Guidelines on the impact of aggregate extraction on European marine sites

Canllawiau ynglyn ag effaith cloddio cerrig mân ar safleoedd morol Ewropeaidd

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Guidelines on the impact of aggregate extraction on European marine sites

Preface

The 1990s have witnessed a "call to action" for marine biodiversity conservation. The global Convention on Biodiversity, the European Union's Habitats Directive and recent developments to the Oslo and Paris Convention have each provided a significant step forward. In each case marine protected areas are identified as having a key role in sustaining marine biodiversity.

The Habitats Directive requires the maintenance or restoration of natural habitats and species of European interest at favourable conservation status, with the management of a network of Special Areas of Conservation (SACs) being one of the main vehicles to achieving this. Among the habitats and species specified in the Annexes I and II of the Directive, several are marine features and SACs have already been selected for many of these in the UK. But to manage specific habitats and species effectively there needs to be clear understanding of their distribution, their biology and ecology and their sensitivity to change. From such a foundation, realistic guidance on management and monitoring can be derived and applied.

One initiative now underway to help implement the Habitats Directive is the UK Marine SACs LIFE Project, involving a four year partnership (1996-2001) between:

English Nature
Scottish Natural Heritage
Countryside Council for Wales
Environment and Heritage Service of the Department of the Environment for Northern Ireland Joint Nature Conservation Committee (JNCC), and
Scottish Association of Marine Science (SAMS).

The overall goal of the project is to establish management schemes on 12 of the candidate marine SAC sites. A key component of the Project is to assess the interactions that can take place between human activities and the Annex I and II interest features on these sites. This understanding will provide for better management of these features by defining those activities that may have a beneficial, neutral or harmful impact and by giving examples of management measures that will prevent or minimise adverse effects.

Seven areas where human activity may impact on marine features were identified for study, ranging from specific categories of activity to broad potential impacts. They are:

- Port and harbour operations
- Recreational user interactions
- Collecting bait and shoreline animals
- Water quality in lagoons
- Water quality in coastal areas
- Aggregate extraction
- Fisheries.

These seven were selected on the grounds that each includes issues that need to be considered by relevant authorities in managing many of the marine SACs. In each case, the existing knowledge is often extensive but widely dispersed and needs collating as guidance for the specific purpose of managing marine SACs.

Our existing knowledge on each of these activities varies and therefore, whilst working to a common aim, each study has been targeted to the particular gaps and needs of most relevance in managing activities on the SACs.

The reports from these studies are the results of specialist input and wide consultation with representatives of both the nature conservation, user and interest bodies. They are aimed at staff from the relevant authorities who jointly have the responsibility for assessing activities on marine SACs and ensuring appropriate management. But they will also provide a valuable resource for industry, user and interest groups who have an important role in advising relevant authorities and for practitioners elsewhere in Europe.

The reports provide a sound basis on which to make management decisions on marine SACs and also on other related initiatives such as the Biodiversity Action Plans and Oslo and Paris Convention. As a result, they will make a substantial contribution to the conservation of our important marine wildlife. We commend them to all concerned with the sustainable use and conservation of our marine and coastal heritage.

Sue Collins
Chair, UK Marine SACs Project
Director, English Nature.

Dr Margaret Hill
Head Maritime and Earth Science Group
Countryside Council for Wales

Canllawiau ynglyn ag effaith cloddio cerrig mân ar safleoedd morol Ewropeaidd

Rhagair

Yn ystod y 1990au bu galw am i rywbeth gael ei wneud dros gadwraeth bioamrywiaeth morol. Mae'r Cytundeb byd-eang ar Fioamrywiaeth, Gorchymyn Cynefinoedd yr Undeb Ewropeaidd a datblygiadau diweddar i Gytundeb Oslo a Pharis oll wedi darparu cam arwyddocaol ymlaen. Ym mhob achos mae ardaloedd morol gwarchodedig yn cael eu cydnabod fel rhai sy'n chwarae rhan allweddol mewn cynnal bioamrywiaeth morol.

Mae'r Gorchymyn Cynefinoedd yn gofyn am gynnal neu adfer cynefinoedd a rhywogaethau naturiol o ddiddordeb Ewropeaidd ar safleoedd cadwraeth ffafriol. Un o'r ffyrdd pennaf o sicrhau hyn yw drwy reolaeth ar rwydwaith o Ardaloedd Cadwraeth Arbennig (ACA). Ymhlith y cynefinoedd a'r rhywogaethau sydd wedi'u nodi yn Atodiad I a II y Gorchymyn, mae nifer ohonynt â nodweddion morol ac mae ACA eisoes wedi'u dewis ar gyfer nifer o'r rhain yn y DU. I reoli cynefinoedd a rhywogaethau penodol yn effeithiol, fodd bynnag, mae angen dealltwriaeth glir ynglyn â'u dosbarthiad, eu bioleg a'u hecoleg a'u sensitifedd i newid. Ar sail y wybodaeth yma, gellir llunio a gweithredu canllawiau realistig ynglyn â rheolaeth a monitro.

Un fenter sydd ar y gweill ar hyn o bryd i gynorthwyo i weithredu'r Gorchymyn Cynefinoedd yw Prosiect LIFE ACA Morol y DU, sydd wedi golygu partneriaeth bedair blynedd (1996-2001) rhwng:

English Nature
Scottish Natural Heritage
Cyngor Cefn Gwlad Cymru
Cydbwyllgor Gwarchod Natur (JNCC/*CGN*) Gwasanaethau Amgylchedd a Threftadaeth
Adran yr Amgylchedd Gogledd Iwerddon, a
Scottish Association of Marine Science (SAMS)

Nod terfynol y prosiect yw sefydlu cynlluniau rheoli ar gyfer 12 o'r safleoedd yACAF. Rhan allweddol o'r Prosiect yw asesu'r ymadweithiau all ddigwydd rhwng gweithgareddau dynol a nodweddion o ddiddordeb Atodiad I a II ar y safleoedd yma. Bydd y ddealltwriaeth yma yn arwain at reolaeth well o'r nodweddion hyn a hynny trwy ddiffinio'r gweithgareddau rheini fyddai o bosibl yn cael effaith fuddiol, niwtral neu niweidiol a thrwy roi esiamplau o ddulliau rheoli fydd yn rhwystro neu'n lleihau effeithiau niweidiol.

Cafodd saith o feysydd ble y byddai gweithgaredd ddynol yn debygol o effeithio ar nodweddion morol eu henwi ar gyfer astudiaeth, yn amrywio o gategorïau penodol o weithgaredd i effeithiau posibl eang. Dyma'r saith maes a enwyd:

- Gweithrediadau porthladd a harbwr
- Ymadweithiau rhywun sy'n eu defnyddio ar gyfer hamddena
- Casglu abwyd ac anifeiliaid y traeth
- Ansawdd y dwr mewn morlynnoedd

- Ansawdd y dwr mewn ardaloedd arfordirol
- Cloddio cerrig mân
- Pysgodfeydd

Cafodd y saith yma eu dewis oherwydd fod pob un ohonynt yn cynnwys materion sydd angen cael eu hystyried gan awdurdodau perthnasol wrth reoli nifer o'r ACA morol. Ym mhob achos, mae'r wybodaeth sydd ar gael ar hyn o bryd yn aml yn eang ond yn wasgarog iawn ac angen ei goladu fel canllaw ar gyfer y diben penodol o reoli'r ACA morol.

Mae'r wybodaeth sydd gennym ar hyn o bryd ar bob un o'r gweithgareddau hyn yn amrywio ac felly, tra'n gweithio tuag at nod cyffredin, mae pob astudiaeth wedi'i thargedu ar gyfer y bylchau a'r anghenion penodol sydd fwyaf perthnasol wrth reoli'r gweithgareddau ar y SCA.

Mae'r adroddiadau sy'n deillio o'r astudiaethau hyn yn gynnyrch cyfraniad arbenigol ac ymgynghori eang gyda chynrychiolwyr y cyrff gwarchod natur, y defnyddwyr a'r rhai â diddordeb. Maent wedi'u paratio ar gyfer staff yr awdurdodau perthnasol sydd â chyd gyfrifoldeb am asesu gweithgareddau mewn ACA morol a sicrhau rheolaeth berthnasol. Ond byddant hefyd yn darparu adnodd werthfawr i ddiwydiant, grwpiau defnyddwyr a grwpiau o rai â diddordeb sydd â swyddogaeth bwysig o gynghori awdurdodau perthnasol. Byddant yn adnodd werthfawr hefyd i ymarferwyr mewn lleoedd eraill yn Ewrop.

Mae'r adroddiadau yn sylfaen cadarn ar gyfer gwneud penderfyniadau rheolaeth ynglyn ag ACA morol a hefyd ar fentrau perthnasol eraill fel y Cynlluniau Gweithredu Bioamrywiaeth a Chytundeb Paris. O ganlyniad, byddant yn gwneud cyfraniad pwysig i gadwraeth ein bywyd gwyllt morol pwysig. Rydym yn eu cymeradwyo i bawb sydd yn ymwneud â defnydd cynaliadwy a chadwraeth ein treftadaeth forol ac arfordirol.

Sue Collins
Cadeirydd, Prosiect ACA Morol y DU
Cyfarwyddwr, English Nature

Dr Margaret Hill
Pennaeth Grwp Gwyddorau Daear ac Arforol
Cyngor Cefn Gwlad Cymru

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Summary

Objectives of the guidelines

The EC Habitats Directive aims to promote the conservation of habitats and species within the European Union by designating sites known as Special Areas of Conservation (SACs). The UK Marine SACs Project aims to promote the implementation of the Habitats Directive in marine areas through trialing the establishment of management schemes on twelve sites in the UK and by providing proven good practice and guidance to practitioners in the UK and Europe. To support the establishment of these management schemes, the Project is undertaking a series of tasks to collate and develop the understanding and knowledge needed. One of the areas for providing guidance to those developing the schemes concerns the interaction between human activities and marine features. Human activities have an important role in the management of marine features and may have both beneficial and damaging impacts.

This report has been prepared to provide information and guidance on aggregate extraction activities. There are a number of objectives for the series of guidance documents forming part of the UK Marine SACs Project. These are:

- to identify the activity and circumstances where the impact on conservation features is minimal or beneficial;
- to identify the operations and circumstances where potential for adverse effect does exist;
- to identify existing guidance and procedures which can be used to exercise appropriate controls for avoiding, minimising or addressing these impacts.

The target audience for these guidelines are:

- Relevant authorities;
- Country conservation agencies;
- Industry and interest groups;
- European practitioners;
- Competent authorities.

The overall aim of this task is to provide information on the potential impacts of aggregate extraction on marine and coastal habitats and species listed in Annexes I and II of the Habitats Directive and provide guidance on the assessment of potential impacts. In particular, the project will:

- review and summarise literature on the effects of aggregate (including maerl) extraction on Annex I habitats and Annex II species;

- identify circumstances where cumulative impacts may occur and make recommendations on how thresholds could be set for assessing such cumulative impacts;
- provide a framework for decisions on the significance of aggregate extraction and effects on SACs;
- review information on appropriate monitoring packages and draw out best practice;
- investigate the methods used for cumulative impact assessment in the UK and overseas (to cover both the scientific and procedural aspects);
- make recommendations on how management schemes for Marine SACs might be linked to assessments of the environmental impacts of aggregate extraction licences.

Potential individual and cumulative impacts of marine aggregate extraction

One of the objectives of this document is to review available information regarding the potential direct, indirect, individual and cumulative impacts of marine aggregate extraction on the marine environment. Table 1 summarises the potential impacts of marine aggregate extraction on a range of Annex I habitats and Annex II species and gives an indication of the likely duration of impact on each habitat and species. A study of the recovery of the benthic community following dredging of gravel substrate at a site in East Anglia has shown that diversity and biomass returned to pre-dredging levels after three years, but the number of individual animals per unit area remains at a lower level in the dredged site.

Examination of the distribution of licensed areas for marine aggregate extraction in relation to marine and coastal cSACs provides an indication of the European sites that could potentially be influenced by the effects of aggregate extraction, either in isolation or potentially through the cumulative effects of multiple offshore licensed areas. It can be seen that the European sites most likely to be affected by aggregate extraction are those on the eastern and south-eastern coasts of the UK and the Severn Estuary /Bristol Channel, where extraction activity is concentrated. As at April 2000, the only SAC within which aggregate extraction takes place is the Severn Estuary (currently pSAC and SPA), whilst maerl extraction occurs within the Fal and Helford cSAC.

Potential for cumulative effects

Cumulative effects may occur as a result of aggregate extraction at one site, from several sites in proximity, or in combination with effects of other activities such as fishing, waste disposal, capital and maintenance dredging, coastal defences, anchoring or installation of offshore structures. Table 2 summarises possible combined impacts with other activities. In most cases, the potential for the cumulative impacts of several aggregate extraction licences occurs indirectly through changes in nearshore waves, sediment transport or plumes, rather than through direct effects of removing the substrate and benthos.

Table 1 Potential impacts on Annex I habitats and Annex II species

Qualifying feature	Potential impact					
	ReMoval of Substratum/Benthos	**Increased Turbidity**	**Changes in Sediment Composition**	**Changes in Htydrodynamics/Sediment Transport**	**Water Chemistry Effects**	**Behavioural changes due to disturbance**
Annex 1 Habitat						
Sublittoral sandbanks	M-L	S	M-L	M-L	S	
Estuaries	M-L	S	M-L	M-L	S	
Mudflats and sandflats	M-L	S	M-L	M-L	S	
Lagoons				M-L		
Large shallow inlets and bays	M-L	S	M-L	M-L	S	
Reefs		S	M-L		S	
Sea cliffs and shingle/stony banks				M-L		
Saltmarshes and salt meadows				M-L		
Coastal sand dunes				M-L		
Rocky habitats and caves		S		M-L	S	
Annex II Species						
Marine Mammals	S-M	S			S-L	S
Fish	S-M	S	M-L		S	S

KEY: S=Short-term impact M=Medium-term impact L=Long-term impact

Short term impacts are those which are expected to occur over a period of a few hours up to several days. Medium term impacts are expected to have a duration of several months up to 1 year, with long term impacts lasting more than 1 year. If an impact is indicated as being short term, this does not mean that it is necessarily insignificant, and *vice versa***.**

Table 2 Possible impacts of various activities when combined with aggregate extraction

Potential Impact	Activity								
	Fishing	Organic Pollution/ Eutrophication	Other Pollution	Coastal Alteration	Spoil and Waste Disposal	Capital and Maintenance Dredging	Anchoring of Large Vessels	Other Aggregate Extraction areas	Offshore Structures
Increased Turbidity	✓	✓			✓	✓		✓	
Removal of Substrate/ Effects on Benthos	✓	✓	✓	✓	✓	✓	✓	✓	
Modification of Sediment Composition	✓	✓			✓	✓	✓	✓	✓
Excessive Sedimentation	✓	✓			✓	✓		✓	
Water Chemistry Effects		✓	✓		✓	✓		✓	✓
Increased Primary Production	✓	✓				✓		✓	
Increased Food Supply	✓	✓				✓		✓	
Changes in Hydrodynamics	✓			✓	✓	✓		✓	✓
Changes in Sediment Transport				✓	✓	✓		✓	

KEY: ✓= Possible combined impact that may require further investigation

Guidance on cumulative impact assessment

Environmental Statements produced for the assessment of proposed aggregate extraction licences have rarely in the past considered in combination effects (i.e. the impact of aggregate extraction in combination with other activities, such as commercial fishing). The cumulative effects of aggregate dredging on hydrodynamic parameters (e.g. wave height, sediment transport) are addressed through the licensing system. However, the impact of any such cumulative effect on biological interests must also be considered. The Habitats Directive requires the effect on a site of a project to be assessed individually and in combination with other projects: this is a particular, specialist, type of cumulative impact assessment.

The report identifies guidance on cumulative environmental impact assessment (CEIA) methodology, particularly that which has been developed in North America and by the EC. The main components of a CEIA framework are outlined in Table 3.

Following the review of CEIA methodologies and procedures, guidelines are developed for applying these methodologies to aggregate extraction proposals. A number of examples of cumulative environmental impact assessment (unrelated to aggregate extraction) are presented. It is recommended that, where needed, scoping of the Appropriate Assessment is carried out early in the CEIA process.

Monitoring

One purpose of monitoring is to document whether impacts identified as unacceptable are evident, or whether conditions that will lead to an unacceptable impact are occurring. A monitoring programme should provide the site manager with clearly interpretable information about whether a threshold of adverse condition has been, or is likely to be, reached, so that decisions about continued or modified site use can be made.

Guidelines on the purpose of monitoring are reviewed and it is concluded that the most fundamental step in the development of a monitoring programme is to define the goals and objectives of the monitoring programme. This stage is often not documented properly and therefore the resulting data collection efforts lead to little useful information for decision-making. Where possible, a monitoring programme should set specific thresholds for conditions (biological and physical) which should not be exceeded.

Table 3 Assessment framework for Cumulative Environmental Impact Assessment

Main components of a CEIA methodology	
Basic EIA Steps	Tasks to complete for a CEIA
Scoping	Identify regional issues of concern Select appropriate regional valued Ecosystem Components (VECs) Identify spatial and temporal boundaries Identify other actions that may affect the same VECs Identify potential impacts due to actions and possible effects
Analysis of Effects	Complete the collection of regional baseline data Assess effects of proposed action on selected VECs Assessment of effects of all selected actions on selected VECs
Identification of Mitigation	Recommend mitigation measures
Evaluation of Significance	Evaluate the significance of residual effects Compare results against thresholds or land use objectives and trends
Follow-up	Recommend regional monitoring and effect management

Monitoring programmes can be designed to meet a number of objectives:

- to document the baseline conditions at the start of an EIA;
- to test impact predictions and thus further environmental understanding and improve predictive capability for future activities of the same type;
- to modify mitigation measures if there are unpredicted harmful effects on the environment;
- to verify the effectiveness of mitigation measures;
- to assess performance and monitor compliance with agreed conditions specified in operating licenses;
- to provide early warning of undesirable change so that corrective measures can be implemented; and,
- to provide evidence to refute or support claims for damage compensation.

The report identifies a useful approach to monitoring using a multi-tiered structure with each level having its own unacceptable environmental threshold. Experts in a number of relevant disciplines should be drawn together in the development of monitoring programmes to allow a thorough examination of the wide range of factors that must be considered. The aim of the tiered approach is to avoid an over-intensive programme which can result in unnecessary monitoring and therefore waste resources.

A number of operational monitoring programmes are reviewed, including those for Hastings Bank aggregate extraction area, the Oresund Fixed Link and the Harwich Haven Approach Channel Deepening.

Recommendation for integrating assessment of plans and projects into schemes of management for marine SACs

The report suggests several ways to link the management schemes and the consideration of aggregate extraction projects. These are:

- the management group could be a consultee in the licence determination process;
- the management group could fulfil an important role in identifying possible cumulative impacts, especially with other operations and activities, and as an expert opinion in scoping Environmental Impact Assessments;
- co-ordinating the surveillance and condition monitoring of marine SAC features with monitoring the impacts of aggregation extraction or other operations;
- zoned management of activities or operations such as aggregate extraction, in the management scheme.

1. Introduction

1.1 UK Marine SACs Project

This report has been prepared as part of the UK Marine SACs Project. The overall aim is to promote the implementation of the Habitats Directive in marine areas through the establishment of management schemes on twelve sites in the UK and by providing proven good practice and guidance to practitioners in the UK and Europe.

As part of the project a series of tasks to collate and develop the understanding and knowledge required to support the establishment of these management schemes are being undertaken. One of the areas for providing guidance to those developing the schemes concerns the interaction between human activities and marine features. Human activities have an important role in the management of marine features and may have both beneficial and damaging impacts. This report provides guidance on the potential impacts, both individual and cumulative, relating to aggregate extraction activities. It is one of seven studies bringing together guidance on these impacts and promoting the means of avoiding significant damage to features listed in the Habitats Directive.

1.2 Objectives of the guideline series

The objectives of the series of guideline documents are:

- to identify the activity and circumstances where the impact on conservation features is minimal or beneficial;
- to identify the operations and circumstances where potential for adverse effect does exist;
- to identify existing guidance and procedures which can be used to exercise appropriate controls for avoiding, minimising or addressing these impacts.

The target audience for these guidelines are:

- Relevant authorities – to inform in the development and implementation of management schemes and to assist them in meeting their statutory obligations.
- Country conservation agencies – to improve understanding of the operations and environmental management undertaken with respect to aggregate extraction.
- Industry and interest groups – to provide guidance and awareness of the potential impacts of the activity on European sites and promote good environmental practice.
- European practitioners – to act as a guide for those involved in implementing the Habitats Directive throughout Europe and to provide an example of how the development and implementation of management schemes can be facilitated.

1.3 Background to European Marine Sites

1.3.1 Habitats and Birds Directive

In May 1992, the Member States of the European Union adopted 'Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora'. This is more commonly referred to as the Habitats Directive. The main aim of the Directive is to promote the maintenance of biodiversity and it requires Member States to work together to maintain or restore to favourable conservation status certain rare, threatened, or typical natural habitats and species. These are listed in Annex I and II to the Directive respectively.

One of the ways in which Member States are expected to achieve this aim is through the designation and protection of a series of sites, known as Special Areas of Conservation (SACs).

Council Directive 79/409/EEC on the conservation of wild birds, more commonly known as the Birds Directive, complements the Habitats Directive by requiring member states to protect rare or vulnerable bird species through designating Special Protection Areas (SPAs). Together, the terrestrial and marine SPAs and SACs are intended to form a coherent ecological network of sites of European importance, referred to as Natura 2000.

1.3.2 UK implementation

The requirements of the Habitats Directive have been transposed into UK legislation through the Conservation (Natural Habitats &c.) Regulations 1994 and the Conservation (Natural Habitats &c.) Regulations (Northern Ireland) 1995, known as the Habitats Regulations.

Unlike the situation on land, where SACs and SPAs are underpinned by Sites of Special Scientific Interest (SSSIs), there is no existing legislative framework for implementing the Habitats Directive in marine areas. Therefore the Regulations have a number of provisions specifically for new responsibilities and measures in relation to marine areas.

The Regulations place a general duty on all statutory authorities exercising legislative powers to perform these in accordance with the Habitats Directive. The term 'European marine site' is defined to mean any SPA and SAC site, or part of a site, that consists of a marine area. Marine is defined as including intertidal areas. The new duties in connection with the management of marine sites are summarised below.

1.3.3 Management schemes

In the UK, management schemes may be established on European marine sites as a key measure in meeting the requirements of the Habitats Directive. Each scheme will be prepared by a group of authorities having statutory powers over the marine area. These 'relevant authorities' are those who are already involved in some form of regulatory function and would therefore be directly involved in the management of a marine site. They include the following:

- Country conservation agency;
- Local authorities;
- Environment agencies;
- Sea Fisheries Committees;
- Port and harbour authorities;
- Navigation authorities;
- Lighthouse authorities.

A scheme may be established by one or more of the relevant authorities. It is expected that one will normally take the lead. Once established, all the relevant authorities have an equal responsibility to exercise their functions in accordance with the scheme. Each site can have only one management scheme.

The Habitats Regulations set out which authorities have responsibilities for managing these sites and how they are to be managed, as described below.

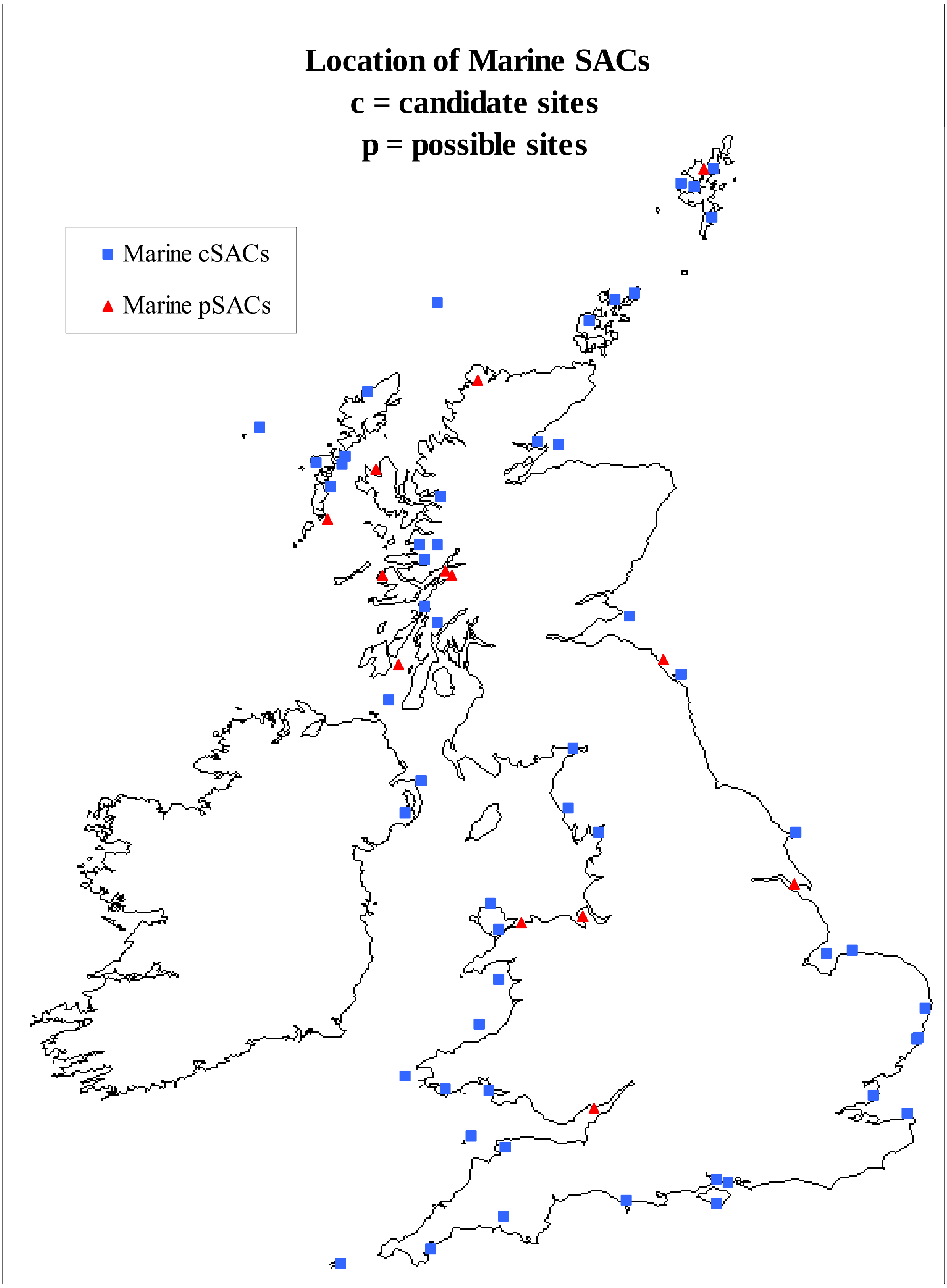
Whilst only relevant authorities have the responsibility for establishing a management scheme, government policy (DETR guidance on “European marine sites in England and Wales”) strongly recommends that other groups including owner and occupiers, users, industry and interest groups are involved in developing the scheme. To achieve this it suggests the formation of advisory groups and a process for regular consultation during the development and operation of the scheme.

Within the Regulations the nature conservation bodies have a special duty to advise the other relevant authorities as to the conservation objectives for a site and the operations that may cause deterioration or disturbance to the habitats or species for which it has been designated. This advice forms the basis for developing the management scheme.

The scheme will encourage the informed management and use of an area without detriment to the environment, based on the principle of sustainability. European marine sites have been selected with many activities already taking place and it is recognised that these activities are normally compatible with the conservation interest at their current levels. Only those activities that would cause deterioration or disturbance to the features for which a site has been designated need to be subject to restrictions under a management scheme.

