the cSAC are assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to increased suspended sediments is assessed here as low. The reef habitat within the cSAC is assessed as having a high tolerance, adaptability and recoverability and therefore an overall low sensitivity to increased suspended sediments.

The 2 - 20 mgl^{-1} dredge plume zone covers much of the centre and northeast of the cSAC (see Figure 9.16). However these dredge plumes are likely to be undetectable against background levels (See Chapter 7). It is much more likely that the areas overlapped by the 20 - 100 mgl^{-1} plumes will experience measurable changes to suspended sediment loads compared to background levels. The impact will be routine but temporary as dredge plumes dissipate after each dredging campaign. The area of overlap with these more concentrated sediment plumes is much smaller, covering around 10% of the cSAC, however, it does overlap with areas of qualifying interest sandbank and reef features including the Docking Shoal Sabellaria reef and the Silver Pit south Sabellaria reef as well as portions of the Inner Dowsing Overfalls and North Ridge sandbanks.

As a result there is considered to be a high degree of interaction [(5)] with the qualifying reef interest features (two of the three reef features being affected). Noting the high value of the reef features and the high degree of interaction between the higher concentration suspended sediment plumes and the qualifying reef interest features of the cSAC, as well as the low - medium magnitude of the effect, but noting the low sensitivity of the qualifying reef interest features to the effect, the effect of suspended sediment plumes is predicted to be of minor significance. The assessment of overall affects to *Sabellaria* reef across the whole of the MAREA study area predicts the effects will be Not Significant, however the effects here relate to specific reefs with a high degree of overlap with the potential effects of dredging.

In regard to the sandbank features there is considered to be a low degree of interaction with the qualifying sandbank interest features (approximately 2% of the sandbank features of the cSAC being affected). Noting the high value of the sandbank features and the low degree of interaction between the higher concentration suspended sediment plumes and the qualifying sandbank interest features of the cSAC, as well as the low - medium magnitude of the effect, but noting the low sensitivity of the qualifying sandbank interest features to the effect, the effect of suspended sediment plumes is predicted to be not significant.

Sand Deposition

The effect of sand deposition across the study area has been assessed as being of small magnitude as it is local in extent, has a short term effect, a routine frequency and will cause a low change relative to the baseline.

Although there will be a potential deposition of sediments out to 2.5 km from dredge areas, this is a very conservative prediction which is very likely to overestimate the extent of sand deposition (See Chapter 7 for more details).

The conservation objectives for the cSAC provide guidance on the sensitivities of the cSAC interest features to various activities. The sandbank features of the cSAC are assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to smothering by sand deposition is assessed here as low. The reef habitat within the cSAC is assessed as having a low tolerance, adaptability and recoverability to smothering and therefore an overall high sensitivity to sand deposition.

(1) It should be noted that the sensitivity rating here differs from that used in the Physical Impacts Assessment chapter since here it applies to the sandbank benthic assemblages likely to be present as opposed to the physical structure itself.
(2) This is a precautionary rating as the boundary of the feature has not been mapped and the area of reef is therefore unknown.

(3) In reality the impacts will be addressed in licence conditions and be mitigated by survey, mapping their extent, and avoiding the features during dredging.
(4) In reality the impacts will be addressed in licence conditions and be mitigated by survey, mapping their extent, and avoiding the features during dredging.

(5) This is a precautionary rating as the boundaries of the two affected features have not been mapped and the area of reefs is therefore unknown.

Although there will be a high degree of overlap between the areas of potential sand deposition and the cSAC, in reality the degree of interaction will be much smaller, and changes above background levels of sediment re-suspension and settlement are likely to be restricted to the immediate vicinity (<200 m) of active dredge areas (East Channel Association, 2002) (see Chapter 7). However as a number of the future 15 year extraction zones of existing Licence Areas (481/1, 481/2, 107 and 440) and Application Areas (439) are situated within the cSAC, there will still be around a 5% overlap with the cSAC resulting in a small degree of interaction between the areas of sand deposition and areas of sandbank qualifying interest feature habitat within the cSAC. The reef habitat qualifying feature is much smaller and more restricted in size within the cSAC but one of the three qualifying reef features lies within an extraction area therefore there is considered to be interaction with one of the three reef features resulting in a high degree of interaction [1].

As a result of the high value of the receptor, small magnitude of the effect, the low sensitivity of the sandbank qualifying features and the small degree of interaction, the effects to the sandbank habitat qualifying interest features of the cSAC are predicted to of minor significance.

As a result of the high value of the receptor, the small magnitude of the effect but the high sensitivity of the reef features and the relatively high degree of interaction the effects to the reef qualifying features of the cSAC are predicted to be of moderate significance.

Changes to Sediment Particle Size

A change in sediment particle size has been assessed to be local in extent, short term, routine and cause a low change relative to the baseline resulting in a small magnitude.

The conservation objectives for this cSAC do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to particle size. However the sensitivity of the sandbank habitat qualifying interest features to other effects relating to changes to sediments, including changes to suspended sediment and smothering is considered to be low. The sandbank features of the cSAC are assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to sediment particle size is assessed here as low.

Similarly there is no specific consideration of the effects of changes to sediment particle size on reef habitat qualifying interest features. The sensitivity of the reef habitat qualifying interest features to other effects relating to changes to sediments are assessed; they are considered to have high sensitivity to smothering and low sensitivity to changes in suspended sediment. Sabellaria reef requires a certain degree of suspended sediment in the water column to be able to construct their tubes (Hendrick *et al.*, 2010) and changes to the size of the sediment particles available could theoretically have an effect on the growth of reefs. The reef habitat within the cSAC is therefore assessed as having a medium tolerance, adaptability and recoverability to changes in particle size and therefore an overall medium sensitivity to changes to particle size.

(1) This is a precautionary rating as the boundary of the feature has not been mapped and the area of reef is therefore unknown.

There is a relatively large degree of overlap between the areas of potential changes in particle size distribution and the sandbank and reef habitat qualifying interest features of the cSAC, of up to 25% of the sandbank feature, and two of the three qualifying reef features. The areas of potential changes in particle size however represent a very conservative prediction of the total maximum extent of potential changes to particle size distribution and the actual area affected is likely to be restricted to areas in the immediate vicinity of the extraction areas (see Chapter 7). However the areas of effect are still likely to interact with one of the qualifying reef features resulting in a high degree of interaction, and to a lesser degree with around 5% of the sandbank habitats within the cSAC, resulting in a low degree of interaction.

As a result of the high value of the receptor, the small magnitude of the effect, the low sensitivity of the receptor and the small degree of interaction, the effects to the sandbank habitat qualifying interest features of the cSAC are predicted to be not significant. As a result of the small magnitude of the effect but the moderate sensitivity of the receptor and the relatively high degree of interaction the effects to the reef qualifying features of the cSAC are predicted to be of minor significance.

Changes to Wave Heights

The changes to wave heights have been modelled using two return periods, a 10 in 1 year wave height, and a 1 in 200 year wave height to assess impacts of both regular and very infrequent wave sizes. The magnitudes of all of the potential effects of changes to wave heights across the study area are considered to be of small-medium magnitude.

Given the depth of water found within the cSAC in the areas affected by changes to wave heights and the nature of the qualifying interest features, they are considered to have low sensitivities to changes to wave heights and the conservation objectives for the cSAC do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to wave heights (JNCC/NE, 2009). Both the reef and sandbank habitat features of the cSAC are assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to wave heights is assessed here as low.

The modelling of changes to wave heights shows a small degree of overlap between effects from Licence Area 440, 481/1, 481/2 and 107 and the cSAC of up to +/- 5% wave height for 1 in 200 year waves. These areas show a very small degree of overlap with less than 1% of the qualifying interest feature sandbank habitats.

Given the high value of the receptor, the small-medium magnitude of the effect, the low sensitivity of the qualifying interest features habitats and the very small degree of the interaction, the effect of changes to wave heights is predicted to be not significant.

The modelling of changes to wave heights does not show any degree of overlap with the area of effect and the qualifying interest reef features of the cSAC. Given the lack of interaction, No effects to the qualifying interest reef features are predicted.

Change to Tidal Currents

The changes to tidal currents within the study area have been assessed as being of medium magnitude.

The conservation objectives for the cSAC do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to tidal currents (JNCC/NE, 2009). Both the reef and sandbank habitat features of the SAC are therefore assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to changes to tidal currents is assessed here as low.

The modelled changes to tidal current speeds interact with a large area of the cSAC. However the area of interaction with the qualifying interest sandbank features is around 5% of the total habitat resulting in a small degree of interaction with the sandbank qualifying interest. Given the high value of the sandbank features, the medium magnitude of the effect, and the low sensitivity of the qualifying sandbank interest feature to the effect together with the small extent of the interaction, the overall effect to the reef feature is considered to be not significant.

There is a larger degree of interaction with the reef features, with one of the three reef features occurring within the area of interaction resulting in a large degree of interaction with the reef feature [2]. The majority of the changes

(2) This is a precautionary rating as the boundary of the feature has not been mapped and the area of reef is therefore unknown.

relate to a decrease in current speed of up to 0.05 ms^{-1}. However small areas relate to decreases of up to 0.20 ms^{-1} (see Figure 9.17). Given the high value of the reef qualifying features, the medium magnitude of the effect, and the low sensitivity of the qualifying interest features to the effect together with the large extent of the interaction, the overall effect to the reef feature is considered to be of minor significance.

Changes to Benthic Community Composition

A change to the composition of the benthic community as a combined result of the physical effects of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence in the existing licence areas as in the majority of cases the seabed that is dredged will have been dredged previously. As a result it is classified as a medium-large magnitude effect.

In the context of the cSAC qualifying interest sandbanks features habitats, the qualifying interest feature habitats support benthic communities, and the conservation objectives of the site require the distribution and composition of the communities to be maintained. However for the cSAC qualifying interest reef features habitats, the qualifying interest features actually comprise benthic communities and the effects of dredging for these benthic communities have been assessed in Section 9.2.

As a result the qualifying interest sandbank features of the cSAC are considered to have a low tolerance and adaptability and recoverability to changes to benthic community composition and the overall sensitivity to changes to sediment particle size is assessed here as high.

The level of interaction between changes to benthic community composition and the sandbank habitat within the cSAC is considered to be relatively low. The potential extraction zone of Application Area 439 overlaps with the qualifying interest feature Inner Dowsing Overfalls sandbank habitat. In addition small areas of potential sand deposition from the future 15 year extraction zones for existing Licence Areas (481/1, 481/2, 107 and 440) and Application Area 439 overlap with areas of sandbank qualifying interest feature habitats and this effect may result in changes to community composition. Overall the effect is predicted to interact with approximately 5% of the qualifying interest feature sandbank habitat, resulting in a low level of interaction. As a result of the high value of the sandbank qualifying features, the medium to large magnitude, the high sensitivity of the qualifying interest features and the low level of interaction with predicted changes to benthic community composition the effects are predicted to be of minor significance.

Figure 9.16 Marine cSAC and rMCZ and Modelled Suspended Sediment Plumes

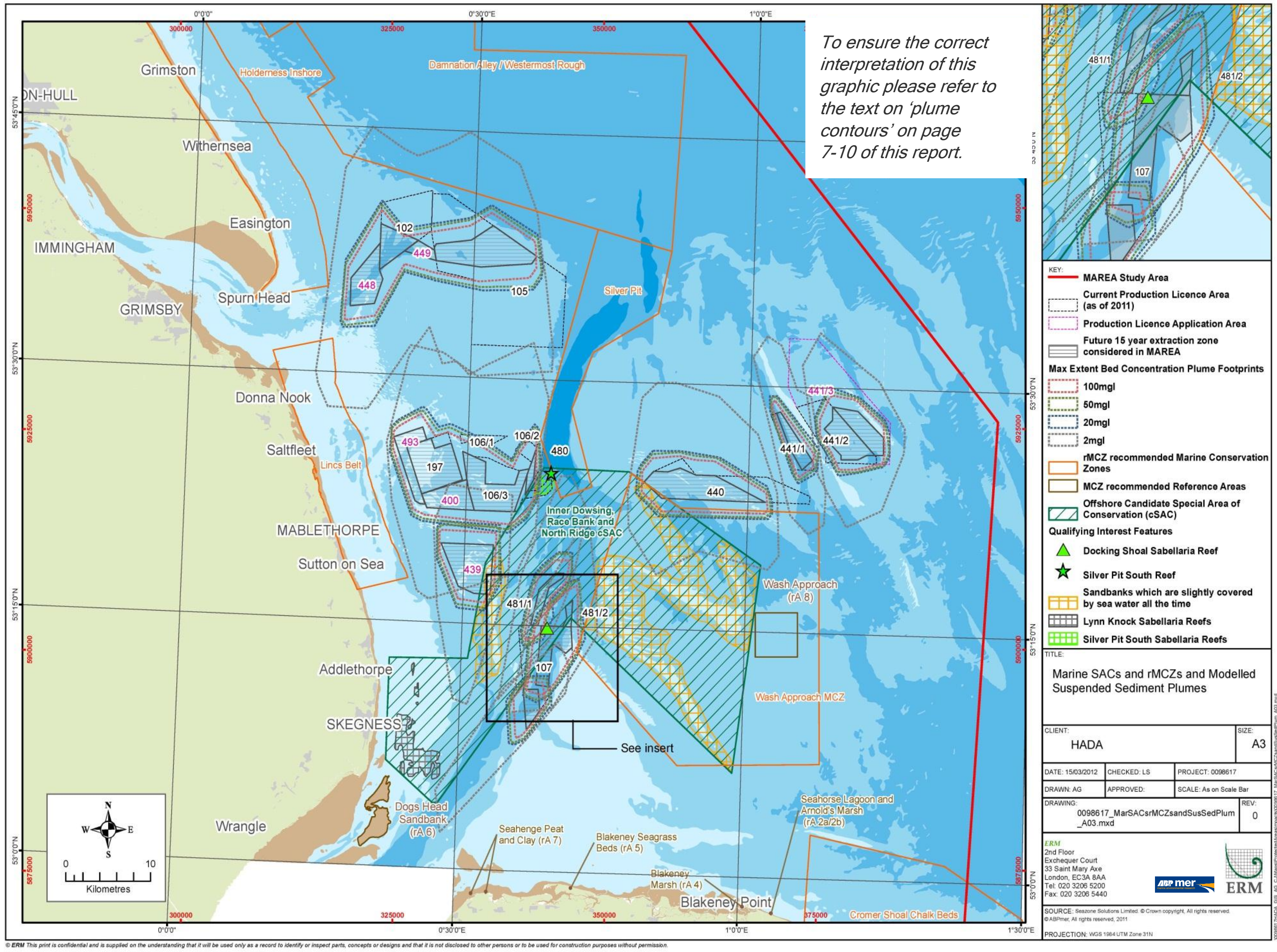
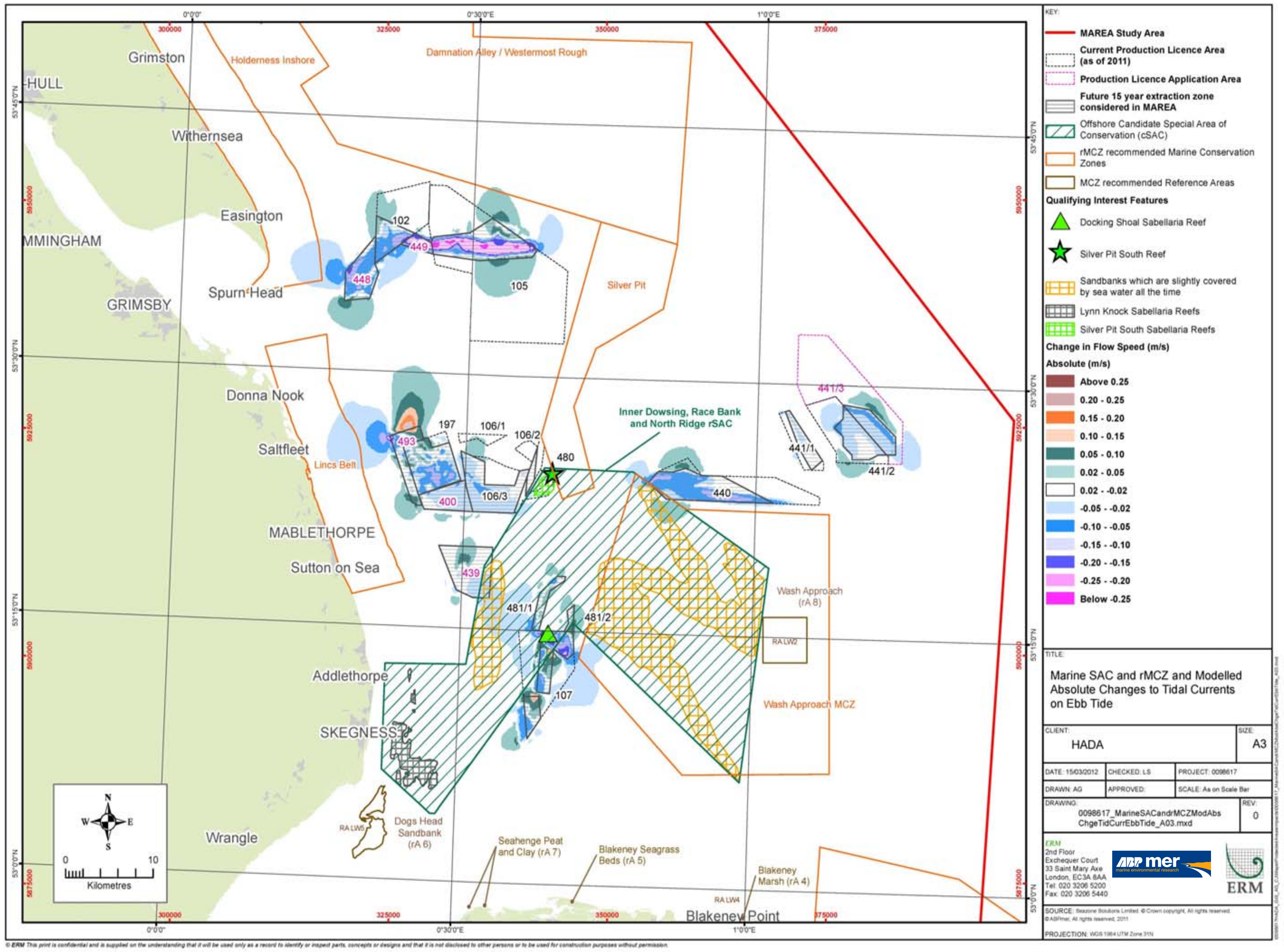


Figure 9.17 Marine cSAC and rMCZ and Modelled Absolute Changes to Tidal Currents on Ebb Tide



9.6.4 The Wash and North Norfolk Coast SAC

The Wash and North Norfolk Coast SAC has been assigned the following conservation objectives.

- Subject to natural change, maintain the large shallow inlet and bay in favourable condition, in particular:
    - o Subtidal sandbanks;
    - o Intertidal mudflat and sandflats;
    - o Subtidal boulder an cobble communities;
    - o Subtidal mixed sediment communities (e.g. Sabellaria spinulosa reefs);
    - o Glasswort and other annuals colonising mud and sand;
    - o Atlantic salt meadows; and
    - o Mediterranean saltmarsh scrubs.
- Subject to natural change, maintain the sandbanks with are slightly covered by seawater all the time in favourable condition in particular:
    - o Gravel and sand communities; and
    - o Muddy sand communities.
- Subject to natural change, maintain the mudflats and sandflats not covered by seawater at low tide in favourable condition, in particular:
    - o Sand and gravel communities;
    - o Muddy sand communities; and
    - o Mud communities.
- Subject to natural change, maintain the glasswort and other annuals colonising mud and sand in favourable condition in particular:
    - o Annual Salicornia saltmarsh community;
    - o Annual sea-blite (Suaeda maritima) saltmarsh community; and
    - o Ephemeral saltmarsh vegetation with Sagina maritima saltmarsh community.
- Subject to natural change maintain Atlantic salt meadows in favourable condition in particular:
    - o Low marsh to low-mid marsh communities; and
    - o Mid and mid-upper marsh communities.
- Subject to natural change, maintain Mediterranean saltmarsh scrubs in favourable condition in particular:
    - o Shrubby sea-blite (Suaeda vera) saltmarsh community;
    - o Shrubby sea-blite (Suaeda vera) and Limonium binervosum saltmarsh community; and
    - o Transitional communities.

- Subject to natural change, maintain in favourable condition the habitats of common seals, in particular:
  - Intertidal mudflats and sandflats.

The predicted and modelled effects of the proposed dredging which will interact with the site are assessed below.

Fine Sediment Plume / Elevated Turbidity

As discussed in Section 9.6.3, the magnitude of all sediment plume effects are considered to be of small - medium or medium magnitude for this assessment.

The <2 mgl^{-1} contour dredge plume from Licence Area 107 extends into a very small area of SAC over 10 km from the edge of the Area. At this distance the dredge plumes are likely to be undetectable against background levels (See Chapter 7) and therefore there is not predicted to be any interaction between SAC and the actual dredge plume. As a result no effects to the SAC are predicted.

9.6.5 NG4 Wash Approaches rMCZ

The conservation objectives for all rMCZs assessed in this Chapter are contained in Annex P.

Direct Removal of Sediment

The magnitude of the effect of direct removal of sediment has been assessed as being of medium-large magnitude.

rMCZ NG4 Wash Approaches has been designated for the presence of subtidal sands, subtidal mixed sediments and subtidal sands and gravels. The conservation objectives for the site list the sensitivity to physical removal by extraction of the subtidal sands as low to high, the sensitivity of mixed sediments as high and the sensitivity of the subtidal sands and gravels as medium (Net Gain, 2011) . This assessment of sensitivity is based on removal of up to 30 cm of sediment, in turn based on low historical dredging activity from EMS data. Given that the area of overlap runs along the very edge of the future dredging zone, this low level of removal, and therefore in turn the assessment of sensitivity, is predicted to be applicable to the proposed activities.

As a result the subtidal sands are considered to have a medium tolerance and adaptability and recoverability to changes to direct removal of sediment and the overall sensitivity of medium.

The subtidal mixed sediments are considered to have a low tolerance and adaptability and recoverability to changes to direct removal of sediment and the overall sensitivity of high.

The subtidal mixed sediments are considered to have a medium tolerance and adaptability and recoverability to changes to direct removal of sediment and the overall sensitivity of medium.

The area of interaction between the rMCZ and the future extraction zones is limited to a very small area of overlap between the western edge of Licence Area 440 and the northern edge of the rMCZ. The area lies along a common border between the MCZ and Licence Area 440, and represents less than 1% of the rMCZ. According to the mapping of qualifying interest features for the rMCZ the area of overlap contains both mixed sediments and sand and gravels (Netgain, 2011).

As a result of the high value of the qualifying features, the very small area of overlap, despite the medium-large magnitude of the effect and the high and moderate sensitivity of the habitats present, the overall effect is considered to be of minor significance and possibly not significant.

Fine Sediment Plume / Elevated Turbidity

As discussed in Section 9.6.3, the magnitude of sediment plume effects are considered to be of small to medium or medium magnitude for this assessment.

The conservation objectives for the site list subtidal mixed sediments as having a medium to no sensitivity to changes in water clarity, and do not list suspended sediment/elevated turbidity as a pressure for either of the other features. As a result of the range of sensitivities given, and the likely short term and intermittent nature of dredge plumes which make it more likely that the receptors will have a lower sensitivity, the subtidal mixed sediments are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity and subtidal sands and subtidal sands and gravels are also considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity. This assessment of sensitivity is based on a change in one rank on the WFD scale e.g. from clear to turbid in one year, and is considered to be precautionary for the regular but temporary and localised increases in suspended sediments predicted for the proposed dredging activities.

The largest area of effect within the rMCZ relates to the modelled 19 - 2mgl^{-1} near bed sediment plume zone resulting from dredging activity within Licence Area 440. In reality this area of effect will be within the natural variation of suspended sediment levels for much of the year (see Chapter 7) and an effect to the rMCZ would be difficult to distinguish from background fluctuations. The area of interaction between higher concentration suspended sediment plumes and the rMCZ is limited to very localised areas around Licence Area 107 and Licence Area 481/2, and a slightly larger area around Area 440 which extends approximately 1.5 km into the rMCZ in the north western corner of the site, affecting around 2% of the site. As a result there is considered to be a small degree of interaction.

Given the high value of the receptor, the medium magnitude of the effect, the low sensitivity of the receptors and the limited extent of interaction, the overall effect of elevated suspended sediment levels on the rMCZ are predicted to be not significant.

Sand Deposition

The effect of sand deposition across the study area has been assessed as being of small magnitude. Although the assessment shows potential deposition of sediments out to 2.5 km from the dredge areas, this is a very conservative prediction which is very likely to overestimate the extent of sand deposition (see Chapter 7 for more details).

The sandy sediments within the rMCZ have been assessed in the conservation objectives as having a high sensitivity to high changes to the siltation rate (classified as 30 cm of fine material added to the seabed in a single event) and medium sensitivity to low changes to the siltation rate (classified as 5 cm of fine material added to the seabed in a single event) (Net Gain, 2011). High changes in the siltation rate (as defined by the conservation objectives) are not predicted to occur beyond around 200 m of the future dredge zone (see Chapter 7), and the vast majority of the area affected by siltation within the rMCZ is likely to experience low changes to the siltation rate. Therefore the subtidal sands qualifying feature is considered to have a medium tolerance and adaptability and recoverability to increases in sand deposition and therefore an overall medium sensitivity.

The mixed sediments qualifying feature has been assessed as having medium sensitivity to high siltation rate changes and no sensitivity to low siltation rate changes (Net Gain, 2011). Given the low predicted change in siltation rates over the majority of the area of interaction, the mixed sediments qualifying feature is considered to have a high tolerance and adaptability and recoverability to increases in suspended sediment and therefore an overall low sensitivity.

The subtidal sands and gravels qualifying feature has been assessed as having no sensitivity to medium sensitivity to both high and low siltation rate changes (Net Gain, 2011). Given this range of potential sensitivity together with the low change in siltation rates predicted over the majority of the area of interaction, the subtidal sands and gravels qualifying feature is considered to have a high tolerance and adaptability and recoverability to increases in suspended sediment and therefore an overall low sensitivity.

Due to the conservative nature of the prediction of the potential area of effect, the actual area of interaction is likely to be limited to a small area in the north western corner of the rMCZ where there is likely to be a small area of sand deposition associated with dredging activity in Licence Area 440 resulting in a small degree of interaction.

Due to the high value of the receptor, the small magnitude of the effect, the moderate to low sensitivity of the receptors and the very small interaction of the effect with the rMCZ, the overall effects are considered to be Not Significant.

Changes to Sediment Particle Size

Changes to particle size distribution have been assessed as being of small magnitude.

The conservation objectives for the rMCZ do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to particle size (Net Gain, 2011). However in line with the assessment of the sensitivity of Annex 1 Sandbank habitat SAC qualifying interest features, the sensitivity of the subtidal sands rMCZ qualifying interest feature is considered to have a high tolerance and adaptability and recoverability and the overall sensitivity to changes to sediment particle size is assessed here as low.

Neither the conservation objectives for the subtidal mixed sediments or the subtidal sands and gravels qualifying features contain a specific assessment of sensitivity to changes to particle size (Net Gain, 2011). Both habitats tend to occur in more stable environments and are considered to be slightly more sensitive to changes to the particle size of their constituent sediments and therefore both are considered to have a medium tolerance, adaptability and recoverability and an overall sensitivity of medium.

There is a potential area of effect up to 4 km from future extraction zones, however in reality changes to sediment particle size are likely to be restricted to localised presence of sand streaks within a few hundred metres of the extraction zones associated with localised increases of the sandy sediment fraction of deposited material (see Chapter 7). As a result, the areas of interaction are likely to be limited to the north-western corner of the rMCZ where there may be an overlap between effects from the extraction zone of Licence Area 440 resulting in a small degree of interaction.

As a result of the high value of the receptor, the small magnitude of the effect, the low and moderate sensitivities of the qualifying interest features and the very limited interaction, the overall effect is considered to be not significant.

Changes to Wave Heights

The magnitude of the effect of changes to wave heights have been assessed as being of small-medium magnitude for both changes to 1 in 200 and 10 in 1 year return periods.

The conservation objectives for the site do not list changes to wave heights as a potential pressure for subtidal sands or subtidal sands and gravels (Net Gain, 2011). As a result both of these features are assessed here as having a high tolerance, adaptability and recoverability and an overall low sensitivity. The conservation objectives do assess the sensitivity of subtidal mixed sediments, and consider them to have no to low sensitivity. The rMCZ sensitivity criteria define changes to wave heights as a change in nearshore significant wave height >3% but <5%. The modelling results show changes to wave heights within the site as between 2-3% and therefore the assessment of sensitivity is considered to be precautionary. As a result they are assessed here as having a high tolerance, adaptability and recoverability and an overall low sensitivity.

The modelling results show no overlap between predicted changes to wave heights for 10 in 1 year waves and the rMCZ. For 1 in 200 year waves, there is a small area of overlap between waves of up to 5% larger in the north of the rMCZ associated with dredging activity in Licence Area 440. The modelling of absolute changes to wave heights suggests that there will be a maximum of 10-20 cm increases to wave heights within a small area of the north of the rMCZ affecting around 2% of the rMCZ, resulting in a small degree of interaction.

Give the high value of the receptor, the small-medium magnitude of the effect, the low sensitivities of the qualifying interest features and the small degree of interaction, the overall effect is considered to be not significant.

Change to Tidal Currents

The changes to tidal currents within the Study Area have been assessed as being of medium magnitude.

The conservation objectives for the site assess the sensitivity of subtidal sands and subtidal mixed sediments as having a low to no sensitivity to changes to local tidal currents, and do not consider changes to tidal currents as a potential pressure to subtidal sands and gravels (Net Gain, 2011). The sensitivity criteria for rMCZs define changes to currents as peak mean spring tide flow change between 0.1m/s to 0.2m/s over an area >1km^2 or 50% of width of water body for > 1 year. The modelling results show changes of a maximum of 0.05-0.1 and therefore the assessment of sensitivity is considered to be precautionary. As a result all of the qualifying interest features are assessed as having a high tolerance, adaptability and recoverability and an overall low sensitivity to changes to tidal currents.

The modelling of changes to tidal currents suggests percentage changes of up to +/- 10% in areas in the north and west of the rMCZ interacting with up to approximately 10% of the rMCZ. The modelling of absolute changes suggests that the effect will result in changes of +/- 0.05 ms^{-1} in small areas on the west and north edges of up to around 1% of the rMCZ. Overall, there is considered to be a very small degree of interaction

Given the high value of the receptor, the medium magnitude of the effect, the low sensitivity of the qualifying interest features and the very small area of interaction, the overall effect is considered to be not significant.

9.6.6 NG 5 - Lincs Belt rMCZ

Fine Sediment Plume / Elevated Turbidity

As discussed in Section 9.6.3, the magnitude of all sediment plume effects are considered to be of medium magnitude for this assessment.

The Links Belt rMCZ has been designated because it supports five qualifying features: subtidal coarse sediment, subtidal sand, subtidal mixed sediment, peat and clay exposures and subtidal sands and gravels.

The conservation objectives for the site list subtidal mixed sediments as having a medium to no sensitivity to changes in water clarity, and do not list suspended sediment/elevated turbidity as a pressure for any other feature (Net Gain, 2011). This assessment of sensitivity is based on a change in one rank on the WFD scale e.g. from clear to turbid in one year, and is considered to be precautionary for the regular but temporary and localised increases in suspended sediments predicted for the proposed dredging activities. As a result of the range of sensitivities given for subtidal mixed sediments in the conservation objectives, and the likely short term and intermittent nature of dredge plumes, the subtidal mixed sediments are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity.

As the conservation objectives do not list changes to water clarity as a sensitivity for any of the other qualifying features, as a precautionary approach, all other qualifying interest features are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity.

The suspended sediment plume modelling shows an overlap between the 19-2 mgl^{-1} suspended sediment contours potentially resulting from dredging activity within the future extraction zone of Application Area 448 interacting with around 10% of the rMCZ. However the licence area lies over 4.5 km from the rMCZ and it is likely that at this distance the concentration of suspended sediments in the dredge plume which overlaps with the rMCZ will be indistinguishable from background levels (see Chapter 7). Therefore there is actually considered to be a small degree of interaction.

As a result of the high value of the receptor, the medium magnitude of the effect, the low sensitivity of the qualifying interest features and the small level of interaction between the modelled sediment plume and the rMCZ, the overall effect is considered to be not significant.

Changes to Wave Heights

The effect of changes to wave heights have been assessed as being of small-medium magnitude for both changes to 1 in 200 and 10 in 1 year return periods.

In the conservation objectives for the rMCZ, subtidal mixed sediments are assessed as having low to no sensitivity to changes to wave heights and peat and clay exposures are considered to have a low sensitivity (Net Gain, 2011). The rMCZ sensitivity criteria define changes to wave heights as a change in nearshore significant wave height >3% but <5%. The modelling results show changes to wave heights within the rMCZ up to 15% for 1 in 200 year waves and therefore the assessment of sensitivity is considered to be conservative in relation to the proposed dredging activities. As a result subtidal mixed sediments and peat and clay exposures within Lincs Belt rMCZ are considered to have a medium tolerance, adaptability and recoverability and overall medium sensitivity to the predicted changes in wave heights. None of the other features are considered to be sensitive to changes to wave heights. As a result the other qualifying interest features of the rMCZ are considered to have high tolerance, adaptability and recoverability and an overall low sensitivity to changes to wave heights.

The modelling of changes to wave heights for 1 in 200 year waves shows a large area of interaction between the rMCZ and the effects from extraction in Application Areas 400, 439 and 493 and Licence Area 197, with the largest area of overlap associated with Application Area 493 and Licence Area 197. The modelling shows large areas of 5-10% increase in wave height, with smaller areas of up to 15% increases in wave height. In absolute values, this corresponds with maximum changes of up to 40 cm increases, with change of 10 cm or over affecting around 40% of the rMCZ. The largest area of increases in wave heights relates to increases of up to 20 cm, resulting in a worst case large degree of interaction.

For 10 in 1 year waves, the modelling of percentage changes also shows a large area of interaction with around 35% of the rMCZ from extraction zones in Application Area 493 and Licence Area 197 relating to changes of up to 10%. However the modelling of absolute changes shows only a very small area of interaction of up to 5% with increases of up to 20 cm in wave height resulting in a small degree of interaction.

Although the magnitude of the effect has been assessed as being small-medium and there is a relatively small area of interaction for more regular 10 in 1 year waves, there is a relatively large area of interaction for 1 in 200 year waves. Given the high value of the receptor, the small-medium magnitude of the effect, the low - medium sensitivity of the qualifying interest features and the potentially high level of interaction for extreme wave conditions, the overall effect is considered to be of minor significance.

Change to Tidal Currents

The changes to tidal currents within the Study Area have been assessed as being of medium magnitude.

In the conservation objectives for the rMCZ, subtidal sands and subtidal mixed sediments are considered to have a low to no sensitivity to changes to tidal currents and none of the other features are considered to be sensitive (Net Gain, 2011). The sensitivity criteria for rMCZs define changes to currents as peak mean spring tide flow change between 0.1m/s to 0.2m/s over an area >1km^2 or 50% of width of water body for > 1 year. The modelling results show changes of a maximum of 0.02-0.05 and therefore the assessment of sensitivity is considered to be precautionary. As a result all the qualifying interest features of the rMCZ are considered to have high tolerance, adaptability and recoverability and an overall low sensitivity to changes to tidal currents.

The modelling results show a large area of overlap of around 25% of the rMCZ between the percentage change to tidal currents for both ebb and flood tides across the centre of the rMCZ resulting from dredging activity in Application Area 493. The area of interaction represents an area of decreases in tidal current speeds by up to 5%. The modelling of absolute values suggests that the area of actual effects will be less, around 15% and result in medium degree of interaction with a decrease in tidal current speeds of up to 0.05 ms^{-1}.

As a result of the high value of the receptor, the medium magnitude of the effect and the low sensitivity and medium area of interaction, the overall effect is considered to be of minor significance.

9.6.7 NG 6 - Silver Pit rMCZ

Fine Sediment Plume / Elevated Turbidity

As discussed in Section 9.6.2, the magnitude of all sediment plume effects are considered to be of medium magnitude for this assessment.

The Silver Pit rMCZ has been designated for the presence of subtidal sands, subtidal mixed sediments, Ross worm (*Sabellaria spinulosa*) and subtidal sands and gravels.

The conservation objectives for the site list subtidal mixed sediments as having a medium to no sensitivity to changes in water clarity, and do not list suspended sediment/elevated turbidity as a pressure for any other feature (Net Gain, 2011). This assessment of sensitivity is based on a change in one rank on the WFD scale e.g. from clear to turbid in one year, and is considered to be precautionary for the regular but temporary and localised increases in suspended sediments predicted for the proposed dredging activities.

As a result of the range of sensitivities given, and the likely short term and intermittent nature of dredge plumes, the subtidal mixed sediments are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity.

All other qualifying interest features are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity.

The modelling results show a limited area of around 2% of overlap between the south of the rMCZ and the edge of 2-19 mgl^{-1} sediment plume contour from dredging activity at Licence Area 481/1. The licence area is over 8 km from the rMCZ and at this distance the actual sediment plume is unlikely to be distinguishable from background suspended sediment levels (see Chapter 7). This is a very small degree of interaction.

Therefore, despite the high value of the receptor, the medium magnitude of the effect and the medium and low sensitivities of the qualifying interest features, as a result of the very small area of interaction and the likely very low concentration of the sediment plume within the rMCZ, the overall effect is considered to be of not significant.

Sand Deposition

The effect of sand deposition across the study area has been assessed as being of small magnitude. Although the potential deposition of sediments extends out to 2.5 km from active dredge areas, this is a very conservative approach which is very likely to overestimate the extent of sand deposition (See Chapter 7 for more details).

The sandy sediments within the rMCZ have been assessed in the conservation objectives as having a high sensitivity to high changes to the siltation rate (classified as 30 cm of fine material added to the seabed in a single event) and medium sensitivity to low changes to the siltation rate (classified as 5 cm of fine material added to the seabed in a single event) (Net Gain, 2011). High changes in the siltation rate (as defined by the conservation objectives) are not predicted to occur beyond around 200 m of the future dredge zone (see Chapter 7), and the vast majority of the area affected by siltation within the rMCZ is likely to experience low changes to the siltation rate. Therefore the subtidal sands qualifying feature is considered to have a medium tolerance and adaptability and recoverability to increases in suspended sediment and therefore an overall medium sensitivity.

The mixed sediments and Ross worm qualifying features have been assessed as having medium sensitivity to high siltation rate changes and no sensitivity to low siltation rate changes (Net Gain, 2011). Given the low change in siltation rates predicted, the mixed sediments qualifying feature is considered to have a high tolerance and adaptability and recoverability to increases in suspended sediment and therefore an overall low sensitivity.

The subtidal sands and gravels qualifying feature has been assessed as having no-sensitivity to medium sensitivity to both high and low siltation rate changes (Net Gain, 2011). Given this range of potential sensitivity together with the low change in siltation rates predicted, the subtidal sands and gravels qualifying feature is considered to have a high tolerance and adaptability and recoverability to increases in suspended sediment and therefore an overall low sensitivity.

Due to the conservative nature of the prediction of the potential area of effect, the actual area of interaction is likely to be limited to a small area in the north western corner of the rMCZ where there is likely to be a small area of sand deposition associated with dredging activity in Licence Area 480 which interacts with around 3% of the rMCZ resulting in a small degree of interaction.

Due to the high value of the receptor, the small magnitude of the effect, the moderate to low sensitivity of the receptors and the local extent of the effect which has a very small interaction with the rMCZ, the overall effects are considered to be not significant.

Changes to Sediment Particle Size

The magnitude of changes to particle size distribution has been assessed as being of small magnitude.

The conservation objectives for the rMCZ do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to particle size (Net Gain, 2011). However in line with the assessment of the sensitivity of Annex 1 Sandbank habitat SAC qualifying interest features, the sensitivity of the subtidal sands rMCZ qualifying interest feature is considered to be low. The subtidal sands features of the rMCZ are therefore assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to sediment particle size is assessed here as low.

Neither of the conservation objectives for the subtidal mixed sediments or subtidal sands and gravels qualifying features contains a specific assessment of sensitivity to changes to particle size. Both habitats tend to occur in more stable environments than mobile sandbanks and are considered to be slightly more sensitive to changes to the particle size of their constituent sediments and therefore both are considered to have a moderate tolerance, adaptability and recoverability and an overall sensitivity of medium.

The Ross worm, *S. spinulosa*, requires particles of a certain size to build its tubes (usually sand or shell fragments). If the particle sizes change to become unfavourable for tube building it will put a strain on survival of the worm. Based on this, the Ross worm has been assessed to have a medium tolerance and high recoverability to changes in particle size giving a medium sensitivity.

There is a potential area of effect up to 4 km from future extraction zones, however in reality changes to sediment particle size are likely to be restricted to localised presence of sand streaks within a few hundred metres of the extraction zones (see Chapter 7). As a result, the areas of interaction are likely to be limited to a very small area of less than 5% in the south western corner of the rMCZ where there may be an overlap between effects from the extraction zone of Licence Area 480, resulting in a small degree of interaction.

As a result of the high value of the receptor, the small magnitude of the effect, the low and moderate sensitivities of the qualifying interest features and the very limited interaction, the overall effect is considered to be not significant.

9.6.8 NG 8 - Holderness Inshore

Changes to Sediment Particle Size

The magnitude of changes to particle size distribution has been assessed as being of small magnitude.

The NG 8 Holderness Coast rMCZ has been designated because of its intertidal mixed sediments, subtidal coarse sediments, subtidal sands, peat and clay exposures, subtidal chalk, subtidal sands and gravels and Ross worm reefs and the geological feature of Spurn Head. None of the conservation objectives for the qualifying interest features of the rMCZ assess the sensitivity to changes to sediment particle size (Net Gain, 2011). Based on the assessments assigned to other rMCZs (see Section 9.6.6 and Section 9.6.7), the following sensitivities have been assigned.

The subtidal sands features of the rMCZ are assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to sediment particle size is assessed here as low.

The subtidal coarse sediments and the subtidal sands and gravels qualifying features are both considered to have a medium tolerance, adaptability and recoverability and an overall sensitivity of medium.

