Section 4

Regional Ecological Monitoring Programme

4. Ecological Monitoring

4.1. Definitions

To provide a process for assessing the impact of the dredging the following components are required:

Impact Hypothesis

Overall hypotheses, through which the impact of dredging activity may be determined to have occurred and against which actions will need to be set if exceeded.

To prove or disprove an hypothesis the following elements are required:

Detectable Difference

A statistical or other readily identifiable value or values, on a temporal or spatial scale, which allow a difference to be identified between impact and/or reference areas. The importance of this term is that some data sets or values may be so variable that valid (statistical or otherwise) differences on a spatial or temporal scale cannot be demonstrated.

Theoretical Framework

Separate theoretical frameworks within which, changes in different components of the benthic community may be measured and assessed using defined detectable differences and which may be used to prove or disprove the hypothesis.

Threshold

A value or series of values, which will be determined through measurement of natural and anthropogenically induced differences within the theoretical frameworks and which when exceeded, will result in an action with respect to regional monitoring and/or extraction operations. Two generic thresholds have been included in the impact hypothesis but refined thresholds will be required for various components of the ecosystem during the life of the monitoring work.

The final part of the process is the Action.

Action

An action will be required once a threshold, related to a proven impact hypothesis has been exceeded. This action is within the remit of the TWG to determine. They will include, for example changes to area of dredging activity, remedial activities, reduction in dredging intensity, modification of dredging activity, increased monitoring, etc. as necessary in proportion to the level of impact.

4.2. Objectives, Hypotheses and Thresholds

4.2.1. Generic Objectives

Box 22 The Objectives of the Regional Ecological Monitoring Programme

The objectives of the regional ecological monitoring are as follows:

- **To provide a regional view of the pre-dredge status of seabed habitats and biota in the Eastern English Channel in the vicinity of the proposed dredging.**
- **To provide a regional reference point against which predictions concerning localisation of impacts due to dredging may be tested.**
- **To provide a coherent programme of monitoring within which the predictions concerning impacts due to dredging may be tested.**
- **Ensure results of monitoring in individual licence areas are compatible across the regional area.**
- **To develop thresholds that may be applied to enable limitation of impacts.**
- **To place the conservation importance of the area into a regional and national context through the development of a Habitat and Biodiversity Action Plan.**

Ecological studies under the following headings are required to achieve the above objectives:

- **Seabed sediment studies.**
- **Benthic infaunal and epifaunal communities.**
- **Benthic epifaunal communities, biotopes and habitats.**
- **Commercially important epifaunal species, specifically scallop and crab.**
- **Demersal fish species and associated epibenthic communities.**
- **Pelagic fish species with benthic spawning.**

The rationale for employing each of these methods is based on a relatively well established range of effects resulting from dredging activity. These impacts relate to the type of substrata, the spatial extent and intensity of dredging and frequency of activity. Emu Ltd (2004) reviewed the range of impacts with respect to these variables.

The following summary is taken from this document and is relevant with respect to conditions anticipated in the EEC:

- **Where repeated intensive trailer dredging occurs, dredged areas can become almost totally devoid of fauna with species diversity reduced by ~70% and biomass by ~90%. Less frequent or spatially less intense dredging decreases impacts, either through temporary recovery or reduced initial damage.**
- **Species groups most seriously damaged are sessile epifauna unable to tolerate disturbance and/or smothering, e.g. anemones, bryozoans, hydrozoans. Complex community structures can also be disturbed.**
- **Where trail dredging has left deep trenches, additional impacts arise including; limited sediment deposition on un-impacted edges; destabilised sediments on steep sided trench walls; and mobile sediments devoid of fauna in the bottom of the tracks or depressions.**
- **Theoretical dredging impacts to benthos on deep water (>30m) complex stable gravel, suggests that the presence of higher numbers of longer-lived and slower-growing species is likely to significantly extend the recovery time compared to shallower sites. For example Dog Cockles in Eastern English Channel may live for 14years with recruitment of juveniles at 5 yearly intervals; as a result the recovery of a population may take 15-20 years.**
- **Secondary impacts from sandy sediment generated by screening or overspill can extend the areas of impact and the timescales for recovery, related to changes to habitat, sediment type and sediment stability.**
- **The degree of primary and secondary impacts seems to be closely linked to dredging intensity and screening rates, frequency of dredging, nature of the prevailing tidal currents and the resource material being dredged.**

Based on these anticipated consequences due to dredging activity the following theoretical impact structure has been developed which is the basis for the survey arrays and sampling strategy developed in this document.