The primary focus of a management scheme is to manage activities taking place within or adjacent to a European marine site, hence promoting its sustainable use. However, it may also provide guidance for the assessment of plans and projects, particularly those of minor or repetitive nature. A plan or project is any operation which requires an application to be made for a specific statutory consent, authorisation, licence or other permission. Not all types of plan or project fall within the statutory functions of relevant authorities, but are consented or authorised by other statutory bodies, termed competent authorities (e.g. central government departments).

Figure 1.3.4 Map of candidate (cSACs) and possible (pSACs) Marine Special Areas of Conservation in the UK (May 2001).



1.3.4 UK marine SACs

In the UK, candidate marine SACs have been selected for ten features listed in Annex I and II of the Directive (see Table 1.3.4 and Section 4 for further details). At May 2001 there were 54 sites that had been forwarded to the European Commission as candidate marine SACs (see Appendix A).

In addition to the marine habitats listed in Table 1.3.4, sites have also been selected for coastal habitats or species such as saltmarsh, sand dune, shore dock and otter. Such sites generally include the intertidal zone but are part of ecological systems that extend above high water. These coastal SACs are discussed in this report in so far as they could be affected by aggregate extraction, particularly where extraction may occur in, or influence intertidal or coastal habitats and species.

Table 1.3.4 Key features for the selection of marine SACs

Annex I habitat	Annex II species
Estuaries	Bottlenose dolphin
Large shallow inlets and bays	Common seal
Sandbanks which are slightly covered by seawater at all times	Grey seal
Mud and sandflats not covered by sea water at low tide	
Reefs	
Lagoons	
Submerged or partially submerged sea caves	

Map showing the locations of marine and coastal SACs around the UK coast are presented in Figure 1.3.4 and Appendix A. Where available, the boundaries of marine SACs are shown to give some indication of their seaward extent. A map of the aggregate extraction areas which are currently licensed by the Crown Estate has also been overlaid onto these figures, giving an indication of the location of extraction areas in relation to SACs. In addition, to the marine SAC sites, there are also around 126 classified and potential SPAs in the UK with an intertidal element.

1.4 Background to aggregate extraction

Dredging offshore for aggregates began in the early twentieth century but it did not reach a significant scale until the 1970s as markets for marine aggregates expanded and dredging technology improved. Almost all marine aggregate extraction takes place under licence for specified areas of the seabed owned by the Crown Estate. Permission is granted by the Department of Transport, Local Government and the Regions (DTLR formerly DETR), the National Assembly for Wales or the Scottish Executive (see Section 2 for further details).

1.4.1 Resources and utilisation

Demand for marine aggregate in England and Wales has currently been estimated at approximately 20-24 million tonnes per annum from a peak of 28 million tonnes in 1989 (DETR, 2001). Of this, approximately 50% goes to the UK construction industry, 20% to beach nourishment schemes and the remaining 30% is exported. Demand for aggregate has increased steadily over the past 40-50 years and the proportion that will be met from marine sources is expected to rise (data from BGS Seminar, February 1999).

In particular, marine dredged material is increasingly needed for beach nourishment as part of ‘soft’ coast protection and sea defence schemes. There are currently 74 areas licensed by the Crown Estate and 37 licence applications in the pipeline. Within the existing licensed areas there are resources of 300 million tonnes, and a further estimated 300 million tonnes of reserves in prospective areas. These amounts are sufficient to provide over 20 years supply at current extraction rates (data from BGS Seminar, February 1999).

Sand and gravel deposits on the seabed that comply with the relevant quality standards (BS 882) are not widespread. Economic factors, technical constraints and the occurrence of suitable deposits of sand and gravel dictate the location of dredging areas. Distance from the licence area to the point of landing and market is critical in determining the commercial viability and competitiveness of marine aggregates. Water depth is also fundamental, dredgers can work in a maximum water depth of 50 metres but most extraction takes place between 10 and 35 metres. These factors have led to a concentration of dredging licences in areas such as the Outer Thames Estuary, off Great Yarmouth and around the Isle of Wight, and their absence in others, for example Lyme Bay and the western approaches.

The total area of seabed where licences permit dredging and where extraction may take place is equal to 0.8% of the UK Continental Shelf (Crown Estate 2000, see Table 1.4.1a). The actual area dredged each year is approximately 0.12%. When considered on a regional basis the area subject to aggregate dredging is small, particularly when compared with trawling for fish. The International Council for the Exploration of the Sea (ICES) state that only 0.03% of the North Sea is dredged for aggregates each year, compared with trawling which may have similar impacts on the seabed to dredging (particularly with respect to benthic communities) and covers 54% of the North Sea (ICES 1992).

Table 1.4.1a Area of seabed licensed for aggregate extraction in 1997

Region	Approximate area of seabed/km^2	Total area licensed for dredging/km^2	% of seabed licensed	Total area Dredged per annum km^2	% of licensed seabed dredged annually
Humber	90,000	468.5	0.52	51.3	11.0
East	10,000	404.5	4.05	98.4	24.3
Thames	10,000	328.6	3.29	26.0	7.9
South	40,000	311.9	0.83	36.6	11.7
South West	30,000	51.5	0.17	18.5	35.9
North West	20,000	96.2	0.48	0.89	0.9
Total	200,000	1661.2	0.83	2311.7	14.0

Data from Crown Estate (2000)

The area of seabed dredged and the tonnage extracted compared with the area licensed and the maximum level of permitted extraction vary widely from licence to licence and region to region (Crown Estate 2000, see Table 1.4.1b). These differences mainly reflect:

- **The distribution of sand and gravel** – sediment can occur in well defined areas or in irregular shaped patches with intervening areas of non-productive seabed. This limits the area of a licence that will be actually dredged.
- **Material quality** – some reserves are only acceptable for one-off contracts with some licensed areas only being used occasionally.
- **Market demand** – this varies significantly from year to year and can be strongly influenced by major infrastructure projects such as road, rail and development schemes and beach nourishment requirements.

The following statistics provide an indication of the overall utilisation of the marine aggregate resource in the UK during 1999.

Table 1.4.1b Regional dredging statistics from 1 January 1999–31 December 1999

Dredging area	Permitted removal (tonnes)	Actual Removal (tonnes)
Humber	3,650,000	2,840,261
East Coast	13,375,000	9,131,512
Thames	4,600,000	971,960
South	11,075,000	5,885,332
South West	7,111,000	1,719,803
North West	1,384,999	355,044
Rivers and Misc.	N/A	6,273
Total	41,195,999	20,910,185

Data from Crown Estate (2000)

1.4.2 Dredging plant

The dredging plant utilised in aggregate extraction is almost exclusively the trailing suction hopper dredger. These types of dredgers pump a water-sediment mixture from the seabed to an onboard hopper via a suction pipeline. Once in the hopper, the sediment settles to the bottom and the supernatant water is returned to the sea via an overflow weir (CIRIA, 2000). Trailing suction hopper dredgers are used to dredge all but the strongest materials, but are not suitable for use in restricted areas. Hopper sizes vary from 750 to 25,000 m^3, but hopper sizes of under 3000 m^3 are most common (Bray *et al*., 1997). The dredging process usually involves extensive overflowing, where suspended sediment from the dredger hopper or barge is returned to the sea via spillways (ship-side or centrally mounted). The process may also involve the screening of material, to divide finer fractions from coarser fractions, when a particular sediment fraction is sought. In this case, the discharge of screened material may release much more fine sediment into the water column than overflow on its own (CIRIA, 2000).

Modern dredging vessels are very sophisticated and can dredge with a high degree of precision using satellite navigation systems. Since 1993 it has been a requirement that all vessels dredging on Crown Estate licensed areas must be fitted with an Electronic Monitoring System (EMS) to log all dredging activities. The EMS provides an accurate record of the date, time and position of all dredging activities. The position of the vessel is automatically recorded every 30 second, to within at least 100m but more usually 10m accuracy.

1.4.3 Dredging for maerl and other minerals

Sand and gravel comprise the vast majority of minerals dredged from the seabed and are given most attention in this report. However, the guidance is also relevant to other minerals dredged from the seabed such as maerl, coal and metalliferous minerals.

Maerl is the common name for a number of species of calcified seaweed and is commercially harvested for use as a soil conditioner, animal food additive and for water filtration systems. It has been harvested historically at sites in south west England and Scotland. The dynamics and sensitivity of maerl are described in the UK Marine SACs Project report (Birkett *et al*, 1998).

1.5 Specific objectives of the report

The overall aim of this report is to develop guidance on the potential impacts of aggregate extraction in relation to European Marine Sites and features contained within Annexes I and II of the Habitats Directive.

In particular, the project will:

- Review and summarise literature on the effects of aggregate (including maerl) extraction on Annex I habitats and Annex II species;
- Identify circumstances where cumulative impacts may occur and make recommendations on how thresholds could be set for assessing such cumulative impacts;
- Provide a framework for decisions on the significance of aggregate extraction and effects on SACs;
- Review information on monitoring packages and draw out best practice;
- Investigate the methods used for cumulative impact assessment in the UK and overseas, covering both the scientific and procedural aspects;
- Make recommendations on how management schemes for SACs might be linked to assessments of the environmental impacts of aggregate extraction licences.

Whilst the focus of the report is on features in marine SACs, the information is also relevant to habitats within Special Protection Areas (SPA) for birds.

2. Legislative procedures for aggregate/maerl extraction

2.1 Introduction

The legal and institutional framework governing the extraction of marine aggregates in the UK involves two fundamental issues:

- The legal ownership of the seabed and foreshore, and the creation of private property rights to remove minerals from it;
- The administrative regulation of the exercise of those property rights in the public interest.

These issues are discussed in the following Sections.

2.1.1 Ownership of intertidal and subtidal areas

The ownership of the seabed and foreshore in the UK is a complex subject. The foreshore between the mean high and low water marks and the bed of tidal estuaries below mean low water mark are vested in the Crown Estate, except where ownership has passed to other persons by grant or adverse possession. Land above the mean high water mark is not legally part of the foreshore, and is generally private property. In the Bristol Channel area, for example, the ownership of both the bed and foreshore is divided between the Crown Estate and a variety of other parties. In Wales, this is due particularly to the historical status of the Marcher Lords. In 1849 the Duke of Beaufort was also judicially declared to be the owner of the entire foreshore of the Gower Peninsular, although some of that land has now been transferred to other proprietors. Elsewhere, there are numerous examples of privately owned foreshore, frequently derived from the historic titles of major landowners.

2.1.2 Property rights to remove aggregates

The ownership of land (whether sublittoral, littoral or terrestrial) normally includes the right to take sand and gravel forming part of that land. Consequently, it is usually only landowners who are entitled to remove aggregates or to permit someone else to do so, and they may require payment from anyone who is so permitted. There is no general public right for other persons to take sand or gravel without the landowner’s consent. A licence from the landowner is thus a private contractual arrangement, which may contain any terms agreed between the contracting parties.

2.2 Control of aggregate extraction

2.2.1 The Government View Procedure

The Government control of marine aggregate extraction is presently exercised through the “Government View Procedure”, administered by Planning Directorate in Minerals and Waste Division of the Department of Transport, Local Government and the Regions (DTLR). The Scottish Executive Rural Affairs Department (SERAD) and the National Assembly for Wales Planning Division (NAW) are responsible in Scotland and Wales respectively.

The Government View Procedure is essentially a non-statutory extended consultative process which follows the principles of UK land-based planning procedures. At present, the process is covered by interim procedures published by DETR in 1998. The Government Departments are working towards introducing a statutory planning procedure in 2001 (see Section 2.2.2). These are the two main stages of the current non-statutory process.

Before the applicant applies for a licence, there are informal discussions with coastal experts to identify potential problems.

Stage 1 – Application Stage

- Scoping exercise – informal discussions with key consultees and fishing industry representatives.
- Scoping report for Environmental Statement prepared.
- Applicant commissions Coastal Impact Study and Environmental Impact Assessment (the Environmental Statement).

Stage 2 – Consultation Stage

- Proposal is advertised in the press and consultation papers plus Environmental Statement are sent out.
- Consultees and public submit comments to the applicant.
- Applicant has to resolve any concerns and prepare summary report.

Stage 3 – Confirmation Stage

- Government Department sends summary consultation report and supplementary Environmental Statement to all consultees.
- Further chance for consultees to comment on the licence application.

Stage 4 – Assessment and Determination Stage

- Government Department decides on outcome of application. They have four options:
- Favourable GV.
- Unfavourable GV.
- Informal hearing leading to favourable/unfavourable GV.
- Public Inquiry leading to favourable/unfavourable GV.

Stage 5 – Decision Stage

- Government Departments issue GV letter to applicant.
- Crown Estate issues licence to applicant.

The Crown Estate takes no part in the Government View Procedure. Only when a favourable view is received from Government does the Crown Estate issue a licence. Licensed dredging areas are shown in Figure 2.2.1 (from DETR 2001). The Crown Estate stipulates the exact area in which extraction is allowed, the amount of material that can be extracted in one year and the commercial terms. The Government View, which includes all conditions, is incorporated in the licence. Licences prescribe the maximum annual tonnage of dredged material that may be removed by the licensee and the royalties that must be paid. They are subject to the public rights of navigation and fishing. Licensees must monitor the effects of dredging on the ecology and mineral resources of the area, and must observe specifications in the schedules of the licences. Licences may be revoked if the licensee defaults and under certain other specified circumstances including environmental grounds, provided that six months' notice is given.

2.2.2 Marine Minerals Dredging Regulations

In future, dredging for minerals from the seabed will have a statutory basis under the Marine Minerals Dredging Regulations. These Regulations are at an advanced stage of development and are expected to come into force in England in 2001, accompanied by procedural guidelines (MMG1). Equivalent Regulations will be required in Scotland and Wales.

These statutory Regulations will replace the interim Government View procedure. The Regulations transpose into UK legislation, in so far as marine minerals extraction is concerned, the provisions of EC Directive 85/337/EEC, as amended by EC Directive 97/11/EC, on the assessment of the effects of certain public and private projects on the environment as well as provisions of EC Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive).

2.2.3 Prospecting licences

A two stage system of prospecting for marine aggregates is in operation. The main elements of the system are:

Stage 1: The dredging company makes a request to survey and, if accepted by the Crown Estate, it will be authorised to undertake non-intrusive surveys, such as side scan sonar and shallow seismic profiling plus grab sampling and vibrocores. These are generally referred to as reconnaissance surveys.

Figure 2.2.1 Crown Estate Licenced Dredging Areas (July 2000) – taken from draft Mineral Planning Guidance Note 2, of the former Department of the Environment, Transport and the Regions.

Source: Crown Estate

Stage 2: On the basis of information obtained from reconnaissance surveys, a company will submit a bid for an exclusive option for a defined area or areas. If successful, a 12 month prospecting licence will be granted which will permit further sidescan sonar and shallow seismic profiling, plus more intensive surveys including vibrocores and grab sampling (follow up surveys).

Consents for reconnaissance and follow up surveys are required under Section 34 of the 1949 Coast Protection Act. Consultation takes place with the conservation agencies and fisheries interests, amongst others.

Generally reconnaissance and follow up surveys are not likely to have a significant impact on the marine environment and a Code of Practice is in preparation between British Marine Aggregate Producers Association (BMAPA), Crown Estate, DTLR Ports Division, English Nature and the Countryside Council for Wales in order to expedite consents. Bulk sampling is treated separately, may have more widespread effects, and is not covered by the Code of Practice.

2.3 Other planning, legal and institutional issues

2.3.1 Planning controls over aggregate production

The extraction of aggregates on land is a ‘mining operation’ within the definition of ‘development’ in the Town and Country Planning Act 1990, and is therefore subject to planning control if it takes place within the jurisdictional area of a mineral planning authority. Since planning control is a local government function, it cannot legally be exercised outside local authority jurisdiction.

On the open coast, local government jurisdiction generally coincides with the authority’s seaward boundary which is usually at the mean low water mark, but there is no explicit statutory definition of the location of local government boundaries across estuaries. However, a non-statutory practice has been adopted by the Ordnance Survey since 1883 of depicting administrative boundaries across estuaries ‘where the surface level of a river reaches the surface level of the sea at low water’. The legal question of whether planning control may be exercised in areas beyond low water mark inside local government boundaries has not been definitively decided in England and Wales, although a judicial decision in Scotland in 1976 concluded that it should not. The extent of local authority jurisdiction in the marine environment is covered in detail in Tyldesley and Associates (2000).

Where planning controls are exercised over offshore dredging, they supplant the Government View Procedure. However, it is clear that the seaward boundaries of local government areas are based on historical factors that result in inconsistent demarcation and are unlikely to reflect the requirements of modern environmental management.

2.3.2 Policy frameworks and planning guidance

The publication of central Government guidance for mineral planning authorities and the minerals industry in relation to aggregates is also at a transitional stage. In England, the Department of the Environment issued an updated version of MPG6, Guidelines for Aggregates Provision in England, in April 1994. MPG6 contains policy guidance on marine dredged aggregates as well as those from land-based sources. However, the 1994 edition of MPG6 relates only to England. Both DTLR and the National Assembly for Wales are working towards policy frameworks within which the future use of marine sand and gravel can take place in a way which protects the environment and ensures sustainable development. In England, a consultation paper on marine minerals (MMG 2) was released in February 2001 (Guidance on the extraction by dredging of sand, gravel and other minerals from the English seabed). This draft proposes a precautionary approach when considering applications for new permissions and that there should be a presumption against permitting extraction in new areas unless the issues relating to environmental and coastal impacts are satisfactorily resolved. The National Assembly for Wales is leading the development of a policy framework for marine aggregate extraction in the Severn Estuary and Bristol Channel. This is based on the results of the Bristol Channel Marine Aggregates Study (National Assembly for Wales, 2000). The framework will divide up the Bristol Channel and Severn Estuary into sedimentary environments with policies on aggregate extraction being applied to each area. A draft for consultation was issued by the National Assembly in May 2001 (National Assembly for Wales, 2001).

2.3.3 Additional controls over extraction

There are several additional statutory powers over marine extraction, which may be exercised in parallel with the Government View Procedure. These are coast protection orders under the Coast Protection Act 1949, consents for works in tidal waters under Section 34 of the same Act, and licences under local harbour legislation.

Coast protection orders

Section 18 of the Coast Protection Act 1949 empowers coast protection authorities (i.e. district or unitary councils) to make orders designating areas of the shore and seabed in which the excavation or removal of materials (other than minerals over 50 feet below the surface) requires their licence. It was held in the High Court case of British Dredging (Services) Ltd v Secretary of State for Wales (1975: 1 Weekly Law Reports 687) that a coast protection order may be made on a precautionary basis when it seems necessary or expedient, even if it cannot be proved that erosion or encroachment will be prevented.

Section 34 consents

Under Section 34 of the Coast Protection Act 1949, consent is always required for the removal of objects or materials from the bed of tidal waters below the level of mean low water springs up to the limit of the territorial sea, if obstruction or danger to navigation may result. This includes prospecting surveys (see 2.2.3). In practice, this means that dredging operations must always be subject to the approval of the Secretary of State, although consent can only be refused on navigational grounds. The Merchant Shipping Act 1988, Section 37, permitted the Secretary of State for Transport to delegate this function to harbour authorities which possessed equivalent powers, but this provision was not used.

2.3.4 Licences under harbour legislation

Some harbour authorities have powers similar to Section 34 of the Coast Protection Act 1949 under their local harbour legislation, enabling them to control the removal of materials within their harbour limits. This may only be used to protect navigation, and cannot be invoked for other purposes such as environmental protection.

Most harbour authorities also have statutory powers under local harbour legislation to carry out capital or maintenance dredging for navigational reasons, and to appropriately dispose of the dredged material (ABP 1999). Although such powers normally preserve the property rights of the Crown in the seabed, the Crown Estate will not normally seek to licence such activities. Occasionally, a harbour authority may appoint a dredging company to perform these operations on its behalf, which may then retain the dredgings for use as aggregates.

3. Review of individual impacts of aggregate extraction

3.1 Introduction

These Sections describe the direct and indirect effects of aggregate extraction on the marine and coastal environment, with specific reference to Annex I habitats and Annex II species where appropriate.

Direct impacts relate to those physical and biological impacts at the site of the aggregate extraction e.g. when the habitat under consideration is the targeted resource, for example sublittoral sandbanks. Indirect impacts largely refer to impacts remote from the aggregate extraction site but which are a consequence of the activity (e.g. erosion of coastal habitats due to a change in nearshore physical processes). Both predicted impacts and actual reported impacts are discussed. Impacts of aggregate extraction must be considered against the background of natural changes in our seas and coasts, some of which may be cyclical.

- The following aspects are discussed in the following sections:
- removal of substratum and benthos;
- water quality effects;
- changes in sediment composition; and,
- changes in hydrodynamics and sediment transport;
- alterations in seabed topography;
- natural phenomena.

3.2 Removal of substratum and impact on benthic communities

The most obvious, and often the most significant, impact arising from aggregate extraction is the direct removal of the substratum and the benthic communities at the site of extraction. The significance of this impact depends largely on the extent and depth of dredging activity.

The two main methods used for aggregate extraction in the UK are static (anchor) dredging and, more commonly, trailer dredging. Static (anchor) dredging can leave large hollows in the seabed, due to its method of extraction, which can be as much as 20m in depth and 75m in diameter (Newell *et al.,* 1998). These pits can last for several years and could represent a potential hazard to other activities, such as commercial fishing. One of the factors likely to influence the persistence of dredged pits is the depth of the overlying water. If the disturbed area is below the influence of waves, the pits are likely to remain for a longer period of time than they would in shallower water where sediment redistribution and transport through wave action may lead to relatively rapid infill. Trailer dredging creates troughs up to 20-25cm deep and about 2.5m wide (BMAPA, 1993). The nature of the extraction process with regard to both types of dredging means that the direct impacts on the benthic communities are likely to be spatially patchy and intermittent. The area surrounding the dredged track or area remains physically undisturbed. Consequently, there is a high likelihood that re-colonisation of the disturbed will occur through migration from adjacent areas of similar habitat once aggregate extraction has ceased. Note that these two different methods of extraction do not necessarily involve different types of vessels: trailer suction dredgers can, for example, be used for trailing and static dredging operations.

In terms of impacts on the seabed, the two types of dredger clearly have different impacts (summarised in Table 3.2a).

Table 3.2a Comparison of the impacts of static (anchor) dredging and trailer dredging on substratum and benthos

Parameter	Type of dredging	
	Static (anchor) dredging	Trailer dredging
Depth of deposit worked	Relatively deep	Relatively shallow
Area of seabed worked	Relatively small	Relatively large
Effect on benthic habitats and communities	Local impact high but relatively small area affected	Local impact high and relatively larger area affected
Effect on seabed morphology	Formation of depressions in seabed	Formation of extraction 'trails' over relatively extensive area

The direct impacts of marine aggregate extraction on benthic communities are dependant on the interaction of a number of factors. These include (Newell *et al.,* 1998):

- the nature of the benthos inhabiting the extraction site;
- the intensity (both spatial and temporal) of dredging in a particular area;
- the degree of sediment disturbance;
- recolonisation by passive transport of adult organisms;
- the intrinsic rate of reproduction, recolonisation and growth of the community that normally inhabits particular deposits.

The most obvious short-term direct impact of aggregate extraction on benthic communities is the destruction of all epifauna and most of the infauna (Llanelli Sand Dredging Ltd., 1996). Research has shown that marine aggregates dredging can result in a 30-70% reduction in species diversity, a 40-95% reduction in the number of individuals and a similar reduction in biomass of benthic communities in the dredged area (Table 3.2b). Despite the significant impact on benthic communities within the dredged area, there is little evidence to suggest that significant impacts arise outside the area of extraction.

Table 3.2b The impacts of dredging on the benthic community composition of various habitats (Adapted from Newell *et al* 1998)

Locality	Habitat type	% reduction after dredging		
		Species diversity	Individuals	Biomass
Chesapeake Bay	Coastal embayment mud-sands	70	71	65
Moreton Bay, Queensland	Sand	51	46	-
Klaver Bank, North Sea	Sands-gravels	30	72	80
Lowestoft, UK	Gravels	62	94	90

Recolonisation and the recovery of benthic diversity and species abundance is likely to begin rapidly following the cessation of extraction from a particular area (Newell *et. al.* 1998). However, the nature of the recovery and the longer term impacts of physical disturbance to the benthic community structure are likely to be variable and will depend on a variety of factors, as shown in Box 3.2a. Species that initially re-colonise an area following disturbance are likely to be those adapted to unstable sediment conditions and probably elevated levels of suspended sediment.

Box 3.2a Factors affecting long-term recovery of benthic communities following extraction

The community diversity and richness of the area prior to dredging;
The physical conditions at the impacted area;
The distribution of species within the wider area;
Life cycle and growth rates of species;
Spatial extent and intensity of aggregate extraction;

An important factor which governs the speed and nature of recolonisation of an impacted area is the sediment type that remains following dredging. Extraction may result in the exposure of different seabed sediments than those present prior to the activity occurring. Consequently, a markedly different benthic community to that which was present may re-colonise following the cessation of extraction. However, it is likely that extraction would not be allowed to proceed if the aggregate resource was not of sufficient depth to allow removal without the exposure of a different sediment type. For all Crown Estate licences there is a standard clause which requires that the seabed is left in a similar state (i.e. including sediment type) to that prior to the dredging commencing.

The majority of shallow shelf benthic invertebrates possess pelagic larvae. Re-population of a dredged area will be determined by the number of larvae in the water column passing over the area and by the suitability of the sediment for settlement. Some larvae require very specific conditions for settlement and they can delay metamorphosis until these conditions are encountered. The presence of algal and bacterial films and individuals of the same species may be important in the settlement of larvae and these conditions may be destroyed by dredging. For example, experimental work has shown that *Sabellaria spinulosa* larvae are strongly stimulated to metamorphose and settle by cement secretions of adult or newly settled young *S. spinulosa.* Scallop shells, especially *Pecten maximus*, appear also to have some slight settlement inducing properties (Holt *et al.*, 1998).

Recruitment of individuals from the plankton and metamorphosis are both highly variable functions and therefore the nature of the recovery can not be predicted with any certainty. Initial recovery is likely to be by species tolerant of the physical conditions at the site, but colonisation of the impacted area by adults from adjacent undisturbed areas could also be relatively rapid. Generalist species that are common and widespread are likely to re-colonise successfully and relatively quickly.

The life cycle and growth rate of species that colonise an area will also have an influence on the nature and rate of recovery of the impacted area. Species diversity is often restored fairly rapidly in a disturbed area, but the time taken for biomass to recover to levels before aggregate extraction may be much longer due to the time required for species population and individual growth (Newell *et. al.* 1998; Kenny & Rees 1994, see example given in Box 3.2b). A succession of species occurs in the recolonisation process, with those species that are tolerant of unstable and erosive conditions taking advantage of the conditions of reduced competition which result from extraction.

The recovery of communities typical of mobile sublittoral habitats is likely to be quicker than that of more stable environments. Sublittoral sandbanks, for example, are typically dynamic and characteristic of high energy conditions. The communities associated with such areas are adapted morphologically and behaviourally to these conditions and are able to tolerate disturbance and large-scale sediment movement. In areas of coarser, more stable material, epifaunal species are more likely to occur, including hydroids, bryozoans and ascidians. Areas of mixed sediments may support very rich communities. Recovery of such areas following aggregate extraction is likely to be slower than for sublittoral sandbanks (see Box 3.2b).

