Natural England Commissioned Report NECR213

Designing and applying a method to assess the sensitivities of highly mobile marine species to anthropogenic pressures

First published 25 May 2016

www.gov.uk/natural-england

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Natural England has committed to improve its statutory conservation advice for Marine Protected Areas (MPAs) to meet customer expectations, improve business certainty and better support environmental outcomes. Part of our advice describes the possible effects of activities (or operations) on protected habitats and species. Understanding the sensitivity of protected habitats and species to pressures caused by such activities is a central requirement in determining such effects.

This report was commissioned in order to assess the sensitivity of highly mobile marine species to a range of anthropogenic pressures. Having a robust, repeatable and transparent method in place for determining feature sensitivity facilitates consistency and transparency regarding the application of the evidence base when providing advice on operations. This study, in addition to other sensitivity work on marine habitats and our understanding of how pressures are related to differing marine operations will allow marine stakeholders to assess and manage the environmental impacts of proposed developments.

The report focusses on designing a method and then subsequently applying that method to assessing the sensitivity of 108 (88 birds, 13 fish, 5 mammals and 1 crustacean) marine species to a range of anthropogenic pressures. All species were notified features of existing or planned MPAs in British waters.

This report should be cited as:

PÉREZ-DOMÍNGUEZ, R., BARRETT, Z., BUSCH, M., HUBBLE, M., REHFISCH, M. & ENEVER, R. 2016. *Designing and applying a method to assess the sensitivities of highly mobile marine species to anthropogenic pressures*. Natural England Commissioned Reports, Number213.

Natural England Project Manager - Dr Robert Enever, Marine Conservation Advice, Senior Specialist, Marine Conservation & Management Advice Team, Level 10, Renslade House, Bonhay Road, Exeter, EX4 3AW **robert.enever@naturalengland.org.uk**

Contractor - APEM Limited, Unit 2, Ground floor, Gwaun Elai Business Campus, Llantrisant, South Wales, CF72 8XL **www.apemltd.co.uk**

Keywords - marine, Marine Protected Areas (MPAs), anthropogenic pressures, environmental impacts, protected habitats, species

Further information
This report can be downloaded from the Natural England website: **www.gov.uk/government/organisations/natural-england**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

ISBN 978-1-78354-316-8

Summary

Worldwide statutory nature conservation agencies are required to ensure a sustainable coexistence between nature and modern society. One widely used approach to protect marine biodiversity is the designation of marine protected areas (MPAs). To ensure the efficacy of these protected areas it is essential to implement evidence-led, transparent and robust management strategies for the habitat and species identified as sensitive to degradation by human activities. This report summarises a method of assessing highly mobile species (HMS) sensitivity to standardised marine anthropogenic pressures. The work focused on direct effects and expected consequences on the behaviour and fitness[1] of HMS. The methodology is based on previous approaches used for benthic habitats but adapted to ensure relevance for HMS within MPAs.

Sensitivity to natural or anthropogenic pressure is primarily determined by the HMS ability to resist that pressure by virtue of its physiological tolerance limits and behavioural plasticity (ie Resistance). At the same time, sensitivity also depends upon the capacity to recover from impacts following reduction or removal of the pressure (ie Resilience). Resistance and Resilience scores to standardised pressure intensities are here combined into a pre-formulated high level assessments of sensitivity to present or future human activities.

In line with the above, a sensitive feature is one which has low Resistance (easily affected by human activity), and/or low Resilience (recovery time following an impact is long or impacts are irreversible). Sensitivity assessments for HMSs have been largely unavailable to date partially due to the complexity caused by avoidance behaviours, extended species range, complex life cycles and indirect effects on supporting habitats and food resources. In part, the complexity of assessing overall effects on HMS in comparison to habitat or sessile species assessments can be greatly reduced by making independent assessments of the direct effects caused on the HMS features themselves and the effects on supporting HMS habitats and attributes by the same pressure. This work follows this strategy and is designed to focus on assessing direct sensitivity of HMS features to anthropogenic derived pressures using best available evidence.

To achieve the expected outcomes we firstly reviewed HMS Resistance and Resilience information to direct effects of marine pressures. Secondly, we designed and applied a clear and auditable high-level sensitivity assessment method to identify and score the direct effect of marine pressures on HMS. Thirdly and finally, we identified direct routes of impact, applied the method to a suite of HMS, and provided an appraisal of the strengths and limitations of the assessment.

Methodology

A total of 88 birds, 13 fish (and a crustacean) and 5 marine mammal species were assessed for their sensitity to 36 anthropogenic pressures. All species were notified features of existing or planned MPAs in British waters. Each species was assigned to a functional group (ie an ecological or functional guild) on the basis of feeding and habitat traits, and taxonomical relatedness. This approach was devised to provide a framework to use proxies in the assessment of data deficient species. All features were assessed against the same standardised list of human pressures as defined by the Intersessional Correspondence Group on Cumulative Effects, 2011.

The methodology follows closely the approach developed by Tillin and others (2010) and the recent method update described by MarLIN (Marlin.ac.uk. 2015) who introduced an evidence-based evaluation and audit trail of evidence for the sensitivity assessments. The revised MarLIN methodology referred as Marine Evidence based Sensitivity Assessment (MarESA) and the present methodological update for HMS features were developed in parallel but independently from each other. Briefly the method provides sensitivity scores by combining the species tolerance to a defined

[1] Biological fitness, also known as Darwinian fitness, is here defined as the ability to survive to reproductive age, and produce offspring endowed with the most successful genes resulting in more successful organisms.

intensity of pressure (the benchmark intensity) and recovery potential from a disturbed condition. The method was adapted to ensure relevance to HMS and focused on direct routes of impact. The major steps followed were:

- screening for existing HMS sensitivity information and expert opinion;
- critical appraisal of HMS key elements;
- definition of benchmark intensity scoring;
- Resistance and Resilience scoring; and
- overall sensitivity ranking and confidence scoring.

Screening and appraisal of HMS key elements: A dedicated literature review and collation of expert opinion of where gaps in evidence existed was used to summarise key elements of the HMS-pressure associations. Aspects relevant to the assessment of Resistance and Resilience were summarised in short reviews to support the scores given in the assessments. The screening took into consideration the theoretical effect pathway leading to impacts (direct or indirect) and the types of impact (displacement, mortality or reduced fitness). This exercise provided an initial screening to decide on the relevance of the pressures to HMS or, for data deficient species, a proxy assessment based on predefined functional groups. The high-level review and screening was used first to screen out feature-pressure pairs where the evidence from the review suggested that there was no relevant interaction. These pairs were categorised 'Not relevant' and were not considered further.

Benchmark intensity: The benchmark levels act as reference points to assess sensitivity. The benchmarks were intentionally set without consideration to individual HMS feature Resistance, and therefore do not represent thresholds allowing judgments of relative sensitivities for a pressure to be made across features. Benchmarks were identical between species within each HMS group (bird, fish or marine mammal) and, as much as possible, set to an hypothetical level of pressure relevant to each HMS group. Wherever possible the benchmarks included a population effect criterion general to the HMS group, or if this was not possible and to ensure relevance, the simple presence of the pressure was used as a benchmark criterion. All benchmarks were reviewed at the technical workshops and in consultation with NE and JNCC technical advisors to reduce bias and ensure relevance.

Once the benchmarks were defined, each scoped in feature-pressure pair was classified according to the primary effect pathway. Those pairs where the evidence suggested direct effects on HMS were unlikely were categorised as having 'No direct effect' to indicate that pressure induced effects occur indirectly ie via direct effects on the environment (notably supporting habitat or food resource) in which the species live. These pairs were not assessed further within this work.

Resistance and Resilience scoring: Predefined Resistance categories were defined to reflect a range of expected population responses (impacts) from high resistance (ie no population decline) to no resistance (ie severe decline). For the scoring of direct effects it was assumed that HMS populations exist at their optimal niche and are only experiencing the pressure used in the individual assessments at the level of the predefined benchmark intensity. Scoring was based on the evidence obtained in the initial reviews or by expert input during the technical workshops.

Resilience or recovery from a displacement-type impact was scored simply based on the likelihood that the feature might return to the area within a certain period of time after the removal of the pressure in the site. For mortality-type impacts Resilience score was based upon the likelihood that the population might return to its pre-impact size within certain time periods. This was assigned using direct species evidence on species lifespan, fecundity and generation times. Arbitrary time periods of three, six and twelve years were used to define the Resilience score categories and to ensure alignment with current reporting cycles on designated features. Confidence scores were assigned to each Resistance and Resilience scoring which were based on the quality (information sources), applicability and geographical relevance, and degree of concordance (agreement between studies) of evidence that was available to support the Resistance and Resilience assessments.