Table 1 Anticipated Effects of Dredging Activity - Four principal impact areas may be described:

Title and character of activity	Anticipated effect
Active Dredge Zone (ADZ) – in the process of being dredged at the time or immediately preceding the survey period. This is a subset of the Primary Impact Zone (PIZ) as it will not be static over time, but will always remain within the PIZ.	Complete or almost complete loss of fauna, both epifauna and infauna in the immediate vicinity of the dredging activity. Defined as highly significant detectable differences from baseline and reference areas.
Primary Impact Zone (PIZ) – comprising the area that may be actively dredged during the lifetime of the licence and hence subject to relatively severe direct impacts at times.	Partial lost of both epifauna and infauna due to direct and indirect effects. Partial recovery may occur in this area due to the cessation of dredging in part so of the zone, however, continued effects may be felt from indirect sediment deposition and seabed sediment mobilisation. Defined as significant detectable differences from baseline and reference areas.
Secondary Impact Zone (SIZ) – This area falls outside of the area that will be actively dredged, although it may be subject to peripheral and indirect impacts.	Partial loss of fauna, primarily the epifauna, due to deposition and or mobilisation of the seabed sediments. Impacts will be on a gradient from the immediate boundary of the PIZ to the outer edge of the SIZ at which point no impacts are anticipated. Defined as marginal detectable differences from baseline and reference areas.
No impact and reference areas.	No anticipated loss of fauna due to any activity related to dredging. No detectable difference from baseline.

Based on the above classifications the following Impact Hypotheses have been proposed which will be used as the basis for the assessment of adverse effects due to the dredging activity.

Biological Monitoring Impact Hypothesis 1

Biological changes, occurring as a consequence of physical changes to the sediment, attributable to the extraction of marine aggregate in the ECR, will be limited to the vicinity of dredging activity.

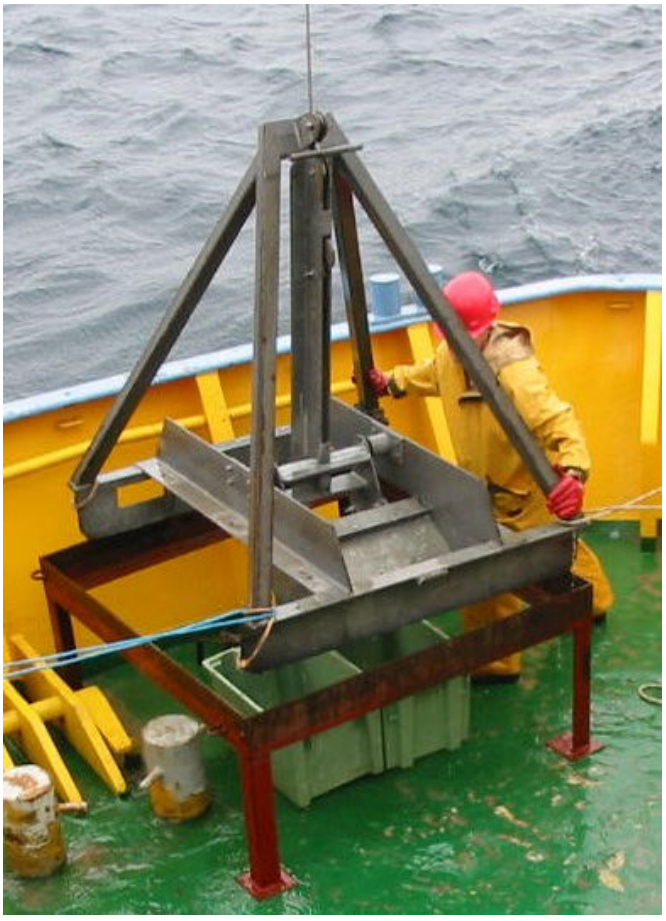
Biological Monitoring Impact Hypothesis 2

The benthic fauna within areas of intensive dredging activity in the ECR will be adversely affected but will recolonise relatively rapidly (i.e. within months) after cessation of dredging activity and will be structurally comparable to adjacent assemblages within 5 years.

Each of the proposed study areas will have a series of theoretical frameworks specific to the component of the ecosystem investigated, which will guide the techniques needed to achieve the aims or prove/ disprove the hypotheses.

Where proposed the theoretical frameworks will range from highly specific and statistically rigorous to generic and qualitative in nature. Where differences can be demonstrated statistically the relevance of the significance will then be determined through the development of thresholds, which will be the responsibility of the Technical Working Group. Similarly the TWG will need to define the subsequent actions, which might include a change to dredging activities, remediation or rehabilitation of dredged sites or modification to monitoring techniques.

Some of the theoretical frameworks and associated detectable limits may operate within the confines of individual licence blocks, while others will only be relevant within a regional perspective. On this basis a matrix of applicability has been provided, see **Table 2**.



A Hamon grab will be employed for seabed sampling during thee regional biological monitoring programme.

4.3. Aims and Theoretical Frameworks

It is proposed that aims, theoretical frameworks and limits of detectable difference are considered together. Many of the activities in the monitoring programme will not have clear limit of detectable difference established initially, hence they will need to be defined during the course of the programme of work. For those components of the ecosystem which can be statistically tested, limits of detectable difference will be based on conventions provided in Cohen (1988) which defines the magnitude of size of detectable difference (large, medium and small), as a proportion of the standard deviation of a variable.

For the purposes of this programme of work it is anticipated that only large detectable differences will be possible initially, i.e. 0.8-1 times the s.d., which in real terms will relate to changes, for example, of approximately 50% in mean value of the species number. Less overt differences may be measured and thresholds set, using none significance testing methods or from a combination of data across the regional area and through time.