Possibly the most severe effect of aggregate extraction, in terms of impact on benthic communities, is likely to be in the case of biogenic reefs, such as those formed by the tube-dwelling polychaetes *Sabellaria alveolata* and *S. spinulosa*. Other species can also form reef structures, examples being the horse mussel *Modiolus modiolus*, the common mussel *Mytilus edulis* and the polychaete worm *Serpula vermicularis*. These reefs often have distinct and diverse biological communities associated with them and full recovery of the reef community can take up to 10 years or longer following disturbance.

Several research projects on recovery rates are underway, for example by CEFAS for DTLR) and by BMAPA (site specific study in North Sea) and will inform future licence applications.

Box 3.2b Case Study - Benthic community recovery following aggregate dredging

An analysis of the impact of aggregate dredging on community composition and on the recolonisation process in an area of mixed gravel deposits is provided for an experimental area off Norfolk (Kenny & Rees, 1994, 1996). An area of 500 m by 270 m was dredged in April 1992, removing 52,000 tonnes of mixed aggregate. Approximately 70% of the surface deposits down to an average depth of 0.3 m were removed. Species variety, population density and biomass in the dredged site was then compared with that in a nearby reference site for 8 months between March and December 1992. The number of species in the dredged site declined from 38 to 13 species following dredging, whereas the number of species remained at about 35 throughout the 8 months at the reference site. Additionally, the population density of 2769 individuals per m2 prior to dredging was reduced to 129 individuals per m2 post dredging. The population density remained relatively constant at 3300 individuals per m2 at the reference site (Kenny & Rees, 1994).

In the 7 months following the cessation of dredging, the number of species and the population density both showed significant increases. Many of the commoner species present prior to dredging had recolonised the area by December 1992. However, two years after dredging, the average species abundance and biomass were lower than those for the reference site, indicating that the communities in the experimental area had not recovered to the pre-dredge situation (Kenny & Rees, 1996).

Three years after dredging, survey showed that the diversity and biomass of animals were indistinguishable from the control site and matched those of the experimental site before dredging. However, the abundance of animals (number of individuals per unit area) has stabilised at a level significantly less on the experimental site compared to the control site, suggesting a different community structure. Further work is underway to follow further changes and explain this difference in abundance (Crown Estate, 1999).

Maerl extraction

Maerl beds (composed of various species of red coralline algae) have historically been harvested, primarily as a soil conditioner, from beds in Scotland and south-west England. The impacts relating to the extraction of maerl, which is carried out on a commercial basis in the Fal Estuary (within the Fal and Helford cSAC), in Orkney and off the coast of Brittany are also similar to those discussed above. However, in addition, a major factor relating to the scale of impact depends on whether extraction is from live or dead maerl. Red coralline algae are slow growing species and live maerl beds support a very high diversity of associated species. The extraction of live maerl is not considered to be sustainable given the significant adverse impacts to the substratum (the maerl) and associated fauna and flora likely to occur.

The removal of maerl, and the species associated with maerl, during the extraction process has the effect of reducing the extent of habitat and species diversity and abundance of the communities associated with it. The impacts of this may be relatively long term as the species which comprise maerl and associated communities may take some time to fully recover (Birkett *et al.*, 1998). The recovery potential of certain maerl habitats and communities is greatly enhanced if the substratum remaining following maerl extraction is similar to that prior to extraction. The recovery potential of live maerl beds is generally believed to be low. Recovery potential in relation to a single event causing mortality has been classed by OSPAR as poor, with partial recovery likely within approximately 10 years and full recovery likely to take up to 25 years (Birkett *et al.,*1998). The extraction of dead maerl has very similar impacts to those associated with the extraction of gravel. Species assemblages of dead maerl have been likened to those from fine shell gravel substrates (Gubbay, 1988).

3.3 Water quality effects

Aggregate extraction can have a number of potential impacts on various water quality parameters, including water chemistry, and the impacts associated with increased suspended sediment concentration, turbidity and siltation. Guidelines for managing water quality impacts within UK European marine sites have recently been produced as part of the UK Marine SACs Project (Cole *et al*, 1999).

3.3.1 Impacts on water chemistry

Chemical transport at the sediment-water interface is determined by the physical characteristics of the top layer of sediment (porosity, grain size, etc.), the difference in concentration of the material between the sediment and the overlying water, the thickness of the diffusive boundary layer and the activity of organisms in the top sediment layer. Aggregate extraction effectively destroys this boundary and disturbs the chemical gradients between the sediment and the water (Goossens, 1992).

The physical properties of sediments suspended during aggregate extraction are similar to those of existing particles in the water column. However, there may be differences in chemical characteristics. For example, if the extraction process disturbs layers of anaerobic sediment, dissolved oxygen levels in the water can be decreased as anoxic sediments create a biological oxygen demand (BOD). In addition, increased rates of siltation due to the settling of sediment plumes produced during extraction may reduce oxygen exchange in sediments. Disturbance often exposes buried sediment to a more oxic environment. This can result in the mobilisation of heavy metals due to the oxidation of metal complexes. Such reduced oxygen exchange is unlikely to be an issue during dredging of sands and gravels as these deposits generally consist of coarse material with very low amounts of fines, and only low natural levels of heavy metals. For further information on this topic the reader is referred to Cole *et al* (1999).

In some cases the release of organic materials from sediments by aggregate extraction may alter species diversity and increase population density in the vicinity of the dispersion plume. This increase in organic matter can have a considerable beneficial impact on certain species. Enhancement of benthic biota close to dredged areas at Moreton Bay, Queensland has been reported (Newell *et* al, 1998), with the level of enhancement decreasing with increasing distance from the dredged area up to a distance of approximately 2km. This was attributed to the release of organic material during extraction. Extraction activity may leave an available supply of food in the form of damaged animals (e.g. bivalves, crustaceans) that can temporarily support enhanced population levels of fish and marine mammals

The environmental assessment for the Oresund Fixed Link (Oresundkonsortiet, 1998) concluded that there could be a release of chemical compounds in particulate or soluble states, depending on the origin and composition of the type of sediment and the equipment and methods applied during dredging. However, monitoring associated with this project showed that loads of organic matter, nutrients, trace elements and oxygen-consuming compounds are insignificant compared to loads from other sources.

3.3.2 Suspended sediment concentrations and sediment plume dispersal

During the aggregate extraction process, suspension of particulate material into the water column will occur. The amount of resuspension depends on a number of factors including, cohesiveness of the sediment, particle size and local hydrographic conditions. It is important to distinguish between elevated suspended sediments and elevated turbidity, as the former does not necessarily result in the latter. For example, an increase in suspended sediment concentration by a given amount will result in a greater increase in turbidity if the sediment is silt rather than sand. Additional information on turbidity and its effects is provided in Cole *et. al*. (1999) and Parr *et. al*. (1998).

One of the major indirect impacts of aggregate extraction is the creation of a sediment plume and the resulting increased turbidity in the water column. Plume formation can occur in three main ways (Gibb Environmental Sciences, 1992):

- the draghead creates a plume as the vessel moves. Sediment settles out over a relatively short distance;
- overflow from the hopper during dredging;
- discharge of fines and screened material from the dredging vessel.

Sediment plumes arising from aggregate extraction disperse vertically and horizontally in the water column. The extent and area over which they disperse is dependant on the strength and direction of the prevailing currents and winds, and the particle size of the material in question. For example, very fine sand dispersed by dredging may move up to 11km from the dredging site, fine sand up to 5km, medium sand up to 1km and coarse sand less than 50m (Hitchcock & Drucker, 1996).

Studies on a sand suction dredging operation in the Oresund, Denmark concluded that the concentrations of suspended sediment likely to cause a detrimental effect did not persist for more than 150m downstream of the dredge. Additionally, ambient levels of suspended solids were found only 1km from the dredge (Gibb Environmental Sciences, 1992). Even under the most adverse circumstances, concentrations of suspended sediment of 5ppm above background have been shown to persist for only 7-8 hours (HR Wallingford, 1993).

Box 3.3.2 Case Study – Determining the movement of suspended sediment during aggregate dredging

The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) have undertaken studies on the impact of sediment plumes derived from extraction activity in Area 107 (Race Bank and surrounding areas, CEFAS, 1998). The study was initiated to investigate concerns that dredging-derived sediment plumes from Area 107 may pose significant risk to the berried (egg-carrying) hen crabs on Race Bank. This study is the most comprehensive and scientifically advanced to date dealing with the impacts of dredging on the movement of suspended sediments.

CEFAS deployed autonomous bottom landers, known as minipods, which carry timed sediment traps, passive sediment traps and an array of main sensors capable of measuring near-bottom suspended sediment. The aim of the study was to undertake autonomous, appraisals of suspended sediment concentration at various ranges from the dredging activity in Area 107 and to provide information regarding the movement of sediment plumes between Area 107 and Race Bank.

A linear array of four minipods were set between the dredge site and Race Bank in May-June 1995, with the sensors recording at the maximum (near continuous) data-rate. Data from the minipods showed that 'spikes' in suspended load, supposedly due to dredging at Area 107, were only present at Race Bank during spring tides and were absent during neap tides (CEFAS, 1998). This difference was found to be due to the fact that the tidal excursion on spring tides is sufficiently broad (approximately 9km) to span the 6.5km distance from the dredge site to Race Bank, whereas the 4km excursion during neap tides is not sufficient to cover the distance.

The experiment also provided evidence that an individual outwash plume passed in sequence from one minipod to the next across the whole distance from the extraction site to Race Bank. The study concluded that dredging at Area 107 has the potential to deliver an extra 50-150mg/l of suspended sediment to the near-bottom layer at Race Bank during about 7% of the spring/neap cycle. Therefore, the potential impact on crabs at Race Bank is considered to be very limited (CEFAS, 1998). However, the biological aspects of the study are at a too early stage to conclude whether there are any significant impacts on crab populations (CEFAS, pers. comm.).

Some impacts of elevated suspended sediment concentrations and turbidity on flora and fauna may be expected to occur within the immediate vicinity of an extraction area. If the aggregate extraction activity causes a significant increase in the amount of sediment in suspension the efficiency of filter feeding benthic organisms such as bryozoans and hydrozoans may be adversely affected as their feeding apparatus may become blocked (Emu Environmental, 1998). Additionally, phytoplankton and benthic algal productivity may be reduced by elevated turbidity due to a reduction in the depth of light penetration into the water column. For example, in the Oresund, it was envisaged that the growth and biomass of eelgrass would be temporarily reduced along the western and southern coasts of the island of Saltholm and at Kastrup due to shading from suspended material. This was within the immediate vicinity of dredging operations. It was also predicted that a smaller, temporary reduction of the depth limit for eelgrass within an outer impacted zone could occur (Oresundskonsortiet, 1998).

The potential impacts of marine aggregate extraction on the majority of fish species will generally not be as significant as those on benthic communities. Direct long-term impacts are unlikely to occur for fish species as they are mobile and therefore will avoid any area affected by increased sediment loadings and are able to return once dredging activity has ceased. Short-term impacts on fish species may occur. For example, the ability to find prey by visual feeders may be reduced under turbid water conditions. Species that normally inhabit turbid waters and use their olfactory senses for feeding will be less disturbed by any increase in suspended solids than other species.

High concentrations of suspended sediment can have the effect of affecting the migration of certain fish species (Oresundskonsortiet, 1998). This study concluded that fish which migrate through the Oresund during the period March to October, including species such as eel, garfish and lumpfish, could potentially be affected. All of the Annex II fish species in the Habitats Directive undergo migrations between fresh water and the sea at some stages in their life cycles and therefore significant increases in suspended sediment concentrations could present a barrier to migratory pathways.

The presence of surface and sub-surface plumes has the potential to reduce the ability of visually-feeding marine mammals to locate their prey, thereby diminishing their feeding success. However, most animals are likely to move away from areas of elevated turbidity. In addition, as prey abundance is likely to be lower in areas affected by plumes, it is considered that the feeding ability or efficiency of pelagic mammals is unlikely to be adversely affected by extraction activity.

Further information on the impacts and assessment of sediment plumes arising from aggregate and capital and maintenance dredging is provided in CIRIA (2000). A major study is underway, funded by CIRIA, on the modelling of sediment plumes.

3.3.3 Sedimentation as a result of extraction activity

The particle size of material and the rate of sedimentation from the water column are related factors. The larger the particle size, the greater the rate of settlement and therefore larger particles will be deposited closer to the site of production than smaller particles. In general terms, the rapid deposition of material from the water column is likely to have more of an impact on the benthic community due to smothering effects, than gradual sedimentation to which benthic organisms are adapted and able to respond. However, this response depends to a large extent on the nature of the receiving community. Studies have shown that some benthic animals are able to migrate vertically through more than 30cm of deposited sediment (Newell *et al.,* 1998). In contrast, sedentary communities could potentially be adversely affected by both rapid and gradual deposition of sediment.

A temporary increase in sedimentation must be assessed against ambient background conditions and the tolerance of the species or community under investigation. For example, in areas characterised by naturally high rates of siltation, such as the Bristol Channel, the impact of elevated siltation levels arising from aggregate dredging is unlikely to result in significant impacts on benthic species as they are adapted to existing conditions of high siltation. In addition, a number of other factors influence the potential effect of increased siltation rate on benthic communities. These include the type of community, the amount of material in suspension, particle size and the nature of the substrate at the site of deposition. Evidence suggests that for sands and gravels, the impact of siltation on the existing biota is likely to be confined to distances of a few hundred metres from the dredger (Newell, *et al.,* 1998). In the case of aggregate extraction in an area of the Outer Bristol Channel, no impact on the benthos outside the licensed area was expected (Oakwood Environmental, 1999). Additionally, evidence from aggregate extraction in Area 107, off the east coast of England, suggests that there are no obvious gross changes to benthic communities outside the licensed extraction area (H. Rees, CEFAS, pers. comm.).

A change in sediment composition due to the deposition of fine material onto an area of gravel may make it unsuitable for some mobile benthic species. Crabs and lobsters often live in crevices in the seabed, and significant deposition of fine material into these areas can cause them to silt up. Should this occur on a large scale, it is possible that relocation of the species may occur leading to a reduction in the viability of the area for fishing activity. The potential impacts of sedimentation arising from Area 107 on crabs at Race Bank is one aspect of an ongoing CEFAS study (see Box 3.3.2).

The potential impacts of sedimentation on fish species, via impacts on their spawning grounds, are discussed in Section 3.4.

3.3.4 Maerl extraction

The generation of sediment plumes in the water column is possibly the most significant potential indirect effect of maerl extraction. Such plumes, if close to an area of live maerl, can reduce the light penetration in the water column and thus potentially inhibit the growth of maerl and the diverse algal community which is generally associated with live maerl beds. The significance of this effect depends on the sediment characteristics of the area, with the potential for plume generation greater, and therefore the effects more severe, in areas of high fine sand and silt content.

3.4 Changes in sediment composition

The sediment composition of the seabed is a major factor in determining benthic community structure. Disturbance to seabed sediments during the extraction process has a number of effects on sediment composition and benthic infauna and epifauna. These are summarised in Box 3.4.

Should the benthic community become altered due to sedimentation, there may be an impact on the pattern of fish feeding. However, the majority of fish species feed in an opportunistic way and so the impacts on these species are likely to be minimal. The effects would be most noticeable in the case of deposition of sand or silt onto a gravel area where larger crustacean abundance may be reduced as a result of the change in sediment characteristics. This could have a detrimental effect on obligate crustacean feeders such as poor-cod and bib.

Species which require a particular sediment type on which to spawn are perhaps more likely to be susceptible to changes in sediment composition which may arise due to the deposition of sediment from sediment plumes. For example, species which spawn on gravel sediments and produce demersal eggs would be adversely affected by a decrease in the mean particle size of the sediment. Certain species, such as herring *Clupea harengus*, regularly revisit the same localised spawning grounds and produce eggs that sink and become attached to clean gravel substrata. A change in the structure of the spawning ground, such as an increase in the fine content on the substratum due to sedimentation, may prevent their eggs from adhering to the sediment. Given that herring spawning beds are small and that within a gravel area they select specific gravel beds year after year it is suggested that any negative impact, such as substrate change, can influence successful reproduction to a large degree (ICES, 1992).

Box 3.4 Sediment composition change and impact on benthic communities as a result of aggregate extraction
Sediment may be sorted at the drag head during the extraction process. The extent to which this occurs depends on the type of material that is being dredged and the requirements imposed on the dredging company to meet the specifications of a target material. For instance, if the target material is sand, larger particles, for example gravel and boulders, are screened out by an intake grill at the dredge head and the overall result is an increase in the mean particle size of the substratum If the seabed surface sediment remaining after aggregate extraction is of a similar nature to that which existed prior to the activity, then it can be expected that ultimately a benthic community will develop which is similar to that which previously existed. Exposure of a different sediment type may lead to the development of a benthic community with a different structure and species composition. The stability of remaining sediment may be an important factor in controlling community structure (Newell *et al*., 1998). Removal of gravel from an area of mixed sediment may result in an overall decrease in the average sediment particle size and shift the community from one which is characteristic of mixed sediment to one characteristic of sand and mud. This may reduce the suitability of the habitat for a range of species (e.g. sessile epifaunal species that require a more stable habitat for regeneration). Deposition of fine sand and silt onto an area which is composed of a similar sediment type is unlikely to have any significant effect on the biological communities present. Low rates of deposition of sediment from suspension is unlikely to effect mobile benthic organisms as they are able to migrate up through accumulated sediment, often up to several centimetres of more thick

The direct removal of the seabed sediments can also destroy the spawning grounds of fish species which lay their eggs on the sediment surface. The sea lamprey *Petromyzon marinus* spawns on bottom gravels in inshore and estuarine areas and therefore could potentially be affected by the extraction of aggregates from these areas.

3.5 Changes in hydrodynamics and sediment transport

Aggregate extraction has the potential to impact indirectly on the wider marine and coastal hydrodynamic environment. Such impacts, relating to hydrodynamics and sediment transport include the following:

- damage to beaches caused by “draw-down” of sediment into a dredged area;
- changes to wave properties at the coast caused by changes to flow behaviour (for example, refraction, shoaling, breaking) over dredged areas;
- reduction in the shelter to a coast provided by offshore banks, etc;
- changes in tidal currents, particularly if such changes extend close to a coastline;
- disruption in sediment supply to the coast, either locally or at a distance from the dredged area (CIRIA, 1998).

Offshore sand and gravel banks can provide natural protection to the coastline by breaking large waves before they reach the coast and by increasing bottom friction. The result of this is a reduction in wave action at the coastline. Deepening of inshore waters, by dredging from sand and gravel banks, can increase shoreface slopes which allows larger waves to break closer to the shore (Carter, 1988). Propagation of larger waves into shallow water areas (e.g. bays), due to the effect of offshore extraction can lead to increased seabed scour. This will deepen these areas allowing progressively larger waves closer to the shore therefore, leading to an increased risk of coastal erosion and the potential dispersal of sediment offshore. For example, at Hallsands, Devon the removal of an offshore shoal in the early 1900s is thought to have led to increased wave activity, onshore erosion and the destruction of the village. This example serves to highlight the potential impacts of alterations in coastal processes. In reality, such severe impacts are extremely unlikely to occur nowadays given the comprehensive licensing regulations and associated processes of assessment that are now in place.

Similar concern has been raised elsewhere, for example the impact of sand dredging from Helwick Bank in the Bristol Channel on potential erosion along the adjacent coastline. Concerns have been raised that the dredging of Helwick Bank may alter the existing pattern of sediment transport (Llanelli Sand Dredging Ltd., 1996) which could then deprive beaches of sand supplies. In this particular instance it was concluded that limited dredging was unlikely to alter the pattern of sediment transport (HR Wallingford, 1996). However, the study did conclude that wave conditions at the shore might be noticeably increased if the crest level of the Helwick Bank were lowered below a threshold height as a result of aggregate extraction. Further consideration of this case is given in Section 5.1.3.

Changes in local hydrodynamic conditions may have an impact on nearshore and coastal ecology, with potential implications for both marine benthic communities and coastal habitats. These impacts are summarised in Box 3.5.

Box 3.5 Potential impacts of hydrodynamic change on benthic communities and coastal habitats

- Gradual change in nature or direct loss of littoral habitat, for example intertidal mudflats.
- Change in sediment type due to increased erosion and associated consequences for infauna and epifauna
- Increase in shallow water energy conditions, leading to changes in benthic communities, with the removal of species that are less tolerant of turbulent conditions.
- Disruption to the onshore movement of sediment and consequent impact on habitats such as vegetated shingle banks, saltmarshes, sand dune complexes, spits etc., which require dynamic sediment movement. The longer-term effect of this could be the gradual erosion of such habitats, and therefore, the loss of the biological communities associated with them.
- Loss of or erosional damage to coastal structures (e.g. shingle banks, protecting saline lagoons or other habitats) through increased wave activity.

Whenever an area is under consideration for the extraction of aggregate, a coastal impact study is undertaken which assesses the potential for impacts on the coastline caused by any changes in physical processes associated with the proposed extraction. Typically the studies include an assessment of the proposed dredging on bathymetry, wave conditions and sediment transport pathways at the extraction site and the implications of any changes on the adjacent coastline.

Based on the predicted bathymetric changes likely to arise through extraction, mathematical models are applied to assess potential changes to tidal currents and sediment transport pathways. The bathymetric input into the models is provided through existing survey data and enhanced by additional echo soundings and sonar data where appropriate. Tidal flows are validated through available admiralty data and other survey information. Based on the outputs of the modelling work predictions of likely impacts on nearshore processes and, in particular, changes to nearshore wave conditions and patterns of erosion and accretion are made. With respect to this, HR Wallingford state that the results from computer modelling exercises will always show some changes, simply as a result of the numerical errors involved in the large amount of computations. It is therefore necessary to separate out genuine changes in nearshore wave heights from the random errors associated with accumulated small numerical errors. Effectively, a ‘rule of thumb’ is utilised whereby changes in wave height (or period) of less than 3% (positive or negative) are generally regarded as insignificant. Similarly, changes in wave directions of less than 2^o are also regarded as too small to be separated from numerical uncertainties. Predicted changes greater than 5%, even if only in very extreme events, are considered as significant and limitations on proposed dredging may be recommended to avoid the risk of changing the coastal regime (HR Wallingford 1996). These ‘rules of thumb’ cannot be regarded as definitive. It is also necessary to consider whether the modelling results show any pattern, (e.g. a consistent increase (or decrease) in heights when waves approach from a certain sector), and an associated consistent change in nearshore wave direction. In such circumstances even a change of 1-2% may be regarded as of concern.

3.6 Alterations in seabed topography

There is concern among fishermen that changes in the seabed topography as a result of aggregate extraction can have an affect of some crustacean species. This is particularly the case with species which are believed to undergo extensive migrations, such as some crabs and lobsters. Changes in the topography could affect the migration routes of these species and have an affect on the catch rate (CEFAS, pers. comm.). Many crustaceans could also be affected by the removal of burrowing habitats which form an important phase of their life-cycle.

A similar concern regards flatfish species which move onshore in the spring from deeper water. Fishermen rely on this offshore-onshore movement because they know where the fish will be at a particular time of the year. Fishermen consider that dredging, especially from sand and gravel banks, interrupts the onshore movement of these fish, although there does not appear to be any scientific evidence to support this concern (CEFAS, pers. comm.).

Changes in seabed topography may also have an impact on the distribution of fish in other ways. The alteration of the profile of a sandbank, for example, may change the local hydrodynamic conditions. This can have an impact on areas of upwelling, which can be highly productive areas in which fish tend to congregate. Hydrodynamic changes may affect upwelling leading to a reduction in productivity and potential fish aggregation (CEFAS, pers. comm.).

3.7 Natural phenomena

Storm events, cyclical processes of erosion and accretion, sea level rise, and natural changes in the successional stages of benthic colonisation should be considered when assessing the implications of aggregate extraction on designated features. The main issue with regard to these factors is that the impact of each of the various elements is extremely difficult to discern, as they often contribute towards the same environmental ‘signature’. This is essentially a problem of impact identification and therefore one of information availability and analysis.

As an example, the environmental effects of storm events share many characteristics with those associated with aggregate extraction (e.g. changes in erosion/accretion patterns, changes in wave climate and suspended sediment concentrations, etc.). These events, although short term in nature, can lead to long term change within the marine and coastal environment, although some impacts are of a more temporary nature (e.g. suspended sediment concentrations). Given the predicted increase in storminess due to climate change the effects associated with this aspect may become more important in the longer term and have a greater overall impact relative to other activities or phenomena.

Box 3.7 Case Study – Area 107, minipod deployment and recording of storm induced suspended sediment concentrations
A study by CEFAS concerning the impacts of dredging at Area 107 involved the use of instruments to measure and record suspended sediment levels (see Section 3.3.2). An initial deployment of minipods was made in the winter of 1994/95, at a time when no dredging activity took place on Area 107. Data from the minipods documented the relative amplitudes and durations of a major storm and a major flood event. A number of individual and short-lived peaks in suspended loads were recorded by the minipods at the time of a storm around 1-3 January 1995. This local effect was overwhelmed several days later when the floodwaters, caused by the same storm spread offshore from eastern England as a turbid and greatly extended plume. This flood maintained a high turbidity at the Race Bank more or less until the end of the record on January 18 1995, long after the storm which gave rise to it had passed (CEFAS, 1998).

Careful identification of habitats and species and a good understanding of the life-cycles, sensitivity and vulnerability of a habitat, a species and/or community is essential for determining the impact of potential natural perturbations. Ideally, an extensive baseline dataset is necessary to identify seasonal and cyclical changes in the structure of communities. This, however, is not generally possible within the timescale of scientific study for an aggregate extraction application. It is therefore recommended practice to select a control area, outside the area of influence from dredging, which can be monitored to determine changes related to other factors. This control area should be as similar as possible to the area of extraction. An example of such an occurrence relates to *Sabellaria* reefs. *Sabellaria* undergoes a natural cycle of erosion whereby it undergoes a phased development beginning with a settlement and building phase, which terminates with an important platform phase. At this stage the reef becomes very vulnerable to erosion and consequently undergoes a destruction phase, which brings the cycle back to dead eroded reef on which new *Sabelleria* can settle. Such natural cycles need to be determined before potential impacts can be assessed and before monitoring is initiated, otherwise it may be possible for an impact bought about by a natural event to be incorrectly associated with aggregate extraction.

Determining the potential impact of aggregate extraction on factors such as wave climate, current speed etc. may be possible by modelling. However, teasing out the effect of process change due to aggregate dredging in relation to natural 'background' changes on, for example, sedimentary processes within a sandbank system, or erosion along a stretch of coastline is difficult to undertake with any accuracy. However, as part of the assessment process it is important that the effects and contribution to potential impacts associated with aggregate extraction that these phenomena may have is understood and considered. Where possible the effects of natural variations should be documented (i.e. control areas) in order to obtain a baseline against which the predicted impacts of aggregate extraction can be assessed.

4. Guidance on the impacts of aggregate extraction on Annex I habitats and Annex II species

4.1 Introduction

The statutory nature conservation agencies are required under the Habitats Regulations to provide advice as to the conservation objectives on a European Marine Site and the operations that might lead to deterioration or disturbance of the Annex I/II features. This advice provides a starting point for considering the impact of aggregate extraction at a site level.

The following sections provide further generic guidance on the Annex I habitats and Annex II species which could potentially be affected by marine aggregate extraction. Details are provided on the selection features and on the potential impacts relating to marine aggregate extraction which could affect these features. Further detail of the impact, its direct and indirect effects and cumulative impacts can be obtained by referring to Section 3 and Section 5 respectively.

Appendix B summarises the marine and coastal qualifying features for UK marine SACs. This table is based on the information available in May 2001.