Sensitivity rank matrix and confidence scoring: Resistance and Resilience was cross-tabulated to assign features to each of the four sensitivity categories namely: Not sensitive, Low, Medium and High Sensitivity. Proxy sensitivity assessments for data deficient species were scored in the same way but using evidence from other related species in the functional group. The confidence scores associated with the Resistance and Resilience scores were brought forward and the component with the lower confidence score was taken for the combined sensitivity confidence score. All scores were moderated by internal and external review before collation into the final assessment matrix. Taking a standardised approach and obtaining an external review by technical advisors ensured consistency across HMS feature assessments.

In most cases the evidence was enough to provide either species-specific or proxy assessments (the later identified with low confidence scores). However, for some feature-pressure associations where there was evidence indicating a general functional group-- or feature-sensitivity to a pressure, there was no clear evidence of tolerance or potential recovery at the benchmark levels. These pairs were classified as 'Not enough evidence to assess'.

Conclusions and findings

The high-level initial screening phase and subsequent scoping followed similar steps used in Environmental Impact Assessments. It is important to note that this study focused on direct effect pathways on HMS. Therefore, only displacement, and lethal or sub-lethal effects on individuals that are likely to have population consequences were assessed. Indirect effects on HMS through direct effects on habitats, food resource or more complex biotic interactions (competition and predation) are likely to exist and should be considered in addition to this sensitivity assessment on direct effects.

Resistance and Resilience assessments were carried out at the functional group and feature level by summarising all available evidence on type of effects, magnitude and direction (positive or negative) for the species in the functional group. This approach provided consistent assessments across functionally-related features, and more importantly allows proxy assessment for evidence-deficient HMS features. HMS avoidance behaviours probably cause greater population decline and over a shorter time period within a particular site than population declines caused by direct mortality.

Less mobile features or features with restricted access to unaffected areas will be more greatly affected by mortality or loss of fitness if sublethal effects prevail. In general, for a given population decline within a site, impacts resulting in the death of a proportion of individuals within a population will have longer population recovery times (lower Resilience) than an equivalent decline driven by the (temporary) displacement of individuals from the site. Consequently where a pressure could result in both mortality and displacement, Resistance was assessed on the basis of the mortality pathway if, as was usually the case, that scenario led to a more sensitive assessment score, ie the assessments used the worst case scenario.

HMS have the ability to actively avoid harmful pressures. Thus, some pressures (eg visual or noise disturbance), may lead to displacement and relocation outside the MPA site boundaries causing significant reductions in population numbers within that site but without introducing mortality or reproductive failure. Nonetheless such pressures would reduce the ability of the site to support the HMS feature. On the other hand, some pressures which cannot be avoided will lead to direct mortality or reduced productivity of a number of individuals in a population (eg fishing, collision or microbial pathogens). However, for most pressures, both displacement and mortality/fitness effect pathways are likely to contribute to local population declines. An important consideration in assessing the overall sensitivity of HMS in such cases is that their mobility may lead to a lower Resistance score via the displacement pathway than through the mortality pathway as individuals make use of their mobility to avoid a pressure source and reduce the associated direct mortality risk. On the other hand, that behavioural flexibility may lead to a higher Resilience score via the displacement pathway in comparison with that through the mortality pathway as individuals which have not suffered mortality may readily return once the pressure is lowered or ceases; this being at a rate which will almost certainly be faster than that at which the population will replace individuals lost through mortality or reduced productivity. In a real situation a number of site-specific factors, and indeed the level of exposure to the pressure, will affect the degree to which a pressure acts on a feature via one or other pathway and hence the impact on the feature.

Due to the general paucity of direct recovery evidence, Resilience scores have comparatively lower confidence levels. Expert judgement was used to produce an estimate of the recovery potential of a population in years given the expected severity of the impact and the effect pathway. Assessments were possible by considering basic fecundity, adult mortality rate, age at first maturation and lifespan to assess recovery time for pressures resulting in mortality or fitness effects. Information on home range and dispersive capacity was used for pressures resulting in displacement effects.

Overall findings indicate that the pressures which lead to the most frequent assessments of some degree of sensitivity in the case of all three taxa are very similar and include within the top ranking pressures: removal of target species, removal of non-target species, introduction of microbial pathogens, collision with manmade structures (above water for birds, and below water for fish and marine mammals), introduction of light, barrier to species movements, marine litter, and direct disturbance (noise for all HMS groups) and visual disturbance for birds. Birds in particular show high sensitivity to above water collision while fish and mammals are generally assessed as highly sensitive to underwater noise (and vibration).

Migratory fish features have some level of sensitivity to the largest number of pressures that could be assessed. Deoxygenation, salinity effects, temperature, genetic modification and suspended solids were additional relevant pressures across fish features.

The confidence arraigned to Resistance and Resilience scores were highly dependent on the HMS group. For bird features visual disturbance, introduction of invasive species and removal of individuals by hunting or by-catch resulted in “high” confidence scores. Conversely sensitivity of birds to pressures of: noise, collision below the water surface, suspended solids, introduction of light and emergence regime were almost always associated with low confidence scores. Confidence scores for fish (and lobster) were “high” for barriers to species movement (in particular diadromous features) and changes to water flow. On the other hand sensitivity to water quality deoxygenation, genetic modifications and removal of target and not-target species pressures frequently scored “medium” and “low” and wave exposure, introduction of microbial pathogens, electromagnetic changes, and visual disturbance all have “low” confidence scores. Marine mammal features have “high” confidence scores associated with visual disturbance and removal or target and non-target species. Sensitivity assessments to the rest of the assessed direct pressures have “medium” confidence sensitivity scores with the exception of collision below water generally assessed as “low” confidence in the group.

Interpretation and use of the sensitivity assessment

It is clear that the outcomes of the HMS feature assessments are subjective in nature and depend heavily on applicability and quality of the underlying evidence base, selection of benchmark, scoring thresholds, confidence in the assessments and the level of experience of the technical consultants providing the final scoring. As such the assessment provides an indication of sensitivity rather than a precise evaluation and score.

It is also important to stress that the sensitivity assessments, other than for the purpose of scoping direct effects, take no account of the indirect effects that pressures may have on these HMS mediated through significant effects on their supporting habitats or other resources on which they depend. It is also important to note that these assessments are simplifications of functional responses which are necessarily assessed on hypothetical scenarios representing the average expected condition. They are generic, do not incorporate exposure in the scoring, are very dependent on the particular benchmark levels used, do not account for spatial or temporal scale, and are often based on limited scientific evidence on the precise magnitude of responses to pressures.

Clearly the sensitivity assessments will be applicable to multiple specific activities and geographical areas (case work) as the assessments are based on generic pressure scenarios (benchmarks) acting on a hypothetical free-living population in a pristine environment and living within the optimal niche of the species. However, the sensitivity assessment is not an impact assessment and this sensitivity assessment should only be used as a guide to inform the site-specific assessments conducted on specific sites and activities. The magnitude of specific activities has not been assessed as the sensitivity assessment is based on theoretical benchmarks.

Nevertheless, the limitations implicit in the method are acceptable when the sensitivity outcomes are to provide a high-level standardised screening and ensure consistency for scoping and assessment exercises or are used by trained biologists to guide management decisions. For example, scores can be interpreted by comparing the magnitude of the actual activity that will take place (case work) with the benchmarks to provide an indication of whether the HMS is likely to be more or less sensitive than the reported sensitivity assessment. Due to the relative simplicity of the approach the sensitivity outcomes can be easily reviewed and updated as new evidence becomes available.

Valid inferences are possible if the limitations of the approach are clearly understood and users pay careful attention to:

- the evidence provided and confidence assigned to each assessment;
- the benchmark used and how it compares with site-specific pressures if scores will be used to inform management;
- the possibility of significantly greater sensitivity of local populations, eg those with low population numbers, reduced genetic diversity or having a strong social coherence which could greatly amplify population effects;
- the nature of the effect and understanding of the effects of pressures (eg, direct or indirect impacts);
- the main pathway of effect, which is typically displacement from preferred habitats or fitness related;
- the functional group and scoping of relevant pressures for proxy assessments;
- the possibility of cumulative and in-combination effects;
- the possibility of indirect effects; and
- the need to allow for an independent review by experienced practitioners and relevant stakeholders.

