Marine Management Organisation

Scoping of a robust approach to the assessment of co-existence of activities in marine plan areas

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Scoping of a Robust Approach to the Assessment of Co-existence of Activities in Marine Plan Areas

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Report prepared by: ABP Marine Environmental Research Ltd in association with eftec and Ichthys Marine Ecological Consulting Ltd

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Executive Summary

ABP Marine Environmental Research Ltd (ABPmer) in association with eftec and Ichthys Marine Ecological Consulting Ltd were commissioned by the Marine Management Organisation (MMO) to scope a robust and flexible co-existence assessment approach that can be applied to all sectors/activities identified in the Marine Policy Statement and is compatible across all functions in the MMO. This project should be viewed as a scoping report examining the feasibility of developing a comprehensive approach to the complex consideration of co-existence in the marine environment. The project sought to explore a comprehensive approach to co-existence assessment and to establish the current feasibility of developing such an approach that could incorporate physical, environmental, social and economic variables.

Co-existence is defined in the draft East marine plans as “where multiple development, activities or uses can exist alongside or close to each other in the same place and/or at the same time” (MMO, 2013a, p145). Co-existence is the main focus of this report and this includes co-location, considered to be a subset of co-existence defined as “where multiple developments (often structures), activities or uses co-exist in the same place by sharing the same footprint or area in the marine environment. ‘Footprint’ can include both the physical location of a development or activity, e.g. a built structure, and a wider area associated with the development or activity, e.g. a surrounding safety zone” (MMO, 2013a, p145).

MMO staff were consulted on their requirements for co-existence assessment across the relevant main functions of the MMO – marine planning, marine licensing, marine conservation and fisheries management. This involved detailed discussions about the nature of outputs, their likely use, the level of information required to inform such an approach and the type of decisions that the assessment would be intended to inform.

A conceptual understanding of the requirements for a co-existence assessment process informed the focus of a literature review to identify existing tools that might inform initial and/or detailed co-existence assessments. Based on the findings of the literature review there are no existing fit-for-purpose tools that provide all of the suggested functionality for a co-existence assessment approach for use within marine planning, marine licensing and marine conservation. However, there are a number of tools that might contribute to the implementation of a co-existence assessment process. The choice of tools will depend on the particular issues at hand and the availability of data.

Based on the outcomes of the consultation with MMO staff and the review of available tools, a framework for undertaking co-existence assessments and its potential application within marine planning, licensing and conservation enforcement is proposed (Section 4.1; Figure 4). Fisheries co-existence interests are better represented incorporated into assessments under the MMO’s other functions and therefore no separate process is required.

The framework is based around the potential interactions between human activities or between human activities and the natural environment and the associated economic, environmental and social impacts. It seeks to compare a ‘co-existence’ option with a ‘no co-existence’ option in order to establish the relative impact of co-existence. It is recognised that such assessments can be highly complex owing to the nature and number of potential interactions that need to be considered, but this level of detail is necessary to adequately understand the potential outcomes of the interactions in terms of their economic, social or environmental impacts.

A three stage process for co-existence assessment is proposed comprising:

- **Screening** – in this step, locations within which activities clearly cannot co-exist are identified (mainly applicable to marine planning)
- **Initial assessment** – a qualitative/semi-quantitative assessment of potential interactions between human activities or between human activities and the natural environment is undertaken using readily available information and simple assessment tools (mainly applicable to marine licensing and marine conservation, and a high level qualitative assessment only likely to be applicable to marine planning to identify strategic benefits where there is a strong need and likelihood of a positive co-existence decision that is supported by stakeholders)
- **Detailed assessment** – a detailed quantitative (monetised) assessment is undertaken building on the initial assessment and using existing and potentially novel collected data, using more complex assessment tools where appropriate (applicable to the regulatory and conservation management functions, and potentially applicable to marine planning in the long term).

Within marine planning, current limited information availability is likely to generally preclude the use of detailed assessments, and project/location specific assessments are unlikely to be feasible. Depending on available time scales it could be possible to collect additional data where this was deemed appropriate; however initial assessments would only be carried out where there is a strong requirement to support option development and appraisal, and plan policy development.

Within marine licensing, initial project specific assessments could be undertaken by developers at the screening/scoping stage and, where required, detailed project specific assessments could be prepared at the assessment stage of the pre-application phase. This would be driven by co-existence policies within the marine plans. High level guidance may be required to help ensure consistency and robustness of information submitted by applicants in response to co-existence policies.

Within the MMO’s marine conservation function, management measures for Marine Protected Areas (MPAs) could not be developed specifically as a means to encourage co-existence. However, the measures and byelaws could look to not unnecessarily preclude activities where they would not pose a significant risk to the sites/species. Both initial and detailed co-existence assessments could be required at the project level but this must be undertaken within the legal obligations the MMO has to ensure conservation objectives and the MPAs are not negatively affected by marine activities. In particular, detailed assessments are likely to be necessary to identify management measures for potentially required activities within the MPAs and the associated costs and benefits. This process is effectively being followed for the current conservation assessment processes being taken forward for commercial fishing activities affecting Natura 2000 sites and the process for identification of management measures within Marine Conservation Zones (MCZs).

The complexity of the assessments potentially requires a wide range of spatial and non-spatial data and information to characterise the interactions and impacts, particularly where it might be necessary to seek to value costs and benefits of 'co-existence' and 'no co-existence' options. The relative significance of some of the interactions and impacts varies at site level, which therefore requires a level of site specific data. Not all of the data and information that may be needed to inform co-existence assessments is readily available and the quality of information where it exists is variable.

Recommendations
The recommendations below support the application of co-existence assessment across MMO main functions and may be required should the MMO seek to fully develop the approach proposed in this report.

1. MMO fully develops and adopts a three stage co-existence assessment process comprising screening, initial assessment and detailed assessment, based around the concept of assessing the interactions and impacts between human activities or between human activities and the natural environment. The framework should seek to compare 'co-existence' and 'no co-existence' options using economic evaluation methods within an overall cost benefit framework to facilitate decision-making.
2. MMO defines the relevant mandatory protection zones and buffers applicable to the screening step, in agreement with the key stakeholders.
3. MMO initiates work to develop a series of interaction tables covering all of the economic sectors identified in the Marine Policy Statement with significant stakeholder input. These tables should identify the key interactions between activities, suggested methods for assessing the interactions, suggested information requirements to support application of the co-existence assessment methodology and also identify relevant existing information sources. The information requirements will vary depending on whether the co-existence assessment is being undertaken at the plan or project level.
4. Existing assessment tools should be used to inform initial assessments of the interactions between human activities and the natural environment and their associated impacts.
5. Social impacts should be assessed during the detailed assessment stage using the Social Impacts Taskforce framework at present as this provides strong linkages between the assessment of economic and social impacts.
6. MMO undertakes an initial trial application of the screening process within marine planning in the short term to evaluate a range of potential co-existence opportunities using available data.
7. A further trial application of the initial and/or detailed assessment (Recommendation 6) should be undertaken within marine planning in the long term to indicate whether there is likely to be sufficient information to identify

the relative importance of significant interactions at marine planning stage and thus help to inform location-specific co-existence policies.

8. MMO look to develop high level guidance on the way that co-existence issues could be taken account of by developers.
9. MMO maintains relevant spatial data layers in accordance with their existing data management practices.
10. MMO updates information on the costs of impacts and mitigation measures every two years.

1. Introduction

ABP Marine Environmental Research Ltd (ABPmer) in association with eftec and Ichthys Marine Ecological Consulting Ltd were commissioned by the Marine Management Organisation (MMO) to scope the potential to develop a robust and flexible co-existence assessment approach that can be applied to all sectors/activities identified in the Marine Policy Statement across all functions in the MMO. This project should be viewed as scoping report examining the feasibility of developing a fully comprehensive approach to the complex considerations of co-existence in the marine environment when environmental, social and economic aspects are incorporated. The project sought to explore the nature of such an approach to co-existence assessment and to establish the feasibility of developing such an approach. This report therefore discusses high level requirements MMO functions may place upon a co-existence framework and proposes a potential framework that could deliver these requirements if fully developed in the future.

Co-existence is defined in the draft East marine plans as “where multiple developments, activities or uses can exist alongside or close to each other in the same place and/or at the same time” (MMO, 2013a, p145). Co-existence is the main focus of this report and this includes co-location, which is considered to be a subset of co-existence, defined as “where multiple developments (often structures), activities or uses co-exist in the same place by sharing the same footprint or area in the marine environment. ‘Footprint’ can include both the physical location of a development or activity, e.g. a built structure, and a wider area associated with the development or activity, e.g. a surrounding safety zone” (MMO, 2013a, p145).

The UK Government Sustainable Development Strategy sets out the need for all Government policy to be in line with the principles of sustainable development (HMG, 2005). The principles of sustainable development for the marine area are expressed through the five high level marine objectives which take forward the UK vision for the marine environment of "clean, healthy, safe, productive and biologically diverse oceans and seas" (Defra, 2002, p3). These high level objectives are: (1) Achieving a sustainable marine economy; (2) Ensuring a strong healthy and just society; (3) Living within environmental limits; (4) Promoting good governance; and (5) Using sound science responsibly.

It is becoming increasingly important that space within the marine environment is utilised effectively to ensure activities can be undertaken in a sustainable manner with minimal conflict between users. The Marine Policy Statement indicates that, “The Marine Plan should identify areas of constraint and locations where a range of activities may be accommodated. This will reduce real and potential conflict, maximise compatibility between marine activities and encourage co-existence of multiple uses” (Defra, 2011, p13).

The sustainable development guidance to the MMO further notes that “In reaching impartial decisions based on the best available evidence, the MMO should take a risk-based approach that allows for uncertainty, recognising the need to use sound science responsibly. It should identify and take into account the potential benefits and anticipated adverse impacts (which may be economic, environmental and/or social), including the multiple and cumulative impacts of proposals when viewed with other projects and activities. The MMO will need to weigh the potential positive and negative impacts of each proposal, drawing on different, identifiable lines of evidence to consider the potential impacts..." (Defra, 2010, p4).

In order to meet these challenges, gaining a better understanding of the potential for co-existence of activities is one of the priority areas of research identified within the MMO's Strategic Evidence Plan[1] (SEP). This project sits within the MMO Co-location Research Programme, and builds on a previous study undertaken by the Centre for Environment, Fisheries and Aquaculture Science (Cefas) (MMO, 2013b) which recommended development of a more comprehensive approach to assessing co-location potential than matrices based on hard constraints. This report is the second output of the MMO Co-location Reseach Programme.

1.1 Objectives

The main objectives of the project are as follows:

1. **Scoping** - Explore and establish the requirements that may be placed on a co-existence assessment approach by relevant MMO functions including marine planning, licensing and conservation. Factors such as the nature of outputs, their likely use and the level of information required should be considered.
2. **Review a range of tools that could inform development of a co-existence assessment approach** - Descriptions should include a summary of the nature of data inputs required, the expected output type/format/level of detail and any significant associated limitations.
3. **Consider the potential value of incorporating local relevance into a co-existence assessment approach** - Broadly consider and assess the best potential strategies for incorporating methodologies within the tool to assess both the conceptual level interactions and specific local requirements.
4. **Supply and input of co-existence data** - Describe how best to supply and input relevant co-existence data into the assessment approach to ensure the outputs are based on up to date information. The approaches proposed should consider how best to allow evolution of the approach as new data becomes available.
5. **Evaluate risks and uncertainties associated with different methodologies** – Identify where evidence gaps broadly need to be filled to reduce the risk/uncertainty and where significant further development or testing is required for the methodologies.
6. **Make recommendations on most appropriate methodology and data repository** - Discuss in more depth the level of further development required and/or evidence gaps that need to be filled before full development of the approach can occur.

[1] http://www.marinemanagement.org.uk/about/documents/strategic_evidence_plan.pdf accessed July 2013

1.2 Study approach

This study has involved detailed discussions with MMO staff on the potential scope of a co-existence assessment approach across each of the MMO's main functions. A focused literature review was undertaken to identify existing tools that might inform and support co-existence assessments. The findings of the literature review have been summarised and the potential options for the use of particular tools within the overall co-existence assessment process have been considered. A framework for undertaking co-existence assessments and its application within marine planning, licensing and conservation management was developed based on the outcomes of the discussions with the MMO and the review of available tools. The proposed framework was then applied to a hypothetical case example to illustrate the application of an initial co-existence assessment with respect to two potentially competing marine interests.

The types of economic, environmental and social information and/or data that are likely to be required as part of a co-existence assessment have been reviewed. This has included taking account of the potential limitations associated with information and/or data requirements and their likely availability to inform a co-existence assessment. Based on the outcomes of this study a set of recommendations have been proposed describing steps necessary to this work forward to full development of the framework and assessment methodologies.

2. MMO Requirements for Co-existence Assessment Approach

2.1 Introduction

MMO staff were consulted on the requirements for a co-existence assessment approach across each of the MMO's main relevant functions – marine planning, marine licensing, marine conservation and fisheries management. This involved discussions about the nature of outputs, their likely use, the level of information required to inform such an approach and the type of decisions that the assessment would be intended to inform. The consultation process has been important in defining project requirements and focusing future project tasks to ensure that study outputs would provide maximum benefit and value to the MMO.

Based on these discussions, the general scope for a co-existence assessment approach that would be relevant across all of the MMO functions includes the following:

- Economic, social and environmental variables – one of the principal requirements for the MMO is to develop an assessment approach that can provide a balanced appraisal of all these variables at an appropriate strategic level. Displacement issues are also important, i.e. where activities might go when they are moved out of an area
- Consideration of co-existence potential informed by interactions between different activities and between activities and the natural environment
- A flexible and proportionate approach – a flexible approach to the assessment of co-existence potential is needed which is proportionate to the level of information available at the appropriate strategic level (i.e. plan versus project level). The approach must recognise the uncertainties associated with the scope for co-existence
- Transparency – any co-existence assessment approach will need to be transparent. Input from marine users will be an essential part of the full development of any approach and the process itself together with the balanced evaluation of this information
- Robust science and data - the success or usefulness of any co-existence assessment process or tool will be dependent on the quality of underpinning evidence that is available. The quality of the information will be proportionate to the scale of the assessment, e.g. the confidence in the data/information associated with high level screening and assessments will be lower than for more detailed assessments
- Appropriate spatial scales – strategic/regional spatial scales are considered most relevant at the marine planning phase and site specific issues are more relevant at the project level licensing phase
- Appropriate temporal scales and seasonal variations – these are important considerations in order to define where activities might overlap over time. For example, the marine plans have a 20 year plan timescale and therefore considerations of how available resources are managed over time will be important.

The following sections provide a summary of the requirements across each of the MMO functions associated with the consideration of co-existence and a potential assessment approach.

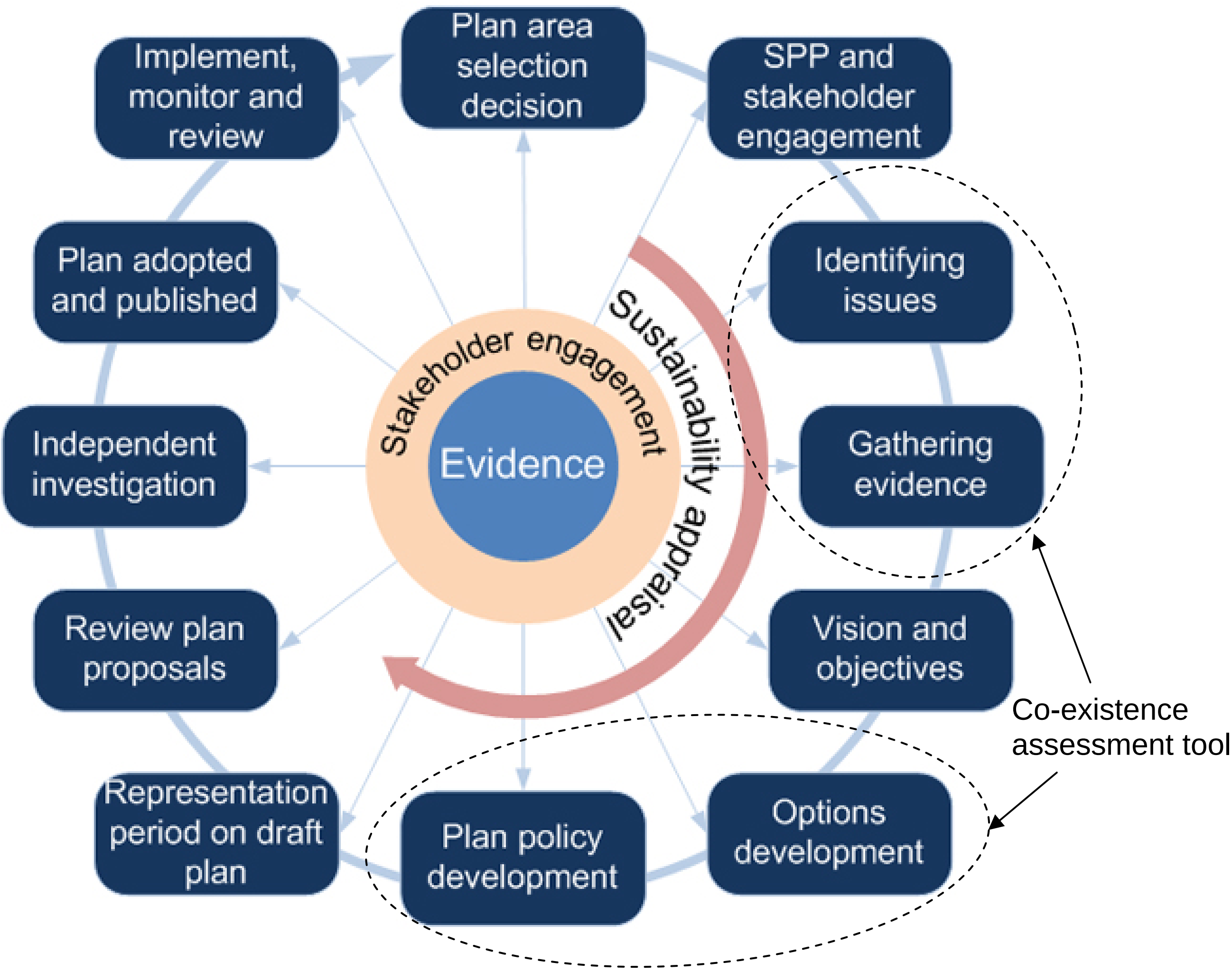
2.2 Marine planning

The existing marine planning process followed by the MMO is illustrated in Figure 1 and the elements that are considered to be relevant to the scope of any co-existence assessment approach are indicated by the dotted lines. The screening of co-existence issues would primarily be undertaken as part of 'identifying issues' and 'gathering of evidence'. The assessment tools used in the spatial options appraisal stage of marine planning (e.g. environmental impact and socio-economic impact tools within the context of the Sustainability Appraisal) are an existing mechanism for assessing the impacts (and costs and benefits) of spatial allocations. Stakeholders also have the opportunity to feed into the options development stage. Co-existence issues are essentially a subset of this spatial allocation process in providing an opportunity to consider the scope for deriving additional benefit from particular spatial allocations.

To date, a high level approach to identifying initial strategic prioritisation of sectors/activities within specific areas has been used by the MMO marine planners. Limited spatial prioritisation has been undertaken for the draft East marine plans. A draft policy has been applied whereby activities should demonstrate that they will have no impact on a certain specific activity in an area, failing that they should minimise impact or failing that they should present a case for their development. The Crown Estate's Marine Resource System (MaRS) tool was used to identify some areas of potential interest for future marine aggregate dredging and tidal energy, as well as areas within Round 3 offshore wind farm zones where activities were more compatible with offshore wind, taking account of 'hard' and 'soft' constraints. Draft Plan options also considered the relative merits of assigning specific areas to future offshore wind or marine aggregates development.

For the South marine plans, it is the intention to develop additional data layers and processes identifying the distribution of economic resources and to consider in more detail options for spatial policies and the potential for co-existence. It may be possible to define the spatial trends of some sectors and activities into the future using existing forecasting tools, although there is an inherent uncertainty surrounding this process which needs to be recognised. The co-existence assessment approach will need to use best available evidence that is proportionate to the scale of the assessment in making decisions about where consideration of co-existence may be necessary in the future i.e. where demand/competition for space/resources will be high. Furthermore, there may be activities/sectors that require some degree of protection (e.g. emerging technologies that fulfil critical policy objectives) and thus it will be important to provide sufficient safeguard to these whilst allowing for future growth of other activities.

Figure 1: The marine planning process (adapted from figure published on MMO website[2]).



In considering the potential for co-existence, a flexible approach is needed which recognises uncertainties surrounding the scope for co-existence at the plan-making stage. Assumptions made at the plan-level are likely to be subject to a number of uncertainties and practical issues of co-existence within specific areas are likely to require further consideration at the project-level phase i.e. when local scale issues become important considerations and the high level resource use maps can be validated against site specific information. Marine plans should therefore allow for some flexibility should issues arise at the project level related to co-existence. The MMO is currently undertaking a programme of work to explore the implementation of plan-led management, but no details were available at the time of preparing this report.

Strategic/regional spatial scales are considered most relevant in co-existence for marine planning. To inform co-existence potential, the spatial distribution of existing and potential future marine resources could initially be mapped at a coarse scale at the plan-level to identify locations where interactions may occur between

[2] http://www.marinemanagement.org.uk/marineplanning/about/process.htm accessed July 2013

activities/sectors competing for the same space/resource. Although the availability of information at the plan level may limit the extent to which co-existence impacts can be quantified, it would be possible to undertake some qualitative assessments using high level screening/scoping tools (e.g. compatibility matrices and interaction tables). For example, for interactions between activities and Marine Protected Areas (MPA) features it would be possible to build on existing sensitivity/vulnerability matrices for MPA features. Site specific co-existence opportunities are more likely to be considered as part of the licensing process (see Section 2.3).

There needs to be a process for mediation through the options stage within plan making so that the MMO can fulfil its role as an enabler, i.e. addressing where opportunities for co-existence or conflicts arise. Co-existence must still be in line with wider policies and vision objectives for the plan area, even where space is at a premium and there may be a need to ensure an activity does not preclude the use of the area by others. Although Government policy and marine plans will drive and promote co-existence, actual decisions to deliver co-existence are more likely to be made at the marine licensing project-level phase when there is greater clarity on project impacts and interactions. Given that individual developers should address Government policy as part of their application, there is value in including co-existence within marine plans to help enable effective use of space/resources where appropriate (e.g. where there is a high potential demand for space/resources in certain areas backed by a strong evidence base).

2.3 Marine licensing

At present, there are no specific drivers for developers or regulators to take account of co-existence at the marine licensing phase. Following this, issues related to co-existence have so far been considered as and when applications are received with an aim to minimise negative interactions of activities. However, this would change if marine plan policies that take account of potential co-existence opportunities come into force across English waters providing a driver for co-existence.

While plan policies may seek to define spatial requirements going forwards where robust evidence is available to support such policies, at present there is limited scope to undertake full detailed co-existence assessment for specific projects in specific locations at the plan level. Marine plan co-existence policies could, however, provide a driver for the MMO's regulatory function to facilitate the specific practical application co-existence through the marine licensing process. Marine licence applicants interested in exploiting areas with associated co-existence policies could be provided with the opportunity to feed into the development of a co-existence assessment, including the consideration of the potential to co-exist with certain other activities and/or of seeking to minimise displacement in terms of delivering sustainable development[3] and supporting economic growth.

The key stages involved in the existing marine licensing process are illustrated as a flow diagram in Figure 2. Any co-existence assessment would most effectively be applied in the initial pre-application stages of the marine licensing process, although it should be recognised that in some cases, decisions on co-existence may need to

[3] Sustainable development is defined in the draft East marine plans as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

be made post-consent, particularly where Rochdale Envelope[4] approaches have been used by developers or where the potential for co-existence may be dependent on operational practices.

Figure 2: The marine licensing process (adapted from process included in MMO, 2011).