4.2 Annex I habitats

This Section presents a list of UK marine and coastal habitats listed in Annex I of the Habitats Directive. For each habitat, a brief description is given. This description is based on that provided by the JNCC (Report No. 270) (JNCC, 1997). This is followed by a summary list of the potential impacts of aggregate extraction. It is important to note that not all of the impacts listed will apply to all of the sub-features listed. For example, the potential for impact on muddy sand habitats and communities are likely to be different from impacts on eelgrass beds. The impacts that are listed are intended to give an indication of the likelihood of impact to the broad feature shaded in grey.

4.2.1 Sandbanks which are slightly covered by seawater all the time

This habitat is defined as consisting of soft sediment types that are permanently covered by shallow seawater, typically at depths of less than 20m below chart datum (JNCC, 1997). Sites have been selected to cover the geographical and ecological range of variation of the following categories:

1. gravely and clean sands;
2. muddy sands;
3. eelgrass (*Zostera marina*) beds; and
4. Maerl beds.

Eelgrass and maerl beds are considered to be of particular ecological value because they support a diversity of species. Shallow sandy sediments are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms. Mobile fauna at the surface of the sandbank may include shrimps, prosobranch molluscs, crabs and fish. In areas of coarser, more stable material epifaunal attached species are present including foliose algae, hydroids, bryozoans and ascidians. Areas of mixed sediments can support very rich benthic communities.

Aggregate extraction from these habitats can have several direct impacts, but there are also consequences for the wider marine environment in terms of the indirect impacts, in particular the potential impacts on hydrodynamics and sediment transport, which may have potential knock-on effects for some coastal habitats.

Potential impacts of aggregate extraction:

- removal of substratum and benthos;
- increased turbidity;
- changes in sediment composition;
- changes in hydrodynamics and sediment transport;
- water chemistry.

4.2.2 Estuaries

Estuaries can be defined as the downstream part of a river valley, subject to the tide and extending from the limit of brackish water (JNCC, 1997). Inputs of sediment from the river, shelter from wave action and, often, low current flow lead to the presence of extensive sediment flats. Similar large geomorphological systems where seawater is not significantly diluted by freshwater are considered as ‘large shallow inlets and bays’.

The littoral and sublittoral sediments of estuaries support biological communities that vary according to geographic location, the type of sediment, tidal currents and salinity gradients within the estuary. The head of an estuary is often characterised by soft sediments, dominated by oligochaete worm communities. Towards the sea, where the water is less turbid and more saline, the sediment communities are dominated by ragworms, bivalves and small crustaceans.

The effects of aggregate and maerl extraction in estuaries are similar to those described for sandbanks. In addition to the direct impacts of aggregate extraction, indirect impacts include changes in hydrodynamics and sediment transport, which could potentially have a significant impact on estuarine sediment processes and subsequently the range of estuarine habitats.

Potential impacts of aggregate extraction:

- removal of substratum and benthos;
- increased turbidity;
- changes in sediment composition;
- changes in hydrodynamics and sediment transport;
- water chemistry

4.2.3 Mudflats and sandflats not covered by seawater at low tide

Littoral mudflats and sandflats are submerged at high tide and exposed at low tide. They form a major component of estuaries and embayments in the UK but also occur along the open coast. The physical structure of the intertidal flats can range from the mobile, coarse-sand beaches of wave-exposed coasts to the stable, fine-sediment mudflats of estuaries and embayments. This habitat can be divided into three broad categories (JNCC, 1997):

1. *Muddy sands*. A wide range of organisms can colonise these sediments such as lugworms *Arenicola marina* and bivalve molluscs. On the lower shore beds of the mussel *Mytilus edulis* can develop. Beds of the littoral dwarf eelgrass *Zostera noltii* or narrow-leaved eelgrass *Z. angustifolia* and eelgrass *Z. marina* may also occur.
2. *Mudflats*. These form in the most sheltered areas of the coast. The sediment is stable and communities are dominated by polychaete worms and bivalve molluscs. There is typically a high biomass of species in these sediments and this is important as a food source for waders and wildfowl.
3. *Clean sands*. This habitat occurs at mid- to low-tide levels on clean, sandy beaches on the open coast and in bays around the UK where wave action or strong tidal streams prevent the deposition of finer silt. These sediments are constantly mobile and therefore abrasive. Species colonising these areas tend to be robust and include amphipod crustaceans, some polychaete worms and bivalve molluscs.

The potential direct and indirect impacts on this habitat are very similar to those described for 'Estuaries'. Most of the significant impacts on these habitats will occur as a result of intertidal extraction which is uncommon within the UK.

Potential impacts of aggregate extraction:

- removal of substratum and benthos;
- increased turbidity;
- changes in sediment composition;
- changes in hydrodynamics and sediment transport;
- water chemistry.

4.2.4 Coastal lagoons

Lagoons are areas of shallow, coastal salt water, wholly or partially separated from the sea by sandbanks, shingle or, less frequently, rocks. Lagoons may be clustered on particular stretches of coast where they are dependant on specific local physical processes. These clusters have been considered particularly important for conservation of structure and function. Five basic classes of saline lagoon are recognised (Downie 1996):

- Saline lagoon inlets – lagoons where there is a permanent connection with the sea and where, if a sill is present it is subtidal.
- Isolated saline lagoon – these are pools which are completely isolated from the sea by a barrier of rock or sediment. The only input of salt water is through groundwater seepage or by overtopping of the barrier.

- Percolation saline lagoon – these lagoons are separated from the sea by a permeable barrier of shingle or pebbles.
- Sluiced saline lagoon – lagoons where the ingress and egress of water from the lagoon to the open sea is modified by human mechanical interference.
- Silled saline lagoon – generally rocky basins that possess a sill between mean high water or spring tides and mean low water of spring tides.

The water in lagoons can vary from brackish (owing to dilution with freshwater) to hypersaline (with a higher salinity than seawater as a result of evaporation). There are significant ecological differences between sites as the plant and animal communities of lagoons vary according to the physical characteristics and salinity regime of the lagoon.

Potential effects on this habitat could occur from indirect impacts as a result of changes in nearshore coastal hydrodynamics and sediment transport arising from aggregate extraction in other areas. Such impacts would be confined to those lagoon types in which local coastal processes are integral to their structure and function (e.g. isolated and percolation lagoons). Potentially these lagoon types could be adversely affected if the sand or shingle banks separating the lagoons from the sea were eroded and/or breached due to a reduction in the supply of sediment forming these coastal structures.

Potential impacts of aggregate extraction: • Changes in hydrodynamics and sediment transport.

4.2.5 Large shallow inlets and bays

Large shallow inlets and bays are complex systems interlinking the terrestrial and aquatic environments and comprise an interdependent mosaic of sublittoral, littoral and surrounding terrestrial habitats. They are large indentations of the coast, generally more sheltered from wave action than the open coast. They are relatively shallow, usually averaging less than 30m depth.

Potential effects on this habitat result from direct and indirect impacts. Examples of extraction within large shallow inlets and bays, including the extraction sites at Helwick Bank within the Bristol Channel and maerl extraction within Falmouth Bay.

Potential impacts of aggregate extraction: • Removal of substratum and benthos; • Increased turbidity; • Changes in sediment composition; • Changes in hydrodynamics and sediment transport; • Water chemistry.

4.2.6 Reefs

Reefs are rocky marine habitats or biological concretions that rise from the sea bed. They are generally sublittoral but may extend as an unbroken transition to the littoral zone. Two main types of reef can be recognised, those where the structure is created by the animals themselves (biogenic reefs) and those where animal and plant communities grow on raised or protruding rock (JNCC, 1997).

Several species can form littoral and sublittoral biogenic reefs, for example the tube-dwelling polychaetes *Sabellaria alveolata* and *S. spinulosa*. Other species can also form reef structures, examples being the horse mussel *Modiolus modiolus*, the common mussel *Mytilus edulis* and the polychaete worm *Serpula vermicularis*.

A rich and diverse fauna is often found associated with biogenic reefs. *Sabellaria* reefs modify their environment by the concretion of coarse sand particles into tubes which form a consolidated sediment structure. For this reason, rich benthic communities can develop in areas where, due to substrate conditions, they would not normally be able to do so.

The structure of biogenic reefs means they are especially susceptible to direct destruction by dredging and this is a major threat to this habitat. The main potential indirect effect of aggregate extraction on *Sabellaria* reefs arises from the effects of deposition of large quantities of fine material due to the generation of sediment plumes during the extraction process.

The indirect impact of increase in suspended sediment concentration and associated siltation could effect rocky reefs which are generally subjected to relatively low levels of turbidity. Many of the species associated with rocky reefs (e.g. red algae, sponges and hydroids) are sensitive to increases in either turbidity, due to the reduced light penetration for photosynthesis (red algae) or increases in suspended sediment concentrations which could settle and smother certain species (sponges and hydroids).

Potential impacts of aggregate extraction:

- Removal of substratum and benthos;
- Increased turbidity;
- Changes in sediment composition;
- Changes in hydrodynamics and sediment transport;
- Water chemistry.

4.2.7 Sea cliffs and shingle or stony beaches

a. Vegetated sea cliffs of the Atlantic and Baltic coasts

All selected sites have an exceptionally well-developed zonation of vegetation. The series includes rock types ranging from soft shales, mudstones, limestones and chalk through to igneous formations. The coast of England holds a major proportion of European coastal chalk exposures.

Exposure to the sea is a key determinant of the type of vegetation, and in the UK this exposure is greatest in the south-west and northern coasts. The long fetch generates high waves and swell and the prevailing winds deliver salt spray to the cliff face and cliff tops. Cliff structure and geomorphological processes are major influences on cliff vegetation. ‘Hard’ cliffs are characteristic of igneous and metamorphic rocks. ‘Soft’ cliffs have a sloping or slumped profile often with a distinct undercliff and are usually formed from sedimentary rock formations.

b. Annual vegetation of drift lines

This habitat occurs on deposits of shingle lying at or above mean high water spring tides. These deposits occur as fringing beaches that are subject to periodic displacement or overtopping by high tides or storms. The vegetation is ephemeral and composed of annual or short-lived perennial species and is very distinctive. Colonising species can withstand periodic disturbance and are tolerant of saltwater inundation.

c. Perennial vegetation of stony banks

This vegetation develops on foreshore beaches where material is deposited at the limit of high tide. More permanent ridges are formed as storm waves throw pebbles high up on the beach, from where the backwash can not remove them. Several beaches may be piled against each other and extensive coastal structures can form. The stability, the amount of fine material accumulating between the pebbles, climatic conditions, width of the foreshore and past management of the site combine to control the ecological variation.

The potential impacts of aggregate extraction on all of the habitats listed above are indirect and would result from potential change to coastal processes resulting from hydrodynamic and sediment transport modification due to offshore aggregate extraction. The potential deepening of offshore waters could cause an increase in wave height and allow wave propagation closer to the shore which could result in potential erosion of these habitats. Additionally, any areas which are deepened by aggregate extraction, could act as sediment sinks and decrease sediment supply to these habitats. Overall, changes in hydrodynamic and sedimentary processes could result in increased erosion of these coastal habitats or disruption to the existing ecological system. Direct impacts could only occur as a result of extraction from those habitats (examples b and c above), which would not be permitted through the licensing procedure.

Potential impacts of aggregate extraction: • Changes in hydrodynamics and sediment transport.

4.2.8 Saltmarshes

The following Annex 1 saltmarsh habitats are found on the UK coast:

a. Salicornia and other annuals colonising mud and sand
b. Spartina swards (*Spartinion*)
c. Atlantic salt meadows (*Glauco-Puccinellietalia*)
d. Mediterranean and thermo-Atlantic halophilous scrubs (*Sarcocornetea fruticosi)*

The potential impacts on these intertidal habitats are indirect and could result from potential changes in coastal processes due to changes in hydrodynamics and sediment transport. Water depth increase due to extraction could lead to an increase in wave height and allow wave propagation closer to the shore which could result in potential erosion of these habitats. Additionally, any areas which are deepened by aggregate extraction could act as sediment sinks, decreasing sediment supply and potentially increasing erosion of these habitats.

Potential impacts of aggregate extraction:

- Changes in hydrodynamics and sediment transport.

4.2.9 Sand dunes

The following Annex I sand dune habitats are found on the UK coast:

a. Embryonic shifting dunes
b. Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)
c. Fixed dunes with herbaceous vegetation (grey dunes)
d. Decalcified fixed dunes with *Empetrum nigrum*
e. Eu-atlantic decalcified fixed dunes (*Calluno-Ulicetea*)
f. Dunes with *Hippophae rhamnoides*
g. Dunes with *Salix repens* spp. *argentea* (*Salicion arenariae*)
h. Humid dune slacks
i. Machair
j. Coastal dunes with *Juniperus* spp.

Embryonic shifting dunes and shifting dunes along the shoreline with marram, *Ammophila arenaria* (white dunes) will be discussed in further detail here as they are the most susceptible to the potential impact of aggregate extraction.

1. Embryonic shifting dunes. The vegetation associated with this habitat exists in a highly dynamic state and is dependant on the continued operation of physical processes at the dune/beach interface. It is the first type of vegetation to colonise areas of incipient dune formation at the top of the beach. On a prograding dune system this vegetation may be the precursor to the main dune building vegetation dominated by marram *Ammophila arenaria*. In most cases embryonic shifting dunes are transient and will be either displaced by marram-dominated vegetation as the dunes develop (JNCC, 1997).

2. Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes). This habitat encompasses most of the vegetation of unstable dunes where there is active sand movement. The species composition of this habitat is controlled by the rate of sediment accretion. This is a dynamic vegetation type maintained only by change. The habitat can occur on both accreting and eroding dunes, but will rapidly changes and disappear if stability is imposed (JNCC, 1997).

Dune systems represent varying stages in ecological succession. Some stages of this succession are more dynamic than others and require a source of sediment. These stages, described above, are therefore most likely to be affected by any change in sediment supply resulting from hydrodynamic changes caused by aggregate extraction.

Potential impacts of aggregate extraction:

- Changes in hydrodynamics and sediment transport.

4.2.10 Submerged or partly submerged sea caves

Cave communities vary considerably depending on the structure and extent of the cave system, their degree of submergence and of exposure to scour and surge, and the nature of their geology. There may be tunnels or caverns with more than one entrance, in which vertical or overhanging rock faces provide the principal marine habitat. Caves are typically colonised by encrusting animal species but may also support shade-tolerant algae near their entrances.

Physical conditions, such as inclination, wave surge, scour and shade change rapidly from the cave entrance to the inner parts of the cave. Shallow water caves are frequently subject to strong wave surge and tend to have floors of coarse sediment, cobbles and boulders. These materials are highly mobile and scour the cave walls. Typical characteristic species are mussels *Mytilus edulis*, barnacles *Balanus crenatus*, cushion sponges, encrusting bryozoans and colonial sea-squirts, depending on the degree of water movement and sour at particular points in the cave system.

Caves that occur in deeper water are subject to less water movement from the surrounding sea, and silt may accumulate on the cave floor. The sponges *Dercitus bucklandi* and *Thymosia guernei*, the soft coral *Parerythropodium corallioides*, solitary sea-squirts, bryozoans and sessile larvae of jellyfish are characteristic of deeper cave systems (JNCC, 1997).

An alteration in the physical conditions affecting caves resulting from changes in coastal processes arising from aggregate extraction could affect the communities of the caves.

Potential impacts of aggregate extraction:

- Changes in hydrodynamics and sediment transport;
- Increases in turbidity;
- Water chemistry

4.3 Annex II species

This Section presents a list of UK marine and coastal species listed in Annex II of the Habitats Directive. For each species, a brief description is given. This description is based on that provided by the JNCC (Report No. 270) (JNCC, 1997). This is followed by a summary list of the potential individual impacts of aggregate extraction. Further details of each of these impacts is given in Sections 3 and 5.

4.3.1 Marine mammals

The following mammals are listed in Annex II of the Habitats Directive and regularly occur in UK seas and coasts:

a. Bottlenose dolphin (*Tursiops truncates*)

The bottlenose dolphin is widely distributed in North Atlantic, West African, Mediterranean and UK coastal waters. In UK inshore waters it occurs predominantly in Cardigan Bay and the Moray Firth. There are small groups off Dorset, around Cornwall and in the Sound of Barra. Dolphins from all these areas may move some distance from the core range on occasions. The total population in inshore waters of the UK is probably between 300 and 500 individuals.

b. Harbour porpoise (*Phocoena phocoena*)

Harbour porpoises are widely distributed in all waters around the UK with the exception of the English Channel. They are concentrated around the northern Isles of Scotland, in the offshore waters of the central North Sea, and in the shelf waters to the west of Scotland and in the Irish Sea.

c. Common seal (*Phoca vitulina*)

The UK holds 28 000 common seals, or 50% of the EC population. The common seal is widespread but the population density varies greatly from place to place. Seal haul-out areas and important breeding colonies are important for the conservation of the species.

d. Grey seal (*Halichoerus grupus*)

The UK holds 115 000 grey seals, or 50% of the world population and 95% of the EC population. There are breeding colonies all round the coast from the Scilly Isles to the North Norfolk Coast, although these colonies vary greatly in size.

e. Otter (*Lutra lutra*)

The otter is scarce over much of England, with stronger populations in Scotland, Wales and Ireland. The otter can occur in a wide range of ecological conditions, with populations occurring in coastal areas where they utilise shallow, inshore marine areas for feeding but also require fresh water for bathing and terrestrial areas for resting and breeding holts. Coastal otter habitat ranges from sheltered wooded inlets to more open, low-lying coastal areas.

The removal of substratum and benthos is an indirect impact in the case of marine mammals and relates to effects on the food chain and potential impacts on prey availability. Increased turbidity could displace fish species which form a significant part of the diet of these mammals.

There is little published data concerning the direct effects of aggregate extraction on marine mammals. According to US Department of Interior, Minerals Management Service (1991), the degree to which mammals might be affected by mining operations for hard minerals depends on a number of variables. Six of these are relevant to the impacts of the extraction of marine aggregates.

- the location of the activity, particularly the proximity to marine mammal habitats;
- the physical presence and numbers of animals, either year round, seasonal or migrants or occasional visitors;
- the customary, or preferred habitats of animals;
- their activities and behavioural attributes in a habitat;
- their feeding habits and food preferences.

The mining method and technology employed, will determine the characteristics and extent of sediment plumes at or near the surface, within the water column, or near or on the seafloor.

There are a number of potential indirect effects of aggregate extraction on mammals. However, given the mobility of these species it is unlikely that there will be any significant ecological impact on these species. The following points summarise the potential effects:

Decreased feeding success and prey availability in areas of increased activity-related turbidity;

- death or injury due to collisions with dredging and other activity-related vessels;
- behavioural and stress related reactions to increased noise and activity of support vessels and mining, and from support base or onshore processing operations.

Potential impacts of aggregate extraction:

- Increased turbidity;
- Behavioural change due to disturbance.

4.3.2 Fish

a. Sea lamprey (*Petromyzon marinus*)

The sea lamprey is found in estuaries and easily accessible rivers. It spawns in fresh water but completes its life cycle in the sea and requires clean gravel for spawning and marginal silt or sand for the burrowing juvenile ammocoetes. Features such as weirs and dams, as well as polluted sections of river may act as a barrier to the fish, impeding migration to spawning grounds.

b. Allis shad (*Alosa alosa*)

The allis shad is rare in the UK. This species grows in coastal waters and estuaries but migrates into rivers to spawn, swimming up to 100 km upstream. Population declines in many parts of Europe have been attributed to the effects of pollution, over-fishing and river obstructions to migration.

c. Twaite shad (*Alosa fallax*)

Spawning stocks of the twaite shad are known to occur in only a few rivers in Wales and the Welsh/English borders, with the possibility of additional populations in rivers flowing into the Solway Firth. On the River Usk and the River Wye, twaite shad are known to spawn at night in a shallow area near deeper pools, in which the fish congregate. The eggs are released into the water column, with a proportion being deposited in the gravel. The remainder are carried downstream, developing as they go. These species return from the sea to spawn in spring. Population declines in many parts of Europe have been attributed to the effects of pollution, over-fishing and migratory route obstructions.

d. River lamprey (*Lampetra fluviatilis*)

The river lamprey is widespread in the UK. The UK populations are considered important for the conservation of the species at an EC level. The species requires clear water and gravels, silt or sand for spawning. The species normally spawns in fresh water but completes part of its life cycle in the sea. Pollution or obstacles that the adults can not surmount during the spawning migration, such as weirs or artificial dams, impede migration.

The above four species of fish are Annex II species. In addition, it is considered that impacts on other species of fish could have an indirect effect on the marine mammals mentioned in Annex II.

Potential impacts of aggregate extraction:

- Removal of substratum and benthos;
- Increased turbidity;
- Behavioural changes due to disturbance.

4.4 Impact summary

Table 4.4 summarises the potential direct and indirect individual impacts of aggregate extraction on Annex I habitats and Annex II species. An indication is given as to the duration of the potential impact. Short term impacts are those which are expected to occur over a period of a few hours up to several days. Medium term impacts are expected to have a duration of several months up to 1 year, with long term impacts lasting more than 1 year. If an impact is indicated as being short term, this does not mean that it is necessarily insignificant, and *vice versa.*

Table 4.4 Potential impacts on Annex I habitats and Annex II species

	Potential Impact					
	Removal of Substratum/Benthos	**Increased Turbidity**	**Changes in Sediment Composition**	**Changes in Hydrodynamics/Sediment Transport**	**Water chemistry effects**	**Behavioural changes due to disturbance**
Annex I Habitat						
Sublittoral sandbanks	M-L	S	M-L	M-L	S	
Estuaries	M-L	S	M-L	M-L	S	
Mudflats and sandflats	M-L	S	M-L	M-L	S	
Lagoons				M-L		
Large shallow inlets and bays	M-L	S	M-L	M-L	S	
Reefs		S	M-L		S	
Sea cliffs and shingle/stony banks				M-L		
Saltmarshes and salt meadows				M-L		
Coastal sand dunes				M-L		
Rocky habitats and caves		S		M-L	S	
Annex II Species						
Marine Mammals	S-M	S			S-L	S
Fish	S-M	S	M-L		S	S

KEY: S=Short-term impact M=Medium-term impact L=Long-term impact

Short term impacts are those which are expected to occur over a period of a few hours up to several days. Medium term impacts are expected to have a duration of several months up to 1 year, with long term impacts lasting more than 1 year. If an impact is indicated as being short term, this does not mean that it is necessarily insignificant, and *vice versa*

5. Cumulative impacts

Cumulative impacts are effects on the environment, either from the summation of individually minor but collectively significant impacts, or as a result of the interaction of impacts from one or more sources. Thus, cumulative impacts might occur as a result of aggregate extraction at a single site, from multiple sites in close proximity, or in combination with effects from other activities such as fishing, waste disposal, dredging, coastal defences, anchoring or installation of offshore structures. The Habitats Directive (Article 6(3) requires that the effects of plans and projects are assessed individually and in combination with other plans and projects. This ‘combined’ impact assessment is therefore a particular type of cumulative impact assessment, focusing on SACs/SPAs and the features for which they were selected.

This Section outlines the potential cumulative impact of aggregate extraction and the impacts of various activities which may combine with the aggregate extraction to increase or reduce the scale of impacts on Annex I and II features of marine and coastal SACs.

5.1 Cumulative impacts with other aggregate extraction areas

5.1.1 Extent of aggregate extraction

Aggregate extraction tends to be concentrated within certain areas around the UK coastline. This is due to several factors, with the following being the most significant:

- distribution of suitable aggregate resources;
- extent of local resources (e.g. depth of deposit);
- strict specifications for material, e.g. gravel of a particular clast size;
- economic viability of travelling distances (e.g. proximity to port facilities for off-loading).

These factors, when taken together, tend to restrict economically viable extraction to a few key areas around the UK coastline (Figure 2.2.1). Applications for new aggregate extraction areas are likely to be sought in close proximity to existing licensed areas, i.e. areas where economic viability has already been proven. However, this does not necessarily preclude the potential exploitation of resources from areas that are currently unworked, as economic forces may change.

As extraction tends to be concentrated within certain areas there is increasing concern that whilst the impact of individual licensed areas may be small, there is the possibility that cumulative impacts arising from a number of licence areas may occur. Cumulative impacts are generally defined as the cumulative environmental effects of past, present and reasonably foreseeable future actions. With regard to aggregate extraction, the potential cumulative physical impacts of both current applications and existing licences are assessed as part of the coastal studies initiated when new licence applications are proposed. However, the biological impacts of cumulative hydrodynamic/physical change are rarely considered. The issue of cumulative effect is generally recognised by applicants for licences, but is often not satisfactorily considered in the assessment process (CEFAS pers. Comm.). A comprehensive literature research undertaken by Oakwood Environmental Ltd (1999) found no reference to cumulative environmental impact assessment (CEIA) work undertaken for marine aggregate extraction anywhere in the world, although cumulative hydrodynamic change is considered in licence applications.

5.1.2 Potential for cumulative impacts affecting SACs

Table 5.1.2a Location of main marine aggregate extraction areas around the UK coast and marine and coastal SACs in the vicinity (as at April 2000)

Number of licensed extraction areas	Nearby coastal (C) or marine (M) SACs
East coast (Humber region) (see Appendix A)	
8	Flamborough Head (C, M)
	The Wash and North Norfolk Coast (C, M)
	North Norfolk Coast and Gibraltar Point Dunes (C, M)
South-east coast (see Appendix A)	
44	Winterton-Horsey Dunes (C)
	Benacre to Easton Bavents Lagoons (M)
	Minsmere to Walberswick Heaths and Marshes (C)
	Orfordness-Shingle Street (C, M)
	Essex Estuaries (C, M)
Severn Estuary (see Appendix A)	
7	Severn Estuary (M)
Isle of Wight (Appendix A)	
8	Solent Maritime (M)
	South Wight Maritime (M)
	Solent and Isle of Wight Lagoons (C)
	St Albans Head to Durlston Head (C)

Examination of Appendix A and Table 5.1.2a provides an indication of the marine and coastal SACs (as at April 2000) that could potentially be influenced by the effects of aggregate extraction, either in isolation or potentially through the cumulative impacts of multiple offshore licensed areas. These figures clearly show that the European sites most likely to be affected by aggregate extraction are those on the eastern and south-eastern coasts of the UK and the Severn Estuary. As at April 2000, the only SAC within which aggregate extraction takes place is the Severn Estuary (currently pSAC and SPA), whilst maerl extraction occurs within the Fal and Helford cSAC.

Table 5.1.2b Possible impacts of various activities when combined with aggregate extraction

	Activity								
	Fishing	**Organic Pollution/ Eutrophication**	**Other Pollution**	**Coastal Alteration**	**Spoil and Waste Disposal**	**Capital and Maintenance Dredging**	**Anchoring of Large Vessels**	**Other Aggregate Extraction areas**	**Offshore Structures**
Increased Turbidity	✓	✓			✓	✓		✓	
Removal of Substrate/ Effects on Benthos	✓	✓	✓	✓	✓	✓	✓	✓	
Modification of Sediment Composition	✓	✓			✓	✓	✓	✓	✓
Excessive Sedimentation	✓	✓			✓	✓		✓	
Water Chemistry Effects		✓	✓		✓	✓		✓	✓
Increased Primary Production	✓	✓				✓		✓	
Increased Food Supply	✓	✓				✓		✓	
Changes in Hydrodynamics	✓			✓	✓	✓		✓	✓
Changes in Sediment Transport				✓	✓	✓		✓	

KEY: ✓= Possible combined impact that may require further investigation

Therefore, there are few sites where cumulative impacts on SAC features involve the direct biological effects of removing the substrate and benthos. In most cases, the potential for cumulative impacts on SACs and their features occurs through physical and chemical changes.