Overall, this study provides evidence-based sensitivity scores which, when combined with an assessment of the magnitude of specific activities, will assist in helping to determine potential impacts and appropriate conservation measures for HMS within the marine environment.

Acknowledgments

First and foremost the authors of this study offer their sincerest gratitude to the Natural England (NE) team for their support throughout the duration of the project. Their contributions have been utterly essential to deliver the project. A particular mention is due to Natural England and Joint Nature Conservation Committee advisers who assisted with the development of the sensitivity scoring and provided useful discussions on the intended application of the sensitivity method. We would like to make special mention of Richard Caldow, Claudia Stauss, Joanne Ziemann, Claire Ludgate, Tom Hardy, Randolph Velterop (NE), and extend thanks to Dr Julie Black (JNCC), Adrian Fewings and Adam Waugh (Environment Agency). Thanks are due to the teams of independent technical advisers; Lucy Wright from the British Trust for Ornithology (birds); Nicola Quick from SMRU Marine (Marine mammals); and Mario Lepage from IRSTEA (French National Research Institute of Science and Technology for Environment and Agriculture) and Steve Coates and Steve Colclough from SC2 Ltd. (fish); who participated in the project workshops. Additional consultation was held with Vera Mendão from the Projecto Delfim - Centro Português de Estudo dos Mamíferos Marinhos. We are deeply grateful to all for sharing knowledge of different competences, valuable discussions, feedback on multiple versions of scoring tables and pressure benchmarks, and provision of external quality assurance to the work done by APEM consultants.

Contents

List of tables

List of figures

1 Purpose of the report

The purpose of this report was to produce evidence-led population sensitivity assessments of highly mobile species (HMS) to standardised marine anthropogenic pressures. The report has focussed on the main steps undertaken to develop a consistent method to assess direct effects on the behaviour and fitness of HMS features (species which are explicitly protected within marine protected areas, MPAs). Indirect effects, typically those mediated by effects on the feature supporting habitats or any other supporting ecological component (ie prey item or predatory species) were excluded from this work. These indirect effects are considered in a parallel work introducing detailed evaluation of recent evidence on which to base habitat sensitivity assessments (Marlin.ac.uk. 2015). Recently formulated habitat assessments follow a similar evidence-based approach and updated sensitivity methodology equivalent to the one described in this work known as the Marine Evidence based Sensitivity Assessment approach (hereafter MarESA) (Marlin.ac.uk. 2015). This work is part of the same assessment framework and can be used to assess indirect sensitivity of any HMS to a given pressure by simply considering direct sensitivities of habitat attributes that support the HMS features.

The report has been structured in three main sections: evidence review, method development and a final guidance section designed to aid in the interpretation and application of the sensitivity assessments. The report deliberately focuses on the core method and adjustments made to sensitivity assessment methodologies used elsewhere (such as for benthic habitats) to ensure relevance for HMS. Additional information detailing evidence search protocols, supporting tables and workshop outcomes are presented in appendices.

The work presented here was commissioned by Natural England (the body responsible for advising on nature conservation issues in England) to further develop a method of assessing sensitivity to anthropogenic pressures of HMS of conservation importance.

2 Need for a pressure sensitivity tool

There has in recent times been a worldwide drive for policy makers to devise, and their statutory nature conservation agencies and regulators to implement, measures to control damaging and potentially damaging activities in the marine environment. One of the principal measures which has been implemented by the governments of many countries is the establishment of direct protection schemes for threatened habitats and species such as Marine Protected Areas (MPA) (Morris and others, 2014). These schemes have proven effective to protect sensitive habitats and species from excessive pressure by halting or reversing the observed impacts following MPA declaration (24).

In the United Kingdom the government enshrined its commitment to the establishment of an ecologically coherent network of MPAs to help conserve marine ecosystems and marine biodiversity in the Marine & Coastal Access Act 2010. The MPA network in UK waters is currently in the process of being developed and includes sites which are, or will be, designated under both national legislation ie Marine Conservation Zones (MCZs) and European legislation ie Special Areas of Conservation (SACs designated under the Habitats Directive) and Special Protection Areas (SPAs) designated in accordance with the requirements of the EC Birds Directive (24).

For each of these MPAs, the statutory nature conservation bodies in the relevant part of the UK are required to publish a package of Conservation Advice. Natural England publishes the packages which concern sites in English territorial waters. The packages contain both Conservation Objectives (CO) for each of the notified features of the sites, and advice on the potential significance of human activities on those features (ie advice on operations). The purpose of the advice is, amongst other intentions, to allow stakeholders to identify all the notified features of the site and to make a preliminary assessment of the likelihood that any activity which they may currently be undertaking, or planning to undertake, may have a significant effect on any of those features, in the light of their CO. To deliver this package, Natural England has undertaken a programme of work to develop a matrix-based tool which can be interrogated to establish an evidence-based assessment of the sensitivity of each feature within a site to any one of a wide variety of potential human activities. The tool is based on an assessment of the sensitivity of those features to each of the various pressures which any given human activity may exert on those features.

Highly mobile species features

Large marine fauna include a variety of generally predatory species most notably birds, marine mammals and migratory fishes but also other large marine species such as sea otters, cephalopods and mega-crustaceans. They are collectively regarded as highly mobile species (HMS) and have traditionally been used to champion both single-species conservation measures (e.g. threatened or rare species lists) and more recently MPA designations (24). HMS are, at some point in their life cycles exposed to marine anthropogenic pressures either directly affecting their performance or indirectly affecting the habitats and resources they rely upon. Although their mobility provides certain natural resistance to pressures during certain periods of their lives, critical life history stages (eg migration, nesting/calving/spawning, foraging and nursery periods) can be very sensitive to direct acute and chronic disturbance. Worldwide, MPAs, single areas or integrated networks, are considered an integral part of HMS protection.

Standardised sensitivity assessments for most HMS are currently unavailable, hampering the effective management of MPAs. HMS by virtue of their own mobility can and often do moderate their exposure to damaging pressures by fleeing affected areas. Drastic behavioural responses to acute pressures, typically displacement from MPA boundaries, may only last for short periods with the bulk of the population returning to their source areas once the pressure ceases. Even if no physical harm is done, sub-lethal effects in the form of increased energy expenditure or vulnerability to predation to the displaced individuals or dependant offspring may reduce fitness of a population and lead to significant impacts. Finally, if no alternative areas are available or the pressure exceeds normal physiological tolerance, severe effects on HMS features such as stress, reduced food intake, increased vulnerability to predators and diseases, and increased mortality rates are expected.

As described above, biological, physical and chemical pressures may affect HMS directly by altering normal behaviour or interacting with the individual's physiology. But HMS are also sensitive to impacts on their supporting attributes (typically habitat but also food resources and other biological interactions such as competition). Indirect effects to HMS caused by anthropogenic interactions with their supporting habitat are in many cases more important than those pressures which directly affect the feature itself. Sensitivity assessments for marine and coastal habitats in the UK have been widely studied (25; 25; 25. To this end, by understanding the supporting habitat requirement of HMS allows us to determine, using pre-existing evidence, the sensitivity of those supporting habitats to standardised anthropogenic pressures. By combining the supporting habitat sensitivities assigned to HMS with the results presented in this study (direct effects of pressures on HMS) enables us to assess the sensitivity of HMS in full to a proposed plan/or project through linking activities to pressures (a schematic representation of the combined sensitivity assessment strategy is presented in Appendix 6).

This work is designed to focus on assessing the direct sensitivity of HMS features to anthropogenic pressures using best available evidence.

Defining sensitivity

The sensitivity of a species to exposure at a particular level of natural or anthropogenic pressure is primarily determined by each organism's ability to resist that pressure by virtue of its physiological tolerance limits and (in case of HMS) also by its behavioural plasticity. At the same time, sensitivity also depends upon the resilience or capacity to recover from an altered state following reduction or removal of that pressure and the ability to adapt to change (8). Under this relatively simple conceptualisation, sensitivity is determined by intrinsic factors only, at either the individual or population level. It is important not to be confused with vulnerability or risk, which is the likelihood that a species or individual will be exposed to a level of anthropogenic or natural pressure to which it is sensitive (24).

In line with the above, 25 presented a method to assess sensitivity based on independent scores of:

a) Resistance, or tolerance, to a defined level of pressure, and
b) Resilience, or recovery from the pressure.