The Ross worm habitat within the rMCZ is assessed as having a medium tolerance, adaptability and recoverability to changes in particle size and therefore an overall medium sensitivity to changes to particle size.

As peat and clay exposures and chalk exposures are solid substrates they are not considered to be sensitive to changes to sediment particle size. The intertidal mixed sediments qualifying feature and Spurn Head geological feature are restricted to the coastline and are outside the area of interaction with changes to sediment particle size and are therefore not considered to be sensitive to this effect.

There is a small area (around 1%) of overlap with the south-eastern corner of the rMCZ, over 2.5 km from the future extraction zone within Application Area 448. In reality changes to sediment particle size are likely to be restricted to the localised presence of sand streaks within a few hundred metres of the extraction zones (see Chapter 7) and there is considered to be a very small degree of interaction.

As a result of the high value of the receptor, but the very small area of interaction and the small magnitude of the effect, and given the low and medium sensitivity of the qualifying interest features the overall effect is considered to be Not Significant.

Change to Tidal Currents

The changes to tidal currents within the Study Area have been assessed as being of medium magnitude.

The conservation objectives for the site assess the sensitivity of subtidal sands as having a low to no sensitivity to changes to local tidal currents, and do not consider changes to tidal currents as a potential pressure to any other qualifying interest features (Net Gain, 2011). The sensitivity criteria for rMCZs define changes to currents as peak mean spring tide flow change between 0.1m/s to 0.2m/s over an area >1km^2 or 50% of width of water body for > 1 year. The modelling results show changes of a maximum of 0.02-0.05 and therefore the assessment of sensitivity is considered to be precautionary. As a result all of the qualifying interest features are assessed as having a high tolerance, adaptability and recoverability and an overall low sensitivity to changes to tidal currents.

The modelling of changes to tidal currents suggests percentage changes of up to +/- 10% in small areas in the south east of the rMCZ, affecting around 3% of the rMCZ. The modelling of absolute changes suggests that the effect will result in changes of +/- 0.05 ms^{-1} in a similar area on the edge of the rMCZ, resulting in a small degree of interaction.

Given the high value of the receptor, the medium magnitude of the effect, the low sensitivity of the qualifying interest features and the very small area of interaction, the overall effect is considered to be not significant.

9.6.9 NG9 - Holderness Offshore

Fine Sediment Plume / Elevated Turbidity

As discussed in Section 9.6.2, the magnitude of all sediment plume effects are considered to be of small to medium or medium magnitude for this assessment.

The NG9 Holderness Offshore rMCZ has been designated because of its subtidal coarse sediment and subtidal mixed sediment. The conservation objectives for the rMCZ do not consider elevated turbidity a potential pressure for subtidal sands but assesses subtidal mixed sediments as having medium to no sensitivity to water clarity changes (Net Gain, 2011). This assessment of sensitivity is based on a change in one rank on the WFD scale e.g. from clear to turbid in one year, and is considered to be precautionary for the regular but temporary and localised increases in suspended sediments predicted for the proposed dredging activities, especially as the potential changes to turbidity are predicted to be relatively low (within the 19-2 mgl^{-1} suspended sediment contour). As a result, for this assessment all qualifying interest features are considered to have a high tolerance, adaptability and recoverability and an overall low sensitivity to elevated turbidity.

The modelling results show a low degree of interaction of around 5% of the rMCZ and the edge of 2-19 mgl^{-1} sediment plume contour from dredging activity at Licence Areas 105, 109 and Application Area 449. The licence area is over 3 km from the rMCZ and at this distance the actual sediment plume is unlikely to be distinguishable from background suspended sediment levels (see Chapter 7).

Therefore, despite the high value of the receptors and the medium magnitude of the effect, as a result of the low sensitivities of the qualifying interest features, and the low degree of interaction of the sediment plume with the rMCZ, the overall effect is considered to be not significant.

Changes to Sediment Particle Size

The magnitude of changes to particle size distribution has been assessed as being of small magnitude.

The conservation objectives for the rMCZ do not contain a specific assessment of the sensitivity of the qualifying interest features to changes to particle size (Net Gain, 2011). However in line with the assessment of the sensitivity of Annex 1 Sandbank habitat SAC qualifying interest features, the sensitivity of the subtidal sands rMCZ qualifying interest feature is considered to be low. The subtidal sands features of the rMCZ are therefore assessed as having a high tolerance and adaptability and recoverability and the overall sensitivity to changes to sediment particle size is assessed here as low.

The subtidal mixed sediments qualifying feature is considered to have a medium tolerance, adaptability and recoverability and an overall sensitivity of medium.

There will be a very small area of overlap between the area of potential changes to sediment particle size and less than 1% of the rMCZ. As stated in Chapter 7, the predicted area of effect is very precautionary and the actual area of effect is very unlikely to overlap with the rMCZ.

As a result of the high value of the receptors, the small magnitude of the effect, the low to medium sensitivities of the qualifying interest features and the very small area of interaction with the likely effect, the overall effect is considered to be not significant.

9.6.10 Summary of Direct Effects on Designated Sites

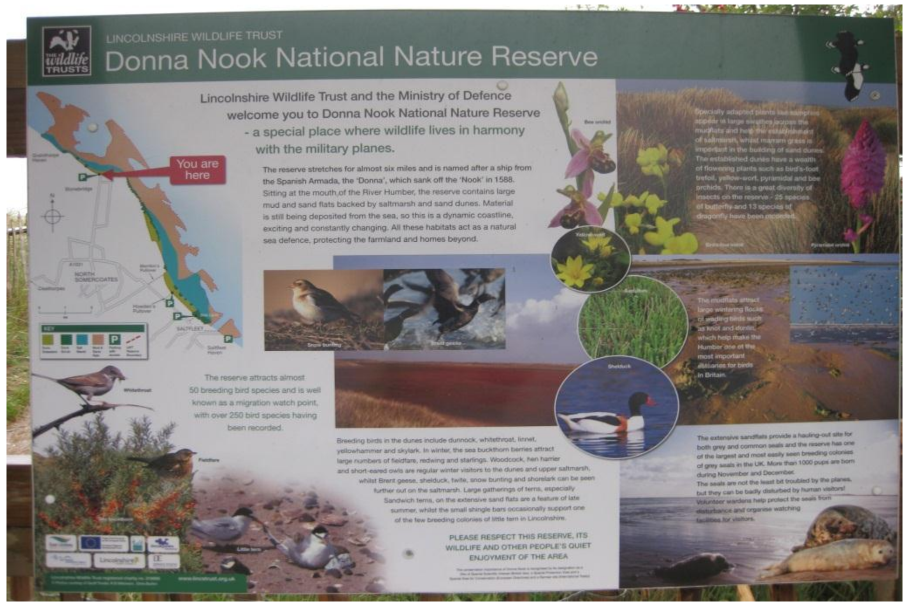
A summary of the direct effects of the proposed future dredging across the study area to designated sites is presented in Table 9.14 below.

No direct effects to coastal designated sites are predicted. The majority of effects to rMCZs are predicted to be not significant. A number of effects to the Inner Dowsing and Race Bank SAC are predicted to be of Minor or Moderate Significance, with removal of sediment potentially resulting in an impact of Major Significance to reef qualifying features and moderate – major significance to sandbank qualifying features.

9.6.11 Summary of Potential Impacts to Mobile Qualifying Interest Features Outwith Designated Sites

As explained in the introduction a number of protected sites in the Humber area have not been considered in this chapter because there is no overlap between them and the modelled effects of dredging. However, some of these sites do have qualifying interest features comprising mobile species which may interact with the potential effects of the proposed dredging activities. Impacts to these species have been assessed in other sections of this MAREA, as summarised in Table 9.15 below.

Signboard at the Donna Nook National Nature Reserve



Little Tern (Sterula albifrons)

Source:Shutterstock.com

Grey Seal (Halichoerus grypus) Hauling Out on a Sandbank

Source Shutterstock.com

Table 9.14 Summary of Direct Effects to Designated Sites

RECEPTOR	Inner Dowsing and Race Bank SAC		The Wash and North Norfolk Coast SAC	NG 4 Wash Approach rMCZ	NG 5 - Lincs Belt rMCZ	NG 6 - Silver Pit rMCZ	NG 8 - Holderness Inshore	NG 9 - Holderness offshore
	Reef features	Sandbank features						
Presence of the Vessel								
Removal of Sediment	Major *	Moderate - Major *	No interaction	Minor	No interaction	No interaction	No interaction	No interaction
Fine sediment plume/Elevated turbidity	Minor	Minor	No effects	Not significant	Not significant	Not significant	No interaction	Not significant
Sand Deposition	Moderate	Minor	No interaction	Not significant	×	Not significant	No interaction	No interaction
Changes to sediment particle size	Minor	Not significant	No interaction	Not significant	×	Not significant	Not significant	Not significant
Changes to Wave heights	No Interaction	Not significant	No interaction	Not significant	Minor	No interaction	No interaction	
Changes to Tidal Currents	Minor	Not significant	No interaction	Not significant	Minor	No interaction	Not significant	
Underwater noise	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Loss Access								
Changes to Benthic Community composition	N/A	Minor	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Change to distribution of fish	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Changes to seabed features								

* In reality the impacts will be addressed in licence conditions and be mitigated by survey, mapping their extent, and avoiding the features during dredging.

	Not affected

Table 9.15 Summary of Potential Impacts to Mobile Qualifying Interest Feature Species outwith Designated Sites with the Study Area

Qualifying Feature Species	Designated sites for which the species is a qualifying interest feature	Where Addressed in MAREA	Assessment of Impact
Little tern	Gibraltar Point SPA, Humber Flats, Marshes and Coast SPA and Ramsar Site, North Norfolk Coast SPA and Ramsar Site, The Wash SPA and Ramsar site, Gibraltar Point SSSI, North Norfolk Coast SSSI, The Wash SSSI, The Lagoons SSSI, Saltfleetby-Theddlethorpe Dunes SSSI, Blakeney NNR, Scolt Head Island NNR, Saltfleetby-Theddlethorpe Dunes NNR, Gibraltar Point NNR, Holkham NNR	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Common tern	North Norfolk Coast SSSI, Humber Estuary SSSI, Blakeney NNR, Scolt Head Island NNR	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Sandwich tern	North Norfolk Coast SPA and Ramsar Site, North Norfolk Coast SSSI, Blakeney NNR, Scolt Head Island NNR	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Mediterranean gull	North Norfolk Coast SPA and Ramsar Site	Impacts are assessed in Section 9.5	Not Significant
Kittiwake	Flamborough Head SPA, Flamborough Head SSSI	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Northern gannet	Flamborough Head SPA, Flamborough Head SSSI	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Razorbill	Flamborough Head SPA, Flamborough Head SSSI	Impacts are assessed in Section 9.5	Not Significant - Minor Significance
Guillemot	Flamborough Head SPA, Flamborough Head SSSI	Impacts are assessed in Section 9.5	Minor Significance
Atlantic puffin	Flamborough Head SPA, Flamborough Head SSSI	Impacts are assessed in Section 9.5	Minor Significance
Common seal	The Wash and North Norfolk Coast SAC, The Wash SSSI, Blakeney NNR	Impacts are assessed in Section 9.4	Minor Significance
Grey seal	Humber Estuary SAC, Humber Estuary SSSI, Donna Nook NNR, Blakeney NNR	Impacts are assessed in Section 9.4	Minor Significance
Sea lamprey	Humber Estuary SAC, Humber Estuary SSSI	Impacts are assessed in Section 9.3	Not Significant
River lamprey	Humber SAC, Humber Estuary SSSI	Impacts are assessed in Section 9.3	Not Significant

Future extraction zones for Licence Areas 481/1, 481/2, 107 and 440 as well as Application Area 439 overlap with the boundary of the Inner Dowsing, Race Bank and North Ridge cSAC, and future extraction zones for Licence Areas 480 and 106/3 lie adjacent to it. As a result of the sensitivity of the qualifying interest features to the potential effects of dredging it is likely that a Habitats Regulations Assessment screening assessment will be required to be undertaken to inform licence applications in these Licence Renewals and Application Areas. In particular, the future extraction zones of Licence Area 107 and Application Area 439 overlap with areas of Annex 1 Habitat within the cSAC boundary. Pre-dredge baseline surveys will be undertaken for each 15 year licence and application area that will, among other things, establish the presence and extent of Sabellaria reef features. At that time suitable mitigation measures will be agreed with NE/JNCC/MMO to avoid damage to such reefs if found to be present.

Area 440 also has a very small area of overlap with the NG4 Wash Approaches rMCZ which will also need to be assessed further at the EIA stage.

Although they do not overlap with any designated sites, Application Area 493 and Licence Renewal Area 197 may result in changes to wave heights or tidal currents which have the potential to result in effects to the NG5 Lincs Belt rMCZ.

Seabirds which originate from breeding colonies within designated sites around the coastline of the MAREA study area forage widely across the study area and may interact with a number of licence areas. At the EIA stage all licence areas should undertake a review of the likely use of the licence area by seabird species arising from designated sites, which may involve an HRA Screening Assessment for birds originating from Flamborough Head and Bempton Cliffs SPA, and the North Norfolk Coast SPA. The maximum known foraging range for little tern is 11 km so it is unlikely that sites other than Application Area 493 and Licence Renewal Area 197 are close enough to breading colonies to affect this species.

Seals may also forage widely across the MAREA study area and individual licence areas should contain an assessment of the likely effects on marine mammals. It is thought unlikely that any of the proposed dredging activity will result in direct impacts to the seal populations at the Wash and North Norfolk Coast SAC or Humber Estuary SAC and it is not predicted that HRA Screening assessments will be required in relation to these qualifying interest features for any licence areas.

10 THE HUMAN ENVIRONMENT - ASSESSMENT OF REGIONAL IMPACTS

10.1 INTRODUCTION

This section describes the potential regional impacts on the human environment as a result of future marine aggregate extraction activities in the Humber and Outer Wash Region.

The topics covered in this section include:

- impacts to fisheries (Section 10.2);
- impacts to infrastructure (Section 10.3);
- impacts to recreation (Section 10.4);
- impacts to shipping and navigation (Section 10.5); and
- impacts to archaeology (Section 10.6).

Each section considers the potential impacts that may arise as a result of the effects of dredging discussed in Chapter 7.

Pilot Looking Out from the Superstructure of a Dredger

10.2 POTENTIAL IMPACTS TO COMMERCIAL AND RECREATIONAL FISHERIES

10.2.1 Introduction

As discussed in Section 6.2, the most important fisheries in the area, which could potentially experience impacts from dredging operations, can be divided into the following groups:

- mussel fishery;
- cockle fishery;
- brown shrimp fishery;
- shellfish (crab and lobster) fishery; and
- recreational fisheries.

Mussel Fishery

The mussel fishery in the Humber and Outer Wash is targeted by small and large vessels using suction and mechanical dredging to collect mussels either for seed, which can be sold in Europe or used for 'lays' [(1)] closer inshore, or to be sold directly to markets for consumption. Mussel fishing areas are located in three locations within the MAREA study area: high intensity mussel fishing takes place within The Wash, seed mussel beds are located south of the Humber Estuary adjacent to the shore, and mussel dredging takes place further offshore. The vessels that target the mussel fishery are from ports located in King's Lynn and Boston.

Cockle Fishery

The cockle fisheries within the Humber and Outer Wash study area are located south of the Humber Estuary. The fishery supports approximately 50 vessels. The fishery is predominantly hand-worked by vessels under 15 m, however, dredging is sometimes allowed in The Wash when stock levels are high enough to sustain it. The principal fishing grounds are located on the inner Wash sands at Wainfleet, Roger, Gat, Holbeach and Daseleys and along the northeast Lincolnshire coast. The majority of vessels that target cockles are from King's Lynn and Boston.

Brown Shrimp Fishery

A large brown shrimp fishery is found in the Humber and Outer Wash area. The locations of fishing grounds vary throughout the year but cover the majority of the southern part of the MAREA study area. An area of high intensity fishing extends along the coast from the Humber Estuary to The Wash. Approximately 40 vessels (of all sizes) from King's Lynn, Boston and Brancaster exploit the fishery throughout the year.

(1) Lays are areas of suitable habitat that are 'stocked' with seed (juveniles) by fishermen and harvested when mature.

Shellfish (Crab and Lobster) Fishery

During consultation it was highlighted that the vessels targeting crab also targeted lobster; therefore, the two fisheries will be considered as one in this assessment. The crab and lobster fishing grounds targeted by less than 10 m vessels are located along the coastlines of north Norfolk, northeast Lincolnshire and north of the Humber Estuary up to 6 nm from shore. The over 10 m fleet is mainly based at Holderness and Bridlington and these vessels target fisheries out to 12 nm.

Recreational Fisheries

Recreational fisheries are widespread across the region with sea angling of particular importance. Sea anglers use small boats which are either privately owned or from a chartered fleet in ports such as Bridlington or Grimsby. Recreational fisheries operate year round in the Humber and Outer Wash and are important to the economy of the region.

Value of Fisheries in the Humber and Outer Wash Region

The fisheries in the region play a key role in the economy by supporting both small and large vessels. Species of high commercial value are crab, lobster and brown shrimp. Mussels from the region also support a growing demand for seed mussels in Europe which is profitable. Recreational sea fisheries attract a number of people to the region which supports local businesses and livelihoods, including angling charter boats, tackle shops and angling guides.

In light of their importance at a local, regional and national scale and their value (in GBP) the value of each fishery is assessed as follows:

- Mussel fishery – Medium;
- Cockle fishery – Low/Medium;
- Brown shrimp fishery – High;
- Shellfish (crab and lobster) fishery – High;
- Recreational fisheries – Medium.

10.2.2 Identification of Potential Impacts on Commercial and Recreational Fisheries

Types of Impact

Table 10.1 details the predicted effects of dredging with reference to whether or not they have the potential to impact the five fisheries considered in this assessment.

The potential impacts of dredging may affect the ability for fisheries to operate either directly via loss of access to fishing grounds or sand deposition, or may occur as a consequence of impacts to benthic (shellfish) or fish species in the region (see Sections 9.2 and 9.3). Collision risk for fishing vessels is discussed in Section 10.4.

Table 10.1 Matrix of Potential Impacts of Dredging on Commercial and Recreational Fisheries

RECEPTOR	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	change to benthic community Composition	Change to distribution of fish	Changes to seabed features
Mussel fishery	■	■	■	■	■	■	■	■	■	✓	✓	■	■
Cockle fishery	■	■	■	■	■	■	■	■	■	X	X	■	■
Brown shrimp fishery	■	■	■	■	■	■	■	■	■	✓	✓	■	■
Shellfish (crab and lobster) fishery	■	■	■	■	■	■	■	■	■	✓	✓	■	■
Recreational fisheries	■	■	■	■	■	■	■	■	■	✓	■	✓	■

■	Not affected
x	No interaction
✓	Potential Interaction

Loss of Access

The current baseline dredging vessel movements in the MAREA study areas accounts for 0.7% of total ship movements annually (Appendix H). Using the maximum future extraction scenario the dredging activities in terms of vessel movements will be almost triple the baseline. However, in overall traffic terms, dredging activity will still represent a low proportion of approximately 2%. Loss of access as a result of increased dredging vessel traffic is therefore a small magnitude effect based on it being site specific in extent and regularly occurring (routine) but also transient (temporary) and constituting a low level change relative to the baseline.

Changes to Benthic Community Composition

A change to the composition of the regional benthic community as a result of dredging operations is a localised effect that is medium term in duration and constitutes a medium level change from baseline conditions. The effect is considered to be intermittent in occurrence because the majority of dredging occurs along tracks that have been dredged before and therefore the frequency of previously un-dredged seabed (and the associated benthic communities) being affected is relatively low. As a result it is classified as a medium-large magnitude effect.

It should, however, be noted that the benthic impact chapter has assessed the effects on commercial benthic species. Generally the effects ranged from not significant to minor with a moderate impact only having been predicted to berried brown crabs. Consequently, applying a medium-large magnitude effect is a conservative approach to the assessment of effects on commercial fisheries.

Changes to the Distribution of Fish

Changes to the distribution of fish species may have consequences for the recreational fisheries in the area, which are influenced by direct impacts to the fish populations inhabiting the study area. These changes may affect recreational fisheries by making the areas that are usually fished less productive or cause the fish population to move away which could result in fishing vessels moving away from these areas. However, it is not anticipated that there will be any impacts from dredging on target fish species over and above a level of minor significance (see Section 9.3); therefore, populations of target species are expected to return to the same locations once the disturbance from dredging vessels has ceased. A change to the distribution of fish species as a result of dredging operations is therefore a small magnitude effect based on its localised and transient nature, the fact that it is a low level of change relative to baseline levels but that it is regularly occurring (routine).

10.2.3 Mussel Fishery

Loss of Access

Loss of access is a small magnitude effect based on the effect being regularly occurring (routine) but being site specific in extent, constituting a low change relative to the baseline and being temporary in duration.

The mussel fishery (see Figure 6.15 in Commercial Fisheries Baseline) is mainly located in the Inner Wash and close to the Lincolnshire Coast; however, some of the mussel fishing grounds lie adjacent to the future 15 year extraction zones of Areas 107, 197, 400, 440, 441/1 and 493. The seed mussel area is located very close to the boundary of the future 15 year extraction zones within Areas 400, 439 and 493 resulting in the potential for the fishery to be affected if a dredging vessel is present at the boundary of one of these extraction zones while a seed mussel fishing vessel is in the area or while the dredge vessel is transiting from the extraction zone to port. The area of the mussel fishing grounds close to the future 15 year extraction zones is small in comparison to the size of the entire fishery in the study area.

The mussel fishery is considered to have high tolerance due to the small area of the mussel fishery that will be affected by loss of access and because the highest intensity mussel fishery is mainly present in The Wash, away from the aggregate extraction zones. The fishery also has high adaptability due to the relatively small areas of the fishery that is close to dredge areas and hence the ability of the mussel fishing vessels to avoid dredgers by moving to other areas of the mussel fishing ground. The fishery has high recoverability from this effect because after the dredger has passed through, the fishing activity in the area will recover rapidly from any adverse effects. In consideration of the tolerance, adaptability and recoverability, the sensitivity of the mussel fishery to loss of access is considered to be low.

Freshly Harvested Mussels (Mytilus edulis) at Burnham Harbour

Source: Shutterstock.com

Based on these assessments, acknowledging the high value, of the fishery but noting the small magnitude of the effect, low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of loss of access on this fishery is considered to be not significant at the regional scale.

Changes to Benthic Community Composition

A change in benthic community composition is a medium-large magnitude of effect based on the local extent of the effect and the intermittent frequency, the medium term duration of the effect (which will be between 1 and 10 years) and the medium change relative to the baseline.

The benthic impact assessment (see Section 9.2) concludes that the only effect of dredging that could impact mussels is changes to sediment particle size and this was assessed to be an effect of minor significance. Taking into account that mussels will not be affected by any other changes in the benthic environment the impact on the mussel fishery is expected to be not significant at a regional level.

10.2.4 Brown Shrimp Fishery

Loss of Access

Loss of access is a small magnitude effect based on the effect being regularly occurring (routine), site specific in extent, a low change relative to the baseline and of temporary duration.

Consultation with local fishermen indicated that the brown shrimp fishery in the Humber and Outer Wash overlaps with all but two of the future 15 year extraction zones (Area 441/2 and Application Area 441/3) (see Figure 6.13 in Section 6.2). Therefore, the fishing fleet is expected to interact with the dredging vessel traffic and will potentially have to move away from preferred grounds on some occasions to avoid collisions.

The area of highest intensity fishing is close to shore and only overlaps with future 15 year extraction zones 107 and 481/2 although it is also adjacent to future 15 year extraction zones in Area 197, and Application Areas 400, 439 and 493. Fishing vessels targeting this high intensity fishing ground close to Area 107 may have to move to avoid collisions with dredging vessels; the main interaction with dredging vessels will be as the dredge vessels transit from the future 15 year extraction zones to port.

The moderate intensity fishing ground overlaps with 10 of the future 15 year extraction zones in the centre of the MAREA study area; however, this fishing ground is large and approximately more than three quarters of the fishing ground does not overlap with the future 15 year extraction zones.

A low intensity brown shrimp fishing ground is present east of the Humber Estuary which overlaps with future 15 year extraction zones in Areas 102 and 105 and in Application Areas 448 and 449. Vessels fishing in this area may have to move from preferred fishing grounds to avoid collisions with dredging vessels. In addition, dredging has been ongoing in the region for over 40 years alongside the brown shrimp fishery without any detrimental effects on the health of the brown shrimp fishery.

The brown shrimp fishery is considered to have medium-high tolerance due to the relatively small area of the brown shrimp fishing grounds that will be directly affected by the total potential loss of access. The fishery also has a high adaptability because vessels are able to move to avoid collisions with dredging vessels and can target other locations; in addition, the recoverability is high because the vessels can return to the fishing grounds once the vessels have left the area. Taking into account tolerance, adaptability and recoverability, the sensitivity of the brown shrimp fishery to loss of access is considered to be low.

In consideration of the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of loss of access on the brown shrimp fishery is considered to be not significant at the regional scale.

Changes to Benthic Community Composition

A change in benthic community composition is a medium-large magnitude of effect based on the local extent of the effect and the intermittent frequency, the medium term duration of the effect (which will be between 1 and 10 years) and the medium change relative to the baseline.

The benthic impact assessment (see Section 9.2) concluded that the effect of sediment removal and changes to sediment particle size on brown shrimp will be of minor significance; the effect of sand deposition was assessed to be not significant. The brown shrimp fishery operates throughout much of the Humber and Outer Wash area so is expected to have high tolerance and high adaptability to changes to benthic community composition in the vicinity of the future 15 year extraction zones. The recoverability of the fishery is expected to be high because the brown shrimp fishery will be able to return to targeting brown shrimp when they become available again in instances where brown shrimp are affected in the ways discussed above. The overall sensitivity of the brown shrimp fishery to changes to benthic community composition is low.

As stated in Section 9.2 6.5 % of all brown shrimp fishing grounds (but only 0.64% of the high intensity areas) overlap with the future 15 extraction zones. The area within which changes to sediment particle size are predicted to overlap is 34% of the brown shrimp fishing ground. Overall, the interaction between brown shrimp fishery and changes to benthic community composition is small.

Taking into account the medium-large magnitude of effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to benthic community composition on the brown shrimp fishery is considered to be not significant at the regional scale.

10.2.5 Shellfish (Crab and Lobster) Fishery

Loss of Access

Loss of access is a small magnitude effect based on the effect being regularly occurring (routine) but site specific in extent, comprising a low change relative to the baseline and being of temporary duration.

The under 10 m vessels that target shellfish in the Humber and Outer Wash study area are located away from the future 15 year extraction zones (see Figure 6.20 in Commercial Fisheries Baseline) so the potential for interaction with dredging vessels will only arise when dredge vessels are transiting from the future 15 year extraction zones to port.

The fishing grounds targeted by over 10 m vessels overlap with future 15 year extraction zones 105, 106/3 and 107 (see Figure 6.20 in Section 6.2); these fishing grounds are targeted with moderate intensity so it is likely that vessels fishing in these locations may on occasion have to move from preferred fishing grounds to avoid collision with dredging vessels. The majority of the other fishing grounds do not overlap with any of the future 15 year extraction zones so the only potential interaction to fishing in the rest of this fishing area could occur with dredging vessels in transit.

The shellfish fishery is considered to have high tolerance due to the small area of the fishing grounds that will be directly affected by loss of access at any time. The fishery has high adaptability because of the large extent of the fishery meaning that vessels will be able to move to avoid collisions with dredging vessels and that they can target other locations; in addition, the recoverability is high because the vessels can return to the fishing grounds once the vessels have left the area. Taking into account tolerance, adaptability and recoverability, the sensitivity of the shellfish fishery to loss of access is considered to be low.

Based on the small magnitude of the effect, the high value and low sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of loss of access on the shellfish fishery is considered to be not significant at the regional scale.

Changes to Benthic Community Composition

A change in benthic community composition is a medium-large magnitude effect based on the local extent of the effect and the intermittent frequency, the medium term duration of the effect (which will be between 1 and 10 years) and the medium change relative to the baseline.

As explained in Section 9.2 the impact on <10 m vessels targeting shellfish was assessed to be not significant. A small proportion of the total shellfishery (including > 10 m vessels) will, however, be affected by sediment removal (1.8%) and sand deposition (7.75%). These interactions were assessed to result in a regional impact of minor significance in Section 9.2.

Section 9.2 assessed the impact on berried [(1)] females to be of moderate significance; however, berried female brown crabs cannot be landed (ICES, 2007) so this will not affect the shellfishery in the Humber and Outer Wash. Overall, the impact to the regional shellfishery is expected to be not significant at the regional level.

10.2.6 Recreational Fisheries

Loss of Access

Loss of access is a small magnitude effect based on the effect being regularly occurring (routine); however, it is site specific in extent, comprises a low change relative to the baseline and is temporary in duration.

The shark fishery which targets smoothound and spurdog is growing in importance for recreational fisheries (Coastal Observation, 2011) and is largely located in inshore areas. Other important species targeted by recreational vessels include cod, bass and whiting and these fishing grounds are predominantly located around wrecks in the study area (Nigel Proctor, 2011). As explained in Section 6.6 wrecks from aircrafts and ships are scattered throughout the MAREA study; recreational fishing vessels focus their fishing effort on the high concentration of wrecks in the mouth of the Humber Estuary and at ship wrecks along the North Norfolk coast (Nigel Proctor, 2011).. All of these locations are outside of the future 15 year extraction zones and are therefore only expected to interact with dredging vessels as dredging vessels transit between the dredging areas and port.

Recreational fisheries tend to focus on specific areas such as in the vicinity of wrecks. Recreational fisheries therefore tend to have more restricted fishing grounds than other fisheries; taking this into account, recreational fishing vessels have medium tolerance to loss of access because fishing grounds targeted are more restricted. The adaptability of recreational vessels is medium based on the ability of fishing vessels to avoid dredging vessels even though the fishing grounds are restricted. Recreational vessels will be able to continue fishing in their preferred location once dredging vessels have left the area; therefore, the recoverability of recreational vessels is high. Based on the consideration of their tolerance, adaptability and recoverability, the sensitivity of recreational fisheries to loss of access is considered to be medium.

In consideration of the medium value and sensitivity of the receptor, but noting the small magnitude of effect and the small degree of interaction the cumulative impact of loss of access on the recreational shellfish fishery is considered to be not significant at the regional scale

(1) Females carrying eggs.

Changes to Distribution of Fish

The main species targeted by recreational fishing vessels are cod, ling, pollack, whiting, smoothound and spurdog. The main fishing grounds targeted by recreational vessels do not overlap with the future 15 year extraction zones so are not expected to be affected by dredging activity. Dredging vessels in transit may cross through the recreational fishing grounds but are not expected to affect the distribution of fish because the Humber and Outer Wash has many shipping routes across the region and dredging vessels transiting to the future 15 year extraction zones will only contribute 2% of the additional future total vessel movement in the region.

The recreational fishery has a low tolerance to a change in the distribution of fish species, as it is limited in terms of available fishing grounds. Recreational fisheries have a medium adaptability as they can avoid dredging locations by moving to other areas to fish, however this may result in a decrease in available fishing opportunities and increased fuel and time costs. The recreational fleet is thought to have a high level of recoverability as recreational vessels may re-enter an area rapidly following completion of dredging activity. Taking into account the tolerance, adaptability and recoverability, the sensitivity of the recreational fisheries to a change in the distribution of fish is considered to be medium.

Based on these assessments of the medium value and sensitivity of the receptor but noting the small magnitude of the effect and the small degree of interaction between the receptor and the effect, the cumulative impact of changes to fish distribution on inshore fisheries is assessed as being not significant at the regional scale.

Recreational Fishing and Sailing Boats Moored near Wells-next-the-Sea

Source: ABPmer

10.2.7 Summary of Impacts

Table 10.2 summarises the significance of cumulative effect of dredging on commercial and recreational fisheries at a regional scale.

Table 10.2 Summary of Impacts to Commercial Fisheries

	Mussel fishery	Brown shrimp fishery	Shellfish (crab and lobster) fishery	Recreational Fisheries
Sand Deposition	Not significant			
Loss of Access	Not significant	Not significant	Not significant	Not significant
Changes to the Benthic Community Composition	Not significant	Not significant	Not significant	
Changes to Distribution of Fish				Not significant

	Not affected

At the EIA stage, the following interactions between licence areas and certain fisheries will require further exploration.

Brown shrimp Fishery:

- Area 107 is located within a high intensity fishing ground.
- Areas 493, 197, 400, 439, 106/3, 480, 481/1, 481/2, 440, 441/1 all overlap with the moderate intensity fishing grounds.
- Areas 102,105, 449, 448 overlap with low intensity fishing grounds

Shellfish (Crab and Lobster) Fishery:

- Areas 105, 106/3 overlap with >10m vessel moderate intensity summer fishing grounds.
- Area 107 overlaps with moderate intensity fishing grounds.

10.3 Potential Impacts to Coastal and Offshore Developments and Infrastructure

10.3.1 Introduction

As discussed in Section 6.3 the MAREA study area contains a diverse range of coastal and offshore developments and infrastructure. This includes major ports and harbours that service a busy international shipping industry, subsea gas pipelines, wellheads and platforms that provide the UK with an indispensable energy supply, and telecommunications cables that support the country's growing communication needs. Each of these infrastructure features are of national importance in terms of their high economic value and the critical role they play in supporting the daily operations of the country.

Offshore wind is a relatively new industry to the region, with the Lynn and Inner Dowsing sites currently in operation and two further sites currently under construction. Over the forthcoming years and decades, further offshore windfarm sites are planned for development subject to consent. These developments are also considered to be of national importance in terms of their economic value and their contribution to the UK achieving its renewable energy and greenhouse gas targets.

The marine disposal sites within the MAREA study area no longer have economic value as operational disposal sites, but their stability must be maintained to prevent environmental degradation that could occur if the materials they contain were significantly disturbed.

Coastal defence and maintenance activities occur at numerous locations in the MAREA study area in order to protect vulnerable coastal populations and property from flooding and to maintain local tourism value through beach replenishment schemes. The military and naval interests in the study area include coastal RAF bases, firing ranges, and areas used for air combat and submarine training and exercise.

The infrastructure in the MAREA study area is large scale and has significant importance to both UK and international economies as well as to British national security. As such, all of the infrastructure features described in the baseline are considered to be of regional or national importance and are all therefore high value receptors.

For the purposes of the assessment, comparable infrastructure features described in the baseline are grouped together in the following categories.

- Ports and other coastal developments (including harbours and port expansions and coastal maintenance schemes);
- offshore renewables installations (excluding cables);
- wellheads and platforms;
- pipelines and cables (including gas-related infrastructure and pipelines telecommunications cables and offshore windfarm cables);
- marine disposal sites; and
- military and naval activities.

10.3.2 Identification of Potential Impacts to Coastal and Offshore Developments and Infrastructure Receptors

Table 10.3 identifies the predicted effects of dredging with reference to whether or not they have the potential to impact various infrastructure features that are present in the MAREA study area.

Table 10.3 Matrix of Potential Impacts of Dredging on Developments and Infrastructure

Receptor	Presence of the vessel	Removal of sediment	Fine sediment plume/elevated turbidity	Sand deposition	Changes to sand particle size	Changes to wave heights	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss off access	Change to benthic community composition	Changes to distribution of fish	Changes to seabed features
Ports and coastal developments	■	x	■	x	■	x	x	■	■	x	■	■	■
Offshore renewables installations	■	x	✓	■	■	✓	✓	x	■	✓	■	■	✓
Well Heads and platforms	■	■	■	■	■	■	■	■	■	■	■	■	■
Pipelines and Cables	■	■	■	■	■	■	■	■	■	■	■	■	■
Marine disposal sites	■	■	■	■	■	■	■	■	■	x	■	■	■
Military and naval activities	■	■	■	■	■	■	■	■	■	■	■	■	■

■	Not affected
x	No interaction
✓	Potential Interaction

Wellheads, platforms, pipelines, and cables are all surrounded by a 500 m safety zone that is observed by dredging vessels. As such, there is no potential for dredging activities to interact with this infrastructure and so they are not considered further in this assessment.

Military and naval activities are also scoped out of the assessment because military activities take precedence over dredging activities so any potential interactions would result in restricted access for dredging vessels with no impacts foreseen for the military or navy.
Potential interactions between an effect of dredging and a particular receptor that showed no spatial overlap within the MAREA study area have been classified as having 'no interaction'. This is the case for ports and harbours and for coastal development schemes which are located on the coast and have no potential interaction with any of the effects of dredging.

Where a potential interaction does exist in spatial terms, the effect is discussed below. In the ensuing discussion it is important to note that the standard approach to assessing sensitivity is not entirely appropriate in relation to developments and infrastructure. Where possible, sensitivity is expressed in the same terms as other receptors but where this is not feasible, sensitivity is determined using professional judgement with full explanation and justification provided.

10.3.3 Offshore Renewables Installations

Fine Sediment Plume

The presence of suspended sediment plumes during dredging operations that has a concentration above background levels is a small - medium magnitude effect for 2-20 mgl^{-1} and 20 - 50 mgl^{-1} plumes and a medium magnitude effect for plumes of 50 - 100 mgl^{-1} and >100 mgl^{-1}. This is based on the local extent of the plume (for the 20-50 mgl-1 and 50-100 mgl-1 plume) or site specific extent (for the > 100 mg l -1 plume) and them being regularly occurring (routine). However, the effect is temporary and only constitutes a low change relative to the baseline conditions for the 2-20 and 20 - 50 mgl^{-1} plume and a medium change relative to baseline conditions for the 50-100 mgl^{-1} and > 100 mgl^{-1} plumes.

Offshore windfarms are sensitive to fine sediment plumes during construction and operational maintenance as they can reduce the visibility of commercial divers and Remotely Operated Underwater Vehicles (ROVs) present in the water column and on the seabed.

Within the study area, there is one operational offshore windfarm (Lynn and Inner Dowsing), two that are under construction (Lincs and Sheringham Shoal), and one consented windfarm (Humber Gateway). There are a further five Crown Estate Round 2 sites (Westermost Rough, Race Bank, Docking Shoal, Triton Knoll, and Dudgeon), and a section of the Round 3 Hornsea zone also falls within the study area. A report commissioned by The Underwater Centre (Maritime Journal, 2011) states that 1.3 divers are needed for every ten turbines during operational phases, with divers most commonly working at depths of 20-39 m. The windfarms detailed in Section 6.3 involve an anticipated total of 736 turbines, which will therefore require up to 96 divers for operational maintenance. No information is available regarding the numbers of divers below the surface at any one time on a regional scale, but it is likely that commercial divers will be below the surface during some dredging operations over the next 15 years.

An increase of 20 mg l^{-1} above background levels would not generally disrupt windfarm maintenance diving operations, but increases of 50-100 mg l^{-1} have the potential to prevent such operations. The modelled 20 - 50 mg l^{-1} and 50 - 100 mg l^{-1} plume concentrations affect the south and east of the Humber Gateway site and the south of the Triton Knoll site. No other windfarm sites are affected by this effect (Figure 10.1).

Approximately 25% of the Humber Gateway site is affected by a plume of 50 -100 mg l^{-1} plume and 37% by a 20 -50 mg l^{-1} plume from dredging in Areas 102, 449, and 448. Approximately 8% of the Triton Knoll site is affected by the 50 - 100 mg l^{-1} plume and 6% by the 20 - 50 mg l^{-1} plum from Area 440. On a regional scale, these interactions amount to less than 5% of the total windfarm area within the study area.

The assessment is based on the assumption that dredging takes place throughout each licence area and at all times, whereas in practice there will be a small number of dredge vessels operating within the region at any one time. The quantity and extent of plumes associated with one or two dredging vessels within a licence area would therefore be smaller than the plume extent presented in Figure 10.1.

Based on the medium magnitude of the effect, the high value but low sensitivity of the receptor, and the very small degree of interaction between the receptor and the effect, the cumulative impact of fine sediment plumes on offshore windfarms is assessed to be not significant at a regional scale.

However, the described interactions may be significant at a site-specific scale so it is recommended that the licence holders of areas 102, 449, and 440, and application area 448, communicate with the operators of Humber Gateway and Triton Knoll in order to appropriately mitigate any such effects.

Changes to Wave Heights

A change of 2-5 % to a 1 in 200 year wave height will have a small - medium magnitude effect due to the sub-regional extent of the change, the long-term nature of the effect but noting the rare frequency of the effect and the small change relative to the baseline.

An increase in wave height of 2-5% (or 0.1-0.2 m in absolute terms) at MLWS for a 1 in 200 year NE wave has been modelled across an area of approximately 7-8 km^2 within the Humber Gateway site, with some lesser reduction(2-10% less or 0.2-0.4 m less) along the southern boundary of the windfarm site (Figure 10.2).