4.3.1. Benthic infaunal and epifaunal communities

Although frequently separated into two compartments benthic infaunal and epifaunal communities form one ecological and interrelated unit. The reason for separation is primarily due to the differing means of sampling the communities. This section will deal with theoretical frameworks which are relevant to whole communities including both epifauna and infauna, where they have been sampled and measured using the same technique. The basic assumption is that benthic grabbing using a Hamon grab ($0.1m^2$) is the proposed sampling method. Additional analysis may be conducted on the separate infauna and epifauna data components so that comparison with previous studies in the area will be possible. The subsequent Sections 4.3.2. to 4.3.3., will deal with the epifaunal communities alone, including the surface visible communities as a separate measurable unit.

It will be possible to compare two features of the benthic communities; community structure and community composition. These may be considered in isolation and in combination.

Community Structure

Structural components on a per site basis, will include the following primary variables, which will be measured at each site:

- **Species number**
- **Total abundance**
- **Biomass**

More complex variables will include a range of diversity indices as follows:

- **Shannon Wiener Diversity (H^1 $\log_e$)**
- **Margalef's species Richness (d)**
- **Pielou's Evenness (J^1)**
- **Simpson's index of Dominance (?)**

A review of the historic data acquired in the original site surveys has indicated different degrees of variation, in relation to the mean, specific to the variable. This has relevance to the number of samples required to determine if a statistically based hypothesis can be rejected with confidence. The following theoretical frameworks are, therefore, based on the variables that are most likely to be able to identify differences, with minimal sampling effort, due to their relatively small inherent variability. This does not imply that the other primary variables or other derived variables should be ignored in subsequent data analyses, it simply indicates that the statistical certainty of determining a detectable difference is reduced for these variables.

Prior to employing the following tests an initial baseline test using ANOVA will be required, with the impact of dredging being the factor considered. The baseline assessment will be needed to establish that the ADZ, PIZ, SIZ and reference areas are sufficiently similar, such that no statistical difference can be determined between them. Should differences exist between the impacted areas and the appropriate reference area, these will be investigated further to identify the source of variation. These subsequent analyses will be based on t-tests to identify specific differences between data sets. The consideration of reference areas will also be based on the multivariate analysis described in the section Composition and Structure Combined. These analyses will assist in confirming the suitability of the reference areas. Adjustment to the location of the reference areas may be required as a consequence of this initial analysis.

Theoretical Framework 1

On a year to year basis, the dredging activity may have a measurable impact on the number of species, abundance, biomass or derived community statistics in the ADZ, PIZ and SIZ.

This framework may be applied to individual licence areas, combined licence areas and to the region as a whole. A proposed detectable limit of difference has been determined for species number and the employment of a suitable threshold value based on this detectable difference may be developed within 5 years.

In the case of the number of species a detectable difference may be measured with a good degree of statistical certainty (based on pair-wise comparisons of means, one tailed, t test) if a large (i.e. a value greater than 0.8-1 times the standard deviation of the species numbers) reduction in mean number of species occurs. This may be evident between impacted areas on a year to year basis and may be identified as occurring outside of the limits of natural change, which will be defined through equivalent analysis of the reference area/areas. In this respect all reference areas must be sampled every year.

Benthic Response Index

The benthic response index is still a relatively untried measure of community response to disturbance within the UK. It contains aspects of structure as well as composition. Pearson (2001) suggested that, based on experience in the US (Smith, *et al*, 1997) a similar response index for communities in the UK could be developed. The basis of the BRI is that the communities, after initial analysis using multivariate techniques, can be placed into a disturbance gradient. This will be possible in the case of the regional monitoring activity as a whole, once dredging has commenced. From this analysis the individual response (abundance values) of species to disturbance due to dredging may be determined along the gradient. The index will be calculated as the abundance weighted average disturbance tolerance of species in a sample. Thresholds have previously been defined in five levels of biological response, with respect to baseline conditions and loss of key community attributes. This technique is clearly at a developmental stage in the UK, but during the course of the five years of the monitoring programme it is suggested that a valid response index for the species and communities present in the Eastern English Channel may be developed. No hypothesis or threshold is currently proposed.

Composition and Structure

The analysis of the combined composition and structure of the benthic communities is best conducted using multivariate techniques. The theoretical frameworks presented here relate to the outputs of PRIMER analysis, which is the recommended multivariate analytical package for all of the benthic studies.

The primary objective of multivariate techniques is to group sites or samples into clusters, which comprise of sites with similar species composition and species abundance. A measure of this similarity is provided and is one of the most important variables in the determination of change from the baseline or reference sites. Prior to the development of thresholds using this technique it will be necessary to identify the degree of similarity between the reference areas and the impacted areas. The amount of change, which may then result in an action, will need to be developed over the five years of the regional study, but some measures may be expected to be available within 3 years.

Theoretical Framework 2

On a year to year basis, the clustering of benthic community sites will correspond to the different impact zones and reference areas.

The development of detectable differences will relate to variation within the baseline data and subsequent variation on a year to year basis. At the simplest level the separation of a single cluster of sites into two or more identifiable clusters within the MDS plot, corresponding to dredging activity, may be considered as a detectable difference. This may also be measured employing the PRIMER subroutine ANOSIM, with significance testing possible of similarity between a priori groupings related to the ADZ, PIZ, SIZ and reference sites, as well as temporally separated data. This framework is applicable to all licence areas and to the region as a whole.

