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JNCC Pressure Mapping Methodology

Physical damage (Reversible Change) - Habitat structure changes - removal of substratum (extraction)

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Summary

There are a growing number of human activities occurring within the marine environment. Concern over the possible impacts of these activities on the marine and coastal environment has led to the development of national, regional, and global commitments that aim to preserve, and, where possible, to mitigate impacts on marine environments (UKMMAS, 2010).

Different human activities exert a variety of pressures and these pressures will, in turn, have different levels of impact on habitats and species. To enable management of these impacts, we need to better understand how human activities and biodiversity interact spatially and temporally. We can then assess the sensitivity of the habitats and species that are exposed to these activities, and thus the associated pressures. When combined, exposure and sensitivity provide an indication of a habitat's 'vulnerability' to impacts.

To support this vulnerability assessment approach, JNCC are developing methods for creating geospatial pressure datasets for use at a regional and national scale. The term pressure is defined as '*The mechanism through which an anthropogenic activity has an effect on any part of the ecosystem'.* The nature of the pressure is determined by activity type, intensity and distribution. These datasets are created using a GIS to delineate their spatial extent and all activities that are known to exert the pressure are considered. In the UK one of the priority pressures on benthic habitats is 'Physical damage (Reversible Change) - Habitat structure changes - removal of substratum" hereafter referred to as 'extraction', which is described as the 'physical damage caused by selective extraction (e.g. by exploration and exploitation of living and non-living resources on seabed and subsoil)'.

Activities known to exert the pressure of extraction were evaluated in this pressure mapping method. Aggregate extraction and navigational dredging (both capital and maintenance) were identified as being the most widely recognised causes of the pressure and/or having the greatest spatial extent. To create the pressure dataset, the spatial extents of the two activities, together with intensity information where available, were mapped in a GIS and combined (using an R script) to produce yearly pressure footprints.

The production of the extraction geo-data layer from human activities datasets is based upon a range of assumptions and as such has a number of associated limitations. The method recommended within this report is specifically designed for use within UK wide and regional pressure assessments, rather than smaller-scale MPA assessments. Activities datasets are often subject to licence fees and data-sharing restrictions. As such, for navigational dredging, freely-available licence area data were used rather than actual area of the activity. These data also do not include intensity information (hours dredged).

For future work, it is recommended that intensity is considered further as a metric for the pressure maps in order to recognise areas where impact has the potential to be greater than others. Additionally, research on recovery rates of specific sediment types in different regions of the UK (based on knowledge of natural environmental parameters) could be used to update yearly pressure layers where recovery may have occurred.

Contents

1 Introduction

1.1 Background

Marine pressures can be defined as ‘the mechanism through which an activity has an effect on any part of the ecosystem’. The nature of the pressure is determined by activity type, intensity and distribution (Robinson *et al* 2008). As such, pressure does not equate to impact in this context.

Concern over the possible impacts of anthropogenic pressures on the marine and coastal environment has led to the development of national, regional, and global commitments that aim to preserve, and, where possible, to mitigate impacts on marine environments (UKMMAS 2010). Of relevance to the UK is the Marine Strategy Framework Directive (MSFD 2008/56/EC) and the EC Habitats (92/43/EEC), which both require assessment of human activities within the marine environment. As such, determining the distribution and intensity of pressures is a key step in understanding the potential impacts of human activities.

An assessment of impact can be undertaken through a vulnerability assessment approach. Different human activities exert a variety of pressures and these pressures will, in turn, have different levels of impact on habitats and species. A vulnerability assessment essentially evaluates where, spatially, activities occur within the marine environment, and thus what level of ‘exposure’ marine habitats or species have to pressures associated with these activities. By ascertaining how sensitive each marine habitat and species is to these pressures it is then possible to predict their vulnerability: Exposure x Sensitivity = Vulnerability.

1.2 Pressures prioritisation

A prioritisation exercise was undertaken by JNCC to identify the relative importance of different pressures acting on benthic habitats in order to focus efforts on data collection and mapping for those pressures. This exercise reviewed a list of ranked pressures developed for Charting Progress 2 (CP2) (UKMMAS 2010), and compared this to other assessments of anthropogenic pressures (e.g. Scotland’s Marine Atlas and the 2010 OSPAR Quality Status Report (Baxter *et al* 2011; OSPAR 2010) to see if similar pressures were ranked in a comparable order. No evidence could be found to justify re-ranking the priority pressures, and as such the priority pressure list for seabed habitats at a UK scale is based on the CP2 assessment. In prioritising anthropogenic pressures on benthic habitats, consideration was given to their spatial extent, coincidence with features, and the intensity/significance of their effect on the features.

From this exercise, pressures were identified as high, medium, low and very low priority (JNCC 2011). The three highest priority pressures on seabed habitats were considered to be:

- Biological Pressures – “Removal of target species”
- Physical Damage – “Habitat structure changes - removal of substratum (extraction)”
- Physical Damage – “Habitat structure changes - abrasion & other physical damage”

Methodologies for pressures mapping are being developed for both of the physical damage high priority pressures. This report focuses on the pressure **“Habitat structure changes - removal of substratum” (hereafter referred to as “extraction”).**

1.3 Aims

The aim of this paper is to present a recommended method for the creation of a standard UK-wide geo-data layer using available data (currently from 2006-2015) to map the extent and spatial distribution of extraction on the seafloor from human activity. It is hoped that this method might be adopted as a common approach to aid comparison between studies in the future. Updates with more recent data can, and should, be made as and when new datasets become available.

The method presented can be used to map extraction pressure, but does not consider the relative vulnerability of seabed habitats to this pressure. Habitat type and associated sensitivity to extraction are not considered within this report. The geo-spatial pressure layer developed as a result of this method would need to be used in association with sensitivity and prevailing conditions information before any assessment of vulnerability is made. Moreover, the geo-data layer for extraction is one in a series of pressure layers, and may be used alongside these other pressure layers to support monitoring and assessment of impacts from a variety of marine activities.

2 Extraction pressure

2.1 Definition of extraction and potential impacts

This paper adopts the definition of the pressure ‘Physical damage (Reversible Change)’ provided by the Marine Strategy Framework Directive (MSFD, 2008/56/EC) and further developed by the OSPAR Intersessional Correspondence Group on Cumulative Effects (OSPAR 2011). ‘Physical damage (Reversible Change) - Habitat structure changes - removal of substratum” has been defined as:

“Unlike the "physical change" pressure type where there is a permanent change in sea bed type (e.g. sand to gravel, sediment to a hard artificial substratum) the "habitat structure change" pressure type relates to temporary and/or reversible change, e.g. from marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed remains similar to the pre-dredge structure and as such biological communities could re-colonise; or from navigation dredging to maintain channels where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed”.

Under this pressure definition, any change to habitat structure is temporary and reversible. As such, the residual substrate is assumed to be similar to the pre-dredge substrate and would support re-colonisation of benthic species. Removal of coarse sediment through mineral extraction and capital dredging where the substrate, post-activity, is a different habitat type are both dealt with under the “physical change (to another seabed type)” pressure.

Extraction results in the removal of seabed deposits together with associated benthic fauna. The majority of benthic macrofauna inhabit the upper most layers of sediment thus making them highly susceptible to damage from extraction (Hill *et al* 2011).

Extraction has been reported to result in suppression of species diversity, population density and biomass on a local scale, i.e. where the drag head has passed (e.g. Newell & Woodcock 2013; Boyd & Rees 2003), or in some cases almost total defaunation (Walker *et al* 2003, from Desprez 2000). However, extraction of sediment has variable effects on benthic communities depending on the intensity and frequency of disturbance and the environmental setting in which it occurs. Any impact on benthic faunal communities is likely to be influenced by the natural environmental conditions in the area, with higher energy environments likely to recover more quickly (Foden *et al* 2009; Hill *et al* 2011).