Figure 10.1 Interaction of Fine Sediment Plumes with Offshore Windfarm Sites

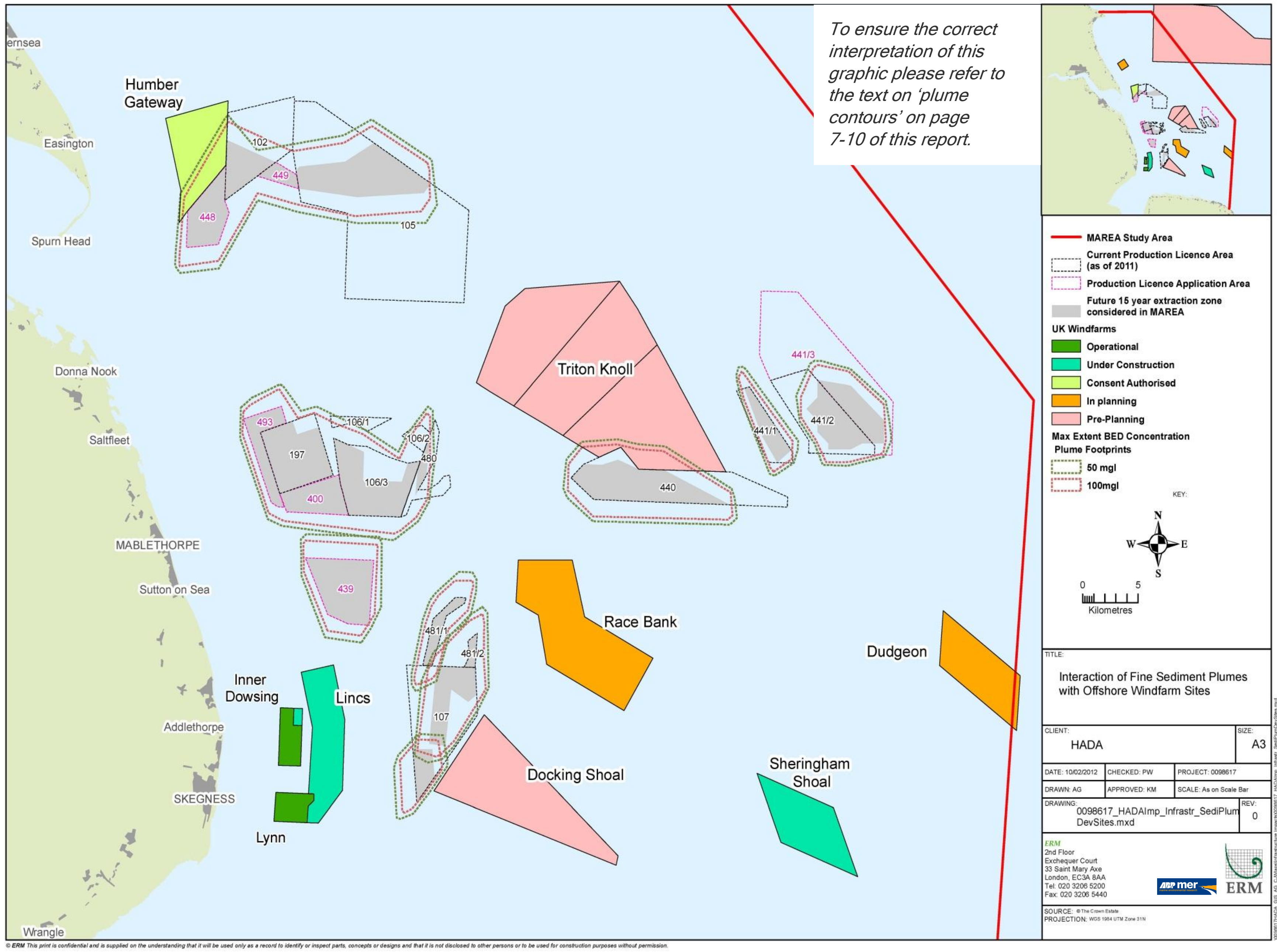
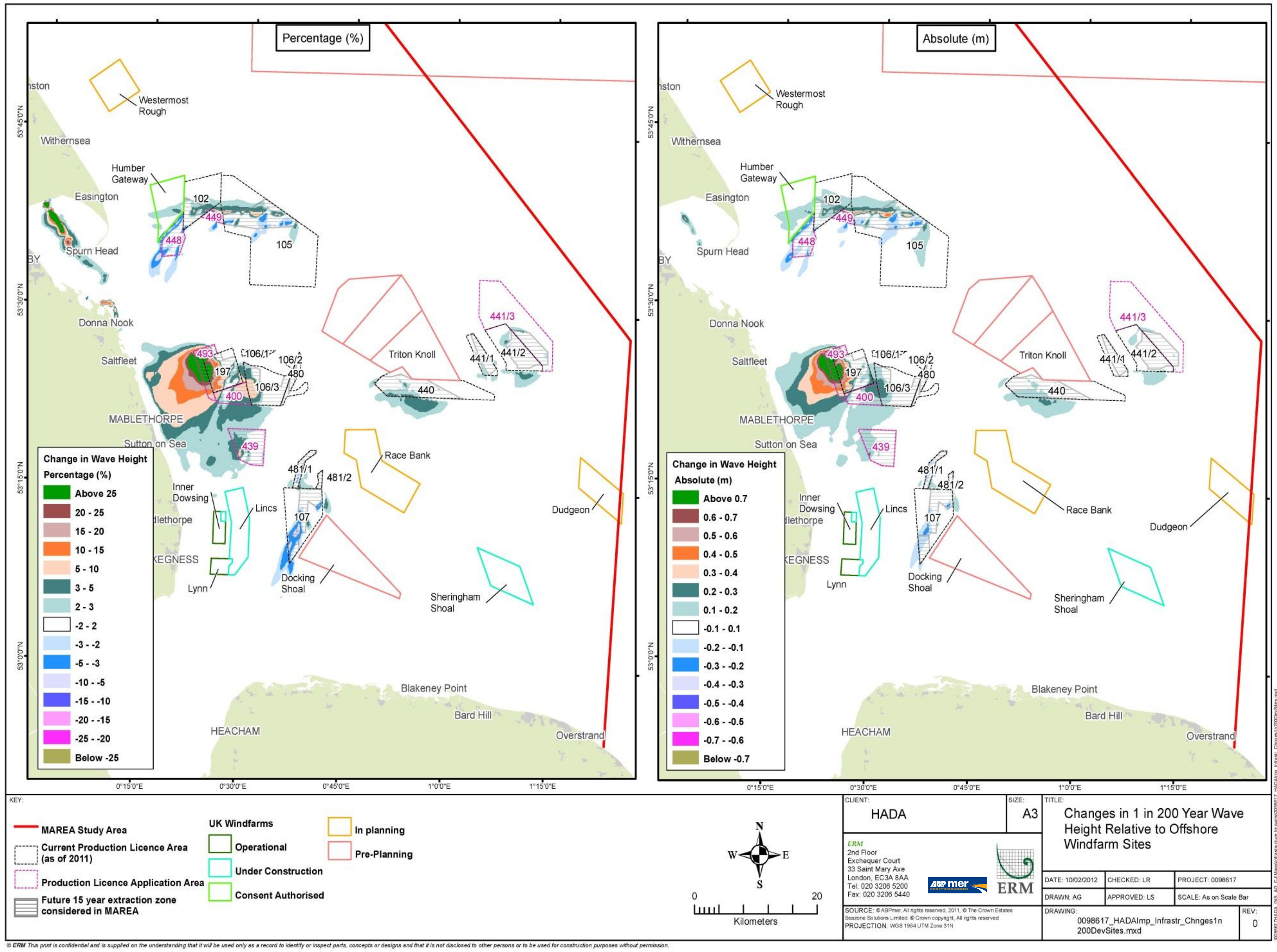


Figure 10.2 Changes in 1 in 200 Year Wave Height Relative to Offshore Windfarm Sites



A change of 2-5 % to a 10 in 1 year wave height will have a small - medium magnitude effect due to the sub-regional extent of the change, the occasional frequency of the effect, and the small change relative to the baseline. However, this effect is also long-term.

An increase in wave height at MLWS of 2-3% has also been modelled for a 10 in 1 year NE wave over an area of less than 2 km^2 within the Humber Gateway site. However, this change is imperceptible in absolute terms as it is in the range of 0-0.1 m. No other windfarm sites interact with this effect (Figure 10.3).

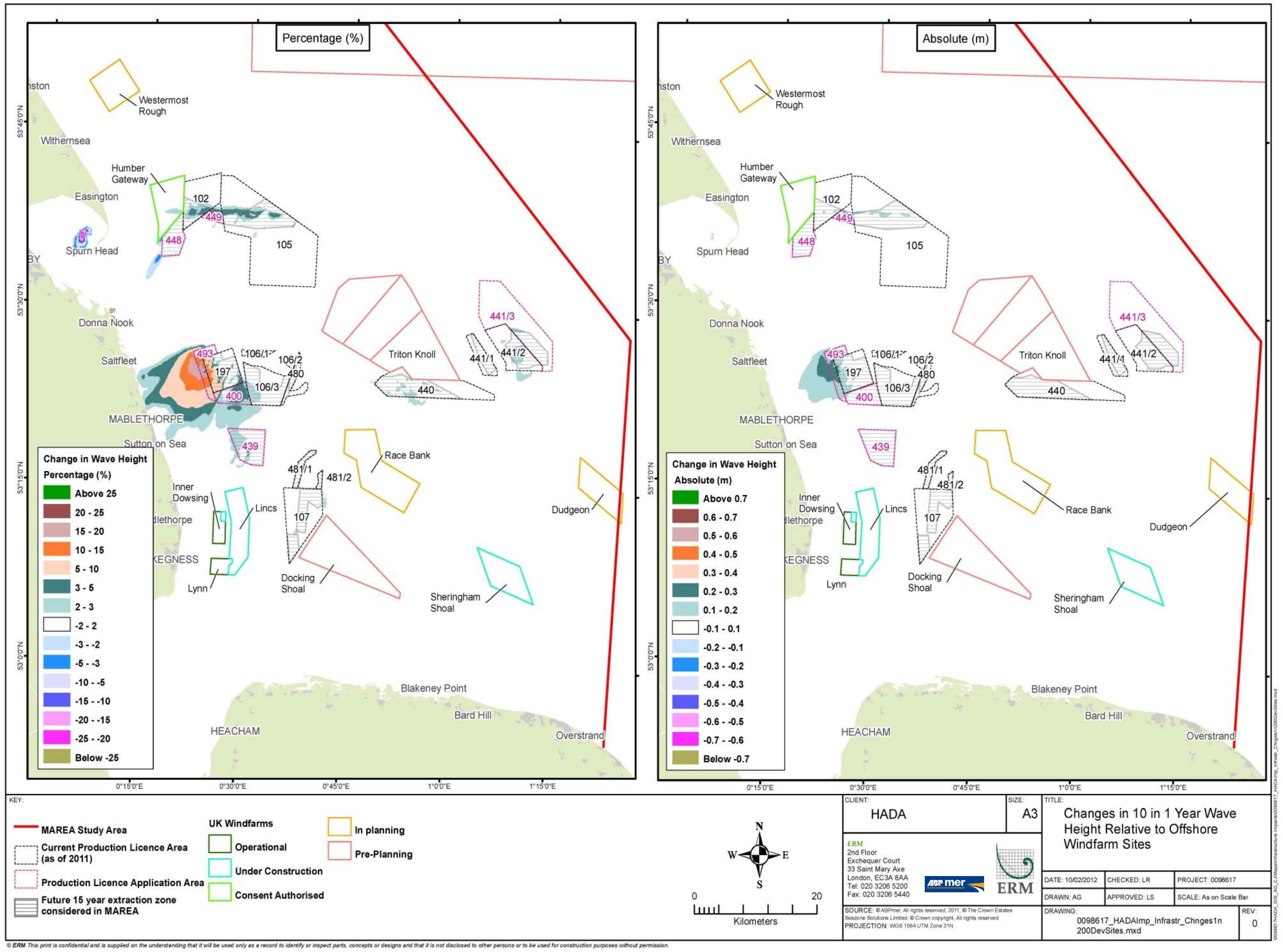
Offshore windfarms have a high tolerance to changes in wave heights as the turbines, substations, and the related construction and maintenance vessels are designed to withstand changes in sea condition. The small change in wave heights modelled relative to baseline conditions will not adversely affect the turbines. Adaptability and recoverability are not appropriate terms for assessing the impact of this effect so are not discussed further.

The sensitivity of offshore windfarms to changes to wave heights is considered to be low as they are designed for the variable sea conditions that exist in the North Sea, taking account for extreme conditions. The interaction between the effect and offshore windfarms at a regional scale is also considered to be low because the Humber Gateway is the only site with any potential to experience a change in wave heights. Although the project has been consented for offshore works, it is not yet under construction. The Humber Gateway site covers an area of approximately 35 km^2, so the affected area constitutes a maximum of 22.8% of this site for the 1 in 200 wave, or 5.7% for the 10 in 1 year wave.

This assessment is based on the assumption that the complete dredging tonnage used for this assessment is taken in each licence area, whereas in practice the overall tonnage for each licence area will be lower than stated in the MAREA. The changes in wave heights associated with a smaller take in aggregates would therefore be smaller than the modelled effect.

Based on these assessments of the small - medium magnitude of the effect, the high value but low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect on a regional scale, the cumulative impact of changes to wave heights on offshore windfarms is assessed to be not significant at the regional scale.

Figure 10.3 Changes in 10 in 1 Year Wave Height Relative to Offshore Windfarm Sites



Changes to Tidal Currents

A modelled change of 2-10% to tidal currents as a result of dredging is considered to be a medium magnitude effect as the effect is local, the duration is long-term, the event is frequent (routine) and the change relative to the baseline is low. The sensitivity of offshore windfarms to changes in tidal currents is considered to be low as they are designed to withstand North Sea tidal flows in terms of their structural integrity and scour protection.

A decrease of 0.02-0.10 ms^{-1} or 2-10% is predicted in peak flood flow speed on the spring tide at the southern tip of the Humber Gateway windfarm site. This is also true of the peak ebb flow on the same tide, but an increase of 0.02-0.05 ms^{-1} (or 2-3%) in peak ebb flow speed is also predicted towards the central eastern edge of the windfarm site.

An increase of 0.02-0.10 ms^{-1} or 2-10% is also predicted in peak flood flow speed on the spring tide at the central southern edge of the Triton Knoll windfarm site. This is also true of the peak ebb flow on the same tide.

A decrease of 2-5% is predicted in peak flood flow speed across a large central portion of the Docking Shoal offshore windfarm site. However, this amounts to a maximum decrease of 0.02-0.05 ms^{-1} over only some areas of the site. There is also a comparable percentage decrease predicted in peak ebb flow on the spring tide across a large area of the Docking Shoal windfarm site. However, this only amounts to a decrease in actual terms of 0.02-0.05 ms^{-1} over a small area in the north of the site. The scale of these decreases is not considered to be of sufficient extent to cause any detriment to offshore windfarm structures and infrastructure as they are designed to withstand the wide natural variations in tidal flows in the region.

Based on these assessments of the medium magnitude of the effect, the high value but low sensitivity of the receptor and the very small degree of interaction between the receptor and the effect, the cumulative impact of changes to sediment transport rates on offshore windfarms is assessed to be *not significant* at the regional scale.

Changes to Seabed Features

The seabed features considered within this assessment are the banks and shoals (including sandbanks) and overfalls within the MAREA study area. The removal of sediment from seabed features on which offshore windfarm infrastructure is also located has the potential to create an interaction by changing sediment transport and wave heights. Area 440 overlaps with approximately 36% of the Triton Knoll sandbank as described in Chapter 4, which also falls within the Triton Knoll offshore windfarm site that is currently in the early stages of planning. In addition, the northern edge of the Docking Shoal sandbank overlaps with a small part of the future 15 year extraction zone of Area 107, which is within approximately 630 m of the northern corner of the Docking Shoal windfarm site that is also in planning awaiting development consents.

Change to seabed features is a small magnitude effect based on a local extent, medium term duration, routine frequency, but low change relative to baseline.

Chapter 8 found changes to seabed features as a result of sediment removal to be of minor significance, and that the changes in extreme wave height resulting from the future dredge scenario are also of minor significance to seabed features.

View of Offshore Windfarm from the Lincolnshire Coast

Source: Shutterstock.com

Given the close proximity of Areas 440 and 107 to the Triton Knoll and Docking Shoal offshore windfarm sites respectively, and the potential for impacts of minor significance to occur to the sandbank seabed features on which these windfarms are planned it is possible that future sediment removal in these areas could affect future windfarm development at these sites. It is likely however, that the dredging industry will be consulted by windfarm developers at the pre-construction stage in order that they may understand the potential implications of aggregate dredging in these areas. No other sandbanks or other seabed features coincide with offshore windfarm sites in the MAREA study area. The issue is therefore considered to be not significant at a regional scale.

Loss of Access

Loss (or interruption) of access to areas as a result of dredging activities results in a small magnitude effect, based on the fact that the effect is site specific in extent, temporary in duration, routine in frequency, and results in a low change relative to baseline conditions.

Offshore windfarm construction typically involves a number of vessels working simultaneously, around which there is usually a safety exclusion zone of at least 500 m. Where offshore windfarm construction sites are directly adjacent to active dredge zones, there is potential for a conflict of marine space usage and a potential loss of access to either industry.

This could potentially be relevant to the Humber Gateway site because the windfarm site boundary connects the boundaries of the future 15 year extraction zones of Area 102 and Area 448 along a length of 7.4 km. There is also a potential interaction at the Triton Knoll site where the windfarm site boundary connects with the future 15 year extraction zone of Area 440 along a length of 2.3 km (Figure 6.34). The north-western perimeter of the Docking Shoal offshore windfarm site is located approximately 630 m from the nearest edge of a future 15 year extraction zone in Area 107, which is close but not a direct interaction.

Adaptability and tolerance are considered to be high because operational planning and regular communication between the two industries can prevent this interaction. The recoverability of this effect is also considered to be high because the effect would be temporary and localised and would never prevent access to an entire offshore windfarm site. Based on the consideration of tolerance, adaptability and recoverability, the sensitivity of offshore windfarms to a loss of access is considered to be low.

Based on these assessments of the small magnitude of the effect, the high value but low sensitivity of the receptor and the very low degree of interaction between the receptor and the effect on a regional scale, the cumulative impact of loss of access on windfarms is assessed to be not significant on a regional scale. It will be important for the dredging industry to maintain lines of communication with the offshore wind industry in order to ensure that the level of interaction is minimised.

It is recommended however, that the issue is addressed at the EIA stage for Areas 102, 448, 440, and 107 in order to ensure that the correct procedures are in place to minimise any potential interactions.

10.3.4 Summary of Impacts

Table 10.4 summarises the significance of the cumulative impacts of dredging on infrastructure at a regional scale.

Table 10.4 Regional Significance of Impacts to Infrastructure from Dredging in the Humber and Outer Wash

Effect of Dredging	Offshore Renewables Installations
Removal of sediment	
Sand deposition	Not significant
Changes to wave height	Not significant
Changes to tidal currents	Not significant
Loss of access	Not significant
Changes to seabed features	Not significant

	Not affected

The only potential interactions with infrastructure identified were with offshore windfarms. Whilst no significant impacts were identified on a regional scale, it is recommended that licence and application areas that are very near or directly adjacent to offshore windfarm sites (i.e. Areas 102, 449, 448, 440, and 107) consult with the operators of those windfarms to ensure that there are no interactions in terms of access and safety.

As many of the offshore windfarm sites within the MAREA study area are in the early stages of planning, it is likely that additional data regarding details such as turbine locations, construction methods and schedules, and construction vessel traffic densities and routing will become available within the timeframe of the MAREA. It is therefore important that licence-specific EIAs consult closely with windfarm developers in order that the assessments are based on the most current and detailed data available.

It is possible that further offshore infrastructure may enter planning within the timescale of the MAREA so licence-specific EIAs need to address the potential for additional developments and activities to occur, beyond those addressed in this MAREA. This may be achieved through consideration of new planning applications and through consultation with the MMO in the context of the ongoing marine spatial planning process.

10.4 Recreation

10.4.1 Introduction

As discussed in Section 6.3 a range of recreational activities takes place in the MAREA study area. Both sailing and power boat cruising are common including both day sailing excursions and longer passenger trips. Dinghy and yacht sailing activity also occurs in nearshore waters.

Yacht and Motor Boat on a Norfolk Estuary

Source: Shutterstock.com

The general sailing area along the coast includes three racing areas on the Holderness coast, the Humber Estuary and along much of the Lincolnshire coast. Although this is primarily inshore, racing areas do overlap with three of the HADA dredging areas: Application Areas 448 and 493 and Licence Area 102.

Cruising is a popular recreational activity in the MAREA study area as around the rest of the UK. The UK's cruising routes are divided into three categories based on usage (see Section 6.4). Both low and medium use cruising routes intersect with dredging licence areas in the MAREA study area but no heavy use cruising routes intersect with any dredge areas (the only heavy use cruising area within the study area is that in the Humber Estuary, further inshore).

There are also a number of popular dive sites, both along the coastal zone and further offshore within the study area. These are primarily associated with wrecks which do not coincide with any of the licence or application areas.

Seven blue flag beaches are located around the coastline of the MAREA study area which, along with other key coastal areas of recreational importance such as nature reserves, are considered to be sensitive receptors to any potential changes to coastal processes. However, as concluded in Chapter 8, there were found to be no significant impacts on coastal processes or to areas within 1 km of the coast line in the study area as a result of dredging. Therefore impacts to receptors as a result of a change in coastal processes have been scoped out of any further consideration in this assessment.

The Strategic scoping report for marine planning in England published by the MMO in June 2011 notes that it is difficult to determine the economic value of marine leisure due to the wide range of activities and the lack of statistics. Some indications are provided, however, which suggest that the leisure boating industry around the whole of the UK employs 35,000 people and had a UK turnover of nearly £2 billion in 2006/7 (MMO, 2011a).

The report also provides an indication of the ancillary value of other recreational activities around the coast of the UK, reporting that the small commercial marine industry had a turnover of £1.84 billion in 2006/07 and the surf industry of £200 million in 2007. The total expenditure from recreational fishing was reported to be £538 million for England and Wales in 2003. The MMO report notes that these sources and others provide a total estimated market turnover due to leisure and recreation of £2.74 billion and £1.29 billion Gross Value Added (GVA). The report also highlights that the estimated income for coastal towns from tourism in the UK is calculated at £4.8 billion, resulting in a GVA of £2.26 billion (MMO, 2011a).

The United Kingdom Marine Monitoring and Assessment Strategy reports that for the leisure-boating industry the South East dominates with the greatest revenue share (36.1%) followed by the South West (24.1%) and the East of England (12.3%) (UKMMAS, 2010). In light of this indication the value of recreation for the Humber area is rated as medium value.

10.4.2 Identification of Potential Impacts on Recreation

Table 10.5 identifies the potential impacts of dredging operations in the MAREA study area on the four main recreation activities in the study area: racing, sailing, cruising and diving.

Table 10.5 Matrix of Potential Impacts of Dredging on Recreation

RECEPTOR	Presence of Vessel	Removal of sediment	Fine sediment plume / elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave height	Changes to tidal currents	Changes to sediment transport rates	Underwater Noise	Loss of access	Changes to benthic community composition	Changes to distribution of fish	Changes to seabed features
Racing	✓	■	■	■	■	x	x	■	■	✓	■	■	■
Sailing	✓	■	■	■	■	x	x	■	■	✓	■	■	■
Cruising	✓	■	■	■	■	x	x	■	■	✓	■	■	■
Diving	x	■	x	■	■	x	x	■	■	x	■	■	■

■	Not affected
x	No interaction
✓	Potential Interaction

It is predicted that there will be no interaction between recreational diving and presence of the vessel, changes to wave height, changes to tidal currents, and the fine sediment plume because the known dive sites in the MAREA study area are located away from the licence and application areas.

It is predicted that there will be no significant interaction between racing, sailing or cruising and changes to waves or tidal currents on the basis of the very small actual changes that will occur at any one point in time in the MAREA study area in the context of the design parameters of these vessels, as well as the low potential of these changes to interact with recreational vessels at any point in time.

10.4.3 Overview of Potential Relevant Effects

Increased vessel presence has the potential to result in impacts to recreational activities primarily from the amenity perspective. The loss of access has the potential to impact recreational vessels through requiring them to potentially change their course to avoid dredge vessels, this impact being of more significance for vessels that are less easily manoeuvrable. These two potential effects of dredging, and how they may affect recreational activities, are discussed further below.

It should be noted that the potential for safety and navigational risk, including collision risk, is not covered in this chapter. This is discussed in Section 10.5 and more information provide in Appendix H on the navigation risk assessment that has been carried out for the MAREA.

Vessel Presence

The presence of additional vessels (including dredging vessels) in the MAREA area waters could have an impact on recreational activities from an amenity perspective. An increase in vessel traffic (including dredging vessels) may alter the perception that recreational vessel users have of the area, and affect their experience in using this region.

The HAM 311 Trailing Suction Hopper Dredger by 'Rainbowing' (Pumping Water and Sand)

An increase in presence of dredging vessels as a result of increased dredging activity in the study area is a small magnitude effect based on the effect being routine in occurrence, but site specific, transient and constituting a low level change relative to baseline vessel movements in the region.

Loss of Access

Recreational users of the MAREA study area could experience loss of access to an area of the sea at any one particular time as a result of dredging activity. This loss of access could result from the presence of a dredge vessel whilst dredging or transiting to a dredge area, and this would require recreational vessels to change their course, or avoid certain areas, to avoid dredge vessels.

Loss of access to areas of the study area caused by an increase in dredging operations is a small - medium effect based on it being site-specific in extent, temporary in duration and a low level change relative to the baseline; however, it is of routine occurrence.

10.4.4 Racing

Vessel Presence

From an amenity perspective, racing vessels are also deemed to have a medium - high tolerance and adaptability to increases in dredger traffic. As racing vessels are recreational to some extent they are used to the experience of a certain number of vessels being in their vicinity. Due to the low change of this effect relative to the baseline (just 2% above baseline shipping levels), racing will have a high recoverability because visual amenity is only affected when a dredger is actually present. Taking tolerance, adaptability and recoverability into account, racing has a low sensitivity from an amenity perspective.

The degree of interaction between racing areas and areas of increased vessel presence is small since most racing activity is concentrated around the coastal areas. Where overlaps do occur, the degree of increase in future vessel presence ranges from low in the majority of the affected areas, increasing to medium and high in some small pockets. The majority of the areas where the highest future vessel increase is predicted are almost all further offshore than the racing areas, with only small areas of overlap between racing areas and these areas of highest predicted vessel increase. These small areas of overlap are found around the Humber Estuary and in the eastern section of the Greater Wash Racing Area.

Based on these assessments of the small magnitude of the effect, the medium value and sensitivity of the receptor, but noting the small degree of interaction between the receptor and the effect, the cumulative impact of vessel presence on racing vessels from an amenity perspective is assessed to be not significant at the regional scale.

Loss of Access

Racing vessels will be affected by the loss of assess to parts of the sea when in use by a dredging vessel but the loss of access will be transient depending on the location of dredging operations within the licence areas. Racing vessels have the ability to avoid other vessels and therefore have a high tolerance and adaptability to a loss of access requiring them to divert around a dredge vessel. Racing patterns and routes may change slightly but can be readily accommodated. Due to the low change of this effect relative to the baseline (just 2% above baseline shipping levels), racing will also have a high recoverability; once the dredging vessel has moved off the licence or passed by while in transit normal patterns of use can resume. Taking tolerance, adaptability and recoverability into account, racing areas have a low sensitivity to the presence of additional dredger traffic from a loss of access perspective.

Sailing

Source: Shutterstock.com

The degree of interaction between the racing vessels and the impact of loss of access to areas of the sea at any one point in time is small as explained above.

Based on these assessments of the small magnitude of the effect, the medium value and low to medium sensitivity of the receptor and the small degree of interaction between the receptor and the effect, the cumulative impact of loss of access on racing vessels is assessed to be not significant at the regional scale.

10.4.5 Sailing

Vessel Presence

In regard to the amenity perspective, sailing vessels are deemed to have a medium - high tolerance and high adaptability to increases in dredger traffic because visual amenity is only affected when a dredger is actually present. Due to the low change of this effect relative to the baseline (just 2% above baseline shipping levels), racing will have a high recoverability. Taking tolerance, adaptability and recoverability into account, racing areas have a medium sensitivity from an amenity perspective.

The degree of interaction between sailing areas and areas of increased vessel presence is small - medium since most sailing activity is concentrated around the coastal areas, although sailing activity is noted to extend further offshore than the racing areas identified. Where overlaps do occur, the degree of increase in future vessel presence ranges from low in the majority of the affected areas, increasing to medium and high in some small pockets. The majority of the areas where the highest future vessel increase is predicted are almost all further offshore than the sailing areas, with only small areas of overlap between racing areas and these areas of highest predicted vessel increase. These small areas of overlap are found around the Humber Estuary, in the entry to The Wash and on the North Norfolk Coast towards the east of the MAREA study area, north of Overstrand. Consequently, sailing vessels are not likely to interact to a large degree with areas of the highest vessel increase and therefore the potential of affecting the sailing experience from an amenity point of view will be limited.

Based on these assessments of the small magnitude of the effect, the medium value and sensitivity of the receptor, but noting the small degree of interaction between the receptor and the effect, the cumulative impact of vessel presence on racing vessels from an amenity perspective is assessed to be *not significant* at the regional scale.

Loss of Access

Sailing routes will be affected by the loss of assess to areas of the sea being used by dredge vessels whilst dredging or in transit but the loss of access will be transient depending on the location of dredging operations within the licence areas.

Sailing vessels have the ability to avoid other vessels and therefore have a medium - high tolerance and high adaptability. Due to the low change of effect relative to the baseline, sailing will have a high recoverability. Once the dredging vessel has moved off the licence or passed by while in transit normal patterns of use can resume. Taking tolerance, adaptability and recoverability into account, sailing vessels have a low sensitivity to this effect.

The degree of interaction between sailing areas and areas of increased vessel presence is small - medium since most sailing activity is concentrated around the coastal areas, as detailed further above.

Based on these assessments of the small magnitude of the effect, the medium value and low to medium sensitivity of the receptor and the small - medium degree of interaction between the receptor and the effect, the cumulative impact of loss of access on sailing vessels is assessed to be not significant at the regional scale.

10.4.6 Cruising

Vessel Presence

In regard to the amenity perspective, cruising vessels are deemed to have a medium - high tolerance and adaptability to increases in dredger traffic. Due to the low change of this effect relative to the baseline (just 2% above baseline shipping levels), racing will have a medium recoverability because visual amenity is only affected when a dredger is actually present. Taking tolerance, adaptability and recoverability into account, racing areas have a medium sensitivity to an increase in vessel presence from an amenity perspective.

The degree of interaction between cruising routes and areas of future increased vessel presence is high. Of these areas of overlap a large number of the cruising routes of low or medium usage intersect fully or partly with areas of the highest future shipping density. However only 2% of this vessel increase is attributable to dredging.

Based on these assessments of the small magnitude of the effect, the medium value and low sensitivity of the receptor and the large degree of interaction between the receptor and the effect, the cumulative impact of the risk of collision as a result of dredging vessel presence on cruising vessels is assessed to be minor at the regional scale, although in reality the user experience of the area would change little.

Loss of Access

Cruising routes will be affected by the loss of access to parts of the sea as a result of dredging activity and transit but this loss of access will be transient depending on the location of dredging operations within the licence areas. Cruising vessels will have a medium - high tolerance and adaptability and a high recoverability in relation to loss of access as, once the dredging vessel has moved off the licence or passed by while in transit, normal patterns of use can resume. Taking these factors into account the sensitivity of the receptor is low to medium.

The degree of interaction between cruising routes and licence areas and transit routes is small. Eight cruising routes pass through dredging areas within the study area; of these routes three are of light use and five are of medium use. However, this area of interaction only constitutes a small proportion of available cruising area.

Based on these assessments of the small magnitude of the effect, the medium value and low to medium sensitivity of the receptor and the small - medium degree of interaction between the receptor and the effect, the cumulative impact of loss of access on cruising vessels is assessed to *be not significant* at the regional scale.

10.4.7 Summary of Impacts

Table 10.6 summarises the significance of the cumulative impacts of recreation activities and the impacts of dredging at a regional scale.

Table10.6 Regional Summary of Impacts to Recreational Activities

Effect of Dredging	Racing	Sailing	Cruising	Diving
Vessel Presence	Not significant	Not significant	Not significant	Not significant
Loss of Access	Not significant	Not significant	Not significant	

Not affected

Impacts to recreation from dredging are predicted to be not significant. Therefore no action is required to study the potential impacts further at the licence specific EIA stage other than to present the specific mitigation measures to be adopted.

Recreational Boats Moored in Tidal Creeks near Wells next the Sea

Source: ABPmer

10.5 Shipping and Navigation

10.5.1 Overview

Anatec UK Ltd carried out an assessment of the sensitivity of shipping and navigation to future increased dredging operations in the Humber and Outer Wash MAREA study area. As described in the Section 6.5 the study area was divided into 10,463 cells and a navigational sensitivity ranking was assigned to each cell using shipping density, ship-to-ship collision risk, recreational usage, fishing vessel density and navigational features as the criteria.

Please refer to Appendix H for more detailed information on this methodology.

10.5.2 Future Shipping Density

Future shipping density was calculated based on the existing merchant shipping activity within the region with the addition of future dredging activity based on maximum extraction information for the full MAREA period supplied by HADA members. The results were used to rank the cells from 1 (lowest density) to 5 (highest density).

It should be noted that high shipping density leads to high sensitivity even if it is associated with existing shipping passing through the area rather than increased dredging activity.

Consultation with stakeholders including the Humber and Wash ports identified the main factor likely to affect future shipping densities to be vessels associated with offshore windfarms.

This will include large construction vessels as well as smaller support vessels, but the numbers and frequency of passage of these vessels is currently unknown as it will vary according to the phase of development of the relevant windfarm sites. The planned Able Marine Energy Park and Green Port Hull projects in the Humber Estuary are likely to be significant sources of this type of vessel traffic in the MAREA study area over the coming decades. The Port of King's Lynn anticipates an increase in shipping traffic over the next 15 years. However, it is not possible to immediately quantify these increases in regional shipping traffic until the windfarm developments generate the necessary data and undertake their own studies. Other ports in the area are not currently predicting significant increases in vessel traffic over the next 15 years.

Windfarm Construction Vessel

There is a degree of uncertainty associated with future shipping densities as economics and other influences may affect the shipping industry in the area. These changes could not be directly accounted for in the modelling and are therefore not represented. However, future windfarm sites have been given an increased score within the navigational sensitivity ranking to account for the increased numbers of ships that are likely to be present in these areas over the next 15 years.

10.5.3 Future Ship-to-Ship Collision Risk

Future case ship-to-ship collision modelling was carried out using the baseline merchant shipping AIS data plus the expected activity relating to the future dredging tonnages based on the maximum extraction rates as provided by the HADA dredging companies for the full MAREA period. The future ship-to-ship collision risk results were calculated using the COLLRISK model, ranking the cells from 1 (lowest risk) to 5 (highest risk).

The main factors influencing the risk are shipping densities, speeds, courses, types, sizes and visibility conditions. Further details on the model are provided in Appendix H. It is noted that high ship-to-ship collision risk leads to high sensitivity even if it is associated with existing shipping passing through the area rather than increased dredging activity. Figure 10.4 shows the modelled future ship-to-ship collision risk based on maximum extraction rates.

River Ouse at Kings Lynn UK Passenger Ferry and Sunset

Source: Shutterstock.com

The model identified a future ship-to-ship collision risk level in the order of 1 major collision within the study area in 4.40 years. This amounts to a future increase in collision risk of 3.1% within the study area compared to the level of collision risk associated with existing dredging activity. This is the result of the increased dredger activity within the Licence Areas and main transit routes assumed in the future dredging scenario. Areas of change in collision risk frequency are shown in Figure 10.5.

An Old Working Boat Tied up at Low Tide for Repair - King's Lynn

Source: Shutterstock.com

Figure 10.4 Overview of Future Ship-to-Ship Collision Risk (Maximum Dredging)

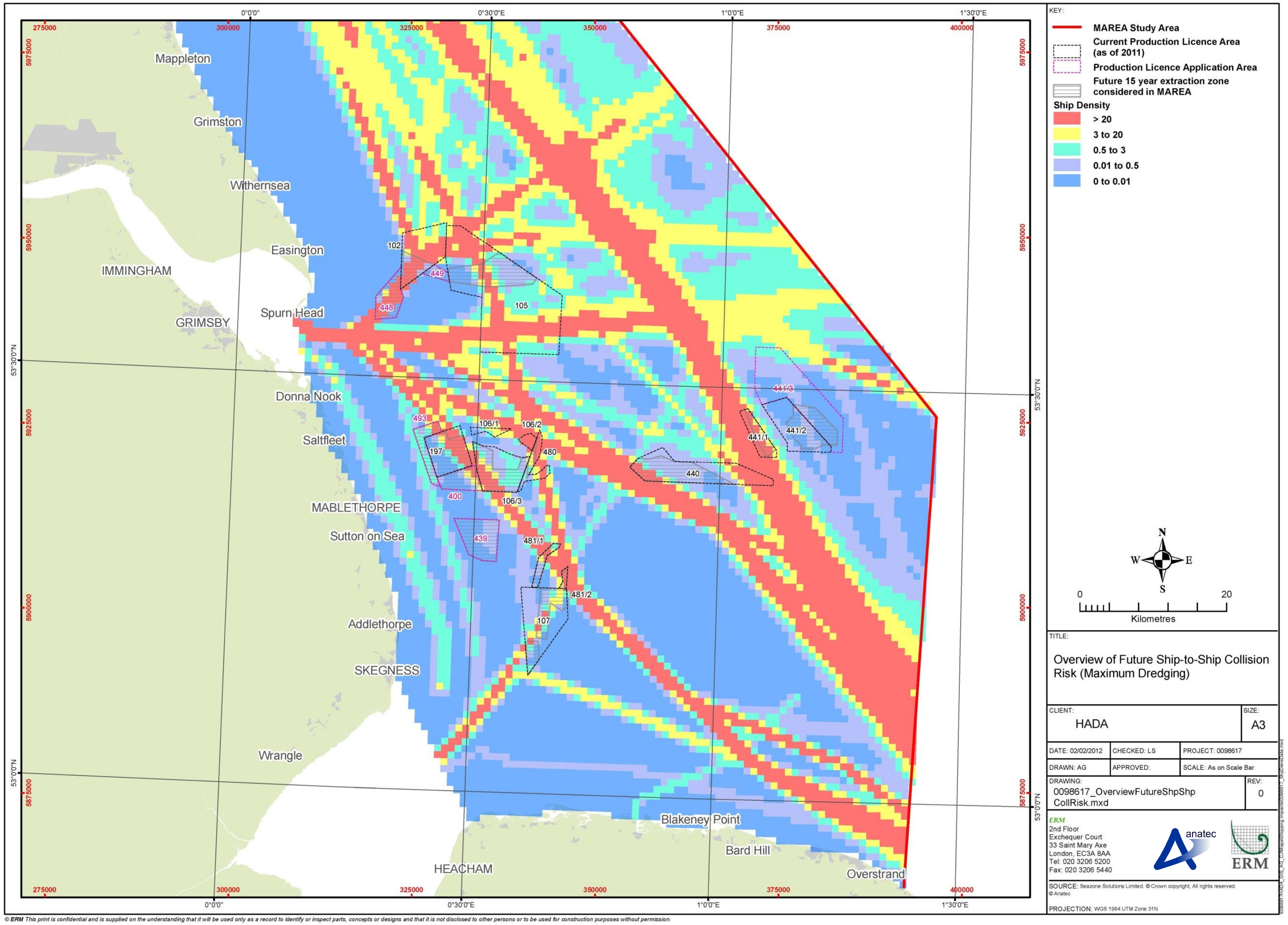
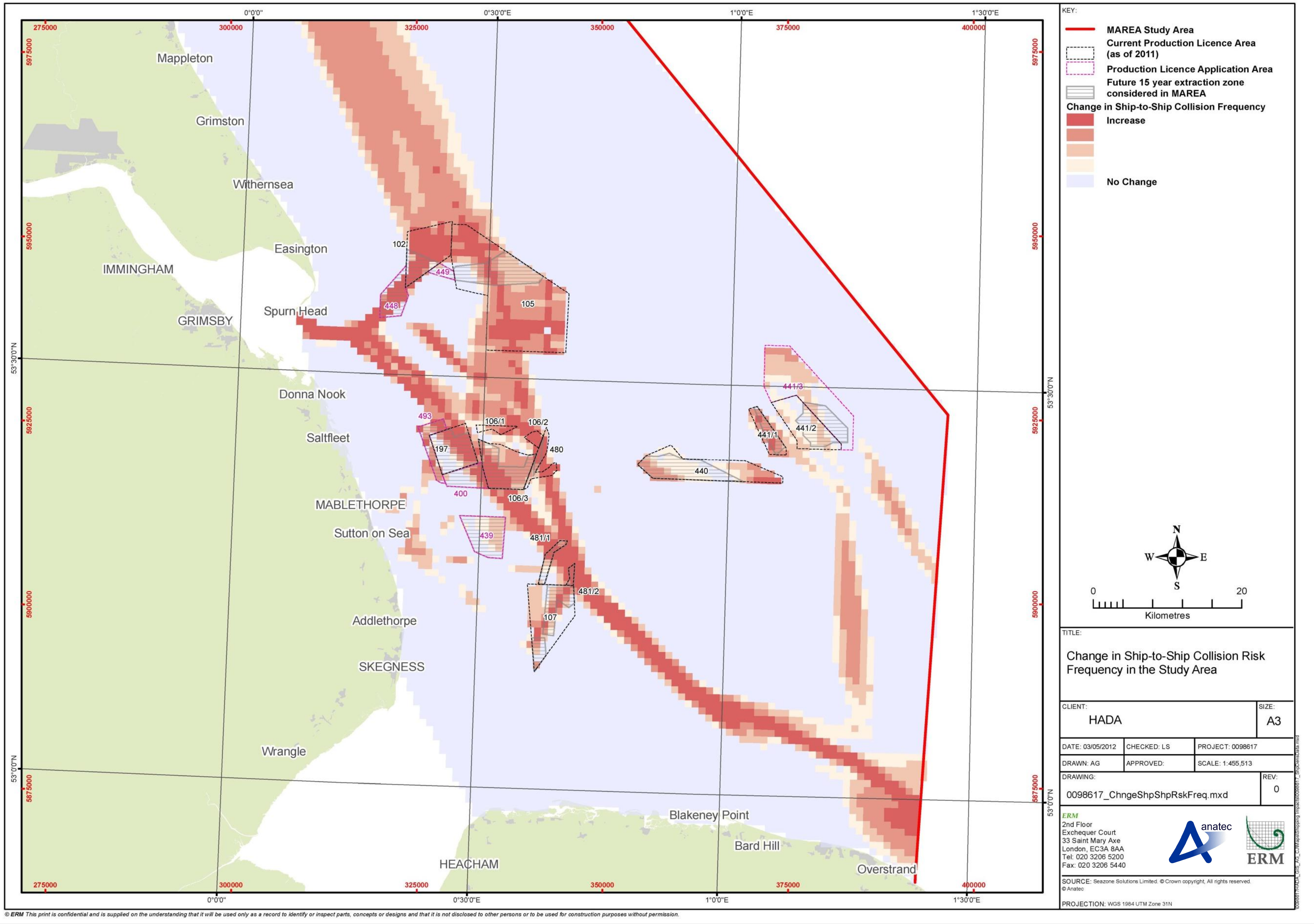


Figure 10.5 Change in Ship-to-Ship Collision Risk Frequency in the Study Area



10.5.4 Future Navigational Sensitivity Ranking

A navigational sensitivity ranking for each model grid cell was estimated using criteria based on the previously described shipping densities and ship-to-ship collision risk, as well as on recreational usage, fishing vessel density, and navigational features.