The method then combines Resistance and Resilience to derive an overall sensitivity rank. A similar approach forms the basis of the Texel-Faial criteria used by OSPAR to identify 'threatened and declining' species and 24, who define a sensitive feature when it has:

a) a low Resistance (easily adversely affected by human activity / impact); and/or
b) a low Resilience (recovery following an impact is likely to be achieved only over a long period).

In order to ensure that the approach used within this report is as transparent as possible, it is essential to clearly define the sensitivity criteria upon which the pressure-sensitivity matrix will be based for the HMS and follow a similar evidence-based approach as MarESA (Marlin.ac.uk. 2015).

- *Pressure* – The mechanism by which an activity, usually anthropogenic in nature, may influence a receptor (in this case HMS feature).
- *Impact* – The effects of a pressure on a population (HMS population in this case).
- *Resistance* – The ability of a species or feature to cope with a pressure without resulting in an impact (at the population level?).
- *Resilience* – The capacity of a species or feature to recover from a population impact.

- *Sensitivity* – A species' combined ability to resist (or tolerate) a pressure and recover from any impacts induced by the pressure (resilience).

Aims and objectives

There were three main aims to this project. Firstly, we aimed to review and identify HMS Resistance and Resilience information to direct effects of marine pressures. Secondly, we set out to design and apply a clear and auditable high-level sensitivity assessment method to score direct effects of marine pressures on HMS. Thirdly, we identified direct routes of impact and applied the method to a suite of HMS and provide an appraisal of the strengths and limitations of the method.

This was to be achieved through the following objectives:

- Identification of current evidence applicable to HMS and environmental assessments & integration of expert opinion.
- Critical appraisal and screening of information for 1) key elements of the feature, 2) quality of the evidence.
- Gap assessment & screening of direct impact routes (peer reviewed).
- Proposal of a feature-specific sensitivity assessment method in line with existing sensitivity-related work.
- Scoping of relevant pressures and defining a benchmark intensity for each feature-pressure pair.
- Provision of Resistance & Resilience scores for each feature-pressure pair.
- Provision of confidence and an overall sensitivity rank matrix (peer reviewed).

3 Overview of sensitivity assessment methodology

The study was designed to address the aims in a step-wise approach that involved an initial comprehensive literature review followed by a systematic appraisal and synthesis of information. For ease of implementation the assessment adopted a high-level approach using the sensitivity scoring methodology provided by 25. Briefly the method by 25 provides sensitivity scores by combining the species tolerance to a defined intensity of pressure (the benchmark intensity) and recovery potential from a disturbed condition, and involves four main stages:

1. definition of the species key ecological & demographical attributes,
2. assessment of the species Resistance and confidence scoring,
3. assessment of the species Resilience and confidence scoring, and
4. the combination of Resistance and Resilience scoring to provide a sensitivity rank with an associated confidence assessment (Figure 1).

The method aims to provide a framework upon which rapid assessments of direct effects of pressures on HMS can be assessed using the best evidence currently available. Throughout the development of the study the methods utilised were frequently reviewed by external advisors as part of the quality assessment process.

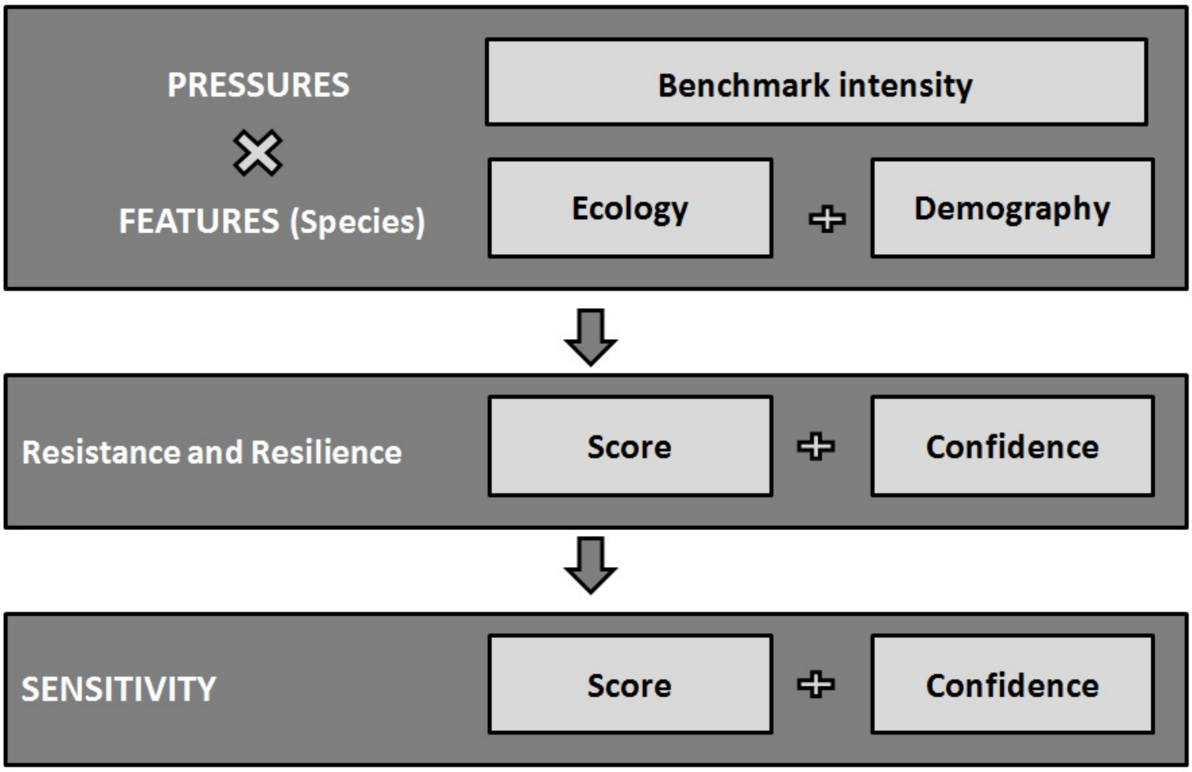


Figure 1 Sensitivity assessment method.
Ecology and demography indicate key species features used to score sensitivity and confidence. The arrows indicate the sequence of events and the audit points for the assessments.

HMS features and functional groups

A total of 107 HMS were selected for assessments. The majority (88) were birds, followed by fish (13), marine mammals (5) and one macro crustacean (Table A2. 1 of Appendix 2). All species were notified features of existing or planned MPAs in British waters, with most of them featuring in existing or planned MPAs around England. To facilitate the assessments and to provide a means whereby assessments could be made for all species, including even those which proved to be data-deficient, each species was assigned to one or a number of functional groups. Two broad classification criteria for grouping species were used. The first sought to categorise and group species on the basis of the nature of their occurrence as features of existing or planned MPAs ie as breeding features in coastal sites, non-breeding features in coastal sites and/or as species at sea ie in fully marine MPAs. The second sought to categorise and group species on the basis of their principal feeding mode eg benthic-demersal feeding birds. Full definitions of the groupings are given (Table A2. 2 of Appendix 2) and the groupings to which each feature was allocated are given in Table A.2.1 of Appendix 2.

Bird functional groups were based on the OSPAR common indicator and bird functional groups as recommended for the implementation of bird indicators for the Marine Strategy Framework Directive (MSFD) by International Council for the Exploration of the Sea (24). This initial assignment was later refined with the outcomes of the literature review and expert knowledge. Functional group definitions for fish and marine mammals were based on ecologically uniform groups according to common ecological traits and taxonomical relatedness. All functional group assignments were audited by a second expert and later reviewed at the technical workshop to prevent bias.

These functional groups combined species with similar life history characteristics and/or ecological traits such that the sensitivity of each species within that functional group to the various pressures might be assumed to be similar (25). For example all wading birds were grouped together in the same feeding mode group as in broad terms they feed in the same habitats within MPAs ie in shallow water or on exposed susbtrates in intertidal areas. Similarly all species that breed in coastal sites in Britain were given feature status and assessed independently from non-breeding populations of the same species. These functional groups provide a framework to use proxies in the assessment of data deficient species.

Human pressures and impacts

A pressure is considered as the mechanism by which an activity, usually anthropogenic in nature, may influence a receptor (in this case a population of an HMS feature). Natural change and extreme events could lead to similar pressures on features although it is expected that any viable population is resilient enough to avoid long lasting effects. For the purpose of this work we assumed that HMS populations exist at their optimal niche conditions and are only experiencing the pressure used in the individual assessments. Therefore, the sensitivity assessments take no account of any background effects on the species of natural change, extreme natural events or climate change.