Enquiries

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Pre-application

- Screening and consultation
- Scoping and consultation
- EIA/ HRA/ WFD/ MCZ assessment
- Monitoring to inform an application

↓

Application

- Application notice
- Application consultation
- Dealing with objections
- EIA consent decision notice
- License decision
- Appeals

↓

Post-consent

- Long-term review and submissions of new evidence

Environmental and socio-economic interactions and displacement effects are evaluated by the developer as part of the assessments that are required to accompany an application (e.g. Environmental Impact Assessment (EIA), Habitats Regulations Appraisal (HRA), Water Framework Directive (WFD) assessment, etc.). However, these assessments do not specifically consider co-existence, which involves the determination of potential opportunities for activities/sectors to co-exist and requires the positive cooperation of parties for their potential mutual benefit. The current focus is on avoiding areas of conflict rather than promoting co-existence.

Socio-economic impacts are often assessed in less detail than environmental impacts within EIAs because there is little guidance available on requirements for

[4] The 'Rochdale envelope' describes the maximum extent of a development (or maximum extents for a series of components) for which the environmental effects are assessed. Where project design or construction methods change during the consenting process within the 'envelope' they are considered not to compromise the validity of the environmental impact assessment.

socio-economic assessment and there are sensitivities about publicly disclosing quantitative information on potential impacts that may be subject to compensation claims from affected parties. Such issues therefore tend to be dealt with in more detail through consultation and the use of mitigation measures within licence conditions. Mitigation measures can limit and/or manage any incompatibility impacts between the developer's project and existing marine activities/sectors. Any licensing conditions must, however, be proportionate to the scale of the project and relevant. The aggregates industry, for example, currently has a fisheries liaison code of practice as a condition within their licences. This is aimed at reducing operational conflicts between the two industries who operate within close proximity to one another.

While the Marine Policy Statement broadly encourages consideration of co-existence within marine plans, this does not currently place a specific obligation on developers to consider co-existence. The draft East marine plans (MMO, 2013a) include more specific policies to maximise co-existence (GOV 2) and minimise displacement (GOV3) which could be important licensing considerations for future developments in these plan areas (see Section 4.3). If more explicit co-existence policies were included within marine plans where there is sufficient evidence to support such policies at the plan-making stage, the most effective approach would then be for the developer and the MMO to take account of co-existence requirements as early as possible in the marine licence application process.

It may be appropriate for the MMO to develop high level guidance on how co-existence might be taken account of by developers. This guidance could include information on the nature of evidence the MMO might expect to see as part of the application process to quantify the potential benefits of co-existence and/or impacts of displacement, as well as potential enhancement measures and the possible benefits of co-existence. This would help to ensure that a consistent approach is used by developers. In practice there are a number of factors that influence the approach adopted in assessments for a particular project. These include the availability of data/information, the time frame for the evaluation, the preferred use of tools by consultants (e.g. models), the resources available, and the appropriate level of effort for the assessment (i.e. expectations placed upon applicants must be proportionate for the project in question).

2.4 Marine conservation management

Management measures for marine protected areas (MPAs) may have consequences for the potential for co-existence of activities/sectors and may necessarily result in the displacement of some existing activities/sectors. Consultation is the primary tool used currently by the MMO to work through any compatibility issues. This is supported by information on the potential vulnerability of conservation features to human pressures, for example, the marine conservation zone (MCZ) sensitivity matrix (Tillin *et al*., 2010), the Joint Nature Conservation Committee's (JNCC) pressures-activities matrix, and information on commercial fishing impacts on European protected habitats and species compiled to inform assessments of commercial fishing activities within marine Natura 2000 sites.

The assessment of the significance of interactions between marine activities and protected features requires judgements to be made, taking account of the vulnerability of features to the pressures from human activities, the spatial extent of any resulting impacts and the importance of the particular features affected.

The MMO has a legal obligation to ensure conservation objectives and the MPA network are not negatively affected by marine licensable activities, or activities which could be regulated through an MMO byelaw (e.g. fishing or recreational activities). The conservation objectives of Natura 2000 sites would have a reduced scope for allowing co-existence, although it is often possible for human activities to continue with appropriate mitigation measures. There may therefore be some albeit limited opportunities for co-existence to be considered through work being undertaken to ensure activities comply with the requirements of Article 6 of the European (EU) Habitats Directive and also in relation to MCZs; for example, where activities would not have a negative impact on a site or species then management measures need not preclude their occurance. However, management byelaws could not be developed specifically as a mechanism to encourage co-existence. Encouragement of these socio-economic interests should be undertaken through other mechanisms such as marine planning.

As noted in Section 2.2 above, the MMO must take account of broader marine conservation interests when considering interactions between human activities and the wider natural environment within the marine planning process and marine licensing process.

2.5 Fisheries

Fisheries are often not compatible with other activities and although in some cases adjustments could be made to make co-existence more feasible, the cost of these adjustments can be disproportionate. The major driver surrounding fisheries management and co-existence is the issue of displacement and the main driver for fisheries displacement is the location and development of other activities. This can be best managed through effective marine planning and marine licensing approaches to co-existence. Co-existence assessment might be applied to fisheries management but it is envisaged this could be best undertaken through approaches described for marine licensing where appropriate therefore a separate approach is not required.

It is recognised that assessment of the impact of displacement and cost of not co-locating for fisheries is challenging. Few fisheries and fish stock displacement models have been developed and these tend to be site specific and of variable accuracy. Consultation with fishermen will remain an important mechanism for gaining insight into potential displacement impacts, although decisions on co-existence should be primarily based on empirical evidence where feasible. Overall, therefore, a data improvement exercise may be required.

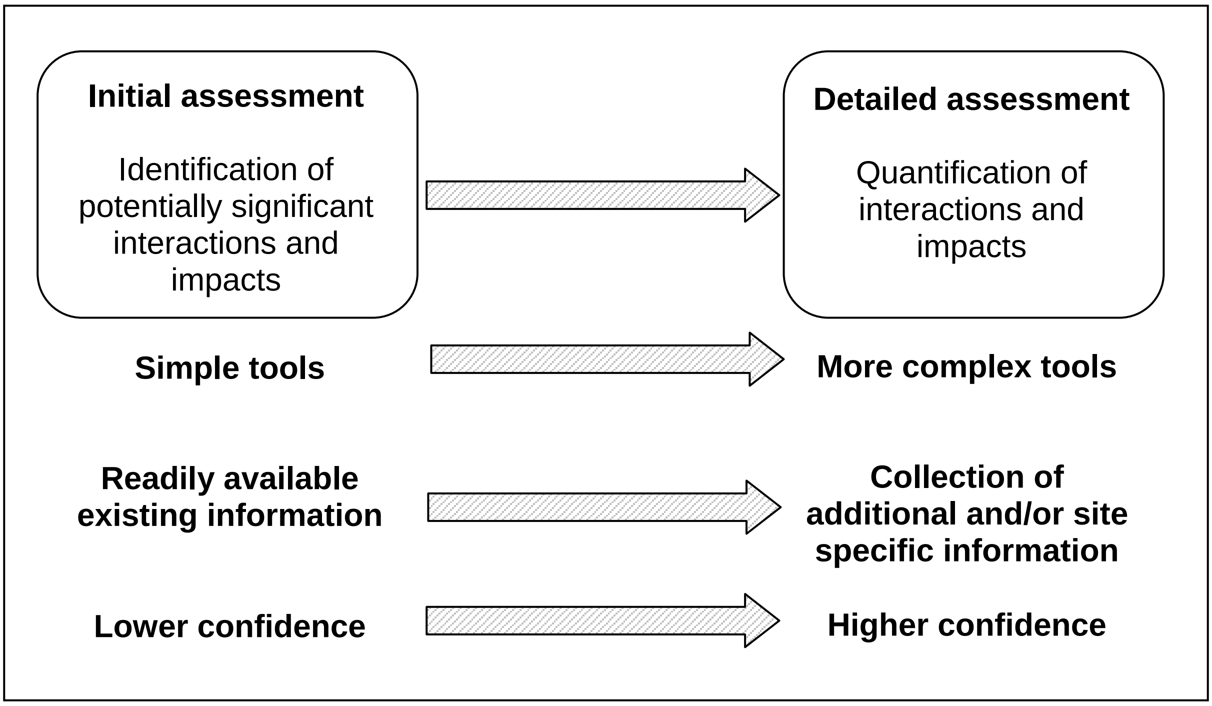
3. Options for Tools to Support the Co-existence Assessment Approach

3.1 Introduction

The scope for co-existence critically depends on the interactions that may occur between two or more co-existing activities or between activities and the environment and the extent of any economic, social or environmental impacts to the respective interests that arise as a result of those interactions. There may be a number of different interactions arising between co-existing activities and the effects of these interactions may vary on a location-specific basis depending on the magnitude and scale of the interaction and other site specific factors. Any detailed co-existence assessment process will therefore need to be able to take account of all relevant significant interactions at site level if it is to provide robust outputs and, in particular, to be able to compare the impacts of the 'co-existence' versus 'no co-existence' option.

Such detailed assessments will necessarily be data hungry and much of the data required to inform such assessments may not currently exist or may be inaccessible. Given these challenges in undertaking detailed co-existence assessments, it will be helpful if the process is incremental so that initial assessments can be carried out using existing information and simple tools with the provision for more detailed assessment using additional/site specific data and more complex tools where necessary (see Figure 3). While there may be less confidence in the outputs from initial co-existence assessments, it may still be possible to make decisions on co-existence potential in clear-cut cases.

Figure 3: Schematic of a generic co-existence assessment process.



This conceptual understanding of the requirements for a co-existence assessment process informed the focus of a literature review to identify existing tools that might inform initial and/or detailed co-existence assessments.

Based on the findings of the literature review there are no existing fit-for-purpose tools that provide all of the suggested functionality for a co-existence assessment tool for use across relevant MMO functions. However, there are a number of tools that might contribute to the implementation of a co-existence assessment process. These include:

- **Compatibility matrices** which identify at a high level, the potential compatibility between different human activities
- **Interaction tables** which identify the types of interaction between human activities
- **Impact assessment tools** which can be used to quantify interactions between human activities and between human activities and the natural environment
- **Appraisal and economic evaluation tools** which can help to present information on the relative costs and benefits of 'co-existence' and 'no co-existence' options
- **Cross-cutting tools** which are tools that contain elements of one or more of the above categories.

This section summarises the findings of the detailed literature review included in Annex A and considers options for the use of particular tools within the overall co-existence assessment process.

3.2 Compatibility matrices

3.2.1 Description of existing tools

A wide range of initiatives have sought to develop compatibility matrices which indicate relative compatibility between different human activities in the marine environment (e.g. Juda and Hennessey, 2001; Thompson *et al*., 2008, Lee and Stelzenmuller, 2010, MMO, 2013b).

A matrix can be described as a grid of numbers, letters or symbols arranged in rows and columns, which lists categories along each axis and describes the relationship between the categories (MMO, 2013b). Such matrices can be useful for decision makers in the development of marine plans if the categories are taken as marine activities. A number of studies have constructed sectoral interactions matrices at various spatial scales which consider the relationship between human activities.

All of the compatibility matrices require a spatial database of current and future human activity in order to apply them spatially. Many of the matrices have been developed through stakeholder consultation and engagement and therefore incorporate stakeholder perceptions (e.g. Thompson *et al*., 2008; Tay Estuary Forum, 2011; Moray Firth Partnership, 2012). Some of the matrices have identified relative compatibility rather than providing simple yes/no answers or traffic light systems to indicate compatibility (red/amber/green). For example Juda and Hennessey (2001) developed a compatibility matrix using a rating system of 1-10 and Lee and Stelzenmuller (2010) generated an activity matrix reflecting relative levels of potential conflict between sectors using a five point scoring system. Such matrices are probably more reflective of real world circumstances where the compatibility of many interactions varies depending on site specific factors.

Some of the compatibility matrices take account of the compatibility of activities only and others take account of the compatibility of some of the underlying interactions. However, these are still generally relatively simplistic and none of the matrices take account of the full range of potential interactions. The range of activities listed in the matrix developed by Juda and Hennessey (2001), for example, is very restrictive and would require significant development to be of use in practice. The Tay Estuary Forum (2011) aimed to acquire more detailed information on the compatibility of interactions among sectors through consultation, however, this matrix only considered perceptions of interactions between industries.

While these high level matrices give an indication of the relative compatibility of different human activities, they generally do not provide any of the underlying detail relating to the interactions between the activities which determine relative capacity for co-existence. Furthermore, the nature, scale and intensity of interactions between activities and their consequent impacts can be site specific and therefore average compatibility metrics may have limited validity at site level. Nor do existing compatibility matrices generally take account of the potential for temporal separation of activities, which can often be an important factor facilitating co-existence within the same sea space.

Given the uncertainties associated with compatibility matrix outputs, confidence in any resulting assessments would necessarily be low. However, there are a limited number of situations in which compatibility rules for human activities are clear cut, for example, where statutory requirements impose exclusion zones for reasons of health and safety or to protect specific features. These are effectively ‘hard’ constraints. In these instances, the use of compatibility matrices is helpful in identifying where co-existence is not possible. Relevant examples include:

- Statutory exclusion zones around certain offshore installations (e.g. oil and gas and offshore renewables installations)
- Safety and operational efficiency zones around cables and pipelines (these are guideline distances)
- Safety zones around construction activities
- Protection zones around marine historic environment assets.

It would be possible to map these areas and identify activities that were not compatible. For example, there is an exclusion zone that varies between 100 and 750m depending on the type of vessel, around wrecks protected under the Protection of Military Remains Act 1986 which would preclude any form of dredging or infrastructure development within this zone. However, it would not preclude commercial or recreational vessels from sailing through this area.

Within The Crown Estate’s Marine Resource System (MaRS) tool, to which the MMO has access, there is a range of decision rules that can be applied to spatial data which make assumptions about the likely compatibility of human activities (i.e. an embedded high level compatibility matrix). This includes decision rules relating to hard constraints and associated data layers which could be used by MMO as part of its screening process for co-existence assessment. This is already an implicit part of the existing marine planning process that has used the MaRS tool, but it could be made more explicit as part of a co-existence assessment. The MaRS tool also includes additional decision rules relating to softer constraints which are assessed using a weighting and scoring system to identify areas of lower constraint for potential development activity. Development of the MaRS tool is an on-going process.

3.2.2 Recommendations on compatibility matrices

Overall, it is recommended that the co-existence assessment framework includes a tool that can identify areas of ‘hard’ constraint where co-existence between certain activities is not possible. It is suggested that this could be based on the ‘hard’ constraints and data layers defined within the MaRS tool, supported by information on which of the Marine Policy Statement activities are considered to be constrained within those areas. This tool could be used within the initial stages of marine planning to identify areas where co-existence for certain activities would not be possible. While the MaRS tool also identifies and assesses ‘soft’ constraints which could be used to infer relative co-existence potential, this (and other existing compatibility matrices) are not considered to provide a sufficiently robust basis for co-existence policies.

3.3 Interaction tables

3.3.1 Description of existing tools

Understanding the interactions between activities or between activities and the natural environment is fundamental to identifying the associated impacts which in turn govern co-existence potential. These interactions are equivalent to the concept of impact pathways widely used within environmental assessment. Clear descriptions of these interactions and how they might be assessed is therefore considered fundamental to effective co-existence assessment.

Based on the literature review, there are no comprehensive tables identifying the potential interactions between different human activities. This is probably because there has not yet been a driver to develop such a comprehensive matrix to date. Some of the existing compatibility matrices incorporate some elements of interaction (for example, Van der Wal *et al*., 2011). Information on the interactions between offshore renewables and other marine activities is available from work to assess the socio-economic impacts of draft offshore wind, wave and tidal energy plans in Scotland (for example, Marine Scotland, 2012; 2013b). Examples of interactions between other human activities are commonly found in Environmental Statements for marine development projects but are not necessarily comprehensive. Nor is there a central repository for such information. However, the information that is necessary to develop a comprehensive set of interaction tables is likely to be available but would require some careful consideration and potentially also stakeholder input to ensure the level of detail is adequate and fit for purpose.

There are a number of sources of information on the potential interactions between human activities and the natural environment. These include various sector specific reviews for example in relation to ports (ABPmer, 2007), marine aggregates (Tillin *et al*., 2011), offshore wind (OSPAR Commission, 2008), wave and tidal development (ABPmer, 2009). A lot of this information has been drawn upon in developing assessment tools to inform Marine Protected Area planning and management. For example, the JNCC pressures vs. activities matrix (JNCC, undated) identifies specific categories of human pressure associated with a wide range of human development activities in the marine environment. This matrix is considered sufficient as a starting point for identifying the potential interactions between human activities and the natural environment, which can be integrated with impact assessment tools (see Section 3.4 below) to assess co-existence potential.

3.3.2 Recommendations on interaction tables

Given the centrality of interactions to the understanding of co-existence potential, it is recommended that interaction tables form a core component of a co-existence assessment framework. In particular, interaction tables should be developed covering the potentially significant interactions between different human activities. The interaction tables should be developed collaboratively with industry to draw on their expertise to identify potentially significant interactions and impacts.

3.4 Impact assessment tools

3.4.1 Description of existing tools

A wide range of methods are likely to be required in seeking to quantify and assess the significance of potential interactions between human activities and between human activities and the natural environment. These range from the use of expert judgement through to the application of complex models. In selecting suitable tools and methods, it is important to seek to ensure that they are fit for purpose, for example, appropriate to use with the available data, the errors surrounding impact estimates are understood, and that the level of resolution of assessment tools and methods are appropriate to the issues being assessed. Given the limitations of available data, particularly at the marine plan-making stage, the use of simple tools and expert judgement are likely to be preferred in the initial stages of co-existence assessment. More complex tools may be applicable in circumstances where detailed assessment is required to inform decision-making.

3.4.2 Assessing the economic impact of interactions between human activities

Various methods have been developed and applied to the assessment of interactions between human activities, particularly within project level and strategic environmental assessments and economic impact assessments. However, there are few reference documents that provide guidance on methodologies and the methods used tend to be project specific. In relation to fisheries, the UK Fisheries Environment Network (UKFEN) has published general guidance on undertaking assessments of impacts to the commercial fishing sector (UKFEN, 2012). There are also specific examples of assessments of fisheries impacts, for example in relation to interactions with offshore renewables development (Marine Scotland 2013a) and MPAs (Finding Sanctuary *et al.*, 2012, Marine Scotland, 2013b).

Existing guidance and practice have generally applied relatively simple methods for assessing fisheries impacts. However, it is recognised that the issue of fisheries displacement is highly complex and inadequately captured within existing methodologies. Various fisheries displacement tools have been developed which attempt to model the behaviour of displaced fleets but such models tend to be fairly site specific and have a high level of uncertainty associated with their predictions (e.g. fleet-based bio-economic simulation software to evaluate management strategies (Ulrich *et al.*, 2007) and individual-based modelling to improve the ability to predict fishers' responses to management changes (Bastardie *et al.,* 2012)).

These fisheries displacement models can also be used to assess the potential impact of co-existence decisions. However, although such models can provide a means to test assumptions and to compare a fleet's likely response to different management scenarios, there is only limited potential to reliably predict displacement impacts across the numerous vessels that operate in English waters. Location-specific issues and temporally changing conditions mean that up-to-date information on fishing practices will almost inevitably need to be collected in order to guide and validate assumptions of fishermens' behaviour. Location-specific issues are likely to be particularly important for determining the potential for displaced fishermen to make up earnings elsewhere. Quantitative, spatially defined data on fishing activities will then become important for determining the economic impact of displacement. Overall, the use of complex displacement models is considered to be of limited value and the assessment of compatibility between fishing activities and other industries should still be undertaken largely through consultation and expert judgement.

For other sectors, Marine Scotland (2013a) includes methodologies for assessing interactions between offshore renewables development and a wide range of other sectors, including aquaculture, carbon capture and storage installations, flood and coast defence, military interests, oil and gas infrastructure, ports and harbours, commercial shipping, recreational activities, telecom cables and tourism. These methodologies are largely based on a spatial analysis using Geographic Information System (GIS) to quantify the scale of an interaction and then using simple criteria to estimate monetary values, taking account of potential mitigation measures that could be implemented. For example, in relation to the interaction between offshore renewables arrays and commercial shipping, the methodology seeks to identify the number of vessels (p.a.) transiting through an area for proposed development of arrays and to estimate the average route deviation as a distance and as a time (based on an average steaming speed). The potential additional fuel costs that might be experienced by vessels transiting the route can then be estimated using indicative information on fuel consumption (litres per hour) and an average fuel price (pence per litre). This provides a simple means of quantifying and monetising this interaction. In order to obtain a more accurate estimate, a more detailed understanding of the characteristics of vessels passing through the area would be required, possibly allied to a model of shipping movements.

The identification of a detailed set of simple and complex methods for assessing the economic impacts of interactions between different human activities is beyond the scope of this project. Should the development of comprehensive interaction tables be taken forward, it would be helpful to develop a corresponding set of assessment methods for each interaction, drawing on the available literature. However, it is likely that many of the methods will need to be adapted to take account of the particular circumstances of each co-existence assessment and the availability of data, so the choice and application of methods will need to remain flexible within the overall co-existence assessment approach.

3.4.3 Assessing social impacts

As with economic assessment methods, a range of approaches to social impact assessment have been developed for project level and strategic environmental assessment and also to inform Government impact assessments.

The MMO is currently taking forward research to explore how social interactions English marine plan areas might be assessed (e.g. MMO, 2013g). An indicator-based evaluation framework has been proposed which is linked to the Marine Policy Statement. At its core are specific objectives of marine spatial policy, generally reflecting both national and plan area goals, that have been selected for evaluation. The framework specifies a set of social benefit and ecosystem services[5] value indicators that will be measured annually (e.g. job creation from marine plan led activity). These indicators should have an evidenced causal relationship with both marine plan policy outputs and with eventual social impacts. In many cases modelling work will be required to both establish the nature of this relationship and to calculate how much social impact can be attributed to a unit change in each indicator. Further work needs to be undertaken before the proposed framework can be implemented. This will include undertaking a detailed evaluation of the proposed framework, including trial analysis of real data for chosen indicators (MMO, 2013g).

There are a large number of methodologies that have been proposed for undertaking social impact assessment at plan or project level, for example, The Interorganizational Committee on Guidelines and Principles for Social Impact Assessment (1994); International Petroleum Industry Environmental Conservation Association (IPIECA) (2004) and Ecorys (2010) among many others. These methodologies identify a range of dimensions of social impact including culture, health, crime, education employment, etc. and offer various methods for undertaking such assessments generally involving high levels of public consultation.

Within the UK, a specific methodology has been developed and advocated by the Social Impacts Taskforce of the Government Economic Service (GES) and Government Social Research (GSR) (Harper and Price, 2011) for assessing the social impacts of plans and policies. This methodology has been successfully applied to evaluate marine policies (Marine Scotland, 2013a; b) and fits well with wider cost benefit assessment processes. This methodology takes a social capitals approach to the consideration of social impacts, drawing on information on the distribution of economic impacts to identify and assess potential social impacts on the basis that social impacts will be strongly connected to the nature, scale and distribution of the economic impacts. It makes use of information collected and analysed as part of a wider economic assessment and distributional analysis and therefore fits well with existing Treasury Green Book guidance (HM Treasury, 2003).The methodology assess social impact in relation to a number of key areas (Table 1) and considers impacts by location and by social group (age, gender, income, minorities, etc.).

[5] Humankind benefits from a multitude of resources and processes that are supplied by ecosystems. These include products like clean drinking water and processes such as the decomposition of wastes.

Given that the Social Impacts Taskforce framework has been specifically developed to support the evaluation of plans and policies within the UK, its use within the co-existence assessment approach would be logical. It is possible that, over time, the indicator framework methodology proposed by the MMO (2013g) could also be integrated within the assessment framework.

Table 1: Key areas of social impact included in Social Impacts Taskforce framework.