Impacts from changes in sediment type are now mitigated for through aggregate extraction licences where it is detailed in the MMO's model condition document that '*the Licence Holder must ensure that upon cessation of dredging the substrate must continue to be sediment of a similar grade to the conditions that existed before dredging commenced with due allowance being made for natural sediment movements and natural variability'* (Walker *et al* 2013). With mitigation measures in place to maintain sediment of a similar grade in areas of extraction, it is likely that aggregate areas could recover more quickly.

2.2 Feature sensitivity and exposure to extraction

A feature's sensitivity to a pressure is measured in accordance with a pre-defined benchmark. The use of a benchmark ensures that the sensitivities of different species or communities are assessed with respect to the same level of change or perturbation (MarLIN n.d.). For extraction, the benchmark is defined as "*Extraction of substratum to 30cm (where substratum includes sediments and soft rocks but excludes hard bedrock). The benchmark is based on a single event that removes sediment material to the depth of 30cm and that exposes sediments/substrate of the same type"* (Tillin & Tyler-Walters 2010).

2.3 Relationships between activities and pressures

In order to understand how activities exert pressures on the marine environment, it is first necessary to consider which activities contribute to a given pressure. To identify the links between activities and the pressures they exert, a matrix has been created (JNCC 2013). This matrix uses the standardised list of pressures (OSPAR 2011) and a corresponding standardised list of activities to be considered (JNCC 2014) and was based on a review by JNCC of the five most significant pressure/activity matrices (Annex I). This combined pressures-activities matrix was used to identify the activities for inclusion within this report (see section 2.4).

The scale at which any geo-data pressure layer will be used also helps to determine which activities data are appropriate to include. For instance, for regional and national (i.e. broad-scale, regional sea, UK-wide) assessments, the contribution of some activities to the overall pressure footprint will be negligible and may compromise the use of other information (e.g. measures of intensity or frequency), may complicate the generation of pressure-data layers, or may limit the operational application in assessments. Under these circumstances, it is recommended that the activities used to generate the extraction layer be prioritised to use only those that are of greatest importance in terms of spatial footprint. In contrast, at smaller spatial scales, e.g. within Marine Protected Areas, activities with a smaller footprint will likely have a larger effect on any overall assessment of impact and may need to be considered within smaller scale geo-data pressure layer development.

2.4 Activities to include in the pressure layer

The combined pressures-activities matrix (JNCC 2013) identified 19 activities associated with extraction. For the purposes of this report only those activities that were considered to be the most widely recognised and/or the most spatially extensive causes of extraction were taken forward for mapping. In Annex II we reviewed studies which identified links between activities and the extraction pressure. The activities that were identified as having a link in all studies were considered further in this method.

These activities were chosen by undertaking a review of the five studies that were used to create the combined pressures-activities matrix (Annex I: A description of the studies considered within the combined JNCC pressure-activities matrix), and ranking the percentage of times that the pressure-activity link was made across each of these studies (Annex II: A prioritised list of activities associated with extraction).

Two activities were subsequently removed from the final list: Coastal defence and land claim protection (beach replenishment) as this was considered to duplicate the navigational dredging and aggregates pressures[1], and coastal quarrying which was considered to primarily be a terrestrial pressure. The key activities that are therefore included within this method are listed in Table 1.

Table 1. Activities considered within the method to produce an extraction geo-data layer. These activities are described fully in sections 2.4.1 and 2.4.2.

Activity		**Definition**
Aggregate extraction		Dredging of aggregate materials (sand, gravel and crushed rock) for use in the construction industry and for coastal protection.
Navigational dredging	Capital dredging	Removal of substratum to create new or to deepen existing harbour facilities.
	Maintenance dredging	Removal of substratum to deepen or maintain navigable waterways or channels

2.4.1 Aggregate extraction

The UK is the one of world's largest producers of marine aggregates (Foden *et al* 2009) and approximately 20% of the sand and gravel used in England and Wales is supplied by the marine aggregates industry (TCE & BMAPA 2014). In 2014, a total of 16.94 million tonnes of sand and gravel were dredged from areas totalling 85.66km^2 (total dredge footprint, representing 11.80% of the licensed area) within The Crown Estate licensed areas in England and Wales (TCE & BMAPA 2015).

At a UK-scale, marine aggregate dredging is more spatially extensive than other activities exerting an extraction pressure (Eastwood *et al* 2007; Foden *et al* 2009; Stelzenmuller *et al* 2010), although the area of seabed exposed to extraction is very small compared to the UK seabed as a whole. For comparison, the area of UK seabed that was exposed to benthic fishing in 2007 was approximately 52.20% whilst the area exposed to aggregate dredging in 2007 was 0.05% (Foden 2011).

However, whilst the spatial footprint of the activity may be small at the UK-scale, activities causing extraction (not just limited to aggregates) may have a more significant impact when considered per habitat or feature or at the scale of individual marine protected areas, particularly as the types of habitat targeted by this pressure are limited to sands and gravels, and in the case of aggregate extraction, deposits of sands and gravels with sufficient volume. These deposits are concentrated in particular regional seas, e.g. Eastern English Channel, Celtic Sea (mainly around the Bristol Channel), Southern North Sea and a small

[1] The materials used in coastal defence and land claim are largely obtained from either navigational dredging and/or aggregate extraction and, as such, extraction from beach replenishment was considered to be already covered by these activities.

amount in the Irish Sea (Highley *et al* 2007). As such, cumulative impacts could be more significant in a regional or habitat context (Tillin *et al* 2011).

It should also be kept in mind that activities that exert extraction pressure are not uniformly distributed across a given area (Newell & Woodcock 2013). Distribution of activity often varies even within a licence area. For example, in 2014 aggregate dredging took place within just 11.80% of the total licensed area (85.66km^2 of a licence area of 726.00km^2) (TCE & BMAPA 2015).

2.4.2 Navigational dredging

Many ports and harbours require dredging on a regular basis to maintain shipping access to entrances and basins. Larger one-off dredging may also be required as part of the development of navigational channels or construction projects. In the UK, 25-50 million tonnes (wet weight) of sediment are dredged for disposal each year (Defra 2012). Navigational dredging can be split into two types:

- **Capital dredging** is undertaken to create or deepen navigational channel, berths or trenches or to remove material during construction projects. It involves the removal of sediments that have been deposited over many years (consolidated sediments). The name of this type of dredging derives from the implications that the work requires the payment of a single capital sum.

- **Maintenance dredging** is undertaken regularly to maintain access to shipping channels, berths and other areas at their designated depths. It involves removing sediments that are recently deposited, such as mud, sand and gravel. Maintenance dredging may vary from an almost continuous activity throughout the year to an infrequent activity occurring only once every few years. For the purposes of marine licensing, the Marine Management Organisation (MMO) classify maintenance dredging as activity where the level of the seabed to be achieved by the proposed dredging is not lower than it has been at any time during the past ten years and there is evidence that dredging has previously been undertaken to that level (or lower) during that period.

Management and licensing of aggregate dredging and navigational dredging are discussed further in section 4.1.

3 Existing methodologies to map extraction pressure

There have been a number of previous attempts to map extraction, often as part of wider assessments of the cumulative impacts of anthropogenic pressures on the marine environment. This review presents key studies in which marine extraction has been mapped and briefly discusses the complexities associated with mapping this pressure (Table 2). Most of these key studies have come from published peer-reviewed papers, but grey literature also provides a source of studies. In particular, ‘Area Involved’ reports from the Crown Estate (TCE) and British Marine Aggregates Producers Association (BMAPA) contain summary information on TCE area of seabed licensed, dredged and surrendered each year based on GIS data and Electronic Monitoring System (EMS) data, and include regional charts to show the extent and intensity of aggregate dredging operations, as well as a review of cumulative dredge footprints currently undertaken over a 15 year period (TCE & BMAPA 2014, 2015).