Recreational Usage

The recreational component of the sensitivity ranking was based on the RYA Coastal Atlas, with close proximity to a cruising route scored as 1 for low, 2 for medium, and 3 for high usage. Cells overlapping a general sailing or racing area scored an additional 1 per type of area. The maximum recreational ranking was therefore 5.

Low tide in Wells Next the Sea

Source: Shutterstock.com

Fishing Vessel Density

Fishing vessel density per cell was categorised based on the satellite tracking data with grid cells ranked from 0 (no activity) to 5 (highest activity).

HAM 316 Trailing Suction Hopper Dredger

Navigational Features

Proximity to an existing navigational feature (e.g. TSS, Anchorage Area, or offshore windfarm) was also considered within the navigational sensitivity ranking. Increased dredging activity adjacent to an established navigational feature could increase the cumulative impact and subsequent navigational sensitivity. The presence of at least one of the above features resulted in the cell being ranked as 5.

10.5.5 Results of Ranking

The scores per cell were summed (maximum 25) and distributed into five sensitivity ranges, each containing approximately one-fifth of the cells (see Table 10.7). A colour-coded plot of the navigational sensitivity rankings is presented in Figure 10.6.

Table 10.7 Ranking of Cells by Shipping Navigational Sensitivity

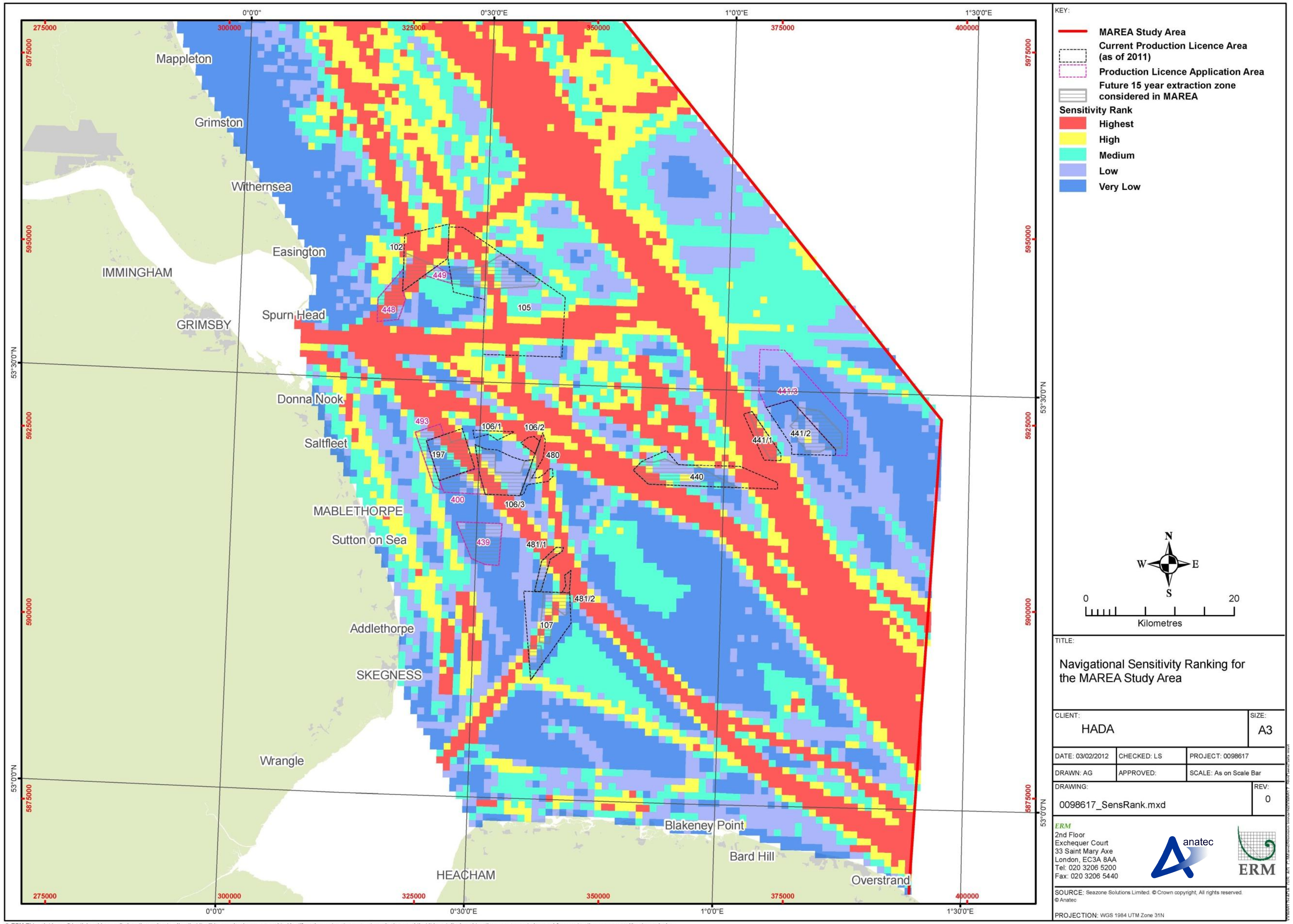
Ranking	Sensitivity Score	Percentage of Grid
Very Low	1	22%
Low	2	17%
Medium	3	19%
High	4	16%
Very High	5	26%

The higher encounter hotspots shown in Figure 6.50 indicate where there is existing congestion of shipping due to high traffic levels and/or reduced sea room. The high sensitivity ranked grid cells shown in Figure 10.6 correspond to these encounter hotspots as areas that are more sensitive to future increases in aggregate dredging activity due to the already high levels of shipping.

RNLI Sea Rescue Vessels

Source: Shutterstock.com

Figure 10.6 Future Navigational Sensitivity Ranking for the MAREA Study Area



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10.5.6 Navigational Sensitivity in Relation to Licence Areas

The following sections highlight areas of particular navigational sensitivity within the various Licence Areas (as shown in Figure 10.6), and explains the reasons for their rankings.

Dredge Areas East of Spurn Point (Areas 102, 105, 448, and 449)

The majority of the future 15 year extraction zones of Area 102 and 448 are ranked as being Highest navigational sensitivity, due to overlapping the New Sand Hole branch of the Humber TSS and, thus, having high ship density and associated collision risk. Recreational routes also traverse these Areas.

The future 15 year extraction zone of Licence Area 105 has a number of cells assessed to be High to Very High sensitivity, mainly towards the centre of the Area, due to high shipping density associated with merchant shipping routes.

The bulk of the future 15 year extraction zone of Application Area 449 is ranked as Medium sensitivity, partly due to it overlapping the Humber DW Anchorage.

Dredge Areas off the Lincolnshire Coast (Areas 106, 107, 197, 400, 439, 480, 481, and 493

The 15 year extraction zones of Licence Areas 106/3, 107, 197, 480, 481/1 and 481/2 all overlap areas of Highest navigational sensitivity due to high shipping densities.

The 15 year extraction zones of Licence Areas 481/1 and 481/2 are close to the Docking Shoal and Race Bank offshore wind farms, and the sea room available for vessels in the area is restricted. Licence Area 197 overlaps RYA Sailing and Racing areas. Sections of the future 15 year extraction zone of Licence Area 107 are in the Highest rank due to high shipping density and ship to ship collision risk caused by merchant shipping routes entering and exiting The Wash.

Although not comprising the identified 15 year extraction zones for this MAREA, Licence Areas 106/1 and 106/2 also contain areas of Highest navigational sensitivity.

The future 15 year extraction zone of Application Areas 400 and 493 are mainly lower sensitivity apart from the eastern fringes.

The future 15 year extraction zone of Application Area 439 is below average navigational sensitivity rank as it does not intersect with any major routes and is not in the vicinity of areas of high density recreation or fishing.

Offshore Dredge Areas (Areas 440 and 441)

Licence Area 440, including the future 15 year extraction zone, extends east-west across Triton Knoll and partly into the Outer Dowsing Channel and therefore has a range of sensitivities as the traffic varies across the sand banks and shipping channels. There is also high fishing density and recreational cruising routes overlapping the area. The future 15 year extraction zone of Area 441/1 is mainly Highest navigational sensitivity due to being in the Outer Dowsing Channel.

The majority of the future 15 year extraction zone of Licence Area 441/2 falls as Low navigational sensitivity, with one patch of High sensitivity caused by high density fishing and the presence of a recreational route.

The future 15 year extraction zone of Application Area 441/3 is mainly of Very Low to Low sensitivity.

10.5.7 *Summary of Navigational Sensitivity in Relation to Dredge Areas*

Areas with the higher sensitivity rankings correspond to the more sensitive areas in navigational terms for future licence renewals and new licence applications. The results for these areas tend to be characterised by high shipping densities and an associated high ship-to-ship encounter and collision risk and in some cases, further risk associated with proximity to IMO Routeing measures or windfarm projects.

Table 10.8 Average Navigational Sensitivity Factors per Dredge Area

Dredge Area	*Ship Density*	*Collision Risk*	*Navigational Feature*	*Fishing*	*Recreation*	*Overall Sensitivity*
102	High	High	High	Very Low	Low	Very High
105	Low	Low	Very Low	Very Low	Very Low	Low
106/1	Medium	Medium	Very Low	Very Low	Very Low	Medium
106/2	Very High	Very High	Very Low	Very Low	Very Low	Very High
106/3	Medium	High	Very Low	Very Low	Very Low	Medium
107	Medium	Medium	Very Low	Very Low	Low	Medium
197	Medium	Medium	Very Low	Very Low	Medium	Medium
440	Medium	Medium	Very Low	Very Low	Low	Medium
441/1	Very High	Very High	Very Low	Very Low	Very Low	Very High
441/2	Low	Low	Very Low	Very Low	Very Low	Low
480	Medium	High	Very Low	Low	Very Low	Medium
481/1	Medium	Medium	Very Low	Very Low	Very Low	Medium
481/2	Very High	Very High	Very Low	Very Low	Low	Very High
400	Medium	Medium	Very Low	Very Low	Very Low	Medium
439	Medium	Medium	Very Low	Very Low	Very Low	Medium
441/3	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
448	High	High	Medium	Low	Low	High
449	Very Low	Very Low	High	Very Low	Very Low	Medium
493	Medium	Medium	Very Low	Very Low	Medium	Medium

Table 10.9 describes the future site-specific assessment work / updates that may be appropriate at the ES stage for the Licence Areas according to their average sensitivity rankings.

Table 10.9 Recommended Future Work based on Sensitivity Factors

Recommended Level of Work Required per Sensitivity Factor	Very Low	Low	Medium	High	Very High
Validation of shipping (densities and routeing) to demonstrate that the baseline data reflected within the MAREA are still current.	✓	✓	✓	✓	✓
Site-specific review of latest windfarm developments / proposals and potential effect on shipping routes passing through or near site.	✓	✓	✓	✓	✓
Site-specific assessment of the change in collision risk due to future dredging activity (subject to validation findings, above).	×	×	✓	✓	✓
Site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA, Humber and Wash Ports).	×	×	✓	✓	✓

10.5.8 Cumulative Impacts to Navigational Risk

This section considers the potential cumulative impacts of the anticipated future dredging operations based on the regional tonnage scenario, in total across all Licence Areas within the MAREA study area.

Overall, baseline dredging activity associated with HADA member companies represents approximately 0.7% of the total ship movements within the MAREA Study Area annually. In general, shipping activity was largely dominated by merchant shipping heading to/from ports in the Humber.

Using the maximum future extraction scenario (worst case), the dredging activity in terms of vessel movements will be almost triple the baseline. However, in overall traffic terms, dredging activity will still represent a low proportion of approximately 2%.

This additional dredger traffic will mainly be using existing, established routes to/from the dredge areas.

In terms of collision risk for the study area, the navigational risk for the future scenario is in the order of 1 major collision within the study area in 4. 4 years [(1)]. This is compared to 1 in 4.54 years for the baseline scenario, which represents an increase of approximately 3.1% and broadly reflects the additional traffic and likely increase in encounters.

The level of change in shipping densities and collision risk resulting from the future dredging scenario in the study area is not anticipated to cause a significant cumulative impact on navigational risk. A similar change in traffic levels may be observed from normal fluctuations in commercial shipping in the area due to changing trading patterns between ports.

The new dredge areas will be marked on charts and all are in proximity to existing licence areas. Site-specific consultation and potentially enhanced mitigation is planned to minimise any additional risk or obstruction, taking into account the navigational sensitivity of each area.

It is recommended that all licence areas validate the shipping data (densities and routeing) at the individual EIA stage to demonstrate that the baseline data reflected within the MAREA are still current or have not significantly changed.

All licence areas except from 105 and 441/2 and 441/3 (i.e. those licence areas with an overall navigational sensitivity of medium, high, or very high) should carry out site-specific assessments of the change in collision risk resulting from the proposed future dredging activity (subject to the validation of the shipping data), and carry out site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA and the relevant port authorities). Site-specific mitigation measures should also be developed and described (see Section 13 of Appendix H).

(1) Please note, predicted collisions are for any type of vessel and may not specifically involve a dredger.

10.5.9 In-Combination Navigational Concerns

There is potential for activities relating to offshore windfarm developments, ports, and offshore oil and gas developments to pose a navigational risk in-combination with that posed by dredging vessels.

Offshore Windfarms

Current dredging operations in Licence Area 102 are adjacent to Humber Gateway Wind Farm, Licence Area 107 is in line with Docking Shoal Wind Farm and Licence Area 440 is adjacent to Triton Knoll Wind Farm. Application Area 448 lies adjacent to Humber Gateway Wind Farm.

During construction phases at windfarms within the MAREA study area there is likely to be an increased volume of traffic associated with these developments which may increase ship-to-ship encounters with passing merchant shipping and dredging operations in close proximity to these sites. These routes to and from proposed windfarms have not been taken into consideration in this study, but a further review should be undertaken based on the latest available information at the time of making the individual licence applications.

Offshore Lincolnshire Windfarm

In addition, The Crown Estate Round 3 Hornsea Zone overlaps with approximately 138 nm^2 of the north-eastern part of the study area (see Section 6.3). Any future development within the Round 3 Zone is not considered to significantly affect routeing of aggregates dredgers as they tend to follow a route to the west of the Zone when travelling between the North and the dredge areas. A number of the vessels tracked intersected the Zone, mainly those which used the northeast approaches via New Sand Hole section of the Humber TSS or transited the study area from north or south. It is not likely that dredger routes will be affected by the Hornsea Zone, as routes tend to pass west of the Zone. However, development of the Zone could re-route merchant shipping both into the dredge areas and onto transit routes used by the dredgers.

Port Developments

The MAREA study area excludes ports in the Humber and The Wash. However, the majority of vessels tracked within the study area were travelling to or from these ports. The planned Able Marine Energy Park and Green Port Hull in the Humber Estuary in particular are planned to provide facilities for shipping traffic associated with marine renewable energy projects that is likely to significantly increase the amount of shipping passing through the mouth of the Humber. Grimsby Outer Harbour project may not increase shipping movements but will displace shipping traffic and could lead to larger ships.

The Port of King's Lynn in The Wash anticipates an increase in trade and therefore also an increase in future shipping activities in the region.

The Port of Boston also intends to carry out future proofing works. It is predicted that this will not cause an increase in vessel numbers but may result in an increase in the length and draught of vessels passing through the MAREA study area before making their approach into the port. Vessel size is expected to increase on average by 10 m length and 1500 DWT.

Oil and Gas Developments

There are 14 platforms and 17 safety zones to be found within the study area (Section 6.3). Two of these, Pickerill A and Pickerill B, are located on the boundary of Application Area 441/3. In the wider context of commercial shipping in the MAREA study area, oil and gas developments are not anticipated to contribute significant amounts of shipping traffic or navigational concern.

10.6 Archaeology and Cultural Heritage

10.6.1 Introduction

The overview of the baseline archaeological resource provided in Section 6.6 considered four categories: prehistoric archaeology, eroded coastal archaeology, maritime archaeology and aviation archaeology. This section goes on to consider the potential for impacts to the archaeological resources within these categories. One of the four categories, eroded coastal archaeology, is not covered in this section as the most inshore of the aggregate dredging areas, Application Area 448, is over 9 km east of the closest coastline; therefore impacts to this category of resource have been scoped out. The values of the three categories of resource are summarised in Table 10.10.

Table 10.10 Value of Archaeological and Cultural Heritage Resources in the MAREA Study Area

Receptor	Value	Summary
Prehistoric Archaeological and Cultural Heritage Resources		
Late Pleistocene Glacio-fluvial Sediments	high	Late Pleistocene glacio-fluvial gravels, which are widespread within the Study Area, are the primary target of aggregate dredging. However the archaeological value of these sediments is based on their potential to preserve *in situ* or derived Palaeolithic artefacts and other archaeological material. This potential is extremely rare. These materials may be expected to found within Unit 3 sediments in the Northern and Central areas of the study area.
Estuarine Alluvium and Peat	high	The fluvial processes of the Holocene have resulted in the deposition of alluvial sediments and the formation of peat (in marshy areas associated with fluvial margins), within the Humber region (Gaffney et al. 2007, 2009; Tappin et al. 2011). With the gradual rise in sea level which led to the inundation of the study area in the Late Mesolithic, some of these sediments will have sealed and buried deposits or landscape features in which Late Devensian and early Holocene in situ archaeological material may be present; these deposits are also principal palaeoenvironmental archives of past landscapes, environments and climate. Similarly due to the high preservation potential for palaeoenvironmental remains and *in situ* archaeological material, peat has archaeological value in itself.
Isolated Prehistoric Finds	medium	Although archaeological material from secondary contexts is by its nature not from *in situ* contexts, recent discoveries have shown that it nevertheless 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 rapidly evolving (Hosfield and Chambers 2004).
Maritime Archaeological and Cultural Heritage Resources		
Known, Charted Wrecks	high	The relative potential importance of the various periods into which the known, charted wrecks within the study area fall will vary from wreck to wreck, however all of the known wrecks in the study area will have a greater or lesser degree of archaeological potential and value.
Shipping Casualties / Recorded Losses	high	The recorded losses in the study area will each have a greater or lesser degree of archaeological potential and value should they be identified on the seabed. Due to this variability at a regional scale, known charted wreck sites must be regarded as a high value receptor.
Unknown, Uncharted Wreck Sites	high	The bias of the records of both charted wrecks and documented shipping casualties towards vessels lost from the mid-18th century onwards has already been discussed, as has the potential for the presence within the study area of unknown watercraft and vessels dating from the Mesolithic period to the modern day. 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.
Isolated Maritime Finds	medium	Isolated maritime finds are isolated or derived artefacts which are 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.
Aviation Archaeological and Cultural Heritage Resources		
Known, Charted Aircraft Crash Sites	high	Within the study area there are five charted sites known to be aircraft wrecks, all of which are automatically protected by the Protection of Military Remains Act 1986.
Recorded Aircraft Losses	high	There are 68 recorded losses listed by the NRHE within the study area. The sites date predominantly to the period between 1939 and 1945. One dates to 1946. In addition, over 200 WWII Air/Sea Rescue Operations are recorded to have taken place in the study area. The location, distribution of the physical remains of these recorded aircraft losses on the seabed is poorly understood. However, these sites are likely to be of special archaeological interest, and would be automatically protected by the Protection of Military Remains Act 1986 should they be located.
Isolated Aircraft Finds	medium	Isolated aircraft finds will consist of derived, 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 can give insights into patterns of historical aviation across the study area or may indicate the presence of a recorded but uncharted aircraft crash site.

The wreck of The Sheraton at the base of the Hunstanton Cliffs

Source: Shutterstock.com

10.6.2 Identification of Potential Impacts on Archaeology

Of the effects of dredging, sediment transport, substrate removal, bathymetry changes and elevated turbidity/sand deposition [(1)] have been identified by

Wessex Archaeology as most likely to lead to an impact on the archaeological record. The nature of these impacts is enlarged upon below.

- As described in Chapter 7 there are likely to be no changes to sediment transport regimes. As such this effect has been scoped out from the following impact assessment.

- Bathymetric change is in practice an effect deriving from substrate removal. Following substrate removal sediments and possibly archaeological features and structures such as wrecks may be destabilised and become at risk of erosion and other damage. As bathymetric change derives from the primary impact of substrate removal, the interactions between dredging activity and subsequent 'effects' is in the first instance likely to be in the close proximity to primary substrate removal. Therefore the interaction of substrate removal and bathymetric change are thought to be closely linked and discussed together in the following sections.

- The sand deposition effect is caused by the suspension of fine sediment in the water during aggregate extraction, resulting from the action at the drag-head and 'overflow' from the hopper. In this case there is considered to be little effect of the density plume falling rapidly back to the seabed, and the finer sediment remaining in suspension for longer and falling gradually to the seabed over a larger area; in general a minor positive impact can be anticipated.

The process of marine aggregate extraction and the effects of substrate removal, bathymetric changes, sediment transport and sand deposition may result in the following impacts upon prehistoric, maritime and aviation archaeology:

- Impact 1: Direct damage to both *in situ* and derived archaeological material.

- Impact 2: Dispersal of *in situ* material resulting in the disturbance of relationships between structures, artefacts and their surroundings or contexts.

- Impact 3: Loss of derived prehistoric artefacts and isolated wreck and aircraft artefacts and debris within the volume of aggregate.

- Impact 4: Destabilisation of sites through the loss of overlying or adjacent sediments prompting physical instability, erosion, corrosion and biological or chemical decay.

(1) Wessex Archaeology's report refers to the impact of the 'sediment plume' but since this effect is concerned with deposition of material on the seabed, for consistency, in this main MAREA section we refer to this effect as 'sand deposition' so as to be consistent with terminology used in the other MAREA chapters.

- Impact 5: Burial of sites, potentially protecting and promoting favourable preservation.

10.6.3 Uncertainty and the Precautionary Principle

As acknowledged by a number of noted sources (Offshore Wind, 2011) uncertainty and the precautionary principle are very important in certain aspects of archaeological assessment. Uncertainty can arise with regards to such matters as the presence/absence of features; if present, (eg as an anomaly) what they comprise; and, if present, their value and sensitivity. Uncertainty can manifest itself, for example, when assessing potential cultural heritage receptors, which are often indicated only by documentary sources with poor spatial locations; or geophysical anomalies that have archaeological potential but require further investigation in order to be verified as receptors. In this assessment, and in accordance with normal EIA practice, where there is significant uncertainty the 'precautionary principle' is applied both in terms of rating the significance of impacts and in determining appropriate mitigation. Further detail in regard to how the precautionary principle has been applied in this assessment is provided in Section 10 of Appendix H.

10.6.4 Magnitude of Effects

The magnitudes of these effects are summarised below. Overall, the regional impacts of substrate removal, bathymetry change and sand deposition on archaeological and cultural heritage receptors range from low to high magnitude.

Removal of Sediment (including the concept of Bathymetry Change)

The removal of sediment, as a result of dredging activity, ranges from being a low to high magnitude effect for various types of archaeological receptors (see Appendix G for further detail).

It should be noted that the following assessment deals with the potential impacts to archaeology should interaction occur and mitigation measures have not been considered. However dredging vessels have a number measures in place to avoid important archaeological sites, including avoidance behaviour by respecting exclusion zones, and follow reporting protocols for archaeological discoveries.

Sand Deposition

Sand deposition as a result of dredging is a low-medium magnitude effect (see Appendix G for further detail).

10.6.5 Sensitivity of Receptors

The sensitivity of the three categories of resource to removal of sediment (including the concept of bathymetry change) and to the effects of sand deposition are summarised in Table 10.11 and Table 10.12 respectively.

10.6.6 Degree of Regional Interaction

The degree of regional interaction between the archaeological and cultural heritage resources and the potential effects of dredging are summarised in Table 10.13.

Aggregates Discharging at the Wharf

Table 10.11 Sensitivity of Archaeological and Cultural Heritage Resources to Removal of Sediment (including Bathymetric Change Where Relevant)

Receptor	Sensitivity	Summary
Prehistoric Archaeological and Cultural Heritage Resources		
Late Pleistocene Glacio-fluvial Sediments	high	As they are the principal deposits targeted by the marine aggregate industry, Late Pleistocene glacio-fluvial sediments and archaeological material within them will be unable to tolerate the negative effects of dredging. Impacts from sediment removal will result in a permanent change to the receptor. Secondary negative effects from erosion and exposure caused by bathymetric change may also occur. The adaptability and tolerance of the receptor to these effects is low. Similarly, the receptor's recoverability or ability to return to its pre-impact state after substrate removal is low and Late Pleistocene glacio-fluvial gravels must therefore be regarded as a receptor of high sensitivity to the effects of substrate removal.
Estuarine Alluvium and Peat	high	Alluvial and peat deposits will be unable to tolerate the primary effects of sediment removal and secondary effects of bathymetric change, resulting in a permanent change to the receptors. The adaptability and tolerance of the receptors are low. Similarly, the measure of the receptors' recoverability is low. With regard to substrate removal, alluvium and peat are therefore receptors of high sensitivity. (However, on the assumption that alluvial and peat deposits are not targeted by the marine aggregate industry the degree of interaction will be minimal)
Isolated Prehistoric Finds	medium	The adaptability and tolerance of isolated prehistoric finds to substrate removal is low. This is because while derived material is still susceptible to direct damage and the potential for the loss of artefacts within the volume of aggregate remains, damage and dispersal resulting in the loss of the relationship between the artefact and its archaeological context has already occurred to artefacts that are in a secondary context. For the same reasons, the exposure of derived material is not of the same degree of concern as *in situ*, primary context archaeological deposits. However, isolated archaeological material will be unable to tolerate the effects of substrate removal, resulting in a permanent change to the receptor. The receptor's recoverability is low. Prehistoric finds can be regarded as receptors of medium sensitivity to the effects of substrate removal.
Maritime Archaeological and Cultural Heritage Resources		
Known, Charted Wrecks	High	Where substrate removal results in a direct impact to the archaeological record, known charted wreck sites will be unable to tolerate the effects, resulting in a permanent change in the receptor. The adaptability and tolerance of the receptor is low and it is therefore a high sensitivity receptor.
		With regard to the indirect effects of bathymetry change on the archaeological record, charted wreck sites will generally be unable to tolerate the effects of destabilisation listed above, resulting in permanent change in the receptor. The adaptability and tolerance of the receptor is low and it is therefore a high sensitivity receptor.
Shipping Casualties / Recorded Losses	High	Where substrate removal results in an impact to the archaeological record the physical remains of recorded shipping casualties, but previously unlocated/unknown wreck sites, will be unable to tolerate the effects, resulting in a permanent change in the receptor. The adaptability, tolerance and recoverability is low. Due to the uncertainty of their location and therefore their potential for impact from substrate removal, recorded shipping casualties should be regarded as a receptor of high sensitivity.
		With regard to the effects of bathymetry change on recorded shipping casualties/previously unlocated wreck sites, they will generally be unable to tolerate the effects of destabilisation listed above, resulting in permanent change in the receptor. These sites should be regarded as a receptor of high sensitivity.
Unknown, Uncharted Wreck Sites	High	Particularly where substrate removal results in an impact to the archaeological record the remains of unknown, uncharted wrecks would be unable to tolerate the effects, resulting in a permanent change in the receptor. As such, the adaptability, tolerance and recoverability is low. Due to a lack of any certainty as to their numbers and location, and the consequent potential for them to be impacted by substrate removal and bathymetry change, unknown and uncharted wrecks should be regarded as a receptor of high sensitivity.
Isolated Maritime Finds	medium	The adaptability and tolerance of isolated maritime finds to substrate removal is low. Although this receptor is scattered and ephemeral in nature if adversely affected by substrate removal, it will be unable to recover, resulting in permanent change. As such recoverability is low. It is suggested that isolated maritime finds be regarded as a receptor of medium sensitivity.
		Isolated maritime finds may become exposed as a result of bathymetry change, and smaller less dense objects may be moved by tidal flow and localised currents. Although this receptor is scattered and ephemeral in nature if adversely affected by bathymetry changes, it may be unable to recover, resulting in permanent change. As such the recoverability to this effect is low. It is suggested that isolated maritime finds be regarded as a receptor of medium sensitivity.
Aviation Archaeological and Cultural Heritage Resources		
Known, Charted Aircraft Crash Sites	High	Known, charted aircraft crash sites will be unable to tolerate negative effects deriving from substrate removal or bathymetry change resulting in a permanent change in the receptor. As such, the adaptability, tolerance and recoverability is low and it is therefore a high sensitivity receptor. However, because the extent and distribution of this receptor is fairly accurately known and the marine aggregate industry avoids seabed structures and obstructions such as wrecks, the direct interaction between known aircraft crash sites and substrate removal should be small and able to be avoided under most circumstances. There are no known aircraft crash sites within the current licence areas with the MAREA study area.
		With regard to the effects of bathymetry change on the archaeological record, charted aircraft crash sites will be unable to tolerate the effects of destabilisation listed above, resulting in permanent change in the receptor. The adaptability and tolerance of the receptor is low and it is therefore a high sensitivity receptor.
Recorded Aircraft Losses	High	Particularly where substrate removal results or bathymetric change results in an impact to the archaeological record, the physical remains of recorded aircraft losses would be unable to tolerate the effects, resulting in a permanent change in the receptor. As such, the adaptability, tolerance and recoverability is low. 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 study area. Due to the uncertainty regarding their precise location and the potential, therefore, for impact from aggregate dredging to occur, recorded aircraft losses should be regarded as a receptor of high sensitivity.
Isolated Aircraft Finds	medium	The adaptability and tolerance of isolated aircraft finds to substrate removal is low. Although this receptor is scattered and ephemeral in nature if adversely affected by substrate removal, it will be unable to recover, resulting in permanent change. As such the measure of the receptor's recoverability is low. Isolated maritime finds are regarded as a receptor of medium sensitivity.

Table 10.12 Sensitivity of Archaeological and Cultural Heritage Resources to Sand Deposition

Receptor	Sensitivity	Summary
Prehistoric and Eroded Coastal Archaeological and Cultural Heritage Resources		
Late Pleistocene Glacio-fluvial Sediment	Low	With regard to the effects of sand deposition estuarine alluvium and peat are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Estuarine Alluvium and Peat	Low	With regard to the effects of sand deposition, estuarine alluvium and peat are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Isolated Prehistoric Finds	Low	With regards to the effects of sand deposition changes, isolated prehistoric finds are likely to be unaffected or positively affected, and are thus regarded as a receptor of low sensitivity.
Maritime Archaeological and Cultural Heritage Resources		
Known, Charted Wrecks	Low	With regard to the effects of sand deposition, known charted wrecks are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Shipping Casualties / Recorded Losses	Low	With regard to the effects of sand deposition the remains of recorded shipping casualties are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Unknown, Uncharted Wreck Sites	Low	With regard to the effects of sand deposition the remains of shipping casualties are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Isolated Maritime Finds	Low	With regard to the effects of sand deposition isolated maritime finds are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Aviation Archaeological and Cultural Heritage Resources		
Known, Charted Aircraft Crash Sites	Low	Sand deposition effects upon known aircraft crash sites are likely to result in a positive, or no change, and are thus regarded as a receptor of low sensitivity.
Recorded Aircraft Losses	Low	With regard to the effects of sand deposition, the remains of recorded aircraft losses are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.
Isolated Aircraft Finds	Low	With regard to the effects of sand deposition, isolated aircraft finds are likely to be unaffected or positively affected and are thus regarded as a receptor of low sensitivity.

Table 10.13 Degree of Regional Interaction between Archaeological and Cultural Heritage Resources and Relevant Effects of Dredging

Receptor	Degree of interaction	Summary
Prehistoric and Eroded Coastal Archaeological and Cultural Heritage Resources		
Late Pleistocene Glacio-fluvial Sediments	small	Late Pleistocene glacio-fluvial sediments were discussed as sedimentary Unit 3a in the geotechnical assessment of the MAREA (see *Section 6.6* for more information). The unit was observed in 83 vibrocores (out of 628 assessed) within current aggregate licence areas within the study area. These were all in the northern or central parts of the study area. These late Pleistocene glacio-fluvial sediments, which are widespread within the study area, are the primary target of aggregate dredging. However, the archaeological value of these sediments is based on their potential to preserve *in situ* or derived Palaeolithic artefacts and other archaeological material. The glacio-fluvial origin of these sediments indicates that the presence of such archaeological material is likely to be extremely rare. Therefore, the interaction with dredging activity and archaeological material within this receptor is likely to be a small degree of regional interaction between impacts and receptor in this case.
Estuarine Alluvium	small	Estuarine alluvium, which overlies the Pleistocene gravels, was identified as sedimentary Unit 3b in the MAREA geotechnical assessment. As a sediment type of archaeological interest due to the preferential conditions for preserving palaeoenvironmental proxy indicator macro and microfossils and potentially *in situ* archaeological materials, this receptor has archaeological value in itself. The age and distribution of this receptor may be of special interest for its potential to contain Mesolithic archaeology. Sixty-two vibrocores containing Unit 3b deposits were observed within current aggregate licence areas within the study area, with a further vibrocore containing Unit 3b immediately adjacent to another licence area. The majority of these were located in the central parts of the study area. The extent of estuarine alluvium within the study area is not fully known and the degree to which the impacts overlap with the location and distribution of the receptor is thus unknown. Given this uncertainty, a precautionary approach has been adopted. However, based on the assumption that the aggregate industry will avoid areas in which estuarine alluvium is present or overlies gravels for operational purposes, it is reasonable to assume that there is likely to be a small degree of regional interaction between the impact and receptor in this case.
Peat	small	The occurrence of peat deposits within the study area is not fully understood and the degree to which the spatial extent of the impact overlaps with the location and distribution of the receptor is thus unknown. Regionally there are important peat formations that were investigated during the Humber REC. The coverage of geophysical and geotechnical survey datasets and sediment logs is not sufficient to exclude the presence of peat from the MAREA region. As with alluvium above, however, and based on the assumption that, for operational purposes, the aggregate industry will avoid areas in which peat is present or overlies gravels, there is likely to be a small degree of regional interaction between the impact and receptor in this case.
Isolated Prehistoric Finds	medium	There is a high potential for derived finds to be present within the potential areas of impact and the MAREA study area as a whole. However, whilst this potential exists, it is not possible to quantify or predict the volume or distribution of such artefacts. Inconclusively dated finds of bone reported under the TCE/BMAPA/EH protocol (2005) may be prehistoric or more recent. Due to the uncertainty regarding their location, isolated prehistoric finds must be viewed with caution, and as such a medium degree of regional interaction between the impact and the receptor is suggested in this case.
Maritime Archaeological and Cultural Heritage Resources		
Known, Charted	medium	Although the distribution of charted wreck sites (Figure 6.55 in Section 6.6) shows some areas with higher concentrations there is a fairly widespread and general distribution of wrecks across the study area. Figure

Receptor	Degree of interaction	Summary
Wrecks		6.55 in Section 6.6 demonstrates that most of the Future 15 year Extraction Zones include at least one charted maritime site within its boundaries. Although most of the Future 15 year Extraction Zones include charted maritime sites, Figure 6.55 in Section 6.6 also shows that the vast majority of charted sites within the study area lie outside the current Licence Areas and Application Areas. Due to the widespread distribution but small number of sites within dredging areas, a medium degree of regional interaction between dredging impacts and the known, charted wreck sites receptor is suggested. It should be noted, however, that the aggregates industry aims to avoid shipwrecks due to the potential damage they can cause to dredging equipment. As such, precautionary exclusion zones are usually emplaced around known shipwreck sites.
Shipping Casualties / Recorded Losses	medium	There are 1166 recorded shipping casualties or losses listed within the study area (Figure 6.56 in Section 6.6). Of this total, 15 are placed at Named Locations within the Future 15 year Extraction Zones of Areas 439, 448, and 105. Although these losses are not currently tied to known positions on the seabed there is potential for remains to survive in some form within the region. Similarly, the potential exists for the remains of shipping casualties at Named Locations which are located outside Licence or Application Areas to be present within these potential areas of impact. The shipping casualties ascribed to a Named Location within a Future 15 year Extraction Zone are far outnumbered by the total number of documented losses listed within the study area. However, due to the lack of positional data this receptor must be regarded with a degree of uncertainty and a precautionary approach is adopted accordingly. On this basis, a medium degree of regional interaction is suggested between the dredging impacts and shipping casualties as a receptor.
Unknown, Uncharted Wreck Sites	Medium	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 study area. It is not possible to quantify the extent of unknown and uncharted sites within the impact areas. As an AMAP, the Humber offshore region has a high potential for ship loss coinciding with a high potential for the preservation of archaeological materials (Bournemouth University 2007). However, it must be noted that the conditions favourable for preservation of archaeological material within the study area will be predominantly provided by finer-grained sediments rather than by the coarse gravel deposits targeted by the aggregate industry. There is a great deal of uncertainty regarding the distribution and extent of unknown, uncharted wreck sites within the potential impact areas and across the study area as a whole. Consequently a precautionary approach is adopted and a medium degree of regional interaction between the impact and the receptor is anticipated. By the time Future 15 year Extraction Zones are dredged, they will have been subject to detailed geophysical survey and review. As such, the potential for encountering unknown, uncharted wrecks within the Future 15 year Extraction Zones will have been significantly reduced.
Isolated Maritime Finds	Medium	Isolated maritime finds comprise not only wrecks of vessels, but also debris which is associated with maritime activities. This can include, for example, artefacts which were accidentally lost or material deliberately thrown overboard from a vessel. While there is the potential for isolated finds of this nature within the Future 15 year Extraction Zones and across the study area 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 suggests a high potential for such finds to be present on the seabed. Due to the uncertainty regarding their location, isolated maritime finds must be approached with caution, and as such a medium degree of regional interaction between the impact and the receptor is suggested in this case.
Aviation Archaeological and Cultural Heritage Resources		
Known, Charted Aircraft Crash Sites	None	Data regarding the physical location of aircraft remains on the seabed are extremely limited. Consequently, the known aviation resource alone must not be viewed as indicative of the total number of aircraft crash sites within the study area. The known resource lists only five aircraft crash sites within the study area, none of which lie within a Licence or Application Area. On the basis of the known resource, therefore, no regional interaction is expected between the known, charted aircraft receptor and the aggregate extraction impacts.
Recorded Aircraft Losses	Medium	In contrast to the small known resource, records of aircraft losses at sea are extensive. For the purpose of this report, recorded aircraft losses are those documented losses listed by the NRHE at Named Locations and the records of WWII Air/Sea Rescue Operations. There are 69 documented aircraft losses listed by the NRHE within the study area (Figure 6.57 in Section 6.6). The total number of WWII Air/Sea Rescue Operations within the study area was extracted from contemporary maps which are sometimes ambiguous and unclear and thus must be considered with caution. The maps imply, however, that somewhere in the region of 110 Air/Sea Rescue Operations took place within the study area. Of the 69 documented losses, one is recorded as being within a Future 15 year Extraction Zone. This site is linked to a Named Location (described as 'Inner Dowsing Overfalls, Lincolnshire') which is located within the Future 15 year Extraction Zone of Area 439. Although this record is not currently tied to known aircraft remains on the seabed, such remains should be expected to survive in some form within the Future 15 year Extraction Zone of Area 439 or its vicinity. Similarly, there is the potential for the physical remains of aircraft losses listed in other Named Locations to be present within these licence areas. Most of the Licence and Application Areas had WWII Air/Sea Rescue Operations either within them or in reasonably close proximity. Nonetheless, it is clear that the majority of recorded aircraft losses and WWII Air/Sea Rescue Operations in the study area lie outside Licence and Application Areas. There is no single comprehensive list of aircraft losses in UK territorial waters and thus the numbers presented above must not be considered definitive. Additionally, the positional data for the NRHE recorded aircraft losses and WWII Air/Sea Rescue Operations is poor. Given these factors, and the automatic protection afforded military aircraft under the Protection of Military Remains Act (1986), a medium degree of regional interaction is suggested between the impacts and the location and distribution of the receptor. Geophysical survey of the future 15 year extraction zones may identify a proportion of the as yet unlocated aircraft losses, but aircraft wrecks can be difficult to identify in geophysical survey data and some sites may not be identified in this way.
Isolated Aircraft Finds	Medium	Isolated finds relating to aviation activity may also be present within the potential areas of impact and the study area as a whole. Most aircraft came to be on the seabed as a result of in-flight accident, technical malfunction 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 artefacts rather than a coherent aircraft wreck. It is not possible to predict the volume and distribution of such artefacts across the study area. However, a consideration of the known aircraft crash sites and the documented aircraft losses suggests a high potential for such material in or on the seabed. Due to the uncertainty regarding their location, isolated aircraft finds must be approached with caution and, as such, a medium degree of regional interaction between the impact and the receptor is suggested in this case.

10.6.7 Significance of Impacts

Prehistoric Archaeology

Table 10.14, Table 10.15 and Table 10.16 provide summaries of the results of the impact assessment for prehistoric archaeology receptors against the effects of substrate removal, bathymetric change and sand deposition, respectively. Note that for the receptor late Pleistocene glacio-fluvial gravels, if Palaeolithic artefacts and materials are present, the significance of impact will automatically be Major Negative due to the rarity of such archaeology.

Table 10.14 Summary of Variables assessed with regards to Substrate Removal and Prehistoric Archaeology

Impact Assessment Criteria	Late Pleistocene glacio-fluvial sediments	Estuarine Alluvium	Peat	Isolated Prehistoric Finds
Interaction between Effects and Receptors	Small	Small	Small	Medium
Magnitude of Effect	Medium/High	Low / Medium	Low / Medium	Low / Medium
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	High	High	High	Medium
Significance of Impact	Moderate Negative	Minor / Moderate Negative	Minor / Moderate Negative	Moderate Negative

Table 10.15 Summary of Variables Assessed with Regards to Bathymetric Change on Prehistoric Archaeology

Impact Assessment Criteria	Late Pleistocene glacio-fluvial sediments	Estuarine Alluvium	Peat	Isolated Prehistoric Finds
Interaction between Effects and Receptors	Small	Small	Small	Medium
Magnitude of Effect	Medium/High	Medium	Medium	Medium
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	High	High	High	Medium
Significance of Impact	Moderate Negative	Minor / Moderate Negative	Minor / Moderate Negative	Moderate Negative

Table 10.16 Summary of Variables Assessed with Regards to Sand Deposition and Prehistoric Archaeology

Impact Assessment Criteria	Late Pleistocene glacio-fluvial sediments	Estuarine Alluvium	Peat	Isolated Prehistoric Finds
Interaction between Effects and Receptors	Large	Small	Small	Medium
Magnitude of Effect	Low	Low	Low	Low
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	Low	Low	Low	Low
Significance of Impact	Positive	Positive	Positive	Positive

Maritime Archaeology

Table 10.17, Table 10.18 and Table 10.19 provide a summary of the results of the impact assessment for maritime archaeology receptors against the effects of substrate removal, bathymetric change and sand deposition accordingly, respectively.