Relevant pressures and their associated definitions followed the criteria proposed by the Intersessional Correspondence Group Cumulative Effects 2011 (25), which in turn closely follows previous initiatives (25; 24; Marine.scotland.gov.uk 2015; Marlin.ac.uk 2015). These comprehensive lists of pressures have been derived from conceptualisation of impact pathways primarily on benthic marine habitats (Tillin and others 2010; Marine.scotland.gov.uk 2015; Marlin.ac.uk 2015).

A total of 36 anthropogenic pressures within 6 general pressure themes were considered for the assessments (Table A3. 1 of Appendix 3). For consistency, the initial list of pressures and benchmark intensities were taken from 25. The initial list of pressures and linked definitions and benchmarks were refined according to the literature review findings (see Section 4) and input from the expert workshops to increase relevance to mobile species.

Unlike sessile or limited mobility species, HMS are in some instances able to mitigate the effect of pressures by behaviour (eg swimming away from noise). The technical review identified those pressures that are likely to result in behavioural or displacement effects rather than pressures that cause direct mortality or reduced productivity (Table A3.2 – route of impacts column). This exercise provided an initial screening to decide (1) the relevance of the pressures on HMS or the predefined functional group (feature[2]), (2) the nature of the effect pathway leading to impacts (direct or indirect) and (3) the types of impact (displacement, mortality or reduced fitness). It was also used to define the pressure benchmark intensities used for the HMS sensitivity assessments. For consistency with previous work, the initial scoping and later refinement of the benchmarks followed 25. The existing benchmarks were modified according to the expected range of pressure intensities experienced by each HMS group (bird, fish or marine mammal) before avoidance behaviours were considered. These pressure ranges were used to determine a realistic benchmark value for each HMS group and pressure combination. Benchmark levels for some pressures could not be realistically defined and the presence of the pressure was used as a conservative benchmark criterion to determine the sensitivity scoring. The technical advisors later provided further review at the technical workshops.

[2] In this context feature indicates species group, functional group, individual HMS or a combination of these terms.

4 Development of the HMS feature-pressure sensitivity matrix

The sensitivity scoring and matrix was completed in a step-wise approach that involves an initial search for information through a comprehensive literature review and, subsequently, appraisal and synthesis using the sensitivity scoring methodology provided by Tillin and others (2010). The method was adapted to ensure relevance to HMS and focused on direct routes of impact. The major steps followed were:

1. screening for existing HMS sensitivity information and expert opinion;
2. critical appraisal of HMS key elements;
3. definition of benchmark intensity scoring;
4. Resistance and Resilience scoring; and
5. overall sensitivity ranking and confidence scoring.

In addition to the main objective and in recognition of the important role of the water column as supporting habitat for HMS, an independent assessment of water column habitat sensitivities to the complete list of human pressures was undertaken. The sensitivity of the water column “supporting habitat” was assessed as part of this work because it was not included by the parallel MarLIN led habitat sensitivity review (Marlin.ac.uk. 2015) and is considered important for a number of HMS features (Appendix 3 Tables A3.2 to A3.4).This independent habitat assessment followed the same five major steps described above. To ensure consistency with existing benthic habitat assessments (25; 25; 24; Marine.scotland.gov.uk 2015; Marlin.ac.uk. 2015) key biotic and abiotic attributes of the water column habitat were evaluated in terms of likely effects resulting from benchmark exposure levels as done for the HMS. The assessments were based on direct effect on habitat-defining attributes such as volume, structure (water stratification, currents and mixing dynamics), physicochemical parameters (water clarity, oxygenation, temperature, salinity, sediment load, nutrients, etc.) and productivity including phytoplankton and zooplankton. The assessment methods mirrored those developed for the assessment of HMS except that the benchmarks were those defined by 25 as well as the updated MarESA methodology (Marlin.ac.uk. 2015).

Water column and available benthic habitat assessments were then used in the screening of pressure relevance and type of effect (direct vs. indirect) for all the HMS features assessed. No further use was given to the water column sensitivity assessment and the sensitivity method concentrated on direct effects on HMS features exclusively (Appendix 6).

Review of existing HMS sensitivity information

The literature review was conducted using major bibliographic search engines including Scopus, Web of Science, Biomed, Google Scholar and the World Wide Web, as well as by direct scrutiny of relevant guidance documents and reports. The search strategy was devised according to the scoping methods recommended by the 24. The search protocol and overall results are presented in Appendix 1. Our search results were compiled as 'EndNote' libraries and organised within specific literature folders according to the method described by Busch and others (2015). A total of 29,626 bibliographic records were identified by the initial searches. This number was reduced in a two-step relevance screening to a total of 1,042 documents from which 823 were finally used to inform the sensitivity scoring (Appendix 1).

First, a pre-screening protocol was implemented focusing on the (1) relevant biological and ecological elements of the features and (2) the HMS responses to pressures and sensitivity scoring methodologies. All three HMS groups, birds, fish and marine mammals, were assessed independently and individual bibliographic lists kept for each feature. The aim of this step was to assess from the abstract, or by a quick assessment of the full text, for the more promising documents. Life history traits and functional group-specific search terms (eg wading birds, coastal bird aggregations, migratory fish assemblages, functional group-characterising species, etc.) were refined in the search and pre-screening steps.

The final screening for evidence of direct pressure effects and scientific quality (eg objectivity, experimental design and applicability of the evidence) was conducted during the development of the HMS-pressure matrix and sensitivity assessments. The selection of relevant titles on functional groups was similar to that employed to identify species-specific evidence. The selected final pool of studies was used to inform the method development as well as the Resistance and Resilience assessments. Key elements of the HMS-pressure associations were summarised in short reviews (including expert opinion where gaps existed) to support the scores given in the assessments. Peer reviewed journal articles, reports, conference proceedings, serial publication and books or book sections dated between 1948 and 2014 accounted for almost all of the selected records. However, the vast majority of records were from publications published since the 1990s (Appendix 1).

Pressure screening and effect pathway

The information gathered during the literature review was summarised by HMS functional groups and pressure type to provide a general description of the magnitude and direction of the effects as well as the impact pathways. This high level review was used, first, to screen out feature-pressure pairs where the evidence from the review suggested that there was no relevant interaction (eg deoxygenation and birds or marine mammals, fish and risk of collision with above water structures, etc.). These pairs were categorised '*Not relevant'* and were not considered further.

Next, each remaining feature-pressure or functional group-pressure pair was classified according to the primary effect pathway. Those pairs where the evidence suggested direct effects on HMS were unlikely (eg. pressures affecting a physical or biological quality of features other than the feature under assessment) were categorised as having '*No direct effect'*. A 'No direct effect' classification does not indicate that the pressure may not have an effect on an individual's mortality or productivity, just that any pressure induced effects occur indirectly ie via direct effects on the environment (notably supporting habitat) in which the animals live.

Pressure benchmark intensity

The sensitivity of a feature to the pressures exerted by an activity depends upon its ability to resist that pressure and its Resilience to it ie ability to recover from that pressure. Clearly both of these elements of sensitivity depend upon the level or intensity of that pressure. Thus, in order to ascribe single scores to the Resistance and Resilience of a feature to a pressure and hence its sensitivity, it was necessary to define a benchmark intensity or level of that pressure at which that assessment is made. The benchmark levels act as reference points to assess whether, according to the life history and ecology of the feature, it is reasonable to expect deviations in demography/population structure or (in the case of HMS) displacement from normal habitats. This section describes the adaptation of the Pressure Benchmarks used by 25 to increase their relevance for HMS assessments and the criteria used to develop new benchmarks or to redefine pressures in order to allow sensitivity judgement to be made.

Benchmarks vs Thresholds

It is important to note that the sensitivity assessments at these defined benchmarks do not signify thresholds above which the defined sensitivity score applies and below which there is lower or no sensitivity. Benchmarks were identical between species/functional groups within each HMS group but were different between HMS groups and provided the necessary reference against which individual HMS features can be assessed. That is, the benchmarks were intentionally set without consideration to individual HMS feature tolerance, and therefore cannot be considered thresholds. Importantly the benchmark approach allows judgments of relative sensitivities across features within a HMS group for a pressure, and equally, across pressures for a feature.