With the exception of Korpinen *et al* (2012), all of the studies reviewed only considered marine aggregate extraction when mapping the activities associated with extraction pressure. This was partly due to data on other potential activities, such as navigational dredging, not being available for use. In addition, aggregate extraction is the most widely researched and well-understood activity causing extraction pressure. The 'Area Involved' reports are industry-specific for aggregate dredging only.

In their attempt to quantify the magnitude and distribution of cumulative impacts of anthropogenic pressures within the Baltic Sea, Korpinen *et al* (2012) incorporated additional data on both capital and maintenance dredging data within their pressure score for extraction. Both Foden *et al* (2009, 2011) and Anderson *et al* (2013) recognised the contribution of navigational dredging to extraction; however, neither included this activity within their analysis due to the lack of suitable data.

It should also be noted that the geographical scales of these studies differed as follows:

- England and Wales (Eastwood *et al* 2007; Stelzenmuller *et al* 2010; Foden *et al* 2011);
- England only (TCE & BMAPA 2015);
- Baltic Sea (Korpinen *et al* 2012); and
- Eastern North Sea (Anderson *et al* 2013).

3.1 Selected activity data layers

The majority of the studies considered within this review used Electronic Monitoring System (EMS) data, obtained from TCE, to represent the distribution and intensity of extraction (Eastwood *et al* 2007; Foden *et al* 2009, 2011; Anderson *et al* 2013; TCE & BMAPA 2015). Since 1993, all UK aggregate dredging vessels have been monitored electronically by TCE using an EMS. When aggregate dredging equipment is deployed, this system provides a secure readout of the vessel location, and whether it is dredging, every 30 seconds. When EMS datasets are supplied to JNCC these vessel locations are spatially aggregated into 50 x 50m blocks and categorised into three intensity categories based on the number of hours dredged (TCE 2009).

If EMS data are not available there are alternative approaches for mapping aggregate extraction. One such approach adopted by Anderson *et al* (2013), was to use data on permitted licence areas to derive the spatial footprint of extraction. This is a more simplistic method that, due to the ease with which information relating to licence boundaries can be accessed, is often easier to implement. However, activity is never uniform within a licence area and as such this method will inevitably result in a large overestimate of extraction. Another approach taken by Korpinen *et al* (2012) was to assign information pertaining to the quantity of material dredged (tonnes) to point data defining the location of dredge activities (obtained from dredge companies and responsible authorities within each country). Again this is a more simplistic approach; however, in contrast to the Anderson *et al* (2013) method described above, the use of point data is likely to underestimate the extraction as it does not account for the full spatial extent of contributing activities.

Both the Korpinen *et al* (2012) and Anderson *et al* (2013) assessments of human uses and pressures spanned multiple countries. Anderson *et al* (2013) highlighted that detailed data was often not available for all of the countries included within their study and that in order for datasets from different countries to be comparable, national datasets often had to be generalised to a "greatest common denominator". This is potentially another reason why licence area and point information were chosen over EMS in these studies.

3.2 Footprint versus intensity

In many of the studies, information relating to intensity (i.e. number of hours dredged) was removed when combining extraction information with other pressure geo-data layers. Both Eastwood *et al* (2007) and Foden *et al* (2009 & 2011) only used the spatial extent or "footprint" of EMS data within their wider cumulative assessments of pressures. Reasons for omitting intensity information included, i) a lack of suitable data for pressures and ii) complications associated with deriving common metrics capable of expressing intensity across all pressures types. This indicates that there is more evidence available for marine aggregate dredging than other types of dredging.

Three of the six studies reviewed incorporated intensity information within their pressure assessments (Stelzenmuller *et al* 2010; Korpinen *et al* 2012; TCE & BMAPA 2015). Stelzenmuller *et al* (2010) developed a geospatial modelling framework in order to quantify the cumulative impacts of human pressures on the marine environment. Within this model the proportion of a grid cell impacted by extraction was calculated using a summary of the average dredging activity (hours per 50 x 50m cell) derived from EMS data. In order to resolve the issue of combining pressure layers that had different units, measures and levels of generalisation, Stelzenmuller *et al* (2010) used 'fuzzy set theory' and a membership function to standardise each raster cell of the layer to a measure of the possibility of belonging to the entire set along a continuous scale of 0 to 1.

In an attempt to quantify the magnitude and distribution of cumulative impacts of anthropogenic induced pressures within the Baltic Sea, Korpinen *et al* (2012) calculated an impact index value. This followed a method originally defined by Halpern *et al* (2008), in which the intensity value of each pressure is log-transformed and normalised on a scale between 0 and 1. For extraction, a value was attributed to each point location based on the quantity of material dredged (tonnes) per km^2, averaged from regional data. The quantity of dredged material was then summed per cell when associated with the index grid.

In the Area Involved Report (TCE & BMAPA 2015) EMS data were used so intensity of dredging could be calculated. This was simple metric of how long areas had been dredged for over an annual period: high – >1 hour and 15 minutes, medium – 15 minutes to 1 hour and 15 minutes, and low – between >0 and 15 minutes.

3.3 Summary

There are a number of existing methods for mapping extraction that differ in their approach to both activities considered and data included. The decision as to which method to follow will depend upon a number of factors including:

- i) the objective of the study;
- ii) the scale of interest; and
- iii) the availability of data.

Considering the findings of this review, this paper recommends a method for the creation of a standard UK-wide extraction geo-data layer with the purpose of aiding the provision of advice in relation to both monitoring and assessment of the state of the marine environment.

Table 2 – An overview of existing methods to map extraction.

Reference	Study Aim	Location	Activities Considered	Data Type Selected	Temporal Extent	Intensity Considered
Eastwood *et al* 2007	To describe and quantify the major sources of direct physical pressure from human activities on seabed environments in UK waters	England and Wales (regional sea reporting areas defined by Defra)	Aggregate Extraction	EMS	2004	No – spatial footprint only
Stelzenmuller *et al* 2010	To quantify the cumulative impacts of human pressures on the marine environment using a geospatial model framework	England and Wales (regional sea reporting areas defined by Defra)	Aggregate Extraction	EMS	2001-2007	Yes – fuzzy set theory was used to standardise each raster cell along a continuous scale from 0-1
Foden *et al* 2011 (also see Foden *et al* 2009)	To develop a method for evaluating the impact of several human activities that constitute four direct pressures on the UK (England and Wales) seabed community: smothering, abrasion, obstruction (sealing), and extraction and to examine whether cumulative effects are of spatial or temporal concern in UK waters.	England and Wales (regional sea reporting areas defined by Defra)	Aggregate Extraction	EMS	2007	No – spatial footprint only
Korpinen *et al* 2012 (also see HELCOM 2010)	To quantify the magnitude and distribution of cumulative impacts of anthropogenic pressures for the Baltic Sea.	The Baltic Sea	Aggregate Extraction & Navigational Dredging	Point data defining the location of dredge activities	2003-2007	Yes – A value was attributed based on quantity of material dredged (tonnes).
Anderson *et al* 2013	To produce spatially explicit “human impact indices” for pressures in the eastern North Sea.	Eastern North Sea (Demark, Germany, Sweden & Norway)	Aggregate Extraction	Permitted licence areas	2011	No - spatial footprint only
TCE & BMAPA 2015	To calculate the area affected by aggregate dredging	UK waters	Aggregate Extraction	EMS	2014	Yes – intensity was considered based on time spent dredging

4 Development of a method for creating an extraction pressure layer

In order to develop the extraction pressure mapping method and data layer, the following steps were taken:

- review of available data types for aggregate dredging and navigational dredging activities;
- development of R script to combine data; and
- development of pressure maps.