It is proposed that the employment of the relative Index of Multivariate Dispersion will also be of particular relevance to within cluster dispersion and may provide a measure, which can be statistically relevant. However it is suggested that the limits of rIMD values per cluster will not be available until the end of the first five year programme.

Following on from the overall analysis of the site similarity data it will be possible to superimpose other analyses to better define the causal basis of any change detected. The most pertinent is BIO-ENV which relates (using Spearman rank correlation) the environmental variables most likely to be contributing to change of the benthic community.

Theoretical Framework 3

On a year to year basis, measures of dredging activity will be assessed with respect to their influence as the environment/physical variables responsible for clustering of the site data.

Measures of dredging activity will include, for example:

- **Quantity, by weight, removed**
- **Increase in depth to seabed**
- **Frequency of activity (per year) using EMS data**
- **Period since last dredged**

Additional data with respect to naturally occurring environmental variables will be analysed including sediment particle size derived statistics and basic parameters such as percentage gravel fraction and percentage sand fraction. Other data will include intensity of fishing activity where available. These analyses will be applicable to all licence areas and to the region as a whole.

Given that impacts are anticipated and are likely to be considered acceptable within the ADZ during the period of dredging activity, the employment of this framework and suitable thresholds will be particularly relevant in determining when seabed conditions are no longer affected by dredging, i.e. during the recovery period. The determination of a threshold will, for example, relate to a period of time in which impacts are still evident and the resulting action may be, for example, proactive seabed rehabilitation.

4.3.2. Epibenthic communities, biotopes and habitats

Communities

The impact of the dredging activity on epibenthic communities alone will be measured by investigating changes in a similar way to that employed for the infauna. The employment of a 2m epibenthic beam trawl will be one of the principal tools in achieving this objective, however, it will not be possible to achieve the same degree of statistical power using the epibenthic 2m beam trawl survey methods due to the smaller number of samples collected. Determination of significant difference, with sufficient power to discriminate relevant differences can only be achieved on a regional basis or through a combination of licence areas. The theoretical framework for assessment of impacts using this data is most appropriately considered using the PRIMER package as specified above.

Theoretical Framework 4

On a year to year basis, the clustering of benthic community sites will correspond to the different impact zones and reference areas.

The same provisos with respect to detectable differences and threshold development as apply to the grab data, are also relevant to the epifauna data collected by beam trawl.

Theoretical Framework 5

On a year to year basis, measures of dredging activity will be assessed with respect to their influence as the environment/physical variables responsible for clustering of the site data.

Definition of measures of dredging activity and associated environmental variables are the same as those for the grab data.

Biotopes and Habitats

Consideration of the benthic epifaunal biotopes, habitats and composite species will be one of the primary contributors to the Habitat and Biodiversity Action Plan for the Eastern English Channel. The Habitat and Biodiversity Action Plan is described separately in the Monitoring Blueprint and is supported by a JNCC Statement of Advice (JNCC, 2004). Currently no clearly defined areas exist although habitats and biotopes which may be designated have been determined.

The biotopes or habitats, which are the focus of the Habitat and Biodiversity Action Plan, may be defined on the basis of visible extent. These include the following (note these are explained more fully in the BAP) which are considered as designated habitats or biotopes in the subsequent theoretical framework:

- ***Sabellaria spinulosa* reefs;**
- **Reef (stony, bedrock and biogenic reef);**
- ***Ophiothrix* sp aggregations;**
- **Sandbanks slightly covered by seawater at all times;**
- **Sublittoral sands and gravels**

The biotopes and habitats of interest will not limited to those above, as greater biotope and habitat definition (based on Conner *et. al* (2004)), will become available during the course of the monitoring programme and more specific requirements may emerge which could, consequently, require more specific studies to be initiated.

The theoretical frameworks described in this section are based on the employment of several survey techniques but are principally based on sidescan sonar and seabed video.

Theoretical Framework 6

Boundaries, of designated habitats and or biotopes, will be determined and fluctuations in these boundaries will be assessed with respect to influencing factors, both natural and as a result of dredging activities.

Due to the current lack of knowledge of both the spatial distribution and temporal variability of the designated habitats in the area, limits of detectable difference and suitable thresholds will need to be determined. Practical constraints with respect to accurately measuring the area or extent of these features will be one of the first issues that needs to be resolved in relation to identifying limits of detectable difference. Should these features be satisfactorily measured then thresholds may be proposed. This framework will be applicable to relevant licence areas and to the region as a whole. Limits of detectable difference and a possible threshold will be available for trial in the long-term.

For designated features within SAC or other defined Habitats Directive sites, it is normal for any loss of the feature to be considered as a significant effect. However, in the EEC area natural variability may well be significant and it is suggested that after the first three years of survey, upper and lower limits of variability (i.e. the limits of detectable difference) may be provisionally identified, based on boundaries or areas established in suitable reference locations. A threshold may subsequently be determined based on exceedance of a percentile of the mean value over this initial three year period.

Theoretical Framework 7

On a year to year basis, the frequency of occurrence and abundance of the principal species which are determining the designated biotopes will not be expected to vary outside of those occurring naturally.