Table 10.17 Summary of Variables Assessed with Regards to Substrate Removal and Maritime Archaeology

Impact Assessment Criteria	Known Charted Wreck Sites	Shipping Casualties / Recorded Losses	Unknown Uncharted Wreck Sites	Isolated Maritime Finds
Interaction between Effects and Receptors	Medium	Medium	Medium	Medium
Magnitude of Effect	Medium	Medium	Medium	Medium
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	High	High	High	Medium
Significance of Impact	Moderate / Major Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate Negative

Table 10.18 Summary of variables assessed with regards to bathymetric change on prehistoric archaeology

Impact Assessment Criteria	Known Charted Wreck Sites	Shipping Casualties / Recorded Losses	Unknown Uncharted Wreck Sites	Isolated Maritime Finds
Interaction between Effects and Receptors	Medium	Medium	Medium	Medium
Magnitude of Effect	Medium	Medium	Medium	Medium
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	High	High	High	Medium
Significance of Impact	Moderate / Major Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate Negative

Table 10.19 Summary of variables assessed with regards to Sand Deposition and maritime archaeology

Impact Assessment Criteria	Known Charted Wreck Sites	Shipping Casualties / Recorded Losses	Unknown Uncharted Wreck Sites	Isolated Maritime Finds
Interaction between Effects and Receptors	Medium	Medium	Medium	Medium
Magnitude of Effect	Low / Medium	Low / Medium	Low / Medium	Low / Medium
Value of Receptor	High	High	High	Medium
Sensitivity of Receptor	Low	Low	Low	Low
Significance of Impact	Positive	Positive	Positive	Positive

Aviation Archaeology

Table 10.20, Table 10.21 and Table 10.22 provide a summary of the results of the impact assessment for aviation archaeology receptors against the effects of substrate removal, bathymetric change and sand deposition accordingly carried out above.

Table 10.20 Summary of Variables Assessed with Regards to Substrate Removal and Aviation Archaeology

Impact Assessment Criteria	Known Charted Aircraft Crash Sites	Recorded Aircraft Losses	Isolated Aircraft Finds
Interaction between Effects and Receptors	None	Medium	Medium
Magnitude of Effect	Low / Medium	Low / Medium	Low / Medium
Value of Receptor	High	High	Medium
Sensitivity of Receptor	High	High	Medium
Significance of Impact	Minor / Negligible Negative	Moderate / Major Negative	Moderate Negative

Table 10.21 Summary of Variables Assessed with Regards to Bathymetric change on Prehistoric Archaeology

Impact Assessment Criteria	Known Charted Aircraft Crash Sites	Recorded Aircraft Losses	Isolated Aircraft Finds
Interaction between Effects and Receptors	Small / None	Medium	Medium
Magnitude of Effect	Medium	Medium	Medium
Value of Receptor	High	High	Medium
Sensitivity of Receptor	High	High	Medium
Significance of Impact	Minor / Negligible Negative	Moderate / Major Negative	Moderate Negative

Table 10.22 Summary of variables assessed with regards to Sand Deposition and aviation archaeology

Impact Assessment Criteria	Known Charted Aircraft Crash Sites	Recorded Aircraft Losses	Isolated Aircraft Finds
Interaction between Effects and Receptors	Small	Medium	Medium
Magnitude of Effect	Low	Low	low
Value of Receptor	High	High	Medium
Sensitivity of Receptor	Low	Low	Low
Significance of Impact	Positive	Positive	Positive

10.6.8 Summary of Impacts

Table 10.23 summarises the significance of the cumulative impacts of dredging on archaeological and cultural heritage receptors at the regional scale.

Table 10.23 Regional Summary of Impacts to the Receptors

	Removal of Sediment (including consideration of bathymetric change)	Sand deposition
Pleistocene fluvial gravels	Moderate *	Positive
Estuarine Alluvium	Minor/Moderate	Positive
Peat	Minor/Moderate	Positive
Isolated Prehistoric Finds	Moderate	Positive
Known Charted Wreck Sites	Moderate/Major	Positive
Shipping Casualties	Moderate/Major	Positive
Unknown Uncharted wreck Sites	Moderate/Major	Positive
Isolated Maritime Finds	Moderate	Positive
Known Charted Aircraft Losses	Minor/negligible	Positive
Recorded Aircraft Losses	Moderate/Major	Positive
Isolated Aircraft Finds	Moderate	Positive

* Note that for the receptor late Pleistocene glacio-fluvial gravels, if Palaeolithic artefacts and materials are present the significance of impact will automatically be Major Negative due to the rarity of such archaeology.

The impacts to archaeology and cultural heritage from the removal of sediment as a result of dredging are predicted to be significant and range from minor to potentially major. The impacts from sand deposition are assessed as being positive for all receptors.

It should be noted that these impacts are assessed without the consideration of inherent mitigation measure that are undertaken by the dredging industry, such as avoidance behaviour and observing exclusion zones. These measures greatly reduce the likelihood of impacts to a number of archaeological receptors occurring.

The coincidence of individual Licence Areas and historic environment receptors has been summarised in Table 10.24. The actual presence of evidence within or in close proximity to Licence Areas has been noted with a 'Y' or 'N'; absence of evidence does not necessarily mean that the receptor is not present, not least because of the regional-scale of the datasets used and acknowledged biases in third-party records. Equally, the presence of receptor types such as isolated finds or unknown uncharted wrecks cannot by definition be known until they are encountered. The coincidence of licence areas and receptors is such that none of the licence areas can be regarded as 'clear' of interactions with any of the archaeological receptors that have been assessed.

Prehistoric Archaeology

There are 31 palaeolandscape features of archaeological interest that intersect with licenced dredging areas across the entire MAREA region. In addition, sedimentary units of archaeological interest are observed in the northern and central areas of the study area. In general, where dredging activity targets these sediment, units-3a (Late Pleistocene glacio-fluvial sediments receptor) and 3b (estuarine alluvium) (and 3/4 where geophysical data cannot be distinguished further as was described in Section 6.6), there is increased potential for encountering material of Upper Palaeolithic and Mesolithic interest as well as the inherent direct impact upon these sediment units of palaeoenvironmental and palaeolandscapes importance.

The full extent of these sedimentary units across the region cannot be evaluated from the geophysical and geotechnical datasets examined for this MAREA but they are likely to extend outwith the studied extent into the wider region. Finds reported under the BMAPA protocol are inconclusive for defining the potential for prehistoric archaeological material in the region. There are instances of bone being reported from Area 107 in the south but it is not clear how old the material is. Generally there is potential for encountering either sediment units of archaeological interest and/or palaeolandscape features in all areas of the study area that have been geophysically assessed.

Maritime Archaeology

There are known charted wrecks in most of the Licence Areas, except Areas 449, 480, 441/2, 441/3, 106/1, 106/2, 481/1 and 481/2. Licence Areas 448, 105, 400 and 107 have the highest concentration of known wrecks. The potential for the remains of shipping casualties to be present in each Licence Area is highlighted by the identification of the Humber region as an Area of Marine Archaeological Potential (AMAP) by the ALSF Navigational Hazards Project (Bournemouth University 2007). Both the presence in each Licence Area of known charted wrecks and the overall potential for shipping casualties suggest that each Licence Area has the potential to contain as yet unknown, uncharted wrecks. This potential extends to include isolated maritime finds in each Licence Area as several have been found in the region, concentrated in the southern licence areas. These have, in most instances, been reported through the Marine Aggregate Industry Protocol.

Aviation Archaeology

None of the Licence Areas contain known, charted air crash sites. However, Area 439 contains a reported aircraft loss. Again, difficulties in identifying and recording air crash sites and aircraft losses, combined with the high level of aviation activity in the region during WWII, suggest that the entire region has the potential to contain isolated aircraft finds, and possibly entire crash sites.

Table 10.24Summary of sensitivity of Individual Licence Areas and Future 15 Year Extraction Zones (F15EZ)

Licence Area	Associated Geophysical Zone	Geophysical Features	Prehistoric Archaeology			Maritime Archaeology				Aviation Archaeology		
			Late Pleistocene Glacio-fluvial Sediments (Unit 3a)	Estuarine Alluvium and Peat (Unit 3b)	Isolated Prehistoric Finds	Known Charted Wrecks◊	Shipping Casualties / Recorded Losses	Unknown Uncharted Wrecks	Isolated Maritime Finds	Known Charted Air Crash Sites◊	Recorded Aircraft Losses	Isolated Aircraft Finds
Significance of Impact (most significant impact)			Moderate Negative	Minor / Moderate Negative	Moderate Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate Negative	Minor / Negligible Negative	Moderate / Major Negative	Moderate Negative
102	Northern	Y	Y	Y	N	Y	N	?	N	N	N	N
102 F15EZ	Northern		Y	Y	N	Y	N	?	N	N	N	N
105	Northern		Y	Y	N	Y	Y	?	N	N	N	N
105 F15EZ	Northern		Y	Y	N	Y	Y	?	N	N	N	N
448	-	-	-	-	N	Y	Y	?	N	N	N	N
449	-	-	-	-	N	N	N	?	N	N	N	N
106/1	Central	Y	N	N	N	N	N	?	N	N	N	N
106/2	Central		Y	N	N	N	N	?	N	N	N	N
106/3	Central		Y	Y	N	Y	N	?	Y	N	N	N
106/3 F15EZ	Central		Y	Y	N	Y	N	?	‡	N	N	N
197	Central		Y	Y	N	Y	N	?	N	N	N	N
197 F15EZ	Central		Y	Y	N	Y	N	?	N	N	N	N
400	Central		Y	Y	N	Y	N	?	N	N	N	N
480	Central		Y	Y	N	N	N	?	N	N	N	N
480 F15EZ	Central		Y	Y	N	N	N	?	N	N	N	N
493	Central		Y	Y	N	Y	N	?	N	N	N	N
440	-	-	-	-	N	Y	N	?	N	N	N	N
440 F15EZ	-	-	-	-	N	Y	N	?	N	N	N	N
441/1	-	-	-	-	N	Y	N	?	N	N	N	N
441/1 F15EZ	-	-	-	-	N	Y	N	?	N	N	N	N
441/2	-	-	-	-	N	N	N	?	N	N	N	N
441/2 F15EZ	-	-	-	-	N	N	N	?	N	N	N	N
441/3	-	-	-	-	N	Y	N	?	N	N	N	N
441/3 F15EZ	-	-	-	-	N	N	N	?	N	N	N	N
439	-	-	-	-	N	Y	Y	?	N	N	Y	N
481/1	Southern West	Y	-	-	N	N	N	?	N	N	N	N
481/2		-	-	-	N	N	N	?	N	N	N	N
107	-	-	-	-	Y	Y	N	?	Y	N	N	N
107 F15EZ	-	-	-	-	*	Y	N	?	*,**,†, ⌐, ≡	N	N	N

* Unidentified bone (CEMEX_0015); ** Wrought iron (CEMEX_0015); † Roman mortarium sherd (CEMEX_0301); ‡ Refractory brick (Hanson_0190); ⌐ Modern Leather Shoe Sole (CEMEX_0300); ≡ Ships timber from a carvel vessel (CEMEX_0294); Values denoted as '-' indicate data are not available for that area/receptor.

N.B. No mitigation measures are considered here although ordinarily, where the position of receptors such as ship and aviation wrecks is known, they are avoided to prevent damage to dredging equipment and contamination of the aggregate. Equally aggregate dredgers will avoid known areas of alluvium and peat because they would represent contaminants in sand and gravel cargoes which could adversely affect the quality of the aggregates produced at the receiving wharf.

In conducting EIAs for individual licence areas, it will continue to be necessary for historic environment data to be sought for the licence area and its immediate vicinity from the principal third-party records. Specifically, it will be necessary to check if any existing records have been altered or new records added as these third-party records are continually being updated. Further information on the approach to be taken to archaeology assessments at the EIA stage is provided in Appendix G.

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11 IN-COMBINATION REGIONAL IMPACTS

11.1 INTRODUCTION

As noted by the MMO a large number of human activities take place in the offshore east coast region of England (MMO, 2011). Of particular note for the MAREA study area is the large number of active and proposed offshore windfarms. The MAREA study area also contains a number of significant ports and harbours, and offshore oil and gas infrastructure. Activities including fishing, shipping and marine recreation are also relatively constant across the study area. These activities have been discussed in detail in Sections 6.2, 6.3, 6.4 and 6.5.

As well as having potential impacts in their own right, each of the human activities that take place within the MAREA study area has the potential to impact upon sensitive receptors in-combination with each other and in-combination with marine aggregate extraction.

In the context of this MAREA, in-combination impacts are interpreted as impacts that may potentially arise as a result of other human activities that produce effects that are also one of the '13 effects of dredging' discussed in Chapter 7, where these effects impact the same receptors in sufficient magnitude to warrant assessment. In-combination impacts can occur as a result of:

1. The physical overlap of impacts between dredging and other activities (e.g. sediment plumes from dredging and windfarm construction) affecting the same receptor location; and/or

2. The impacts of different activities (e.g. dredging noise, windfarm construction noise and shipping noise) affecting the same mobile receptor in different parts of its regional range.

11.2 IN-COMBINATION ASSESSMENT METHODOLOGY

11.2.1 Overview of Approach

In reviewing the available data sources and references on the activities and projects identified as relevant to this part of the assessment, it is apparent that the available data have not been produced in a way consistent with the MAREA assessment data. This means that a straightforward approach to an in-combination assessment is not possible. For future windfarms for example, due to the early design stage of many of these projects, modelling studies investigating issues such as predicted changes to wave heights are not yet available and cannot be directly compared or overlain with the predicted changes to wave height GIS layers developed for this MAREA.

It should also be noted that an in-combination assessment is not entirely within the remit of what the marine aggregate industry is required to assess, but is however considered a key issue for the purposes of the regional assessment, particularly as an issue of relevance to future EIAs.

Acknowledging this background, this chapter aims to highlight the potential for in-combination impacts by presenting information from two perspectives and, where necessary, making some conservative assumptions:

1. First, a series of discussions is presented for each relevant human *activity* (e.g. windfarm development or commercial fishing). These sections describe the typical impacts resulting from them and how these may act in-combination with impacts from aggregate dredging. This discussion also aims to flag up particular potential sources of in-combination impact for specific licence areas that can be considered in more detail at the EIA stage (these issues are discussed in more detail in Chapter 13).

2. Second, a brief summary is provided of the human activities in the study area that may result in in-combination impacts to any one particular *receptor* group. It should be noted that, as the discussion is based on the '13 effects of dredging' assessed in the MAREA, this assessment does not consider all possible effects of human activity on all regional receptors, such as potential fisheries bycatch of marine mammals for example.

11.2.2 Identification of Sources of In-combination Impact

Table 11.1 presents a matrix of the 13 identified effects of dredging with an indication of whether they also have potential to materially result from other activities and planned developments within the Humber and Outer Wash MAREA study area. These potential impacts may arise either during the construction period or long term undertaking of each activity, and this should be taken into account by the reader when interpreting the matrices for the purposes of future EIA assessments. The potential interactions will also differ in terms of degrees of significance which has not been indicated here. The matrix has been compiled using professional judgement and experience of impact assessments for other industries. The associated discussion below is therefore essentially an indicative scoping exercise to inform future EIAs.

Table 11.1 In-Combination Interactions Matrix

Effects of Dredging	Commercial Fishing	Commercial Shipping	Recreational Sailing	Ports and Harbours	Coastal Developments	Offshore Windfarms	Cables and Pipelines	Oil and Gas Infrastructure (excluding pipelines)	Waste Disposal Sites	Military Activities
Presence of the vessel	●	●	●	■	■	●	■	●	■	●
Removal of sediment/changes to seabed topography	■	■	■	■	■	●	●	■	●	■
Fine sediment plume/elevated turbidity	■	■	■	●	●	●	●	■	■	■
Sand deposition	■	■	■	●	●	●	●	■	■	■
Changes to sediment particle size	■	■	■	■	■	■	■	■	■	■
Changes to wave height	■	■	■	■	■	●	■	■	■	■
Changes to tidal currents	■	■	■	●	●	●	■	■	■	■
Changes to sediment transport rates	■	■	■	●	●	●	■	●	■	■
Underwater noise	●	●	■	●	■	●	■	●	■	●
Loss of access	●	●	●	■	■	●	■	●	■	●
Change to benthic community composition	●	■	■	●	■	●	■	●	●	■
Change to distribution of fish	●	■	■	●	■	●	■	●	●	■
Changes to seabed features	■	■	■	■	■	●	■	■	■	■

●	A similar effect may be produced by the listed activity
■	No similar effect produced by the listed activity

For the purposes of this part of the assessment, the sources of in-combination impacts are grouped so that similar activities or impact sources are addressed together as follows.

- Commercial fishing.
- Commercial and recreational shipping.
- Coastal developments (including ports and harbours).

- Offshore industry and infrastructure [1] (telecommunications cables, oil and gas infrastructure such as wellheads, pipelines, and platforms, and waste disposal sites.
- Offshore windfarm.
- Military activities.

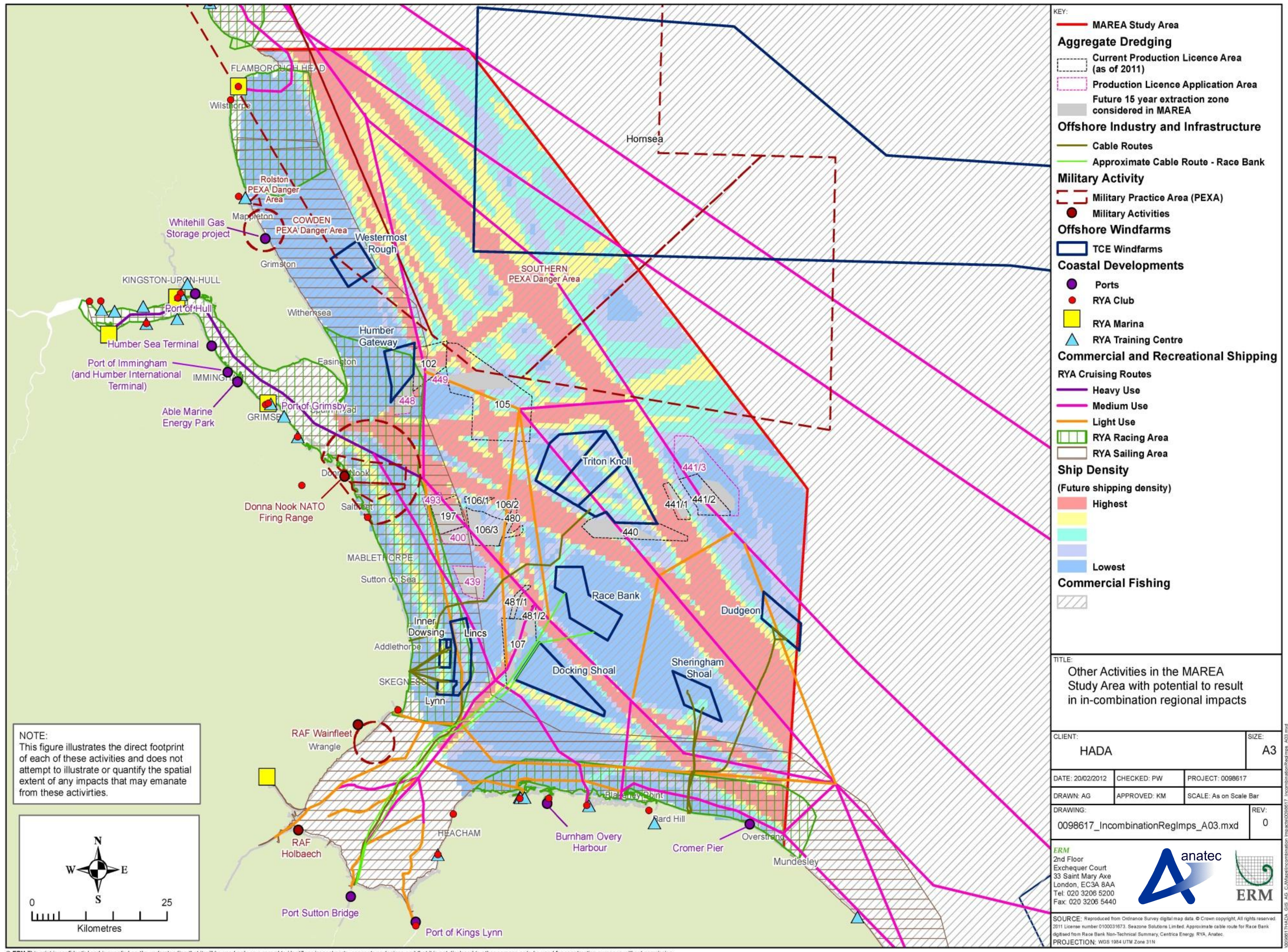
The spatial extent of these various human activities, superimposed together along with the areas where dredging will occur, are illustrated on Figure 11.1. It should be noted that this figure only illustrates the direct footprint of each of these activities rather than illustrating the spatial extent of any impacts that may emanate from them.

11.2.3 Identification of Potential Receptors to In-Combination Impacts

The receptors of relevance to the in-combination assessment are the same as those assessed throughout this MAREA as follows.

- Seabed features;
- coast;
- water quality;
- benthic ecology;
- fish ecology;
- marine mammals;
- birds;
- designated areas;
- fisheries;
- infrastructure;
- shipping, sailing, and navigation; and
- archaeology.

Figure 11.1 Human Activities Acting In-Combination in the MAREA Study Area



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(1) excluding offshore windfarms

11.3 Potential In-combination Impacts from Aggregate Dredging and Commercial Fishing

Commercial fishing practices have the potential to cause five effects that coincide with the 13 effects of dredging, with potential in-combination impacts upon six of the identified receptors, as shown in Table 11.2.

Table 11.2 Potential In-combination Interactions between Commercial Fishing and Aggregate Dredging

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Presence of the vessel	■	■	■	■	■	•	•	■	■	■	•	■
Underwater noise	■	■	■	■	•	•	■	■	■	■	■	■
Loss of Access	■	■	■	■	■	■	■	■	•	■	•	■
Change to benthic community	■	■	■	•	•	•	•	■	•	■	■	■
Change to distribution of fish	■	■	■	■	•	•	•	■	•	■	■	■

■	No interaction
•	Potential interaction at a regional scale

The presence of commercial fishing vessels adds shipping traffic to the area and produces underwater noise from vessel engines and the deployment of fishing gear. Commercial fishing by vessels over 10 m in length occurs across the whole of the MAREA study area. Vessels of less than 10 m also fish in the study area, focussing primarily on shellfish species. Removal of fish and shellfish species by commercial fishing practices has the potential to affect the regional composition of benthic communities and wider distribution of predating fish.

The spatial extent of commercial fishing in the study area has been discussed in Section 6.2 indicating that commercial fishing occurs throughout the study area but that some of the target species, particularly shellfish, are fished with varying local intensity in definable zones (e.g. crab and lobster are caught largely close to shore and brown shrimp are caught across the south of the study area).

The nature and degree of significance of any in-combination effects arising from commercial fishing activity and dredging will be spatially and temporally specific within each of the licence and application areas in the study area.

The main implications of the effects of dredging in-combination with fishing activities are primarily to benthic and fish ecology as a result of direct removal and disturbance, with low level secondary implications for the marine mammals and birds that feed upon affected species, although the relative influence of aggregate dredging is likely to be very small in comparison to commercial fishing. Although fishing patterns in the area may change from year to year in terms of such matters as catches, target species and areas fished, there is currently no evidence to suggest that fishing effort or intensity in the MAREA study area as a whole is likely to substantially increase over the next 15 years. So while future EIAs may need to update area specific fishing activity they are unlikely to identify a potentially significant change to in-combination impacts from the two industries.

It should be noted that aggregate dredging has been occurring in the region for over 40 years, over which period it has been operating side by side with the fishing industry, with impacts from these two industries being successfully managed in partnership between both industries and the marine regulators. Future EIA will need to consider in-combination effects between dredging and commercial fishing on benthic ecology in particular. Implications for specific licence areas are detailed in Chapter 12.

11.4 Potential In-combination Impacts from Aggregate Dredging and Commercial Shipping / Recreational Sailing

Commercial shipping and recreational sailing have the potential to cause three effects which coincide with the 13 effects of dredging, with potential in-combination impacts upon five of the identified receptors as shown in Table 11.3.

The issue of vessel presence and navigational safety is of concern to all users of the MAREA study area. Given the heavy shipping traffic that occurs throughout the region from a range of industries (the spatial extent is indicated on Figure 11.1), the impact of vessel presence on ecological receptors and the contribution of this to navigational risk are not unique to dredging and are not spatially limited to any part of the study area. All future EIAs for licences within the study area will need to consider the regional navigational risk study undertaken within this MAREA, applying more recent data if necessary. Future EIAs are not expected to identify potentially significant changes to in-combination navigational risk at the regional scale.

The underwater noise produced by dredging vessels is comparable with that of other large vessels as discussed in Chapter 7 and therefore contributes to regional ambient shipping noise in-combination with other industries.

Table 11.3 Potential In-combination Interactions between Aggregate Dredging, Shipping, and Sailing

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Presence of the vessel	■	■	■	■	■	•	•	■	•	■	•	■
Underwater noise	■	■	■	■	•	•	■	■	■	■	■	■
Loss of Access	■	■	■	■	■	■	■	■	•	■	•	■

■	No interaction
•	Potential interaction at a regional scale

11.5 Potential In-combination Impacts from Aggregate Dredging and Coastal Developments

Coastal developments assessed in this section include ports, harbours, and coastal defences as the effects they cause are broadly comparable. Coastal developments have the potential to cause six of the same effects as those caused by dredging, with potential in-combination impacts upon ten of the identified receptors, as shown in Table 11.4.

Coastal developments can cause seabed disturbance through the introduction of materials and structures and through maintenance dredging that can increase local turbidity. Coastal activities, such as maintenance dredging also have the potential to impact archaeological resources directly, requiring demolition ('clearance'). In these cases such activities are subject to specific mitigation measures. Effects related to bathymetric change and the re-deposition of disturbed sediments also have the potential to affect local archaeological sites. The introduction of structures such as coastal defences has the potential to change localised tidal currents with potential secondary effects on coastal sediment transport rates and marine communities in the longer term.

Table 11.4 Potential In-Combination Interactions between Dredging and Coastal Developments

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Fine sediment plume/elevated turbidity	■	■	•	•	•	•	•	■	■	■	■	■
Sand deposition	■	•	■	•	•	■	■	■	■	■	■	•
Changes to tidal currents	■	•	■	•	■	■	■	■	■	■	■	•
Changes to sediment transport rates	■	•	■	•	■	■	■	■	■	■	■	•
Underwater noise	■	■	■	■	•	•	■	■	■	■	■	■
Change to benthic community	■	■	■	•	•	•	•	■	•	■	■	■
Change to distribution of fish	■	■	■	■	•	•	•	•	•	■	■	■

■	No interaction
•	Potential interaction at a regional scale

As indicated on Figure 11.1, these effects are also not likely to overlap spatially with those arising from aggregate dredging as this activity in the MAREA study area does not occur in the vicinity of ports, harbours, or other coastal developments. Whilst there is some potential for coincident coastal development activity and aggregate dredging to cause in-combination impacts on sensitive ecological receptors, the differing spatial distributions and limited temporal overlap reduces the possibility for significant in-combination impacts to occur.

11.6 Potential In-combination Impacts from Aggregate Dredging and Offshore Industry and Infrastructure (Excluding Windfarms)

Offshore developments (excluding windfarms) assessed in this section include telecommunications cables, oil and gas infrastructure (e.g. wellheads, pipelines, and platforms), and waste disposal areas. These types of offshore development have the potential to cause seven effects which are the same as the 13 effects of dredging, with potential in-combination impacts upon 11 of the identified receptors, as shown in Table 11.5.

Table 11.5 In-combination Interactions between Dredging and Offshore Developments

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Presence of the vessel	■	■	■	■	•	•	•	■	■	■	•	■
Removal of sediment/changes to seabed topography	•	■	■	•	•	■	■	■	■	■	■	•
Fine sediment plume/elevated turbidity	■	■	•	•	•	•	•	•	■	■	■	■
Sand deposition	■	■	■	•	•	■	■	•	■	■	■	•
Loss of access	■	■	■	■	■	■	■	■	•	•	•	■
Change to benthic community	■	■	■	•	•	•	•	•	•	■	■	■
Change to distribution of fish	■	■	■	■	•	•	•	•	•	■	■	■

■	No interaction
•	Potential interaction at a regional scale

The locations of the offshore developments in the Humber MAREA area are indicated on Figure 11.1. The effects of offshore developments that are comparable with those of dredging occur primarily during their construction phase. The scale of these effects, and the extent to which they impact upon receptors in-combination with those from dredging, depends largely on the spatial distribution of the offshore developments being considered. Most of the offshore developments present in the region (excluding offshore windfarms) are in already place and have been there for some time so can largely be considered to be part of the baseline environment. There are no known developments of substantial scale planned, other than offshore windfarms, so very few future interactions are predicted at a regional scale within the next 15 years.

The effects from the presence of telecommunications cables tend be very short term and occur only during their construction or during periods of maintenance. Effects will be localised to the immediate vicinity of the cable route, which is narrow and linear. On a regional scale, the potential for significant in-combination impacts from this type of offshore development is likely to be negligible. Given that the only existing telecommunications cables are to the north of the study area, future dredging licence EIAs will only need to consider in-combination impacts from these should additional routes be installed in their vicinity.

Oil and gas installations are not frequently installed or removed since the North Sea is a mature province for oil and gas exploration and production, and each site covers a relatively small area compared to windfarm sites. Platforms and wellheads are typically surrounded by a safety exclusion zone, which results in a loss of access to other marine users. Despite this, there is an ongoing navigational risk associated with these developments that results from the presence of vessels servicing these structures. It will be necessary for future dredging licence EIAs to report upon any expected changes to nearby oil and gas infrastructure that may occur simultaneously with dredging activities.

Whilst waste disposal sites have the potential to impact upon benthic and fish communities as a result of the dumping of materials and the consequential changes to seabed topography and sediment type, none of the waste disposal sites within the study area are actively used. Future EIAs will need to consider the implications of any future waste disposal at these sites or at other locations that may be planned, for example in relation to offshore windfarm construction.

11.7 Potential In-combination Impacts from Aggregate Dredging and Offshore Windfarms

Offshore windfarms have the potential to cause 11 of the 13 effects of dredging, with potential in-combination impacts upon all of the identified receptors, as shown in Table 11.6. Offshore windfarms are perhaps the most significant potential source of in-combination impact in the region, with other human activities including aggregate dredging.

Offshore Windfarm

Source Shutterstock.com

Table 11.6 In-combination Interactions between Dredging and Offshore Windfarms

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Presence of the vessel	■	■	■	■	●	●	●	■	■	■	■	■
Removal of sediment/changes to seabed topography	●	■	■	●	●	■	■	■	■	●	■	●
Fine sediment plume/elevated turbidity	●	■	●	●	●	●	●	■	■	●	■	■
Sand deposition	●	●	■	●	●	■	■	■	■	●	■	●
Changes to wave height	●	●	●	■	■	■	■	■	■	●	■	■
Changes to tidal currents	●	●	●	●	●	■	■	■	■	●	■	■
Changes to sediment transport rates	●	●	■	●	■	■	■	■	■	■	■	●
Underwater noise	■	■	■	■	●	●	■	●	■	■	■	■
Loss of access	■	■	■	■	■	■	■	■	●	●	●	■
Change to benthic community	■	■	■	●	●	●	●	■	●	■	■	■
Change to distribution of fish	■	■	■	■	●	●	●	●	●	■	■	■

■	No interaction
●	Potential interaction at a regional scale

The effects of offshore windfarms that are potentially shared with those of dredging, and which have the most potential to contribute to in-combination impacts, occur primarily during their construction phase.

Offshore windfarm construction involves a variety of large and small vessels, such as jack-up barges, cable laying vessels, and support or crew vessels. All of these will add to the shipping traffic in the area and produce underwater noise.

The construction of offshore windfarms commonly produces underwater noise from activities such as piling, seabed preparation and the installation of rock armour and scour protection.

Seabed preparations typically involve the movement of seabed sediments, which can change bathymetry and seabed topography, and cause sediment turbidity and sand deposition.

In relation to archaeological resources, although foundation impacts tend to be restricted horizontally they may be very deep, which is a concern for buried deposits of prehistoric interest in contrast to generally shallow aggregate dredging. However, vertical impacts from windfarms arising from turbine foundations have tended to be offset by carrying out detailed assessment, scientific dating and analysis of suitable recovered material. The impact of turbines offset by geoarchaeological investigation of deep sequences, together with geophysics-based results for marine aggregates that are extensive, is probably resulting in a positive in-combination impact on the prehistoric archaeological heritage through the research dividend being created for future management.

Offshore windfarms can also change the distribution of benthic, epibenthic, and pelagic species as the seabed character is changed through both the redistribution of sediments and the introduction of hard substrates such as rock armour, and through the overall footprint of structures on the seabed. The extent or significance of such changes will, however, depend on the particular sensitivity of the communities present at the site in question.

Operating windfarms are relatively recent introductions and the future planned level of development is considerable in comparison with other infrastructure in the MAREA study area. The locations of planned and operational windfarms and the numbers of turbines involved are presented in Section 6.3. Given that the total numbers of turbines are expected to exceed 700 across the region, and that construction activities are likely to occur over many years, it is reasonable to predict that these developments may provide a significant source of regional scale effects with potential to impact upon receptors in-combination with the future dredging scenario.

A number of cumulative assessments have been carried out for the projects that will be developed in the region, including for example the EIAs for the Humber Gateway Offshore Windfarm (HGOWF), the Westermost Rough offshore windfarm (WMROWF), the Lincs Offshore Windfarm and Docking Shoal Offshore Windfarm. An Appropriate Assessment was also undertaken of the Humber Gateway Offshore Windfarm by DECC in May 2009 (1). These include assessments of the likely in-combination effects resulting from the development of windfarms in the vicinity of several licensed and application dredging areas.

Although none were predicted to have any more than minor significance on receptors, a number of potential effects were identified. Sediment plumes are produced during windfarm construction. Depending on the distances between windfarm construction sites and dredging areas and the tide and current regime, sediment plumes from windfarms may combine with those from dredging, resulting in higher exposures for some organisms. The only significant impact identified however, was on reproducing female crustaceans in the vicinity of the Humber Gateway site. Loss of benthic habitat due to the permanent installation of turbines or to piling noise impacts was expected to add to the loss of similar habitats in dredged areas. Displacement of fish from these areas may then result in increased foraging distances for marine mammals. Marine mammals were also expected to experience some disturbance due to increased shipping traffic, in areas where both windfarm construction and maintenance vessels and aggregate dredging vessels coincide but they were considered likely to become accustomed to these increased levels.

Most of the assessments concluded that for the majority of potential effects relating to suspended sediment concentrations, any changes from baseline conditions were within the tolerance of natural year on year variations. The assessment for Docking Shoal concluded that it was possible that in-combination effects might be experienced by receptors such as marine mammals. While these effects would often be low level, localised and short term it is possible that their impacts on receptors might accumulate over time, becoming noticeable only in the long term and at a population level. However, such pressures are likely to be relatively far less significant than other existing threats, such as increasing fishing pressure and changes in climate.

Future EIAs by either the aggregates sector or the windfarm sector should examine the potential for site-specific in-combination impacts as more detail emerges on the likely activities (e.g. the precise locations of turbines, routes for cables, construction programmes, volumes and routes of construction shipping). As aggregate dredging is a relatively predictable activity that takes place within strict bounds, it may be deemed more pertinent for the onus of assessing effects at the site-specific level to fall upon the windfarm operator but with both parties consulting with each other on optimal mitigation measures where these might be required to address predicted significant in-combination impacts.

11.8 Potential In-combination Impacts from Aggregate Dredging and Military Activities

Military activities cause three of the same effects of dredging, with the potential to interact in-combination with dredging and impact upon five of the identified receptors, as shown in Table 11.7.

(1) Record of the Appropriate Assessment Undertaken Under Regulation 48 of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) for an Application Under: a) Section 36 of the Electricity Act 1989; and b) Section 5 of the Food and Environment

Table 11.7 In-combination Interactions between Dredging and Military Activities

Effect	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Presence of the vessel	■	■	■	■	•	•	•	■	■	■	■	■
Underwater noise	■	■	■	■	•	•	■	■	■	■	■	■
Loss of access	■	■	■	■	■	■	■	■	•	■	•	■

■	No interaction
•	Potential interaction at a regional scale

The main impacts from military activities that may act in-combination with dredging relate to a loss of access for other marine users and the implications of underwater noise for marine mammals and fish. Any combined loss of access would be temporary and localised, and on a small scale within a regional context.

Underwater noise sources from military activities and dredging are not directly comparable in acoustic terms and it is often difficult to obtain information regarding the precise timing and location of military activities due to security issues.

Both of these activities are currently ongoing, albeit with military activity more intermittent than dredging. The potential in-combination impacts do not require further assessment at the site-specific EIA stage.

11.9 Overview of Sources of In-Combination Impacts to Receptor Groups

Fish ecology, marine mammals, birds, and commercial fisheries are identified as being most susceptible to impacts from human activities in-combination with impacts from dredging. Benthic ecology and shipping are also affected by numerous human activities in the MAREA study area, as summarised in Table 11.8.

Table 11.8 Summary of In-combination Interactions with Receptor Groups

Human Activity	Seabed Features	Coast	Water Quality	Benthic Ecology	Fish Ecology	Marine Mammals	Birds	Designated Areas	Fisheries	Infrastructure	Shipping and Navigation	Archaeology
Commercial and recreational fishing	■	■	■	•	•	•	•	■	•	■	•	■
Shipping and sailing	■	■	■	■	•	•	•	■	•	■	•	■
Coastal developments	•	•	•	•	•	•	•	•	•	■	■	•
Offshore industry and infrastructure (excluding windfarms)	•	■	•	•	•	•	•	■	•	•	•	•
Offshore windfarms	•	•	•	•	•	•	•	•	•	•	•	•
Military activities	■	■	■	■	•	•	•	■	•	■	•	■

■	No interaction
•	Potential interaction at a regional scale

Impacts to ecological receptors should be assessed in future EIAs within a context of the other listed activities in the study area that cause the same effect. For example seabirds (e.g. gannets, auks, terns, or gulls) breeding at sites such as the North Norfolk Coast SPA could be affected by in-combination impacts from offshore windfarms and aggregate dredging. Future EIAs should consider any such potential, making use of studies produced by the offshore wind industry to ensure that a broad and current evidence base is referred to.

Impacts to shipping and navigation should also be given careful consideration as any such impacts may have implications for the vessel movements associated with other activities including fishing, commercial shipping, recreational sailing, offshore windfarms, gas platforms and ports.

In regard to archaeological resources, due to the different characteristics of impacts on the archaeological heritage arising from marine aggregates compared with other scheme types, and subject to the archaeological heritage being adequately assessed and appropriately mitigated across all scheme types, in-combination impacts in the study area are not anticipated to compromise the historic environment at a regional scale. Further discussion around this is provided in Appendix G.

11.10 Summary

This section has discussed the potential sources of in-combination impact from human activities in the MAREA study area, including aggregate dredging. The assessment has focused on those effects which are produced by aggregate dredging and therefore it should be noted that this chapter has not considered all sources of potential in-combination impact (for example the effects of fishing on marine mammals through by-catch).

The in-combination impacts which might be particularly relevant for specific licence areas are discussed in Chapter 12 of this document. Some broad conclusions are however provided below about the potential extent and nature of in-combination impacts in the MAREA study area.

- The MAREA study area is located within a zone off the east coast of England which is noted by the MMO to have ongoing high densities of human activity which are expected to continue and be added to by proposed offshore windfarm development. In terms of the potential in-combination effects found in this area it should be recognised that aggregate dredging makes a relatively small contribution to an overall anthropogenic effects that result from human activities such as commercial fishing, windfarm construction and commercial and recreational shipping.

- Activities such as fishing, along with aggregate dredging, are established and long standing activities in the region and these activities have been carried out together to date to the satisfaction of marine regulators. Infrastructure such as oil and gas platforms, wellheads and telecommunications cables are also essentially already installed in the region, and their presence is not likely to lead to significant in-combination effects with other regional human activities in the future.

- In contrast, the large number of windfarms that are either operational, under construction or proposed in this region is of potential significance from an in-combination impact perspective. This human activity is likely to attract particular scrutiny in terms of the impacts which may occur as a result of windfarms in addition to and in-combination with other human activity in the region including aggregate dredging. Issues of note relating to windfarm development in this region may include increased vessel traffic, underwater noise, footprint loss to turbine bases and general disturbance of the benthic environment. Particular scrutiny may be applied to the potential in-combination impacts which might result from multiple windfarm sites such as Triton Knoll, Race Bank and Docking Shoal which lie in a linear pattern through the centre of the MAREA study area.

12 MAREA SUMMARY - IMPLICATIONS FOR INDIVIDUAL LICENCE AREA EIAS

12.1 OVERVIEW

The following sections provide summary tables of the conclusions of the MAREA impact assessment for each receptor topic. The sections also discuss the proposed treatment of each effect in future EIAs for individual licence areas. EIAs would also be expected to refer to the conclusions of the MAREA in regard to the cumulative impact part of the EIA assessment. (1)

The following rationale has been applied in completing this section.

- If an effect has been identified as being not significant at the regional scale, it is likely, but not guaranteed, that this effect can be scoped out at the licence area specific scale. However, if the effect is linked to one licence area or a small number of areas or may occur in-combination with other development projects, it may be necessary to re-assess at the EIA scoping stage to establish whether assessment of this effect is required in the EIA.