In practice thresholds are not useful to define theoretical sensitivities when 'realistic' pressure levels need to be assessed independently from the activities causing them. Often in real life identical pressures may result from different activities (eg impact pilling and airguns used in geotechnical investigation produce noise pollution) but typical pressure levels (loudness of the noise and duration) are unlikely to be identical, and will be highly influenced by the scale of the activity. In-combination effects and uncertainty on the real pressure levels causing population changes effectively prevented the use of species thresholds in this work.

Defining approach to benchmarking

Where possible, benchmarks were scaled to reflect a single hypothetical but realistic and quantifiable level of pressure arising from an undefined marine activity. 25 used three benchmark levels namely Low-Medium, Medium and Medium-High (L-M, M, and M-H, respectively). We opted for a simplified single benchmark approach equivalent to the medium level benchmark proposed for previous work. The main reason for this decision was based on the ability of most HMS to control exposure to increasing levels of pressure by eliciting directed avoidance responses. In fact all pressures where displacement is a significant expected response (eg noise, reduction of intertidal area, visual disturbance, etc.) may well render high benchmark levels of pressure totally inappropriate as they are too improbable to be experienced for any amount of time. A high benchmark level will produce low confidence assessments.

Some species at some periods in their life cycles are less likely to be displaced and will certainly suffer direct mortality or loss of fitness. Similarly, other pressures will primarily cause mortality, eg pressures unlikely to be detected by individuals or those that could affect the entire population range of the feature (introduction of invasive species or microbial pathogens, collision risk, direct commercial exploitation, by-catch removal, etc.). In this case three graded benchmark levels would have been tractable. But, having different benchmark levels for different HMS life stages or pressures would equally have required additional assumptions and would certainly have compromised the intended aims of producing a simple score to assess features sensitivity across a list of standardised pressures.

Wherever possible the benchmarks included a quantitative population effect criterion general to the HMS group and defined using expert judgement. This was necessary to ensure the benchmark was compatible with the expected quality and type of sensitivity evidence available for the assessments. For example each HMS feature group was assigned a different benchmark for the pressure 'Removal of non-target species' as follows.

For bird features, where more information is available including rate processes and population or demographic models, the benchmark was:

- Numbers of individuals of feature removed as by-catch equates to in excess of 10% of the rate of natural mortality of the population of the site under consideration eg increases annual mortality of that site's population of individuals from 10% to 11%.

For fish features, which is a comparatively less well-known HMS group but for which population estimates in the form of stock assessments or catch statistics generally exist, the benchmark was:

- Extraction of features as a non-target species removes 10% of the individuals from the population of the site under consideration.

Finally for marine mammals, which is a HMS group with the largest uncertainties in population estimates and potentially very sensitive to any direct mortality, the benchmark was:

- The introduction of bycatch risk in areas used by features.

A final important consideration for benchmarking was to ensure, as much as possible, comparability with former sensitivity assessments. As such most of the necessary changes were generally limited to pressures with the potential to affect HMS directly.

Revised pressures and re-defining existing benchmarks

Many of the pressure benchmarks used in this study were standardised ones from existing sensitivity work 25 . However, the definition of benchmark intensities relevant to HMS features required a re-definition of some pressures and their benchmarks. For example, 'Collision above or below water with static or moving objects not naturally found in the marine environment' replaced the original pressure 'Death or injury by collision' to allow the definition of specific benchmarks representing a likely level of pressure from structures or machinery causing significant collision risk.

Benchmarks defined according to existing guidelines / standards (eg Hydrocarbon/PAH contamination, deoxygenation, suspended solids, etc.) were not altered. Generic quantitative benchmark definitions were reviewed and where appropriate these were modified to be more relevant to each of the three principal groups of HMS considered here ie mammals, birds and fish. Most of these revised benchmarks were set at levels which define degrees of change from the baseline (eg set change in salinity units, percentage of population at risk of collision, area/volume of biologically relevant structures removed, etc.). Generally changes were limited to the extent and duration of the pressure and only occasionally resulted in a complete redefinition of the benchmark (ie type of or magnitude). For some pressures, however, finding a level of benchmark intensity reflecting a hypothetical yet realistic level of pressure was not possible due to large uncertainty and lack of consensus between reviewers. Benchmarks were then defined simply as the likely presence of the pressure within the expected population range (eg introduction of pathogens, or alien or invasive species).

Revised and new benchmarks were designed according to the likely range of pressures arising from activities that are considered to be the main threats to HMS. Expert judgment is an integral part of this process as judgments of intensity and extent of expected (typical) pressure field, links to population areas and ultimately effects on HMS are multifaceted and complex in nature. To prevent bias the benchmark definitions were agreed across the four technical workshops. The initial list of marine pressures and their associated definitions were reduced to those relevant to HMS. A total of 36 different pressures and benchmark definitions were finally agreed in consultation with the technical advisors (Tables A3. 1, A3. 2, A3. 3, and A3. 4 of Appendix 3).

Resistance scoring

Scoring tables

The scoring was based on discrete categories of *Resistance* of the HMS to the benchmark pressure level (Table 1 and Table 2) using agreed assessment scales adapted from 25 . The population effect criteria for the Resistance scoring were revised for the different HMS groups based on evidence of population effects found during the review phase or by best professional judgment during the technical workshops (further information on the technical workshops is provided in 19 and Annex 1). It is important to note that these tables are not benchmarks but provide a series of potential pre-scored levels of Resistance that encompass the full range of possible responses of an idealised population to a pressure exerted on it at a previously defined benchmark. In other words the tables reflect discrete biological relevance levels according to a predefined level of pressure.

The Resistance definitions for birds and fish were identical. The technical reviewers setting the criteria for birds and fish considered it reasonable to assume that a population which demonstrates a decline of up to 10% in numbers on a site as a consequence of the effect of a pressure, and thereby persists in numbers in that site at a level of 90% or more of the baseline population size, is exhibiting at worst a medium degree of resistance to that pressure. On that basis, only population declines of greater magnitude were considered indicative of either low or no resistance to the effects of a pressure. The definitions for marine mammals are different and more precautionary (Table 1 and

Table 2 respectively). Marine mammal technical reviewers felt strongly that a population decline of 10% in a site could have extremely detrimental effects for a small and socially coherent marine mammal group (which have no equivalent in fish or birds), especially if mortality affects the individual(s) leading the group.

Assessments

Initially, Resistance assessments were carried out at the functional group level by summarising all available evidence on type of effects, magnitude and direction for the species in the functional group. A brief justification text was produced to support the assessments. Functional group summaries were then used to provide a common foundation for the species-specific evidence reviews and assessments. Species reviews for each relevant pressure were then created to produce sensitivity assessments. This approach provided consistent assessments across functionally-related features, and more importantly allows assessment for evidence-deficient HMS features. When no direct evidence on a specific HMS was found, the functional group level assessment was used to try to make *judgments by proxy* of the feature's Resistance and Resilience to pressure. Necessarily these assessments scored low confidence (see confidence scoring, Table 5).

Species-specific Resistance scores to a pressure were assessed on the basis of the expected changes to the population that might occur at the benchmark pressure intensity. As discussed in Section 4, HMS avoidance behaviours are likely to cause a greater population decline over a shorter time period within a particular site than population declines caused by direct mortality. Less mobile features or features with restricted access to unaffected areas (ie a ground nesting bird exposed to predation by a non-native predator in a remote breeding island) will be more greatly affected by mortality. In general, for a given population decline within a site, impacts resulting in the death of a proportion of individuals within a population will lead to longer population recovery times (lower Resilience) than an equivalent decline driven by the (temporary) displacement of individuals from the site. Consequently where a pressure could result in both mortality and displacement, Resistance was assessed on the basis of the mortality pathway if, as was usually the case, that scenario led to a more sensitive assessment score ie we used the worst case scenario.

Table 1 Taxon-specific Resistance (tolerance) assessment scale: Bird and Fish features

Resistance (Tolerance)	Description
None	A **severe decline** (>50%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism.
Low	A **significant decline** (>10 and ≤50%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism.
Medium	A **moderate decline** (loss of up to 10%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism.
High	**No population decline** is expected within the site. Effects affecting key functional and physiological attributes of the species (eg food intake rate, energy expenditure rate) may occur but are buffered from feeding through to changed rates of reproduction or mortality and hence population size by virtue of species' flexibility to respond to the pressure eg by redistribution within a designated site, dietary shifts, increased foraging effort, etc.