For each new aggregate licence application, the Coastal Impact Study considers impacts in isolation, and also potential hydrodynamic change as a result of the combined effect of extraction from existing and proposed licensed areas in the vicinity of the proposed site. As an example, for Area 451 (St. Catherines, Isle of Wight) the likely change in hydrodynamic processes was determined for the maximum extraction in existing licensed areas and eight proposed areas. The studies indicated that the cumulative impact of extraction within all of these areas, including Area 451, on in-shore conditions, and therefore on the South Wight Maritime cSAC, was not likely to be significant (Oakwood Environmental Ltd, 1999).

Assessing the cumulative impacts of individual extraction licences in combination on physical processes is fraught with difficulty and constrained by a number of factors. The actual physical parameters affected by aggregate extraction from a number of areas will be the same as those identified for individual areas (see Section 3). Therefore, the resulting cumulative impacts will be of a similar nature to the effects that arise from individual extraction sites but may operate on a different scale. To ascertain the nature of these cumulative impacts, and the scale at which they operate, it is necessary to consider spatial and temporal factors (e.g. timing of extraction, location within licensed area), potential for synergy and whether effects are incremental or decremental. Furthermore, lack of availability of data from adjacent aggregate extraction areas, due to ownership by different companies, may hinder the assessment of cumulative impacts. The following sub-sections consider the likely scope of cumulative impacts of the indirect effects of aggregate extraction from more than one licensed area (ie from physical and chemical changes). These are summarised in Table 5.1.2b.

5.1.3 Cumulative impacts by changes in nearshore wave activity

Changes in inshore wave conditions are linked to bathymetric change within the licensed area following extraction. Modelling work can be undertaken to gain an understanding of the potential cumulative impact of extraction on bathymetry and hence wave conditions. Such a study has been undertaken by HR Wallingford with respect to the impact of extraction from Helwick Bank and implications of this on wave conditions along the adjacent coastline (HR Wallingford, 1990, 1996). By assuming a 0.5m reduction in the crest height of part of the bank, the equivalent of the removal of approximately 3 million m^3 of sediment (out of total volume of 300 million m^3 in Helwick Bank), it was calculated that there would not be any significant change in nearshore wave conditions, even under storm conditions. The volume of material ‘removed’ in the simulation was far in excess of the quantities applied for at the time (1990) or since (230 000 tonnes removed between 1992-1996). Observed changes in Helwick Bank indicate that there has been a small reduction in crest height at the eastern end of the feature and a slight increase at its western end. This change is considered to only have had a small effect on waves in the lee of the bank. The observed changes in the morphology of the bank, despite the removal of 230 000 tonnes of sand, indicate that natural sediment transport processes have compensated for the volume loss.

The work on Helwick Bank indicates that the cumulative impact of aggregate dredging on wave conditions can be assessed through consideration of the link between volume change and bathymetry and suggests that generally the greater the material volume extracted, the higher the probability that there will be a change in nearshore wave conditions. However, this generalisation does not reflect the complexity of the situation. For instance, as with the example of Helwick Bank, aggregate resources may form part of a dynamic sedimentary system. Any modification to the morphology of the feature, or removal of sediment, may be counterbalanced by re-distribution or accretion so that the feature is once more in equilibrium with external forcing mechanisms (e.g. wave climate). If this is the case, then the compensatory sediment would have to be derived from a source within the system itself, which in turn may lead to impacts elsewhere. In the case of Helwick, evidence suggests that additional sediment arrived from a source to south and that it is most unlikely that there has been any disruption in the transport of sand from the Bank into Carmarthen Bay (HR Wallingford 1996). Although there is only limited evidence, it is suggested that the cumulative impact of the removal of sediment from a number of licensed areas, that form part of a large offshore dynamic sedimentary transport system, could be relatively insignificant or negligible with respect to effect on nearshore wave climate. In this situation measuring or documenting the cumulative impact of aggregate extraction would be extremely difficult, as the processes that control dynamic offshore sedimentary structures are not fully understood or completely predictable.

Some aggregate resources, such as the large areas of Quaternary sands and gravels deposited in the North Sea and off the south coast during the last glacial cycle may not form part of the present day sediment transport system. These areas may, therefore, not be replenished following extraction, although their morphology could be altered through wave and current action. Extraction from these areas may have an incremental effect on nearshore wave action, as slight changes in bathymetry take place as extraction proceeds over time. The scale of likely effect would depend on the volume of material removed from the resource area and several other key factors such as the orientation of the resource feature in relation to the coastline, proximity to the coast and prevailing wind/wave climate etc. Modelling work could be utilised to determine the point at which the incremental loss of material from an aggregate resource may have a significant impact on nearshore wave action. Potentially, it may be possible to set a threshold level at which it is predicted that further change in bathymetry could lead to a significant increase in nearshore wave activity, and extraction could be limited to ensure that this threshold is not reached.

5.1.4 Cumulative impacts by changes in sediment transport

Extraction may also alter local sediment transport pathways through alteration in tidal current patterns within the area of extraction or by reducing potential sources of mobile material within the transport network. Changes in currents are likely to be localised and linked to the loss of volume of material and the effect this has on local bathymetry. Potentially the greater the amount of extraction from an offshore area the more likely that tidal currents, and therefore sediment transport, will be affected. However, the situation is complex, and the overall impact of extraction from a number of adjacent licensed areas, or from within one area is unlikely to represent the sum of the impacts of each individual licensed volume. The potential cumulative impact will be linked to a number of factors. These include:

- Whether the resource forms part of an existing dynamic sediment transport system that interacts with sedimentary processes along the coastline. Although, tidal currents and sediment transport may be affected within the area of extraction this impact may not feed through to sediment supply along the coast as the offshore and nearshore systems may not be linked, or the linkages remain unaffected.

- The proximity of licensed areas to each other, and location of extraction within these areas.
- Prevailing wave and wind conditions. These are likely to slightly differ at each location.

As with determining potential changes in nearshore wave conditions, evaluating changes in tidal currents and sediment transport due to extraction from a number of sites is difficult. Modelling could be used to predict changes associated with each extraction area and calculate residual currents. Determining how these residual currents interact and what their effect on sediment transport would be, requires a large amount of data collection and understanding of the sedimentary and hydrodynamic processes operating within offshore areas. At present, data of this type is generally not detailed enough (or unavailable) for conclusions regarding the cumulative impacts of aggregate extraction on sediment transport to be made. It may be possible at the simplest level to determine that there is sediment interchange between offshore areas where extraction occurs, or could occur, and European marine sites. However, it is considered that assessing any actual impacts of disruption to sediment transport is likely to be extremely difficult and at best subjective. A precautionary approach will therefore be needed.

5.1.5 Cumulative impacts of sediment plumes

Sediment dispersal is controlled by factors such as wave climate, sediment type and current velocity. Within a single licensed extraction area these factors may be broadly similar and therefore the plumes created through extraction may have similar properties (e.g. direction of dispersal). However, when considering the potential for cumulative effects arising due to extraction from a number of resource areas the situation with regard to sediment dispersal is considerably more complex. The cumulative effect relates to interaction between sediment plumes and the probability of this occurring. The actual impacts are the same as those likely to occur for an individual dispersal event (e.g. increased deposition on the seabed, smothering of benthic communities etc.). However, the likely significance of an impact could be increased as dispersal from a number of sites may lead to, for example, a higher rate of sedimentation within a particular area. The probability of this occurring, i.e. of sediment plumes affecting the same area, is strongly controlled by spatial aspects related to the site and the temporal nature of the activity.

The spatial characteristics of a plume will be controlled by a number of factors including wave/wind climate, tidal currents and the nature of the sediment being extracted (see Section 3.2). At the broad scale, it is likely that sediment plumes will have similar characteristics with regard to the broad direction of dispersal (e.g. plumes may disperse in a south-westerly direction where winds from the east dominate and the main offshore current direction is to the south). However, the variation in these factors at the local level is such that it is considered highly unlikely that extraction would generate plumes that cover exactly, or possibly even approximately the same areas. This is particularly so where the licensed blocks cover a large offshore area (e.g. off the east coast of Norfolk/Suffolk). Even where repeated extraction takes place from the same licensed area the path of sediment dispersal is highly unlikely to be the same each time.

The timing of any extraction activity also controls the potential for cumulative impact. The spatial characteristics of a plume, as shown by the work on Area 107, may be influenced by tidal conditions at the time of extraction. In addition, interaction between plumes can only take place if extraction from a number of areas occurs at the same time. Even differences of a few hours may make a difference in the direction of dispersal and the distance over which a plume travels (see results of CEFAS monitoring of Area 107 reported in Section 3.2.)

5.2 Cumulative effects with fishing

The effects of fishing on marine communities varies depending on the method of fishing, the characteristics of the physical environment and the biological communities present in the area. The potential effects of fishing on Annex I and II habitats and species has been reviewed and assessed as part of the UK Marine SACs Project (Gubbay & Knapman,1999) and for further information the reader is referred to this report. For the purposes of this study it is important to note that the effects of some fishing techniques (e.g. trawling) are similar to those associated with aggregate extraction (ICES 1992).

The most potentially destructive category of fishing is the use of towed gear, as used in trawling. Some methods of trawling, such as those using the rockhopper otter trawl and the Newhaven scallop dredge, are designed for use on rocky or mixed sediment areas. Other trawling methods are designed for softer sediments. The impacts of the different methods are variable and may include:

- increased turbidity;
- removal of benthic communities/physical damage;
- modification to substratum.

These potential impacts could combine with the potential impacts from aggregate extraction and have a greater cumulative impact on a number of Annex I habitats and Annex II species. The main impacts resulting from both activities are very similar. The latter two are longer-term direct impacts, although both occur on a relatively localised scale in and around the dredge area.

The potential for fishing activity to have a cumulative impact with aggregate extraction is highlighted by the work undertaken by CEFAS (referred to in Section 3.3.2). Between April and July 1997, 5 minipods (for measuring and recording near-bottom suspended sediment concentrations) were deployed over a wide area around Area 107. The results from these deployments showed that sediment plumes from dredging activity reached as far as approximately 9 km from the site, but not the three most distant minipods at Burnham Flats Buoy, Burnham Flats or Skegness (CEFAS, 1998).

The minipod deployed at Burnham Flats Buoy recorded abnormally large spikes in suspended load which were uncorrelated with dredging activity at Area 107. Additionally, the peaks were most frequent during neap tides during calm weather when the processes of local resuspension, due to wind and tide, are minimal. It was concluded that disturbance of the seabed due to beam trawlers working the edge of Burnham Flats and Ridge were the most likely cause of the elevated suspended sediment. This conclusion would, however, need to be correlated with fishing records (CEFAS, 1998).

The scale of the individual and cumulative impacts, in the short and long term, are dependant on the sensitivity of the species in the area, their ability to recover from disturbance and the ambient environmental conditions. For example, the impacts on an area which is dominated by slow growing megafaunal benthic species are likely to be more severe than in an area of smaller, faster growing species as slower growing species will take longer to recover from disturbance.

5.3 Cumulative effects with organic pollution and eutrophication

The potential impacts resulting from organic pollution sources can be summarised as follows:

- increased turbidity;
- increased rates of sedimentation;
- decreased semidment and water column oxygen levels;
- increased food supply to suspension feeders (eg brittlestars);
- increased primary productivity (both phytoplankton and macroalgae).

Aggregate extraction may increase the overall level of organic matter in the water column. In combination with other activities which input organic material into the water, or in areas of existing high organic loadings, aggregate extraction may increase the potential for algal growth or may alter benthic species diversity and abundance in the vicinity of the extraction area. However, within the coastal and nearshore marine environment there is very limited spatial overlap between potential organic sources of pollution and areas of aggregate extraction. Therefore, the potential for significant in combination impacts is considered to be low, particularly as aggregate resources generally have a low organic content. In reality, the significance and scale of impacts on marine habitats and species from water quality aspects, such as eutrophication, will be dependent on the nature of primary water pollution sources.

The impacts identified above may be more significant for areas characterised by live maerl biotopes. Should increased nutrient levels in the water column stimulate the growth of opportunistic, fast growing algae the light penetration to the maerl could be reduced. In combination with increased turbidity and higher sedimentation due to extraction, the reduction in light penetration to maerl and its potential for growth could be significant.

5.4 Cumulative effects with other forms of pollution

Other pollutants of the marine environment (excepting those covered in ‘Organic pollution and Eutrophication’) include synthetic organic compounds (such as tributyl tin) which is used in anti-fouling paints on ships, heavy metals and hydrocarbons.

The potential impacts associated with these pollutants can be summarised as:

- changes in water and seidment quality;
- impacts on biological communities, either physically or physiologically.

The impacts on biological communities due to this type of pollution are usually less obvious in the short term than impacts related to aggregate extraction. Pollutants often act in a physiological manner, affecting organisms at the cellular level which then feeds through to the population and community level over the longer term. Levels of stress arising from pollution can reduce the thresholds of sensitivity of certain species and this should be considered where aggregate or maerl extraction occurs in an area known to be subject to pollution.

The nature of aggregate and maerl resources are such that extraction would be unlikely to increase levels of pollutants, particularly as these tend to occur in greater concentrations in fine sediments.

5.5 Cumulative effects with capital and maintenance dredging

Capital and maintenance dredging activities are generally undertaken in nearshore waters with the objective of maintaining navigable channels, generally in approaches to ports and harbours. The frequency of such activities varies between regions and, indeed, within localised areas, due to the differences in sediment loadings and tidal streams and currents, amongst other factors. (ABP 1999) gives a review of impacts on Annex I/II features.

Potential impacts associated with capital and maintenance dredging can be summarised as:

- changes in hydrodynamic and sediment transport processes;
- temporary increase in suspended sediment concentrations;
- temporary changes in water quality;
- modification of substrate;
- direct loss of and smothering of benthic communities.

Apart from modification to local hydrodynamics, all of the impacts associated with dredging are of a temporary nature, although the time scale over which they occur varies. Due to the similarity of environment in which dredging takes place and the fact that the dredging plant used in capital and maintenance dredging is the same to that used in aggregate dredging, the environmental impacts of both activities are extremely similar. Consequently, the potential for in combination impacts is largely additive. However, in reality the opportunity for these additive impacts to occur is extremely low. This is due to the very limited spatial overlap between the activities, as the vast majority of capital and maintenance dredging takes place from within existing navigational channels and/or within the immediate nearshore area where aggregate extraction activity is at a very low level.

Where aggregate or maerl extraction is within shallower water close to the coast, such activity may change tidal currents and hence sediment transport processes, along a coastline. Recent research by HR Wallingford (CIRIA 1998), has recommended that modelling changes in tidal flows should be carried out when dredging is proposed in water depths of less than 10m (below lowest tide level), and where sediment on the surface of the seabed is regularly mobilised by tides and waves. Similar precautionary measures are recommended when considering the deepening of channels to ports or estuaries. This is due to the potential for dredged channels to intercept or disrupt existing sediment transport routes. Not only could interception lead to increased deposition within the channel itself, but potentially sediment could be diverted or taken out of the nearshore system with consequent impacts for sediment feed onto adjacent shorelines.

5.6 Cumulative effects with disposal of dredged material

The effects of disposal of spoil arising from dredging are well studied (ABP 1999). A number of potential impacts arising from this activity can be identified:

- increased turbidity;
- smothering of benthic communities;
- changes in water quality (e.g. reduced oxygen levels, release of contaminants);
- modification of the substratum composition.

All of the above impacts arise through sediment dispersal during aggregate extraction. There are strict regulations in place to control the disposal of materials and numerous designated disposal areas exist, which are regulated by DEFRA. It should therefore be relatively straightforward, through spatial analysis of sediment dispersal, to determine whether there is likely to be a cumulative (additive) impact associated with disposal and extraction.

5.7 Cumulative effects with coastal alteration and coastal defences

Coastal alteration by, for example, beach nourishment, construction of breakwaters, promenades and other coastal defences, may result in changes to physical processes acting within a coastal cell. The effects of this can either be localised, such as scouring of the coast adjacent to the structure, or at some distance from the structure, due to the formation and subsequent effects of tide driven or wind and wave driven eddies, or the influence on the longshore transport of sediments. Changes in the hydrodynamic regime may cause different sediment types to be transported to different areas or may deplete or increase sediment supply, thus affecting substratum composition and hence the predominant community type.

The potential impacts of coastal alteration can be summarised as follows:

- changes in hydrodynamic regime;
- changes in sediment transport processes;
- substrate and benthic community change.

The Coastal Impact Study commissioned by the applicant should ensure that aggregate extraction will not have an identifiable impact on the coast. However, the potential may exist for the development of some synergistic effect in combination with the construction or changes associated with coastal defences or other developments.

As with assessment of extraction, it should be possible to predict the in combination effect of extraction and the construction of a new coastal structure on factors such as erosion or accretion within the coastal zone. This is because offshore extraction has the capability to modify the nearshore hydrodynamic conditions under which a coastal structure has to function. Determining the likely impact of a coastal structure on coastal processes, through modelling work, should therefore provide an indication of the cumulative effect on hydrodynamic conditions and sediment transport, as any changes due to aggregate extraction can represent the baseline conditions.

In general, the spatial separation between construction work in the coastal zone and aggregate extraction further offshore, makes it unlikely that the two activities will impact upon the same processes. They do, however, both occur with the Severn Estuary and Bristol Channel. The potential exists for coastal structures to further modify any hydrodynamic or process changes resulting from aggregate extraction which manifest themselves in the nearshore zone (e.g. a reduction in sediment supply). Theoretically, increased wave activity at the coast due to offshore aggregate extraction may combine with a reduction in sediment supply due to coastal construction and lead to greater coastal erosion than through either activity in isolation. However, the potential for this is extremely low given that any potential extraction activity likely to have an adverse impact on coastal processes would not be allowed to progress through the assessment procedure.

The limited extraction which occurs within intertidal areas is of greater concern, particularly when considered in combination with coastal alteration. These potential impacts could be of significance with respect to Annex I habitats, such as intertidal mudflats and sandflats, estuaries, lagoons, large shallow inlets and bays, saltmarsh and sand dunes. Up until relatively recently there were a number of littoral extraction sites around the UK. Recent legislation and increasing environmental awareness has, however, curtailed the use of most of these sites. The following examples illustrate the damage that can occur to coastal habitats as a result of sand extraction within the intertidal zone:

Isles of Scilly

Sand extraction occurred at Bar Point on the Isles of Scilly until concern was expressed regarding erosion of the sand dunes in this area. As a result of this concern, the activity was stopped by a Coast Protection Order.

Taw-Torridge (Braunton, Devon)

Sand extraction was undertaken from the littoral zones within this area until relatively recently. Evidence of erosion of the sand dunes has now halted this activity.

West Coast of the Lizard, Cornwall

Farmers within this area have an ancient right to extract sea sand from the intertidal zone. This activity was, however, causing erosion of the sand dunes nearby and English Nature are currently in the process of trying to terminate this ancient right.

5.8 Cumulative effects with anchoring of large vessels

The potential impact of anchoring large vessels could cause physical disturbance to benthic communities, including maerl, raising the potential for cumulative effects.

Generally, the area of seabed likely to be affected by this activity will be small. The impacts would be most serious should they occur in sensitive environments such as maerl biotopes or if sensitive species such as *Sabellaria* spp. are directly impacted. There is little reported evidence of the effect of anchoring on habitats and species, although there is some evidence of an adverse effect due to moorings. In Loch Creran, the movement of mooring blocks and chains caused severe damage, on a very local scale, to *Serpula vermicularis* reefs.

In the Fal estuary, there is evidence that maerl and other organisms are crushed by the swinging action of mooring chains. Additionally, several activities associated with yachting, such as temporary anchoring, or permanent moorings can damage maerl. In addition, large vessels often drop anchor within Falmouth Bay. Such activities could increase the overall level of damage to or loss of maerl habitat. However, the scale of impact is likely to be small and very difficult to quantify in comparison to that caused by extraction itself and/or other activities such as fishing.

5.9 Cumulative effects with offshore structures

Offshore structures include oil and gas platforms, drilling rigs and offshore wind turbines. Potential impacts associated with offshore structures which could combine with impacts from aggregate extraction include the following:

- impacts on benthos during construction;
- changes in local hydrodynamic system;
- risk of pollution events;
- modification of the wave climate;
- accumulated drilling discharges.

However, it is considered to be unlikely that there would be any additive impacts as a result of aggregate extraction and activities associated with the offshore energy industries due to the disparate locations in which these activities occur. Nevertheless, this may be a future consideration. The most likely potential occurrence of cumulative impact could be associated with development of offshore windfarms on sandbanks in relatively shallow water which is within the depth range of aggregate dredging plant.

6. Guidance on methods of cumulative impact assessment

6.1 Introduction

The Habitats Directive Article 6(3) states that any plan or project not directly connected with or necessary to the management of an SAC/SPA, but likely to have a significant effect on it, either individually or **in combination with other plans or projects**, shall be subject to an appropriate assessment of its implications for the site in view of the site's conservation objectives. This 'combined' assessment is a particular, specialist, type of cumulative impact assessment.

Since the mid-1990s, EIA practitioners and regulators in the UK have noted an increased awareness and interest in cumulative impacts and their assessment. Following the early lead taken by North America, this issue is rising up the EIA agenda in Western Europe. If cumulative effects are to be assessed effectively, standardisation is required in order to provide consistent and useful information to decision-makers. Canadian experience indicates EIA practitioners need consistent guidelines and clear standards for what they term cumulative effects assessments (CEAs).

General guidance on impact assessment is based on a wide variety of research and experience gained from development projects. Some site specific studies have sought to assess potential impacts of aggregate extraction and to determine the scale of impacts on sensitive receptors. Specific studies have also been initiated to determine effects of this extraction on fish resources, benthic species, and upon habitats. They have also dealt with the impacts on habitats and species associated with other activities which occur in and around the seabed (e.g. fisheries, pollution).

The aim of this Section is to recommend a method for the CEIA of aggregate extraction proposals based on available guidance. The guidance outlined in the following sections forms the basis for an evolving procedure which can be adapted as the results of new studies is made available. Investigations relating to the sensitivity of habitats and species, and hence their susceptibility to damage, are particularly relevant. In this context, a study is currently being undertaken by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) to consider the cumulative environmental impacts of marine aggregate extraction. This study, amongst other tasks, involves a programme of scientific sampling of key biological and environmental measures relevant to the assessment of cumulative impacts.

6.2 Existing guidance on cumulative impacts

A comprehensive search was made of the available literature on methodologies used for the assessment of cumulative environmental effects. This search included the internet, British library and the EIA schools at the University of Manchester and Oxford Brookes. In addition a wide range of organisations were contacted directly for any relevant handbooks, guidelines and project examples. These included:

- the Canadian Environmental Assessment Agency;
- the International Association for Impact Assessment (IAIA);

- the project team for the Oresund Link/Dredging Scheme, Denmark;
- US Department of the Interior – Minerals Management Service;
- English Nature; and
- a number of environmental consultants

6.2.1 North American guidance

The Canadian Environmental Assessment Act came into effect in 1995, requiring by law that Cumulative Effects Assessment (CEA) be incorporated as a vital component of EIA. The Canadian and US guidance documents present a framework for CEA before discussing the tools that can be applied at different stages of the process.

Because CEA is a burgeoning practice, there is no accepted standard. The major difficulty with CEA, says Baxter, is the 'fuzziness' regarding how much to assess; or what are the responsibilities of doing project CEA (Baxter, 1999). The CEA Act inadequately defines the bounds of cumulative impact assessment and this deficiency is reflected in assessment practice. While this guidance is helpful and can usefully contribute to thinking on cumulative impacts in the UK, the CEA guidance is tailored to Canadian procedures.

Equivalent guidance in the United States has been produced by the US Council on Environmental Quality – Considering Cumulative Effects Under the National Environmental Policy Act, Washington D.C.

The strategic cumulative effects of marine aggregates dredging is also the subject of a research project recently undertaken for the US Department of the Interior, Minerals Management Service by Oakwood Environmental Ltd., 1999. This study outlines a framework for the assessment of strategic cumulative impacts resulting from aggregate extraction and draws on examples from the south east of the Isle of Wight to illustrate the complexity of the issues involved.

6.2.2 EC guidance

Cumulative effects are referred to in Annex III of the original EIA Directive (85/337/EEC) and in Annex IV of the amending Directive (97/11/EC). Some reference to cumulative effects also appears in Part 1 of Schedule 4 of the Town and Country Planning EIA Regulations (SI 1999 NO. 293).

i. *EC guidelines for the assessment of indirect and cumulative impacts as well as impact interactions* (Hyder Consulting, 1999)

The first EC guide on cumulative effects was published in May 1999. The Guidelines were commissioned by the EC and prepared by Hyder.. The document describes the tools and techniques available for the assessment of cumulative effects, indicates that stages of EIA at which these methods are appropriate and many examples. This guidance is welcome for three reasons:

- It is good to see DGX1 being proactive in commissioning this work and giving a European focus to the subject;

- Consideration of cumulative effects should move from the small print of the Annex to everyday practice; and
- It provides UK practitioners with readily accessible and directly applicable information on the assessment of cumulative effects

Fuller and Sadler (1999) criticise the guidelines on the following grounds:

- the document is not well organised;
- an inordinate proportion of the document is devoted to explaining basic EIA tools;
- the more complex issues associated with the assessment of cumulative effects are avoided or dealt with superficially;
- the document fails to provide a clear and comprehensive framework for consideration of the effects (ibid.)

ii. *EC guidance on Article 6 of the Habitats Directive* (European Commission, 2000)

This gives guidance on the interpretation of key concepts in Article 6 including ‘either individually or in combination with other plans or projects’. It indicates that the combination provision should be applied to projects which are completed, approved but not completed, and those which have been proposed.

6.2.3 UK Guidance

The consideration of cumulative impacts appears to be a relatively new occurrence in the UK. There is no definitive guidance on the assessment of impacts of cumulative activities on the existing environment. There is now, however, a growing awareness of the need to consider impacts in combination as required by Article 6(3) of the Habitats Directive.

For aggregate extraction, this will be transposed to UK law by the forthcoming marine minerals dredging regulations (see section 2.2.2). The draft marine minerals guidance note for England (DETR, 2001), states that the EIA for any new aggregate extraction licence will need to demonstrate that the permission is unlikely to contribute to any unacceptable impacts, taking account of all relevant activities in an area, not just those connected with aggregate extraction. There is no guidance on the method of CEIA, but some suggestions to reduce cumulative impacts are given (see section 6.5.6).

6.2.4 Definition of cumulative effects

Cumulative environmental effects can be defined as follows:

“The effect on the environment which results from effects of a project when combined with those of other past, existing and imminent projects and activities. These may occur over a certain period of time and distance” (Canadian Environmental Assessment Agency, 1999).

A further definition of cumulative impacts, from recent European work, basically adapted from that given above, is as follows:

"Impacts that result from incremental changes caused by other past, present or reasonably foreseeable future actions together with the project" (Hyder Consulting 1999).

The draft marine minerals guidance note (DETR 2001) for England, defines cumulative impacts as 'effects on the environment, either from the summation of individually minor but collectively significant impacts, or as a result of the interaction of impacts from one or more sources. Thus, in this context, cumulative impacts might occur as a result of aggregate dredging at a single site, from multiple sites in close proximity, or in combination with effects from other human activities, such as fishing, pipeline discharges or the disposal of harbour dredgings'.

Cumulative impacts can be additive or interactive. Additive impacts are those in which one unit of change to the environment may be added to (or subtracted from) another unit. Interactive impacts are such that the net accumulation of the units of change to the environment is more or less than the sum of all the units of change. Cumulative impacts can also have an effect in terms of the overall temporal impact, scale of impact and/or spatial impact.

From all guidance available it is clear that the key aspects for consideration in CEIA (Cumulative Effects Impact Assessment) are:

- the temporal and geographic boundaries of the effects of activities;
- the interactions between the activities and the overall ecosystem;
- the environmental effects of the project, and past and future (proposed) projects and activities; and
- the thresholds of sensitivity of the existing environment.