- If an effect has been identified as being potentially significant (significance ranging from minor to major) at the regional scale, it is likely that it will also need to be considered at the EIA stage for each licence area. If the identified potentially significant regional effects are associated with one licence area, if a few licence areas dominate a regional impact assessment rating, or if the effects are amenable to mitigation, then they are highlighted within this chapter. Recommendations are then made where appropriate for individual licence areas to undertake assessment at the EIA stage.

This chapter aims to provide a useful prompt on likely relevant issues for each licence area. Since the chapter focuses mainly on issues that were deemed to be potentially significant at the *regional* level, however, the reader is advised to review all previous chapters to thoroughly understand the full range of topics applicable to any one licence area and not to rely on this chapter alone.

12.1.1 Impacts to Seabed Features

Table 1.1 summarises the significance of the cumulative impacts of dredging on seabed features (as defined in Chapter 4) as physical structures at the regional scale.

(1) Whilst recommendations are given for EIAs required for all Areas, it should be noted that Area 481/1, 481/2 and 480 have valid permissions well into the 2020s with modern EIA based permissions.

Table 12.1 Regional Significance of Impacts to Seabed Features from Dredging in the Humber and Outer Wash Area

Effect of Dredging	Seabed features as physical structures	
Removal of sediment	Minor significance	
Sand deposition	Not significant	
Changes to sediment particle size	Not significant	
Changes to wave height	Not significant - as no changes in sediment transport rate from the 10 in 1 year wave.	Extreme wave conditions - Minor significance
Changes to tidal currents	Not significant - as no changes in sediment transport rate from changes to tidal currents	

Regional impacts to seabed features from the effects of changes to wave heights and changes to sediment transport rates associated with dredging are predicted to be not significant at the regional scale. Impacts to the overfalls along the Lincolnshire coast should be considered in more detail at the EIA stage. The overfalls off the Lincolnshire coast overlap with Areas 197, 439 and 400.

EIAs for Areas 440 and 441/3 will need to consider impacts from sediment removal from seabed features on a site-specific basis given their location over Triton Knoll and another unnamed offshore bank respectively. EIAs for Areas 197, 400, 439 and 493 will need to consider impacts from sediment removal from seabed features and EIAs for Areas 197 and 493 will need to consider impacts from changes in wave height on seabed features.

12.1.2 Impacts to the Coastline

No impacts to the coastline require consideration at the EIA stage, as summarised below.

- Sand deposition has been assessed as having no potential interaction with the coastline as it predominantly occurs within the licence areas and may change bedforms up to 2.5 km from licence area boundaries. The licence areas, however, are all more than 10 km from the coast.

- Changes to sediment particle size due to dredging have been assessed as having no interaction with the coastline as changes may occur up to 4 km from the licence area boundary but the licence areas are all more than 10 km from the coast.

- The 10 in 1 year wave has been shown not to produce a measurable or permanent change in sediment mobility or seabed morphology across the MAREA study area and has not been considered further.

- Changes to sediment transport have been assessed as having no interaction with the coastline as changes in bed shear stress do not exceed the critical bed shear stress required to move larger sediment size fractions. In addition, regional sediment transport pathways do not move from the offshore region to the nearshore but instead the majority of sediment is transported along the coast from nearby sediment sources (such as cliffs).

- With regard to changes to seabed features, only changes to the overfalls along the Lincolnshire coast have been assessed as being significant. Impacts to these features could occur due to sediment removal, which would affect those overfalls within the licence areas, or through changes to wave height, which could affect those overfalls between the licences and the coast. However, wave height changes are not predicted to extend to, or affect, the coast even though there will be potential changes to the seabed features. Therefore no interaction between changes to seabed features and the coast is predicted. However, given the sensitivity of the coastline in this region this effect should be considered in more detail at the EIA stage for Areas 197 and 493.

- The supporting studies predict no changes to tidal currents at the coastline, even using maximum dredging tonnages and footprints, therefore further investigations into the potential impacts on coastal habitats or coastal defences are not required at the EIA stage.

12.1.3 Impacts to Water Quality

Table 12.2 summarises the significance of the cumulative impacts of dredging on water quality at the regional scale.

Table 12.2 Regional Significance of Impacts to Water Quality from Dredging in the Humber and Outer Wash Region

Effect of Dredging	Water Quality
Fine sediment plume/elevated turbidity	Not Significant
Changes to wave height	Not Significant
Changes to tidal currents	Not Significant

Impacts to water quality from dredging are predicted to be not significant. No action is required to study the potential impacts further at the licence specific EIA stage other than describing the normal good working practice that will be adopted and to report mitigation measures.

12.1.4 Impacts to Benthic Ecology

Biotopes

Table 12.3 and Table 12.4 summarise the significance of the cumulative impacts of dredging on biotopes at the regional scale.

Table 12.3 Summary of Impacts to Impacts to Biotopes (1 of 2)

Effect	Sensitive Receptors								
	SS.SCS.ICS.HeloMsim	SS.SCS.ICS.Glap	SS.SCS.ICS.SLan	SS.SCS.CCS.PomB	SS.SCS.CCS.MedLumVen	SS.SCS.CCS.Pkef	SS.SSa.IFiSa.IMoSa	SS.SSa.IFiSa.NcirBat	SS.SSa.iFiSa.TbAmPo
Removal of Sediment	Minor Significance	Minor Significance	Minor-Moderate Significance	Minor Significance	No Interaction	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Fine sediment plume/ elevated turbidity	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant	Not Significant
Sand deposition	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance
Changes to sediment particle size	Not Significant	Not Significant	Minor Significance	Minor Significance	Minor Significance	Not Significant	Not Significant	Not Significant	Minor-Moderate Significance
Changes to tidal currents	Not Significant	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Minor Significance	Not Significant
Changes to sediment transport rates	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features	No Interaction	Not Significant	No Interaction	Minor Significance	No Interaction	No Interaction	Not Significant	Minor Significance	Not Significant

Table 12.4 Summary of Impacts to Impacts to Biotopes (2of 2)

Receptor	Sensitive Receptor						
	SS.SSa.IMuSa.FfabMag	SS.SSa.CFiSa.ApriBatPo	SS.SSa.CMuSa.AalbNuc	SS.SBR.PoR.SspiMx	SS.SCS.CCS.Blan (SS.SCS.CCS Complex)	SS.SCS.CCS.Nrrix (SS.SCS.CCS Complex)	SS.SSa.IFiSa.ScupHyd (SS.SSa.IFiSa Complex)
Removal of sediment	Minor Significance	No Interaction	No Interaction	Moderate Significance	Not Significant	Not Significant	No Interaction
Fine sediment plume/ elevated turbidity	Not Significant	Not Significant	Not Significant	Not Significant	Minor Significance	Minor Significance	No Interaction
Sand deposition	Minor Significance	Not Significant	No Interaction	Minor Significance	Minor Significance	Minor Significance	No Interaction
Changes to sediment particle size	Minor Significance	Minor Significance	No Interaction	Not Significant	Minor Significance	Minor Significance	Minor Significance
Changes to tidal currents	Minor Significance	Moderate Significance	No Interaction	Not Significant	Not Significant	Not Significant	No Interaction
Changes to sediment transport rates	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction	No Interaction
Changes to seabed features	Minor Significance	Minor Significance	No Interaction	Not Significant	No Interaction	No Interaction	No Interaction

Each licence specific EIA will need to re-assess the existing data to determine which biotopes are likely to be present within the study area. Table 12.5 presents the interactions between dredging effects and biotopes within the MAREA study area that may need to be considered as part of the EIA for each licence area.

Table 12.5 Summary of Impacts to Biotopes

	Presence of vessel	Removal of Sediment	Fine sediment plume/ elevated turbidity	Sand deposition	Changes to sediment particle size	Changes to wave height	Changes to tidal currents	Changes to sediment transport rates	Underwater noise	Loss of access	Benthic community composition	Change to distribution of fish	Changes to seabed features
SS.SCS.ICS.HeloMsim	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.ICS.Glap	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.ICS.SLan	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.CCS.PomB	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.CCS.MedLumVen	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.CCS.Pkef	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.IFiSa.IMoSa	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.IFiSa.NcirBat	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.iFiSa.TbAmPo	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.IMuSa.FfabMag	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.CFiSa.ApriBatPo	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.CMuSa.AalbNuc	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SMu.CSaMu.AfilMysAnit	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SBR.PoR.SspiMx	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.CCS.Blan	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.CFiSa.EpusOborApri	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SCS.CCS.Nrrix	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓
SS.SSa.IFiSa.ScupHyd	×	✓	✓	✓	✓	×	✓	×	×	×	×	×	✓

Consideration required at the EIA stage	✓
Does not need to be considered	×

Protected Species and Habitats and Commercial Species

Table 12.6 summarises the significance of the cumulative impacts of aggregate dredging on protected species and habitats, and on commercial species, at the regional scale.

Table 12.6 Summary of Impacts to Protected Species and Habitats and Commercial Species

RECEPTOR	presence of the vessel	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to wave heights	changes to tidal currents	changes to sediment transport rates	underwater noise	loss of access	change to benthic community composition	change to distribution of fish	changes to seabed features
Protected Species and Habitats													
Ross worm (Sabellaria spinulosa) individuals and reef		Moderate/ Major significance	Not significant		Minor significance		Not significant	No Interaction					
Honeycomb worm (Sabellaria alveolata) and reef		Not significant	Not significant		Not significant		Not significant	No Interaction					
Blue mussel reef (Mytilus edulis)		No Interaction		Not significant	Not significant		No Interaction	No Interaction					
Horse mussel (Modiolus modiolus)		Minor significance		Minor significance	Not significant		Minor significance	No Interaction					
European edible sea urchin (Echinus esculentus)		Minor significance	Not Significant	Not significant	Minor significance		Not significant	No Interaction					
The amphipod Leptocheirus hirsutimanus		Not significant	Not Significant	Not significant	Not significant		Not significant	No Interaction					
Edwardsiidae		Minor significance	No Interaction	No Interaction	No Interaction		No Interaction	No Interaction					
Commercial Species													
European lobster		Minor significance		Minor significance				No Interaction					
Brown crab		Minor/ Moderate significance *		Minor significance				No Interaction					
Pink Shrimp and Brown Shrimp		Minor significance		Not significant / Minor significance	Minor significance			No Interaction					
Cockles		No Interaction		No Interaction	No Interaction			No Interaction					
Mussels		No Interaction		Not significant	Minor significance			No Interaction					
Whelks		No Interaction		No Interaction	No Interaction			No Interaction					
Velvet crab		No Interaction		No Interaction				No Interaction					

* The moderate significance rating is for berried female brown crabs

Table 12.7 presents the interactions between dredging effects and protected species and habitats that may be present within the licence area and which will need to be considered as part of the EIA for each licence area.

Table 12.7 Summary of Impacts to Protected Species and Habitats

	removal of sediment	fine sediment plume/ elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 441/1						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 441/2						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 441/3						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 400						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 439						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 440						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 481/2						
Ross worm (*Sabellaria spinulosa*)	✓	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 493						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 106/3						
Ross worm (*Sabellaria spinulosa*)	✓	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 480						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	✓	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 102						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	✓	×	×	✓	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 105						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×

	removal of sediment	fine sediment plume/ elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 107						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 448						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	✓	✓	×	×	✓	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 449						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 481/1						
Ross worm (*Sabellaria spinulosa*)	×	×	×	✓	✓	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×
Area 197						
Ross worm (*Sabellaria spinulosa*)	×	×	×	×	×	×
Honeycomb worm (*Sabellaria alveolata)*	×	×	×	×	×	×
Blue mussel reef (*Mytilus edulis*)	×	×	×	×	×	×
Horse mussel (*Modiolus modiolus*)	✓	×	✓	×	✓	×
European edible sea urchin (*Echinus esculentus*)	✓	✓	✓	✓	✓	×
The amphipod *Leptocheirus hirsutimanus*	×	×	×	×	×	×
Edwardsiidae	✓	×	×	×	×	×

Consideration required at the EIA stage	✓
Does not need to be considered	×

Table 12.8 presents the interactions between dredging effects and commercially important species that may be present within the licence area and which will need to be considered as part of the EIA for each licence area.

Table 12.8 Summary of Impacts to Commercially Important Species

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Area 441/1						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 441/2						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	×	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 441/3						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	×	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 400						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 439						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×

	removal of sediment	fine sediment plume/elevated turbidity	sand deposition	changes to sediment particle size	changes to tidal currents	changes to seabed features
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 440						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 481/2						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 493						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 106/3						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 480						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 102						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 105						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 107						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 448						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 449						
European lobster	×	×	×	×	×	×
Brown crab	×	×	×	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	×	×	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 481/1						
European lobster	×	×	✓	×	×	×
Brown crab	×	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×
Area 197						
European lobster	✓	×	✓	×	×	×
Brown crab	✓	×	✓	×	×	×
Pink shrimp and Brown shrimp	✓	×	✓	✓	×	×
Cockles	×	×	×	×	×	×
Mussels	×	×	✓	✓	×	×
Whelks	×	×	×	×	×	×
Velvet crab	×	×	×	×	×	×

12.1.5 Impacts to Fish Ecology

Table 12.9 summarises the significance of the cumulative impacts of dredging on fish ecology at a regional scale.

The impacts to fish ecology that are predicted to be significant are assessed as being minor - moderate and are likely to affect at most only a small proportion of the regional population of any one species at any one time.

The following points are noted regarding impacts that may require further consideration at the EIA stage.

- Impacts to herring: all licence areas except for 441/1, 441/2, 441/3 and 107 overlap with the potential herring spawning area, resulting in regional impacts of potentially minor significance for the effects of removal of sediment, fine sediment plume, sand deposition and changes to tidal currents. This issue may require discussion at the EIA stage for the other licence areas.
- Impacts to sole: all licence areas are located within documented sole spawning and nursery grounds and therefore may be associated with impacts to sole resulting from changes in benthic community composition.
- Impacts to thornback ray, lesser spotted dogfish and spotted ray: Thornback ray, lesser spotted dogfish and spotted ray may be impacted by removal of sediment and sand deposition to levels of minor significance. The future 15 year extraction zones of the following licence areas overlap with the spawning grounds of thornback ray: 481, 439, 493, 400, 197, 106, 107, 480 and 440. Lesser spotted dogfish and spotted ray are also known to spawn in a wide area throughout the North Sea and English Channel; therefore there could also be some overlap between spawning grounds and any of the future 15 year extraction zones.

Table 12.9 Summary of Impacts to Fish Ecology

Effect of Dredging	Salmon	Sea Trout	Allis Shad	Twaite shad	Eel	Sea Lamprey	River Lamprey	Smelt	Seahorse	Cod	Bass	Whiting	Sole	Haddock	Grey Gurnard	Gobiidae	Snake pipefish	Red mullet	Bib	Pogge	Dragonet	Plaice	Lemon sole	Dab	Brill	Sandeel (both genus)	Herring	Sprat	Mackerel	Atlantic horse mackerel	Smoothound	Spurdog	Starry Smoothound	Tope	Spotted Ray	Lesser spotted dogfish	Thornback ray
Presence of Vessel																																					
Removal of sediment										NS	NS		NS	NS	NS	NS		NS	NS	NS	NS	NS	NS	NS	NS	NS											
Fine sediment plume	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	NS		NS	NS	N S
Sand deposition										NS	NS		NS	NS		NS	NS	NS	NS			NS	NS	NS	NS	NS											
Changes to sediment particle size													NS									NS	NS	NS	NS	NS											
Changes to wave height																																					
Noise	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	NS
Changes to tidal currents																						NS														NS	NS
Changes to benthic community composition	NS				NS			NS	NS	NS	NS			NS	NS	NS		NS	NS	NS	NS	NS	NS	NS		NS	NS	NS			NS	NS	NS		NS	NS	NS
Changes to distribution of fish	NS	NS	NS	NS		NS	NS	NS		NS	NS	NS		NS	NS				NS						NS				NS	NS	NS	NS	NS		NS	NS	NS
Changes to seabed features													NS									NS	NS	NS	NS	NS											NS

NS	Not significant
	Minor significance
	No interaction
	Not affected

12.1.6 Impacts to Marine Mammals

Table 12.10 summarises the significance of the cumulative impacts of dredging on marine mammals at the regional scale.

Table 12.10 Regional Significance of Impacts to Marine Mammals from Dredging in the Humber and Outer Wash MAREA Study Area

Effect of Dredging	Harbour Porpoise	Seals
Presence of the vessel	Not significant	Not significant
Fine sediment plume/elevated turbidity	Not significant	Minor significance
Underwater noise	Minor significance	Minor significance
Change to benthic community composition		Not significant
Change to the distribution of fish	Not significant	Not significant
Changes to seabed features		Not significant

■ Not affected

The impacts to marine mammals from dredging are predicted to range from not significant to minor significance. As the species of concern commonly travel and forage alone or in small groups, impacts are not likely to affect large proportions of their regional populations at any one time.

Impacts to marine mammals will be discussed in all the individual EIAs in the context of 'deliberate disturbance' to European Protected Species and measures that may be taken to avoid this. The EIAs for all licence areas will also need to be responsive to any changes that may occur as the Marine Strategy Framework Directive is implemented in the UK with regard to underwater noise.

12.1.7 Impacts to Birds

Table 12.11 summarises the significance of cumulative effects of dredging on birds at a regional scale.

Impacts to birds will need to be revisited within the individual EIAs in light of any new data that may become available from other sources and studies, but the conclusions are unlikely to change. The significant impacts will be of particular relevance for EIAs for the following licence areas.

- Impacts to red-throated divers from vessel presence should be assessed at the individual licence level for the following future 15 year extraction zones: 448, 493, 197, 400, 106/3, 480, 439, 481/1, 481/2 and 107.

- Auks are vulnerable to impacts since during their moulting period they are unable to fly. The following future 15 year extraction zones overlap with auk distribution during moulting: 106/3, 440, 441/1, 480, 481/1, and 481/2.

Table12.11 Summary of Impacts to Birds

	Red-throated Diver	Northern Gannet	Kittiwake Summer	Kittiwake Winter	Gulls Summer	Gulls Winter	Terns	Auks Summer	Auks Winter
Presence of Vessel	Minor significance	Not Significant	Not significant	Not significant	Not significant	Not significant	Not significant	Minor significance	Not significant
Fine Sediment Plume	Minor significance	Not significant	Not significant	Not Significant	Not significant-Minor	Not significant	Not significant -Minor	Minor significance	Not significant-Minor
Changes to the Distribution of Fish	Not significant	Not significant			Not significant	Not significant	Not significant	Not significant	Not significant
Changes to Seabed features							Not significant	Not significant	Not significant

■ Not affected

12.1.8 Impacts to Protected Areas

A summary of the direct effects of the proposed future dredging across the study area to designated sites is presented in Table 12.12.

No direct effects to coastal designated sites are predicted. The majority of effects to rMCZs are predicted to be not significant. A number of effects to the Inner Dowsing and Race Bank SAC are predicted to be of minor or moderate significance, with removal of sediment potentially (ie before mitigation) resulting in an impact of major significance to reef qualifying features and moderate – major significance to sandbank qualifying features.

Table 12.12 Summary of Direct Effects to Designated Sites

RECEPTOR	Inner Dowsing and Race Bank SAC		The Wash and North Norfolk Coast SAC	NG 4 Wash Approach rMCZ	NG 5 - Lincs Belt rMCZ	NG 6 - Silver Pit rMCZ	NG 8 - Holderness Inshore	NG 9 - Holderness offshore
	Reef features	Sandbank features						
Presence of the Vessel								
Removal of Sediment	Major *	Moderate - Major *	No interaction	Minor	No interaction	No interaction	No interaction	No interaction
Fine sediment plume/Elevated turbidity	Minor	Minor	No effects	Not significant	Not significant	Not significant	No interaction	Not significant
Sand Deposition	Moderate	Minor	No interaction	Not significant	×	Not significant	No interaction	No interaction
Changes to sediment particle size	Minor	Not significant	No interaction	Not significant	×	Not significant	Not significant	Not significant
Changes to Wave heights	No Interaction	Not significant	No interaction	Not significant	Minor	No interaction	No interaction	
Changes to Tidal Currents	Minor	Not significant	No interaction	Not significant	Minor	No interaction	Not significant	
Underwater noise	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Loss Access								
Changes to Benthic Community composition	N/A	Minor	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Change to distribution of fish	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction	No interaction
Changes to seabed features								

* In reality the impacts will be addressed in licence conditions and be mitigated by survey, mapping their extent, and avoiding the features during dredging.

(black)	Not affected

Future extraction zones for Licence Areas 481/1, 481/2, 107 and 440 as well as Application Area 439 overlap with the boundary of the Inner Dowsing, Race Bank and North Ridge cSAC, and future extraction zones for Licence Areas 480 and 106/3 lie adjacent to it. As a result of the sensitivity of the qualifying interest features to the potential effects of dredging it is likely that a Habitats Regulations Assessment screening assessment will be required to be undertaken to inform licence applications in these Licence Renewals and Application Areas. In particular, the future extraction zones of Licence Area 107 and Application Area 439 overlap with areas of Annex 1 Habitat with the cSAC boundary.

Area 440 also has a very small area of overlap with the NG4 Wash Approaches rMCZ which will also need to be assessed further at the EIA stage.

Although they do not overlap with any designated sites, Application Area 493 and Licence Renewal Area 197 may result in changes to wave heights or tidal currents which have the potential to result in effects to the NG5 Lincs Belt rMCZ.

Seabirds which originate from breeding colonies within designated sites around the coastline of the MAREA study area forage widely across the study area and may interact with a number of licence areas. At the EIA stage all licence areas should undertake a review of the likely use of the licence area by seabird species arising from designated sites, which may involve an HRA Screening Assessment for birds originating from Flamborough Head and Bempton Cliffs SPA, and the North Norfolk Coast SPA. The maximum typical foraging range for little tern is 11 km so it is unlikely that licence areas other than Application Area 493 and Licence Renewal Area 197 are close enough to breeding colonies to affect this species.

Seals and harbour porpoise also forage widely across the MAREA study area and individual licence areas should contain an assessment of the likely effects on marine mammals. It is thought unlikely that any of the proposed dredging activity will result in direct impacts to the seal populations at the Wash and North Norfolk Coast SAC or Humber Estuary SAC and it is not predicted that HRA Screening assessments will be required in relation to these qualifying interest features for any licence areas.

12.1.9 Impacts to Commercial fisheries

Table 12.13 summarises the significance of cumulative effects of dredging on commercial and recreational fisheries at a regional scale.

Table 12.13 Summary of Impacts to Commercial Fisheries

	Mussel fishery	Brown shrimp fishery	Shellfish (crab and lobster) fishery	Recreational Fisheries
Sand Deposition	Not significant			
Loss of Access	Not significant	Not significant	Not significant	Not significant
Changes to the Benthic Community Composition	Not significant	Not significant	Not significant	
Changes to Distribution of Fish				Not significant

■ Not affected

All potential impacts were anticipated to be not significant at the regional scale. These findings were based on regional level consultation around the locations of certain fisheries. At the EIA stage, the following interactions between licence areas and certain fisheries may, however, require further investigation or corroboration to check that the information is up to date at the time that the EIA is delivered.

Brown shrimp fishery:

- Area 107 is located within a high intensity fishing ground.
- Areas 493, 197, 400, 439, 106/3, 480, 481/1, 481/2, 440, 441/1 all overlap with the moderate intensity fishing grounds.
- Areas 102,105, 449, 448 overlap with low intensity fishing grounds

Shellfish (crab and lobster) fishery:

- Areas 105, 106/3 overlap with >10m vessel moderate intensity summer fishing grounds.
- Area 107 overlaps with moderate intensity fishing grounds.

12.1.10 Impacts to Infrastructure

Table 12.14 summarises the significance of the cumulative impacts of dredging on infrastructure at a regional scale.

Table12.14 Regional Significance of Impacts to Infrastructure from Dredging in the Humber and Outer Wash

Effect of Dredging	Offshore Renewables Installations
Removal of sediment	
Sand deposition	Not significant
Changes to wave height	Not significant
Changes to tidal currents	Not significant
Loss of access	Not significant
Changes to seabed features	Not significant

■ Not affected

The only potential interactions with infrastructure identified were with offshore windfarms. Whilst no significant impacts were identified on a regional scale, it is recommended that licence and application areas that are very near or directly adjacent to offshore windfarm sites (i.e. Areas 102, 449, 448, 440, and 107) consult with the operators of those windfarms to address potential interactions in terms of access and safety, and to develop the necessary management measures as required.

As many of the offshore windfarm sites within the MAREA study area are in the early stages of planning, it is likely that additional data regarding details such as turbine locations, construction methods and schedules, and construction vessel traffic densities and routing will become available within the next 15 years. This MAREA provides future offshore windfarm developers with information on the likely significant cumulative effects of marine aggregate extraction which will in turn allow them to better assess the cumulative effects of their developments. It is important that licence-specific EIAs consult closely with windfarm developers in order that the assessments are based on the most current and detailed data available.

It is possible that further offshore infrastructure may enter planning within the timescale of the MAREA so licence-specific EIAs need to address the potential for additional developments and activities to occur, beyond those addressed in this MAREA. This may be achieved through consideration of new applications and through consultation with MMO in the context of the ongoing marine spatial planning process.

12.1.11 Impacts to Marine Recreation

Table 12.15 summarises the significance of the cumulative impacts of recreation activities and the impacts of dredging at a regional scale.

Table12.15 Regional Summary of Impacts to Recreational Activities

Effect of Dredging	Racing	Sailing	Cruising	Diving
Vessel Presence	Not significant	Not significant	Not significant	Not significant
Loss of Access	Not significant	Not significant	Not significant	

	Not affected

Impacts to recreation from dredging are predicted to be not significant. Therefore no action is required to study the potential impacts further at the licence specific EIA stage other than to present the specific mitigation measures to be adopted.

12.1.12 Impacts to Shipping and Navigation

Table 12.16 summarises the sensitivity rankings given to each Area which has been considered in this MAREA. Areas with the higher sensitivity rankings correspond to the more sensitive areas in navigational terms for future licence renewals and new licence applications. The results for these areas tend to be characterised by high shipping densities and an associated high ship-to-ship encounter and collision risk and in some cases, further risk associated with proximity to IMO Routeing measures or windfarm projects.

Table 12.17describes the future site-specific assessment work / updates that may be appropriate for sites ranked as 'very low', 'low', 'medium', 'high' or 'very high' to take them forward to the EIA stage.

All future EIAs, where required, for licences within the study area will need to consider the regional navigational risk study undertaken within this MAREA, applying more recent data if necessary. Future EIAs are not expected to identify potentially significant changes to in-combination navigational risk at the regional scale.

All licence areas except from 105 and 441/2 and 441/3 (i.e. those licence areas with an overall navigational sensitivity of medium, high, or very high) should carry validate the shipping data assessed in this MAREA and carry out site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA and the relevant port authorities). Site-specific mitigation measures should also be developed and described (see Section 13 of Appendix H).

Table 12.16 Average Navigational Sensitivity Factors per Dredge Area

Dredge Area	*Ship Density*	*Collision Risk*	*Navigational Feature*	*Fishing*	*Recreation*	*Overall Sensitivity*
102	High	High	High	Very Low	Low	Very High
105	Low	Low	Very Low	Very Low	Very Low	Low
106/1	Medium	Medium	Very Low	Very Low	Very Low	Medium
106/2	Very High	Very High	Very Low	Very Low	Very Low	Very High
106/3	Medium	High	Very Low	Very Low	Very Low	Medium
107	Medium	Medium	Very Low	Very Low	Low	Medium
197	Medium	Medium	Very Low	Very Low	Medium	Medium
440	Medium	Medium	Very Low	Very Low	Low	Medium
441/1	Very High	Very High	Very Low	Very Low	Very Low	Very High
441/2	Low	Low	Very Low	Very Low	Very Low	Low
480	Medium	High	Very Low	Low	Very Low	Medium
481/1	Medium	Medium	Very Low	Very Low	Very Low	Medium
481/2	Very High	Very High	Very Low	Very Low	Low	Very High
400	Medium	Medium	Very Low	Very Low	Very Low	Medium
439	Medium	Medium	Very Low	Very Low	Very Low	Medium
441/3	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
448	High	High	Medium	Low	Low	High
449	Very Low	Very Low	High	Very Low	Very Low	Medium
493	Medium	Medium	Very Low	Very Low	Medium	Medium

Table 12.17 Recommended Future Work based on Sensitivity Factors

Recommended Level of Work Required per Sensitivity Factor	Very Low	Low	Medium	High	Very High
Validation of shipping (densities and routeing) to demonstrate that the baseline data reflected within the MAREA are still current.	✓	✓	✓	✓	✓
Site-specific review of latest wind farm developments / proposals and potential effect on shipping routes passing through or near site.	✓	✓	✓	✓	✓
Site-specific assessment of the change in collision risk due to future dredging activity (subject to validation findings, above).	×	×	✓	✓	✓
Site-specific consultation with key navigation stakeholders for the region (to include Trinity House, MCA, Humber and Wash Ports).	×	×	✓	✓	✓

12.1.13 Impacts to Archaeology and Cultural Heritage

Table 12.18 summarises the significance of the cumulative impacts of dredging on archaeological and cultural heritage receptors at the regional scale.

Table12.18 Regional Summary of Impacts to Archaeological Receptors

	Removal of Sediment (including consideration of bathymetric change)	Sand deposition
Pleistocene fluvial gravels	Moderate *	Positive
Estuarine Alluvium	Minor/Moderate	Positive
Peat	Minor/Moderate	Positive
Isolated Prehistoric Finds	Moderate	Positive
Known Charted Wreck Sites	Moderate/Major	Positive
Shipping Casualties	Moderate/Major	Positive
Unknown Uncharted wreck Sites	Moderate/Major	Positive

	Removal of Sediment (including consideration of bathymetric change)	Sand deposition
Isolated Maritime Finds	Moderate	Positive
Known Charted Aircraft Losses	Minor/negligible	Positive
Recorded Aircraft Losses	Moderate/Major	Positive
Isolated Aircraft Finds	Moderate	Positive

* Note that for the receptor late Pleistocene glacio-fluvial gravels, if Palaeolithic artefacts and materials are present, the significance of impact will automatically be Major Negative due to the rarity of such archaeology.

The impacts to archaeology and cultural heritage from the removal of sediment as a result of dredging are predicted to be significant and range from minor to potentially major. The impacts from sand deposition are assessed as being positive for all receptors.

It should be noted that these impacts are assessed without the consideration of inherent mitigation measure that are undertaken by the dredging industry, such as pre-dredge surveys, avoidance behaviour and observing exclusion zones. These measures greatly reduce the likelihood of impacts to a number of archaeological receptors occurring.

The coincidence of individual Licence Areas and historic environment receptors has been summarised in Table 12.19. The actual presence of evidence within or in close proximity to Licence Areas has been noted; absence of evidence does not necessarily mean that the receptor is not present, not least because of the regional-scale of the datasets used and acknowledged biases in third-party records. Equally, the presence of receptor types such as isolated finds or unknown uncharted wrecks cannot by definition be known until they are encountered. The coincidence of licence areas and receptors is such that none of the licence areas can be regarded as 'clear' of interactions with any of the archaeological receptors that have been assessed.

In conducting EIAs for individual licence areas, it will continue to be necessary for historic environment data to be sought for the licence area and its immediate vicinity from the principal third-party records. Specifically, it will be necessary to check if any existing records have been altered or new records added as these third-party records are continually being updated. Further information on the approach to be taken to archaeology assessments at the EIA stage is provided in Appendix G.

Table 12.19 Summary of sensitivity of Individual Licence Areas and Future 15 Year Extraction Zones (F15EZ)

			Prehistoric Archaeology			Maritime Archaeology				Aviation Archaeology		
Licence Area	Associated Geophysical Zone	Geophysical Features	Late Pleistocene Glacio-fluvial	Estuarine Alluvium and Peat (Unit 3b)	Isolated Prehistoric Finds	Known Charted Wrecks◊	Shipping Casualties / Recorded Losses	Unknown Uncharted Wrecks	Isolated Maritime Finds	Known Charted Air Crash Sites◊	Recorded Aircraft Losses	Isolated Aircraft Finds
Significance of Impact (most significant impact)			Moderate Negative	Minor / Moderate Negative	Moderate Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate / Major Negative	Moderate Negative	Minor / Negligible Negative	Moderate / Major Negative	Moderate Negative
102	Northern	Y	Y	Y	N	Y	N	?	N	N	N	N
102 F15EZ	Northern		Y	Y	N	Y	N	?	N	N	N	N
105	Northern		Y	Y	N	Y	Y	?	N	N	N	N
105 F15EZ	Northern		Y	Y	N	Y	Y	?	N	N	N	N
448	-	-	-	-	N	Y	Y	?	N	N	N	N
449	-	-	-	-	N	N	N	?	N	N	N	N
106/1	Central	Y	N	N	N	N	N	?	N	N	N	N
106/2	Central		Y	N	N	N	N	?	N	N	N	N
106/3	Central		Y	Y	N	Y	N	?	Y	N	N	N
106/3 F15EZ	Central		Y	Y	N	Y	N	?	‡	N	N	N
197	Central		Y	Y	N	Y	N	?	N	N	N	N
197 F15EZ	Central		Y	Y	N	Y	N	?	N	N	N	N
400	Central		Y	Y	N	Y	N	?	N	N	N	N
480	Central		Y	Y	N	N	N	?	N	N	N	N
480 F15EZ	Central		Y	Y	N	N	N	?	N	N	N	N
493	Central		Y	Y	N	Y	N	?	N	N	N	N
440	-	-	-	-	N	Y	N	?	N	N	N	N
440 F15EZ	-	-	-	-	N	Y	N	?	N	N	N	N
441/1	-	-	-	-	N	Y	N	?	N	N	N	N
441/1 F15EZ	-	-	-	-	N	Y	N	?	N	N	N	N
441/2	-	-	-	-	N	N	N	?	N	N	N	N
441/2 F15EZ	-	-	-	-	N	N	N	?	N	N	N	N
441/3	-	-	-	-	N	Y	N	?	N	N	N	N
441/3 F15EZ	-	-	-	-	N	N	N	?	N	N	N	N
439	-	-	-	-	N	Y	Y	?	N	N	Y	N
481/1	Southern West	Y	-	-	N	N	N	?	N	N	N	N
481/2		-	-	-	N	N	N	?	N	N	N	N
107	-	-	-	-	Y	Y	N	?	Y	N	N	N
107 F15EZ	-	-	-	-	*	Y	N	?	*,**,†, ⌐, ≡	N	N	N

* Unidentified bone (CEMEX_0015); ** Wrought iron (CEMEX_0015); † Roman mortarium sherd (CEMEX_0301); ‡ Refractory brick (Hanson_0190); ⌐ Modern Leather Shoe Sole (CEMEX_0300); ≡ Ships timber from a carvel vessel (CEMEX_0294); Values denoted as '-' indicate data is not available for that area/receptor. N.B. No mitigation measures are considered here although ordinarily, where the position of receptors such as ship and aviation wrecks is known, they are avoided to prevent damage to dredging equipment and contamination of the aggregate. Equally aggregate dredgers will avoid known areas of alluvium and peat because they present a contamination risk.

12.1.14 In-combination Effects

In-combination effects were discussed in Chapter 11. This section briefly summarises the approach that may be appropriate to apply to EIA assessments for specific licence areas in regard to in-combination effects. Where in-combination effects are anticipated to be of particular relevance to certain licence areas, this is noted.

In-Combination Effects between Aggregate Dredging and Commercial Fishing

In-combination effects arising from commercial fishing activity and dredging may be relevant to each of the licence and application areas in the study area. While future EIAs may need to update area specific fishing activity they are, however, unlikely to identify a potentially significant change to in-combination impacts from the two industries.

In-Combination Effects between Aggregate Dredging and Commercial Shipping

The issue of vessel presence and navigational safety is of concern to all users of the MAREA study area. Given the heavy shipping traffic that occurs throughout the region from a range of industries, the impact of vessel presence on ecological receptors and the contribution of this to navigational risk are not unique to dredging and are not spatially limited to any part of the study area. All future EIAs for licences within the study area will need to consider the regional navigational risk study undertaken within this MAREA, applying more recent data if necessary. However, future EIAs are not expected to identify potentially significant changes to in-combination navigational risk at the regional scale.

In-Combination Effects between Aggregate Dredging and Coastal Developments

Any effects that arise from coastal developments are not likely to overlap spatially with those arising from aggregate dredging as the extraction activity in the MAREA study area does not occur in the vicinity of ports, harbours, or other coastal developments.

In-Combination Effects between Aggregate Dredging and Offshore Industry (Excluding Offshore Windfarms)

There are no known developments of substantial scale planned, other than offshore windfarms, so very few future interactions are predicted at a regional scale within the next 15 years. Given that the only existing telecommunications cables are to the north of the study area, future dredging licence EIAs will only need to consider in-combination impacts from these should additional routes be installed in their vicinity. It will be necessary for future dredging licence EIAs to report upon any expected changes to nearby oil and gas infrastructure that may occur simultaneously with dredging activities. Future EIAs will need to consider the implications of any future waste disposal at these sites or at other locations that may be planned, for example in relation to offshore windfarm construction.

In-Combination Effects between Aggregate Dredging and Windfarms

In-combination effects between offshore windfarms and dredging activities may be particularly relevant to consider in detail in the EIAs for Area 440 due to its proximity to the Triton Knoll windfarm site, Areas 102 and 448 due to their proximity to the Humber Gateway windfarm site, and to Area 107 due to its proximity to the Docking Shoal windfarm site.

In-Combination Effects to Specific Receptors

Impacts to ecological receptors should be assessed in future EIAs within a context of the other listed activities in the study area that cause the same effect. For example seabirds (eg gannets, auks, terns or gulls) breeding at sites such as the North Norfolk Coast SPA could be affected by in-combination impacts from offshore windfarms and aggregate dredging. Future EIAs should consider any such potential, making use of studies produced by the offshore wind industry to ensure that a broad and current evidence base is referred to.

Impacts to shipping and navigation should also be given careful consideration as any such impacts may have implications for the vessel movements associated with other activities including fishing, commercial shipping, recreational sailing, offshore windfarms, gas platforms and ports.

In-combination impacts to archaeological resources are not likely to be significant and therefore is not anticipated to warrant specific consideration at the EIA stage.

12.2 Regional Monitoring

It is recommended that the HADA companies continue to work together to develop a regional approach to managing dredging activity as licence renewals are forthcoming in the coming years. This includes regional monitoring where possible that is beneficial to both operators and industry regulators. At the time of writing, the industry has already begun dialogue with The Crown Estate and MMO 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 MAREAs and other studies.
- Work together with all the other companies in the region on 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 its advisors on a regional basis.
- Be transparent through 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.
- Work with the Crown Estate to deliver plans.

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REFERENCES

A

Able UK, 2011. *Able Humber Port* [online] Available at: <http://www.ablehumberport.com/> [Accessed 25 July 2011].

ABPmer, Met Office and POL, 2008. Atlas of UK Marine Renewable Energy Resources: Atlas Pages. *A Strategic Environmental Assessment Report, March 2008*. Produced for BERR. Report and associated GIS layers [online] Available at:: http://www.renewables-atlas.info/ [Accessed 01 August 2011].

ABPmer, 2011. Humber MAREA - *Physical Processes Study: Assessment of Sediment Plumes*. ERM Ltd and Humber Aggregate Dredging Association (HADA). Report no. 1841.

Agnalt, A-L. 2008. Fecundity of the European lobster (*Homarus gammarus*) off southwestern Norway after stock enhancement; do cultured females produce as many eggs as wild females? ICES Journal of Marine Science, 65: 164–170.

ALSF, 2010. Improving Sustainability Indicators for Marine Aggregate Dredging Final Report MEPF Ref No: MEP F 09/P95.

ALSF, 2010. Reduction of environmental impacts of dredger operations MEPF Ref No: MEPF 09/P133.

Anatec Ltd, 2011. Navigation Impacts Review, Humber and Outer Wash Dredging Areas (Technical Note).

Aquamaps, 2011. *Aquamaps* [online] Available at <http://www.aquamaps.org>. [Accessed on 1 July 2011]

Associated British Ports (ABP), 2011. *Associated British Ports*. [online] Available at: http://www.abports.co.uk/index.htm [Accessed 25/07/11].

B

Balson, P.A., Tragheim, D.G. and Newsham, R., (1998) *Determination and prediction of sediment yields from recession of the Holderness coast, Eastern England. Proceedings of the 33rd MAFF Conference of River and Coastal Engineers*, July 1998.

Bannister, C., 2006. *Towards a National Development Strategy for Shellfish in England. Executive Report. Prepared for the Sea Fish Industry Authority. Funded by FIFG Projects*; 05/ENG/44/30 & 05/ENG/44/03.

Becker, G.A., 1990. *Die Nordsee als physikalisches System. in: Lozan*, J.L., Lenz, W., Rachor, E., Waterman, B. and Westerhagen, H (eds). Warnsignale aus der Nordseewissenschafteliche Fakten. Paul, Parey, Berlin and Hamburg. 428 pp.

BERR, 2007. *Aerial Surveys of Waterbirds in Strategic Wind Farm Areas: 2005/06 Final Report*.

Betts, C.J., 2001. *Checklist of protected British species*. Second Edition. Christopher Betts Environmental Biology, Worcester. 54 pp.

BGS, 1998. *Inshore seabed characterisation of selected sectors of the English coast: summary report*: British Geological Survey, Marine Geology Series, Technical Report WB/98/046.

BGS, 1992. *Marine sand and gravel resources of the Humber, British Geographical Survey*. Technical report WB/92/1.

BGS, 2010. The South Coast Regional Environmental Characterisation. A report prepared by British Geological Survey, Cefas, MES, Wessex Archaeology and Sussex Sea Fisheries District Committee for the Marine Aggregate Levy Sustainability Fund (MALSF). Ref: MEPF 08/02.

Biodiversity Reporting and Information Group (BRIG) Ed: Maddock, A., 2008a. JNCC UK *Biodiversity Action Plan - Priority Habitat Descriptions*. (updated 2010).

Biodiversity Reporting and Information Group (BRIG) Ed: Maddock, A., 2008b. JNCC: *North Norfolk Sandbanks and Saturn Reef SAC Selection Assessment*: Version 4.0, (2008).