Key Area	Access	Experience
Access to services	Change in opportunity to use services or time to access services	Change in quality of service provided or received
Crime	Change in opportunity for criminal activities	Change in level of crime (perceived or actual)
Culture and heritage	Change in opportunity to access culture and heritage Change in existence of culture/heritage, or knowledge of it (especially loss) Change in number of visits to cultural/heritage sites	Change in quality of cultural or heritage through change in context, quality of visits
Education	Change in opportunity to access education services	Change in quality of education services
Employment	Change in employment opportunities	Change in quality of employment opportunities
Environment	Change in opportunity to access environment Change in existence of environment, or knowledge of it (especially change in habitats) Change in number of visits to environmental sites	Change in quality of environment through change in quality of habitats, species supported or change in quality of visits
Health	Change in level of disease or symptoms (physical and mental health)	Change in self-assessed quality of health

3.4.4 Assessing environmental impacts

Many different approaches have been developed for assessing environmental impacts and thus there are many options in the choice of tools to be applied. However, there are relatively few documents that provide detailed guidance on standard methods for the assessment of marine environmental impacts and the choice of tools is not clear-cut.

For broad scale assessments of risk to marine environmental features, various risk assessment tools have been developed. In particular, sensitivity matrices are a key assessment tool as they identify the sensitivity of environmental receptors to a range of human pressures and can be used to identify the potential vulnerability of features when combined with information on the distribution and intensity of human pressures. Various initiatives have compiled information on the sensitivity of ecological features to human pressures including the Marine Life Information Network (MarLIN) database[6], the MB0102 Pressures versus MPA Features sensitivity matrix (Tillin *et al.*, 2010), the Scottish MPA sensitivity matrix (SNH, undated) and the work to develop sensitivity information for the project to implement the provisions of Article 6 of the Habitats Directive to commercial fishing activities (Defra, 2013). ABPmer (2013c) also provides a sensitivity matrix for geodiversity[7] features.

These sensitivity matrices are being used to support the planning and management of UK MPAs. They already have a level of acceptance from stakeholders and MMO should therefore make use of them in evaluating the potential for co-existence of human activities with MPAs. Given that different matrices have been developed for specific purposes, the choice of which matrix to use to support co-existence evaluation should be governed by the particular issue at hand.

Such information is also of value in seeking to assess co-existence potential between human activities and the natural environment outside of MPAs. However, none of the existing risk assessment matrices are comprehensive in their coverage of environmental receptors or human pressures. For example the MB0102 Pressures versus MPA Features sensitivity matrix (Tillin *et al.*, 2010) only included broad level habitat types (EUNIS level 3) and did not comprehensively consider the varying types or intensity of pressures acting on a feature. It would be possible to develop a composite feature sensitivity matrix from a number of sources to support marine planning if this was considered necessary, or simply to make use of existing matrices as appropriate.

In addition to these relatively simple impact assessment tools, there is a range of more complex modelling tools that can be used to assess environmental impacts on specific environmental receptors. These include, for example:

- Hydrodynamic, sediment transport and morphological modelling tools that can be used to investigate changes in physical processes and morphology (see The Estuary Guide website[8]). These processes also strongly influence the distribution of seabed habitats
- Water quality models that can assess changes in water quality and infer ecological conditions (see STOWA/RIZA, 1999)
- Seabed habitat models that can be used to predict changes in the distribution extent, and or condition of broad-scale habitats (e.g. DEPOMOD (Cromey *et al.*, 2002); estuary habitat models (ABPmer 2007, 2008); HabMap (CCW, 2011)

[6] http://www.marlin.ac.uk/ accessed July 2013
[7] The natural range (diversity) of geological features (rocks, minerals, fossils, structures), geomorphological features (landforms and processes) and soil features that make up the landscape.
[8] http://www.estuary-guide.net/guide/analysis_and_modelling/index.asp accessed July 2013

- Seabird collision risk models (SNH, 2000)
- Underwater noise propagation models (OSPAR Commission, 2009) and effects models (Nedwell *et al*., 2007).

Such tools are commonly used within EIAs where there are complex impacts, supported by simple tools and expert judgement. Should detailed assessment be required, the choice of tool would largely depend on the information that was available (or which could be collected) and the specific issues at hand.

3.4.4 Recommendations on impact assessment tools

A wide range of tools will be required to support the assessment of economic, social and environmental impacts. Simple tools will be required to inform initial co-existence assessments but more detailed assessments may require more complex tools.

The choice of tools to assess economic impacts arising from interactions between human activities should build on existing guidance and tools. For initial assessments, the specific tools should reflect the issues being addressed. If a comprehensive set of interaction tables is developed, it would be helpful for these tables to also identify suitable methods for assessing impacts, based on existing literature and consultation with industry. Within initial assessments, spatial analysis within GIS is likely to be an important method for quantifying interactions. For more detailed assessments, the choice of tools will be situation specific reflecting data availability and the issues at hand.

The Social Impacts Taskforce methodology (Harper and Price, 2011) has been developed to support social impact assessment of UK plans and policies and is therefore an appropriate tool to use to support co-existence assessment. It has already been successfully applied to the assessment of marine policies. A key strength is that it provides strong linkages to the assessments of economic impacts and is relatively simple to apply, although the outputs from such assessments tend to be qualitative. In the longer term, the indicator framework methodology proposed within MMO 2013g could also be integrated within the assessment framework.

Some simple risk assessment tools (matrices) have already been developed for use within the UK to assess interactions between human activities and MPA features. The tools could be developed to apply to non-MPA features to support the wider assessment of environmental interactions, particularly to broaden coverage for key receptors which are currently under-represented in existing matrices (birds and marine mammals). For more detailed assessments, the choice of tools will be situation specific reflecting data availability and the issues at hand.

3.5 Appraisal and evaluation tools

3.5.1 Description of existing tools

Appraisal tools are helpful when seeking to compare ‘co-existence’ versus ‘no co-existence’ options. The most commonly used appraisal tools include cost benefit analysis (CBA), multi-criteria analysis (MCA) and trade-off analysis. These tools can make use of both quantitative and qualitative information including application in association with ecosystem services frameworks or more narrow financial criteria. A number of reviews of the characteristics of these tools have been undertaken, for example, ABPmer and eftec (2010) in relation to MPA planning, and Turner *et al.* (2010) for the Marine Strategy Framework Directive (MSFD). CBA is routinely used to inform impact assessments of public sector policies including for the marine environment e.g. Marine Scotland (2012; 2013b) for offshore renewables socio-economic assessments and Cefas (2012) for MSFD Impact Assessment.

In order to compare ‘co-existence’ and ‘no co-existence’ options, it is generally helpful to present information on a consistent basis. In this respect, economic evaluation presented within a cost benefit framework can be useful in providing information in terms of monetary valuation.

Economic evaluation can involve the combination of a number of different economic tools. These tools can be differentiated between those that assign value to a particular change or impact (i.e. valuation) and those that compare the impacts from one option against another (i.e. appraisal). These tools are in routine use to help to present information to inform decision making.

Economic appraisal and the use of environmental valuation techniques should be guided by the following principles:

- Fitness for purpose: the decision-making context, legal requirements, option characteristics, location, habitats, services, human populations and scale of impacts will determine the effort, methods, and level of accuracy that are appropriate
- Sensitivity analysis: limitations of data and uncertainty over environmental effects and monetary values can be partly addressed by sensitivity analysis, again proportionate to the decision in-hand
- Transparency: ensuring an ‘audit trail’ of methods and full reporting of key assumptions, limitations, omissions and uncertainties
- Decision-supporting: CBA and valuation methods involve approximations of value based on imperfect indices of social welfare. Other information will also often be relevant. These methods are decision support tools, and an aid to structuring certain types of information. They are not a replacement for deliberation or consideration of other evidence.

These points need to be taken into account during the development of the appraisal methodology, and in its application, including in reaching decisions about appropriate levels of effort, and where to target resources in resolving uncertainties or improving valuation data.

In applying economic evaluation in decision tools, as described above, there are many technical caveats and considerations. Key points in considering co-existence decisions include that:

- Marginal values[9] for some ecosystem services can vary significantly depending on the scale of a change. This can make scaling values up or down challenging

[9] Marginal value is the additional value gained or lost by an incremental change in provision of a flow, or in the level of a stock.

- Ecosystem service levels may be strongly affected by the cumulative impacts of different drivers, and this must be taken into account in valuation and decision making. In other words, the same resources may be subject to multiple ongoing pressures, and analysis of values focusing on just one pressure could overlook issues associated with the overall impacts. For example, when determining fisheries policy it may be necessary to consider not only the level of fishing effort or harvest, but also the impacts of marine pollution, destruction of fish nursery habitats, climate change and so on
- Where resources become very scarce, marginal values may change so rapidly that valuation becomes difficult; if dealing with thresholds and essential resources (i.e. 'critical natural capital') and services, valuation may become inappropriate.

Valuation methods
When considering economic valuation methods it is important to remember that value involves several related concepts. While many people might consider the natural environment and its component resources to have 'intrinsic' value (a value in their own right), the concept of an asset's value which is the most relevant to policy-making is of contribution to human welfare relative to other assets. In addition, the value concept of interest here is not the value of the entire natural environment, but of relatively small changes in its quality and/or quantity.

Exchanging goods and services in markets provides a ready-made indicator of value, in the form of price, which also signals how much of input resources should be allocated to production of different types of goods and services. However, there are many types of resources which contribute hugely to human welfare which cannot be traded in markets – many environmental resources (such as clean air) and ecosystem services (such as water filtration and flood prevention) are amongst the foremost examples of such 'non-market' goods and services.

Economic valuation of the majority of ecosystem services (e.g. habitat, and carbon storage) valuation can only be undertaken if the quality of the service change is known and this requires a process of scientific analytical measurement (physical, chemical and biological). Where primary data on marine ecosystem services cannot be obtained, a qualitative assessment for each ecosystem service might be undertaken based on the existing evidence drawn from the literature and databases, and on expert judgement, including that elicited at focus groups and stakeholder meetings.

Within the choices of methods available to value economic, social and environmental impacts in monetary terms, preferences for evidence can be determined according to a 'valuation hierarchy':

1. Market prices (where they exist) are preferred as the first source
2. For impacts that do not have markets (non-market), there are two sources of value:
    a. Surrogate market data, obtained by observing behaviours associated with market prices (known as revealed preferences) (e.g. purchase price of a house reflect its structure, size and also community cohesion in the area, air quality and landscape which are not directly

measurable, or what individuals spend on travel for a recreational visit reflects their enjoyment of the activity, scenery, environmental quality, etc.)

b. Hypothetical-market data, in particular to value intangible or unquantifiable impacts known as stated preferences (e.g. while the number of water supply interruptions is known, its costs in terms of disruption and distress to customers is not possible to quantify using market or surrogate market data).

Alongside these methods, expenditure measures are also available to inform policy making, but they do not measure economic value. For example, expenditure on cleaning up beaches implies a minimum level of welfare that is gained from the resulting improvement in beach cleanliness, but does not mean that cleaning further beaches will result in a level of value equivalent to these costs.

Finally, where valuation evidence (from any of the available methods) does not exactly relate to the impacts being valued, it may be adjusted to give an indication of value using value transfer. UK Government has developed best practice guidelines on the use of value transfer (eftec, 2010). These give guidance on how to assess the robustness of value evidence transfer. This takes into account the relevance of the evidence in terms of the geography, the scale and timing of environmental change, the numbers and socio-economic groups of beneficiaries, and the decision-making context.

The better the match of valuation evidence to the issues being analysed, the more robust the value transfer. Ideally data are adjusted based on statistical evidence (e.g. in proportion to the differences in beneficiary populations, or scale of environmental change). However, expert judgement is often necessary, and should be laid out transparently. The different sources of uncertainty inherent in this approach usually result in a range of values.

Appraisal methods

Incorporation of value measurements in policy and decision-making processes can involve formal methods of appraisal such as cost-benefit analysis (CBA) or cost-effectiveness analysis (CEA), using monetary values, or multi-criteria analysis (MCA), using scores and weights derived from experts, decision-makers and/or stakeholder interaction.

A key issue amongst these methods is that CBA and MCA aim to identify the most beneficial of a number of objectives or the optimal level for an objective. CBA looks at the most efficient way to achieve a given objective. Values can be used in a wide range of contexts, for example to help decide on courses of action such as coastal development proposals, to determine where and how much of the marine environment to protect from exploitation, to formulate resource management policies, to determine compensation payments for damage to marine features, and so on.

Both CBA and MCA aim to account for all the different dimensions of effects of different options (various environmental, social and economic impacts), and can in principle encapsulate any values which humans can express. In MCA, the impacts are measured in different units then ‘scored’ in terms of their relative impacts under each category. The overall evaluation stage is then implemented via weights applied to the different attributes. However the weights may often be applied to the general concept of an effect (e.g. 'air pollution') rather than a precise level of that effect, which can make it difficult to understand exactly what has been valued, and how. In addition values are only included for effects which are identified as relevant to the options (and for practical reasons, the number of such effects is limited). These uncertainties limit the robustness and replicability of MCA. However, as a tool for helping people to understand their values and their practical implications, MCA may be very useful. Furthermore MCA may be useful where CBA is not feasible – in particular, in cases in which for ethical reasons, non-welfare goals are sought. By definition these goals fall outside the standard CBA framework of balancing costs and benefits. Often the reason is not that costs or benefits cannot be measured, but rather that the use of individual welfare-estimates is too contested, or viewed by (some) stakeholders as illegitimate.

Each of the appraisal methods discussed above can help determine tradeoffs. There are further tools that can are more specifically focussed on tradeoffs. Two of these, spatial planning tools such as Marxan, and switching analysis, are reviewed in more detail in Annex 1.

3.5.2 Recommendations on appraisal and evaluation tools

While monetisation of all impacts of co-existence may not be possible, the presentation of information within a cost-benefit framework using economic evaluation techniques is helpful in clarifying the gains and losses, identifying the trade-offs that may need to be made and in focusing attention on the major impacts influencing the decision at hand. The use of economic evaluation methods and a simple cost-benefit framework to capture information should therefore facilitate decision-making.

3.6 Cross-cutting tools

3.6.1 Description of existing tools

There are a number of cross-cutting tools (i.e. tools that perform a number of functions) that have some features that are relevant to co-existence assessments (Annex 1). However, all of these tools incorporate many simplifying assumptions that are not always explicit and outputs from such tools are therefore subject to significant uncertainty.

For example, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) and Artificial Intelligence for Ecosystem Services (ARIES) tools seek to provide information concerning how ecosystem services change in response to changes in human pressures and have the potential to contribute to the assessment of potential environmental impacts, at plan level. The InVEST tool applies an approach which is based on 'production function' modelling, linking spatially explicit maps of habitat types to specific ecosystem service outputs. The main difference between these two tools is that InVEST determines ecosystem service provision and value via ecological and economic production functions, whereas ARIES assigns ecosystem service provision and value directly according to the habitat and management characteristics, with the ecosystem service provision and values drawn from other site-based studies. Critically, such tools rely on having a detailed underlying habitat map and then seek to model ecosystem service provision based on a set of rules, but there are many uncertainties associated with such rules. For example, both models assess ecosystem services provision based on benthic habitats. Nevertheless, there are a number of other factors that drive marine ecosystem services provision, for example physical factors and water column processes that are not captured by these models and thus significant uncertainty will attach to model outputs.

The tool Marxan with Zones is primarily an MPA planning tools which uses an optimization algorithm to develop proposals for MPA networks based on a set of defined criteria. The tool can take account of MPA criteria, such as the presence and extent of features to be protected, together with socio-economic factors, which are represented in the model as a cost. The tool has been successfully used to explore possible MCZ networks which minimise impacts on socio-economic interests (ABPmer, 2010a). The tool can thus be used to inform multiple use planning if required. However, the tool is limited by the underlying data (e.g. distribution of environmental features) and the simplistic approach to defining the cost factors for socio-economic activities.

3.6.2 Recommendations on cross-cutting tools

None of the cross-cutting tools are considered to have immediate application within co-existence assessments.

4. Proposed Framework and its Application Within MMO Functions

Based on the requirements for an outline assessment process and the review of available tools, this section presents a proposed framework for undertaking co-existence assessments. The potential application of this framework within relevant MMO functions is then described in Sections 4.2 to 4.4.

4.1 Proposed framework

The co-existence assessment framework (Figure 4) is proposed as a three stage process:

- Screening
- An initial (high level) assessment
- A detailed assessment.

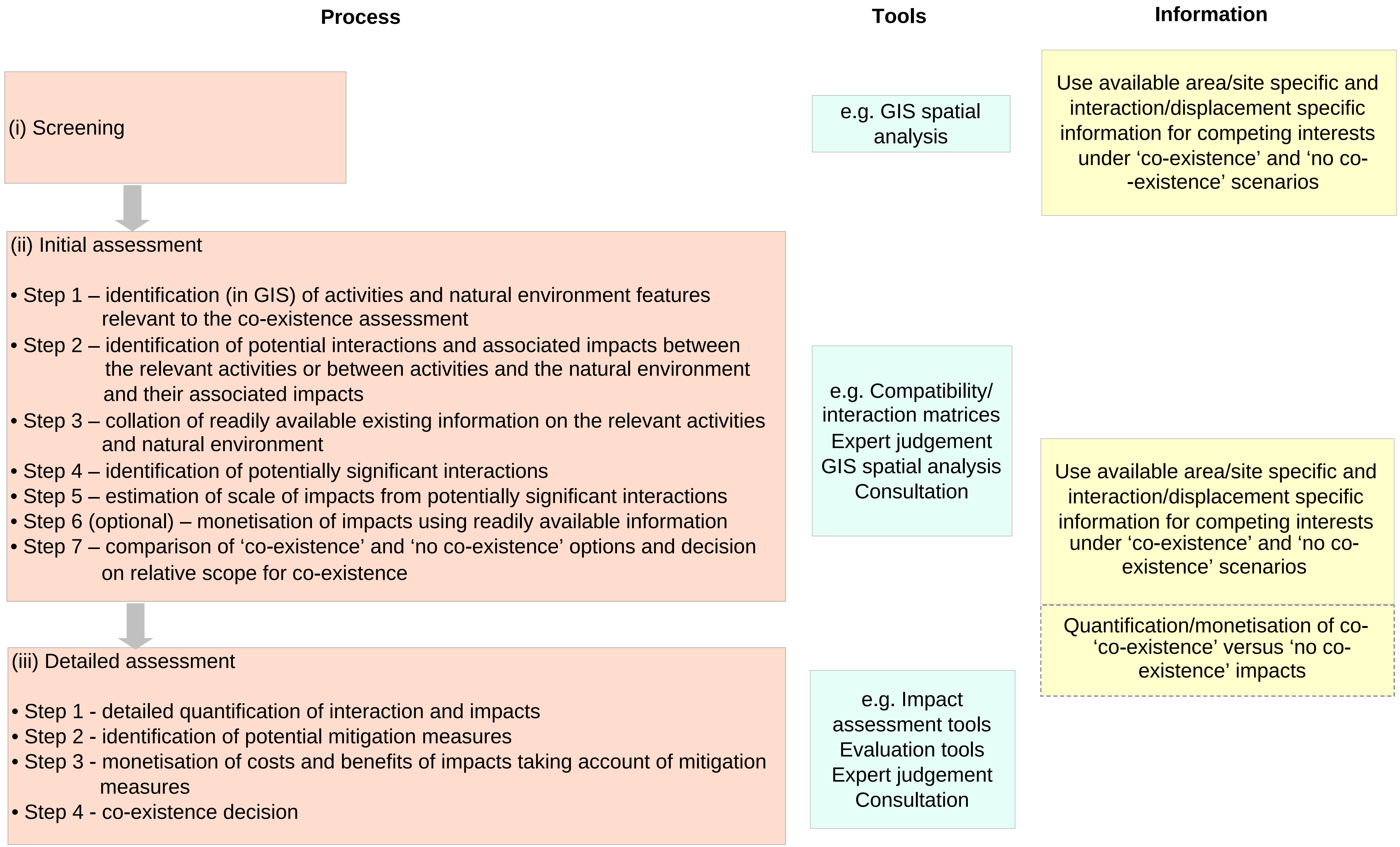
This provides the flexibility to take account of differing levels of information availability and/or the relative importance of the co-existence issue being considered. It also ensures that co-existence can be considered in a proportionate manner so that early decisions can be taken at the highest level possible to seek to minimise collection of unnecessary information.

The screening step is primarily aimed at identifying locations where co-existence between activities will not be feasible for health and safety reasons or where other mandatory protection zones are in place. The screening step is mainly relevant to the general plan level stages of marine planning as such issues should already have been taken into account by project level developments applying for marine licences.

The main assessment framework is then based on the need to understand and quantify the interactions between different human activities or between human activities and the natural environment in order to be able to estimate the potential economic, social or environmental impacts. It also proposes incorporation of a cost benefit appraisal framework and the use of economic evaluation techniques as helpful tools to facilitate comparisons between 'co-existence' and 'no co-existence' options.

The initial assessment would make use of readily available existing information and simple tools in order to understand the relative magnitude of particular interactions and their impacts. The detailed assessment would seek to quantify and monetise impacts where feasible using additional information and more complex tools.

Figure 4: Proposed generic framework for the assessment of co-existence.



4.1.1 Screening

The screening step is mainly applicable to the marine planning process as 'hard' constraints will already have been taken into account by project level developments applying for marine licences. The screening step identifies locations where co-existence between activities will not be feasible for health and safety reasons or where other mandatory protection zones are in place. This would include safety zones around submarine telecommunications or power cables, safety zones around offshore installations, protection zones around historic environment features or areas that pose unacceptable navigational safety risks (e.g. large commercial vessels transiting through offshore wind farms). It could also be applied to some military practice and exercise areas, particularly live firing ranges, where there is little practical prospect for significant marine infrastructure to be developed. However, there is not a prohibition on development within these areas and it is therefore considered to be more appropriate to address such issues through the more detailed co-existence assessment framework.

The screening process is already effectively applied within the MMO's marine planning process. The MaRS tool which has been used to identify potential resource use areas for certain activities already takes account of 'hard' constraints in identifying such areas. Spatial data layers for statutory health and safety zones already exist within the MaRS tool. They could be used to identify areas where co-existence between certain activities would not be possible under any circumstances. Such areas occupy a relatively small proportion of UK seas. The wider MMO marine planning process already takes account of safety constraints in developing plan policies.

Stakeholder engagement undertaken during screening would help to identify the scope for co-existence and provide additional relevant information on the potential interactions if necessary. It would also be possible to define the other mandatory protection zones which are described above, in agreement with the relevant stakeholders, to ensure that a standardised approach to screening is applied in marine planning.

4.1.2 Initial assessment

The initial assessment would primarily involve a high level assessment of potential 'co-existence' and 'no co-existence' interactions and impacts. The aim would be to identify the potential relevance and significance of interactions and consequent impacts. This would be achieved using readily available information on the likely nature of the competing interests associated with a possible co-existence area and information on the wider characteristics of that area. Where potential interactions were considered likely to be significant on the basis of available information, they could be scoped in for more detailed assessment if appropriate. It may also be possible to incorporate this information within a partial cost benefit analysis to facilitate comparison of options at this stage if sufficient information is available, although a cost benefit analysis would be more likely to be applied to the detailed assessments and is unlikely to be feasible in marine planning at present.

The validity of any assessment will be dependent on the reliability of the underlying information and data. If the outputs are based on low quality data, circumstantial evidence or high level assumptions, then the confidence in the value of the outputs will necessarily be low. While outputs from the application of the co-existence assessment process may be subject to uncertainty and information gaps, it should be recognised that the initial assessment is primarily seeking to identify the relative scale of impacts. In this sense, as long as all of the significant interactions and their relative scales have been identified, it will be possible to infer the relative impacts of 'co-existence' and 'no co-existence' options to inform decision-making. Furthermore, the initial assessment will be helpful in highlighting what further information might be required should it be considered necessary to examine interactions and impacts in more depth before decisions are made. Consultation and engagement with stakeholders will be important throughout the initial assessment process to ensure that their views are taken into account, particularly given the likely limitations of the data. This can be facilitated through existing consultation and engagement processes.