Due to the sensitivity of some of the biotopes and habitats to sampling using epibenthic trawl methods, data with respect to the above hypothesis will be collected using video techniques. The viability of establishing statistically valid data will be developed over the first three years of the monitoring programme, based on replicate drop down sampling procedures along fixed transects within and across the boundary of designated biotopes. Constraints to the establishment of statistically valid data include variability in physical conditions that may lead to loss of visibility and hence potential to assess the species under investigation.

Abundance or frequency of occurrence (in the case of colonial species) of the principal species determining the biotopes will be quantified through counts taken from the video records. Proposed detectable differences and possible thresholds relevant to dominant species will include statistical limits set against expected species abundance or frequency of occurrence.

Potentially useful species will include the following:

- ***Ophiothrix spp***
- ***Pentapora foliacea***
- ***Urticina felina***
- ***Alcyonium digitatum***
- ***Flustra foliacea***

This framework is applicable to relevant licence areas and to the region as a whole. Detectable limits of difference and a possible threshold will be available for trial in the long-term.

4.3.3. Commercially important epifaunal species, specifically scallop and crab

Several commercially important epifaunal invertebrate species exist in the Eastern English Channel regional area (Poseidon, 2002). These have been identified as follows:

- ***Cancer pagurus*** **(Brown or Edible crab)**
- ***Maja squinado*** **(Spider crab)**
- ***Pecten maximus*** **(King Scallop)**
- ***Aequipecten opercularis*** **(Queen Scallop)**

Assessment of the effects of dredging activity through regional monitoring will be focussed on this group of species.

The crustacean species will be investigated through data analysis of catch from existing fisheries in the area. It is anticipated that this will be developed with the co-operation of the fishing industry in the area.

No limits of detectable difference of thresholds can yet be suggested for this component of the work due to the paucity of data on the occurrence of crab in the area as a whole.

The occurrence and distribution of *Pecten* and *Aequipecten* will be assessed through species specific sampling methods, which will include equipment currently employed by the fishing industry and epibenthic beam trawls. These will allow population assessments to be conducted.

It has been proposed that no theoretical frameworks are put in place for this aspect of the monitoring, the newly acquired data most usefully being considered with respect to both historic data and internationally recorded landings based on ICES rectangles.

The objective therefore will be to investigate trends in the data within these contexts, identifying any changes that may be occurring locally, potentially attributable to the dredging activity.

4.3.4. Demersal fish species and associated epibenthic communities

The demersal fish populations have been shown to have well defined relationships with epibenthic communities in the eastern Channel area (Ellis and Rogers, 2001). Similarly epibenthic communities have been determined for several licence areas using 2m and 3m beam trawling methods. To measure the demersal fish and associated epibenthic communities the use of the 4m beam trawling method is recommended. Because of the apparent community interaction between the epibenthos and the fish species, the data may be treated as a single, community data set, at each sampling site as well as through analysis of individual species. In all cases, these data should initially be considered without rigorous hypotheses attached, selecting individual invertebrates and demersal fish species for recording and enumeration, with the possibility of subsequently testing differences in population measures for some of these species.

All possible data in terms of species types should be recorded from all catches for future development of hypothesis testing. Comparison with international landings will be one of the initial means of measuring difference specific to the EEC.

More specifically attention will be given to multivariate techniques, which may demonstrate interaction between the invertebrates and fish species. Based on the above, no hypotheses or theoretical frameworks have been proposed, consequently no thresholds will be applicable to this type of survey currently.

Where individual species can be selected and recorded for population measures the following may apply.

Individual population structures for selected species

It will be possible to use certain species, which are relatively long lived within the community, to determine changes within the population structure, which in turn may be occurring due to dredging activity.

The following species, based on Ellis and Rodgers (2001) and which have long-time series data available through CEFAS, have been provisionally identified for investigation:

- ***Trisopterus minutes***
- ***Raja clavata***
- ***Pleuronectes platessa***
- ***Solea solea***
- ***Aspitrigla cuculus***
- ***Callionymus lyra***

The limits of detectable difference and threshold levels relating to the above population structure data cannot be proposed currently, due to the lack of knowledge related to population structure of relevant species. Standard frequency size class data presentation will be employed for the chosen species. Year to year differences will be measured and differences outside of those occurring within similar populations found at the reference sites and in the wider area will be used to establish and refine thresholds.

4.3.5. Pelagic fish species with benthic spawning

This specifically refers to Herring (*Clupea harengus*), which has been identified to spawn in several areas within the EEC region (Poseidon, 2002, Gardline 2003).

The assessment of herring spawning in the eastern Channel will be achieved through use of data collected by the internationally coordinated annual herring larvae survey of the southern North Sea and eastern Channel. This survey is conducted during the winter months for the purpose of collecting annual indices of herring spawning stock biomass. Data for the <10mm length group from the survey will be requested annually from the Herring Assessment Working Group Chair, via CEFAS.

It is anticipated that data compilation for several preceding years will enable generic biomass limits to be defined. However, determination of suitable limits of detectable difference and related thresholds, with respect to population changes in the EEC, are unlikely to be acceptable without extensive corroborative evidence being provided on change in the extent of potential spawning areas, identified through field studies. This will require discussion and agreement within the TWG, before trial application as part of the regional monitoring programme.