Bird Life International, 2004. *Birds in Europe: population estimates, trends and conservation status*. Available at: <http://www.birdlife.org/community/2011/01/birds-in-europe-population-estimates-trends-and-conservation-status/> [Accessed 12 December 2011].

Birdlife International Seabird Wikispace, 2011. Available at: http://seabird.wikispaces.com/> [Accessed 22 December 2011]

Bird Life International, 2011a. *Welcome to the BirdLife Seabird Wikispace*. [online] Available at: <http://seabird.wikispaces.com/> [Accessed 12 December 2011].

Bird Life International, 2011b. *Black-legged Kittiwake*. [online] Available at: <http://seabird.wikispaces.com/Black-legged+Kittiwake> [Accessed 12 December 2011].

Bird Life International,2011c. *Alcidae*. [online] Available at <http://seabird.wikispaces.com/Alcidae> [Accessed 12 December 2011].

Blanchard J.L., Heffernan O. A. and Fox C. J., 2005. *North Sea Cod (ICES Divs. IVa-c and VIId)*. In: ICES. 2005. Spawning and life history information for North Atlantic cod stocks. ICES Cooperative Research Report, No. 274.

Blue Flag, 2011. *Blue Flag Awarded Beaches in England*. [online] Available at: <http://www.blueflag.org/Menu/Awarded+sites/2011/Northern+Hemisphere/England/List/Beaches > [Accessed 30 August 2011].

BMAPA, 2010a. *Strength from the depths*. Fourth sustainable development report for the British marine aggregate industry.

BMAPA, 2010b. *Marine Aggregate Terminology: A Glossary*. BMAPA, London, 49pp.

Boddeke, R., 1996. *Changes in the Brown Shrimp (Crangon crangon .) population off the Dutch coast in relation to fisheries and phosphate discharge*. ICES Journal of Marine Science, 53: 995 - 1002.

Boolootian, R.A. (ed.), 1966. *Physiology of Echinodermata*. New York: John Wiley & Sons.

Borja, A., 2005. *The European Water Framework Directive: A challenge for nearshore, coastal and continental shelf research*. Continental Shelf Research 25 pp 1768-1783.

Borja, A., Elliott, M., Carstensen, J., Heiskanen, A-S. and van de Bund, W., 2010 *Marine management - towards an integrated implementation of the European Marine Strategy Framework and the Water Framework Directives. Marine Pollution Bulletin* 60 pp 2175-2186.

Bournemouth University, 2007, Enhancing our understanding of the marine historic environment: Navigational Hazards Project, unpublished report.

Bowen, W. D., and Harrison, G. D., 1994. *Offshore diet of grey seals (Halichoerus grypus) near Sable Island, Canada*. Marine Ecology Progress Series, Vol. 112: 1-11.

Boyd, S. E., Limpenny, D. S., Rees, H. L., Cooper, K. M. and Campbell, S. 2003. *Preliminary observations of the effects of dredging intensity on the* *recolonization of dredged sediments off the southeast coast of England* (Area 222). Estuarine, Coastal and Shelf Science, 57: 209-223.

Boyd, S. E., Limpenny, D. S., Rees, H. L., Cooper, K. M. and Campbell, S. 2003. *Preliminary observations of the effects of dredging intensity on the recolonization of dredged sediments off the southeast coast of England* (Area 222). Estuarine, Coastal and Shelf Science, 57: 209-223.

Boyes, S. and Elliott, M. 2006. *Organic matter and nutrient inputs to the Humber Estuary, England. Marine Pollution Bulletin*. 53: 136 – 143.
Braber, L., and Groot, S.J. de. 1973. *The food of five flatfish species (Pleuronectiformes) in the southern North Sea*. [Online] Netherlands Journal of Sea Research 6(1-2): 163-172. Referenced in: ICES FishMap. Sole Fact Sheet. Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf [accessed 26 May 2011].

Bratton, J.H., 1991. British Red Data Books: 3. *Invertebrates other than insects*. Joint Nature Conservation Committee, Peterborough.

Brigham, T., Buglass J. and George, R., 2008, Rapid Coastal Zone Assessment: Yorkshire and Lincolnshire, Humber Field Archaeology Report 235.

British Sub Aqua Club, 2011. [online] Available at <http://www.bsac.com> [Accessed 26 May 2011].

Brown, J. Hill, A.E. Fernand, L. and Horsburge, K.J., 1999. *Observations of a seasonal jet-like circulation at the central North Sea cold pool margin, Estuarine and Coastal Shelf Science*. 48: 343-355.

Buglass, J. and Brigham, T., 2008, Rapid Coastal Zone *Assessment Survey. North Yorkshire. Donna Nook to Gibraltar Point, English Heritage Project Number 3729*. Humber Field Archaeology Report No. 236.

Bull J., Wanless S., Elston D. A., Daunt, F., Lewis, S. and Harris, M.P. 2004. *Local-scale variability in the diet of Black-legged Kittiwakes Rissa tridactyla. Ardea 92*(1): 43-52.

C

Canadian Environmental Quality Guidelines, 2001. *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment*. Technical Guidance for Assessment and Mitigation of the Hydroacoustic Effects of Pile Driving on Fish, ICF Jones and Stokes for the California Department of Transportation, February 2009.

Camphuysen KCJ, 201. Northern Gannets in the North Sea: foraging distribution and feeding techniques around the Bass Rock. *British Birds 104*. February 2011.

CEDA ,2011. *Underwater Sound in Relation to Dredging. CEDA position paper*. [Online] Available at: http://www.dredging.org/documents/ceda/downloads/2011-11_ceda_positionpaper_underwatersound_v2.pdf> [Accessed July 2011]

Cefas, 2001a. *North Sea Fish and Fisheries*. [online] available at <http://www.cefas.defra.gov.uk/media/20461/tr_003.pdf> [Accessed August 2011] ch6.3

Cefas, 2001b. *Technical report produced for Strategic Environmental Assessment – SEA2*: North Sea Fish and Fisheries.

Cefas and Fisheries Research Services, 2001c. *North Sea Fish and Fisheries*. Strategic Environmental Assessment of parts of the central and southern North Sea 2 – SEA2 dti.

Cefas, 2000. *Monitoring and surveillance of non-radioactive contaminants in the aquatic environment and activities regulating the disposal of wastes at sea*. Aquatic Environment Monitoring Report No. 52.

Cefas and Fisheries Research Services. 2001, North Sea Fish and Fisheries. Strategic Environmental Assessment of parts of the central and southern North Sea 2 – SEA2 dti.

Cefas and Fisheries Research Services. 2002, *North Sea Fish and Fisheries. Strategic Environmental Assessment of parts of the central and southern North Sea 3* – SEA3 dti.

Cefas, 2007. *Bass in the North Sea* (ICES Division IVb and c) [Online] Available at <http://www.cefas.co.uk/media/34068/bassnorthsea.pdf> [Accessed 15 April 2009].

Cefas, 2008. *Herring in the North Sea* (ICES Division IV, VIId and IIIa) - 2008. Available a: <http://www.cefas.co.uk/media/31684/herringnorthsea.pdf> [Accessed 25 May 2011].

Cefas. 2011. *The East Coast Regional Environmental Characterisation*. A report prepared by Cefas, BGS, Wessex Archaeology, MES and Envision for the Marine Aggregate Levy Sustainability Fund (MALSF). Ref: MEPF 08/04.

Cefas, 2011. Cefas Centre for Environment, Fisheries & Aquaculture Science [Online] Available at: www.cefas.defra.gov.uk [Accessed 24 May 2011].

Cefas iSEA. *iSEA - interactive Spatial Explorer and Administrator*. [Online] Available at: <http://webarchive.nationalarchives.gov.uk/20060218065600/cefas.co.uk/data/isea---interactive-spatial-explorer-and-administrator.aspx>[Accessed 26 June 2011]

Centric, 2006. *Options for Energy buyers Bloomberg Offices* [Online] <http://www.ofgem.gov.uk/MARKETS/WHLMKTS/CUSTANDINDUSTRY/ENERGYBUYERS/Documents1/16097-Centrica%20Storage%20Presentation.pdf> [Accessed 20 July 2011].

Centrica, 2008. *Docking Shoal Offshore Wind Farm, Environmental Statement. Volume I: Offshore Works*.Regional Environmental Assessment: A Framework for the Marine Minerals Sector. CEFAS, JNCC, Natural England, English Heritage. March 2008.

Clarke, K.R. and Gorley, R.N., 2006. Primer v6*: User Manual/Tutorial. PRIMER-E*, Plymouth.

Clarke, K.R. & Warwick, R.M., 2001. *Change in Marine Communities: an approach to statistical analysis and interpretation*, 2nd edition. PRIMER-E, Plymouth.

Coastal Observatory, 2011. [Online] *General Information on Recreational Angling* . [Online] Available at <http://www.hull.ac.uk/coastalobs/general/recreation/angling.html#Anchor-Sea-15354> [Accessed 15 July 2011]

Collins, M.B. Shimwell, S.J. Gao, S. Powell, H. Hewitson, C. and Taylor J.A., 1995. *Water and sediment movement in the vicinity of sandbanks: the Norfolk Banks, southern North Sea*, Marine Geology. 123: 125-124.

Comely, C.A. & Ansell, A.D. 1988. *Invertebrate associates of the sea urchin Echinus esculentus L. from the Scottish west coast*. Ophelia, 28, 111-137.

Comely, C.A., 1978. *Modiolus modiolus (L.) from the Scottish West coast*. I. Biology. Ophelia, 17, 167-193.

Compagno, L.J.V., 1984 FAO species catalogue. Vol. 4. Sharks of the world. *An annotated and illustrated catalogue of shark species known to date*. Part 2 - Carcharhiniformes. FAO Fish. Synop. 125(4/2):251-655.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O., Reker, J.B., 2004. *The Marine Habitat Classification for Britain and Ireland*. Version 04.05 JNCC, Peterborough [Online] Available at: <www.jncc.gov.uk/MarineHabitatClassification>. [Accessed at 1 August 2011].

Connor, D.W., Breen, J., Champion, A., Gilliland, P.M., Huggett, D., Johnston, C., Laffoley, D. d'A., Lieberknecht, L., Lumb, C., Ramsay, K., and Shardlow, M., 2002. *Rationale and criteria for the identification of nationally important marine nature conservation agencies and wildlife and countryside link) for the Defra working group on the review of marine nature conservation*.

Connor, D.W., Dalkin, M.J., Hill, T.O., Holt, R.H.F., & Sanderson, W.G., 1997. *Marine Nature Conservation Review: marine biotope classification for Britain and Ireland*. Volume 2. Sublittoral biotopes. Version 97.06. JNCC Report, No. 230.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B., 2004. *The Marine Habitat Classification for Britain and Ireland Version 04.05 JNC*C, Peterborough. ISBN 1 861 07561 8 (internet version). http://www.jncc.defra.gov.uk/MarineHabitatClassification (

Cook, A. S. C. P. and Burton, N. H. K., 2010. *A review of the potential impacts of marine aggregate extraction on seabirds*, MALSF MEPF 09/P130

Cooper, W.S. Townsend, I.H. & Balson, P.S., 2008. *A synthesis of current knowledge on the genesis of the Great Yarmouth and Norfolk Bank Systems. The Crown Estate*. 69 pp. ISBN: 978.

Cork Ecology, 2004. *Review of red-throated diver prey species in the Thames Estuary*.

Corten, A., 1986. *Shifts in herring spawning areas in the north western North Sea in relation to environmental changes*. ICES CM CM 1988/H:22, 7pp

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

Covey, R., 1998. *Chapter 6 Eastern England* (Bridlington to Folkestone) (MNCR Sector 6). In: Marine Nature

The Crown Estate, BMAPA and English Heritage, 2005, *Protocol for Reporting Finds of Archaeological Interest*.

Cranmer, G. J. 1986. T*he food of haddock (Melanogrammus aeglefinus) in the North Sea*. ICES CM 1986/G: 86 5pp.

D

N Da, K. and Deniel, C. 1993. Sexual cycle and seasonal changes in the ovary of the red mullet, Mullus surmuletus, from the southern coast of Brittany, 43 (2) 229-244. Cited in ICES., 2008. *Striped red mullet factsheet*. [Online] Available at <http://www.ices.dk/marineworld/fishmap/ices/pdf/redmullet.pdf > [Accessed 23 May 2011].

Daan N (ed), 1989. *Data base report of the stomach sampling project 1981*. Cooperative Research Report 164.

Davies, J., Baxter, J. Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W.G., Turnbull, C., & Vincent, M. (Eds.)., 2001. *Marine Monitoring Handbook* March 2001. Peterborough, Joint Nature Conservation Committee. 405pp.

Davies, C.E., Shelley, J., Harding, P. T., McLean, I. F. G., Gardiner, R. and Peirson, G. eds., 2004. *Freshwater fishes in Britain - the species and their distribution.* Harley Books, Colchester [Online]. Data cited as part of the NBN Gateway http://data.nbn.org.uk [Accessed 24 May 2011].

Defra, 2006. *Flood and coastal defence appraisal guidance FCDPAG3 economic appraisa*l. Supplementary note to operating authorities - climate change impacts.

Defra, et al., 2009. *Accessing and developing the required biophysical datasets and data layers for Marine Protected Areas network planning and wider marine spatial planning purposes* [Online] Available at <http://randd.defra.gov.uk/Document.aspx?Document=MB0102_9721_TRP.pdf>. [Accessed 01 July 2011]

Defra 2011b. Marine Conservation Zones: Update. *Written Ministerial Statement* (WMS 113). 15th November 2011.

Dehnhardt, G., and Kaminski, A., 1995. *Sensitivity of the mystacial vibrissae of harbour seals (Phoca vitulina) for size differences of actively touched objects*. The Journal of Experimental Biology, 198, 2317-2323.

Department of Energy and Climate Change, 2011. *Oil and Gas Portal*, [Online] Available at: <https://www.og.decc.gov.uk/> [Accessed 25 July 2011].

Department of Energy and Climate Change, 2011a. *Index on Statical Tables* Available at <http://www.decc.gov.uk/assets/decc/Statistics/climate_change/1514-ghg-emissions-provisional-2010.xls> Accessed 24/11/2011.

Department of Trade and Industry. 2001. Report to the Department of Trade and Industry. *Strategic Environmental Assessment of the Mature Areas of the Offshore North Sea*. SEA 2.

DTI, 2006. *Aerial Surveys of Waterbirds in Strategic Wind Farm Areas: 2004/05* Final Report.

Dyer, K. and Huntley D., 1999. *The origin, classification and modelling of sand banks and ridges*. Continental Shelf Research, Volume 19, Issue 10, Pages 1285-1330.

E

Earth Snapshot. *Sediments near English Channel*. [Online] Available at: < www.eosnap.com/?p=7153> [Accessed 2 February 2010].

East Channel Association. 2002. *Regional Environmental Assessment*. Prepared by Posford Haskoning on behalf of ECA.

Eaton, M.A., Brown, A.F., Noble, D.G., Musgrove, A.J., Hearn, R.D., Aebischer, N.J., Gibbons, D.W., Evans, A. & Gregory, R.D., 2009. *Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and Isle of Man. British Birds* 102: 296-341.

Eaton, D.R, Brown, J. Addison, J. Milligan, S. Fernand, L. 2003. *Edible crab (Cancer pagurus) larvae surveys off the east coast of England: implications for stock structure*. Fisheries Research. 65: 191 - 199.

Edwards, R., Cefas. 2012. Pers. Comm.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. 2012. *Spawning and nursery grounds of selected fish species in UK waters*. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56 pp.

Ellis, J.R, Milligan, S.P, Readdy, L, Taylor, N, and Brown, M.J., 2010a. *Spawning and nursery grounds of selected fish species in UK waters*. Sci. Ser. Tech. Rep. Cefas Lowestoft, 147:56pp.

Ellis, J, Milligan, S, Readdy, L. South, A. Taylor, N. Brown, M.,2010. *Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones)*. Cefas.

EMU, 2009b. *Sediment Tracer Study in the Eastern English Channel. Report for East Channel Association*. June 2009. Report 09/J/1/12/1258/0866.

EMU, 2011. *Area 473 East - Comparative Study: Final Report. Report for East Channel Association. March 2011*. Report 11/J/1/03/1553/0998.

Emu and University of Southampton. 2009. *Outer Thames Estuary Regional Environmental Characterisation*. A report by Emu Ltd and University of Southampton for the Marine Aggregate Levy Sustainability Fund (MALSF). Ref: MEPF 08/01.

Engås A, and Lokkeborg S., 2002. Effects of seismic shooting and vessel-generated noise on fish behaviour and catch rates, Bioacoustics 12, 313-315.

English Heritage. 2002. *Military Aircraft Sites: Archaeological guidance on their significance and future management*, English Heritage [Online] Available at : <www.english-heritage.org.uk/upload/pdf/Mil_Air_C_Sites.pdf> Accessed 3 August 2011].

English Nature and Environment Agency, 2003. *North Norfolk Coastal Habitat Management Plan*.

English Nature, 2003. *The Humber Estuary European Marine Site. English Nature's advice given under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994*. Interim Advice.

Eno, N.C., Clark, R.A. & Sanderson, W.G., 1997. *Non-native marine species in British waters: a review and directory. Joint Nature Conservation Committee*, 152 pp.

Environment Agency, 2011. [online] Available at: <http://www.environment-agency.gov.uk/news/108218.aspx> [Accessed 16 September 2011].

EON., 2008. *Humber Gateway Offshore Wind Farm Environmental Statement*. Prepared by Environmental Resources Management Ltd.
Emu Ltd., 2009a *Outer Thames Estuary Regional Environmental Characterisation*. On behalf of the Marine Aggregate Levy Sustainability Fund (MALSF).

ERM 2011, *Whitehill Gas Storage Project: Offshore Works Environmental Statement 2011*.[online] Available at < http://www.eon-uk.com/downloads/Offshore_Environmental_Statement_Jan_2011.pdf> [Accessed 8 August 2011]

ERM. 2010. *Marine Aggregate Regional Environmental Assessment of the Outer Thames Estuary. A report prepared by ERM for the Thames Estuary Dredging Association*.

ESFJC, 2007. Eastern Sea Fisheries Committee Annual Report 2007. 88pp.

Evans, P. G. H., Anderwald, P., and Baines, M., 2003. *UK Cetacean Status Review*. SeaWatch Foundation. Report to English Nature and Countryside Council for Wales.
Evans P G H, 1995. *Guide to the Identification of Whales, Dolphins and Porpoises in European Seas. Sea Watch Foundation*, Oxford.

Evans, P.G.H. & Raga, J. A. (ed.), Evans, P. G. H., and Raga, J. A., 2001. *Marine mammals: biology and conservation New York: Kluwer Academic / Plenum Publishers* .

F

FAO, 2007. FISHSTAT Plus - *Universal software for fishery statistical time series*. Food and Agriculture Organization of the United Nations [Online]. Available at: http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp [Accessed at 10 April 2011].

FAO, 2012a. *Crangon crangon* Fact Sheet. [Online] Available from: http://www.fao.org/fishery/species/3435/en [Accessed: 30th March 2012]

FAO, 2012b. *Pandalus borealis* Factsheet. [Online] Available from: http://www.fao.org/fishery/species/3425/en. [Accessed: 30th March 2012].

FishBase, 2010. [online] Available at: <www.fishbase.org> [Accessed 15 July 2011]

Fish Base, 2011a. Available at: <www.fishbase.org> [Accessed 4 January July 2011]

Fish base, 2011b. *Mullus barbatus barbatus Linnaeus, 1758 Red mullet* [Online] Available at: <http://www.fishbase.org/summary/Mullus-barbatus+barbatus.html> [Accessed 8 April 2011]

FishBase 2011c. *Lemon Sole (Microstomus kitt)*. [Online] Available at <http://www.fishbase.org/Summary/SpeciesSummary.php?ID=1382> [Accessed 26 May 2011].

Fish Base, 2011d. Dab (*Limanda limanda*). [Online] Available at < http://www.fishbase.org/Summary/speciesSummary.php?id=695> [Accessed 31 May 2011].

Flemming, N.C., 2006, *Area SEA6 with regard to Prehistoric and Early Historic Archaeological Remain*', [Online] Available at <http://www.offshore-sea.org.uk/site/scripts/consultation_download_info.php?downloadID=135> [Accessed 8 August 2011].

Food and Agriculture Organization of the United Nations FAO, 2009. *Dicentrachus labrax.* Species Fact Sheets. Fisheries and Aquaculture Department [Online] Available at <http://www.fao.org/fishery/species/2291> [Accessed 16 August 2011].

Fox, C., Taylor, M., Dickey-Collas, M, van Damme, C.J.G., Bolle, L., Daan, N., Rohlf, N., Kraus, G., Munk, P. Fossum, P., & Bailey, N., 2005. *Initial results from the 2004 ichthyoplankton survey of the North Sea*. ICES CM 2005/AA:04.

Franklin, A. & Jones, J., 1995. *Monitoring and Surveillance of Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1993*. Aquatic Environment Monitoring Report, MAFF Directorate of Fisheries Research, Lowestoft (44), 68 pp.

Franklin, A., 1972. *The cockle and its fisheries*. 37. The Ministry of Agriculture, Fisheries and Food. In: Tappin, D R, Pearce, B, Fitch, S, Dove, D, Geary, B, Hill, J M, Chambers, C, Bates, R, Pinnion, J, Diaz Doce, D, Green, M, Gallyot, J, Georgiou, L, Brutto, D, Marzialetti, S, Hopla, E, Ramsay, E, and Fielding, H. 2011. The Humber Regional Environmental Characterisation. British Geological Survey Open Report OR/10/54. 357pp.

Frid, C.L.J, Harwood, K.G., Hall, S.J and Hall J.A., 2000. *Long term changes in the benthic communities on North Sea fishing grounds*. ICES Journal of Marine Sciences, 57: 1303-130.

G

Gaffney, V., Fitch, S. and Smith, D., 2009, Europe's Lost World: *The rediscovery of Doggerland, York: Council for British Archaeology*. CBA Research Report 160.

Galbraith, R. D., and Rice, 2004. A. *An Introduction to Commercial Fishing Gear and Methods Used in Scotland*, FRS Marine Laboratory, Aberdeen. Scottish Fisheries Information Pamphlet, No. 25, 44 pp.

Gauci, G.M., 2010. *The U.K. Marine and Coastal Access Bill - A missed opportunity to enhance protection from marine environmental pollution?* Marine Policy 34 pp 498-505.

Gee, T. de, and Kikkert, A., 1993. *Analysis of the grey gurnard (Eutrigla gurnanrdus) samples collected during the 1991 International Stomach Sampling Project*. ICES CM 1993/G: 14. 26 pp. Cited in ICES FishMap. Grey Gurnard Fact Sheet.

Gill, A.B. & Bartlett, M., 2010. *Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel*. Scottish Natural Heritage Commissioned Report No.401.

Gotz. T, Hastie. G, Hatch. L, Raustein. O, Southall. B, Tasker. M and Thompson, F., 2009. *Overview of the impacts of anthropogenic underwater sound in the marine environment. Ospar Commission Biodiversity Series.*

Gregory,R.D.,Wilkinson,N.I., Noble,D.G., Robinson,J.A., Brown,F., Hughes,J., Proctor,D., Gibbons,D.W., and Galbraith,C., 2002 . '*The Population Status of Birds in the United Kingdom, Channel Islands and Isle of Man: an analysis of conservation concern 2002-2007' in British Birds 95*: 410-448 .

Gubbay, S., & Knapman, P.A., 1999. *A review of the effects of fishing within UK European marine sites*. Natura 2000 report prepared for the UK Marine SACs Project. English Nature. (UK Marine SACs Project, vol .12).

H

Halcrow, 2002. *Futurecoast* [CD-ROM] produced for DEFRA, with BGS, ABP MER Ltd., Queen's University of Belfast and University of Plymouth.

Halcrow, 2004. *Lincshore Sea Defence Strategy*. Mablethorpe to Skegness.

Hammond, P.S. Benke, H. Berggren, P. Borchers, D.L. Buckland, S.T. Collet, A. Heide - Jorgensen, M.P. Heimlich-Boran, S. Hiby, A.R. Leopard, M.F and Oien, N., 1995. *Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and adjacent waters*. Final report to the European Commission under contract LIFE 92-2/UK/27.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jorgensen, M.P., Heimlich, S., Hiby, A.R., Leopold, M.F., and Oien, N., 2002. *Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology*, 39, 361-376.

Hassel, A., Knutsen, T., Dalen, J., Lokkeborg, S., Skaar, K., Ostensen, O., Haugland, E. K., Fonn, M., Hoines, A. and Misund, O. A n.d.,. *Reaction of sandeel to seismic shooting: a field experiment and fishery statistics study. Institute of Marine Research, Bergen, Norway*. [Online] Available at <http://www.imr.no/temasider/redskap_og_teknologi/seismikk/63515/resultat_rapporter/Sandeel_report.pdf/nb-no> [Accessed 27 May 2011].

Hawkins, A.D and Johnstone, A.D.F., 1978. *The hearing of the Atlantic salmon (Salmo salar) Journal of Fish Biology.* 13: 655 – 673

Heessen, H.J. L., 1983. *Distribution and Heessen, H.J. L. 1983. Distribution and abundance of young cod and whiting in the south-eastern North Sea in the period 1980-1982*. ICES CM 1983/G:30. 4 pp.

Hedger, R., McKenzie, E., Heath, M., Wright, P., Scott, B., Gallego, A. and Andrews, J., 2004. *Analysis of the spatial distributions of mature cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) abundance in the North Sea* (1980-1999) using generalised additive models. Fisheries Research 70(1): 17-25.

Heip, C. Basford, D. Craegmeerson, J.A. Dewaramer, J.M. Dorjes, J. DeWilde, P. Duinveled, G. Eleftherioui, Herman, P.M.J., Niermann, U, Kingston, P, Kunitzer, Rachor, E, Rumohr, H, Soetaert, K. and Soltwedel, T., 1992. *Trends in biomass, density and diversity of North Sea macrofauna, ICES Journal of Marine Science*. 49: 13-22.

Hendrick, V.J. & Foster-Smith, R.L., 2006. *Sabellaria spinulosa* reef: a scoring system for evaluating 'reefiness' in the context of the Habitats Directive. Journal of the Marine Biological Association of the UK, 86: 665-677. (5.2)

Hendrick, V. J., Foster-Smith, R. L. & Davies, A. J. 2011). Biogenic Reefs and the Marine Aggregate Industry. Marine ALSF Science Monograph Series No. 3. MEPF 10/P149. (Edited by R. C. Newell & J. Measures). 60pp. (5.2)

Hiby, A. R., Duck, C. D., Thompson, D., Hall, A. J. & Harwood, J. (1996). Seal stocks in Great Britain. NERC News January: 20-22. Cited in Pomeroy, P. P., Twiss, S. D., and C. D. Duck., 2000. *Expansion of a grey seal* (*Halichoerus grypus*) breeding

Hiddink, J.G., Jennings, S. & Kaiser, M.J., 2006. *Indicators of the Ecological Impact of Bottom-Trawl Disturbance on Seabed Communities*. Ecosystems, 9: 1190-1199.

Hill, A.E. James, I.D. Liden, P.F. Matthews, J.P. Prandle, D. Simpson, J.H. Gmitrowicz, E.M. Smeed, D.A. Lwiza, K.M.M. Durazo, R, Fox, A.D. Bowers, D.G. Weydert, M., 1993. *Dynamics of tidal mixing fronts in the North Sea (and Discussion). Physical sciences and engineering*, 343: 431 – 446

Hiscock, K. and Tyler-Walters, H., 2003. In: Olenin, S. & Ducrotoy, J.P., 2006. *The concept of biotope in marine ecology and coastal management. Marine Pollution Bulletin*. 53, 20-29.

Hislop, J. R. G. and McKenzie, K., 1976. *Population studies of the whiting Merlanguis merlangus (L.) of the northern North Sea*. Journal du Conseil International pour l'Exploration de la Mer 37(1): 98-111.

Hitchcock, D. R., Newell, R, C. Seiderer, L. J., 1998. *Investigation of benthic and surface plumes associated with marine aggregate mining in the United Kingdom. Contract Report for the US Department of the Interior, Minerals Management Service*. Contract Number 14-35-0001-30763. Coastline Surveys Ltd. Ref 98-555-03 (final).

Hitchcock, D. R., Newell, R, C. Seiderer, L. J., 1998. *Investigation of benthic and surface plumes associated with marine aggregate mining in the United Kingdom*. Contract Report for the US Department of the Interior, Minerals Management Service. Contract Number 14-35-0001-30763. Coastline Surveys Ltd. Ref 98-555-03 (final).

Hoek, W., 1992. *An unusual aggregation of harbour porpoises (Phocoena phocoena)*. Mar. Mamm. Sci., 8, 152-155.

Holland, G.J., S.P.R. Greenstreet, I.M. Gibb, H.M. Fraser and M.R. Robertson, 2005. *Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment*. *Mar Ecol Progress Series* Vol. 303: 269-282, 2005

Holt, R.H.F., 1994. *Marine biological survey of Eyemouth (Berwickshire) to Alnmouth (Northumberland)*. Joint Nature Conservation Committee Report, No. 157. (Marine Nature Conservation Review Report, No. MNCR/SR/24.). Coordinates for *Sabellaria spinulosa* occurrences and reefs.
Holt, T.J., Rees, E.I., Hawkins, S.J. & Seed, R., 1998. Biogenic reefs (Volume IX). *An overview of dynamic and sensitivity characteristics for conservation management of marine SACs*. Scottish Association for Marine Science (UK Marine SACs Project), 174 pp.

T.J. Holt, E.I. Rees, S.J. Hawkins, R. Seed, 1998. Biogenic Reefs (volume IX). *An overview of dynamic and sensitivity characteristics for conservation management of marine SACs*. Scottish Association for Marine Science (UK Marine SAC's Project) in Hendrick, V. J., Foster-Smith, R. L. & Davies, A. J., 2011. *Biogenic Reefs and the Marine Aggregate Industry. Marine ALSF Science Monograph Series No. 3*. MEPF 10/P149. (Edited by R. C. Newell & J. Measures). 60pp. ISBN: 978 0 907545 46 0. (5.2)

Hosfield, R. and Chambers, J. 2004. *The archaeological potential of secondary contexts*: [Online] Available at < http://www.arch.soton.ac.uk/Research/Aggregates/arch-intro.htm>.Accessed at 24 September 2011]

Houghton, A. J., Brooks, A. J. & Tillin, H. M., 2011. *Geogenic Reefs and the Marine Aggregate Industry*. Marine ALSF Science Monograph Series No. 4. MEPF 10/P151. (Edited by R. C. Newell & J. Measures). 49pp. ISBN: 978 0 907545 47 7.

Houthuys, R., Trentesaux, A. and De Wolf, P., 1994. *Storm Influences on a Tidal Sandbank's Surface* (Middelkerke Bank, southern North Sea), Marine Geology, Vol 121, Issues 1-2, Pages 23-41.

Howlett, D.J.. 1990. *The arrival in Britain of Ensis americanus. Conchologist's* Newsletter, No. 114: 301-302. (5.2)

HR Wallingford, 2002. *Southern North Sea Sediment Transport Study, Phase 2*. Report produced for Great Yarmouth Borough Council by HR Wallingford, CEFAS/UEA, Posford Haskoning and Dr Brian D'Olier. HR Wallingford Report EX 4526.

HR Wallingford, 2002. *Southern North Sea Sediment Transport Study Phase 2*. August 2002. Report EX4526 (CH4)

HR Wallingford, 2011a. *Area 473 East. Dredger and plume monitoring study. Report EX 6215*, Release 3.0.

HR Wallingford, 2011b. *Plume Dispersion Arising from Aggregate Dredging by Large Trailer Suction Hopper Dredgers*.

Hyvarinen, H., 1989. *Diving in darkness: Whiskers as sense organs of the ringed seal*. In Proceedings of the seventh biennial conference on the biology of marine mammals, Dec. 5-9, Miami, Fla.

Hunter, E., Buckley, A. A., Stewart, C. and Metcalfe, J. D., 2005. *Migratory behaviour of the thornback ray, Raja clavata L. in the southern North Sea. Journal of the Marine Biological Association of the UK*.

I

ICE,. 2007. Report of the Working Group on the Biology and Life History of Crabs (WGCRAB), 30 April – 3 May 2007, Lowestoft, UK. ICES CM 2007/LRC:09. 87 pp. For permission to reproduce material from this publication, please apply to the General Secretary.

ICES, 2009a. *Report of the Herring Assessment Working Group for the Area South of 62 N, 17-25 March 2009*, ICES Headquarters, Copenhagen. 648 pp.

ICES, 2009b. *Herring in Subarea IV and Divisions IIIa and VIId (North Sea autumn spawners)*. [Online] Available at <http://www.ices.dk/committe/acom/comwork/report/2009/2009/her-47d3.pdf>[Accessed 26 May 2011].

ICES, 2009c. *Cod in Subarea IV (North Sea), Division VIId (Eastern Channel), and IIIa West (Skaggerak*) [Online]. Available at:< http://www.ices.dk/committe/acom/comwork/report/2009/2009/cod-347d.pdf> [Accessed 03 June 2011].

ICES, 2009d. *Whiting in Subarea IV (North Sea) and Division VII d (Eastern Channel)*. Available at: http://www.ices.dk/committe/acom/comwork/report/2009/2009/whg-47d.pdf.

ICES. 2009e. *Plaice in Subarea IV*. [Online] Available at:<http://www.ices.dk/ommitte/acom/comwork/report/2008/2008/ple-nsea.pdf>. [Accessed 03 June 2011].

ICES, 2011a. *Sprat in the North Sea*. ICES advice 2011, book 6. [Online] Available at: http://www.ices.dk/committe/acom/comwork/report/2011/2011/spr-nsea.pdf [Accessed 05 March 2012]

ICES Herring Working Action Group (2011b) *North Sea Herring*. [Online] Available at: http://www.ices.dk/reports/ACOM/2011/HAWG/Sec%2002%20North%20Sea%20Herring.pdf [Accessed 24 May 2011].

ICES. 2011c. *Report of the Herring Assessment Working Group for the area South of 62 deg N (HAWG)*, 16 - 24 March 2011, ICES Headquarters, Copenhagen. ICES CM 2011/ACOM:06 .749 pp.

ICES FishMap, 2011d. *Haddock Fact Sheet*. [Online] Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/haddock.pdf [Accessed 31 May 2011].

ICES FishMap 2011e. *Whiting Fact Sheet*. [Online] Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/whiting.pdf [accessed31 May 2011].

ICES FishMap, 2011f. *Grey Gurnard Fact Sheet*. [Online] Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/greygurnard.pdf [Accessed 17 July 2009].

ICES FishMap, 2011g. *Striped red mullet factsheet*. [Online] Available at http://www.ices.dk/marineworld/fishmap/ices/pdf/redmullet.pdf [Accessed 31 May 2011].

ICES FishMap, 2011h. *Plaice Fact Sheet*. [Online] Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/plaice.pdf [accessed 17 July 2009].

ICES FishMap, 2011i. Sole Fact Sheet. [Online] Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf [Accessed 26 May 2011].

ICES, 2012. *Factors affecting the distribution of North Sea fish*. ICES FishMap. [Online] Available at: http://www.ices.dk/marineworld/fishmap/pdfs/factors.pdf [Accessed 06 March 2012].

ICES, 1965. *Report of the working group on sole. ICES Cooperative Research Report 5: 1-126*. [Online] Reference in: ICES FishMap. Sole Fact Sheet. Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf [Accessed 26 May 2011].

ICES Fish Map Cod, n.d. [Online]. Available at <http://www.ices.dk/marineworld/fishmap/ices/pdf/cod.pdf> [Accessed 20 August 2011]

IUCN. 2011. IUCN red list of threatened species – *Echinus esculentus*. [Online] Available at: http://www.iucnredlist.org/apps/redlist/details/7011/0. Accessed 03/08/2011.

Ivory, P, Jeal, F and Nolan, C., 2004. Age determination, growth and reproduction in the lesser - spotted dogfish Scyliorhinus canicula (L.). Journal of Northwest Atlantic Fishery Science 35 : 89-106.

J

Jackson, A., 2008. *Sabellaria alveolata*. Honeycomb worm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [Online]. Plymouth: Marine Biological Association of the United Kingdom. [cited 24/11/2011]. Available at <http://www.marlin.ac.uk/specieshabitats.php?speciesID=4277> [Accessed 10 August 2011].

Jackson, A. and Hiscock, K., 2008. *Sabellaria spinulosa*. Ross worm. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [Online]. Plymouth: Marine Biological Association of the United Kingdom. [cited 24/11/2011]. Available at: <http://www.marlin.ac.uk/speciessensitivity.php?speciesID=4278.> [Accessed 14 July 2011]

John, S. A., Challinor, S. L., Simpson, M., Burt, T. N. and Spearman, J. 2000. *Scoping the assessment of sediment plumes from dredging*. Construction Industry Research and Information Association, 188p.

Joint Nature Conservation Committee (JNCC), 1999. *The Birds Directive - selection guidelines for Special Protection Areas*. JNCC Peterborough.

Joint Nature Conservation Committee (JNCC), 2009a. *SAC Site selection criteria and principles in the UK*. [online] Available at <http://www.jncc.gov.uk/page-1473> [Accessed 17 September 2009]. (chapter 5.1)

Joint Nature Conservation Committee (JNCC), 2009b. Distribution of SAC with Interest Feature – 1102 *Alosa alosa* [Online] Available at:

<http://www.jncc.gov.uk/ProtectedSites/SACselection/feature_map.asp?FeatureIntCode=S1102> [Accessed 20 August 2011]

Joint Nature Conservation Committee (JNCC), 2010. *Distribution of SAC with Interest Feature* [Online] Available at <http://www.jncc.gov.uk/ProtectedSites/SACselection/species.asp?FeatureIntCode=S1095> [Accessed 16 July 2009].
Joint Nature Conservation Committee (JNCC), 2010a. *Classification of SPAs, pSPAs and areas of search (AoS) for inshore aggregations of waterbirds and Balearic shearwater outwith the breeding season*. Available at: http://jncc.defra.gov.uk/pdf/SPA_AOS_Maps%2020100304.pdf. [Accessed 20 August 2011].

Joint Nature Conservation Committee (JNCC), 2010b. *Maintaining favourable conservation status of harbour porpoise in UK waters*.

JNCC/NE, 2010. Marine Conservation Zone Reference Areas: Guidance documents for regional MCZ projects

Joint Nature Conservation Committee (JNCC), 2011a. *Site Selection Process.* [online] Available at:<http://jncc.defra.gov.uk/page-4560> [Accessed 15 July 2011].

Joint Nature Conservation Committee (JNCC), 2011b. *Whales, dolphins and porpoises*. [online] Available at <http://www.jncc.gov.uk/page-1554> [Accessed 15 July 2011].

Joint Nature Conservation Committee (JNCC), 2011c. *Northern Gannet Morus bassanus*. [online] Available at <http://jncc.defra.gov.uk/page-2875> [Accessed 20 July 2011].

Joint Nature Conservation Committee (JNCC), 2011d. *Marine Conservation Zones*. [online] Available at <http://jncc.defra.gov.uk/page-4525> [Accessed 9 August 2011].

Joint Nature Conservation Committee (JNCC), 2011e. *Inner Dowsing, Race Bank and North Ridge*. [online] Available at <http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030370> [Accessed 14 august 2011]

Joint Nature Conservation Committee (JNCC), 2011f .*North Norfolk Sandbanks and Saturn Reef* [online] Available at < http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030358> [Accessed 6 August 2011]

Joint Nature Conservation Committee (JNCC), 2011g. *Spurn Head* [Online] Available at <http://jncc.defra.gov.uk/pdf/gcrdb/GCRsiteaccount2111.pdf> [Accessed 6 August 2011]

Joint Nature Conservation Committee (JNCC), 2011h. SS.SBR.PoR.SspiMx: *Sabellaria spinulosa* on stable circalittoral mixed sediment [Online]. Available at <http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001112> [Accessed 6 August 2011]

Joint Nature Conservation Committee (JNCC), 2011i. *Habitat accounts – Marine, coastal and halophytic habitats 1110* [Online]. Available at <http://jncc.defra.gov.uk/protectedsites/sacselection/habitat.asp?FeatureIntCode=H1110> [Accessed on 27 October 2011].

Joint Nature Conservation Committee (JNCC), 2012a. SS.SSa.CFiSa.ApriBatPo. *Abra prismatica*, *Bathyporeia elegans and polychaetes in circalittoral fine sand*. [Online] Available at : <http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00001874>. [Accessed 18 June 2011].

Joint Nature Conservation Committee (JNCC), 2012b. *SS.SSa.CMuSa.AalbNuc. Abra alba and Nucula nitidosa in circalittoral muddy sand or slightly mixed sediment*. [Online] Available at: <http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000356> [Accessed 16 June 2011].

Joint Nature Conservation Committee (JNCC), 2012c. *SS.SCS.CCS.Nmix. Neopentadactyla mixta in circalittoral shell gravel or coarse sand*. [Online] Available at: http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000170 [Accessed 28 June 2011].

Joint Nature Conservation Committee (JNCC), 2012d. *SS.SSa.IFiSa.ScupHyd. Sertularia cupressina and Hydrallmania falcata on tide-swept sublittoral sand with cobbles or pebbles*. [Online] Available at: <http://www.jncc.gov.uk/marine/biotopes/biotope.aspx?biotope=JNCCMNCR00000756> [Accessed 26 June 2011].

JNCC/NE, 2009. Offshore Special Area of Conservation: Inner Dowsing, Race Bank and North Ridge Draft Conservation Objectives and Advice on Operations.

Jones, L. A., Coyle, M. D., Evans, D., Gilliland, P. M., and Murray, A. R., 2004a. *Southern North Sea Marine Natural Area Profile: A contribution to regional planning and management of the seas around England*. Peterborough: English Nature. [Online] Available at <http://naturalengland.etraderstores.com/NaturalEnglandShop/CORP146> [Accessed 20 August 2011]

Jones LA, Coyle, MD, Evans D, Gilliland PM & Murray AR., 2004b. *Mid North Sea Marine Natural Area Profile*: A contribution to regional planning and management of the seas around England: English Nature.
Jones, L.A., Hiscock, K. & Connor, D.W. 2000. *Marine habitat reviews: A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs*.