Initial assessments could be undertaken through completion of the following steps:

- Step 1 – identification (in GIS) of activities and natural environment features relevant to the co-existence assessment based on the issues that are identified in each plan area
- Step 2 – identification of potential interactions and associated impacts between the relevant activities or between activities and the natural environment
- Step 3 – collation of readily available existing information on the relevant activities and natural environment
- Step 4 – identification of potentially significant interactions
- Step 5 – estimation of scale of impacts from potentially significant interactions
- Step 6 (optional) – monetisation of impacts using readily available information
- Step 7 – comparison of 'co-existence' and 'no co-existence' options and decision on relative scope for co-existence.

While the process is presented as a series of steps, there will necessarily be a degree of iteration between some of the steps and this should be taken into account when implementing the process.

Step 1 – identification (in GIS) of activities and natural environment features relevant to the co-existence assessment based on the issues that are identified in each plan area

In this step, relevant activities and natural environment features for inclusion in the co-existence assessment should be identified based on the specific issues that are identified in plan areas. Given that the assessment is explicitly spatial, this is best undertaken within GIS. A decision needs to be made on the spatial boundaries (the study area) for the co-existence assessment. This should take account of the likely nature of interactions between activities or between activities and the natural environment which may extend beyond the immediate boundaries of an activity.

Step 2 – identification of potential interactions and associated impacts between the relevant activities or between activities and the natural environment

The potential interactions between relevant activities or between activities and the natural environment should be documented together with their associated impacts. This step should make use of existing interaction tables where they have already been prepared.

Step 3 – collation of readily available existing information on the relevant activities and natural environment

Readily available information on the likely nature of the potential interactions and impacts should be collated - see Section 6 for details of the potential information requirements. This will include a range of spatial and non-spatial data.

Step 4 – identification of potentially significant interactions

Using the available information, potentially significant interactions should be identified and documented for the ‘co-existence’ and ‘no co-existence’ options. This assessment could be undertaken at either a generic level or an area specific level. Given that many of the interactions are likely to be site-specific, assessments undertaken for specific areas using area-specific information are likely to be more robust than generic assessments, but the latter may still be of value within marine planning in allowing indentification of the strategic benefits associated with broad relative compatibilities between activities or between activities and the natural environment. The outcomes of the assessment should be summarised in an appraisal summary table (see Section 5 for a case example).

Step 5 – estimation of scale of impacts from potentially significant interactions

The scale of impacts associated with potentially significant interactions should be estimated for the ‘co-existence’ and ‘no co-existence’ options using available information and documented in the appraisal summary table.

Step 6 (optional) – monetisation of impacts using readily available information

Where information is available to monetise the estimated impacts, this may assist comparison of the options but this is not seen as an essential part of the initial assessment and is unlikely to be broadly feasible at the marine planning stage. Any monetised estimates should be included within the appraisal summary tables.

Step 7 – comparison of ‘co-existence’ and ‘no co-existence’ options and decision on relative scope for co-existence

The estimated impacts of the ‘co-existence’ and ‘no co-existence’ options should be compared to inform a decision on the relative scope for co-existence. Where only a few minor interactions are identified and there is reasonable confidence in the data, there is likely to be greater scope for co-existence. Where more substantial interactions are identified, co-existence may still be possible through application of mitigation measures but this may need to be informed by a detailed assessment.

It is not considered appropriate to include an assessment of potential mitigation measures within the initial assessment because the application of mitigation measures could potentially require significant expenditure by one or more of the interacting activities, for which a clear justification would be required. Where significant interactions are identified between different activities, it is unlikely that co-existence decisions will be straightforward and thus a more detailed assessment will be required to determine appropriate solutions.

4.1.3 Detailed assessment

Where the outcomes of the initial assessment are inconclusive, or where mitigation measures might need to be employed to optimise co-existence, a more detailed assessment could be carried out. This is unlikely to be feasible for marine planning at the regional level at present. Preparation of detailed assessments are more likely to be possible for developers to undertake at the project level as part of marine licensing or when the MMO considers requirements for management measures for MCZs because more information on the specific 'activity' is likely to be available. However, it may be possible to undertake detailed assessments within the marine planning process where this was considered warranted e.g. as a result of a need for specific spatial allocation policies that recommend co-existence/displacement. This is more likely to occur in the long term for specific targeted areas where co-existence is a critical element of planning, provided there was sufficient resources to collect any necessary additional data and/or information to complete the assessment.

It is suggested that the detailed assessment might be undertaken as a four step process, as follows:

- Step 1 - More detailed quantification of potentially significant interactions through the collection of additional information on potential interactions, their impacts and the costs and benefits of such impacts
- Step 2 - Identification of potential mitigation measures for significant impacts – consider mitigation measures that might be implemented to minimise any significant adverse impacts of 'co-existence' and/or 'no co-existence' options
- Step 3 - Monetisation of costs and benefits of impacts associated with 'co-existence' and/or 'no co-existence' options taking account of mitigation measures
- Step 4 - Co-existence decision – making a judgement on the relative strength of co-existence potential to inform marine plan policies where possible and decision making in marine licensing and conservation.

Step 1 – detailed quantification of interactions and impacts

Building on the initial assessment, the detailed assessment would seek to collect/collate additional information on the potential interactions and impacts in order to seek to provide a more detailed estimate of costs and benefits associated with the 'co-existence' and 'no co-existence' options. The information would be documented in the appraisal summary table.

Step 2 – identification of potential mitigation measures

It may be possible to increase the scope for co-existence through adoption of mitigation measures by one or more of the interacting activities. This step would identify potential mitigation measures that might be applied by one or more of the interacting activities, drawing on existing information and/or acquiring additional information (see Section 6 for possible information requirements). This step would need to be taken forward in consultation with the relevant sectoral activities, in particular to determine which mitigation measures might be practical and cost effective.

Step 3 – monetisation of costs and benefits of impacts taking account of mitigation measures

Information on the costs and benefits of the 'co-existence' and 'no co-existence' options taking account of possible mitigation measures would be documented in the appraisal summary table.

Step 4 – co-existence decision

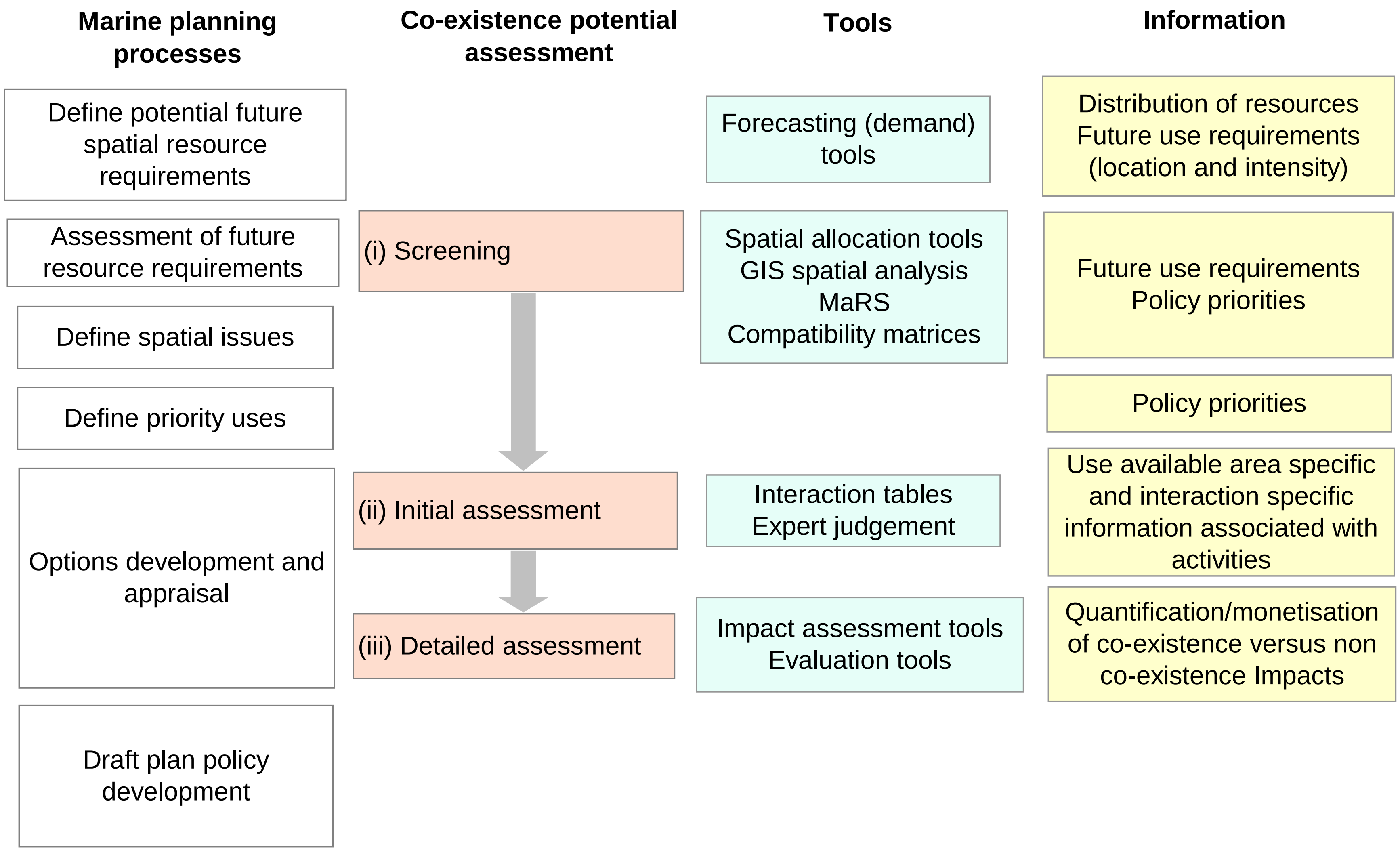
Based on the information provided by the appraisal summary table, a decision would be taken on the scope of any recommended co-existence and any required mitigation measures to minimise adverse impacts. This decision should also take account of any potentially significant wider cumulative effects and site-specific considerations. At present, such an assessment would need to be based on expert judgement.

4.2 Application within marine planning

Figure 5 illustrates how a co-existence assessment process might be applied within the early stages of the marine planning process when initial consideration is given to possible spatial allocations within plan areas. The suggested steps in the process are described below, although it is recognised that marine planning is an iterative process and there is some flexibility in the order and effort applied to individual steps. Furthermore only a subset of existing general planning processes, where they are considered relevant to an assessment of co-existence, are shown on Figure 5. A range of other marine planning processes exist, including analysis of national policy (see Figure 1).

As noted above, the more detailed assessment and some aspects of the initial qualitative assessment are unlikely to be practical for marine planning at present but may become more feasible in the future as data and information holdings grow.

Figure 5: Proposed framework for co-existence assessment within marine planning.



4.2.1 Defining potential future resource requirements

Much of the basic information on existing resource distributions is accessible from existing spatial data holdings managed and maintained by the MMO, and other sources (e.g. Department for Environment, Food and Rural Affairs (Defra), The Crown Estate, Cefas). The initial step of defining potential future resource requirements should involve forecasting how the location and intensity of activities/sectors are likely to vary over time. The South marine plan areas futures analysis project (MMO, 2013c) has started this process for many of the marine activities and further work is in progress for fisheries and aquaculture (MMO, 2013d). The Crown Estate has also undertaken work to predict the future location and intensity of activities/sectors but with a slightly different emphasis. There are few reliable tools for developing future resource demands, but it is possible to get a feel for the future spatial and temporal distribution and intensity of most activities by considering the key drivers of change (MMO, 2013c).

4.2.2 Assessment of future resource requirements and define spatial issues

Plan policies will be applied in certain areas to ensure potential resources are protected and government policy priorities are recognised. This may use tools such as The Crown Estate's MaRS system or other forms of spatial analysis within a GIS environment. Under the proposed framework, such assessments could take account of information on 'hard' constraints in determining areas of potential suitability for future resource exploitation as part of the screening process for co-existence assessment, for example, taking account of the incompatibility between most types of infrastructure when considering co-location (although co-existence may be a more feasible option if the area of resource allows).

The process could also be used to filter out areas subject to significant 'soft' constraints, for example, the MaRS tool uses a weighting and scoring system to identify the relative attractiveness in terms of the distribution and quality of resources of future development areas. However, as noted in Section 3, such assessments of relative compatibility tend to be overly simplistic and are not considered to provide a robust basis for co-existence policies. It is also possible to take account of these 'soft' constraints at later stages in the co-existence assessment process and this may be desirable in order to allow more detailed consideration of co-existence issues at later stages of the process.

Conversely, it would also be possible to seek to integrate consideration of co-existence potential within the initial spatial allocation process by taking account of the likely economic, social or environmental consequences of co-existence at this stage. However, it would not be straightforward to incorporate such an evaluation within a GIS tool owing to the complexity of the interactions and the wide-ranging information requirements for which information may be lacking. For these reasons, this approach is not recommended.

4.2.3 Define priority uses

Where there are competing priorities for the same space, judgements may be required on which activity should be prioritised taking account of Government policy priorities and suitability for specific uses. In this situation, marine planners may look to undertake a screening level assessment and possibly a very high level qualitative assessement to identify strategic benefits and create management areas for co-existence.

Alternatively, when there is no clear steer in national policy about priorities for two activities, it is likely that marine planners would only look to undertake a co-existence assessment at the screening level.

4.2.4 Options development and appraisal

The main co-existence assessment process described in detail in Section 4.1 would sit within the options development process of marine planning and is only likely to be applicable where policies request stronger consideration of co-existence than broad plan level co-existence policies (Figure 5). This proposed framework for co-existence assessment provides for flexibility within the marine planning process where detailed information may be lacking in the short term, but also provides opportunity for more detailed quantitative assessments to be carried out in the longer term if and where required.

Where there are clear Government policy priorities driving the consideration of co-existence, the marine planning processes is likely to focus on undertaking initial assessments if necessary in the short term. This reflects current limitations on the scope for undertaking detailed assessments at the plan level as a result of the relative lack of information and resources available. The initial assessments could either be generic (e.g. based on information in interaction tables and generic information on activities in a plan area) or more area-specific, making use of available spatial data where possible. Confidence in the former would be lower, because most interactions and impacts are location-specific and as such benefit from the availability of area-specific information. However, they may still yield useful information to the marine planning process on the likely scale of interactions and impacts and thus the strategic benefits of co-existence at a high level.

It may be possible to undertake detailed assessments within the marine planning process where this was considered warranted. This is more likely to occur in the long term, provided there was sufficient resources to collect any necessary additional data and/or information to complete the assessment. Such assessments might then be used to inform more prescriptive plan policies where necessary, alongside other assessments and stakeholder engagement, to help drive sustainable use of the marine environment.

4.2.5 Draft plan policy development

The results of the co-existence assessment would feed into draft plan policy development. Levels of uncertainty associated with the outcome of a co-existence assessment carried out as part of the marine planning process will need to be taken into account in the co-existence policy for that area.Where the information was sufficiently robust and the output of a co-existence assessment identifies significant potential for co-existence, it would be possible to frame a location specific co-existence policy within a marine plan. In the absence of location specific data, the use of interaction tables could inform broader plan policies relating to co-existence potential between various activities and interests. Therefore, in circumstances where co-existence potential was less certain but still desirable, it would be possible to include a broader policy which encouraged consideration of co-existence potential at the project level. While such policies might be less spatially explicit, they could still be of value in guiding the location of future development.

It is important to note that some marine planning processes will be undertaken to potentially protect spatial resource areas as a result of other drivers not necessarily directly related to co-existence (e.g. ecosystem services, resource protection). The production of spatial allocation policies will occur only where particular general marine planning processes are undertaken and as determined by the specific drivers concerns. Where specific processes are not undertaken, broader policies will by necessity be written into the plans. If the aim in planning is to spatially allocate where necessary, then it may be that prioritised activities should be identified within specific spatial allocation policies for a given area to ensure other activities allow for their current or potential future presence.

The plan policies, whether broad or specific, will define the approach developers may need to take in evaluating the potential for co-existence at the project-level when submitting applications (see Section 4.3).

4.3 Application within marine licensing

The intial and detailed co-existence assessment processes are potentially particularly applicable when co-existence issues are being considered as part of marine licensing (Figure 6), i.e. at the project level. At present there is no specific requirement to consider co-existence as part of marine licence applications, although some applicants do so on a voluntary basis. However, if co-existence policies are included more widely in marine plans and/or wider Government policy then there would be a stronger driver on developers to undertake a co-existence assessment as part of the pre-application stage of the marine licence application process (e.g. screening/scoping). As discussed under Sections 2.2 and 2.3, although some co-existence assessment may be undertaken at the plan level, significantly more site specific information would be available at the project stage concerning the details of developments and their interactions with other human activities or the natural environment to inform judgements on co-existence.

The draft East marine plans (MMO, 2013a) have included general policies promoting co-existence (GOV 2) and minimising displacement (GOV 3). It is important to note, however, that at the time of writing this report these marine plans were being updated following public consultation which ended on 8 October 2013. The draft policies that were included on co-existence may therefore be subject to change following the outcomes of the public consultation process.

If policy drivers are put in place it may be appropriate for the MMO to provide high level guidance, in consultation with relevant stakeholders, on expectations for consideration of co-existence issues (MMO, 2013e). This may also include information on potential enhancement or mitigation measures, proportionate expectations, and the possible benefits of co-existence. Thus, where marine plans contain general policies promoting co-existence, such as the policies in the draft East marine plans (MMO, 2013e), the MMO could notify applicants at screening or scoping stage of the need to consider co-existence issues in relation to a particular development and also highlight the key co-existence issues that the MMO considers to be relevant based on the high level guidance.

It is likely that applicants would be responsible for considering co-existence issues for their project although this should be considered in a proportionate manner, i.e. given the scale of proposed projects/activities. It may be that applicants could undertake an initial assessment at the screening/scoping stage making use of information on the potential interactions. Further and more detailed assessment could be undertaken, if required, and submitted alongside or as part of the assessment stage of the pre-application EIA.

Where mitigation measures were required to support co-existence as under marine plan policies, these could be incorporated within marine licences. For example, conditions are already included in marine aggregate and offshore renewables licences in relation to fisheries liaison to ensure that unnecessary disruption to commercial fishing activities in or around licensed areas for aggregate extraction and renewable energy is minimised.

Where potentially significant economic, social or environmental impacts were identified as part of an EIA or co-existence assessment, the MMO could include monitoring requirements within marine licences to verify impact predictions. Data collected through such monitoring might also help to inform future assessments of and decisions on co-existence although data management strategies would require careful consideration.

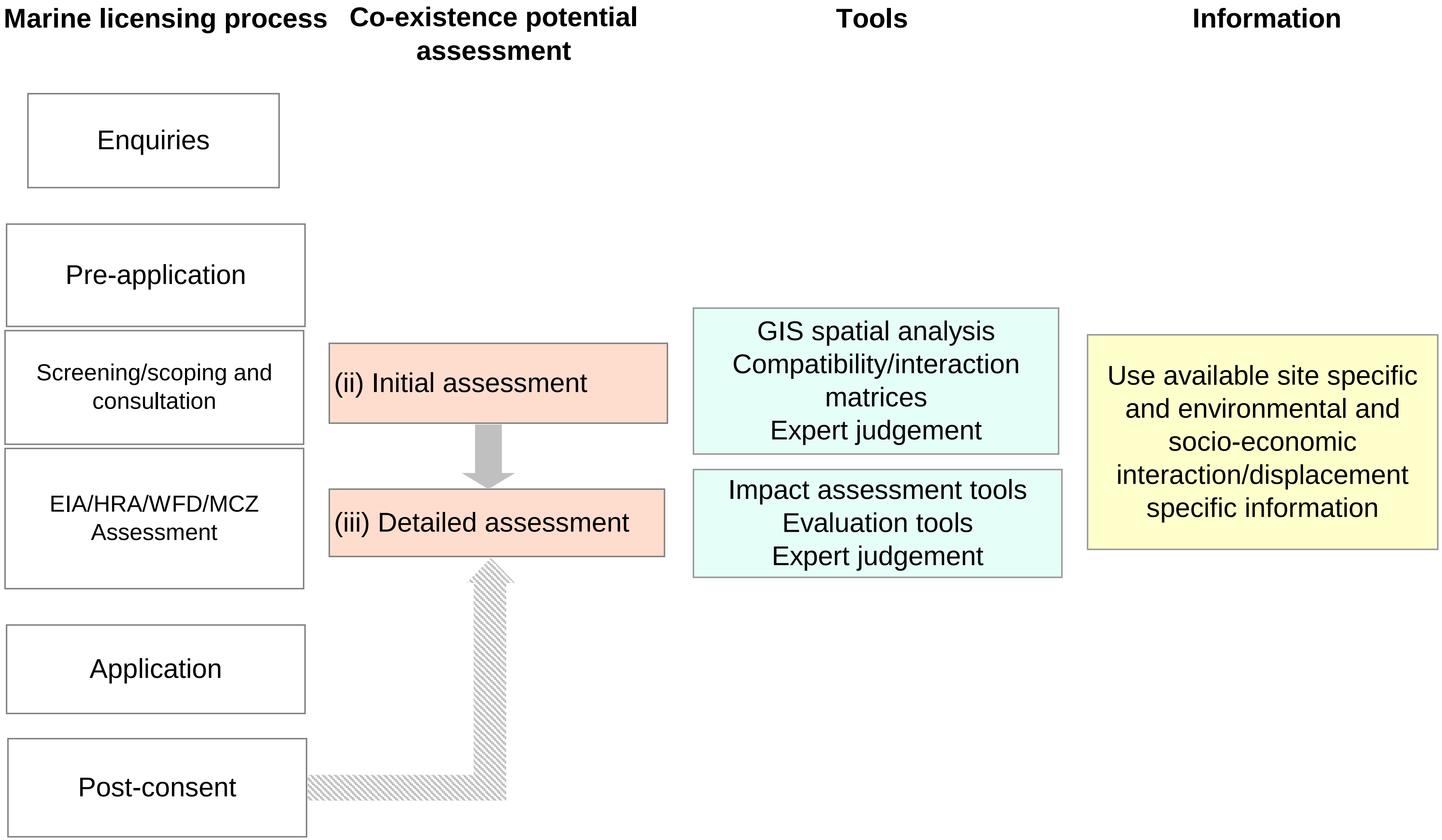
4.4 Application within marine conservation

The consequences and opportunities for co-existence could be taken into account when considering requirements for management measures within MPAs[10], provided that they do not affect the MMO's legal obligation of meeting the MPA conservation objectives (Figure 7). However, as noted under Section 2.4, although management measures would not look to unnecessarily preclude activities where the activities would not pose a significant risk, management measures could not be developed as a means to encourage co-existence.

These processes are already fairly well developed, for example, the risk assessment process adopted to identify the potential compatibility of human activities with feature-specific conservation objectives for MCZ (Natural England and JNCC, 2011) and the process for assessing commercial fisheries compliance with the requirements of Article 6 of the Habitats Directive within Special Areas of Conservation (Defra, 2013). The processes make use of information on the sensitivity of MPA features to human pressures, for example the MCZ pressures-features sensitivity matrix (Tillin *et al.*, 2010), and assessments of the exposure of features to the relevant pressures as part of an overall vulnerability assessment.

[10] In English waters this network comprises European sites and MCZs. European sites include Special Areas of Conservation (SACs) and Special Protection Areas (SPAs).

Figure 6: Proposed framework for co-existence assessment within marine licensing.