The analysis was conducted using R (R Core Team, 2012) and ESRI ArcGIS 10.1 on spatial data within the UK Continental Shelf (UKCS) designated area for 2013.

A summary of the proposed extraction pressure mapping method is provided in Section 5.

4.1 Data availability

This section presents the recommended data available to use for the creation of a UK-wide extraction geo-data layer.

4.1.1 Aggregate Extraction

4.1.1.1 England & Wales

The Crown Estate (TCE) is one of the largest property owners in the United Kingdom and its holdings include the non-hydrocarbon mineral rights of the UK Continental Shelf (UKCS). To extract marine minerals from an area of seabed, a production agreement from TCE and a marine licence from the relevant national marine regulator must be in place. Within English and Welsh waters there are currently around 70 production licences in operation. Information relating to these licences is held by TCE and can be requested in a number of different formats (Table 3).

Datasets depicting the location of marine aggregate exploration, application and licence areas issued on TCE-owned seabed are freely downloadable from the TCE website[2]. These shapefiles provide boundary information defining the areas in which aggregate extraction can occur.

Aggregate extraction is, however, not uniform within these areas. The specific sub-sites within licence areas where aggregate extraction activity is focused at any particular time are called Active Dredge Zones (ADZs). GIS data layers that define the spatial location of the ADZs and their associated attributes (volume of material extracted per year, number of visits per year) are not currently freely available due to commercial data sensitivities; however access to these data may be granted upon request.

[2] http://www.thecrownestate.co.uk/energy-and-infrastructure/downloads/maps-and-gis-data/

EMS data (as described in section 3) can be used to give a detailed picture of the amount of dredging occurring in different licensed areas and regions of the UK (TCE 2009), including amount of time dredged (split into categories of annual dredging duration). Raw EMS data are not currently freely available due to commercial data sensitivities, although access may be granted on request. However, summary data within reports (not available as spatial data) are published through the Area Involved reports (see section 3) which are freely available. Out of the listed datasets (Table 3) it is **the footprint of the marine aggregate EMS data** (both annually and for multiple years with time dredged) that is recommended in this method for inclusion within the extraction geo-data layer, to represent the aggregate extraction activity.

If EMS data are unavailable it is recommended that the user make use of TCE marine aggregate licence areas to inform the spatial location of aggregate extraction within the UKCS. However, when interpreting these data it is important to remember that aggregate extraction is not uniform within these areas, occurring only within a small proportion of the licence areas (ADZs); the use of licence areas will overestimate the footprint.

Table 3. Existing datasets that show the spatial location of aggregate extraction in English and Welsh waters.

Resource Title	**Resource Abstract**	**Data Format**	**Temporal Extent**	**Dredge Metric**	**Availability**
Marine Aggregate Option Areas	Location of current Marine Aggregate Option Areas (areas for which applications can be submitted) issued on The Crown Estate owned seabed	Geospatial (vector polygon)	Not relevant - aggregate areas are subject to relicensing or expiry, as such this data layer is regularly updated	None	Freely available from The Crown Estate website
Marine Aggregate Application Areas	Location of current Marine Aggregate Application Areas (areas for which applications have been submitted) being progressed on The Crown Estate owned seabed	Geospatial (vector polygon)	Not relevant - aggregate areas are subject to relicensing or expiry, as such this data layer is regularly updated	None	Freely available from The Crown Estate website
Marine Aggregate Licence Areas	Location of current Marine Aggregate Licence Areas (areas where a licence has been granted) issued on The Crown Estate owned seabed	Geospatial (vector polygon)	Not relevant - aggregate areas are subject to relicensing or expiry, as such this data layer is regularly updated	None	Freely available from The Crown Estate website
Marine Aggregate Active Dredge Zones	Spatial location and associated attribution of Active Dredge Zones	Geospatial (vector polygon)	Data is updated every six months	None	Available on request to TCE – fee may be required

Marine Aggregate EMS data	Location of all dredging recorded by the Electronic Monitoring Systems of The Crown Estate production licences on an annual basis	Geospatial-gridded (50m x 50m grid) polygon	Data provided on a yearly basis	Number of hours dredged within an ADZ per year	Available on request to TCE – fee may be required

4.1.1.2 Scotland

Historically, aggregate extraction has taken place at two sites in Scottish waters: the Firth of Forth and the Firth of Tay. There are, however, no active licences for aggregate extraction within Scottish waters and as such no data on aggregate extraction exists for use in a UK-wide geo-data layer.

4.1.1.3 Northern Ireland

Marine aggregate extraction does not currently occur within Northern Irish waters.

4.1.2 Navigational Dredging

4.1.2.1 England & Wales

Navigational dredging and the disposal of dredged material to sea are licensable activities within the UK under part 4 of the Marine and Coastal Access Act 2009. Previous to 2009, licensing for the deposit of substances or articles was required under the Food and Environment Protection Act. The Marine Management Organisation (MMO) license these activities for English inshore (within 12nm) and offshore (beyond 12nm) waters and Welsh offshore waters. Natural Resources Wales license these activities in Welsh inshore waters.

Records pertaining to licensable activities undertaken within English waters dating back to 2011 are held by the MMO within their Marine Case Management System (MCMS) and are accessible on the MMO Public Register. These records provide a source of information relating to historic marine anthropogenic activity, including capital and maintenance dredge disposal sites. From the MCMS database, the MMO have produced a set of GIS data layers defining the spatial location of marine licence areas and areas where dredged material has been disposed. The data layers are freely available online through the data.gov.uk website as 'Marine Licences and Applications' (Point, Polygon and Polyline). Older data, pre-2011, is also available from this website from MMO legacy FEPA[3] and Coast Protection Act 1949 (CPA[4]) consents, but only represents waste disposal sites, not licence areas.

There are, however, limitations to the MMO GIS data layers:

- Whilst the waste disposal sites for navigational dredging may often be in the local vicinity of the dredging itself, the footprint of the extraction pressure cannot be accurately delineated from these data as they only indicate the disposal area and not the dredged area.

[3] A FEPA licence was required for activities involving deposit of an article or substance below mean high water springs.
[4] A CPA consent was required for an activity to take place which may be detrimental to the safety of navigation.

- Information on the total quantity of waste licensed for disposal does not equate to the total amount dredged since much of the material will be disposed elsewhere (e.g. landfill).
- Within the licence area, different areas may be dredged at different times throughout the lifetime of the licence, and some areas may not require dredging at all. As the data does not differentiate between these aspects, the data will always over-represent the activity and thus the associated extraction pressure.

Records pertaining to licensable activities undertaken within Welsh waters dating back to 2011 are held by Natural Resources Wales (NRW) and are accessible on request from NRW after a licence of use has been signed. These records provide a source of information relating to capital and maintenance dredge disposal sites. NRW have produced a GIS data layer that defines the spatial location of areas licensed for navigational dredging. Older data, pre-2011, is also available from data.gov.uk from MMO legacy FEPA and Coast Protection Act 1949 (CPA) consents, but only represents waste disposal sites, not navigational dredging licence areas.

4.1.2.2 Scotland

All marine licences for activities occurring within Scottish waters go through the Marine Scotland (MS) Licensing Operations Team. MS therefore holds a large quantity of data in relation to human activities occurring within the Scottish marine environment.