Table 2 Taxon-specific Resistance (tolerance) assessment scale: Marine mammal features

Resistance (Tolerance)	Description
None	A **severe decline** (>10%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism affecting population fitness
Low	A **significant decline** (>5% and ≤10%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism affecting population fitness
Medium	A **moderate decline** (>1% and ≤5%) in the estimated size of the local population within a designated site as a result of increased mortality, reduced reproductive success, displacement from the site or any other mechanism affecting population fitness
High	A **very minor decline** in key functional and physiological attributes of the species which may not be detectable against natural background variation. More pronounced sub-lethal effects may be detectable (eg foraging effort) but these may be buffered from feeding through to changed rates of reproduction or mortality or local population best estimates.

Resilience scoring

Scoring tables

The scoring was based on *Resilience* categories (Table 3) adapted from 25. Resilience for displacement-type impacts was scored independently from Resistance using direct species evidence. The recovery from a displacement-type impact is simply based on how long the feature will avoid the area before returning. For mortality-type impacts it is the time the population requires to return to pre-impact size via demographic processes such as increased survival or productivity (if density-dependent) or immigration.

Avoidance times were used when supported by empirical evidence (direct or proxy), however, direct evidence to assess the likely recovery rate was generally limited. For mortality-type impacts, Resilience scores were assigned with consideration to species lifespan, fecundity and generation times. Arbitrary time periods of three, six and twelve years were used to define the Resilience score categories and to ensure alignment with the Habitat Directive, Marine and Coastal Access Act (MCAA) and MSFD condition reporting cycles. The decision taken was based on the intended use of the sensitivity matrix and considered the likelihood of the feature returning to a pre-impact condition following cessation of the pressure within one reporting cycle (High and Medium), between one and two reporting cycles (Low) and more than two reporting cycles (Very Low).

Assessments

When considering resilience to mortality-type effects of pressures, Resilience scores were assigned having considered the scale of the population decline at the benchmark pressure intensity (Resistance) as this would affect the expected time the population will take to return to the pre-impact state (ie Resilience).

For many HMS features (all groups), the evidence base generated by the review contained very little information documenting the precise rates of recovery from pressures. When no direct evidence on a specific HMS was found, *judgments by proxy* were made of the feature's Resilience using evidence from related species or functional group information, and theoretical understanding of the species life history strategy.

In the case of bird features, the Resilience scoring criteria were formalised according to:

- lifespan;
- age at first maturity;
- adult mortality rate; and
- fecundity / reproductive success.

Each criterion was given one of three possible levels and each feature assigned to one of three categories of recovery potential: Low, Medium and High (see Appendix 4 for details). Although this conceptualisation greatly assisted with the assignment of Resilience scores to all bird features it was not always the case that one feature fall in the same category across all four key demographic traits. A weight of evidence approach was exercised to ensure that the final Resilience score was based on general life history theory (eg continuum between r- and K-selected characteristics) (Pianka 2011) and importantly independent from the Resistance scoring to avoid circularity in the assessment method. Similar criteria and judgements were employed for fish and marine mammal features.

Table 3 Taxon-specific Resilience (recovery) assessment scale

Resilience Category	Description
Very Low	Prolonged recovery possible, but more than 12 years required* for feature recovery ** Typically species with long generation times and low fecundities.
Low	Full recovery within 6 to ≤12 years*
Medium	Full recovery within 3 to ≤6 years*
High	Full recovery within 3 years*

** Following cessation of activities giving rise to the pressure, ** Full recovery indicates a return to the state that existed prior to impact with respect to relevant structural and functional attributes of the HMS under assessment.*

Sensitivity scoring and confidence assessment

Scoring matrix

The Resistance and Resilience scores were cross-tabulated to assign an overall sensitivity score (Table 4). The final sensitivity scoring matrix gives greater weight to the Resistance scores than was the case in the matrices which have been used in previous sensitivity assessments 25. Resistance was considered to be more influential in defining sensitivity for HMS due to the potential for such mobile species to display acute avoidance responses resulting in severe population declines under any Resilience score. Furthermore, adding more weight to the Resistance score ensures that all interactions where Resistance is ‘None’ or ‘Low’ receive a sensitivity score of at least ‘Medium’ that should trigger further site-specific assessment or indicate the need for management measures.

Assessments

Resistance and Resilience scores were combined according to the scoring matrix (Table 4) to produce the final sensitivity score for each pressure-feature combination. Proxy sensitivity assessments for data deficient species were scored in the same way. The confidence scores associated with the Resistance and Resilience scores were brought forward and the component with the lowest confidence score was taken for the sensitivity confidence score. All scores were moderated by internal and external review before collation into the final assessment matrix. Taking a standardised approach and obtaining an external review ensured consistency across HMS feature assessments.

In most cases the evidence was enough to provide either species-specific or proxy assessments (the latter identified with low confidence scores). However, for some feature-pressure associations the evidence base was not considered to be developed enough for sensitivity assessments to be made at the pressure benchmark level either on the basis of species-specific information or by proxy from other members of the functional group. These feature-pressure pairs were therefore not assessed for sensitivity and were classified as '*Not enough evidence to assess'*. Furthermore, there were instances where evidence indicated a functional group or feature-sensitivity to a pressure, but did not allow for an inference of even basic tolerances. Such examples were also categorised as '*Not enough evidence to assess'*. A graphical summary of the assessment method and limitations associated with the scores is provided in Appendix 6.

Table 4 Sensitivity matrix showing the rules for combining Resistance and Resilience scores.
Additional options used during the scoping phase are: a) Not relevant – where the evidence suggests that there is no relevant interaction between the pressure and the feature under assessment (eg Deoxygenation and birds; emergence regime and marine mammals, etc.); b) No direct effects – where the pressure may only indirectly affect the feature under consideration through effects on the feature's supporting habitat or the resources it contains. This option indicates that indirect effects on the feature could be inferred by assessing the direct effect of the pressure on the supporting habitat as a feature, and c) Not enough evidence to assess – where the evidence base is not considered to be developed enough for assessments to be made of sensitivity at the benchmark pressure level. This option should not be taken to mean that there is no information available for features but that the information does not allow inference of even basic tolerances of the species to the pressure under consideration.

	Resistance			
Resilience	**None**	**Low**	**Medium**	**High**
Very Low	High	High	High	Medium
Low	High	High	Medium	Low
Medium	High	High	Medium	Low
High	High	Medium	Low	Not sensitive

Confidence

In the light of the highly variable nature of the quality, quantity, relevance and concordance of the evidence base available on which to base assessments of Resistance, Resilience and sensitivity it was decided necessary to attach confidence scores to each HMS-pressure sensitivity assessment. These confidence assessments were based on the quality, geographical relevance and concordance of evidence that was available to support the Resistance and Resilience assessments (Table 5). The method follows the original pressures-MCZ/MPA features sensitivity project (Defra MB0102) and the recent MarESA approach (Marlin.ac.uk. 2015).

Table 5 Confidence assessment rules for Resistance and Resilience.
The final rank was given based on the summed scores across the three components of the assessment i.e. quality, applicability and concordance (Maximum combined score 15; Minimum score 3). High confidence was assigned to total scores >12; Medium confidence to scores 6 – 12; and Low confidence for scores <6.

Confidence Level	Quality of Information Sources	Applicability of evidence	Degree of Concordance
High	Based on Peer Reviewed papers (observational or experimental) or grey literature reports by established agencies on the feature Score = 5	Assessment based on the same pressures arising from similar activities, acting on the same type of feature in comparable areas (ie Ireland, UK) Score = 5	Evidence agrees on the direction and magnitude of impact Score = 5
Medium	Based on some peer reviewed papers but relies heavily on grey literature or expert judgement on feature or similar features Score = 3	Assessment based on similar pressures on the feature in other areas Score = 3	Evidence agrees on direction but not magnitude of impact Score = 3
Low	Based on expert judgement, which is not clearly documented Score = 1	Assessment based on proxies for pressures eg natural disturbance events Score = 1	Evidence does not agree on concordance or magnitude Score =1

Summary of results

The distribution of sensitivity scores by HMS and functional group suggest that migratory fish features and water column feeding birds have some level of sensitivity to the largest number of pressures that could be assessed (Figure 2). Most functional groups were directly or indirectly sensitive to a similar number of total pressures. However, bony amphidromous fish, Agnata amphidromous fish, water column feeding birds, benthic-demersal feeding birds and marine fish/crustacean were sensitive to the largest number of marine pressures (Figure 2) probably reflecting the potential for additional direct effect pathways affecting these functional groups such as underwater collision, underwater noise, and entanglements in nets (caused by marine litter) or by-catch (removal of non-target species).