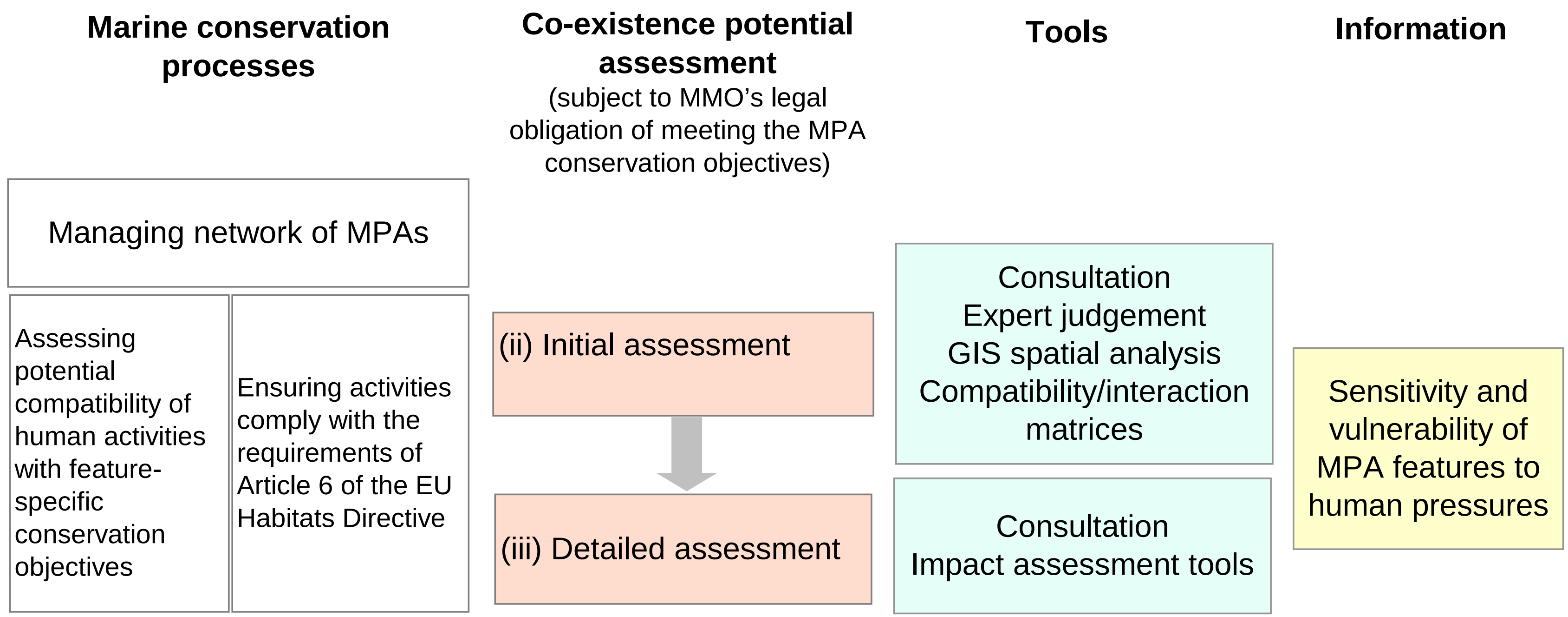


While these processes primarily focus on the compatibility between human activity and feature specific conservation objectives, the increasing requirement to undertake impact assessments to inform policy interventions, also means that such assessments often also include a cost benefit assessment, similar to the proposed framework and process for co-existence assessment. The consideration of potential benefits associated with the protection of conservation features within MPAs is challenging owing to the paucity of valuation data. Increasingly, ecosystem services tools are being used to describe potential benefits, for example Finding Sanctuary *et al.* (2012) and Marine Scotland (2013a).

Given the challenges of assessing the impacts associated with the protection of conservation features, consultation will continue to be an important tool to work through any potential compatibility issues.

While much of the current focus for interaction with conservation features is centred on MPAs, the approach is also applicable when considering wider ecosystem objectives within the context of marine planning (ABPmer, 2010b). Thus, where broader environmental objectives and targets have been established, for example, MSFD indicators and targets, it would be possible to adopt similar approaches within marine planning to those applied to MPAs when considering the potential for human activities to co-locate or co-exist with particular environmental receptors. Outputs from such a process could be used to evaluate the extent to which such co-existence may or may not support achievement of the relevant objectives and targets. In order to implement such an approach, it may be necessary to extend the range of environmental features for which sensitivity information is available.

Figure 7: Proposed framework for consideration of co-existence within marine conservation management.



5. Case Study Application of Proposed Framework

This case example is based on a hypothetical proposal for an offshore wind zone in coastal waters (see Figure 8) and its interaction with hypothetical commercial fishing interests. The case study illustrates the application of an initial co-existence assessment for these two potentially competing interests. Full application of the framework could involve consideration of interactions with other human activities and between human activities and the natural environment as well as possibly undertaking a detailed assessment.

In this hypothetical example, the proposed zone for offshore wind development overlaps with significant commercial fishing interests including beam trawling for flatfish and potting for lobster and crab. It also intersects a number of routes taken by fishing vessels to their fishing grounds.

5.1 Co-existence assessment

Assessment through all steps of the general co-existence assessment framework are shown for the purpose of this hypothetical case study.

5.1.1 Step 1 – identification of relevant activities

The relevant activities considered in the case study are offshore wind development and commercial fishing. As the hypothetical zone is in the initial planning stages, there is no detailed information on design or layout, export cable routes or landfalls.

5.1.2 Step 2 - identification of potential interactions

The nature and scope of interactions between offshore wind development and commercial fisheries are complex and varied. In order to illustrate the potential complexity of interactions and how they might be evaluated, Tables 2 to 4 present a subset of the most critical hypothetical interactions between the commercial fisheries and the offshore renewables sectors as a case example. Tables 2 and 3 indicate how both the commercial fisheries sector and offshore renewables respectively sector might be economically affected both by ‘co-existence’ and ‘no co-existence’ options. The potential social and environmental consequences of the key interactions between both sectors and under ‘co-existence’ and ‘no co-existence’ options are the same and therefore these have been presented within a single table (Table 4). While, for commercial fisheries, many of the interactions are likely to be similar under both ‘co-existence’ and ‘no co-existence’, the relative significance of the impacts may vary. It is important to note that in this case example, the majority of significant impacts are environmental, however, this may not be the case for other interactions between activities.

5.1.3 Step 3 - collation of readily available information

It has been assumed for the purposes of the case study that information is available on the distribution of fishing effort and value by gear type.

5.1.4 Step 4 – identification of potentially significant interactions

For the purposes of this case study it has been assumed that all of the interactions presented in Tables 2-4 are potentially significant, given the limited availability of information.

5.1.5 Step 5 – estimation of scale of impacts from potentially significant interactions

Estimates of the scale of impacts have been made based on information relating to the nature and scale of fishing activity and experience with similar interactions elsewhere. These have been documented in the appraisal summary table (Table 5).

5.1.6 Step 6 – monetisation of impacts using readily available information

In this case example, available information on the economic value of commercial fisheries has been used to estimate a value for potential landings foregone, but this is considered an optional step for the initial assessment. Information on the costs of similar interactions elsewhere has also been used to estimate economic impacts associated with some interactions for the offshore wind and commercial fisheries sectors.

5.1.7 Step 7 – comparison of 'co-existence' and 'no co-existence' options and decision on relative scope for co-existence

A summary of the potential costs and benefits is presented in Table 5. It would be possible to incorporate this information within a partial cost benefit assessment by converting loss of fish landings into Gross Value Added (GVA), where reductions in landings may lead to a reduction in final output, and estimating the impact on the fisheries supply chain using standard economic input-output multipliers, but this may not be necessary within an initial assessment.

The most significant potential impacts identified in this hypothetical case study are likely to be the potential loss of fish landings for the commercial fisheries sector and the potential cost of cable repairs for the offshore renewables sector. It should be noted that loss of landings is likely to occur under both the 'co-existence' and 'no co-existence' options because commercial fishing activity will be excluded from within safety zones around turbines and the presence of OWF structures and cables has the potential to affect the fishing suitability of the area. However, the loss of landings is likely to be much greater under the 'no co-existence' option.

While many of the potential impacts may not be quantifiable at the initial assessment stage, the presentation of information on the likely relative scale of impacts is helpful in identifying the potential impacts of the options.

In the case example, the main differences between the 'co-existence' and 'no co-existence' options are that the offshore renewables sector might experience greater impacts in the 'co-existence' option, associated with repairs to damaged cables, but more support from marine users, as well as potentially longer term benefits. The fishing sector (and in turn the supply chain and market), on the other hand, might experience greater impacts under the 'no co-existence' option as a result of a much larger reduction in landings values (offset to some extent by a larger payment to fishermen). However, in both options, one or more interests is likely to experience significant impacts and thus the scope for full co-existence is limited and would require significant mitigation measures.

Figure 8: Co-existence case example.

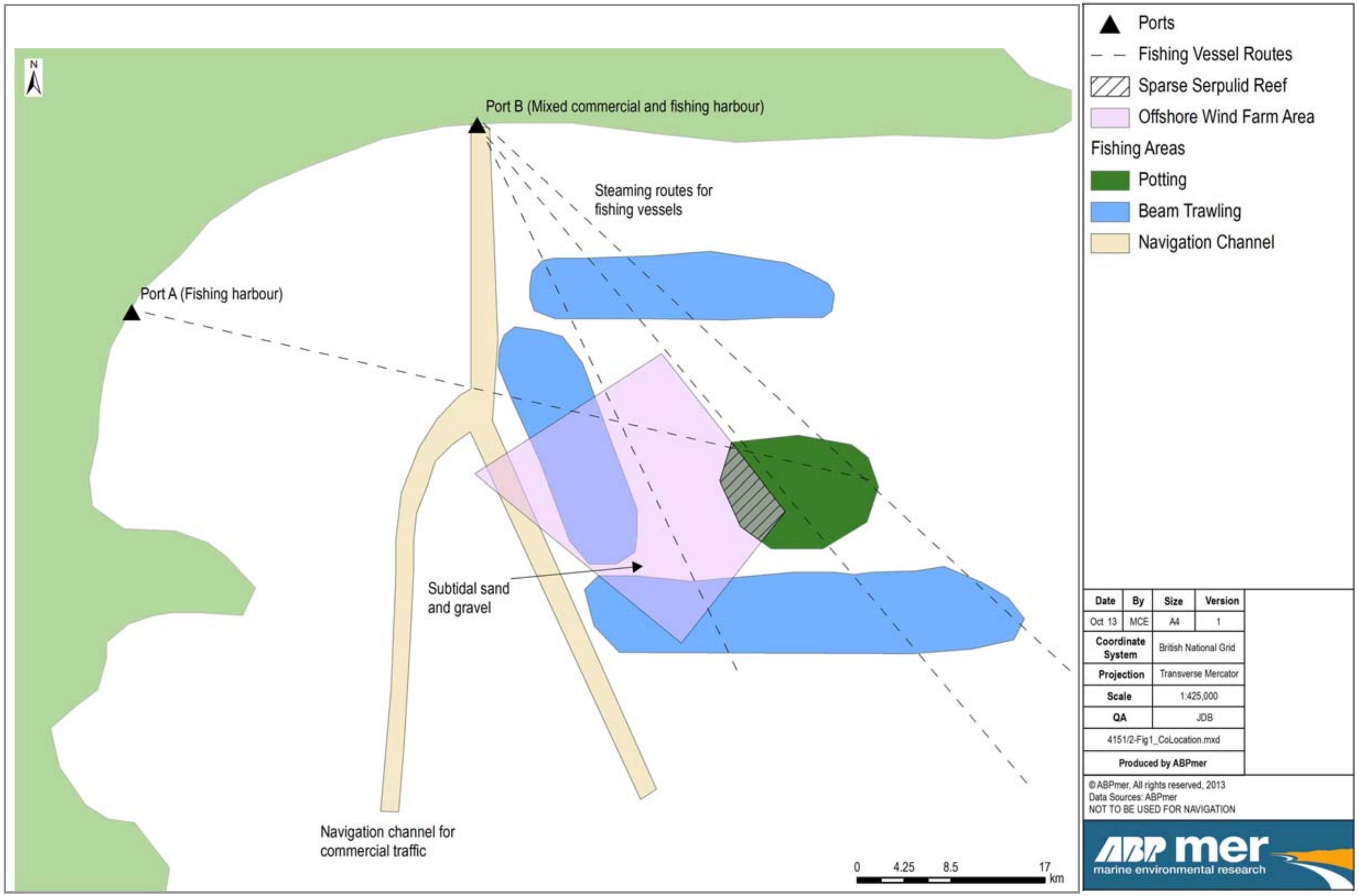


Table 2: Potential economic consequences for commercial fisheries of interactions with offshore renewables[11].

a) Potential consequences of co-existence

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Direct Economic Impacts	Physical obstruction or displacement associated with arrays/substations, intra-array cables or export cables	Exclusion (safety zones) around devices during construction/ operation	Reduced landings (reduced effort)	Estimate of loss of landings	Size/location of exclusion zones; high resolution spatial data on fish landings
		Less suitable fishing grounds (disruption to existing tows/drifts/pot strings) caused by construction or support vessels, devices or cables during construction/ operation	Reduced landings (less efficient effort) or increased costs to maintain landings	Estimate of loss of landings as a result of reduced Catch Per Unit Effort (CPUE) Estimate of additional effort to maintain landings (time/fuel costs)	Scale of disruption to existing tows/ drifts/pot strings; estimate of impact on landings; Employment costs, fuel costs
		Displacement due to increased competition for grounds within arrays or to reduced fishing suitability of grounds during construction/ operation	Reduced landings (conflict in areas to which fishing activity is displaced)	Estimate of cost of displacement interactions	Scale of potential displacement; locations where effort is displaced to; information on existing fishing activity in displacement locations; outcomes of interactions in displaced areas
		Damage to gears during construction	Cost of gear damage	Estimation of frequency of	Information on frequency of

[11] This is not a complete list of interactions but a subset of potentially critical interactions (during construction and operation) and resulting impacts for illustrative purposes only.

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
		and operation		occurrence and average cost of damage	occurrence of gear damage; average cost of gear damage
	Change in navigation risk	Displacement of fishing vessels transiting to and from fishing grounds during construction/operation	Increased fuel/time costs steaming to and from fishing grounds	Estimate number of trips and increased steaming distances/times. Estimate average fuel/labour costs	Scale and frequency of increased steaming distances/time; average fuel and labour costs
		Increased insurance premiums during operation	Increased insurance premiums	Obtain evidence of changes in insurance premiums (in similar circumstances)	Information on changes in insurance premiums
	Changes in harbour facilities	Displacement of fishing vessels from home ports during construction/ operation	Increase/decrease in costs associated with relocating to new home port; changes in steaming distances to and from fishing grounds	Evidence of impacts in similar circumstances	Average additional costs per vessel displaced
		Less suitable facilities/better facilities	Increased turnaround times or improved access/facilities	Evidence of impacts in similar circumstances	Number of vessels affected; average increase/decrease in costs per vessel
		Higher/lower cost of facilities	Increased or reduced harbour dues	Evidence of impacts in similar circumstances	Number of vessels affected; average increase/decrease in costs per vessel

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
	Use of fishing vessels for O&M support	Additional income, employment	Additional income, employment	Evidence of impacts in similar circumstances	Number of vessels affected; average additional income per vessel; use of economy statistics (e.g. Type 1 multipliers) to assess employment effect
Indirect Economic Impacts	Changes in fish/shellfish stocks	Negative or positive changes in fish stocks as a result of impacts to spawning/nursery habitats or to fish populations during construction and/or operation	Reduced landings Increased landings	Evidence of impacts in similar circumstances	Estimated impact on landings
Consequential Economic Impacts	Supply chain to fishing businesses	Reduced activity in supply chain due to decreased fishing activity and/or success	Reduced expenditure in supply chain	Estimated impacts to supply chain based on estimated impacts to fish landings	Estimated impacts to fish landings; use of economy statistics to assess supply chain impact
	Wholesalers/fish processors	Reduced availability of local fish to wholesalers /processors	Reduced income to wholesalers/ processors if cannot obtain fish from elsewhere	Evaluate possible reductions in income and test significance	Estimated reduction in landings; dependence of wholesalers/ processors on local landings

b) Potential consequences of no co-existence

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Direct Economic Impacts	Arrays/substations; intra-array cables; export cables	Reduction in fishing effort	Reduced landings as a result of reduced effort	Estimate of value of loss of landings	Scale of potential displacement; locations where effort is displaced to; information on existing fishing activity in displacement locations; outcomes of interactions in displaced areas
		Displacement of fishing effort during construction/ operation	Reduced landings as a result of conflicts in areas to which fishing activity is displaced Increased/decreased costs associated with changes in steaming distances	Estimate of value of reduction in landings	Scale of potential displacement; locations where effort is displaced to; information on existing fishing activity in displacement locations; outcomes of interactions in displaced areas
		Damage to gears during operation in displaced areas due to reduced sea space for fishing activities	Cost of gear damage	Estimation of frequency of occurrence and average cost of damage	Information on frequency of occurrence of gear damage; average cost of gear damage

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
	Change in navigation risk	Displacement of fishing vessels transiting to and from fishing grounds during construction/ operation	Increased fuel/time costs steaming to and from fishing grounds	Estimate number of trips and increased steaming distances/times. Estimate average fuel/labour costs	Scale and frequency of increased steaming distances/time; average fuel and labour costs
		Increased insurance premiums during operation	Increased insurance premiums	Obtain evidence of changes in insurance premiums (in similar circumstances)	Information on changes in insurance premiums
	Changes in harbour facilities	Displacement of fishing vessels from home ports during construction/ operation	Increase/decrease in costs associated with relocating to new home port; changes in steaming distances to and from fishing grounds	Evidence of impacts in similar circumstances	Average additional costs per vessel displaced
		Less suitable facilities/better facilities	Increased turnaround times or improved access/facilities	Evidence of impacts in similar circumstances	Number of vessels affected; average increase/decrease in costs per vessel
		Higher/lower cost of facilities	Increased or reduced harbour dues	Evidence of impacts in similar circumstances	Number of vessels affected; average increase/decrease in costs per vessel

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
	Use of fishing vessels for O&M support	Additional income, employment	Additional income, employment	Evidence of impacts in similar circumstances	Number of vessels affected; average additional income per vessel; use of economy statistics to assess employment effect
Indirect Economic Impacts	Changes in fish/shellfish stocks	Negative or positive changes in fish stocks as a result of impacts to spawning/nursery habitats or to fish populations during construction and/or operation	Reduced landings Increased landings	Evidence of impacts in similar circumstances	Estimated impact on landings
Consequential Economic Impacts	Supply chain to fishing businesses	Reduced activity in supply chain due to decreased fishing activity and/or success	Reduced expenditure in supply chain	Estimated impacts to supply chain based on estimated impacts to fish landings	Estimated impacts to fish landings; use of economy statistics to assess supply chain impact
	Wholesalers/fish processors	Reduced availability of local fish to wholesalers /processors	Reduced income to wholesalers/ processors if cannot obtain fish from elsewhere	Evaluate possible reductions in income and test significance	Estimated reduction in landings; dependence of wholesalers/ processors on local landings

Table 3: Potential economic consequences for offshore renewables of interactions with commercial fisheries[12].

a) Potential economic consequences of co-existence.

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Direct economic Impacts	Damage to infrastructure	Impact to devices (primarily more of an issue for wave and tidal)	Cost of repair Loss of revenue Cost of payments to fishermen for gear damage	Evidence of impacts in similar circumstances	Information on frequency of occurrence of impacts; average cost of impacts
		Impact to intra-array or export cables	Cost of repair Loss of revenue Cost of payments to fishermen for gear damage	Evidence of impacts in similar circumstances	Information on frequency of occurrence of impacts; average cost of impacts
	Exclusion of fishing activity within safety zones	Cost of payments to fishermen for loss of fishing grounds (safety exclusion zones)	Cost of payments to fishermen	Information of payments in similar circumstances	Information on payments
	Delays caused by fishing vessels or gear being in the proximity of operations	Reduced efficiency of operations	Costs If additional vessel monitoring Costs of delayed operations	Evidence of impacts in similar circumstances	Information on frequency of occurrence of impacts; average cost of impacts

[12] This is not a complete list of interactions but a subset of potentially key interactions (during construction and operation) and resulting impacts for illustrative purposes only.

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Indirect Economic Impacts	None identified				
Consequential Economic Impacts	None identified				

b) Potential economic consequences of no co-existence.

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Direct Economic Impacts	Payments to community projects or to fishermen not to fish within arrays or along export cable routes	Cost of payments to community projects or to fishermen	Cost of payments to community projects or to fishermen	Information of payments in similar circumstances	Information on payments
Indirect Economic Impacts	None identified				
Consequential Economic Impacts	None identified				

Table 4: Potential social and environmental consequences of interactions between offshore renewables and commercial fisheries[13].

Interaction		Potential impact	Potential socio-economic consequence	Assessment methods	Potential information requirements
Social Impacts	Changes in employment	Reduction in employment in fishing industry and associated social impacts	Reduced income and value of fishing industry	Evaluate possible reductions in income and test significance	Estimated reduction in landings; employment costs. Information on relevant social demographics and their response to change
Environmental Impacts	Changes to benthic habitats	Negative or positive changes to benthic habitats in areas excluded or in previously unfished areas during construction and/or operation	Reduced landings Increased landings	Evidence of impacts in similar circumstances	Size/location of exclusion zones; scale of potential displacement; locations where effort is displaced to; information on existing fishing activity in displacement locations; estimated footprint of impact on benthic habitats

[13] This is not a complete list of interactions but a subset of potentially key interactions (during construction and operation) and resulting impacts for illustrative purposes only.

Table 5: Appraisal summary table of hypothetical impacts for 'co-existence' and 'no co-existence' options for commercial fisheries and offshore renewables[14].

Impacts	Costs/ benefits	Co-existence	No co-existence
Economic impacts on commercial fisheries	Costs	Value of loss of landings = £103k p.a. Extended steaming distances to fishing grounds Increased/decreased costs associated with harbour – not assessed, but likely to be same in both options Reduction in supply chain expenditure (based on £103k p.a. loss of landings) Minor impact to wholesalers/processors	Value of loss of landings = £700k p.a. Extended steaming distances to fishing grounds – impact greater than for co-existence Increased/decreased costs associated with harbour – not assessed, but likely to be same in both options Reduction in supply chain expenditure (based on £700k p.a. loss of landings) Moderate impact to wholesalers/processors
	Benefits	Negligible benefit to fish/shellfish stocks One-off payment to fishermen of £500k Minor benefit from provision of O&M services	Possible long-term minor benefit to fish/shellfish stocks One-off payment to fishermen of £2.5m Minor benefit from provision of O&M services
Economic impacts on offshore renewables	Costs	One-off payment to fishermen of £500k Cost of repair to cables £5m every 10 years Cost associated with requirements to monitor/manage activities and reduced operational efficiency	One-off payment to fishermen of £2.5m
	Benefits	-	-
Social impacts	Costs	Minor local impact associated with reduction in employment in fishing industry and associated	Slightly larger but still minor impact associated with reduction in employment in fishing industry and

[14] This is not a complete list of impacts and associated costs and benefits but a subset of those considered relatively important for demonstrative purposes only.

Impacts	Costs/ benefits	Co-existence	No co-existence
		supply chains	associated supply chains
	Benefits	-	-
Environmental impacts	Costs	Minor impact to previously unfished habitats	Minor impact to previously unfished habitats
	Benefits	-	Minor benefit to previously fished habitats within offshore windfarm (OWF) zone

6. Defining Information Requirements

A wide range of spatial and non-spatial data and information is likely to be required to characterise and assess potential interactions and impacts which may inform decisions on co-existence, based on the framework proposed in Section 4. The types of information required will include economic, environmental and social data.

Some of this information will be relevant nationally, but a significant proportion is likely to be site specific. The precise details of the information required will also reflect the choice of tools that are used to process data (see Section 3). Some of the information may be derived from modelled data which incorporates various simplifying assumptions and there will therefore be a level of uncertainty associated with the outcomes of co-existence assessments which will need to be taken into account in decision-making. The level of uncertainty will vary depending on the nature of the activities and interactions being considered, the data and information used to inform the assessment, and any simplifying assumptions used in the analysis.

In order to manage risks in the MMO decision-making processes, it will be important to adequately document the quality of data and information used in co-existence assessments together with any assumptions that have been used in the analysis. This can be achieved through adherence to existing MMO quality assurance protocols (MMO, 2012).