A significant proportion of this information is publically available through the MS National Marine Plan interactive (NMPi) tool which is accessible through the Marine Scotland website[5]. Information on the spatial extent of dredge disposal sites can be obtained through this tool, and can be viewed using the NMPi tool. A dataset on the spatial location and extent of dredge extraction sites is currently being developed by Marine Scotland. At the time of producing the extraction geo-data layer, only 2014 dredge extraction site data were available for use in polygon format.

4.1.2.3 Northern Ireland

Inshore navigational dredging is licensed by the Department of Agriculture, Environment and Rural Affairs (DAERA). The MMO is responsible for marine licensing in Northern Ireland’s offshore (beyond 12nm) areas, but geo-spatial data on navigational dredging licence areas are not currently widely available for Northern Ireland. However, a request can be made direct to DAERA for digitised GI shapefiles.

4.1.2.4 Alternative datasets for UK waters

A slightly higher resolution dataset on maintained navigation channels for all UK waters is available under licence from the UKHO, who provide admiralty chart data in Electronic Navigational Chart (ENC) S-57 format under commercial or non-commercial licences with an associated fee. From this, dredged area vector data can be digitised in a GIS and extracted which provides an estimate of the footprint of dredged areas and associated attributes such as minimum and maximum depth value and quality of the sounding measurement of depth. However, this dataset also has limitations:

[5] http://www.gov.scot/Topics/marine/seamanagement/nmpihome).

- Many of the geospatial polygon layers overlap in extent, making it difficult to ascertain the true extent of navigational dredging.
- The data layer does not provide information on year of dredging and associated licences, and therefore it is unknown if these areas represent recent dredging sites, or historic dredging sites.

Higher resolution data on maintenance and capital dredging areas can be obtained from individual harbour authorities on request but each authority would need to be contacted individually and there is likely to be a fee to cover processing costs.

4.1.2.5 Conclusions

After a review of the data layers available on navigational dredging at a country-level (Table 4), and consideration of their limitations, JNCC recommend that the following are used:

- MMO Marine Licences and Applications polygons for English and Welsh offshore (past 12 nautical miles) waters;
- NRW licence area polygons for Welsh inshore (up to 12 nautical miles) waters;
- Marine Scotland 2014 dredge extraction polygons for Scottish waters, until more up-to-date data layers become available; and
- marine licence area polygons, digitised by DAERA, for Northern Ireland.

Data from harbour authorities or the UKHO could be used if higher resolution information is required, but would require a fee to be paid and a licence to be granted, and would not result in a product which JNCC could make freely available under an Open Government Licence.

Table 4. Existing datasets that show the spatial location of navigational dredging activity in UK waters

Resource Title	Resource Abstract	Data Format	Temporal Extent	Availability
MMO Marine Applications and Licences data	Spatial location of English and Welsh offshore (past 12 nautical miles) licence areas and areas where dredged material has been disposed	Geospatial (vector – point, polyline and polygon)	2011 – present (updated quarterly)	Freely available from data.gov.uk
Welsh inshore (up to 12 nautical miles) marine licence data	Spatial location of navigational dredging licences	Geospatial (vector – polygon)	2011 - present	Available from Natural Resources Wales under licence
MS National Marine Plan interactive tool	Spatial location of disposal sites in Scottish waters	Geospatial (vector – point and polygon)	2005 - 2012	Freely available from the National Marine Plan interactive website
MS dredge extraction data	Spatial location of dredge extraction areas in Scottish waters	Geospatial (vector – polygon)	2014 only	Freely available on request from Marine Scotland
Northern Ireland digitised licence areas	Estimated digitised extent of navigational dredged licence areas in Northern Ireland	Geospatial (vector – polygon)	2004 - 2015	Freely available on request from DAERA

UKHO dredged areas	Admiralty chart data showing spatial location of dredged areas in UK waters	ENC S-57 format – can be converted to vector (polygon) data	1978 - 2015 (some unknown)	Available from UKHO under commercial or non-commercial licences

5 Summary of recommended method to map extraction

The following method is recommended as a standard for the production of an extraction pressure geo-data layer in UK waters. In order to best represent the spatial extent and distribution of extraction, it is recommended that data on both navigational dredging and marine aggregate extraction be combined.

This method was designed using the R statistics system v.3.2.1 and Esri ArcGIS v.10.1 (Esri 2012) within the UK Continental Shelf (UKCS) designated area. A map showing the results of this method is presented in Figure 1. Although the method has been described in four phases (pre-processing, marine aggregate EMS data, navigational dredging data and union), all of the processes occurred within a single R script (Annex III: R Code).

5.1 Data preparation

Pre-processing of the data is vital to producing a reliable geo-data layer. In this instance it is important to ensure that the geographic projection and attribute headings are consistent between data layers in order to facilitate geo-processing. If the area of the seabed exposed to extraction needs to be calculated then the projected co-ordinate system 'Europe Albers Equal Area Conic' should be used[6]. Ideally, it is also recommended that the temporal range of interest is decided beforehand (not currently available for the navigational dredging data). This is to ensure that the aggregate EMS data and navigational dredging data span the same years.

5.2 Marine aggregate data

The data layer recommended for the spatial realisation of aggregate dredging is:

- Electronic Monitoring System (EMS) data. Provided by TCE on a 50m x 50m grid in shapefile (.shp file) format on a year by year basis with a 'dredge' attribute which refers to the amount of time spent dredging within each grid cell per year.

Each area of marine aggregate EMS data (50 x 50 m grid cells) per year has a category of intensity (hours dredged) associated with it:

- High: >1 hour 15 minutes
- Medium: 15 minutes – 1 hour 15 minutes
- Low: <15 minutes

It is recommended that the year attribute and dredge attribute are maintained. The intensity categories should be used within the analysis to assess levels of intensity of aggregate dredging per year. All other attribute information can be disregarded.

[6] Adjusted parallel 1 = 50.2 and parallel 2 = 58

5.3 Navigational dredging data

The data layers recommended for the spatial realisation of navigational dredging are:

- MMO licence areas data (English and Welsh offshore (>12nm) waters). Provided as a shapefile (.shp file) with marine licence attribute and start and completion date of licence.
- NRW licence areas data (Welsh inshore (≤12nm) waters). Provided as a shapefile with marine licence attribute and start and end date of licence.
- MS licence areas data (Scottish waters). Provided as a shapefile with marine licence, start and end date of licence and year attribute.
- DAERA licence areas data (Northern Irish waters). Provided as a shapefile with attributes on whether the dredging is capital or maintenance, year and marine licence.

If these data layers contain information on whether an area is used for capital or maintenance dredging this should be retained. It is recommended that only the dredge type is maintained, as the year represents a range for the licence area which cannot be linked to an exact year of dredging activity.

5.4 Union

The EMS, and recommended navigation dredging datasets were combined to create a UK wide extraction geo-data layer. This combined layer was created by combining spatial data frame objects in R using the rbind function in the maptools package.

For assessment, it is possible to select, analyse and visualise the spatial extent and distribution of extraction over several years at once or in singular years to assess frequency per reporting period (see Figure 1 for an example output). Precise temporal parameters are not recommended within this method as the time scales of interest will differ between project assessments. It is however recommended that, should temporal information on navigational dredging become available, the EMS and Navigational Dredging data span the same temporal range.

5.5 Data limitations/options

The method recommended within this report is specifically designed for use within UK wide and regional pressure assessments. At a more site-specific scale (e.g. Marine Protected Areas) it may be of benefit to quantify the magnitude, effort, intensity or frequency of exposure to extraction within a given area due to the smaller spatial scale of the assessment. For finer scale aggregate dredging data, the track taken by the dredging vessel at the level of individual pings (every 30 seconds) could be used which would increase information on trawling disturbance and seabed features.