Agreement on the definition of suitable spawning grounds and their identification will also be agreed through discussion with CEFAS in the TWG.

Determination of thresholds will be worked towards in both the short and long term, with respect to the listed variables in **Table 2**.

Table 2 Potential thresholds with respect to ecological issues

	Thresholds will be available for discussion in the:	
Relating to:	**Short-term (3 years)**	**Long-term (6 years)**
Regional Monitoring	Benthic species numbers. Benthic community Evenness values. Benthic community Shannon Weiner Diversity index. Corresponding impact zones and benthic (Hamon grab samples) clusters derived from PRIMER.	Corresponding impact zones and benthic (Epibenthic 2m beam trawl samples) clusters derived from PRIMER. Clustering of benthic sites (Hamon Grab and Epibenthic Trawl) related to dredging factors. Biotope or habitat area or boundary. Changes to the principal species of biotopes. Biomass of Herring larvae.
Licence Specific	Benthic species numbers.. Benthic community Evenness values. Benthic community Shannon Weiner Diversity index. Corresponding impact zones and benthic (Hamon grab samples) clusters derived from PRIMER.	Clustering of benthic sites (Hamon Grab) related to dredging factors. Biotope or habitat area or boundary. Changes to the principal species of biotopes. Scallop populations change.

Example of sample gathered during regional 2m beam trawl survey, 2005.

4.4. Survey Methods

Consideration and constraints for all surveys, ecological and physical, are described in **Section 3**.

4.4.1. Sampling techniques and survey arrays

The survey techniques summarised below will be described in detail in the standard operation procedures given in **Annex 3**.

The following principal survey techniques and equipment are recommended:

- **For the survey of seabed sediments – Grab survey.**
- **For the sampling of infauna and small sessile epifauna – 0.1m^2 Hamon grab sampling.**
- **For sampling small species of sessile and vagile epifauna and small fish species – 2m epibenthic beam trawl.**
- **For sampling larger vagile and sessile epifauna and adult and juvenile fish species – commercial 4m beam trawl with CEFAS recommended adaptation.**
- **For scallop post year class 2 – 2m epibenthic beam trawl, 4m beam trawl and a Newhaven design scallop dredge.**
- **For larger and characteristic sessile invertebrates on hard ground – drop down video system.**
- **For biotope and habitat definition – drop down video and sidescan sonar.**

The standard operating procedures given in the Regional Monitoring Blueprint should currently be considered as working methods. These may be refined during the life of the monitoring programme although the essential structure and composite studies will not change.

The following sections summarise the survey techniques and sampling arrays required.

4.4.2. Survey Array for Benthic Infauna and Epifauna using the Hamon Grab

The Hamon Grab sampling strategy has been based on two alternative methods of detecting impacts and change within the regional area. These alternative methods relate to the type of data analysis employed, specifically:

- **Multivariate analyses based on PRIMER.**
- **Univariate testing methods.**

To account for both the requirements of the multivariate methods and the univariate methods an initial survey design has been established, which once analysed using both techniques will demonstrate the relative value of each method and will allow an informed decision to be made on the extent of further sampling.

The BACI principle will be employed throughout, with Primary Impact Zones (PIZ) considered to be the resource areas that will be exploited. The Secondary Impact Zones (SIZ) are based around the PIZ and include those areas that may be affected by sediment deposition and seabed instability. The "control" areas, which are technically reference areas as they cannot be controlled, will be sited in similar sediment types and hydrodynamic conditions, but outside of any likely impacts.

At least two reference areas are required according to the BACI designs suggested by Underwood (1991) although in this instance more reference areas are required due to the natural variation in sediment type over the region. The reference areas are located in six locations which will cover the extent of sedimentary environments in the area. Each of these will be sampled every year. In addition to the reference sites, widely arrayed sampling sites will be surveyed to place the regional environmental sampling into a wider Eastern Channel context. These latter sites are considered to fall outside the influence of the dredging activity in the region.

Figure 6 illustrates the initial baseline array with **Figures 6a-f** illustrating individual licence blocks. The sampling array is stratified-random in principle, in order to enable a range of statistical analyses to be conducted. Some of the sites that have been identified are based on re-selection of a number of those sites previously sampled in the area (Posford Haskoning, 2002). These previous sites, however, were selected on the basis of a mixture of fixed grids and random arrays. The new sites have, therefore, included randomly selected sites from the previous arrays and new randomly selected sites. The stratifications within each licence block have been based on sampling broadly equivalent numbers within the PIZ and SIZ areas, although this is complicated by the inclusion of several dredge zones within some blocks.

Within the PIZ area, approximately 5 sites have been allocated to proposed actively dredged zones (ADZ), where known. Some of these ADZ sites, although not all of them, may be changed from year to year, depending on levels of dredging activity. Within the PIZ overall a minimum of 20 samples, including at least one 5 replicate sample will be collected. By combining adjacent blocks up to 40 samples per PIZ area may be collected (see **Table 4**).

Approximately equal numbers of samples will be collected from the SIZ areas, compared to the PIZ areas, based on the univariate statistical requirements of some of the theoretical frameworks. It should be noted that to achieve the required number of samples in some blocks the resource areas will be combined. Similarly where resource areas are adjacent the data may be combined where appropriate. This is clarified in **Table 4**.