This section reviews the potential information requirements that the MMO might require to support screening and application of the main co-existence assessment framework. An overview of the main types of spatial data layers and non-spatial information that might be required to support the identification of economic, environmental and/or social interactions between human activities is presented. These should not be viewed as definitive lists.

6.1 Information to support screening

Data layers on 'hard' constraint areas and information on specific human activities that will be constrained are required to support screening for the purposes of marine planning. The types of data layers required include:

- Statutory exclusion zones around certain offshore installations (e.g. oil and gas and offshore renewables installations)
- Safety and operational efficiency zones around cables and pipelines (these are guideline distances)
- Safety zones around construction activities
- Protection zones around marine historic environment assets.

Many of these data layers should already be available to the MMO or be available within the MaRS tool which already includes a mechanism for identifying 'hard' constraints.

Some further additional work will be required to identify those Marine Policy Statement activities that would/would not be constrained within these areas.

6.2 Information to support application of main co-existence assessment framework

6.2.1 Spatial information

Spatial information is of particular importance in identifying potential interactions between human activities or between human activities and the natural environment and in quantifying the spatio-temporal extent/magnitude of such interactions as a precursor to assessing impacts and estimating costs and benefits.

Different types of spatial information will be required to identify economic and environmental interactions, described below. Based on the proposed framework, spatial data on social interactions would not be required, as social impacts would be assessed as a consequence of economic or environmental impacts. Social data may, however become necessary if the indicator framework methodology proposed by the MMO (2013g) is integrated into the process.

The MMO already maintains a geodatabase containing a wide range of spatial data layers to inform marine planning and marine licensing. There are also other potentially available sources of information held by other organisations (e.g. Defra, The Crown Estate and Cefas). A recent review of marine social and economic data also produced a catalogue of spatial data layers (MMO and Marine Scotland, 2012). Most of these spatial data sets will be made available through the European Directive 2007/2/EC known as 'INSPIRE'.

The types of spatial data layers that the MMO might require to support to identification of economic interactions between human activities and environmental interactions between human activities and the natural environment are summarised in Tables 6 and 7 respectively and include the current main limitations associated with these layers.

Table 6: Types of spatial information requirements to inform economic interactions.

Information requirements	Examples	Limitations
Distribution and intensity of current human activities.	Locations and rates of natural resource extraction, fish landings by gear type, etc.	Data layers identifying the distribution and intensity of some human activities are currently quite limited (for example, inshore fishing effort, recreational activities, tourism, commercial navigation[15], cables and pipelines). The positional accuracy and spatial resolution of human activity data is also variable. Fixed infrastructure tends to be accurately charted owing to the navigation risk and is spatially well-resolved. The spatial representation of commercial fishing activity is often at a coarser scale (commonly 1/200th International Council for the Exploration of the Sea (ICES) rectangle for Vessel Monitoring System (VMS) data for >15m vessels) and at variable scales for <15m vessels. The positional accuracy of commercial fishing activity for the <15m fleet is also much less well defined than for the >15m fleet, although the 12-15m fleet must also have had VMS fitted as of November 2012. The location and intensity of commercial fishing activity is also variable over time, meaning that information can be quite rapidly out of date. The Crown Estate's UK Fisheries Information Mapping project may be able to provide some of this information.
Distribution and intensity of potential future human activities.	Future proposed developments in The Crown Estate lease areas where this information is available, South Marine Plan Areas Futures Analysis (MMO, 2013c), marine aggregate, fish stocks and their habitat requirements as an	The future distribution and intensity of many human activities is inherently uncertain. Modelled layers for some activities have been developed, for example, the locations of future offshore renewables development can be indicated based on planned development areas or areas for which The Crown Estate has issued leases, but these incorporate various simplifying assumptions and are therefore uncertain and subject to change. The availability of resource and the feasibility of developing in certain areas has also been looked at, for example in the UK Wave and Tidal Key Resource Areas Project (The Crown Estate, 2012). However, for many activities, the location and intensity of activity is unlikely to change significantly over short time scales and maps of current activity can provide a reasonable indication of the future (say 5 to 10 years).

[15] For example, the MMO AIS project has addressed this for South plan areas (MMO 2013f)

Information requirements	Examples	Limitations
	ecosystem service resource to the fishing industry and aquaculture potential layers.	
Distribution and intensity of current and potential future human pressures.	Ongoing work by Cefas and JNCC to develop fishing pressure layers; Defra MSFD Business As Usual (BAU) Report layers (ABPmer and eftec, 2012).	These layers all tend to be modelled layers based on simplifying assumptions about the distribution and intensity of pressures associated with human activities. They are subject to limitations and uncertainties associated with the underlying data on the distribution of human activities. The main focus to date has been in relation to mapping the distribution of pressure associated with bed-disturbing fishing activity (e.g. Vanstaen *et al*., 2010), although other spatial layers exist for other forms of physical disturbance or for changes in habitat type (associated with marine structures), for example, ABPmer and eftec (2012). Aggregate extraction activity maps are also available which provide information on the intensity of dredging within licensed areas over a period of a year.

Table 7: Types of spatial information requirements to inform environmental interactions.

Information requirements	Examples	Limitations
Distribution and intensity of current and potential future human pressures.	Fishing pressure layers; Defra MSFD BAU Report layers (ABPmer and eftec, 2012).	As per economic interactions in Table 6.
Distribution of physical/ecological features.	EU SeaMap; MB0102 MPA data layers (ABPmer, 2013a) as updated through MCZ Regional Projects and Statutory Nature Conservation Bodies (SNCBs).	While considerable progress has been made in mapping and modelling the distribution of ecological features, the quality of seabed habitat maps remains patchy as modelled maps are subject to significant limitations owing to the quality of underlying sediment data and the spatial resolution of such maps. Detailed maps of seabed habitats currently exist for only around 10% of UK seas (Cefas and ABPmer, 2010). The quality of information on the distribution of mobile ecological features (fish, birds, marine mammals) is also spatially variable, reflecting differing levels of survey effort within UK seas. While broad-scale databases such as the European Seabirds at Sea (ESAS) database and the Atlas of Cetacean Distribution in North West European Waters (Reid *et al.*, 2003) and the Small Cetacean Abundance in the North Sea and Adjacent waters (SCANS) and SCANS-II (SCANS-II, 2008) for marine mammals provide some information on feature distributions, their limitations to inform detailed assessments are widely acknowledged.
Information on the health/quality of ecological features.	SNCB site condition reports; modelled layers based on pressure distributions and feature sensitivity.	Information on the health/quality of ecological features within UK seas is generally weak and patchy. Some information for MPAs is available from SNCB site condition monitoring reports. Assessments under the Water Framework Directive also provide some information on the ecological quality of transitional and coastal waters (within 1nm of the territorial baseline). Charting Progress 2 (UKMMAS, 2010) provided an overall assessment of the state of six broad-scale habitat types in UK seas based on expert judgement. Assessments based on modelling pressures and taking account of feature sensitivity have also been undertaken (e.g. ABPmer and eftec, 2012), but these are subject to many limitations and uncertainties.

Improving the availability of spatial data
The marine planning process provides an opportunity to collect additional information on activities within plan areas and to consider potential future use requirements. However, there is likely to be benefit in developing improved national data layers for some existing activities, particularly inshore fishing, commercial shipping and cables.

There is an ongoing programme of work through the Healthy and Biodiverse Seas Evidence Group (HBDSEG) to develop key pressure layers for UK seas commencing with fisheries pressures. The programme is led by JNCC and should deliver a series of priority pressure layers over the next few years.

There are a number of ongoing studies to improve the quality and presentation of seabed habitat maps for UK seas through projects such as Marine Environmental Mapping Programme (MAREMAP), the work to improve the evidence base for MCZ designation and the HBDSEG sub-group on Habitat Mapping. Within marine plan areas, consideration should be given to creating the best possible seabed habitat maps using existing data. Improving the quality of existing habitat maps will be important in seeking to adopt an ecosystem-based approach, as existing habitat maps are generally inadequate to inform plan-making.

Similarly, in order for marine plans to adequately take account of mobile species interests (birds, mammals and fish), the quality of information on the spatial distribution and functional use of marine areas needs to be improved.

Over the next five to ten years the quality of spatial data layers should improve considerably which, in turn, will improve the confidence in co-existence assessments prepared using the framework.

6.2.2 Non-spatial information
A wide range of non-spatial information is likely to be required in order to assess and quantify the costs and benefits of impacts associated with the interactions identified using spatial data (see below). Additional information might then be required to inform the consideration of potential mitigation measures when seeking to ‘optimise’ co-existence, particularly within the context of marine licensing or marine conservation decisions. The types of information required will vary considerably depending on the nature of the impact – economic, environmental or social.

Economic impacts
A range of economic impacts may arise from interactions between human activities, for example, as a result of displacement of one activity by another, impacts to the operational efficiency of activities or requirements to implement mitigation measures to maintain operational efficiency. If a quantitative assessment is required, a wide range of information will be required to inform the assessment of such impacts and compare ‘co-existence’ and ‘no co-existence’ options.

By way of example, based on the hypothetical commercial fisheries and offshore wind zone case example provided in Section 5, the following list of non-spatial information can be identified as potentially being required to inform an assessment of the economic costs and benefits of ‘co-existence’ and ‘no co-existence’ options:

- Understanding of potential behavioural responses of fishermen to offshore developments, spatial restrictions or other management changes (likely to be site specific response)
- Potential outcomes of gear conflicts associated with fisheries displacement (likely to be site specific response)
- Fuel, labour and other running costs for fishing vessels (ideally for a range of different sizes and types of vessels)
- Frequency of gear fouling events (likely to be site specific, for example, depending on exposure of cables)
- Average cost of repair/replacement for fishing gears
- Frequency of damage to power cables (likely to be site specific, depending on degree of cable burial and sediment stability)
- Potential increases in insurance premiums (changed navigation risk)
- Potential displacement of fishing vessels from home ports as a result of changes in access, facilities or costs (likely to be site specific)
- Scale of use of fishing vessels to support O&M activities and associated income (likely to be site specific)
- Value of ecological benefits to fish populations (improvement in spawning or nursery habitat quality and/or increase in exploitable fish stocks)
- Structure of downstream supply chain (wholesalers/processors) and their dependence on fish from particular fishing grounds (likely to be site specific)
- Value of payments to fishermen from offshore wind developers (likely to be site specific, but an average value could be used for planning purposes where necessary).

While this represents the initial list of information considered to be relevant to assess potential economic impacts as a result of interactions between commercial fisheries and offshore renewables, it may not be necessary to collect all of this information for individual sites, particularly where such impacts are considered to only give rise to minor costs. The application of an incremental approach to assessment should help to minimise the collection of unnecessary information at the project level.

Should discussions proceed to identify additional mitigation measures to facilitate co-existence, this might require information on a range of additional issues, for example:

- Costs of alternative cable burial and maintenance strategies
- Costs of alternative array layouts (e.g. greater spacing of turbines)
- Costs of alternative scour protection technologies
- Costs of purchasing and converting vessels to using alternative fishing gears or divers
- Economic viability of alternative fishing gears/methods.

While it is possible, based on the above, to identify specific non-spatial information requirements for assessing the potential economic costs and benefits associated with commercial fisheries and offshore renewables interactions, a full specification for non-spatial data for assessing impacts as a result of interactions between different human activities can only be prepared once all relevant interactions and potential impacts have been documented. However, where the interactions and impacts involve commercial fisheries, the same general types of information are likely to be relevant. Similarly, where the interaction potentially involves the displacement of vessels (commercial vessels, fishing vessels or recreational vessels), similar issues of navigational safety and displacement will arise, although some of the consequential impacts of such displacement are likely to be sector specific.

Environmental impacts
There is an extensive literature on the environmental impacts associated with different human activities in the marine environment and most of the impact pathways are relatively well understood. However, uncertainty remains concerning the scale of impacts at site level owing to uncertainties relating to the specific exposure of environmental receptors to changes in human pressures. The Driver-Pressure-State-Impact-Response (DPSIR) model provides the standard framework within which such assessments are carried out. In particular, an understanding of the relationship between human pressures and the state of the environment is important in seeking to determine the vulnerability of receptors and thus the likelihood of a change in state. A number of studies have sought to collate information on the sensitivity of receptors to human pressures that can be used to inform vulnerability assessments, for example:

- Tillin *et al*. (2010) developed a sensitivity matrix for MPA features to a wide range of human pressures
- A similar matrix has been prepared for Scottish MPAs which includes some additional features, particularly fish and marine mammals (Scottish Natural Heritage (SNH), pers. comm.)
- A sensitivity matrix for Natura 2000 site features has been prepared as part of work to ensure that commercial fishing activities within Natura 2000 sites comply with the requirements of the Habitats Directive (Defra, 2013)
- ABPmer (2013b) also prepared an extensive database of the sensitivity of Natura 2000 features and characterizing species to commercial fishing and aquaculture pressures to inform Appropriate Assessments in Irish Natura 2000 sites
- ABPmer (2013c) prepared an assessment of the sensitivity of Scottish geological and geomorphological features to a wide range of human pressures to inform Scottish MPA planning.

Such sensitivity information is already being used to identify the risks associated with human activities potentially affecting environmental receptors, particularly in the context of the designation and management of MPAs, although the information is also of wider applicability. Such matrices could therefore be used by the MMO to inform wider co-existence assessments relating to human activities and environmental receptors, although the information is not currently collated into a central repository and there are some gaps relating to some receptors, for example, limited coverage of mobile species such as fish, marine mammals and birds.

The approach described above is helpful in identifying changes in the state of environmental receptors and provides an important basis for management of impacts to protected areas and the wider marine environment. However, should it prove necessary to seek to monetise the environmental costs and benefits of ‘co-existence’ and ‘no co-existence’ options, additional information would be required, for example, based on ecosystem services valuation. In particular, this would require:

- Information on ecosystem service values associated with the current condition of relevant environmental features
- An understanding of how changes in pressures might affect ecosystem service values.

Such information is currently very limited, although significant work to improve scientific understanding of marine ecosystem services is being taken forward, for example, through the National Ecosystem Assessment (NEA) Follow-on project and Defra and Marine Scotland funded research to improve the evidence base on marine ecosystem services (eftec and ABPmer, in prep).

Social impacts
Based on the proposed co-existence assessment methodology, the following range of non-spatial social information may be required to undertake a detailed assessment of social impacts:

- Identification of the relevant social groups likely to be affected and their characteristics
- Information on key impact areas, for example, access to services; crime; culture and heritage; education; employment; environment; and health
- Information on how these impact areas may change as a result of 'co-existence' or 'no co-existence' options.

Some of this information is likely to be available from the assessment of economic or environmental impacts. It is recognised that there are particular challenges in seeking to quantify and monetise social impacts (see Section 3.4.3) and the assessment outputs are likely to be primarily qualitative, except where it is possible to estimate impacts on employment.

Improving the availability of non-spatial data
The non-spatial data requirements to support the assessment of economic impacts are disparate, often poorly recorded and tend not to be held in central repositories. Such information is likely to best be collected through consultation with the relevant economic sectors as part of the development of marine plans.

The basic non-spatial information required to support the initial assessment of environmental impacts is largely embedded within or accompanying the existing sensitivity matrices. Information to enable economic valuation of environmental impacts is more disparate, although there are good recent reviews of valuation data, for example, including recent draft outputs from the NEA Follow On Project. The evidence base for valuing environmental impacts will continue to improve over the next few years which will facilitate quantification of co-existence assessments in the future.

As the proposed methodology for undertaking social impact assessment within the co-existence process is derived from the economic assessment, limited additional information will be required and most of the information should be fairly readily available from published sources, for example, social baseline studies and the Office for National Statistics.

7. Conclusions and Recommendations

7.1 Conclusions

The proposed co-existence assessment framework sets out a rational process for considering co-existence opportunities within relevant MMO functions. For the purposes of this project, integrating evaluation of co-existence issues relating to fisheries within marine planning, licensing and conservation management rather than assessing the issues separately is believed to be the most effective approach.

The framework is based around the potential interactions between human activities or between human activities and the natural environment and the associated economic, environmental and social impacts. It seeks to compare a 'co-existence' option with a 'no co-existence' option in order to establish the relative impact of co-existence. It is recognised that such assessments can be highly complex owing to the nature and number of potential interactions that need to be considered, but this level of detail is necessary to adequately understand the potential outcomes of the interactions in terms of economic, social or environmental impacts.

A three stage process for co-existence assessment is proposed comprising:

- **Screening** – in this step, locations within which activities clearly cannot co-exist are identified. This is mainly applicable to marine planning.
- **Initial assessment** - a qualitative/semi-quantitative assessment of potential interactions between human activities or between human activities and the natural environment is undertaken using readily available information and simple assessment tools. This is mainly applicable to marine licensing and marine conservation management. A high level qualitative assessment is only likely to be applicable to marine planning to identify strategic benefits where there is a strong need and likelihood of a positive co-existence decision that is supported by stakeholders.
- **Detailed assessment** – a detailed quantitative (monetised) assessment is undertaken building on the initial assessment and using existing and potentially novel collected data, using more complex assessment tools where appropriate/ This is applicable to marine licensing and marine conservation, and potentially applicable to marine planning in the long term.

It is proposed that the screening stage within marine planning, could build upon the existing information on 'hard' constraints within the MaRS tool to screen out locations where co-existence would not be possible on the grounds of safety or where other mandatory protection zones are in place. This already happens implicitly where the MaRS tool is used to support MMO planning processes.

The initial assessments could be undertaken through completion of the following steps:

- Step 1 – identification (in GIS) of activities and natural environment features relevant to the co-existence assessment

- Step 2 – identification of potential interactions and associated impacts between the relevant activities or between activities and the natural environment and their associated impacts
- Step 3 – collation of readily available existing information on the relevant activities and natural environment
- Step 4 – identification of potentially significant interactions
- Step 5 – estimation of scale of impacts from potentially significant interactions
- Step 6 (optional) – monetisation of impacts using readily available information
- Step 7 – comparison of 'co-existence' and 'no co-existence' options and decision on relative scope for co-existence.

While the process is presented as a series of steps, there will necessarily be a degree of iteration between some of the steps and this should be taken into account when implementing the process.

A range of simple tools have been proposed to facilitate application of the initial assessment process. These include:

- Interaction tables to identify the key interactions between different human activities and associated impacts
- Spatial analysis within GIS to support quantification of interactions and impacts
- Sensitivity matrices identifying the sensitivity of conservation/ ecological features to human activity pressures
- Economic evaluation tools to monetise quantified impacts (optional)
- Presentation of assessment outputs within a cost benefit framework.

Should detailed co-existence assessments be feasible/required, it is proposed that they are undertaken through completion of the following tasks:

- Step 1 - More detailed quantification of potentially significant interactions through the collection of additional evidence on potential interactions, their impacts and the costs and benefits of such impacts
- Step 2 - Identification of potential mitigation measures for significant impacts – consider mitigation measures that might be implemented to minimise any significant adverse impacts of 'co-existence' and/or 'no co-existence' options
- Step 3 - Monetisation of costs and benefits of impacts associated with 'co-existence' and/or 'no co-existence' options taking account of mitigation measures
- Step 4 - Co-existence decision – making a judgement on the relative strength of co-existence potential to inform marine plan policies and decision making in marine licensing and conservation.

There is a wide range of assessment tools that can potentially inform detailed co-existence assessments. The choice of tools will depend on the particular issues at hand and the availability of data.

The complexity of the more detailed assessments potentially requires a wide range of spatial and non-spatial data and information to characterise the interactions and impacts, particularly where it might be necessary to seek to value costs and benefits of ‘co-existence’ and ‘no co-existence’ options. The relative significance of some of the interactions and impacts varies at site level, which therefore requires a level of site specific data.

Within marine planning, limited information availability is generally likely to preclude the use of detailed assessments, although depending on available time scales it could be possible to collect additional data where this was deemed appropriate for specific areas. Not all of the data and information that may be needed to inform co-existence assessments is readily available and the quality of information where it exists is variable. Should an initial co-existence assessment be considered necessary, some of the additional data requirements potentially needed to support co-existence assessment within marine planning could be collected through engagement with stakeholders as part of the marine planning process. Where necessary and where time and resources permit, higher quality data may be collected directly for more detailed assessment. Where this cannot feasibly be obtained, the limitations of the data must be recognised within the co-existence assessment processes and uncertainty should be documented appropriately following existing MMO quality assurance protocols. Where there are significant levels of uncertainty at the specific level, broader, more general policies may be required within the marine plans. It is anticipated that initial assessments would only be carried out where there is a strong requirement to support option development and appraisal and plan policy development.

Within marine licensing, where marine plan policies drive requirements to consider co-existence, it may be appropriate for the MMO to produce high level guidance to help ensure consistency and proportionality of co-existence assessments. It may be that, in response to policies drivers, developers would look to undertake initial assessments at the screening/scoping stage and, where applicable, detailed assessments could be prepared at the assessment stage of the pre-application phase. It is important that expectations for the assessment of co-existence potential are proportionate to the risk and are based on current available knowledge to ensure outputs are robust.

For marine conservation management, co-existence could not necessarily be encouraged through conservation management measures (e.g. MMO byelaws). However, assessment of the potential impact of activities on the interest features and conservation objectives could faciliate the development of management measures that do not unnecessarily preclude marine activities. Co-existence is best encouraged through marine planning and then applied at the marine licensing project level.

7.2 Recommendations

Recommendations are provided below following consideration within this project of potential MMO requirements and scoping the feasibility of fully developing an approach to fulfil those requirements.

To support the application of co-existence assessment across its main functions, it is recommended that the **MMO adopts a three stage co-existence assessment**

process comprising screening, initial assessment and detailed assessment (Recommendation 1), based around the concept of assessing the interactions and impacts between human activities or between human activities and the natural environment. The framework should seek to compare 'co-existence' and 'no co-existence' options using economic evaluation methods within an overall cost benefit framework to facilitate decision-making. Within marine planning, it is likely that only screening and initial assessment could be carried out due to data limitations. Detailed assessments are more likely to be prepared to support marine licensing or marine conservation decision-making.

In order to standardise the approach to screening at the marine planning stage, it is recommended that **the MMO defines the relevant mandatory protection zones and buffers applicable to the screening step, in agreement with the key stakeholders (Recommendation 2).**

While there is a good body of evidence on the interactions between human activities associated with the marine environment, these are not documented in a central repository. Collation of such information is seen as an essential pre-requisite to taking forward robust co-existence assessments either generically, to understand the potential interactions between different human activities or on a area-specific basis to inform more localised policies. It is therefore recommended that the **MMO initiates work to develop a series of interaction tables covering all of the economic sectors identified in the Marine Policy Statement. These tables should identify the key interactions between activities, suggested methods for assessing the interactions, suggested information requirements to support application of the co-existence assessment methodology and also identify relevant existing information sources (Recommendation 3), similar to those presented in Section 5. This process will require significant engagement with marine users. The information requirements will vary depending on whether the co-existence assessment is being undertaken at the plan or project level.**

A number of tools exist to support assessments of interactions between human activities and the natural environment. In particular, a range of sensitivity matrices have been developed to inform the planning and management of MPAs, although existing matrices have limited coverage of mobile features, particularly birds and marine mammals. It is recommended that **these existing assessment tools should be used to inform initial assessments of the interactions between human activities and the natural environment and their associated impacts (Recommendation 4).** In terms of marine planning, these could be used in support of the options development and appraisal process where there is a strong requirement to consider co-existence as a result of specific spatial allocation policies. It may be appropriate to extend the coverage of existing matrices in the light of experience with their application.

The assessment of social impacts is recognised as being particularly challenging. It is recommended that **social impacts should be assessed during the detailed assessment stage using the Social Impacts Taskforce framework (Recommendation 5) at present as this provides strong linkages between the assessment of economic and social impacts**. This methodology has been proposed for use across UK Government for understanding the relationships between the social impacts of policies and also fits well with wider cost benefit assessment processes.