When producing pressure layers at the site specific level it is therefore recommended that the ‘dredge’ attribute which refers to the amount of time spent dredging within each grid cell per year is retained. Other activities may also need to be considered for studies that are conducted at a finer spatial scale or undertaken per feature type.

Information on recovery of extraction sites is not taken into account within the pressure mapping method because recovery is incorporated within the sensitivity score of each habitat type (some habitats recover quicker than others) using the vulnerability assessment approach. However, there is scope to research recovery rates of specific sediment types in different regions of the UK (based on knowledge of natural environmental parameters) and to subsequently remove yearly extraction polygons for those years and sediment types/areas where recovery will have likely occurred.

5.6 Quality assurance

It is recommended that all extraction layers created following this process are quality assured to ensure that they accurately reflect the underlying raw data. Quality assurance steps should include:

- Ensuring that the geographic projection and attribute headings are consistent between data layers before combining.
- Checking spatial positioning of final shapefiles is correct.
- Checking the text within the attribute tables for typological errors.
- Checking known areas of overlap between EMS and navigational dredge area datasets to ensure that there are no duplicate shapefiles.
- Check shapefiles for topology errors and correct any errors found using either ArcMap's topology tools, or via the "Integrate" tool if there are multiple slivers.
- Use the ArcGIS tool "Check Geometry" to check shapefiles for geometry errors. If any errors are found use the ArcGIS tool "Repair Geometry".
- Completing MEDIN/INSPIRE compliant metadata for shapefiles.
- Conducting random spot checks throughout the process to ensure that outputs match the original data.

JNCC has an Evidence Quality Assurance policy (JNCC 2015), which along with an associated set of Evidence Quality Guidance Notes provide a standard for JNCC staff to follow to help ensure that the quality of JNCC scientific advice and evidence is fit for purpose. The development of this report and the extraction geo-data layer have followed the JNCC evidence quality assurance (EQA) process.

5.7 Limitations and assumptions

The production of an extraction geo-data layer from human activities datasets is based upon a range of assumptions and as such has a number of associated limitations.

5.7.1 Aggregate Extraction

EMS data represents the most spatially accurate information on the geographic location of aggregate dredging, however, under certain circumstances (e.g. when vessels undertake related activities such as pumping water), EMS data may contain readings which do not represent actual dredging activity. The data obtained from TCE has been cleaned to try and remove such readings from the dataset; however, it is possible that some of these records may still be present.

EMS data remains the intellectual property of TCE. Pre-approval is required from TCE before the raw data can be used for any reason and outputs created using this data (e.g. the extraction geo-data layer) must be credited to the TCE.

EMS data is produced on a yearly basis and data layers for different years are available for use. With further knowledge on recovery rates of specific sediment types, habitats may have recovered from aggregate dredging, and this should be considered when producing extraction maps.

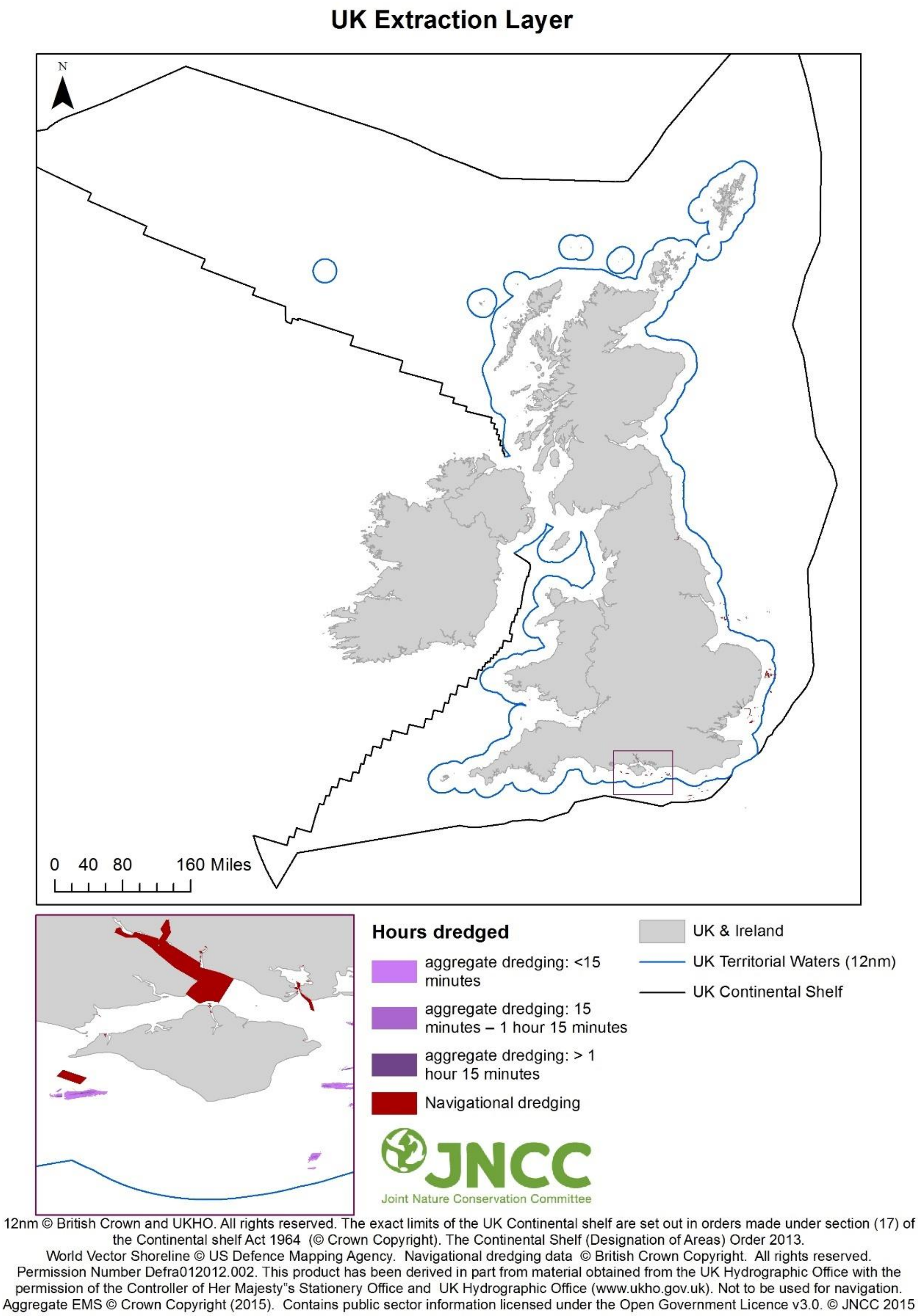

Figure 1. An example extraction map created through the combination of aggregate EMS and navigational dredging data.

5.7.2 Navigational dredging

The four navigational dredging datasets do not provide detail on the exact area of dredging as it is obtained from marine licences. Therefore, the exact spatial location and extent of extraction cannot be accurately delineated from these data. The overall confidence in the spatial location of navigational dredging is therefore not as high as that associated with aggregate EMS which automatically records vessel locations every 30 seconds. Furthermore, information on year or intensity (hours dredged) is not available for navigational dredging data which hinders the development of accurate yearly extraction layers.

5.8 Uses and next steps

The objective of this report is to provide a recommended and standardised method for the development of a pressure layer for extraction. JNCC intends to produce updated extraction layers every year using aggregates and navigational dredging data, which will be made available via the JNCC website (for download and through Web Services).

The extraction layer provides a range of uses including:

- development of the common MSFD indicator ‘BH3 - Extent of Physical damage to predominant and special habitats’;
- initial development of a cumulative effects assessment tool to support offshore MPA condition assessment and reporting requirements and provision of advice to industry on in-combination effects of industry projects;
- supporting the development of MPA management measures;
- development of UK benthic habitat monitoring options under MSFD; and
- supporting development of advice on operations for MPA conservation advice packages.