K

Kaiser, M.J.and Hiddink, J.G., 2007*. Food subsidies from fisheries to continental shelf benthic scavengers*. Marine Ecology Progress Series. 350: 267 - 276.

Kastelein, R. A., Bunskoek, P., Hagedoorn, M., Au, W. W. L. and Haan, D., 2002. *Audiogram of the harbour porpoise* (*Phocoena phocoena*) measured with narrow-band frequency-modulated signals. J. Acoust. Soc. Am. Vol 113 (2): 334-344.

Kingfisher Information Service, 2011. *Cable Awareness*. [online] Available at: < http://www.kisca.org.uk/> [Accessed 25/07/11]

Kober K, Webb A, Win I, Lewis M, O'Brien S, Wilson LJ and Reid JB, 2010. *An analysis of the number and distribution of seabirds within the British Fishery Limit aimed at identifying areas that qualify as possible marine SPAs*. *JNCC Report,* No.431.

Kruuk, H. 1963. *Diurnal periodicity in the activity of the common sole, Solea vulgaris Quensel*. Netherlands Journal of Sea Research 2(1): 1- 28. Referenced in: ICES FishMap. Sole Fact Sheet. [Online] Available at: <http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf> [Accessed 26 May 2011].

Künitzer, A., Basford, D., Craeymeersch, J.A., Dewarumez, J.M., Dörjes, J., Duineveld, G.C.A,. Eleftheriou, A., Heip, C., Herman, P., Kingston, P., Niermann, U., Rachor, E., Rumohr, H. and De Wilde, P.A.J., 1992. *The benthic infauna of the North Sea: species distribution and assemblages*. ICES Journal of marine Sciences: 49 127 – 143.

L

Lalli, C.M. & Parsons, T.R.,1997. *Biological Oceanography: An Introduction*. Second Edition. Butterworth-Heinemann. Oxford. 314 pp.

Last, K.S., Hendrick,V.J., Beveridge, C.M. & Davies, A.J., 2011. *Measuring the effects of suspended particulate matter and smothering on the behaviour, growth and survival of key species found in areas associated with aggregate dredging*. Report for the Marine Aggregate Sustainability Fund, Project MEPF 08/P76. 69 pp.

Lewis, G.A. & Nichols, D., 1979. Geotactic movement following disturbance in the European sea-urchin, *Echinus esculentus* (Echinodermata: echinoidea). Progress in Underwater Science, 5, 171-186.

Limpenny, D.S. Foster-Smith, R.L. Edwards, T.M. Hendrick, V.J. Diesing, M. Eggleton, J.D. Meadows, W.J., Crutchfield, Z. Pfeifer, S. and Reach, I.S. 2010. Best methods for identifying and evaluating *Sabellaria spinulosa* and cobble reef. ALSF Ref No. MAL0008. (5.2)

Lourie, S.A., Foster, S.J., Cooper, E.W.T. & Vincent, A.C.J., 2004. *A Guide to the Identification of Seahorses. Project Seahorse and TRAFFIC North America*. Washington D.C., University of British Columbia and World Wildlife Fund.

Lovell, J.M. Findlay, M.M, Harper, G and Pilgrim, D.A., 2005. *The polarisation of hair cells from the ear of the European Bass (Dincertarchus labrax)*. Comparative biochemistry and physiology, Part A 142: 116 – 121.

Lucas, Z.N. & Natanson, L.J., 2010. *Two shark species involved in predation on seals at Sable Island*, Nova Scotia, Canada. Proceedings of the Nova Scotian Institute of Science 45(2):64-88.)

M

MacLeod, I.D., 1997, *The use of in-situ metal corrosion studies as an archaeological management tool*. In: Delgado, J. (ed.), British Museum Encyclopaedia of Underwater and Maritime Archaeology. British Museum Press, London: 111-113.

Maitland, P. S. and Hatton-Ellis, T. W., 2003. *Ecology of the Allis and Twaite Shad*. Conserving Natura 2000 Rivers Ecology Series No. 3. English Nature, Peterborough.

Maitland PS 2003. *Ecology of the River, Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5*. English Nature, Peterborough.
Maitland, P. S. and Lyle, A. A. 1995. *Shad and smelt in the Cree Estuary, SW Scotland*. Report to Scottish Natural Heritage, Edinburgh.

Marine Aggregate Levy Sustainability Fund (MALSF), 2011. *The Humber Regional Environmental Characterisation* (REC) 2011.
Marine Conservation Society. Seasearch Marine Surveys data from volunteer scuba divers. *Data cited as part of the NBN Gateway* [Online] http://data.nbn.org [Accessed 24 May 2011].

Marine Conservation Society. 2011a. Seasearch divers have found what could be the world's longest chalk reef off East Anglia. Available from: <www.mcsuk.org> [Accessed 5th March 2011].

Marine Conservation Zone , 2011. *Marine Conservation Zone Interactive Map*. [Online] Available at: <http://www.mczmapping.org/> [Accessed at 3 September 2011]

Marine Management Organisation (MMO), [Online] Available at <http://planningportal.marinemanagement.org.uk/> [Accessed 25 July 2011]
Marine Management Organisation(MMO), 2011a. *Strategic Scoping Report for Marine Planning in England*. [online] Available at: <http://www.marinemanagement.org.uk/marineplanning/documents/ssr_final.pdf> [Accessed 15 July 2011].

Marine Management Organisation(MMO), 2011b. *Marine Licensing Guidance 3 Dredging, Disposal and Aggregate Dredging* [online] Available at <http://marinemanagement.org.uk/licensing/documents/guidance/03.pdf> [Accessed 16 September 2011]

Marine Biological Association - Volunteer sightings data held by the DASSH Data Archive Centre. Data cited as part of the NBN Gateway available at <http://data.nbn.org.uk> [Accessed 24 May 2011].

Maritime Journal, *Diver shortage concern for offshore wind*. [Online] Available at: <http://www.maritimejournal.com/features101/marine-civils/diving-and-underwater-services/diver-shortage-concern-for-offshore-wind-industry. [Accessed 20 August 2011].

MarLIN, 2011. MarLin [Online] Available at < http://www.marlin.ac.uk> [Accessed at 10 May 2011].

MarLIN. 2011a. Ross worm – *Sabellaria spinulosa* – General Information [Online] Available at: <http://www.marlin.ac.uk/speciesfullreview.php?speciesID=4278>.[Accessed 3 August 2011].

MarLIN. 2011b. *Biological Traits Information Catalogue*. [Online] Available at: <http://www.marlin.ac.uk/biotic/browse.php?sp=430>2. [Accessed 4 August 2011].

MarLIN. 2011c. Edible crab – *Cancer pagarus* – General information. [Online] Available at: <http://www.marlin.ac.uk/speciesfullreview.php?speciesID=2872>. [Accessed 2 August 2011].

MarLIN. 2011d.Brown Shrimp – *Crangon crangon* – General information. [Online] Available at: <http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3078>. [Accessed 2 August 2011].

MarLIN. 2011e. Queen Scallop – *Aequipecten opercularis*– General information [Online]. Available at: <http://www.marlin.ac.uk/speciesinformation.php?speciesID=2390>. [Accessed on: 27 October 2011].

Mavor RA, Parsons M, Heubeck M and Schmitt S., 2006. *Seabird Numbers and breeding success in Britain and Ireland*, 2005. Peterborough, JNCC (UK Nature Conservation, No. 30.)

Mavor, R.A,, Heubeck M,, Schmitt S., and Parsons M., 2008. *Seabird numbers and breeding success in Britain and Ireland*, 2006

Metcalfe, J.D. and Arnold, G.P.,1997. *Tracking Fish with electronic tags. Nature*, 387: 665 - 666. Referenced in: ICES FishMap, Plaice fact Sheet, available at: <http://www.ices.dk/marineworld/fishmap/ices/default.asp?id=Plaice> [Accessed 2 March 2012].

Mercer, J.P, Bannister, R.C.A. Van Mirren, G.I. Debuse, V. Mazzoni, D. Lovewell, S. Browne, R.A.L. and Ball, B., 2001. *An overview of the LEAR (Lobster Ecology and Recruitment Project) project: results of field and experimental studies on the juvenile ecology of Hommerus gammerus in cobble*. Marine Freshwater Research 52, 1291 – 1301.

MESL, 2009. *Benthic Ecology of Licence Area 481. Pre-dredge Benthic and Epibenthic Resources*. Document No. UMD4811108.

Mitchel, P.I., Newton, S.F. Ratcliffe N and Dunn T.E., 2004. *Seabird Populations if Britain and Ireland: Results of Seabird 2000 census* (1998 – 2002). T & A D Poyser, London.

Ministry of Agriculture, Fisheries and Food. Directorate of Fisheries Research. 1992. Non-Radioactive Contaminants in the Aquatic Environment and Activities Regulating the Disposal of Wastes at Sea, 1990. Aquatic Environment Monitoring Report No 30. Lowestoft, UK. 66 pp. Available from: http://www.cefas.defra.gov.uk/publications/aquatic/aemr30.pdf.

Ministry of Defence (MOD) 2011a. *Search the Byelaws.* [online] Available at: http://www.mod.uk/DefenceInternet/MicroSite/DIO/OurPublications/Byelaws/ [Accessed 25 July 2011].

Ministry of Defence (MOD),2011b*. Low Flying Area.* [online]. Available at <http://www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/AirSafetyandAviation/LowFlying/LFAs/LowFlyingArea11.htm> [Accessed 25 July 2012]

Ministry of Defence (MoD), 2011c *Low Flying Area 05* [online]. Available at< http://www.mod.uk/DefenceInternet/AboutDefence/WhatWeDo/AirSafetyandAviation/LowFlying/LFAs/LowFlyingArea05.htm> [Accessed 25 July 2011]

MIRO (2004) Seabed characterisation and the effects of marine aggregate dredging. Prepared by Andrews Survey.

Moen, F.E and Svensen, E. 2004a. *Marine Fish and Invertebrates of Northern Europe. Publisher KOM. Norway*. In: The Humber Regional Environmental Characterisation (REC) 2011. Marine Aggregate Levy Sustainability Fund (MALSF) (5.2)

Moen, F.E and Svensen, E. 2004b. *Marine Fish and Invertebrates of Northern Europe*. Publisher KOM. Norway. In: Tappin, D R, Pearce, B, Fitch, S, Dove, D, Geary, B, Hill, J M, Chambers, C, Bates, R, Pinnion, J, Diaz Doce, D, Green, M, Gallyot, J, Georgiou, L, Brutto, D, Marzialetti, S, Hopla, E, Ramsay, E, and Fielding, H. 2011. The Humber Regional Environmental Characterisation. British Geological Survey Open Report OR/10/54. 357pp.

Moore, P.G. 1977. *Inorganic particulate suspensions in the sea and their effects on marine animals*. Oceanography and Marine Biology: an Annual Review, 15, 225-363.

Moreno, J. A. 1995. *Guía de tiburones de aguas ibéricas, Atlántico Nororiental y Mediterráneo. S. A. Pirámide* (ed.). 310 p.

Mueller-Blenkle, C., McGregor, P.K., Gill, A.B., Andersson, M.H., Metcalfe, J., Bendall, V.,Sigray, P., Wood, D.T. & Thomsen, F., 2010. *Effects of Pile-driving Noise on the Behaviour of Marine Fish*. COWRIE Ref: Fish 06-08, Technical Report 31st M

Munk, P. & Nielsen, J., 2005. *Eggs and Larvae of North Sea fishes*. Biofolia, Denmark, 215 pp.

Myrberg, A., 2001. *The acoustic biology of elasmobranchs*. Environmental Biology of Fishes. 60: 31 – 35.

N

Natural England, 2009. [Online] Available at: <http://www.naturalengland.org.uk/Images/IDRB-consobj_tcm6-21631.pdf> [Accessed 21 July 2011]

Natural England & JNCC. 2010. Marine Conservation Zone Project Ecological Network Guidance (ENG). 144 pp.

Natural England, 2010. Outer Thames Estuary Special Protection Area. [online] http://www.naturalengland.org.uk/Images/Thames-brief_tcm6-21728.pdf [Accessed 8 June 2011]

Natural England, 2011. *Marine Conservation Zones.* [online] Available at: <http://www.naturalengland.org.uk/ourwork/marine/protectandmanage/mpa/mcz/default.aspx> [Accessed 60July 2011]

Natural England, 2011. *Marine and Coastal Access Act*. [Online] Available at: <http://www.naturalengland.org.uk/ourwork/marine/protectandmanage/act/default.aspx > [Accessed 24 August 2011]

National Research Council (NRC), 2005a. Marine mammal populations and ocean noise: Determining when noise causes biologically significant effects. Washington, DC: The National Academies Press. 126 pp.

National Research Council, Committee on Characterising Biologically Significant Marine Mammal Behaviour, 2005b. *Marine Mammal Populations and Ocean Noise: Determining when noise causes biologically significant effects*. National Academies Press.

Nature Works, 2011. *Razorbil*l [Online] Available at <http://www.nhptv.org/natureworks/razorbill.htm. [Accessed 7th December 2011]

NBN Gateway, 2007. Data providers; Biological Records Centre, Bristol Regional Environmental Records Centre, Countryside Council for Wales, Devon Biodiversity Records Centre, Highland Biological Recording Group, Joint Nature Conservation Committee, Available at <www.searchnbn.net [cited November 2007].Marine Biological Association, Scottish Natural Heritage. http://www.searchnbn.net/gridMap/gridMapLarge.jsp#topOfMap

Neal, K. and Wilson, E 2008. *Cancer pagurus*. *Edible crab*. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 28/11/2011]. Available from: <http://www.marlin.ac.uk/speciessensitivity.php?speciesID=2872.> [Accessed 10 May 2011].

Neal, K. 2008. *Crangon crangon*. *Brown shrimp*. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 29/11/2011]. Available from: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3078. [Accessed 10 May 2011]

Nedwell, J., Langworthy, J., and Howell, D., 2003. *Assessment of sub-sea acoustic noise and vibration from offshore wind turbines on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise*. Subacoustech Ltd. COWRIE.

Nedwell, J, Edwards, B, Turnpenny, A and Gordon, J., 2004. *Fish and marine mammal audiograms*: A summary of available information. Subacoustech report ref: 534R0214

Nedwell J R , Parvin S J, Edwards B, Workman R , Brooker A G and Kynoch J E 2007. *Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters*. Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.

Net Gain, 2011. *Final Recommendations: Submission to Natural England and JNCC. Version 1.1*. August 2011. Available at: <http://www.netgainmcz.org/docs/Net_Gain_Final_Rec_v1_1.pdf.> [Accessed 28 august 2011]

Newell, R.C., Seiderer, L.J., Robinson, J.E., Simpson, N.M., Pearce, B.& Reeds, K.A., 2004. *Impacts of overboard screening on seabed and associated benthic biological community structure in relation to marine aggregate extraction*. Technical Report to the Office of the Deputy Prime Minister (ODPM) and Minerals Industry Research Organisation (MIRO). Project No SAMP.1.022 . Marine Ecological Surveys Limited, St Ives. Cornwall. pp. 152.

Newell, R, Seiderer, J and Hitchcock, D. (1998) *The impact of dredging works in coastal waters: a review of the sensitivity to disturbance and subsequent recover of biological resources on the sea bed*. Oceanography and Marine Biology. 36: 127 – 178

Newell, R.C., Seiderer, L.J., Simpson, N.M. & Robinson, J.E. 2002. *Impact of Marine Aggregate Dredging and Overboard Screening on Benthic Biological Resources in the Central North Sea*: Production Licence Area 408, Coal Pit.

Marine Ecological Surveys Limited Technical Report No ER1/4/02 to the British Marine Aggregate Producers Association. 72 pp.

Nichols, J., 1999. *Saving North Sea herring* (based on an article first published in Fishing news, 12 February 1999 - with updated data for 1998) Cefas.

Noordzee Atlas (2010), [Online] Available at <http://www.noordzeeatlas.nl/en/nzaEn.html> [Accessed 2 February 2010].
Norman, C.P and Jones, M.B. 1992. *Influences of Depth, season and moult stage on the diet of the velvet swimming crab Nector Puber* (Brachyura, Portunidae) Estuarine, Coastal and Shelf Science. 34: 71 – 83

Norris, S. W. (2001) *Near Surface Sea Temperatures in Coastal Waters of the North Sea, English Channel and Irish Sea - Volume II* . Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Lowestoft.

North Norfolk Diving, 2011. [Online] Available at http://www.northnorfolkdiving.co.uk/index.html [Accessed 20 October 2011]

North Norfolk SMP5 East Anglian Coastal Group, *North Norfolk SMP2 Final Plan Appendix C Baseline Processes, 2010*..Avaliable at <http://www.eacg.org.uk/index.php?Itemid=125> Accessed 18 November 2011.

O

ODPM, 2002. *Marine Minerals Guidance 1: Extraction by dredging from the English seabed*. Office of the Deputy Prime Minister. ISBN 0 11 753634 2.

Office for National Statistics, 2011. *Office for National Statistics website* Available at <http://www.statistics.gov.uk> [Accessed 28 May 2011]
Osiris Projects, 2011, Humber Region Profiles Hydrographic and Geophysical Survey. Report reference: C10030b.

Offshore Wind, COWRIE (Collaborative Offshore Wind Research into the Environment) 2007) *Historic Environment Guidance for the Offshore Renewable Energy*
Sector.; http://www.offshorewind.co.uk/Assets/archaeo_guidance.pdf. [Accessed 22 December 2011]

Olenin, S. & Ducrotoy, J.P., 2006. The concept of biotope in marine ecology and coastal management. Marine Pollution Bulletin. 53, 20-29.

Olsgard, F. Schaanning, M.T. Widdicombe, S. Kendall, M.A. and Austen, M.C. 2008. Effects of bottom trawling on ecosystem function. Journal of Experimental Marine Biology and Ecology, 366: 123-133.

OSPAR Commission 2008. Case Reports for the OSPAR List of Threatened and / or Declining Species and Habitats.

OSPAR, 2010. Quality Status Report 2010. OSPAR Commission. London. 176pp.

OSPAR. 2010a. Case reports for the OSPAR list of threatened and/or declining species and habitats - Update. Quality status report 2010.

P

Parvin, S. Nedwell, J., Kynoch, J., Lovell, J., and Brooker, A., 2008. *Assessment of Underwater Noise from Dredging Operations on the Hastings Shingle Bank*. Subacoustech Report Number 758R0137.

Pawson, M.G. & Pickett, G.D. 1987. *The Bass (Dicentrarchus labrax) and management of its fishery in England and Wales*. Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries Research. Laboratory Leaflet No. 59. Lowestoft.

Pawson, M. G. 1995. *Biogeographical Identification of English Channel Fish and Shellfish Stocks.* Fisheries Research Technical Report Number 99. Ministry of Agriculture, Fisheries and Food, Directorate of Fisheries. Lowestoft. 72 pp.

Pears, S. & Worsfold, T.M., 2011. *Analysis of benthos data collected for the Humber Region Marine Aggregate Regional Environmental Assessment (MAREA), with combined analysis of other data from the area*. Thomson Unicomarine Report ERMMAREA11b to ERM, August 2011.

Pearce, B., Taylor, J. and Seiderer, L.J. 2007. *Recoverability of Sabellaria spinulosa following aggregate extraction*. Aggregate Levy Sustainability Fund MAL0027. Marine Ecological Surveys Ltd. 87 pp.
Pearce, B, Hill, J.M, Grubb, L and Harper, G. 2011. *Impacts of Marine Aggregate Extraction on Adjacent Sabellaria spinulosa aggregations and other benthic Fauna*. Marine Aggregate Levy Sustainability Fund.

Peich, L., Behrmann, G., and Kröger, R. H. H. (2001). *For whales and seals the ocean is not blue: a visual pigment loss in marine mammals*. Eur.J.Neurosci. 13, 1520-1528.

Perez-Dominguez, 2008: *Fish Pilot Studies in the Humber Estuary*, UK. Harbasins.

Pfeiffer, S., JNCC. 2012. Pers. Comm. [Phone] [Aril 2012]

Pickett, G.D. *A 3-year bass gillnetting trial (1-31 October 2002-2004) and complementary studies undertaken near Bridlington*, East Yorkshire. CEFAS Contract report C2277.

Pinn, E.H. & Ansell, A.D., 1993. *The effect of particle size on the burying ability of the brown shrimp Crangon crangon. Journal of the Marine Biological Association of the United Kingdom.* 73: 65-377.

Planning Portal, 2011. *Planning Portal Website* [online] Available at: <http://www.planningportal.gov.uk> [Accessed 25 July 2011].

Pollack, C and Barton, C., 2004. Review of red-throated diver prey species in the Thames Estuary., Cork Ecology

Popper, A. and Hastings, M. 2009a. *The effects of human generated sound on fish*. Integrative Zoology, 4; 43 - 52.

Popper, A and Hastings, M., 2009b. *The effects of anthropogenic sources of sound on fishes. journal of fish biology*, 75: 455- 489 (9.3)

Posford Haskoning Ltd, 2003. *North Norfolk Coastal Habitat Management Plan* (CHaMP). Prepared on behalf of English Nature and Environment Agency.

Proctor, N. 2005. *Investigation into the nearshore passage of migratory fish species: Interim report*. IECS.

Proctor, N., Mazik, K. & Thomson, S., 2006. *Baseline study of the marine ecology at the Humber Gateway Offshore Wind Farm Development*. A report by the Institute of Estuarine and Coastal Studies, University of Hull. Report: ZBB649-F-2006.

PSMSL, *Permanent Service for Mean Sea Level website*. [Online] Available at <http://www.psmsl.org/>. [Accessed 29 September 2011]

Pulse Tidal, 2011. *Proven in the Ocean*. [online] Available at: <http://pulsetidal.com/40.html> [Accessed 14 July 2011]

R

RAG 2008, *Regional Environmental Assessment: A Framework for the Marine Minerals Sector*.

Redhead, J. 2011. SAP response to NetGain final recommendations. Available at: http://www.netgainmcz.org/scipanel.php. Accessed: 26/09/11.

Rees, H.L., Pendle, M.A., Waldock, R., Limpenny, D.S. and Boyd, S.E. 1999. *A comparison of benthic biodiversity in the North Sea, English Channel, and Celtic Seas*. ICES Journal of Marine Science 56: 228-246.

Reid, J. B., Evans, P. G. H., and Northridge, S. P., 2003. Atlas of Cetacean distribution in north-west European waters. Joint Nature Conservation Committee.

Renewable UK, 2011a. http://www.bwea.com/ (Accessed 25/07/11)

Renewable UK, 2011b. Offshore Wind Farms. [online] Available at <http://www.bwea.com/ukwed/offshore.asp> [Accessed 20 July 2011].

Renouf, D., 1983. *Ecoholocation in Harbour seals*: Maybe they can do it after all. J. Acoust. Soc. Am. Vol. 74, Iss S1, pp. 575.

Richards, S.D., Harland, E.J., and Jones, S.A.S, 2007. *Underwater noise study supporting Scottish Executive Strategic Environmental Assessment for Marine Renewables*.

Richardson, W. J., Greene, C. R., Malme, C. I. and Thomson, D. H., 1995. *Marine mammals and noise*. Academic Press. Inc., San Diego, CA. ISBN 0-12-588441-9.

Riedman, M., 1990. The Pinnipeds: Seals, Sea Lions, and Walruses. University of California Press.

Rijnsdorp, A. D. and Vingerhoed, B, 2001. *Feeding of plaice, Pleuronectes platessa and sole Solea solea in relation to the effects of bottom trawling*. Journal of Sea Research 45: 219-230. Referenced in ICES FishMap. Plaice Fact Sheet. Available at: <http://www.ices.dk/marineworld/fishmap/ices/pdf/plaice.pdf> [Accessed 31 May 2011].

Rijnsdorp, A. D., Van Stralen, M. and Van der Veer, H. W., 1985. *Selective tidal transport of North Sea plaice larvae, Pleuronectes platessa in coastal nursery areas*. Transactions of the American Fisheries Society 114: 461-470.

Rijnsdorp, A.D., Beek, F.A. van, Flatman, S., Millner, R.M., Riley, J.D., Giret, M., and De Clerck, R. 1992. *Recruitment of sole stocks, Solea solea (L.), in the Northeast Atlantic*. Netherlands Journal of Sea Research 29(1-3): 173-192. Referenced in: ICES FishMap. Sole Fact Sheet. Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf [Accessed 26 May 2011].

Robb, A. P. and Hislop, J. R. G., 1980. *The food of five gadoid species during the pelagic 0-group phase in the northern North Sea*. Journal of Fish Biology 16: 199-217.

Robinson, S.P., Theobald, P.D., Hayman, G., Wang, L.S., Lepper, P.A., Humphrey, V., and Mumford, S., 2011. *Measurement of underwater noise arising from marine aggregate dredging operations*. Marine Aggregate Levy Sustainability Fund (MALSF).

Robinson, S.P., Theobald, P.D., Hayman, G., Wang, L.S., Lepper, P.A., Humphrey, V., and Mumford, S., 2011. *Measurement of underwater noise arising from marine aggregate dredging operations*. Marine Aggregate Levy Sustainability Fund (MALSF).

Robinson et al 2010 using data from: Arveson, P. T., and Vendittis, D. J.,, 2000. *Radiated noise characteristics of a modern cargo ship*. J. Acoust. Soc. Am., 107, 118-129.

Robinson, S.P., Theobald, P.D., Hayman, G., Wang, L.S., Lepper, P.A., Humphrey, V., and Mumford, S., 2011. *Measurement of underwater noise arising from marine aggregate dredging operations*. Marine Aggregate Levy Sustainability Fund (MALSF). (ch7.3.7)

Rochard, E. and P. Elie 1994 La macrofaune aquatique de l'estuaire de la Gironde. Contribution au livre blanc de l'Agence de l'Eau Adour Garonne. p. 1-56. In J.-L. Mauvais and J.-F. Guillaud (eds.) État des connaissances sur l'estuaire de la Gironde. Agence de l'Eau Adour-Garonne, Éditions Bergeret, Bordeaux, France. 115p. Referenced on Fish Base http://www.fishbase.org [Accessed15 May 2011].

Rogers, S. I., Ellis, J.R., and Dann, J. 2001. *The association between arm damage of the common starfish, Asterias rubens, and fishing intensity determined from aerial observation*. Sarsia 86, 107-112.

Royal Air Force 2011, *Royal Air Force Website*. http://www.raf.mod.uk/ [Accessed 25 July 2011]

The Royal Yachting Association and the Cruising Association. 2004. *Sharing the Wind: Recreational Boating in the offshore Wind Farm Strategic Areas*

RPS, 2005. *Humber Gateway Offshore Wind Farm Marine Mammal Survey Report* - Issue 2.

RPS, 2007. *Lincs Offshore Wind Farm Environmental Statement Volume One: Offshore: Chapters 1 to 8*. Centrica Energy.

RPS, 2008. *Marine Mammal Observer's and Passive Acoustic Monitoring Operator's Report during Lynn and Inner Dowsing Offshore Windfarm Installation*. RPS for Centrica (IDW) and (LW) Ltd.

RSPB. 1996. *Birds of Conservation Concern in the United Kingdom, Channel Islands and Isle of Man*. RSPB, BirdLife International, WWT, Game Conservancy Trust, BTO, H&OT, The Wildlife Trusts, The National Trust. RSPB Sandy, BEDS, 1996.

RSPB, 2011a. *Bird Guide* [online] Available at <http://www.rspb.org.uk/wildlife/birdguide/ > [Accessed June 2011]

RSPB, 2011b. *Tracking Gannets from Bempton Cliffs*. [online] Available at: <http://www.rspb.org.uk/ourwork/projects/details/273898-tracking-gannets-from-bempton-cliffs> [Accessed 28 June 2011]

Ruiz, A., 2008. Limanda limanda. Dab. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: <http://www.marlin.ac.uk/species/Limandalimanda.htm> [Accessed 25 May 2011].

Russell, F. S., 1976. *The eggs and planktonic stages of British marine fishes*. Academic Press, London. 524 pp. Cited in ICES. 2008. Striped red mullet factsheet. Available at <http://www.ices.dk/marineworld/fishmap/ices/pdf/redmullet.pdf [Accessed 23 May 2011].

Ryland, J. S. 1964. *The feeding of plaice and sand-eel larvae in the southern North Sea*. Journal of the Marine Biological Association of the United Kingdom 44: 343-364. Referenced in ICES FishMap. Plaice Fact Sheet. Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/plaice.pdf [Accessed 26 May 2011].

S

Marisa Sabatini and Susie Ballerstedt 2007. *Hippocampus hippocampus. Short snouted seahorse*. Marine Life Information Network: Biology and

Sanderson, W.G., 1996. *Rare marine benthic flora and fauna in Great Britain: the development of criteria for assessment*. JNCC Report, No. 240.

Santos, M., B., and Pierce, G. J., 2003. T*he diet of harbour porpoise (Phocoena phocoena) in the Northeast Atlantic*. Oceanography and Marine Biology: an Annual Review 2003, 41, p. 355-390.

Scientific Advice on Matters Related to the Management of Seal Populations, 2009. Special Committee on Seals (SCOS)

The Scottish Government, 2010. *Seal "corkscrew" Injuries FAQS. [online]* Available *at:* <http://www.scotland.gov.uk/Topics/marine/marine-environment/species/19887/20814/corkscrew> [Accessed 15 July 2011]

Scott Wilson (2009) *Flamborough Head to Gibraltar Point Shoreline Management Plan (2).*

SCOS, 2009. *Scientific Advice on Matters Related to the Management of Seal Populations 2009 :[online] Available at:* <http://www.smru.st-and.ac.uk/documents/341.pdf >[Accessed 15 July 2011].

Sear, D. A., Bacon, S. R., Murdock, A., Doneghan, G., Baggaley, P., Serra, C. and LeBas, T. P., 2011, Cartographic, Geophysical and Diver Surveys of the Medieval Town Site at Dunwich, Suffolk, England. International Journal of Nautical Archaeology, 40: 11

Sea Watch Foundation, 2010. *List of Manned Sites, Boat Surveys and Events for NWDW 2010*. [online] Available at: <www.seawatchfoundation.org.uk/event-data2010.php> [Accessed 15/07/11]

Sea Watch Foundation, 2011. *Bottlenose Dolphin (Tursiops truncatus)* [Online] Available at <http://www.seawatchfoundation.org.uk/species.php?uid=2> [Accessed 19 July 2011]

Sea Watch Foundation, 2011a. *Recent Sightings. [Online]* Available at:< http://www.seawatchfoundation.org.uk/recentsightings.php >[Accessed 02 February 2011)

Sea Watch Foundation, 2011b. *Threats*. [online] Available at: <http://www.seawatchfoundation.org.uk/about.php?uid=5> [Accessed 15 July 2011]

Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

Sharples, R.J., Matthiopoulos, J., and Hammond, P.S., 2008. *Distribution and movements of harbour seals around the coast of Britain: Outer Hebrides, Shetland, Orkney, the Moray Firth, St Andrews Bay, The Wash and the Thames*. Report to Geotek. Sea Mammal Research Unit. DTI.

Shipping Guides, 2011. UK shipping Ports [Online] Available at <http://www.portinfo.co.uk/port-information/uk-shipping-ports.html> [Accessed 25 July 2011]

Sicira Offshore Energy ltd (2006) Environmental Statement of the Sheringham Shoal Wind Farm.

Simon Group Ltd, 2011 [online] http://www.simonports.co.uk/ [Accessed 25 July 2011]

Slotte, A., Kansen, K., Dalen, J., and Ona, E. (2004). *Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. Fish*. Res. 67, 143-150

Small Cetaceans in the European Atlantic and North Sea (SCANS-II) Final Report. LIFE04NAT/GB/000245. Available at <http://biology.st-and.ac.uk/scans2/documents/final/SCANS-II_final_report.pdf>

Smith, R.C. Bidigare, R.R. Prezelin, B.B. Baker, K.S. and Brooks, J.M. 1987. *Optical characterisation of primary productivity across a coastal front. Marine Biology*. 96: 575-591.

Smith, I.P. Huntingford, F.A., Atkison, R.J.A, and Taylor, A.C. 1994. *Mate competition in the Velvet swimming crab, Nector puber, Effects of perceived resource value of male antagonistic behaviour*. Marine Biology 120 , 579 - 584. (5.2)

South East England Biodiversity Forum, 2011. *South East England biodiversity forum Website* [Online] Available at: <http://www.sebiodiversity.org.uk/> [Accessed: 27 October 2011].

Soulsby, R. L. 1997. *Dynamics of Marine Sands*. Thomas Telford.

Southern North Sea Sediment Transport Study (SNSSTS) (2002) Phase 2, Sediment Transport Report. Appendix 11 Report on Southern North Sea Longshore sediment transport. Report EX4526, Report for Great Yarmouth Borough Council. HR Wallingford.

Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. (2007). Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals 33(4):411-522.

SSE, 2011. *Gas Storage*. [Online] Available at <http://www.sse.com/OurBusiness/GasStorage/> [Accessed 20 July 2011]
Special Committee on Seals, 2009. *Scientific advice on matters related to the management of seal populations*, 2009. SCOS Main Advice 2009.[online] Available at: <http://www.smru.st-andrews.ac.uk/documents/341.pdf> [Accessed 13 June 2011]

Steyne, H, and MacLeod, I.D., 2011, *In-situ conservation management of historic iron shipwrecks in Port Phillip Bay: a study of J7 (1924), HMVS Cerberus (1926) and the City of Launceston (1865)*. Bulletin of the Australasian Institute for Maritime Arch.

Stone CJ, Webb A, Barton C, Ratcliffe N, Reed TC, Tasker ML, Camphuysen CJ and Pienkowski MW (1995) *An atlas of seabird distribution in north -west European waters*. JNCC, Peterborough.

T

Tappin, D R, Pearce, B, Fitch, S, Dove, D, Geary, B, Hill, J M, Chambers, C, Bates, R, Pinnion, J, Diaz Doce, D, Green, M, Gallyot, J, Georgiou, L, Brutto, D, Marzialetti, S, Hopla, E, Ramsay, E, and Fielding, H., 2011. *The Humber Regional Environmental Characterisation*. British Geological Survey Open Report OR/10/54. 357pp. (5.2)

Tasker, M.L., Amundin, M., Andre, M., Hawkins, A., Lang, W., Merck, T., Scholik-Scholmer, A., Teilmann, J., Thomsen, F., Werner, S., and Zakharia, M., 2010. *Marine Strategy Framework Directive - Underwater noise and other forms of energy*. European Union and ICES.

Frank Thomsen, Sophy McCully, Daniel Wood, Federica Pace and Paul White, 2009. *A Generic Investigation into Noise Profiles of Marine Dredging in relation to the Acoustic Sensitivity of the Marine Fauna in UK waters with particular emphasis on Aggregate Dredging: Phase 1 Scoping and Review of Key Issues* MEPF Ref No: MEPF

Thompson, B.M., Lawler, A.R. & Bennett, D.B., 1995. *Estimation of the spatial distribution of spawning crabs (Cancer pagurus L.) using larval surveys of the English Channel*. ICES Marine Science Symposia, 199, 139-150.

Thomsen, F., Gotz, T., Hastie, G., Hatch, L. T., Raustein, O., Southall, B. L., and Tasker, M., 2009. *Overview of the impacts of anthropogenic underwater sound in the marine environment. OSPAR Commission*.

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). *Effects of offshore wind farm noise on marine mammals and fish, biola, Hamburg, Germany on behalf of COWRIE Ltd*.

Tillin, H. M., Houghton, A. J., Saunders, J. E. & Hull, S. C., 2011. *Direct and Indirect Impacts of Marine Aggregate Dredging. Marine ALSF Science Monograph Series No. 1. MEPF 10/P144.* (Edited by R. C. Newell & J. Measures). 41pp. ISBN: 978 0 907545 43 9 (9.3)

Tortonese, E. 1986. Moronidae. P 793-796. In P.J.P. Whitehead, M. -L. Bauchot, J. -C. Hureau, J. Nielsen and E. Tortonese (eds.). Fishes of the north-eastern Atlantic and the Mediterranean. UNESCO, Paris, vol 2. Referenced on Fish Base http://www.fishbase.org

Turnpenny, A.W.H., Thatcher, K.P., and Nedwell, J.R., 1994. The effects on fish and other marine animals of high level underwater sound. Report FRR 127/94, Fawley Aquatic Research Laboratories Ltd, Southampton, UK. .

Tyler-Walters, H. 2007. *Modiolus modiolus*. Horse mussel. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 05 December 2011]. Available from: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3817.

Tyler-Walters, H. 2008a. *Echinus esculentus*. Edible sea urchin. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 05 December 2011]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=3237.
Tyler-Walters, H. 2008b. *Mytilus edulis*. Common mussel. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 05/12/2011]. Available from: http://www.marlin.ac.uk/speciesbenchmarks.php?speciesID=3848.

U

UK biodiversity Habitat Action plan. 2008 available at <http://ukbap.org.uk/library/UKBAPPriorityHabitatDescriptionsfinalAllhabitats20081022.pdf>. Accessed 27/10/11.

UKCP, 2009. *UK Climate Projections – Sea level Rise*. [Online] http://www.ukcip.org.uk/ukcp09/ [Accessed 8 April 2011].

Uncles, R.J. Stephens, J.A. and Law, D.J. 2006. *Turbidity maxima in the macrotidal, highly turbid Humber Estuary, UK: Flocs, fluid mud, stationary suspensions and tidal bores*. Estuarine, Coastal and Shelf Science 67: 30 – 62.

United Kingdom Marine Monitoring and Assessment Strategy (UKMMAS) (2010). *Charting Progress 2 Feeder Report Productive Seas. Department for Environment Food and Rural Affairs on behalf of UKMMAS* (Eds. Saunders, J. and McKie, J.) 472pp.

V

Vancouver Aquarium, 2011. *Vancouver Aquarium Website*. Available at: <http://www.vanaqua.org/learn/aquafacts/otters-and-pinnipeds/harbour-seals> [Accessed 28 March 2011]

Vanstaen, K. , 2011. *Assessment of the distribution and intensity of fishing activities in the vicinity of aggregate extraction sites*, MEPF/08/P73 MALSF CEFAS

Van der Kooij, J, Scott, B, and Mackinson, S., 2008. *The effects of environmental factors on daytime sandeel distribution and abundance on the Dogger Bank. Journal of Sea Research* 60: 201 – 209.

Vincent, A. C. J. 1995. *A role for daily greetings in maintaining seahorse pair bonds*. Anim. Behav. 49: 258-260.

Voss, R, Dickmann, M and Schmidt, J. (2009) *Feeding ecology of sprat (Sprattus sprattus L.) and sardine (Sardina pilchardus W.) larvae in the German Vight, North Sea. Oceanologia, 51* (1) 2009.

W

Walker, P., Howlett, G. & Milner, R. 1997. *Distribution, movement and stock structure of three ray species in the North Sea and eastern English Channel. ICES Journal of Marine Science*, 54: 797-808.

Walker, A.J.M. 1972. *Goniadella gracilis*, a polychaete new to British seas. Marine Biology 14: 85 – 87.

Walmsley, S.A. and Pawson, M.G., 2007. *The coastal fisheries of England and Wales, Part V: a review of their status 2005-6*. Sci.Ser.Tech.Rep.,Cefas Lowestoft, 140: 83pp.

Ware, S. J. & Kenny, A.J. 2011. Guidelines for the conduct of Benthic Studies at Marine Aggregate Extraction Site (2nd Edition). Marine Aggregate Levy Sustainability Fund, 80 pp.

Warren, P.J. 1973. The fishery for the pink shrimp *Pandalus* montagui in the Wash. Ministry for Agriculture, Fisheries and Food. Laboratory Leaflet No. 28. Lowestoft, Suffolk. Available from: http://www.cefas.defra.gov.uk/publications/lableaflets/lableaflet28.pdf.

Laura Weiss, Cefas, personal communication 30/11/09.

Wenban-Smith, F., 2002. *Palaeolithic and Mesolithic Archaeology on the Sea-bed: Marine Aggregate Dredging and the Historic Environment, Wessex Archaeology*

Wessex Archaeology, 2008b. *Aircraft Crash Sites at Sea: A Scoping Study. Archaeological Desk-based Assessment*, unpublished report 66641.02

Wessex Archaeology, 2011. *HADA Marine Aggregate Regional Environmental Assessment. Archaeological Desk-based Assessment.*.

Wilding. C. and Avant. P., 2009. *Tursiops truncatus. Bottle-nosed dolphin. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme* [on-line]. Plymouth: Marine Biological Association of the United Kingdom.

Wildlife Extra, 2011. *Donna Nook Seal Colony*. [online] Available at <http://www.wildlifeextra.com/do/ecco.py/view_item?listid=14&listcatid=185&listitemid=3967&live=0> [Accessed 15 July 2011].

Wingfield, R. and Evans, C.,1998. *The significance of the shoreface ramp for coastal development: Holderness, eastern England, UK*. Proceedings of Littoral '98.

Williams, A.D, Williams, R. Heimlich, J.R. Evans, P.G.H, Trengz, N.J.C., Ridoux, V. Liret, C. and Savage, S., 1996. *A preliminary report on an investigation into bottlenose dolphins of the English Channel. European Research on Cetaceans*. 10, 217 – 220.

Wilhelmsson, D, Malm, T and Ohman, C .,2006. *The influence of offshore windpower on demersal fish*. ICES Journal of Marine Science 63: 775 – 784.

Woodhead, P.M.J. 1964. Changes in the behaviour of the sole, Solea vulgaris, during cold winters, and the relation between the winter catch and sea temperatures. Helgoländer Wissenschaftliche Meeresuntersuchungen 10: 328-342. Referenced in: ICES FishMap. Sole Fact Sheet. Available at: http://www.ices.dk/marineworld/fishmap/ices/pdf/sole.pdf (accessed26/05/11).

Wymer, J.J., 1985, 'Palaeolithic sites of East Anglia', Geo Books, Norwich.

Wymer, J., 1999, The Lower Palaeolithic Occupation of Britain. England: Wessex Archaeology and English Heritage. Ch6.6.

Z

Zhou, J.L., Fileman, W., Evans, S., Donkin, P., Fauzi, R., Mantoura, C. and Rowland, S.J. 1996. *Seasonal distribution of dissolved pesticides and polynuclear aromatic hydrocarbons in the Humber Estuary and Humber coastal zone, Marine Pollution Bulletin, 32: 5*

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