The application of the co-existence assessment process to inform location-specific marine planning policies is recognised as being particularly challenging. It is currently unclear, the extent to which available spatial and non-spatial data at the marine planning stage could sufficiently inform location-specific co-existence policies to justify the effort associated with undertaking such assessments. It is therefore recommended that the **MMO undertake an initial trial application of the screening process within marine planning in the short term to evaluate a range of potential co-existence opportunities using available data (Recommendation 6).**

A further trial application of the initial and/or detailed assessment (Recommendation 7) should be undertaken within marine planning in the long term to indicate whether there is likely to be sufficient information to identify the relative importance of significant interactions at marine planning stage and thus help to inform location-specific co-existence policies.

More detailed information will be available for consideration of co-existence issues at the project level. In addition to the general statements about the desirability of co-existence in the Marine Policy Statement, The draft East marine plans include general policies promoting co-existence and co-location, which seek to minimise displacement. The outline approach to marine plan implementation, monitoring and review (MMO, 2013e) requires monitoring of the conformance of development projects with these policies. Should any marine plans create policies that drive co-existence assessment, it is recommended that the **MMO look to develop high level guidance on the way that co-existence issues could be taken account of by developers (Recommendation 8).** This will involve significant stakeholder input and be based on the available evidence.

Should the trial application of the framework within marine planning demonstrate sufficient benefit from the approach, and full implementation of the process is taken forward, particular care will be required in acquiring, storing and managing the spatial and non-spatial data necessary to support application of the co-existence assessment process. Many of the required spatial data layers will already be held by the MMO within its geodatabase but some additional data layers will need to be compiled or acquired from MMO partner organisations. Priorities would include inshore fishing, commercial shipping, cables and pipelines. In particular the MMO should continue to ensure that it engages with relevant fora that are co-ordinating the development of human pressures layers. Engagement with stakeholders through the marine planning process also provides an opportunity to acquire plan-specific spatial data. Where data is acquired, it is recommended that the **MMO maintain relevant spatial data layers in accordance with their existing data management practices (Recommendation 9).**

The MMO will also need to initiate collection of appropriate non-spatial data and store and manage this data in accordance with its existing data management practices. Stakeholder engagement through the marine planning process provides an opportunity to acquire relevant data and information. Where information is collected, it is recommended that the **MMO should update information on the costs of impacts and mitigation measures every two years (Recommendation 10).** Such information will be of value in forming MMO decision-making and also provide an information resource on which developers and wider stakeholders can draw.

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Annex 1: Review of Tools

Tables 8 to 12 review the characteristics of a range of tools that have been identified to be potentially relevant to the assessment of co-existence.

Table 8: Review of compatibility matrices.

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
MaRS Compatibility Matrix http://www.marsmapping.co.uk/Login.aspx?ReturnUrl=%2fSites%2fModelsAndProgs%2fdefault.aspx [accessed on 6 September 2013]. This tool from The Crown Estate is able to consider a high number of factors each time a site is analysed and is underpinned by a high-level compatibility matrix.	Spatial Database is managed by The Crown Estate	Yes	A spatial assessment of compatibility between listed human activities.	Sensitive to technical factors such as the categorisation of data layers as representing complete or partial constraints on development; (e.g. available infrastructure); data limitations may lead to an underestimation of constraints.	Many datasets are available and these are frequently updated by The Crown Estate. Confidence levels and quality assurance are applied to datasets. Modelled output can be viewed via a web browser and therefore no software installation required.
Juda and Hennessey (2001). Simple compatibility matrices were assessed.	Requires a spatial database of current (and future) human activities. Uses a	Yes	A spatial assessment of relative compatibility	Must ensure that there is a full list of activities It is a very simplistic matrix.	This matrix could provide the basis for future more complex matrices.

[16] The extent to which the nature of data inputs required might be applicable to varying scales (i.e. from strategic/regional to local scales).

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
	rating system of 1-10 where activities are rated from compatible to incompatible.		between listed human activities.		
Interaction study (Thompson *et al.*, 2008)**..** Clyde SSMEI Project and Moray Firth Partnership.	Requires a spatial database of current (and future) human activities. Industry representatives from sectors were asked to describe the perceived impact of other sectors on their activities following a prescribed format. Any interaction were scored as either incompatible or those that were likely to have conflict, competition, neutral interactions or positive interactions and were presented within the matrix in a colour coded system.	Yes	A spatial assessment of compatibility between listed human activities.	Only considers perception of co-existence potential rather than actual compatibility of interactions among sectors. However, the use of stakeholder engagement throughout the process can be considered a useful methodology.	The methodology for developing the matrix through stakeholder representations is potentially useful.
Tay Estuary Forum (Tay Estuary Forum, 2011). This was to inform the local marine plan for the Firth of Tay and	Requires a spatial database of current (and future) human activities.	Yes	A spatial assessment of compatibility between listed	Stakeholders did not always use the same definitions and some interactions were	The approach to this topic, though not specifically related to co-

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
the east coast of Scotland of the nature, extent and intensity of interactions among the local sectors. Built upon the Sectoral Interactions Matrix (SIM) as developed for the Clyde SSMEI.	Representatives completed a sectoral compatibility matrix and interviews		human activities.	subjective.	existence, is useful to this project as it details how to take a matrix and develop it further through stakeholder representations..
Activity matrix (Lee and Stelzenmuller, 2010). A matrix was developed reflecting levels of potential conflict between sectors which could be used for risk assessment and sustainability appraisal.	Requires a spatial database of current (and future) human activities. A conflict score was assigned to each activity and another.	Yes	The matrix provides a count of activities within an area and assesses all possible combination of overlapping activities with a conflict score given. The scoring system indentifies areas that require further analysis or boundary refinements in order to minimise any potential conflicts.	A defined direct relationship between conflict and potential co-existence of activities would be required to assist in the assessment of co-existence. It may be possible, based on the definition of conflict, to make some inferences on the relationship between conflict level and co-existence potential.	Provides valuable information on potential levels of conflict between activities.

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
UNESCO-IOC (Ehler and Douvere, 2009). The matrix demonstrates whether there is a conflict or potential compatibility where there is an overlap between human activities.	Requires a spatial database of current (and future) human activities. The list of activities and the potential conflict of overlapping activities is colour coded.	Yes	A spatial assessment of compatibility between listed human activities.	The level of conflict is not ideal for co-existence assessments.	The scoring, colour scheme and design of this matrix is useful.
WINDSPEED (Spatial Deployment of Offshore WIND Energy in Europe) (Van der Wal *et al.,* 2011). Takes into account the fact that activities not only complete in spatial terms they will also compete for economic aspects, social perception and political importance. A Decision Support System (DSS) produces a matrix. It is an example of how a matrix can be used to refine the process of co-existing activities.	Requires a spatial database of current (and future) human activities. The matrix was based on positive and negative interactions of activities collected from literature and stakeholders. Calculation rules[17] were also defined. The rules fall into four categories; Exclusions; Economic values; Spatial suitability values; and Refinements to reduce heterogeneity.	Yes	A spatial assessment of compatibility between listed human activities.	Only focused on one sector (Offshore Wind Energy) and considered a restricted number of activities.	Provides a good example of how a matrix can be used in refining the process of co-locating activities.

[17] A calculation rule is a formula or an algorithm that defines how to calculate where a given sea use function has a strong claim on an area and where it has a weaker claim or no claim at all (Van der Wal et al., 2011).

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
GAUFRE Project (Maes *et al.*, 2005)**.** A spatial compatibility matrix considered management types for the co-existence of different marine activities within the Belgium part of the North Sea (BPNS).	Requires a spatial database of current (and future) human activities. All the marine activities undertaken in the BPNS and their potential interactions were analysed.	Yes	The outputs suggested whether temporal, spatial and/or overlapping management measures may be required. In addition there is a scale of interaction between activities from 3 to -3. Where 3 indicated a large beneficial effects and -3 a large hazardous effect.	The format of the matrices is not easy to comprehend.	The underlying methodologies are robust and the list of activities is comprehensive.
Blyth-Skyrme (2011). A simple matrix was created as part of an investigation into the advantages and disadvantages of co-existence of Offshore Wind Farms (OWFs) and MCZs with commercial fisheries.	Requires a spatial database of current (and future) relevant human activities. No information of changes of catch, fisheries displacement or degree of overlap between OWFs and MCZs could be included.	Yes	Nominal scores were given based on spatial gains or losses to commercial fisheries as a result of OWFs and MCZs. Impacts that would affect all gear types resulted in greater scores	Restricted in the activities considered.	A good example of a matrix being used to demonstrate complex interactions between industries.

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
			than if only one type were impacted.		
Dorset C-SCOPE Marine Spatial Plan (C-Scope, 2012). Matrix of the nature extent and intensity of existing interactions among sectors. A spatial assessment of compatibility between listed human activities.	Requires a spatial database of current (and future) human activities. Similar approach to the Clyde SSMEI Project. Stakeholder engagement included face to face interviews, meetings and community road shows to gather infomation regarding socio-economic interactions within the local area.	Yes	A spatial assessment of compatibility between listed human activities.	Stakeholders played a key role in the development of this matrix and therefore there is a level of subjectivity embedded within the matrix.	The methodology was based on the concept of Strategic Environmental Assessment and Sustainability Appraisal which are effective and proven tools for integrating social, economic and environmental issues if used as part of the planning process.
MMO, 2013a. Aimed to provide a generic screening tool for investigating which activities have the potential to co-locate. The outputs are probabilities for conflict and the likely level of intervention required for the co-location of specific activities. Scores and associated colour codes	Requires a spatial database of current (and future) human activities. Activities were included based on expert opinion. Once populated with activities, the interactions of these activities within the	Yes	A spatial assessment of compatibility between listed human activities.	The matrices do not supply definitive answers and cannot assist in zoning processes. It does not take into account local conditions such as environmental or socio-economic impacts of co-	Matrix capture information on the nature and significance of potential compatibility among marine sectors and sub-sectors. It is based on sound scientific

Tool/method name – source/description	Data input requirements	Scalable[16]	Type of output	Significant limitations	Significant benefits
reflect the conflict likely to occur between the two activities. Confidence is greatest for activities where intervention is suggested to be high as they were based on physical constraints for the interactions. Confidence is lower for those interactions scored as likely to be compatible and so require low levels of intervention.	matrices were scored through consideration of a number of questions (e.g. are the two activities likely to interact? If so, how?)			location, which in practice could have a significant influence on decision made on a case-by-case basis.	evidence and on professional expertise where scientific evidence is not available It is user-friendly with a carefully considered scoring system.

Table 9: Review of interaction tables.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Pentland Firth and Orkney Waters Round 1 Wave and Tidal Developments (ABPmer and RPA, 2012). Presents series of potential interaction tables for wave and tidal developments in Pentland Firth and Orkney Waters with other marine activities	Spatial data on the current and future location and intensity of marine activities; non-spatial data to support quantification and valuation impacts.	Yes	Quantitative and qualitative assessment of impacts; value of impacts	Future location and intensity of human activity inherently uncertain. Non-spatial data to support quantification and valuation incomplete.	The study describes the potential for interaction with wave and tidal development, identifies the potential socio-economic consequences and also how socio-economic impact could be assessed.
Socio-economic baseline and data gap analysis for offshore renewables in Scottish Waters (Marine Scotland, 2012)**; Socio-economic assessment of Draft Plan Options for Offshore Renewables in Scottish Waters** (Marine Scotland, 2013a). Information is presented on the potential interactions between offshore wind, wave and tidal	Spatial data on the current and future location and intensity of offshore renewables and other marine activities; non-spatial data to support quantification and valuation impacts.	Yes	Quantitative and qualitative assessment of impacts; value of impacts	Future location and intensity of human activity inherently uncertain. Non-spatial data to support quantification and valuation incomplete.	The interaction tables describe the potential for interaction with offshore wind, wave and tidal development and also identify the potential socio-economic consequences

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
developments and other marine activities.					
JNCC Pressures versus Activities Matrix (JNCC, undated).	Information on the current and future location of human activities	Yes	Identifies potential pressures associated with specific human activities.	Requires information on the intensity of pressures and variability over time.	A potential benefit is that outputs could be combined with information on environmental receptor distributions and sensitivity to model potential receptors vulnerability to pressures.

Table 10: Review of assessment tools.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Economic assessment tools					
Fleet-based bio-economic simulation software to evaluate management strategies (Ulrich *et al*., 2007). Key model components include biological (stock growth and movement), fleet tactics (effort by métier[18]),fishing effort (fishing days by area by métier), fleet structure (entry-exit), harvest (species catchability by area by métier) and economics (costs and earnings by area by métier) modules. Modules can be included or excluded. A utility-maximisation assumption is included, such that displaced effort is assumed to move to the site where the greatest profit per unit area was made in the	Survey data of spatial availability of resource. Logbook and VMS data. Total Allowable Catches (TACs) for relevant stocks Vessel information (length, gear types, engine power, fuel use).	Yes	Predictions of the response of fishing fleets to fuel price fluctuations, changes in resource availability and the introduction of management measures.	Limitations of using VMS data as input data. Complex modelling approach that incorporates a variety of data from different sources. The complexity may limit interest in this approach. Likely to have only limited application for fisheries without up-to-date information on stock availability. Not clear how well the model would deal with gear conflict issues.	The software proved able to reproduce reasonably well some past observed fleet and stock patterns predictions of fleet and stock effects, and to implement alternative and case-specific scenarios, demonstrating its potential application to generic situations and its user-friendliness.

18 This concept is also called 'fisheries' or 'riggings' and describes the activities (e.g. gear and mesh size used, fishing ground, etc.) of a vessel in a fleet during a given period (Ulrich *et al.*, 2007).

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
previous time step.					
Individual-based modelling and using interview data to improve the ability to predict fishers' responses to management changes (Bastardie *et al*., 2012). A base model of economic efficiency for different fleets was developed, using VMS and catch data, and fuel price and fuel use data. Fisheries survey data were included to provide information on resource availability. Interviews with fishermen were used to generate sequential yes-no choice data on the factors that influence trip decisions, covering duration of fishing trip, choice of fishing grounds, when to return to port and the choice of port for landing.	Survey data of spatial availability of resource. Logbook and VMS data. Vessel information (Length, gear types, engine power, fuel use). Interview data generating collective responses to hypothetical management interventions to inform individual-based modelling.	Yes, although it is only likely to be practical for small-scale fisheries.	Predictions of the response of fishing fleets to fuel price fluctuations, changes in resource availability and the introduction of management measures.	Limitations of using VMS data as input data. Complex modelling approach that incorporates a variety of data from different sources. The complexity may limit interest in this approach. It is likely that the approach would need to be adapted for English fleets where most vessels are smaller. Not clear how well the model would deal with gear conflict issues.	Model provides a means to test assumptions and to compare a fleet's likely response to different management scenarios.
Dogger Bank Special Area of Conservation (SAC) Impact Assessment	Assumption made that mobile bottom gears would be excluded from 15%	Yes	Estimates of changes to profitability.	Limitations of using VMS data as input data.	This assessment applied a simplistic approach based

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
(JNCC, 2011). Only vessels >15 m length overall (LOA) thought to operate in the area, so VMS data were considered to accurately reflect fishing activity.	(experimental closure) or 100% of the site. Landings by ICES rectangle and gear type. VMS data (effort).			Only impacts on UK businesses were considered, although the area is fished by vessels from other EU Member States. The outputs may be precautionary in that 15% (experimental closure) or 100% of landings by UK vessels for the ICES rectangles in which the site sits were considered to be lost, although the site covers only part of some rectangles and VMS data appear to show that fishing activity by some fleets was concentrated to the south and east of the site boundary.	on a number of precautionary assumptions but it was considered that modelling the enormous range of complimentary and/or competing factors that influence fishermen's decision-making processes in sufficient detail to successfully predict displacement outcomes in disparate locations was not cost-effective, even if feasible.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Lyme Bay and Torbay SAC Impact Assessment (Natural England, 2010). For the Lyme Bay and Torbay SAC Impact Assessment, a number of management scenarios were costed, with gross value added (GVA) being estimated. The scenarios included an option where all mobile gears were excluded from the site. GVA measures the contribution to the economy of each individual producer, industry or sector by estimating the value of output (goods or services) less the value of inputs used in that output's production process.	Assumption made that mobile bottom gear would be excluded from the site. Landings by ICES rectangle and gear type.	Yes	Estimates of changes to GVA.	The outputs may be precautionary in that landings for all ICES rectangles in which the site sits were considered to be lost, although the site covers only part of some rectangles and fishers may displace to other areas and make up lost earnings. Some <10 m LOA vessel data may not have been included, and the analysis may not have been fully representative of the shellfish fishery in particular. Not predictive of where displaced vessels will displace to, and no replacement of landings was	This assessment applied a simplistic approach based on a number of precautionary assumptions but it was considered that modelling the enormous range of complimentary and/or competing factors that influence fishermen's decision-making processes in sufficient detail to successfully predict displacement outcomes in disparate locations was not cost-effective, even if feasible.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
				assumed to occur for the analysis.	
Wave Hub development EIA - commercial fisheries (Esseen, 2006). An estimate of the annual value of the landings derived from the Wave Hub site was provided based on the total landings derived from the ICES rectangle and the ratio of the area of the development in comparison to the overall area of the ICES rectangle. For the Wave Hub development, it was assumed that all fishing activities would be excluded from the area of the development, such that landings would decline to zero. Likely displacement effects were assessed qualitatively based on interviews and detailed knowledge of the fishing area.	Landings data by ICES rectangle and gear type. Local knowledge of fishing activities in and around the development area.	Yes, but qualitative estimation of displaceme nt effects is likely to be increasingl y difficult as project size increases.	Estimates of the annual first-sale value of fishery products extracted from the development area. In other words, the additional value generated through onward sale of fish and through ancillary industries such as boat building and repair, gear manufacture, fuel supply, transport, etc. is not taken account of (Esseen, 2006). Qualitative assessment of likely displacement effects.	The development site accounted for only 0.203% of the ICES rectangle), so the estimate of landings attributable to the development site is subject to a potentially high level of error. Some <10 m LOA vessel data may not have been included, and the analysis may not have been fully representative of the shellfish fishery in particular. Landings data for non-UK vessels were not obtained.	A simple approach was applied. The analysis provides an estimate of lost earnings. Discussion on potential for displacement is based on local knowledge.
Using catch and VMS data to characterise fishing	Landings data by ICES rectangle and gear type	Yes	Fishing grounds characterised by	Analysis at this detailed level is	The data used were from

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
grounds and predict displacement effects (Gerritsen *et al*., 2012). Detailed catch-by-location data were used to create gridded maps of identified species assemblages taken by Irish otter trawlers around Ireland. 36 spatially distinct fishing grounds were identified through creating a dissimilarity matrix of catches between neighbouring grid cells, and then conducting a hierarchical cluster analysis to identify spatial groupings of grid cells. A management scenario was investigated, where a hypothetical seasonal closure was introduced to limit cod catches. Theoretical responses were modelled under the assumption that effort levels would not change.	Associated VMS data. For a more detailed spatial analysis of total catch profiles as compared with landings profiles, discard data would also be needed.		aggregations of species landed by a particular gear type (can be fishing grounds by aggregations of species caught if discard data are included). The approach provides a basis for developing projections of likely displacement effects.	somewhat complex and would be needed individually for fisheries with different catch profiles. There are significant limitations to using VMS data. Assumptions of displacement would need to be validated through interviews. The assumptions for predicting likely displacement is not always applicable across all fishery types.	conventional sources. The analysis was more comprehensive than standard impact assessment approaches.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Social assessment tools					
Indicator based Evaluation Framework (MMO, 2013b). The MMO is currently taking forward research to explore how social impacts of fisheries, aquaculture, recreation and tourism, and MPAs in marine plan areas in England might be assessed. A framework has been proposed which is linked to the Marine Policy Statement. At its core are specific objectives of marine spatial policy, most likely reflecting both national and plan area goals, that have been selected for evaluation.	A set of indicators which will have an evidenced causal relationship with both marine plan policy outputs and eventual social impacts, for example Job Creation (using data collected annually) and value of marine natural capital (which is incorporates the value of ecosystem services which is soon to be added into the National Accounts). Also required is statistical data for example, the state of the economy, demographic of a seaside town.	Yes	Annual (or biannual) reports against headline indicators of Marine Capital value and job creation due to a marine plan-led activity. In addition a more detailed multi-annual report would ne produced to provide evidence as planed are reviewed and revised.	Information gaps will limit the initial set of indicators. This is a new tool which hasn't been tried and tested.	The indicators 'job creation' and 'natural capital value' potentially offer a quick win solutions to the evaluation of the initial marine plans. The complexity of a marine plan will require an evaluation framework, this is good first step.
Social Capitals Approach (Harper and Price, 2011). This approach 'ensures that the stocks of capital (produced, human, social, natural) are maintained so that the potential for wellbeing is non-declining	Social Impacts (marketed and non-marketed goods and services) need to be defined so that they can be assessed and use the analysis in the social cost-benefit analyses of policy options.	Yes	This tool provides an assessment of social impacts of a policy on people's lives before the implementation of a policy. This helps to design policies	Not all elements impacts on well being of social value have been captured. The framework currently does not consider natural	This methodology has been successfully applied to evaluate marine policies (Marine Scotland, 2013a; b) and fits well with wider

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
over time'. It assess whether the stock of wealth-creating and wellbeing-enhancing assets we pass on to future generations is better or worse than what is available to us today, and is a key analytical component of mainstreaming sustainable development.			and tailor them more specifically for different parts of the population with the aim to make them more effective in achieving improvements in wellbeing.	justice – winner and losers, and the distribution of fairness. Outputs from the framework are largely qualitative.	cost benefit assessment processes. It has been proposed for use across UK Government for understanding the relationships between the social impacts of policies, their effects on the UK's underlying stocks of capital, and implications this has for wellbeing. It makes use of information which fits well with existing Treasury Green Book guidance (HM Treasury, 2003).
Social Impact Assessment (SIA) National Oceanic and Atmospheric Administration (NOAA)	A matrix is developed which demonstrates how social impacts will vary at different stages of the development. This is done using the	Yes	The model forecasts impacts of the development by qualitatively comparing the	In order to produce a decent model appropriate data sources are needed which can	With appropriate data sources it allows for an interpretation of dynamic events

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
(1994). This tool assesses the consequence to human populations of any public or private actions that alter the ways in which people live, work, play, relate to one another, organise to meet their needs and generally cope as member of society.	following: ▪ Data from project proponents ▪ Records of previous experience with similar actions as represented in reference literature as well as other EIS's ▪ Census and vital statistics ▪ Documents and secondary sources ▪ Field research, including informant interviews, hearings, group meeting, and surveys of the general population.		future with the project and without the project. This can be done throughout the whole life cycle of the development from planning and policy development through to abandonment and decommissioning.	be collected frequently. Some groups of people low in power but may be adversely affected do not necessarily participate in the early stages of a project. It is essential these impacts are captured from an early stage. In order to have a meaningful assessment professionally qualified competent people with social science training and experience are needed. There will be gaps in the data.	and can provide monitoring of short term impacts. Frequent monitoring provides a continuous source of evaluation or check on the direction of forecasts made about social impacts.
Social Impact Assessment in the Oil and Gas Industry. (IPIECA,	Project characteristics, uncertainties and timescales. Historical	No – project level only	A qualitative assessment of impacts of the	Expensive to carry out, takes time and often a number of	A SIA can assist in managing project budget and

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
2004). This guide outlines the use of SIAs by the oil and gas industry. It provides managers of existing oil and gas operations or new projects with an understanding of how to make the best use of SIAs.	background of the area. Identification of any vulnerable groups and the participation of stakeholders.		project which is not limited to the area and lifetime of the project, secondary impacts should also be assessed. In addition any cumulative effects with other developments should also be considered. These will be consider if/when developing effective plans for mitigating adverse impact and optimising benefits.	iterations. In addition the timescales can vary	schedule, supporting relationships with relevant stakeholders and builds a competitive advantage for a company.
Causal Chain analysis (ECORYS, 2010). Identifies the significant cause and effect links between proposed changes arising from a new intervention and potential economic, social and environmental impacts.	Input data are derived from financial tables, and organised by priority and measure	Yes	Attempts to prove a causal relationship (chain) between the outputs (e.g. Number of unemployed in vocational training) or direct results of the programme (e.g. Number of those trained	Links between results and impacts are very difficult to establish, especially in the case of complex programmes, where the ability to attribute impacts to individual components/meas	The greater the extent to which a targeted population is covered by a particular set of activities, the easier it will be to establish a causal link between the results of these activities and their