However, the layer can only currently represent the footprint of activities, and due to limitations on data and knowledge, does not represent intensity of all activities. Although hours dredged are mapped for EMS data, it is recommended that the data layers used in this analysis are updated if and when relevant new data becomes available.

For future work, it is recommended that intensity is considered further as a metric for the pressure maps in order to recognise areas where impact has the potential to be greater than others. Research on recovery rates of specific sediment types in different regions of the UK (based on knowledge of natural environmental parameters) could be used to subsequently remove yearly extraction polygons for those years and sediment types/areas where recovery will have likely occurred.

This work came about as part of a drive to improve efforts on data collection and mapping for pressures to support understanding the potential impacts of human activities. A method and data layer has also been created by JNCC for the pressure ‘Physical Damage – Habitat structure changes - abrasion & other physical damage’) (Church *et al, in press)*. Methods papers have also been prepared by Cefas for five additional pressures: Marine Litter (Jenkins 2014); Non-Indigenous Species (Breen & Murray 2014); Organic and Nutrient Enrichment (Koch *et al* 2014); Physical change (to another seabed type) and physical loss to land and freshwater (Goodsir & Koch 2014) and Siltation Rate Changes (Frost *et al* 2014).

In the longer term, it is hoped that UK-wide pressure layers for priority pressures will be produced to support longer term studies of impacts of human activities and monitoring and assessment obligations under national, European and international legislative instruments.

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7 Annex I: A description of the studies considered within the combined JNCC pressure-activities matrix

Project Title	Description	Reference
Business as Usual Projections of the Marine Environment, to inform the UK implementation of the Marine Strategy Framework Directive.	The Marine Strategy Framework Directive (MSFD) 'Business as Usual' (BAU) study uses Drivers-Pressures-Status-Impacts-Response (DPSIR) framework to identify how drivers and pressures change over time and how this may lead to changes in environmental state.	ABPMer 2012
MarLIN marine and coastal activities to environmental factors matrix	This list of maritime and coastal activities and environmental factors was derived from the Marine Conservation Handbook (Eno 1991) as amended by Cooke & McMath (2001) and discussion with the Marine Information Team (JNCC), and the MarLIN Biology & Sensitivity Key Information Sub-programme technical advisory group.	MarLIN 2003
Options for developing Ecosystem Based Management (ODEMM) linkage framework	The ODEMM linkage framework builds on the DPSIR approach (Driver-Pressure-State-Impact-Response) (EEA 1998), which systematically organises information to assess which management responses might help to reduce impacts on the state of the environment.	Koss *et al* 2011
SNH and JNCC Features, Activities, Sensitivities Tool (FEAST).	A pressures-activities matrix created by SNH and JNCC's Scottish MPA Project team. This matrix is based on the Natural England and JNCC matrix produced for the MCZ process. Refinements were made to some activity categories (most notably fishing) to reflect practices in Scotland. The matrix has been merged with the pressures-features matrix (also refined based on the original MB102 matrix) and has been published as an online interactive resource called FEAST (Features, Activities, Sensitivities Tool).	FeAST 2013
Natural England and JNCC simplified pressures activities matrix	A pressures-activities matrix produced by Natural England and JNCC for use in the designation of Marine Conservation Zones (MCZ).	JNCC unpublished

7. Annex II: A prioritised list of activities associated with extraction

Five studies were reviewed, between them containing a total of 19 activities associated with Extraction. For each activity, if a link to Extraction had been identified by the study, this was recorded. For those studies including a particular activity, the percentage of studies identifying a link between the activity and extraction pressure, was calculated. The activities that were identified as having a link in all studies (100%) were considered further in this study.

Activities	**No. of studies with activity included**	**% of studies with activity included, in which activity link to extraction identified**
Coastal defence & land claim protection (including beach replenishment)	5	100%
Extraction – sand & gravel (aggregates)	5	100%
Extraction – Navigational dredging (capital & maintenance)	5	100%
Extraction – Rock & mineral (coastal quarrying)	4	100%
Submarine cable & pipeline operations	5	60%
Extraction of genetic resources, e.g. bioprospecting & maerl (blue technology)	4	50%
Coastal docks, ports & marinas	4	50%
Renewable energy - tidal (excluding cables)	5	40%
Marine hydrocarbon extraction (excluding pipelines)	5	40%
Marine research activities (including physical sample & remote sensing)	4	25%
Power stations including nuclear	4	25%
Fishing – demersal trawling	5	20%
Fishing – dredging	5	20%
Harvesting – seaweed & other sea-based food (bird eggs, shellfish, *etc*)	5	20%
Extraction – water (abstraction)	5	20%
Renewable energy – wind (excluding cables)	5	20%
Renewable energy – wave (excluding cables)	5	20%
Coastal tourist sites (public beaches & resorts)	5	20%
Military - General	5	20%

9 Annex III: R Code

9.1 R code for the creation of the extraction pressure layers

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title: Adds navigational dredging layer to each yearly aggregate dredging layers

author: Graham French/Frankie Peckett edits

date: 2016-11-22

output:

  # rmdformats::readthedown:

  #   lightbox: true

  #   gallery: true

  #   highlight: tango

  #   number_sections: true

  #   fig_caption: true

  #   code_folding: show

  #   self_contained: true

  #   use_bookdown: true

  pdf_document:

  toc: true

toc_depth: 2

number_sections: true

highlight: tango

fontsize: 10pt

geometry: margin=2cm

---

  ```
This script merges each years aggregate dredging layer to the navigational dredging layer to produce a merged extraction layer for each year and a total extraction layer for all years. All layers are transformed to the custom albers projection

```

```{r markdown, echo = FALSE, purl = FALSE, warning = FALSE}

library(knitr)
```
```

opts_chunk$set(echo = TRUE, eval = FALSE, warning = FALSE, error = FALSE, comment = NA)

```

```{r tangle, echo = FALSE, eval = FALSE, purl = FALSE}

opts_chunk$set(echo = TRUE, eval = TRUE)

purl("extractionpressure_dissolve.Rmd", documentation = 1L)

```

Packages

The packages used in the R script are:

```{r packages, echo = TRUE, message = FALSE, warning = FALSE}

library(rgdal)

library(rgeos)

library(maptools)

library(dplyr)

library(stringr)

```

Environment

```{r environment, echo = TRUE}

rm(list = ls())

owd <- setwd(".")

#folderPath <- "D:\\R Data\\2016-17330 Extraction pressure layers\\layers 2016"

folderPath <- choose.dir(caption = "Choose folder containing dredging shape files")

setwd(folderPath)

dir.create(path = "Results", showWarnings = FALSE)

```

Functions

November 2015 extraction layer removed overlapping polygons using a multipart polygon intermediate and losing all attribute fields.