The reference areas comprise 15 samples each including a single, 5 sample, replicate site. Site locations in the reference areas were also randomly selected.

The 15 context/no impact sample sites will be located around and between the main survey blocks (see **Figure 6**). However, due to the proximity of the median line of the Channel, no regional context samples will be collected south of the regional monitoring area.

Site and sample distribution has been designed to give a good degree of statistical validity to the different types of comparison possible, i.e. between different sampling times and between the different levels of likely impact, including un-impacted sites.

On the basis of the combinations indicated in **Table 4** it will be possible to address the individual licence condition requirements as well as an overall regional consideration.

The selection of the variables that can be employed in the investigation of potentially significant effects will be limited by the potential for that variable to demonstrate an effect if modified by the dredging activity (i.e some factors have such a high degree of variability it will be very difficult to be confident in any differences being statistically valid). This has been specified in the relevant theoretical frameworks, although other data will be considered as appropriate during the course of the monitoring activity.

It is proposed that during the initial years of the programme of study a range of analytical techniques are employed. These will include the following multivariate techniques, which are generally considered superior to the univariate comparison methods, in that they are able to demonstrate differences based on whole communities rather than derived statistics or single community variables. In this respect they are considerably more sensitive than univariate techniques. In addition to this the proposed analytical package, PRIMER, has a subroutine referred to as ANOSIM, which is the multivariate equivalent of ANOVA, in that it analyses variance in similarity. Similarity is the basis of the Bray and Curtis classification and MDS ordination techniques that are the principal outputs of PRIMER. No technique is currently available for calculating a relative power of the ANOSIM technique, although, as in all statistical analyses, the more samples included the more powerful the method in detecting population differences. The multivariate technique will also be employed in the definition of appropriate local reference sites in terms of similarity to impact sites as well as placing local variation within the context of wider spatial variation.

By providing two forms of sampling array, i.e widespread, spatially sensitive sampling and and replicate sampling in impact zones, both of the suggested analytical methods may be employed. Future monitoring activities will be based on the outcome of reviews of data analysis to be completed after the first two years post dredging surveys. It is proposed that a reduction in sampling effort may be achieved, at least for several intervening years, until a full re-sampling would be required. However, it should be stressed that the reference sites are sampled every year. It is proposed that the full range of sites are re-sampled, as those sampled in the baseline assessment, in year 5. **Table 7**, indicates the programme of benthic sampling recommended.

4.4.3. Epibenthic 2m Scientific Beam Trawl

The development of the epifaunal species survey array and site intensity has been based on the same principle as that of the benthic infauna, with approximately equivalent numbers in the PIZ and SIZ areas. Six reference areas will also be employed outside of the SIZ. The sampling array has been included in **Figure 7**. The total number of sampling sites has been targeted at 47 trawls of uniform distance (approx 5 minute duration tow or 500m). Single trawls will be conducted at each site. The technique affords a semi-quantitative assessment method for certain components of the epibenthic community, whereas other members of the community may be sufficiently well sampled to provide fully quantitative assessment. The target fauna are the small vagile epibenthic species, the sessile invertebrate epifauna and small fish species.

The primary analytical tool with respect to the data collected using this method, will be multivariate analysis which is able to demonstrate trends through consideration of the whole community at each site sampled. Comparison within individual licence blocks will not be possible, using univariate statistics to demonstrate potential differences with any degree of confidence, until several years data have been accumulated. ANOVA will be applicable to determine sources of variance between the different levels of theoretical impact over several years.

It is anticipated that catches of scallop (*Pecten* and *Aequipecten*) obtained during these surveys will contribute to the studies using more specialist equipment.

Epibenthic 2m Beam Trawl sampling is also summarised in **Tables 4, 6, and 7** to indicate both quantity and timescale.

4.4.4. Epibenthic 4m Beam Trawl

The theory behind the survey array is to demonstrate broad trends over the regional area with the potential to develop hypotheses and thresholds with respect to the region and for individual licence blocks where possible. The sampling sites are therefore distributed over the whole region with the emphasis on an even distribution with respect to relative area of the PIZs and SIZs.

The distribution of these sites is illustrated in **Figure 8**. 45 sites have been allocated, which should be sampled using 15 minute tows. Single samples should be collected at each site, including the areas outside of potential impact. Trawling sites will remain fixed year to year and the sampling should be conducted in the autumn of each year.

The target species will be the larger mobile epibenthic species, a selection of sessile epibenthic species and demersal fish species (see **Annex 3** EMSOP v0.3 071005). Based on the number of trawls it is likely that only spatially aggregated metrics for certain fish and shellfish species will be possible and these may include consideration of data from individual licence blocks.

Tables 4, 6, and 7 comprise a summary of sample numbers and timing.

4.4.5. Scallop Dredging

The scallop dredging survey should be run concurrent with the 4m beam trawling, both of which are commercially conducted methods. Sampling should be conducted using purpose built sampling gear, based on the "Newhaven" dredge. The number and location of the sites will be the same as those for the beam trawls as indicated in **Figure 8**. Dredge sites should remain fixed year to year and the sampling should be at the same time each year. Based on the number of sites it is likely that only spatially aggregated metrics for scallop will be possible and investigation of data from individual licence blocks will be considered in this respect.