6.3 Framework for CEIA

The main components of a CEIA framework are outlined below:

i. **Interpretation of legal requirement** – what are understood to be the parameters of CEIA practice under the EIA Directive and UK regulations?

ii. **Statement of principles for assessing cumulative impacts** – for example: cumulative impacts are the total effect (including direct and indirect) on a given aggregate resource, habitat or ecosystem of all actions taken regardless of who has taken the action.

iii. **Identification of key steps and activities in the CEIA process** – (i.e. necessary to address cumulative effects), for example, as outlined in the Cumulative Effects Assessment Practitioners Guide published by Canadian Environmental Assessment Agency (1999) (see Box 6.3).

Box 6.3 Assessment Framework	
Basic EIA Steps	Tasks to complete for a CEA/CEIA
Scoping	• Identify regional issues of concern • Select appropriate regional valued Ecosystem Components (VECs) • Identify spatial and temporal boundaries • Identify other actions that may affect the same VECs • Identify potential impacts due to actions and possible effects
Analysis of Effects	• Complete the collection of regional baseline data • Assess effects of proposed action on selected VECs • Assessment effects of all selected actions on selected VECs
Identification of Mitigation	• Recommend mitigation measures
Evaluation of Significance	• Evaluate the significance of residual effects • Compare results against thresholds or land use objectives and trends
Follow-up	• Recommend regional monitoring and effect management

Canadian Environmental Assessment Agency (1999)

iv. **Checklist of factors and issues to be taken into account at each stage of the CEIA process** – for example, as described in the CEAA guide.

v. **Guidance on indicators, approaches and tools** – for conducting a CEIA and their application to issues within different time and space scales. The various guides can be used.

A CEIA for a specific aggregate extraction proposal can assess only those environmental effects which result from the specific proposal or from other projects and activities that accumulate or interact with the environmental effects of the project in question. If the environmental effects of other past or future proposed projects are not likely to combine with the specific project they should not be assessed in the CEIA. They should, however, be discussed to ensure they have been considered adequately and to raise awareness of such activities. This is important when considering the potential impacts of other activities (such as fishing activity) that may be undertaken on a seasonal basis. If fishing activity occurs at a different time of year to aggregate extraction, the short-term impacts may not be cumulative and therefore not assessed in the CEIA for the aggregate extraction. It is, however, important to identify such activities and to consider the long-term impacts, such as changes to substratum, that may combine with the impacts of aggregate extraction.

6.4 Problems of undertaking CEIA and their solutions

Work that has been undertaken, both in the UK and overseas, on CEIAs in the past has involved the definition of problem areas and the solutions devised to overcome them. The following is a summary of the solutions to the issues raised:

Applicants should

- Consult with relevant agencies and organisations at an early stage in order to determine all past, present and future activities or projects which may have a cumulative environmental effect when undertaken in combination with the specific project being considered.
- Ensure that all processes undertaken to review cumulative impacts are outlined in the Cumulative Environmental Statement (CES).
- Ensure that all resources are considered when assessing cumulative impacts.
- Be precise when defining resources as this allows for better definition of temporal and spatial boundaries.
- If a project or activity is defined which is within the temporal and spatial boundary identified, but has no cumulative impact, ensure that adequate coverage of the project or activity is included in the CEIA and the reason for no cumulative impact is discussed.
- When undertaking CEIA within marine and coastal ecosystems, it is important to set spatial boundaries with due consideration of hydrological and coastal processes as impacts can be widely influenced by waves, tides and currents.
- Definition of 'future' proposed projects and a time limit for past projects should be clearly defined in guidance on CEIA in order to determine the limits of the assessment. Many 'approved projects' do not proceed for economic, technical or other reasons. The decision to include or exclude a future project from the CEIA should be based on the 'weight of evidence' (Canadian Environmental Assessment Agency, 1999).
- Threshold values cannot be specified as part of general guidance on CEIA due to the wide variation in characteristics of different environments and the scale of impacts resulting from different dredging techniques. Generic thresholds could, however, be specified in terms of maintaining the designated status of a habitat and/or species and thereby maintaining the integrity of the site.
- No one methodology for undertaking a CEIA can be recommended for every situation. A combination of techniques is often required to adequately cover all issues and resources.

These solutions and the information available on past and present techniques of undertaking CEIA have been collated and reviewed to produce the following guidance.

6.5 Recommended procedures for CEIA for aggregate extraction proposals

6.5.1 Introduction

The following sub-sections outline an approach to CEIA that could be followed or adapted for the consideration of a proposal for aggregate or maerl extraction to ensure that due consideration is given to cumulative activities. This methodology follows that generally utilised in CEIA and represents the product of review and analysis of existing published methodologies and approaches.

6.5.2 Scoping

The scoping phase of the study involves the initial identification of parameters that will define the overall limits of the study. The following tasks should be undertaken at this stage:

i. Define the temporal and spatial boundaries of the features affected by the proposed extraction activity (e.g. species or habitats affected either directly or indirectly);
ii. Undertake consultation with other agencies, organisations and individuals who may have an interest, or have responsibility for other activities or projects, in the area;
iii. Identify the pathways through which the environmental effects of the proposed extraction are expected to occur;
iv. Identify relevant past and existing projects and activities and their impacts on the environment of the proposed extraction;
v. Identify future proposed projects and activities and their potential link to the extraction area;
vi. Define appropriate alternatives to the proposed extraction activity and area.

Task (i) is probably the most important, and yet, the most difficult to undertake. Boundary definition should be informed by hydrodynamic modelling studies, as presently undertaken as part of the existing licensing procedure and should include an assessment of the likelihood and extent of any sediment plume arising from the extraction process. Following this, definition of the features (Annex I and II habitats and species) within the area likely to be affected should be undertaken and the geographic areas occupied by these features outside of the project boundary defined. In addition, all possible cumulative activities or projects should be considered to ensure that an activity which occurs outside the project's boundary and which could have indirect impacts is included in the assessment process. Together, these aspects should be integrated to determine the CEIA boundary.

The temporal boundary should also be defined. This will be dependent on the time-scale over which the impacts of the proposed extraction operate. It is likely that this will require consideration of the recovery potential of habitats and species affected directly by dredging activity.

The outputs from the scoping phase should include defined boundaries and a list of potential impacts, both individual and cumulative, which could result from the proposed extraction process and from other activities or projects within the defined boundaries.

6.5.3 Definition of existing features

This phase of the CEIA provides both the background to impact prediction and the assessment of significance, and as well as a baseline against which future monitoring can be assessed. Defining the resource (habitat or species population) effectively comprises two main aspects:

Status

- Extent (e.g. area of habitat or size of population, area utilised by population).

- Condition.
- Potential impacts on the resource likely to arise from future activity.

Sensitivity

- Niches – species will be impacted upon in different ways to a certain impact (e.g. species occupying mobile versus stable habitats).
- Potential for longer term habitat change.

For European Marine SACs the Regulation 33 advice will also provide guidance on the condition and sensitivity of the designated features. The sensitivity of certain habitats and species has been the subject of a recent series of reports in the UK Marine SACs Project (for example Jones, Hiscock & Connor, 2000; Birkett, Maggs & Dring, 1998). In addition, one of the sub-programmes of the Marine Life Information Network for Britain and Ireland (MarLIN) has developed a database that will contain information on the biology and sensitivity of marine species. The information recorded is used to allocate scores of sensitivity to a variety of natural and man-made impacts for species considered to be of importance (e.g. protected under International or UK legislation). The sub-programme is also developing a biotopes and habitats database. The information gained through the programme of data and information research and collation will be made available on the internet and will provide a valuable resource for dealing with the assessment of impacts on marine biological resources.

One of the key aspects in the determination of the resource is consideration of geographical boundaries. This is particularly important for mobile populations, such as fish and mammals, which may rely on a specific habitat of area (e.g. an area of sandbanks for spawning) during part of their life-cycle. The life-cycles of these species will need to be determined in order to assess the temporal affects of aggregate extraction activity.

Longer term trends should also be assessed during this phase in order to determine the life-cycle of the ecosystem. A sandbank, for example, can go through a natural cycle of erosion and accretion and physically move considerably over time, reacting to different weather conditions (e.g. storm events). Another example is that of the reefs constructed by *Sabellaria*. These natural cycles need to be understood to ensure that impact assessment can be considered against the existing situation and enable monitoring to be effectively targeted.

6.5.4 Assessing impacts

Impact prediction involves determining the type and magnitude of impacts that aggregate extraction is likely to have on the baseline environment. Cumulative impact assessment can be undertaken for each feature potentially affected. The range of impacts considered in cumulative assessment will normally be wider than those of individual projects, since the area under consideration is generally larger and the variety of activities greater. Impact predictions should be clearly linked to the key issues identified during the scoping stage and should relate to the environmental conditions of the affected area. Due to the complexity of interactions inherent with cumulative impact assessment it may not be possible to analyse impacts in detail. In many cases only a simple indication of the type and level of potential impacts may be required. During this phase it is necessary to determine whether the cumulative impacts on a feature are additive, interactive or synergistic (see Section 6.2.4).

A range of techniques can be used to predict and represent impact in cumulative assessment. These may be useful at both the scoping and actual assessment stages. The following have been identified by Oakwood Environmental (1999) and are quoted by other authors as useful techniques in CEIA (e.g. Thérivel and Partidário 1996 and Council on Environmental Quality, 1997). Relevant references for the methodologies listed have been reviewed in the Oakwood Environmental (1999) study and are indicated below:

- **Checklists** which show whether the proposal has an impact or not, sometimes with further details on, for instance impact type (positive, negative) and magnitude (an example of which is shown in Table 6.5.4.). Checklists are very useful in identifying key environmental factors and potential impacts and in planning the overall approach to undertaking and planning the CEIA operation. However, checklists do not enable interactions and linkages to be identified and are probably more useful at the scoping stage to identify which activities or potential impacts may require further evaluation before proceeding further in the process. Reference: Canter & Kamath (1995).
- **Networks, or system diagrams**, used for classifying, organising and displaying problems, processes and interactions and to produce a causal analysis of the cumulative effects situation. This is probably the most widely utilised technique within CEIA. Networks enable interactions to be mapped out, both spatially and temporally, and enable indirect impacts to be traced but do not result in quantitative predictions of impacts. Reference: Lee & Gosselink (1988).
- **Matrices**, as with networks this technique enable interactions between activities and individual environmental components to be identified. They are best utilised as a means of presenting and manipulating the quantitative results of modelling, mapping or subjective techniques. Matrices are also a good technique for looking at cause and effect relationships. Reference: Irwin & Rodes (1991).
- **Compatibility or consistency assessment**, which tests whether different elements of an overall scheme are internally consistent. A useful method for dealing with plans and strategies rather than activities. Essentially works through the setting up of objectives for individual elements of an overall plan and then testing these against each other and against prescribed policies. Although the basic premise behind this method has some attributes with regard to in combination assessment it is considered that it would be of limited use for the CEIA of aggregate extraction. Reference: Thérivel and Partidário (1996).
- **Overlay maps of GIS** showing, for instance the spatial boundaries of the various activities under consideration. This method can provide an indication of the sum of potential impacts likely to occur within any one area. GIS zoning and overlay modules can provide interesting solutions, provided that an effort is made to develop the necessary underlying data. An interesting study in this regard was undertaken by the Royal Society for the Protection of Birds (1995), in which a GIS was developed to analyse the impact of the road network on bird habitats. Another example of a GIS oriented approach is the Strategic Environmental Assessment (which considers impacts in combination) of the French northern corridor that was conducted for the French Ministry of the Environment (Ministère de l'Environnment 1994). This study

compares the environmental sensitivity profiles of the region against the environmental impact of different transport modes.

- **Computer models**, may be used in complex situations to provide some form of quantifiable estimate of the likely effects of a number of variables (impacts) operating in combination. Models may be particularly useful in considering long-term effects through the running of multiple scenarios or in dealing with the interactions between indirect effects associated with a number of activities. As with the majority of CEIA techniques, a relatively detailed understanding of the baseline environment and nature of the activities being assessed is required, particularly in order to quantify impacts.
- **Expert opinion** e.g., the use of questionnaires and interviews, consultation etc.

Cumulative impact prediction can involve high levels of uncertainty, such as the likely effects of interaction between activities and the nature of the environment itself. This is particularly true of the coastal and maritime environment where there may be a lack of historical or up to date scientific data on which to base prediction. However, undertaking CEIA requires discipline and a scientific approach, where possible. With respect to this the following techniques may be applicable:

- clarifying assumptions about, for instance, the environmental impacts of activities;
- stating predictions in terms of ranges rather than giving precise figures to reflect uncertainty;
- basing predictions on different scenarios which reflect possible future events and conditions;
- using worst case scenarios based on the precautionary approach;
- carrying out sensitivity analyses to ensure that changing assumptions on which predictions are based does not overly influence the outcome of the predictions.

Table 6.5.4 Example of factors to be considered in assessing cumulative impacts on various Annex I habitats

Habitat	Past Actions Impact	Present Actions Impacts	Proposed Actions Potential Impacts	Future Actions Potential Impacts	Cumulative Effects
Sublittoral sandbanks	Bottom trawling *Reduction in benthic species diversity* *Effects largely dissipated*	Disposal of dredged material (sand) *Increase in proportion of sandy material*	Aggregate extraction (sand) *Removal of substratum and benthic species*	Coastal defence structure *Changes in local hydrodynamic regime leading to offshore erosion*	**Decrease in benthic community diversity and area of habitat** **Possible impacts on bird feeding (auks). Changes to offshore hydrodynamics**
Estuaries	Discharge of sewage effluent *Eutrophication* *Impairs fish migration and reduces benthic community diversity*	Development of estuarine margin ***Loss of some littoral area*** ***Less available bird feeding area***	Aggregate extraction (gravel underlying fine sediment) *Increased turbidity around the estuary mouth*	Further development of estuarine margin *Loss of some littoral area* *Less available bird feeding area*	**Decreased area and quality of littoral mudflats for bird feeding.** **Adverse impacts on overwintering wader populations within the estuary** **Decrease in overall water quality of estuary**
Lagoons	Offshore aggregate extraction **No associated impact**	Coastal protection structure updrift of lagoon *Inhibits longshore drift of material*	Nearshore aggregate extraction (shingle) *Reduction in supply of sediment to coastal landforms* *Likely erosion of the ridge with the possibility of breach*	None anticipated **Not applicable**	**Supply of coarse material to the shingle ridge is reduced leading to the possibility of a breach and loss of the lagoon**
Reefs	Shrimp fishing *Direct destruction of areas of Sabellaria reef and associated community* *Some regeneration since activity ceased*	Designation as SAC and managed for nature conservation interests *Habitat protected therefore further direct damage prevented*	Aggregate extraction (fine sand overlying gravel) *Generation of sediment plume which is likely to smother an area of reef*	Disposal of dredged material near Sabellaria reef *Dispersal of material onto areas of reef*	**Degradation of the reef habitat.** **Likely adverse effect on integrity of SAC**

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6.5.5 Defining the scale of impact

In order to define the scale of any predicted impacts it is necessary to assess their magnitude and significance and determine their acceptability thresholds. This aspect of the CEIA is very site specific as it depends on a number of parameters, including the sensitivity and vulnerability of the existing habitats and species, the existing levels of stress imposed on the environment and the ambient conditions of the environment. In assessing the significance of an impact, a number of aspects are important when making decisions. Examples of these are as follows:

- the area of habitat that will be affected by the activity;
- the effects of the activity on habitats, communities or species;
- the adaptability of the habitat and/or species in question;
- the time-scale over which any effect will occur;
- the reversibility or otherwise of the impact.

Taking these, and other factors into consideration, determining the level of impact significance that aggregate dredging may have on identified European features is a complex process; summarised graphically in Figure 6.5.5a. The conservation objectives and advice on operations for the European Marine Site (the Regulation 33 package) are of crucial importance here. The Habitats Directive makes it clear that the judgement on whether a plan or project will have an adverse effect on a site should use, and focus on, the site's conservation objectives.

For a number of the aspects listed above, it may be possible to set threshold levels at which an impact on or change in Annex I habitats and Annex II species are significant. Given that each SAC is unique in terms of its qualifying Annex I and II habitats and species, it is beyond the scope of this study to suggest threshold values at which an impact is likely to be significant with respect to any particular SAC. In situations where there is insufficient knowledge of the system and the affects of the aggregate dredging activity itself, then definitive threshold levels cannot be set and it may be necessary to adopt a precautionary approach. In the majority of cases, the potential solution to this problem may be to set a range of broad threshold levels, based on existing site information and experience, which can then be utilised to assess both the magnitude and probability of a change or an impact occurring and in turn provide a relative indication of significance. This approach has been adopted in the process framework described below.

Figure 6.5.5a: Framework for assessing potential significance of aggregate extraction impacts on SACs

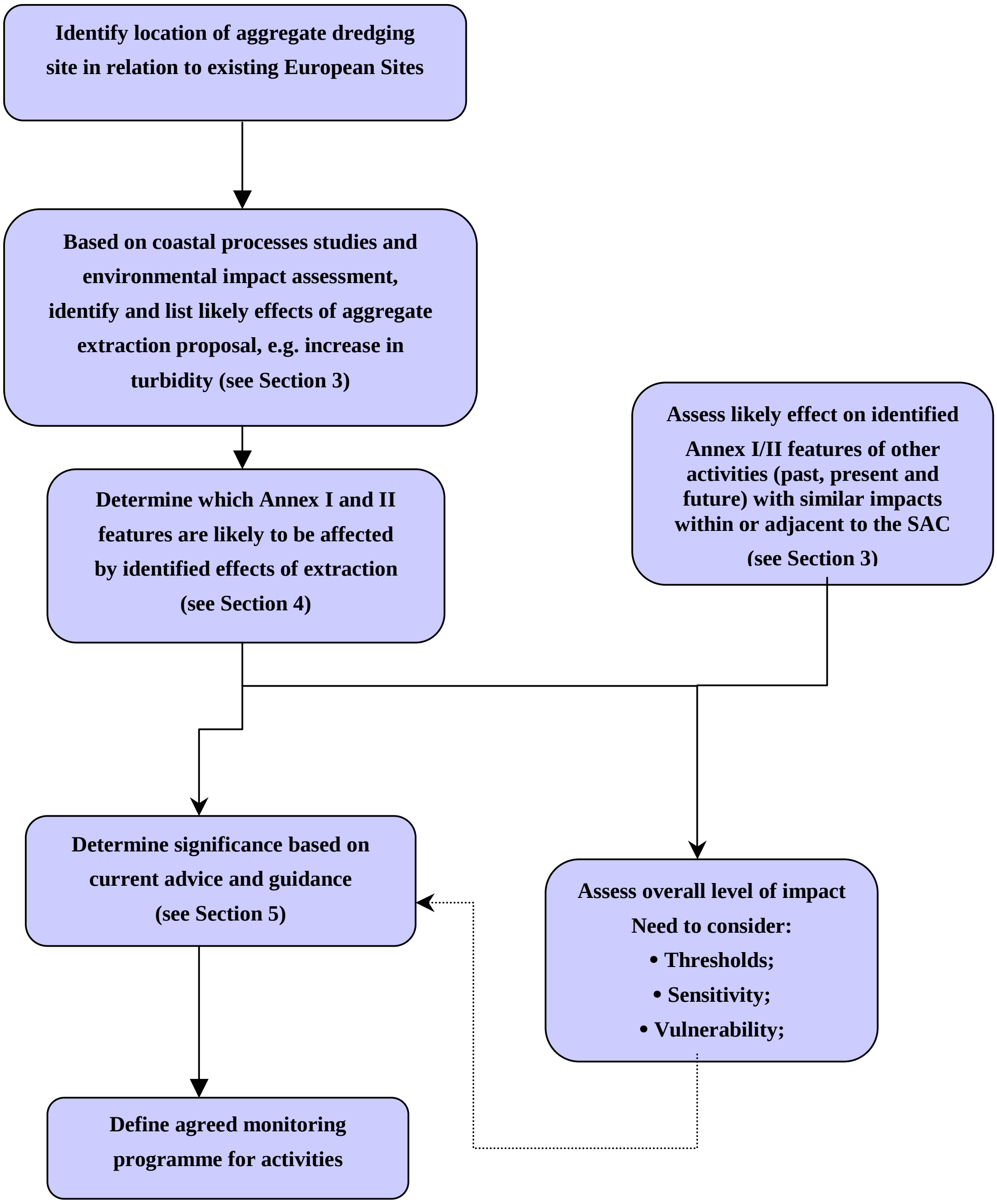
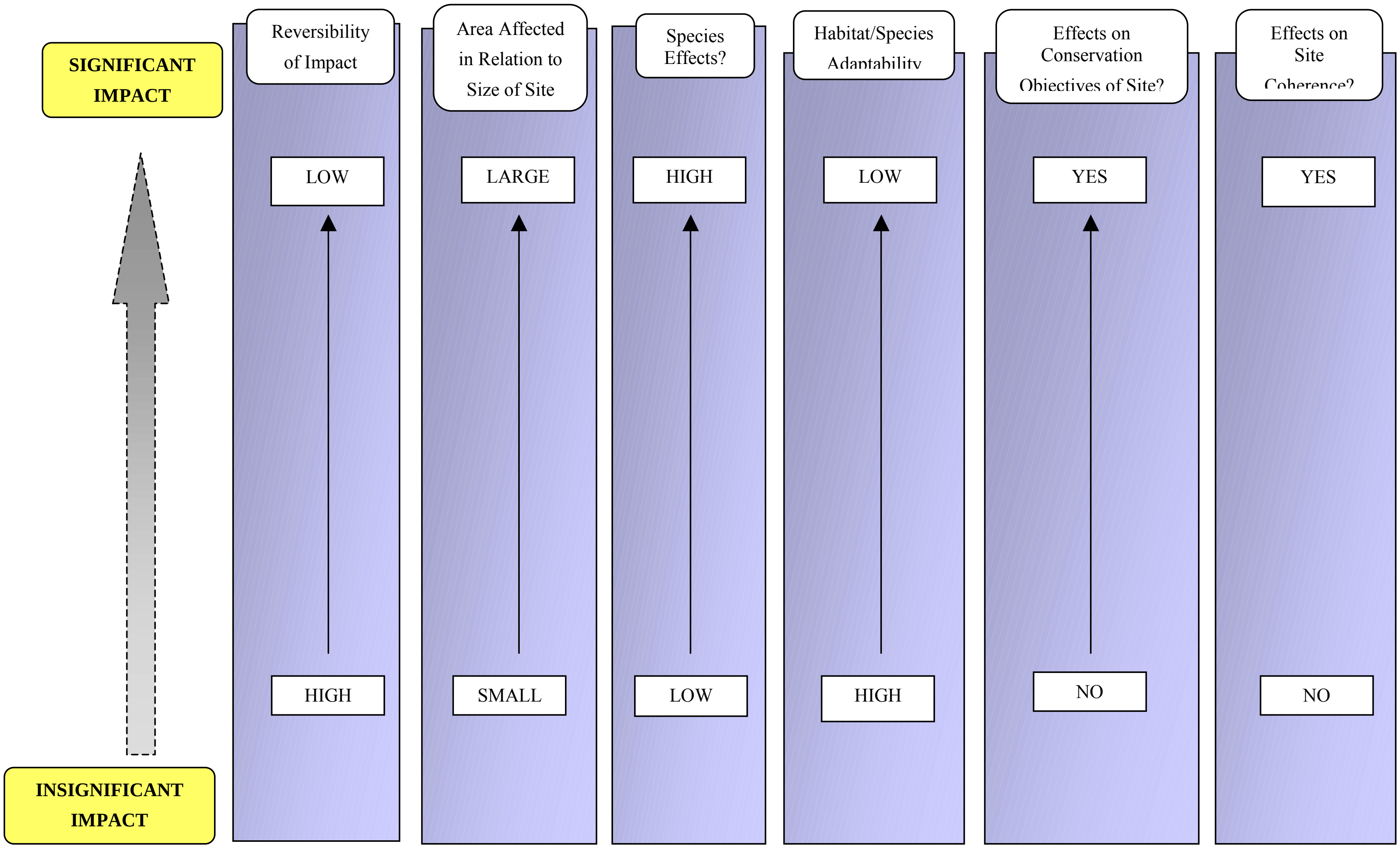


Figure 6.5.5b: An example of factors to consider when assessing significance of an impact



The following steps provide a framework for assessing impacts and significance in relation to designated European features. These steps are fundamental to the determination of risk assessment and form the basis of the 'Guide to Environmental Risk Assessment Package' produced by Associated British Ports (1999). This package is itself based on DETR's publication *A Guide to Risk Assessment and Risk Management for Environmental Protection* (Department of the Environment, 1995). Assessment is undertaken via clearly defined steps, as described below, so that at the end of the process a decision as to the likely significance of the effect of a proposal can be justified. Here, the description of these steps is applied to the impacts of aggregate extraction, but the process could equally apply to the assessment of any proposed plan or project.

Steps taken to assess the likely significant risk of a plan or project

1. **Identification of possible impacts** – Description of each feature of the aggregate extraction process that could, directly or indirectly, cause an environmental effect (see Section 3). This would need to include aspects such as changes to physical processes, changes affecting an ecosystem function, changes to substrate quality and long term or cumulative effects on the environment. Information relating to physical processes should be obtained from the hydrodynamic studies undertaken as part of the licensing process.

2. **Identification of consequences** – Description of the consequences to Annex I and Annex II features that are likely to occur as a result of the identified impacts. The identification of consequences depends on the combination of the impact and the capacity/sensitivity of the feature under consideration. The consequences arising from any one impact may be very wide ranging, affecting the living and non-living environment, either directly or indirectly and over the short or long term. Further information with relation to this is given in Section 3.

3. **Estimation of the magnitude of consequences** – Description of the level of the effect that would occur if a consequence is realised. The quantification of consequences in many cases will be difficult, especially where either the effect of dredging itself is poorly known, (e.g. turbidity plumes), and/or where the marine communities/species under consideration are inadequately documented. However, it may be possible to judge the order of magnitude of effects utilising a semi-quantitative approach based on previous work/experience (i.e. a generic approach based on principles). Utilising this approach, descriptive conditions or 'values' could be attributed to each identified impact and feature so as to end up with a range of magnitude from negligible through to severe. Again, it is stressed, that unless very detailed information is available, this is a judgmental process and has to be considered on a case by case basis.

4. **Estimation of the probability of consequences** – This involves determining the likely probability of an effect being realised. As with the question of magnitude, any estimation of probability or frequency is likely to be semi-quantitative. One consideration in assessing probability is the scale of the operation in relation to the extent of the feature under consideration. Where quantification is not possible, probability could be expressed as a range, (e.g. high, medium, etc.).

5. **Relevance of consequences** – impacts arising from aggregate dredging may be identified that, although they affect certain species or habitats, may have no bearing on the reasons for designation as detailed in the citation and conservation objectives for the site. A decision must therefore be made as to whether a consequence affects, directly or indirectly, the habitats or species for which a site was classified or designated. [Note that this decision is only relevant in the context of the Habitats Directive; i.e. if an impact arises, even if it does not effect the designated features, it should be considered as part of the environmental assessment process in general under the appropriate EIA Regulations.]

6. **Assessment of risk and significance** – for each individual consequence, the combination of its magnitude and probability provides an estimation of the environmental risk. For example, the potential magnitude of the impact of a turbidity plume on a benthic community within an SAC could be high but, due to coastal processes affecting the movement of the plume, increased turbidity might only occur infrequently under certain tidal and wave conditions (low probability). Therefore, the overall risk could be estimated as medium/low for this potential impact. Such an approach can never represent the true complexity of the assessment process, but if used carefully can provide a measure of comparison between identified impacts and act as a baseline from which to develop potential mitigation measures.