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
			brought back into the labour market) and the larger socio-economic evolution of the area.	ures becomes problematic. The more complex the programme, the more difficult the assessment becomes. A further limitation lies in the complexity of distinguishing gross and net effects, as well as dead weights. Double counting is a major risk	impact on more general socio-economic plans. Allows stakeholders to be involved in the generations of possible impacts. It allows economic, social and environmental impacts to be assessed in conjunction with each other.
Quasi experimental approaches (ECORYS, 2010). Where policy options are effectively 'tested' on specific groups or geographical areas are another form of primary data collection that can be used to assess the impact of new policies. The policy experiment allows the impact of the intervention in question to be monitored and measured in real time, meaning such approaches	Good reliable quantitative data are required at two stages of the experiment. Firstly for the basic data about the individuals and entities that will make up the treatment and non-treatment groups. Secondly, updated data are required to undertake a reliable comparison of observed outcomes among the treatment and control groups after the policy trial.	Yes	Quantifiable outputs which compares the treatment and non treatment areas are used to estimate the impact of a change.	The number of individuals or entities in the treatment and non treatment groups needs to be sufficiently large to be able to draw statistically reliable conclusions. The objectives of the intervention and the relevant outcome variables should be clear	A good tool to test new and innovative interventions and gather new knowledge on effectiveness and causal links between interventions and effect. Very valuable tool when existing levels of knowledge about likely cause and

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
can be seen to combine both data collection and assessment of impact.				from the outset and be as simple as possible, if direct causality is to be established. There must be sufficient time to allow a trial phase – such methods can not be used if urgent action is required. Resource and time intensive.	effect of specific social groups are insufficient to make reliable judgements about probable impacts.
Model Family assessment (ECORYS, 2010). An approach that centres on the calculation of the financial consequences of changes in fiscal and social policies for a set of hypothetical families. The calculations allow one to see the effect of policy variations and the effects of changes in household circumstances.	Sets of different households that differ with respect to particular characteristics, such as age, marital status, labour market situation, income situation, housing situation and so on. For each household type, net disposable income can then be calculated, taking into account the current state of a given tax-benefit system.	Yes	The impact of changes in the tax benefit system on the household's disposable income can be calculated. Furthermore, the analysis can be made almost 'continuous' in relation to some variables.	The assumptions made about the hypothetical individual or household necessarily limit the number of possible situations that can be taken into account. Another limitation of the approach is the need to make a large number of assumptions for the selection of	This tool can assess jointly different elements of policy. In addition, the focus on the family level allows the identification of details important to specific population groups and individuals that can be erased at the aggregate level. This tool can also be used to

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
				family types.	compare policies across different countries.
Environmental assessment tools					
Sensitivity Matrices (e.g. MCZ pressure-feature sensitivity matrix) – a matrix in Excel spreadsheet that provides qualitative assessment of sensitivity of MPA features to benchmark levels of human pressures. JNCC also developed a matrix of pressures associated with specific human activities which can be used to link activities to pressures (there is also the Scottish sensitivity matrix that provides additional assessment information for Scottish MPA features).	Spatial distribution and intensity of pressures. Spatial distribution of features	Yes – depends on resolution of data inputs.	A qualitative description and assessment of the sensitivity of feature to a defined pressure.	Sensitivity range for some features (especially Broad Scale Habitat features[19]) can be very large. Some assessments are therefore uncertain. Spatially resolved information on distribution or intensity of pressures often not available. Basic habitat maps poor in many areas.	The outputs can inform basic assessments of the compatibility of human activity with the achievement of conservation objectives for MPA features.

[19] Marine habitats and species that are protected across MPAs are grouped together into broad-scale habitats (e.g. intertidal mud, subtidal biogenic reefs), in order to take the place of more detailed information on biodiversity. See http://jncc.defra.gov.uk/page-4527 [accessed September 2013] for more information.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
General assessment tools					
Expert judgement. The application of expert judgment or opinion is probably the most widely used method for assessing the potential physical, environmental or socio-economic impact, and significance of that impact. It essentially relies on the knowledge and experience of the assessor(s) to draw conclusions from the available data. It can be used to identify and assess direct, indirect and cumulative impacts, together with impact interactions. The assessment can be made by an individual or an expert panel, enabling an exchange of information on different aspects of the impact. The method can be widely applied and is relevant to all cause-effect processes.	It is a very adaptable method, making use of the information available, ranging from a basic literature search to the results from detailed modelling studies. Important variables involved in the assessment include the scale of the change, the sensitivity of the environment and the cause-effect pathways. Once the data on which to make the judgement are available, no specialist software or tools are required.	Yes	The type of output will be a qualitative description that informs the scoping, identification and initial prediction of impacts .	The main limitations of the method are the knowledge and experience of the assessor and the amount of data available on which the assessment is made. As the method is not always auditable, difficulties can arise such as certainty/confidence in the conclusions, particularly for consultees.	The method can be widely applied and is relevant to all cause-effect processes. It is a very adaptable method, making use of the information available, ranging from a basic literature search to the results from detailed modelling studies. No specialist software or tools are required. The financial cost of the method is a reflection of its relative simplicity and speed and, once the data on which to make the assessment has been sourced, is limited to the time

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
					taken by the assessor.
Spatial Analysis of Data layers. This is a general process involving the use and analysis of data layers is important in identifying and evaluating potential conflicts. If there is more detailed information available between socio-economic activities, more advanced forms of spatial analysis is undertaken. Simple analysis would be spatial only. This could be built upon if values and weighting are embedded in the activities and sectors being considered.	Spatial data, locations of sectors and activities. More detailed information can be included on the subjective importance and value of the sectors/activities (e.g. protected habitats). Weighting can also be applied to different activities.	Yes	Simple map overlays which identify where activities and sectors may overlap.	The complexity of the analysis reflects the type and quality of spatial data available. Can only analyse data that has a spatial component and that is available in a suitable format. Case studies in which this tool has been applied have not used explicit information on pressure or pressure intensity to inform spatial analysis, but simply made	Such outputs provide a powerful and simple to understand visual outputs of potential conflicts that may arise when assessing co-existence.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
				assumptions regarding compatibility.	
Life-Cycle Analysis (LCA). This tool assesses environmental impacts associated with all the stages of a project, plan or policy (e.g. carbon footprinting). It gives a holistic view of a project, plan or policy's impacts and benefits.. A key aspect of LCA is weighting the different types of impacts caused by a project, policy or plan to give a single metric. The most popular weighting systems that have been used are integrating monetary values or expert weightings.	Costs in relevant terms (i.e. carbon emissions or energy requirements) for each stage or aspect of a project.	Yes	The outputs of this tool are the range of impacts (i.e. costs) associated with each stage or aspect of the project, plan or policy.	Hard to convert impacts to single common weighting. It is also time consuming to investigate all benefits and costs over a long time span, and difficult to predict future environmental benefits.	Gives a holistic view of project, policy or plan's impacts and benefits. Can include non-market goods or values. There is some flexibility in the weighting methods. Can be used as part of a stakeholder engagement process
Risk Assessment. The quantitative evaluation of risk related to a defined situation from the magnitude of potential loss and the probability of that loss occurring (MMO and	Potential impact pathways from the various sectors/activities need to be identified. Data inputs will depend on whether a qualitative or quantitative risk assessment is	Yes	The outputs provide a quantitative or qualitative evaluation of the costs and benefits of measures and	Without the correct data which is well understood it is difficult to identify risks in the first place and for these risks to be properly	No time and cost implications of monetising benefits. The results can be plotted spatially. Stakeholders can

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Marine Scotland, 2012). Risk Assessment can also take on a qualitative form to assess perceived threats. Within the marine sector, risk assessment has been used for health and safety, environmental and navigation risk.	undertaken and whether CBA is incorporated.		decisions on risk management measures. Risk assessment can be carried out on a spatial basis to identify areas where risk is higher. This is often the approach taken by navigational risk assessments, the results of which can be plotted with GIS tools.	assessed. The risk assessment will need weighting so that different hazards can be compared. However, if the data is not fully understood by the assessor, this will affect the weighting that is placed on the different risks and the weighting of loss can be controversial. The assessment also does not take account for benefits.	be engaged in weighting of potential loss
Modelling. Modelling is a powerful technique for quantifying the cause-and-effect relationships leading to effects. The tool can take the form of mathematical equations describing processes (e.g. underwater noise propagation) or may	Baseline data (e.g. existing seabed sediment distributions, water levels, currents, background noise, temperature, salinity) together with information on the impact and/or activity that is being assessed (e.g. construction methodology,	Yes	Provides quantitative spatio-temporal predictions of impacts associated activities. These can be depicted graphically or spatially in figures	Usually need a lot of data, particularly for complex models. Can be an expensive tool to use. Also can be a challenge to apply when there are many interactions	Provides quantitative predictions. Addresses cause-effect relationships. Outputs can be presented to

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
constitute an expert system that computes the effect of various project scenarios based on a programme of logical decisions (e.g. hydrodynamic and sediment modelling, and water quality modelling).	scheme design).		to aid in the interpretation of impacts.	involved.	integrate time and space.

Table 11: Review of evaluation tools.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Valuation methods – tools that assign value to a particular change or impact					
Market-prices. Data derived from the prices of goods and services sold in markets: Market prices Production functions Avoided costs Replacement costs.	Market-based data, such as price.	Yes, but with limitations where the scale of change becomes sufficient to change to size/ availability of resources and thus influence prices.	Quantitative indicator of value, in the form of price, which signals how much of input resources should be allocated to production of different types of goods and services.	Market prices are rarely equal to values. Market information may require substantial analysis to deliver usable values: for example correcting for taxes and subsidies, estimating how values change with quantity.	The market price method reflects an individual's willingness to pay for costs and benefits of goods, thus, people's values are likely to be well-defined. Price, quantity and cost data are relatively easy to obtain for established markets. The method uses observed data of actual consumer preferences. The method uses standard, accepted economic techniques.
Revealed preference (RP). Methods based on	Surrogate market data that can be	Yes, but subject to	Quantitative (monetary) estimate of	Specific data requirements can	Valuation estimates are derived from

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
values for environmental resources that are 'revealed' by behaviour in associated markets. For example, the values humans place on outdoor recreation can be estimated from information about the time and travel costs incurred to engage in that activity. **Techniques:** Travel cost Hedonic pricing Random utility model.	connected to the level of the environmental good in question (for example what individuals spend on travel for a recreational visit reflects their enjoyment of the activity, scenery, environmental quality, etc.).	uncertainties (see value transfer).	value/benefit gained from a certain activity, aspect, or project/ policy.	be hard to fulfil: needs data set that allows influence of environmental good in question to be distinguished.	real economic choices made by individuals in real markets. Cost can be lower than cost of running stated preference surveys
Stated preference (SP). Methods based on surveys in which people give valuation responses in hypothetical situations. **Techniques:** Contingent valuation Choice experiments.	Hypothetical market data. Understanding of unbiased way to describe environmental change to respondents through survey; and ability to link survey sample to affected population.	Yes, but subject to uncertainties (see value transfer).	Quantitative (monetary) estimate of value/benefit gained from a certain activity, aspect, or project/ policy. Can also give understanding of distribution of values and relative priority of environmental changes.	Accurate implementation is resource intensive – costing over £100k per survey.	Can, in principle, be used to value any specific non-market good. Choice modelling methods can also be used to estimate the value of the attributes of a nonmarket good. This can be useful if different policy options differ in the attribute levels that

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
					they provide
Expenditure measures. Data from budget allocations on the costs of activities, in particular those undertaken to tackle environmental problems (e.g. expenditure on cleaning up beaches).	Expenditure cost data from those managing environmental resources.	Yes, within UK costs of a particular activity unlikely to vary significantly.	Data on costs which implies a minimum level of welfare gained from the outcome (e.g. improved beach cleanliness).	Measures expenditure, not economic value, but this information is often nonetheless useful and relevant to decision makers who are interested in local or regional economic impacts.	Although this does not estimate Total Economic Value (TEV), this information is nonetheless useful and relevant to decision makers who are interested in local or regional economic impacts of changes in ecosystem services.
Value transfer. Allows existing value evidence to be applied to new cases without the need for primary valuation studies. **Techniques:** Point, function and meta-analysis transfer methods	Valuation evidence, preferred in line with 'valuation hierarchy' (see text) and other data (e.g. on environmental change, people affected) to implement UK Government best practice guidelines (eftec, 2010).	Yes, but this adds to data requirements and/or uncertainty of the transfer.	Best estimate of value of non-market resources given current valuation evidence and knowledge of environmental impacts.	Reliant on studies with relevance in terms of geography, the scale and timing of environmental change, the numbers and socio-economic groups of beneficiaries, and the decision-making context. Expert judgment may be necessary.	If based on a careful meta-analysis of several good-quality studies, this approach can be more accurate or reliable, on average, than a single primary study, especially if resources are limited. It is also very useful for rapid assessment, where there is a policy

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
					need to derive estimates more quickly than would be possible using primary valuation studies.
Appraisal methods - combining valuations of individual service changes to make a holistic assessment of overall effects					
Cost benefit analysis (CBA). A decision support method which compares, in monetary terms, as many benefits and costs of an option (project, policy or programme) as feasible, including impacts on environmental goods and services. CBA is designed to target two of the most crucial appraisal questions: "Is a given objective worth achieving?" and if so, "What is the most efficient way of doing this?".	Monetary values of costs and benefits.	Yes, provided necessary data.	Quantitative (monetary) analysis of costs and benefits to identify the most beneficial of a number of objectives or the optimal level of an objective. Result usually presented as the Net Present Value (NPV) or cost benefit ratio for a project or policy proposal. Good practice is to also present significant unvalued impacts alongside monetary results.	Its application to any natural environment category is limited by the availability and quality of the necessary data (e.g. may be reliant on non-market valuation techniques described above). Reliance on market data can overlook cumulative and/or threshold effects on natural environment. Costly and time intensive to assign a value to each impact.	Can be used to assess multiple policy, plan or project goals. Can distinguish between stakeholder groups. Merges non-market with market values. Meaningful measurement units.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
Cost effectiveness analysis. Decision support method which relates the costs of alternative ways of producing the same or similar outcomes to a measure of those resulting outcomes. CEA is equivalent to one dimension of CBA in that it can answer the question of the cheapest or most cost-efficient way of achieving a given objective, but not whether an objective is worth attaining.	Monetary values of costs for alternative projects, and consistent approach to measuring environmental impacts to generate 'effectiveness score'.	Limited, analysis of effectiveness needs to be revisited, and becomes harder to measure consistently, at larger scales.	Ranking of options to achieve an objective.	The main shortcoming of CEA is that it is limited to cost comparisons of options that deliver different quantities/qualities of the same single outcome, and this limits its applicability to more complex issues such as evaluating co-existence of activities. Furthermore, this tool does not monetise benefits making it difficult to compare impacts among different stakeholder groups.	Does not require the valuation of non-market goods. Less costly and time intensive.
Multi-criteria methods. Covers a variety of approaches (e.g. multi-criteria decision making, multi-criteria decision aid, participative multi-criteria analysis, social multi-	Involve: (i) developing a set of criteria for comparing policy or management options; (ii) evaluating the	Limited, analysis of impacts and weightings need to be revisited, and become	Impacts of project/policy are 'scored' in terms of relative impacts under each category, and given different weights derived from experts,	Weights may often be applied to the general concept of an effect (e.g. air pollution) rather than a precise level of that effect, which	Avoids controversy over assigning monetary values to non-market benefits and costs. Open and transparent.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
criteria evaluation). Most use deliberative or participatory approaches for developing weights or evaluations.	performance of each of the options against each criterion; (iii) weighting each criterion according to its relative importance; and (iv) aggregating across options to produce an overall assessment.	harder to measure consistently, at larger scales.	decision-makers, and/or stakeholder interaction.	can make it difficult to understand exactly what is being valued and how. In addition, values are only included for effects which are identified as relevant to the options (and for practical reasons, the number of such effects is limited).	Little economic knowledge required. A good tool to engage stakeholders. Weighted units can easily be used for spatial models.
Impact Assessment. This analysis framework is very similar to CBA, but is specifically applied for complete assessment of a proposed policy or decision, covering appraisal, implementation and ex-post evaluation. Valuation evidence can be important at each of these stages.	See CBA, but can also use evidence from other techniques discussed above (e.g. effectiveness scores).	Yes, but with need to re-formulate data according to scale.	Comparison of options to inform decision makers.	Designed to consider individual decisions, and so can overlook cumulative impacts or risks of crossing thresholds in environmental management.	See CBA.
Trade-off Analysis					
Marxan	Spatially explicit	Yes, can be	Generates alternative	Requires GIS data	Can be used within

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
http://www.uq.edu.au/marxan/ [accessed on 6 September 2013]. This tool was created and is maintained by the University of Queensland, assists in creating efficient spatial solutions to planning problems. Can be useful for comparing conservation goals while reducing cost and/or conflict with other land uses.	data on impacts of activities. Can incorporate socio-economic data such as catch per unit effort, fishing pressure, and catch values. Combinations of GIS layers if multiple variables are to be incorporated.	applied at different scales.	scenarios comparing achievement of conservation goals.	as well as socio-economic data required in other tools. Authors have cited issues with the 'single variable' approach, for example the case of fishermen, where a single variable cannot account well for the choices that fishermen actually make when deciding where to fish.	the broader context of an alternative decision support framework such as CBA or MCA, and may help with issues relating to particular stakeholder groups e.g. fishermen.
Switching analysis. This can be used to examine specific tradeoffs in CBA and other appraisal tools. Identifies the value of parameter that changes recommendations for decision-making (i.e. a threshold value).	Uses data already present in an appraisal.	Can only be undertaken at the same scale as the appraisal it is based on.	Provides analysts with an indication of the level of uncertainty that can be accommodated in a given appraisal case. These are most closely associated with cost-benefit analysis and the calculation of net present value (NPV) for a policy or project proposal. The basic premise is to establish how 'wrong' a	Can only be undertaken at the same scale as the appraisal it is based on.	Informs decision makers about sensitivity of decisions within limits of existing appraisals.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
			value has to be for the policy recommendation to change.		
Expert/stakeholder derived preferences – can be used alongside or instead of valuation and appraisal methods					
Expert assessments. Used to identify and ‘value’ (weight, rank) impacts or options directly.	Clear description of environmental change and inputs from relevant ‘experts’.	Yes, but this can add to uncertainty.	Different weights derived from experts, decision-makers, and/or stakeholder interaction.	Need to justify choice of ‘experts’ and the knowledge base they have for making judgements.	This is a very adaptable method, making use of the information available. No specialist software or tools are required. Low cost and can be undertaken relatively quickly.
Stakeholder-led assessments. Survey approaches, focus groups, citizens’ juries and other deliberative methods for assessing stakeholder views/ preferences on resource management and values.	Unbiased description of environmental change and ability to engage with range of affected stakeholders.	Yes, but at larger scales costs can rise and may produce disparate views.	Collection of views from affected stakeholder groups.	Difficult to establish whether values expressed are representative of wider affected populations.	Stakeholder-led so makes use of real life experience. Participatory nature increases ‘buy in’ from multiple stakeholder groups.

Table 12: Review of cross-cutting tools.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
ARIES (ARtificial Intelligence for Ecosystem Services) http://www.ariesonline.org./ [accessed on 6 September 2013]. This is a web-accessible application that builds and runs ad-hoc models of ecosystem services provision, use and spatial flow in a given area based on a user-dependent set of goals (Villa *et al*., 2009).	Probabilistic and capable of operating in conditions of data scarcity. No data will be required for basic analysis, but user data can be input to improve predictions. ARIES stores hundreds of pre-loaded local through global scale GIS datasets on the ARIES GeoServer.	Yes – but output will depend on the data available.	The outputs show which regions are critical to maintaining the supply and flows of particular benefits for specific beneficiary groups (Villa *et al*., 2009). The results can be exported as Network Common Data Forms (netCDFs), which can be easily imported into external GIS or netCDF viewing platforms for further display and analysis.	Detailed analysis may require data input for region of interest if not already available. Aspects of the model still under development.	It can accommodate a range of different use scenarios, including spatial assessments and economic valuations of ecosystem services, optimisation of payment schemes for ecosystem services, and spatial policy planning.
InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) http://www.naturalcapitalproject.org/InVEST.html [accessed on 6 September 2013]. This tool evaluates how human activities and	Scenario driven and spatially explicit. Spatial distribution and intensity of pressures. Spatial distribution of features.	Spatial resolution of analyses is flexible, allowing users to address questions at the local, regional or global scales. .	Provides output in both biophysical and monetary terms. Maps, trade-off curves and balance sheets.	Requires substantial proficiency in GIS. Limited modelling of feedbacks between	Initial versions of InVEST offer relatively simple models with few input requirements. With validation, these models can also provide

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
climate change affect production and value of terrestrial and marine ecosystem services.				ecosystem services. Changes in human behaviour generally not modelled.	useful estimates of the magnitude and value of services provided.
Marxan with Zones www.uq.edu.au/marxan [accessed on 6 September 2013]. This tool helps users design new conservation areas, report performance of existing conserved areas, and develop multiple-use zoning plans for natural resource management.	Planning unit boundary length, feature zone, planning unit versus feature, zones, costs and zone cost input parameter.	Yes – but output will depend on the data available.	Maps indicating most commonly chosen (least cost) planning units.	Only as good as underlying data. Makes simplistic assumptions about planning cost with respect to socio-economic activities. The assumptions used need to be consistent across model domain.	The advancement of Marxan to include zones represents a shift away from the basic conservation area design problem toward a multiple-zone scheme that supports the efficient allocation of resources across a range of different uses (see Watts *et al.*, 2009).

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
NatureServe Vista www.natureserve.org/Vist [accessed on 6 September 2013].This is a broad assessment and planning decision support tool focused on conservation of specific mapped features or 'conservation elements'. It facilitates capturing spatial and non-spatial information and conservation requirements for elements, defining scenarios of land use, management, conservation, disturbance, etc., and evaluating the impacts of scenarios on the elements. Vista also contains powerful internal tools and interoperability with outside tools to facilitate mitigating site-level conflicts, offsite mitigation, and development of alternative scenarios.	Conservation element information (distribution maps and attributes, expert knowledge such as minimum viable areas). Scenarios: maps of land use and policy attributes that you wish to evaluate against conservation goals. Spatial data representing elements the user wishes to conserve, represent or restore and data depicting land cover and possible land policy scenarios.	Maybe – but output will depend on the data available.	Evaluate, create, implement, and monitor land use and resource management scenarios designed to achieve conservation goals within existing economic, social, and political contexts.	Performance for large, complex regional projects that are conducted at fairly fine resolution is currently poor owing to the ArcView platform of Vista. There are a variety of infrastructure problems that may not make it fully functional. The Vista workflow is extremely complex and not very user friendly (Crist *et al*., 2009a).	Vista can support robust databases typical of sophisticated GIS projects. NatureServe Vista has been demonstrated to work with other planning and modelling tools such as Marxan and others.

Tool/method name – source/description	Data input requirements	Scalable	Type of output	Significant limitations	Significant benefits
InVitro www.cmar.csiro.au/research/mse/ invitro.htm [accessed on 6 September 2013]. This is an ecosystem-level, modelling framework which includes a socio-economic model to evaluate different management strategies. It has been specifically designed to assess multiple use management questions for the marine environment.	Biophysical data (e.g. gridded environment, habitats, primary production, trophic interactions, species life histories, movement and migration), socio-economic data (drivers, markets, costs, social pressures and perceptions), industry data, plan objectives and performance measures.	Yes – but output will depend on the data available.	Individual model outputs, final performance measures.	To date the modelling framework has been used in a limited number of systems. High effort required from a full-time modeller for the construction of the model. Requires Linux operating system	Can produce models at various spatial scales

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