It is possible that certain sites may be deleted and replaced with more targeted sampling sites subsequent to the initial benthic grabbing survey and discussion with local fishermen. This would occur soon after the completion of the benthic survey and before the first year of the scallop dredging.

Tables 4, 6, and 7 comprise a summary of sample numbers and timing.

4.4.6. Acoustic Survey and Video Array

Both acoustic (sidescan sonar) and video techniques will be deployed with the primary purpose of identifying habitat types that are of potential conservation importance. A secondary purpose of the array will be to prevent potentially damaging survey techniques from being deployed in sensitive areas.

The current level of knowledge with respect to habitats or biotopes that are of conservation importance in the Eastern English Channel is not complete. **Figure 5** illustrates the regions currently considered by JNCC to support habitats of potential interest. A review of individual licence ground benthic studies and the REA indicates that the most likely hard grounds are in the south west of the region where they may constitute reef features.

This has been confirmed to some extent by a study undertaken by Gardline (2003) which investigated seabed character with respect to Herring spawning potential. This identified areas of hard ground to the extreme south west of the region, which supported diverse epifaunal communities including dense brittle star beds. Additional potential hard ground areas have been identified in some of the other licence blocks, through the definition of "sub-crop" features. These areas are evident in 461, 475, 473 and 474.

Five levels of activity will be adopted to investigate if the seabed is likely to support hard ground, reef structures, biogenic reefs and other areas of potential conservation interest.

1. A region wide survey will be completed using video attached to the Hamon grab with at least one image of the seabed captured at each site. This will assist in the interpretation of the benthic grab survey and will allow particularly sensitive areas to be avoided in future stages of the grabbing study.

2. Side-scan sonar studies will be conducted in each of the licence blocks on the current permission areas as follows:

473, 474 and 475	Full permission areas plus 0.5km SW, 3km NE and 100m N and S of the boundaries of the permission areas.
458 and 464	Full permission areas plus 0.5km SW, 2km NE and 100m N and S of the boundaries of the permission areas.
461 and 477	Full permission areas plus a 500m margin around the outside of the permission area boundary.
478	Full permission area plus parallel strips 500m either side and extending 2km along the axis of the area.

3. In addition to these licence specific surveys it is proposed that one area to the south west of the region as indicated in **Figure 9** should also be surveyed with 100% coverage. This area is anticipated to be the most likely to contain hard ground or reef features, which may be at risk from the dredging activity. The output from the sidescan sonar studies will be used to identify the extents of possible hard grounds. These areas will require ground truthing using video and it is proposed that a minimum of 10 transects with 5 individual video recording locations area should be overlaid onto these habitats, taking into account probable boundaries between habitat/biotopes. The video transect length over which it will be required to identify possible annual change will initially be set at 1000m (i.e. video drops every 250m), with the possibility to relocate, reduce or extend these transects in subsequent years.

In order to place the variation that may occur within the above survey areas into a natural context a reference area will be selected to the south west of the region, provisionally indicated in **Figure 9**. The same level of sidescan study and video ground truthing will be adopted in this area.

4. Three further sidescan transects (one line only) will be run across the whole of the region as indicated in **Figure 9** to enable as many adjoining extraction sites to be linked as possible. Potential boundaries between habitat types and biotopes will be identified and any year to year change identified.

5. Video studies at sites currently believed to constitute hard ground due to the presence of subcrop. These will comprise multiple (x 5) static video drops over a drift distance of approximately 100m, at sites previously sampled using benthic grabs (see **Figure 10**).

4.4.7. Herring Spawning and Larval Assessment

The output from the sidescan and video studies will also contribute to the assessment of herring spawning areas, through seabed interpretation of spawning potential, following the methods described in Gardline (2003) and in consultation with CEFAS. However the basis for the full assessment of Herring spawning will be through analysis of the data provided by the ICES Herring assessment working group. The distribution and abundance of herring larvae are determined through regular plankton surveys in the eastern channel during winter. Data on the biomass of the larvae will be compiled for the area of the Eastern Channel dredging grounds specifically and compared with data from the wider eastern channel regional to determine if any local effects can be identified.

Tables 4, 6, and 7 indicate the programmes of work anticipated.

4.5. Benthic Sample Analysis

It is recommended that as part of the development of procedures, laboratory methods are developed that can be adhered to by all participants. Several procedures exist, which have been established by individual survey companies and laboratories, as well as organisations such as the EA and the DTLR/CEFAS (2002) protocols. As a basis for development the in-house procedures of Emu Limited will be employed initially. It is anticipated that these will be refined and agreed to in the same way that the field methods should be dealt with, i.e. through the means of inter-laboratory discussion and QA/QC checks. A draft version of an analysis protocol for biological samples taken in the ECR is provided (**Annex 3 EASOP**) for comment.

It is suggested that should several organisations conduct the sampling and sample analysis, that additional replicates are collected from the reference areas to enable inter-laboratory comparison to take place. In addition all laboratories undertaking analysis should be participants in the NMBAQC scheme and should include "own samples" from the EEC studies in the NMBAQC scheme.

Brittlestars have been noted at several sites within the ECR.

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