Taking the identified risks and establishing an overall assessment of significance from these is the crucial step in the process. This stage in the assessment brings in the question of ‘overall threshold acceptability’ i.e. at what level does an impact (or the cumulative impact) become significant in relation to the designated features of a European site. The procedures put forward by the former Department of the Environment (Department of the Environment 1995) and ABP (Associated British Ports 1999) suggest that where a high risk is identified in relation to any designated European feature (and cannot be mitigated; see Section 6.5.6), then the proposed scheme/activity would be likely to have a significant effect. This overall threshold effectively represents an accumulation of a number of different thresholds that have been assessed during the overall process of impact determination. Further information on the assessment of significance is available in the guidance note recently published by English Nature (English Nature 1999).

6.5.6 Mitigation and enhancement

If, as a result of the above assessment procedure, a significant impact on a resource or a number of resources is identified, mitigation measures should be proposed either to eliminate, or reduce the impact to acceptable levels. Mitigation should relate to the cause and effect relationship in the context of each resource and for each identified impact. In the majority of cases, avoidance of an impact should be the primary consideration (which can be achieved by reviewing alternatives to the proposed scheme). There are however several mitigation measures available for potential impacts associated with aggregate and maerl extraction, many of which are already implemented for schemes as part of the licensing agreements.

Examples of available mitigation measures are provided below:

- dredging on an ebb or flood tide to ensure that any suspended sediment moves away from the resource;

- limiting the screening undertaken at a site and imposing strict requirements on the sediment quality of a target resource;
- working in discrete subareas;
- dredging only at certain times of the year;
- delaying implementation of the permission until dredging in adjacent areas has ceased;
- limiting extraction rates;
- restricting the type of dredger.

6.5.7 Definition of residual impacts

Following the identification of viable mitigation measures, it is necessary to determine whether the significance of any impacts previously identified would be reduced to an acceptable level through their implementation. It will, therefore, be necessary to repeat the tasks outlined in Section 6.5.5, taking into account any prescribed mitigation measures. Any significant residual impacts should then be assessed based on their potential to affect environmental interests. Following this final assessment, a decision can be made as to whether the overall scheme proposal, either in isolation or combined with other activities, has a significant environmental effect on habitats and species, and other resources, and therefore whether the scheme should go ahead.

6.5.8 CEIA in relation to appropriate assessment under the Habitats Directive

The determination of significance in CEIA, for activities likely to impact upon European marine sites, should not be confused with the determination of significant effect as part of the appropriate assessment process under the Habitats Directive. Essentially, CEIA can be viewed as a parallel process with links into the appropriate assessment process.

It is recommended that the scoping for the Appropriate Assessment should be carried out at the same time as the scoping of the CEIA, or at least early in the EIA/CEIA process. This is to ensure that data gathered for the EIA will be sufficient to carry out the Appropriate Assessment.

The results of CEIA can be used to:

- Inform the decision on whether a project is likely to have a significant effect on a site, and therefore trigger an Appropriate Assessment;
- Inform and contribute to the Appropriate Assessment and the decision on whether the project will have an adverse effect on the integrity of the site.

6.5.9 Monitoring and post-project evaluation

Monitoring the environmental effects of a scheme in conjunction with the cumulative effects of combined projects and activities is an extremely important aspect of a CEIA study. It is essential to undertake monitoring to assess the accuracy of impact predictions and to ensure the success of any mitigation measures.

In a CEIA it is important to state who has responsibility for monitoring, the frequency and duration of monitoring, and the review procedure for monitoring results. Monitoring is discussed further in Section 7 of this report.

6.6 Examples of CEIA

6.6.1 Introduction

The following examples of CEIA are provided in order to illustrate the techniques used and the variability in the level of detail which is considered for assessing cumulative impacts on resources.

6.6.2 Channel Tunnel Link

A CEIA was undertaken for the Channel Tunnel Rail Link and a widening scheme for Junctions 1 to 4 of the M2 Motorway (Environmental Resources Management, 1994). One of the objectives of this assessment was to identify those significant environmental effects resulting from the two schemes which were either not identified in the individual Environmental Statements, or which had increased in significance as a result of the combination of the two schemes. The cumulative impacts for each environmental topic resulting from the two schemes were determined by a simple additive approach where possible or by a qualitative description of all changes under each topic heading. An example of cumulative ecological effect was predicted on an ancient woodland habitat whereby "the cumulative effect of the two schemes was greater than the sum of the individual effects, in that the woodland habitat would no longer be ecologically viable".

6.6.3 Humber Estuary Study

A recent CEIA was undertaken for the Humber Estuary (CES 1997; Conlon 2000; Piper 2000) when a number of major infrastructure developments were proposed for the Salt End area of Hull. There was potential for cumulative environmental impacts to occur on the north bank of the Humber Estuary. Particular areas of concern were the ecologically sensitive intertidal mudflats downstream, which are designated as a Special Protection Area (SPA) and Ramsar site. The effect on the integrity of the SPA was therefore an important consideration.

A steering group was convened in order to co-ordinate the CEIA comprising of the two local authorities and four scheme proponents (Yorkshire Water Services Ltd., British Petroleum, Associated British Ports and the Environment Agency). The relevant consultants were also involved in this steering group. Potential, cumulative impacts on bird species were identified and were mitigated against by rescheduling certain activities to minimise disturbance during sensitive periods, maintaining adequate high tide roost sites, screening and good construction practice. The residual impact was not considered to "detract from the integrity of the SPA as a whole" (CES, 1997).

Monitoring was recommended during and following construction to establish the accuracy of impact prediction and the efficacy of implementing the recommended mitigation measures. This monitoring was agreed and is being implemented by the Environment Agency for their flood defence improvement works on the Salt End site. Monitoring for operational impacts was discussed and it was concluded that the programme would be established in consultation with the various statutory authorities and developers. The programme would be time limited with tasks specified to identify particular impacts.

6.6.4 Norton Sound, Alaska

Cumulative impacts were thoroughly assessed for a study undertaken by the U.S. Department of the Interior, Minerals Management Service (1991) for a mining program at Norton Sound, Alaska. Cumulative effects were considered for all resources and for all alternative schemes. Cumulative effects on marine plants and invertebrates, including the king crab, were identified and impacts from other mining activities, oil and gas activity, onshore mining, harbour dredging and fishing activities, both commercial and subsistence, considered. One of the major impacts identified as a result of dredging activity was alteration of the cobble habitat that is critical for juvenile crabs and for king crabs in general. In order to mitigate this impact an area proposed for mining was deleted from the proposal.

6.6.5 Tay Estuary, Scotland

An environmental statement prepared for a licence renewal for the continued dredging of aggregates in the Tay Estuary (Oakwood Environmental, 1999), discusses the potential for cumulative impacts. The activity which was identified as having a potential cumulative effect with aggregate extraction, was a proposed land claim resulting in the loss of up to 36 hectares of the intertidal area on the north shore of the Inner Tay (subsequently, this land claim was refused planning permission). Potential cumulative impacts on the estuarine hydrodynamics and on the displacement of birds or fish were considered. Based on past impacts on estuarine processes it was concluded that there would be no cumulative impacts on physical processes as a result of the two proposals. The land claim was likely to displace feeding birds, but it was considered that due to the impoverished mobile sands present in the licence renewal area few, if any bird or fish populations would be displaced by dredging. The general conclusion was therefore that no cumulative effects would arise as a result of these two proposals.

7. Monitoring

7.1 Purpose and definition of monitoring

The term monitoring refers to methods which show whether species, habitats or environmental variables meet targets defined by some standard, such as those set out in law or the objectives of management (Brown 2000). Monitoring methods for Annex 1 and II features of European marine sites are described in the *Marine Monitoring Handbook* (Davies *et al* 2001). This chapter describes best practice and examples of environmental effects monitoring with respect to aggregate extraction.

One purpose of monitoring can be to document whether impacts identified as unacceptable are occurring, or whether conditions that will lead to an unacceptable impact are occurring (Fredette *et al.,* 1990). Impact predictions and the success, or not, of mitigation measures can also be assessed through a well tailored and specific monitoring programme. A monitoring programme should provide the site manager with clearly interpretable information about whether a threshold has been reached where adverse impacts are occurring or are imminent so that decisions about continued or modified site use can be made.

Environmental monitoring can be defined as the systematic collection of environmental data on specified variable, to determine whether or not specific, pre-determined objectives and limits of acceptable environmental change needs have been met (Au, 1995). In the case of aggregate extraction, an example of monitoring could be to determine whether a pre-determined target for suspended sediment concentration during a dredging operation has been exceeded or not.

Two types of monitoring programme may be identified; prospective or retrospective. Prospective programmes consist of repeated observation or measurements that determine if site conditions conform to an already stated standard (Fredette *et al.,* 1990). Desirable and/or undesirable conditions (for example, unacceptable adverse effects) are clearly defined before the sampling has begun. It is necessary to predict what resources in the potentially impacted area are at risk and what magnitude and extent of impact could result from the aggregate dredging. The development of predictions must involve consideration of how and at what thresholds physical and chemical changes (causes) will result in undesirable biological responses (effect) (Fredette *et al.,* 1990). As a result of this:

- resources of concern are identified;
- specific thresholds of conditions (e.g. biological, physical) that should not be exceeded are stipulated;
- the impacts of the aggregate extraction are predicted.

This approach will allow a sampling programme to be developed which will focus on detecting changes in specific conditions rather than looking for any detectable change. Indeed, the concept of monitoring would become more widely accepted if it was recognised that not all of the impacts of any one project need to be comprehensively and intensively monitored (Beanlands and Duinker, 1983). Monitoring should be focussed on environmental components:

- that are most important to decision-making;
- that are most poorly understood; and,
- in which changes of the type and magnitude predicted can realistically be detected.

In contrast to prospective programmes, in retrospective programmes the magnitudes, types and extent of adverse impacts are not defined until after sampling has begun and the data are being interpreted. This is the case with the majority of 'monitoring' programmes and it is often found that the proper questions were not initially asked and therefore have not been addressed. Retrospective programmes do not meet the objectives of monitoring, as described above, and should be avoided.

7.2 Objectives of monitoring programmes

The most fundamental step in the development of a monitoring programme is to define the goals and objectives, or purpose, of the monitoring programme. This stage is often not documented properly and therefore the resulting data collection efforts lead to little useful information for decision-making (US EPA, 1997).

Monitoring programmes can be designed to generate data to meet the following objectives (Box 7.2).

Box 7.2 Objectives of monitoring programmes

The following are examples of objectives of monitoring programmes.

1. to document the baseline conditions at the start of an EIA;
2. test impact predictions and thus further environmental understanding and improve predictive capability for future activities of the same type;
3. to modify mitigation measures if there are unpredicted harmful effects on the environment;
4. to verify the effectiveness of mitigation measures;
5. to assess performance and monitor compliance with agreed conditions specified in operating licenses;
6. to provide early warning of undesirable change so that corrective measures can be implemented; and,
7. to provide evidence to refute or support claims for damage compensation.

The main purpose of monitoring is to feed back results to managers in order that they can take action should a deleterious change be suspected. An example of this feedback process, in relation to dredging, is shown in Figure 7.2.

7.3 Key stages in monitoring programmes

Monitoring programmes have a number of key stages and questions which need to be answered at each of these stages. Figure 7.3 identifies these important stages and provides examples of key questions (or comments) for some of the stages which may to be answered in a monitoring programme in relation to aggregate extraction.

7.4 Tiered monitoring programmes

A useful approach to monitoring is the development of tiered monitoring programmes as described by Fredette *et al.* (1990). In this approach the monitoring is multi-tiered with each level having its own unacceptable environmental threshold. Experts in a number of relevant disciplines should be drawn together in its development to allow a thorough examination of the wide range of factors that must be considered. The aim of the tiered approach is to avoid an over-intensive monitoring programme which can result in unnecessary monitoring and therefore waste money.

The approach involves monitoring each objective by testing a series of null hypotheses (or tiers) each at a different predetermined level of intensity. Box 7.4 illustrates an example of how the tiered approach to monitoring may be applied to an aggregate dredging operation.

Figure 7.2 Flow diagram showing how monitoring results can feed back to control dredging operations (Gray & Jensen, 1993 in Hiscock, 1998)

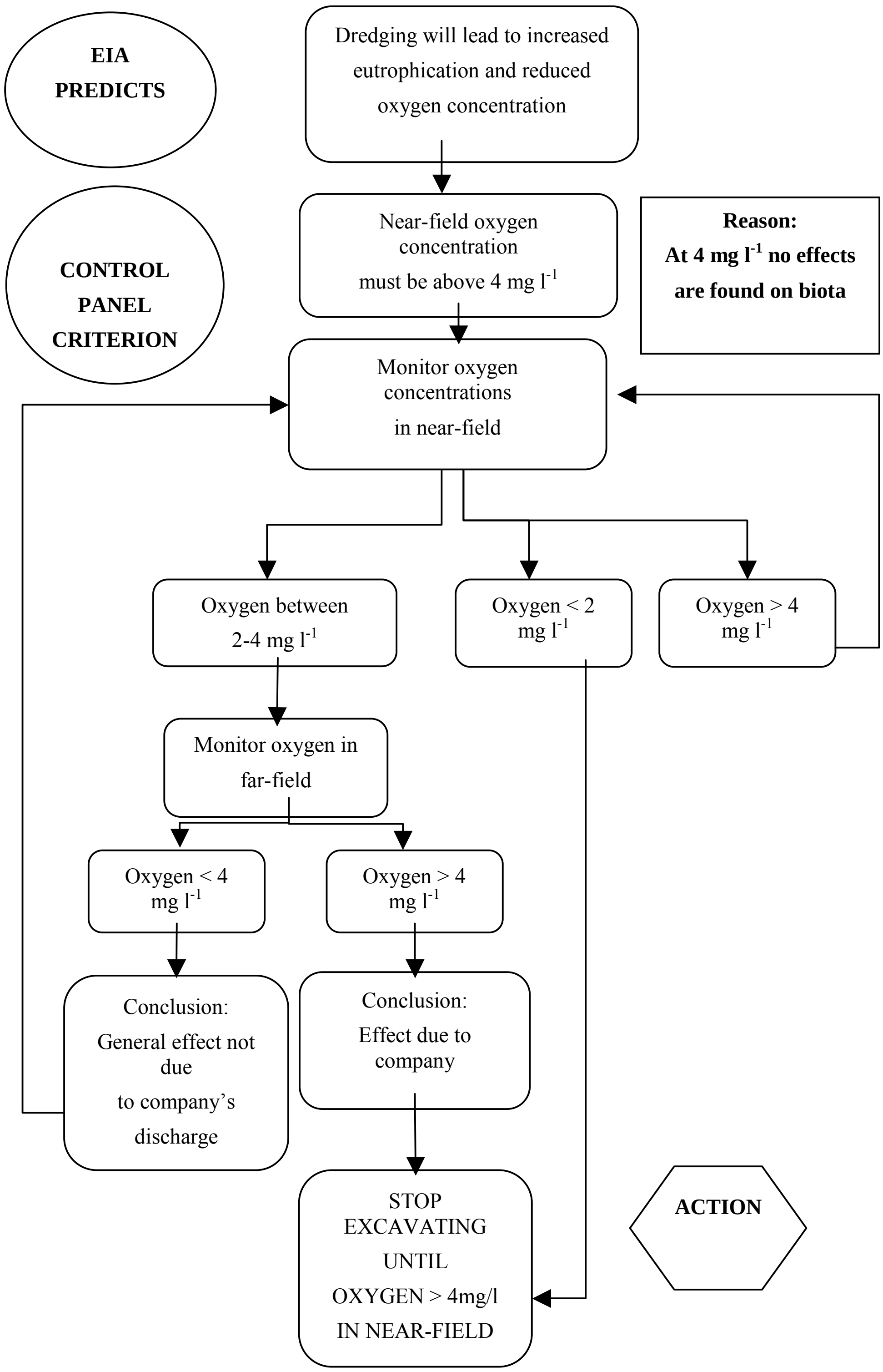
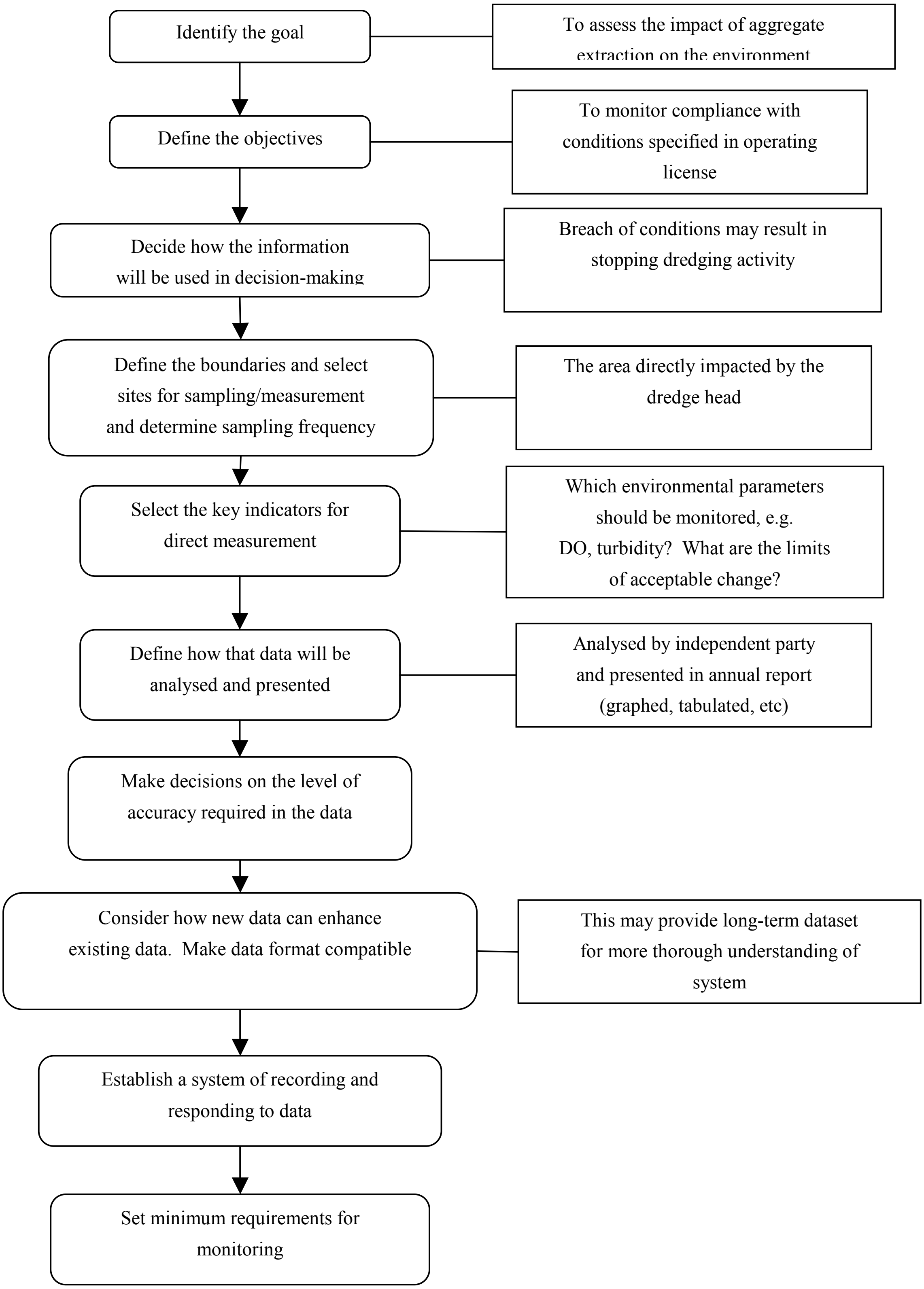


Figure 7.3 Important stages in developing a monitoring programme



Box 7.4 Tiered monitoring programmes

STAGE 1 Define the objective of the monitoring programme

To ensure that no adverse impacts arise on horse mussels (*Modiolus modiolus*) in the vicinity due to increased suspended sediment concentration (and subsequent sedimentation) in the water column.

STAGE 2 Background information collection

Collect and review relevant information to allow prediction of impacts on *M. modiolus*. These predictions are then used to formulate null hypotheses to be incorporated into the tiers of the monitoring programme. For example, it may be determined that *M. modiolus* are adapted to coarse sediment habitats and therefore deposition of fine sediment may be detrimental.

STAGE 3 Tier 1 – Null hypothesis (Ho)

Mean sediment grain size at the site where *M. modiolus* populations exist remains unchanged subsequent to aggregate dredging. The critical threshold for the tier would be a doubling in fines (silts/clays) relative to baseline (from 5 to 10% fines), which has been predicted to be adverse and has been established as the threshold for this tier.

A simple, inexpensive monitoring programme could be set up to test this null hypothesis and would rapidly provide managers with information. If the null hypothesis were rejected, mitigation measures could be put in place, or Tier 2, a more intensive stage in the monitoring programme, would be triggered.

Each tier has its own predicted critical threshold, null hypothesis and sampling design. If the null hypothesis is rejected for one tier, the more intensive monitoring programme at the next tier will be triggered. However, if the null hypothesis for a particular tier was accepted, the application of the more intensive monitoring at the next tier would be unnecessary. If the tiered monitoring approach had not been adopted from the outset, the monitoring programme proposed may have been too intensive, thus wasting resources. The multi-tiered approach also allows time for managers to make modifications in their dredging operations before a significant impact has occurred (Fredette *et al.,* 1990).

7.5 Monitoring of aggregate extraction areas

7.5.1 Requirements

In the past, the majority of monitoring associated with aggregate extraction was undertaken primarily to determine the potential impact of any hydrological changes on the adjacent coastline (e.g. bathymetry measurements), and the dredging contractors generally undertake such monitoring themselves. More recently, monitoring has been requested in order to determine any impacts relating to environmental effects, such as elevated suspended sediment levels and/or turbidity and impacts on benthic communities.

The process of assessing a licence application for aggregate extraction includes the preparation of an Environmental Statement (ES). The ES is then considered by Government Departments, CEFAS and other consultees, and as a result it may be determined that impact predictions within the ES may require monitoring. The ES itself may make recommendations as to monitoring requirements.

7.5.2 Procedure

Monitoring requirements are usually imposed through conditions attached to the extraction licence. The detail of the monitoring programme necessarily varies according to the specific issues associated with each licence area, but general principles regarding the setting of limits of acceptable change (e.g. depth of aggregate resource extracted) and monitoring review can be made. The monitoring programme usually includes pre-dredge baseline surveys and monitoring during and after dredging. Post-dredging surveys usually have to take place within 12 months of dredging finishing.

The setting of limits of acceptable change in a particular environmental parameter is not currently a well-defined process. A detailed knowledge of the environment and issues associated with each individual licence area is needed in order to set limits which have a robust scientific basis. For some areas, more information is available than others and it may be possible to set limits with some confidence for these areas. In other circumstances, the limit or target may be set as a result of impacts predicted in the ES. For example, the ES may highlight that a sediment type which is dissimilar to that currently on the seabed may be exposed in particular parts of the extraction area should dredging exceed a certain depth. A target may then be set in the licence that dredging should not exceed a specified depth to prevent this occurring. Dredging depth would then be monitored and periodically reviewed. It is therefore important that in the preparation of the ES, clear predictions of the impacts which may occur due to dredging in a particular area are made. Where possible the prediction of the impacts should be quantified in order to facilitate the setting of targets or limits. The objective of the monitoring should then be to test these predictions (CEFAS, pers. comm.).

In practice, at present, most monitoring programmes do more to help the understanding of the system than to test results against thresholds. Particularly for physical processes, our knowledge of natural variation and the margins of error in measurements mean it is difficult to set thresholds. There is also the problem of time lag: monitoring during the period of a licence will not pick up subsequent changes. It is important to accept these practical difficulties, but the aim of a monitoring programme should be to measure change against a defined threshold.

As an example of the process, physical and biological requirements for monitoring were required as part of the Government View for an application by Hanson Aggregate Marine Ltd to extract sand and gravel from Area 436 in the southern North Sea, east of Great Yarmouth. Under the Government View procedure, consultations were undertaken with central government departments, local authorities, other interested parties and the public. As a result of the responses received through consultation, a number of monitoring requirements were proposed. These are summarised in Table 7.5

Table 7.5 Summary of the monitoring requirements from a recent Government View relating to dredging at Area 436 in the southern North Sea

Monitoring	Purpose
Pre-dredge/baseline surveys	
Bathymetric and Sidescan Sonar surveys	To establish existing seabed levels and sediment transport pathways and to monitor archaeological deposits
Seabed sediment survey	To establish existing seabed composition
Benthic community survey	To establish the extent of the existing benthic community and to identify suitable control sites for subsequent monitoring
Monitoring (during and post-dredge)	
Bathymetric and Sidescan Sonar surveys	To assess any significant changes to the seabed and water depth
Seabed sediment survey	To review the composition of seabed sediments within the actively dredged areas
Benthic community survey	To assess the nature of any changes to the benthic community resulting from dredging

Detailed monitoring arrangements are included in the schedule of conditions resulting from the Government View Procedure. The specification for the monitoring programme must be approved by DTLR/National Assembly for Wales/Scottish Executive Rural Affairs Department before any dredging commences and a copy of the monitoring programme sent to the Crown Estate Commissioners and the relevant country nature conservation agency. Similarly, any changes to the programme need to be agreed by the licensee with MAFF and approved with the same organisations as stated above. The conditions also stipulate the specification of the monitoring to be undertaken, including timing, period (e.g. annually) and requirement for the reporting of the monitoring results. This latter element includes a list of organisations that the report should be sent to on completion of the annual (or other period) monitoring work e.g. local coastal authorities, Environment Agency, RSPB, Country conservation agency.

In order to determine the actual survey methods for undertaking biological monitoring, reference should be made to the *Marine Monitoring Handbook* (Davies *et al* 2001). These guidelines document the different techniques available for undertaking monitoring of various habitats and species. Other information which is available, and documents valid techniques of monitoring includes the work undertaken for the monitoring of marine benthic communities at UK sewage sludge disposal site (Rees *et al*, 1990) which aims to define the intensity and spatial extent of effects on benthos which are attributable to sludge dumping and to establish whether such effects are increasing in intensity. It would be necessary to ensure that the monitoring can differentiate between the impacts of the project and any combined activities or projects. This is likely to require control areas and integration into monitoring packages for the other activities or projects.

7.6 Review of monitoring

Review procedures for the results of monitoring are one of the most important aspects of a monitoring plan. The procedure for the review of monitoring information can vary, but generally the licensee provides monitoring reports to DEFRA which are then passed to CEFAS for scientific review. The monitoring reports are then examined to determine whether the licence conditions are fulfilled and whether they confirm the predictions made in the ES.

The concept of a periodic review of licence permissions is a theme that has been developed by DETR/DTLR in the emerging statutory regulations and associated policy (MMG2) – the idea being to issue a 15 year permission subject to five-yearly review. In addition, CEFAS and other organisations (including English Nature, CCW and SNH), review data as and when it is submitted. Should monitoring results at any time suggest an unacceptable impact, dredging permissions may be suspended pending a more detailed review.

There are however relatively few examples of aggregate extraction licences that have requirements for habitat and species monitoring incorporated into them. Of those that do, many are relatively recent licences and have not yet reached a stage where there is enough information available to determine actual impacts, or the success of the monitoring scheme. The monitoring programme for Area 436 includes surveying of the pre-dredge benthic communities and for repeat surveys to be undertaken each three year period or the removal of 2.5 million tonnes of aggregate, whichever is the sooner.

Often monitoring is undertaken and the results are not used effectively to ensure the achievement of objectives. The review procedure should therefore be established at an early stage in the development plan and could be agreed with members of a monitoring group (see examples given below). The frequency of review will be dependent on the objectives and the methodology used for survey. The review procedure should also include action to be taken following the review of results should any significant adverse effects be identified. This could include stopping any works until adequate mitigation measures are devised and increasing the frequency of monitoring to ensure the effectiveness of new mitigation.