August 2016 extraction layer required Hours_dred attribute field to be retained so removal of overlapping polygons has been commented out and Hours_dred added for aggregate dredging layers (ID field also added to check Hours_dred correctly assigned to corresponding polygon). Navigational attribute field set as NULL

```{r formatNavigationLayer}

```
Formats navigation layer

@param nameNav string of navigational layer name

@param navId string of letters to use to append for ID to make each polygon ID unique

@return layer spatialPolygonDataFrame of formatted navigational layer

formatNavigationLayer <- function (nameNav, navId) {

  layer <- readOGR(".", nameNav)

  # layer <- gUnaryUnion(layer) # Create multipart polygon

  # layer <- sp::disaggregate(layer) # Split into singlepart polygons

  data <- data.frame (layer = rep("navigation", length(layer@polygons)),

                    year = rep(NA, length(layer@polygons)),

                    ID = rep(NA, length(layer@polygons)), # attribute field to retain

                    Hours_dred = rep(NA, length(layer@polygons))) # attribute field to retain

  # Update rownames to polygonID

  rownames(data) <- sapply(layer@polygons, function(x) str_c(navId, x@ID))

  # Update polygon id to polygonID

  layer <- spChFIDs(layer, sapply(layer@polygons, function(x) str_c(navId, x@ID)))

  layer <- SpatialPolygonsDataFrame(layer, data = as.data.frame(data))

  return(layer)

}
```

August 2016 extraction layer required Hours_dred attribute field to be retained so removal of overlapping polygons has been commented out and Hours_dred added for aggregate dredging layers (ID field also added to check Hours_dred correctly assigned to corresponding polygon). Navigational attribute filed set as NULL

Imports aggregate layer. Extracts year from layer name to add to year attribute field. Calls mergeLayers function to add to navigational layer

```{r formatAggregatesLayer}

# Formats aggregates layer

# @param nameAgg string of aggregates layer name

# @return calls merge layer for aggregates layer

formatAggregatesLayer <- function (nameAgg) {
```

```
  yearAgg <- str_extract(nameAgg, "[[:digit:]]+") # Get year from layer name (note extracts all digits)
  layerAgg <- readOGR(".", nameAgg)
  #layerAgg <- gUnaryUnion(layerAgg) # Create multipart polygon
  #layerAgg <- sp::disaggregate(layerAgg) # Split into singlepart polygons
  dataAgg <- data.frame (layer = rep("aggregate", length(layerAgg@polygons)),
                         year = rep(yearAgg, length(layerAgg@polygons)),
                         ID = layerAgg@data$ID, # attribute field to retain
                         Hours_dred = layerAgg@data$Hours_dred) # attribute field to retain
  # Update rownames to polygonID
  rownames(dataAgg) <- sapply(layerAgg@polygons, function(x) str_c("a", yearAgg, x@ID))
  # Update polygon id to polygonID
  layerAgg <- spChFIDs(layerAgg, sapply(layerAgg@polygons, function(x) str_c("a", yearAgg, x@ID)))
  layerAgg <- SpatialPolygonsDataFrame(layerAgg, data = as.data.frame(dataAgg))
  mergeLayers (nameAgg, layerAgg)
}
```

Merges aggregates and navigational layers. Adds aggregate layer to total extraction layer

```{r mergeLayers}
# Merge and output layers
# @param nameAgg string of aggregates layer name
# @param layerAgg spatialPolygonsDataFrame of aggregate layer
# @param navlayer spatialolygonsDataFrame of navigational layer
# @param projection proj4string of projection
# @return output of shape file of merged aggregate and navigational layers
# @return spatialPolygonDataFrame of total aggregate and navigational layers
mergeLayers <- function (nameAgg, layerAgg, navlayer = layerNavAll, projection = projectionAlbers) {

  # Check layers and transform to same CRS
  if (proj4string(navlayer) != proj4string (layerAgg)) {  # Check CRS
    layerAgg <- spTransform (layerAgg, CRS(proj4string(navlayer)))
    print (str_c(nameAgg, " layer: COORDINATE REFERENCE SYSTEM CONVERTED"))
```

 }

 # Merge layers together

 layer <- spRbind(navlayer, layerAgg) # Add spatialpolygondataframes

 layerAll <<- spRbind(layerAll, layerAgg)

 # Transform layer to albers projection

 layer <- spTransform(layer, CRS(projection)) # Transforms to custom albers

 # Export layer

 writeOGR(layer, ".\\Results" ,str_c("navigation_aggregate","_", nameAgg) ,driver = "ESRI Shapefile")

}

```

# Scripts

## Custom Albers projection

```{r projection}

projectionAlbers <- as.character("+proj=aea +lat_1=50.2 +lat_2=61.2 +lat_0=30 +lon_0=10 +x_0=0 +y_0=0 +ellps=intl +towgs84=-87,-98,-121,0,0,0,0 +units=m +no_defs") # Custom Albers projection

```

Get navigational aggregate layers

```{r getNavigationLayers}

layerNavE <- formatNavigationLayer("MMO_MCMS_Polygon_selection112016", navId="ne")

layerNavNI <- formatNavigationLayer("NI_navigational_dredging_wgs84", navId="ni")

layerNavS <- formatNavigationLayer("2014_dredge_extraction_joined_features_20161024", navId="ns")

layerNavW <- formatNavigationLayer("marine_Dredging_License_Applications_Polygons", navId="nw")

```

Format navigational aggregate layers

August 2016 extraction layer required Hours_dred attribute field to be retained so removal of overlapping polygons has been commented out and Hours_dred added for aggregate dredging layers (ID field also added to check Hours_dred correctly assigned to corresponding polygon). Navigational attribute filed set as NULL

```{r formatNavigationlayers}

# Check navigational CRS are the same and transform NI layer if not

if (proj4string(layerNavE) != proj4string(layerNavNI))

```
  layerNavNI <- spTransform (layerNavNI, CRS(proj4string(layerNavE)))

if (proj4string(layerNavE) != proj4string(layerNavS))

  layerNavS <- spTransform (layerNavS, CRS(proj4string(layerNavE)))

if (proj4string(layerNavE) != proj4string(layerNavW))

    layerNavW <- spTransform (layerNavW, CRS(proj4string(layerNavE)))

Merge navigational layers

layerNavAll <- rbind(layerNavE, layerNavNI, layerNavS, layerNavW) # Merge navigational spatialpolygondataframes

Dissolve new navigational layer

layerNavAll <- gUnaryUnion(layerNavAll) # Create multipart polygon

layerNavAll <- sp::disaggregate(layerNavAll) # Split into singlepart polygons

dataNavAll <- data.frame (layer = rep("navigation", length(layerNavAll@polygons)),

                          year = rep(NA, length(layerNavAll@polygons)),

                          ID = rep(NA, length(layerNavAll@polygons)), # attribute field to retain

                          Hours_dred = rep(NA, length(layerNavAll@polygons))) # attribute field to retain

Update rownames to polygonID

rownames(dataNavAll) <- sapply(layerNavAll@polygons, function(x) str_c("n", x@ID))

Update polygon id to polygonID

layerNavAll <- spChFIDs(layerNavAll, sapply(layerNavAll@polygons, function(x) str_c("n", x@ID)))

layerNavAll <- SpatialPolygonsDataFrame(layerNavAll, data = as.data.frame(dataNavAll))

Create total layer

layerAll <- layerNavAll
```

Get aggregate dredging layers

Need to update to aggregate layer names. Only digits allowed in the name are the year as this is extracted and add to an attribute field using regular expression

```{r getAggregateLayers}

# nameAgg <- c("y2006","y2007","y2008","y2009","y2010","y2011","y2012","y2013","y2014") # November 2015

nameAgg <- c("2006_dredging","2007_dredging","2008_dredging","2009_dredging","2010_dredging",
```

````
        "2011_dredging","2012_dredging","2013_dredging","2014_dredging","2015_dredging") #
August 2016

```

## Add aggregate dredging layers to navigational layer and export

```{r addAggregateLayers}

sapply(nameAgg, formatAggregatesLayer)

```

## Export total extraction layer

```{r extportTotalLayer}

layerAll <- spTransform(layerAll, CRS(projectionAlbers)) # Transforms to custom albers

writeOGR(layerAll, ".\\Results" , "navigation_aggregate_AllYears" ,driver="ESRI Shapefile")

```

## Tidy up

```{r tidyUp}

setwd(owd)

rm(list = ls())

```
````
````