One of the problems with attempting to obtain monitoring information is that the vast majority of data remain unpublished and are often commercially sensitive. This makes it difficult to establish what information exists and, in some cases, makes information difficult to obtain as it is confidential. This situation is, however, improving. BMAPA members are participating in the MARLIN project to assist in disseminating baseline and monitoring data. With the imminent introduction of statutory regulations, availability of monitoring data and transparency will become important. Many BMAPA companies are investigating use of websites to make monitoring data more widely available.

The following schemes illustrate examples of good practice, where successful monitoring techniques and programmes have been instigated in the marine environment much of which is applicable to the monitoring of aggregate extraction.

7.7 Examples of Operational Monitoring Programmes

7.7.1 Area 107

The following information relating to the licence conditions, and specific monitoring requirements for licensed dredging Area 107, was obtained from the Eastern Joint Sea Fisheries Committee (EJSFC), Kings Lynn. The EJSFC is the lead authority on the Wash and North Norfolk Coast SAC Management Group, which is made up of a number of organisations with an interest in the area.

The EJSFC is not only concerned with proposals, including aggregate extraction, which may have potential impacts on fisheries, but also on the Wash and North Norfolk Coast SAC. In terms of potential impacts on the SAC, the EJSFC works closely with, and takes advice from, English Nature.

Licensed dredging Area 107 is located off the Lincolnshire coast in the southern North Sea. In 1994, South Coast Shipping Co Ltd applied to increase the volume of sand to be dredged from two existing aggregate extraction areas within Area 107 (the NE Zone and NW Zone). This licence received a favourable Government View, subject to stringent monitoring conditions. These conditions were largely related to the potential impacts of the extraction on local commercial fishery interests and not specifically on the nature conservation interests of the Wash and North Norfolk Coast SAC. This is because the SAC designation had not been proposed at the time of the dredging application. It is considered that monitoring programme for this site is rather exceptional in terms of the level of biological and other aspects being monitored.

The Area 107 monitoring programme can be divided into three broad components (Box 7.8.1):

- pre-dredge surveys;
- during-dredge surveys; and
- post-dredge surveys.

Brown shrimp monitoring

A brown shrimp monitoring programme was also set up in order to assess the abundance, distribution and biological structure of the shrimp population. Measurements of temperature, salinity, turbidity and seabed type were also monitored as these parameters may have an affect on the amount of shrimps caught.

Other licensing conditions

The dredging licence for this area also contains other conditions relating to the quantity of material to be extracted, the exact location of the extraction areas, the extraction rates, the permitted use of the dredged material and provisions for any wrecks found during the dredging operation.

Box 7.7.1 Area 107 Monitoring
Pre-dredge survey The pre-dredge survey aimed to establish the existing environment prior to the extraction operation. This survey comprised the following components: a. Bathymetric survey b. Benthic survey Before any dredging in the NW Zone a pre-dredge benthic survey was carried out and the results submitted to MAFF, DETR and CEC. During-dredging surveys These one-off surveys focussed on monitoring movements in the sediment plume, particularly during times of southerly and/or easterly water movement. This included: 1. Acoustic Doppler Current Profiling (ADCP), with coincident water column sampling for suspended solids in the wake of each dredging vessel (up to a maximum of three vessels). 2. Aerial (aeroplane) imagery, with photographs taken during and after dredging. 3. Fluorescent particle tracing. Fluorescent particles, mimicking the particle size and density of the outwash sediment, were injected into the outwash. The movement of the particles was monitored for up to three days following injection and monthly at sensitive sites for three months. 4. Examination of the quantity and particle size of settled sediment by the use of sediment traps such as Bonner tubes at selected stations near the extraction area and at sensitive sites, in terms of the fishery interests. Post-dredge surveys In addition to the above monitoring, annual monitoring during and close to the end of dredging, is also being undertaken order to assess any effects of the aggregate extraction on physical and biological regimes in the extraction area and in the areas deemed sensitive because of fishery interests. This was to be undertaken each year throughout the period of the license. Annual monitoring comprised the following components: Sidescan sonar of the extraction area; A coring survey at sites just outside the extraction area and in sensitive fishery sites; A towed camera survey both in and outside the extraction area, to include sensitive fishery sites; A benthic grab survey which is a repeat of the baseline surveys in the NE and NW Zones and control areas plus a number of samples of sensitive fishery areas. Epibenthic trawls, with a total of 10 trawls to take place in the same areas as the benthic survey above.

In order to minimise the effects of the dredging plume, there was a requirement that the licensee should follow a dredging plan. This plan contains the following measures, aimed at mitigating the potential impacts of increased suspended sediment levels of fisheries:

1. During spring tides (two days either side of high water with the greatest range), vessels shall dredge in the NW Zone only. The reason for this measure is that should dredging occur at these times in the NE Zone, the sediment plume would disperse towards Race Bank. This area is an important fishing area and a crab nursery area which feeds a large part of the North Sea crab fishery. The plume generated in the NW Zone would disperse northwards towards the Humber region.

2. In the NE Zone, those vessels only working one cargo per tide shall commence dredging as late as practicable on the ebb tide. This ensures that most of the dredging

takes place on a flood tide, carrying the plume away from Race Bank and Burnham Flats, an important shrimping ground.

The licence also states that a procedure should be implemented for all dredging vessels to mark, record and exchange co-ordinates of any significant areas of clay located. Clay is formed into mounds by aggregate extraction and this provides an obstruction to fisheries. This procedure aims
to minimise the conflict between aggregate extraction and fishery interests.

Review and discussion of monitoring

The monitoring programme for Area 107 is reviewed twice a year in order to assess the results and adapt it accordingly. The monitoring results for Area 107 are currently confidential.

The monitoring of aggregate extraction from the NE and NW Zones is undertaken by CEFAS. The monitoring results are presented to South Coast Shipping Co Ltd (the dredging company) at a scientific meeting. Following this, a second meeting is held at which the results are presented to the fishing industry. This second meeting is attended by representatives of the fishing associations, including those from Lincolnshire, Boston, Kings Lynn, Cromer and Wells. On the basis of any proposals put forward by the fishing associations at these meetings, the monitoring programme may be adjusted (if necessary) to incorporate the knowledge and experience of the local fishermen.

As a result of such meetings the degree of conflict between the fishing industry and the aggregate extraction company is minimised, with both parties increasingly recognising the need for all activities to coexist within close proximity of each other.

7.7.2 The Oresund Fixed Link: design and construction

The Oresund Fixed Link is a transport link between Denmark and Sweden which is just under 16km in length. The environmental assessment work undertaken on the scheme and monitoring programme developed in relation to the construction works demonstrates a range and style of monitoring methodologies and approaches. These methods may be applicable to the monitoring of aggregate extraction and are presented here as examples of best practice monitoring in the marine environment.

Two environmental requirements were specified by the authorities for the construction and operational phases of the link. These were:

- That the Oresund Fixed Link shall not affect the Baltic Sea (this implies that there shall be no net effect on the flow through Oresund, supplying oxygen and salt to the Baltic).
- That the Oresund Fixed Link shall only for a short construction period create conditions which are detrimental to the environment around the construction area. Thus the sediment spillage shall be limited to 5% of the dredged volume, and the spillage intensity shall be controlled depending upon location and time of year.

The first objective is achieved by compensation dredging, the extent of which was determined by hydraulic modelling in connection with calibration measurements of the flow through Oresund. The second objective is achieved by careful planning and execution of the dredging operations (Oresundskonsortiet, 1996).

In March 1995, Oresundskonsortiet undertook a supplementary environmental impact assessment used to further optimise the construction methods. This report also provided a useful tool in the development of the control and monitoring programmes. As a result, the Authorities, Oresundskonsortiet and the Contractors all undertook different monitoring programmes during the construction period.

In March 1998 (two years after the initiation of the construction works), an update of the 1995 impact assessment was produced. This updated assessment presented the full results of the 1993-95 baseline environmental studies and the results from two years of monitoring impacts from the construction works (Oresundskonsortiet, 1998). The following paragraphs present the various monitoring programmes which were initiated in relation to the construction works for the Oresund Fixed Link.

Operational threshold values

A number of operational threshold values for acceptable sediment concentrations were laid down by Oresundkonsortiet on the basis of extensive baseline studies in the Oresund. These threshold values were designed in order to mitigate the potential impacts of the construction works on the most sensitive environmental parameters.

Spill monitoring

The Contractors are contractually obliged to measure sediment spill and are responsible for monitoring the amount of spill leaving the work zone (Oresundskonsortiet, 1998). The work zone is defined as the area being dredged with a surrounding 200m zone. Work methods for individual dredging operations were planned in such a way so that so that spill was limited as much as possible. The work plans are based on geological surveys. The Contractor is then obliged to produce work plans which document that the present limits can be met.

Various methods are used for spill monitoring, as follows:

1. *Transect measurements*

The measurements are carried out in transects perpendicular to the sediment plume. Sediment transport is determined by measuring the concentration of suspended sediment and the current velocity in the water column. Measurements are carried out on a 24 hour basis from a survey vessel carrying turbidity sensors and an acoustic ADCP current meter.

2. *Profile measurements*

These measurements aim to produce a detailed knowledge of both the vertical distribution of suspended material in the water column and the variation in time.

3. *Stationary measurements*

Stationary measurements of sediment spill from reclamation areas are carried out at the outflow of sedimentation basins. Turbidity and flow meters constantly measure the spills.

Box 7.7.2a Operational threshold values (Oresund Fixed Link)
Herring migration through Oresund must be safeguarded by ensuring that a minimum of two-thirds of Drogden and Flinte Channel are kept free of concentrations of suspended materials above 10mg/l during migratory periods; Foraging birds around Saltholm will be safeguarded by ensuring that concentrations of suspended material during April and July-August do not exceed 28mg-l for 90% and 70% of the time respectively; Eelgrass beds and other important vegetation are to be safeguarded by ensuring that the distribution and biomass are not reduced by more than 25%. A larger reduction, however, is accepted at depths of more than 5m; Mussel beds must be safeguarded by ensuring that sedimentation in the outer impact zone does not exceed 15kg/m2/month, and by ensuring that sedimentation does not exceed 60g/m2/day for more than 20% of the time during the period from June to August, when mussel larvae settle; Bathing water quality must be safeguarded by ensuring that concentrations of suspended material above 28mg/l, corresponding to a visibility of 1m, are not exceeded more than 10% of the time. During July, the value must not be exceeded more than 5% of the time.

Oresundskonsortiet feedback monitoring programme

The aim of this monitoring programme was to ensure compliance with environmental objectives. The programme monitoring stations are selected and adjusted in line with present and planned dredging operations so that the locations with maximum expected impact are monitored (Box 7.8.2b).

Box 7.7.2b Feedback Monitoring (Oresund Fixed Link)
The feedback monitoring programme comprises the following: Continual measurement of the sediment spillage from the current dredging area. Barge samples of the dredged material are also taken for analysis of environmentally hazardous substances (heavy metals and PCB's), nutrients and oxygen consuming materials. Monitoring of sedimentation is performed through video surveys and samples taken from the seabed. Sediment characteristics and layer thickness of deposited sediment in bottom samples is assessed. These investigations are supplemented with samples from sediment traps. Monitoring of bed load transport is carried out near the limit of the work zone. This is undertaken by video surveys of the seabed. If significant amounts of spilled material are observed on the seabed, acoustic surveys and sediment sampling aimed at quantifying the potential bed load transport are initiated. Monitoring of eelgrass, comprising fortnightly measurements of shoot density, leaf and root biomass and soluble carbohydrates in the roots/rhizomes from March to November. These measurements are carried out at selected locations outside the inner impact zone. In August/September a survey of eelgrass distribution is carried out by aerial photography. Monitoring of common mussels comprising photographic assessment (fortnightly intervals) of sediment coverage and measurements of biomass (monthly sampling).

The Authorities Control Programme

The Danish and Swedish Authorities have jointly drawn up a detailed programme for the control and monitoring of the environment during construction of the Fixed Link. This focuses on an annual survey of the environmental status of Oresund, and includes the following aspects:

- water quality;
- bathing water quality;
- benthic vegetation;
- benthic fauna;
- common mussels;
- fish;
- birds;
- coastal morphology.

This monitoring programme is continually adjusted according to the results of the monitoring (Box 7.7.2c).

Box 7.7.2c Summary Of Results (Oresund Fixed Link)
Sediment Spillage The monitoring programme did not reveal detectable bed load transport from any of the dredging areas. Additionally, spilled sediment has not increased the general level of suspended sediment in Oresund and it was concluded that the sediment settles or is transported out of Oresund with a rate comparable to the release rate (Oresundskonsortiet, 1998). Benthic Vegetation (Eelgrass) None of the variables monitored showed any decreasing tendency and it was concluded that the construction activities during the first two years of construction have not resulted in measurable large-scale impacts on the eelgrass beds (Oresundskonsortiet, 1998). Benthic Fauna (Common mussels) Based on the results of the feedback monitoring, a feedback index for the biomass of common mussels was calculated with index value 100 representing the baseline. The index values have mostly been close to 100, and often above indicating no negative effect from the construction works (Oresundskonsortiet, 1998).

7.7.3 Hastings Shingle Bank – Bathymetric Monitoring

Under the Schedule of Conditions attached to the Government View for aggregate production licence for the Hastings Shingle Bank, the licensees are required to document changes in sea bed physical conditions and sea bed levels. This is undertaken through the collection of bathymetric data, vibrocore samples and seismic reflection data. Bathymetric soundings are undertaken on an annual basis. Data covering the period 1995-1999 has been analysed for changes in sea bed level using a ground modelling software package and the results presented in a report to inform DTLR, NAW and DEFRA and ensure compliance with the conditions set out in the Government View. The data collected has been utilised in order to provide evidence that:

- Sediment composition within the licence sub-areas X and Y (areas of extraction) remains similar to that existing prior to commencement of the licence.
- An adequate covering of sediment remains over a sufficient proportion of the licence sub areas X and Y at the cessation of the dredging for recolonisation of the benthos.
- The recommendations in HR Wallingford Report EX2635 (1993) are adhered to and specifically that not more than 3 metres of sediment from sub-area X and 6 metres of sediment from sub-area Y are removed.

For the analysis of 1995-1999 bathymetric data sets,the survey data comprised files of tidally reduced soundings (in metres) with corresponding positions in Ordnance Survey Grid Co-ordinates. The sounding data and OSGB positioning data were converted into a regularly spaced grid from which a plot is generated showing bed levels. The difference between the gridded data for each year was then calculated to obtain a representation of areas of apparent shallowing and deepening between the survey periods.

In addition, an overlay of baseline sediment thickness drawn using seismic and sample data sets was utilised to assess resource depletion since the beginning of the new licence in November 1995.

The results of the monitoring undertaken to date show that the sediment thickness in the two Sub-Areas has reduced by 1.5-3.5m over the period 1995-1999. Available seismic data shows that dredging has not altered the characteristics of the sediment on the seabed.

7.7.4 Harwich Haven Approach Channel Deepening

In the summer of 1997, the Harwich Haven Authority (HHA) proposed to deepen the approach channel to the ports of Harwich and Felixstowe from its existing depth of –12.5m CD to –14.5m CD. The channel deepening was required so that the port of Felixstowe could accept the latest generation of new vessels with a draught of 14.0 to 14.5m. A comprehensive monitoring programme was developed as part of this proposal (in collaboration with MAFF, English Nature, the RSPB and the Wildlife Trusts) and is therefore included here. The objectives behind the proposed monitoring are particularly useful and can be applied to many mitigation/monitoring packages (see below).

An appropriate assessment was carried out which concluded that, without mitigation, the proposed scheme was likely to have a significant effect on the Stour and Orwell Estuaries SPA and Hamford Water SPA. Changes in the hydrodynamic regime within the Stour and Orwell Estuaries SPA were predicted, with subsequent effects on sediment supply to intertidal areas within the estuaries and specifically the area of mudflat available for feeding birds. Various mitigation measures and a monitoring strategy was however proposed, which led to the production of a Mitigation and Monitoring Package. A summary of the monitoring proposals, which eventually formed part of the consent for the 1999 works, is given below (Box 7.8.4a).

Box 7.7.4a Monitoring Objectives
• to increase understanding of the processes operating in the Stour Estuary; • to extend the monitoring programme initiated in 1994 for the Stour into the Orwell Estuary and Hamford Water; • to define hydrodynamic processes and sediment budgets such that the mitigation strategy and sediment replacement quantities can be refined, if required; • to define the assemblage of intertidal habitats that provide for the effective geomorphological functioning of the estuaries; • to understand the relationship between morphology, habitat and the populations and distributions of designated bird species; • to determine the effect of mitigation (i.e. the extent to which its objectives are being met); • to ensure that the mitigation measures (and beneficial use schemes) do not cause adverse impacts; • to define the extent of each habitat type and to measure change in habitat distribution; • to monitor the position of the SPA relative to regional and national trends for the designated species.

Monitoring proposals

A number of monitoring proposals were put in place, covering the Stour and Orwell Estuaries, Hamford Water, offshore areas, the channel and disposal grounds, and beneficial use and mitigation placement sites.

The monitoring strategy includes the following components (Box 7.7.4b).

Box 7.8.4b Monitoring Strategy
• a rolling programme of bathymetric surveys throughout the estuary system, targeted (as required) to areas of concern; • topographic surveys of the saltmarsh; • further mapping of benthic communities (rolling programme); • Seasonal monitoring of littoral vegetation; • a pre-dredge acoustic seabed interpretation survey of the seaward area of the channel and disposal grounds, with seasonal surveys every 3 years in areas of fishery interest and anticipated sediment pathways; • monitoring of suspended sediment during dredging and disposal; • monitoring of the abundance and distribution of bird populations throughout the estuaries; • fixed stations for monitoring long term suspended sediment concentrations; • research to better define the sediment transport pathway offshore; • post-dredge benthic surveys in the channel and disposal grounds.

In order to review the results of monitoring, an estuary research group will meet twice a year to discuss the results and any actions which need to be taken.

7.7.5 Barrow RNLI Station – proposed works

Again, although not aggregate extraction, an example of monitoring of an activity within an SAC is given below for Barrow.

The Royal National Lifeboat Institution (RNLI) proposed to reconstruct a new lifeboat station on the original site of the lifeboat station at Barrow. This site occurs within the Morecambe Bay cSAC which is designated for its marine interest, particularly for the lower littoral communities comprising sponges, algae, ascidians and peacock worms. There was potential for impacts on these species as a result of the works and several mitigation measures were recommended to reduce the potential for impacts. As the site was considered to be sensitive to smothering, by increases in suspended sediment concentrations, a monitoring scheme was initiated to record any damage caused as a result of the scheme and to ensure that further mitigation measures were undertaken should any damage occur.

The monitoring was agreed with English Nature prior to works being undertaken and comprised visual and photographic surveys before, during and after dredging in agreed locations. If any impacts were identified then the works must be stopped until further agreed mitigation measures were put in place.

8. Recommendations for integrating assessment of plans and projects into schemes of management for marine SACs

- The management group of Relevant Authorities could be included as a consultee in the licence determination process. This would enable any concerns regarding the location or nature of the proposed aggregate extraction operation to be highlighted at an early stage in the process. Consultation with the group could be referred through the competent authority. The management group fulfil a particularly important role in identifying combined impacts as many of the members will have a good knowledge of activities taking place within and near the site.

- Obtaining expert opinion on potential in combination effects is one method of undertaking impact assessment. Detailed assessment would be outside the scope of the management group. However, initial scoping and consideration of the proposal would enable activities that could have potential individual and in combination impact to be identified and would also be extremely useful in determining boundaries for the assessment (through knowledge of the extent and timing of activities) and identifying other potential sources of information. A direct response to the applicant or his consultant could be provided from the group as a whole. Alternatively, a response could be co-ordinated through the competent authority.

- Management schemes developed for each SAC will also include responsibilities for monitoring. It may be possible to link monitoring packages developed for aggregate extraction areas into management scheme condition monitoring and surveillance programmes. This would allow similar monitoring needs to be identified and potentially for repetition of data collection and assessment to be avoided.

- The distribution of features on some sites may lend themselves to zoned management of activities or operations. At the present time, such an approach may be difficult to take for all sites and its application would depend on a number of factors that would need to be assessed before aggregate extraction licences could be issued under such a framework. These include:

  - establishing the distribution and extent of features of importance within a SAC;

  - understanding the effects of aggregate dredging, at both a temporal and spatial level, and the impact that these may have on a range of habitat types and communities;

  - determining site-specific sensitivities and threshold levels for designated features in relation to the identified effects of aggregate extraction.

Adopting such an approach offers a number of benefits, not least of which would be the ability for extraction to occur under circumstances where the environmental ‘baseline’ has already been established and the uncertainty with regard to impact on environmental interests can effectively be eliminated or significantly reduced. In addition, zoning also offers a mechanism by which the potential cumulative impact of some activities could be avoided, either through limitations on the phasing/timing of activities or through the restriction of some activities to particular areas. However, such a management mechanism could ‘sterilise’ otherwise commercially viable deposits, and therefore the determination of zone boundaries and limits of effects would need careful consideration and agreement between interested parties. In the longer term, the zoning of a site probably offers the most effective means of promoting the sustainable use of existing aggregate and maerl resources and of ensuring that designated areas of marine interest are not adversely impacted upon by this activity.

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Appendix A Maps of possible and candidate marine and coastal SACs and licensed dredging areas. Information correct as at April 2000 (note that the map (Figure1.3.4) and Apendix B have been updated to May 2001

Appendix B Features for which UK marine SACs have been proposed for designation Information correct as at May 2001.

SITE NAME Marine Annex I habitats and Annex II species indicated for each site exclude non-qualifying features	SITE STATUS c=candidate p=possible	*Halichoerus grypus* (Grey seal)	*Phoca vitulina* (Common seal)	*Tursiops truncatus* (Bottlenose dolphins)	Lagoons	Estuaries	Large shallow inlets and bays	Mudflats and sandflats not covered by seawater at low tide	Reefs	Sandbanks which are slightly covered by seawater all the time	Submerged or partially submerged sea caves
Alde, Ore and Butley Estuaries	cSAC					●		●			
Ascrib, Isay and Dunvegan	pSAC		●								
Bae Cemlyn/ Cemlyn Bay	cSAC				●						
Benacre to Easton Bavents Lagoons	cSAC				●						
Berwickshire and North Northumberland Coast	cSAC						●	●	●		●
Braunton Burrows	cSAC							●			
Cardigan Bay/ Bae Ceredigion	cSAC	●		●					●	●	●
Carmarthen Bay and Estuaries/ Bae Caerfyrddin ac Aberoedd	cSAC					●	●	●		●	
Chesil and the Fleet	cSAC				●						
Dee Estuary/ Aber Dyfrdwy	pSAC					●		●			
Dornoch Firth and Morrich More	cSAC		●			●		●	●	●	
Drigg Coast	cSAC					●		●			
Eileanan agus Sgeiran Lios mór	pSAC		●								
Essex Estuaries	cSAC					●		●		●	
Fal and Helford	cSAC					●	●	●	●	●	
Faray and Holm of Faray	cSAC	●									
Firth of Lorn	cSAC								●		

SITE NAME Marine Annex I habitats and Annex II species indicated for each site exclude non-qualifying features	**SITE STATUS c=candidate p=possible**	***Halichoerus grypus* (Grey seal)**	***Phoca vitulina* (Common seal)**	***Tursiops truncatus* (Bottlenose dolphins)**	**Lagoons**	**Estuaries**	**Large shallow inlets and bays**	**Mudflats and sandflats not covered by seawater at low tide**	**Reefs**	**Sandbanks which are slightly covered by seawater all the time**	**Submerged or partially submerged sea caves**
Flamborough Head	cSAC								●		●
Glannau Môn (Cors heli)/ Anglesey Coast (Saltmarsh)	cSAC					●		●			
Humber Estuary	pSAC				●	●		●		●	
Isle of May	cSAC	●							●		
Isles of Scilly Complex	cSAC	●						●	●	●	
Limestone Coast of South West Wales/ Arfordir Calchfaen de Orllewin Cymru	cSAC										●
Loch Creran	pSAC								●		
Loch Laxford	pSAC						●		●		
Loch Moidart and Loch Shiel Woods	cSAC							●			
Loch nam Madadh	cSAC				●		●	●	●		
Loch of Stenness	cSAC				●						
Loch Roag Lagoons	cSAC				●						
Lochs Duich, Long and Alsh Reefs	cSAC								●		
Lundy	cSAC	●							●	●	●
Moine Mhór	cSAC							●			
Monach Islands	cSAC	●									
Moray Firth (marine)	cSAC			●						●	
Morecambe Bay	cSAC				●	●	●	●	●	●	
Mousa	cSAC		●						●		●

SITE NAME Marine Annex I habitats and Annex II species indicated for each site exclude non-qualifying features	**SITE STATUS c=candidate p=possible**	***Halichoerus grypus* (Grey seal)**	***Phoca vitulina* (Common seal)**	***Tursiops truncatus* (Bottlenose dolphins)**	**Lagoons**	**Estuaries**	**Large shallow inlets and bays**	**Mudflats and sandflats not covered by seawater at low tide**	**Reefs**	**Sandbanks which are slightly covered by seawater all the time**	**Submerged or partially submerged sea caves**
Murlough	cSAC		●					●		●	
North Norfolk Coast	cSAC				●						
North Rona	cSAC	●							●		●
Obain Loch Euphoirt	cSAC				●						
Orfordness - Shingle Street	cSAC				●						
Papa Stour	cSAC								●		●
Pembrokeshire Marine/ Sir Benfro Forol	cSAC	●		●	●	●	●	●	●	●	●
Pen Llyn a'r Sarnau/ Lleyn Peninsula and the Sarnau	cSAC	●		●	●	●	●	●	●	●	●
Plymouth Sound and Estuaries	cSAC					●	●	●	●	●	
Rathlin Island	cSAC								●	●	●
Sanday	cSAC		●					●	●	●	
Severn Estuary/ Môr Hafren	pSAC					●		●	●	●	
Solent and Isle of Wight Lagoons	cSAC				●						
Solent Maritime	cSAC				●	●		●	●		
Solway Firth	cSAC					●		●	●		
Sound of Arisaig (Loch Ailort to Loch Ceann Traigh)	cSAC									●	
Sound of Barra	pSAC		●							●	
South Uist Machair	cSAC				●						
South Wight Maritime	cSAC								●		●

SITE NAME Marine Annex I habitats and Annex II species indicated for each site exclude non-qualifying features	**SITE STATUS c=candidate p=possible**	***Halichoerus grypus* (Grey seal)**	***Phoca vitulina* (Common seal)**	***Tursiops truncatus* (Bottlenose dolphins)**	**Lagoons**	**Estuaries**	**Large shallow inlets and bays**	**Mudflats and sandflats not covered by seawater at low tide**	**Reefs**	**Sandbanks which are slightly covered by seawater all the time**	**Submerged or partially submerged sea caves**
South-East Islay Skerries	pSAC		●								
St Kilda	cSAC								●		●
Strangford Lough	cSAC		●		●		●	●	●		
Sullom Voe	pSAC				●		●		●		
Sunart	cSAC								●		
Thanet Coast	cSAC								●		●
The Vadills	cSAC				●						
The Wash and North Norfolk Coast	cSAC		●		●		●	●	●	●	
Treshnish Isles	pSAC	●							●		
Tweed Estuary	pSAC					●		●			
Y Fenai a Bae Conwy/ Menai Strait and Conwy Bay	pSAC					●	●	●	●	●	●
Yell Sound Coast	cSAC		●								