Radionuclide contamination and synthetic compound contamination could not be assessed for any HMS features due to the lack of evidence of direct effect at the benchmarks used. Most physical pressures affecting habitat attributes like damage, nutrient enrichment or change to another habitat type were generally considered to have indirect effects on HMS only (Appendix 5). Almost all features were found sensitive to removal of target and non-target species and introduction of microbial pathogens. Noise (airborne and waterborne), vibration, collision (above and below water), visual disturbance, introduction of light, barrier to species movements and litter were among the top ranking pressures across HMS groups. Deoxygenation, salinity, temperature, genetic modification and suspended solids were additional top ranking pressures for fish features (Appendix 5).

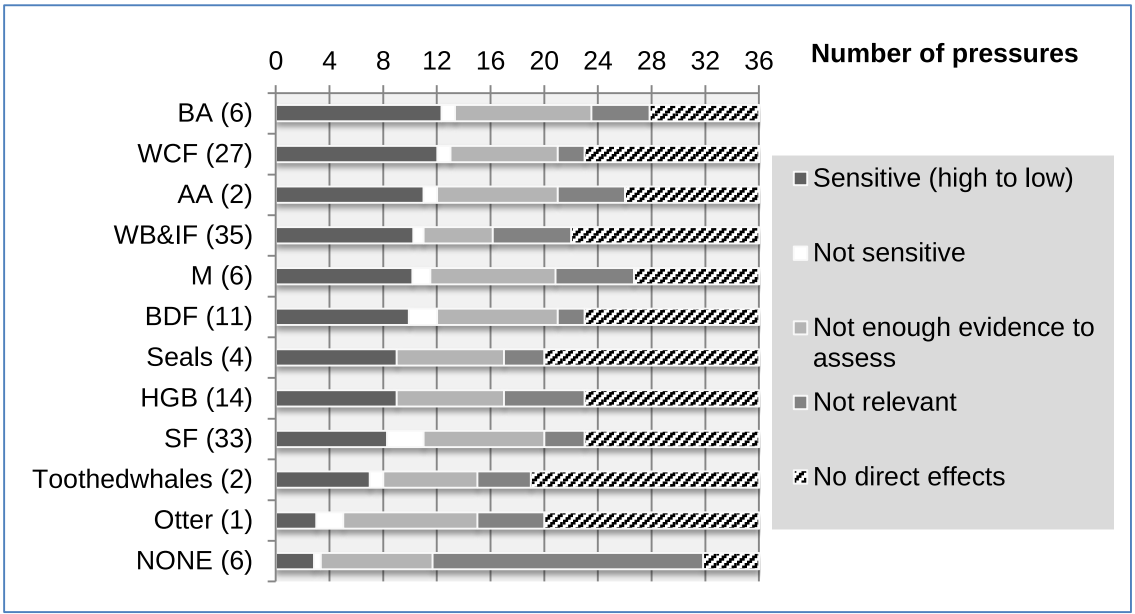
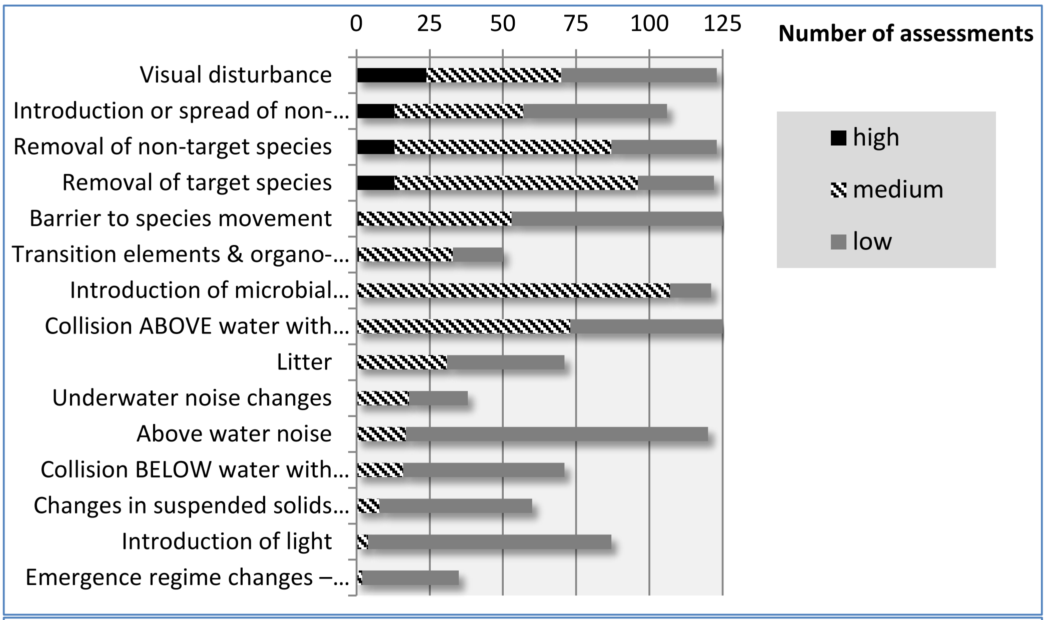


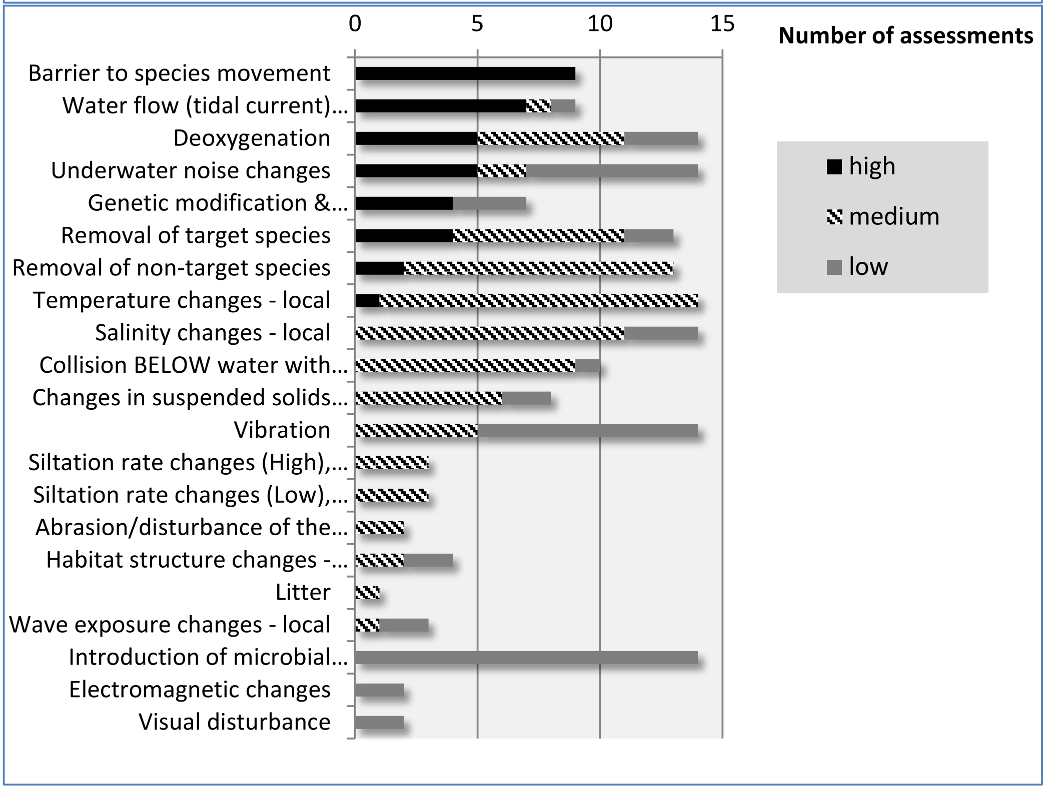
Figure 2 Distribution of scoring categories by functional group.
The functional groups are ranked by the number of pressures for which sensitivity scores could be assessed. The number of features in the functional group is indicated by the number in brackets. Functional group labels are as follows: WCF, Water Column feeding birds; WB&IF, Wading Birds & intertidal feeding birds; BDF, Benthic-demersal feeding birds; HGB, Herbivorous & grazing birds; SF, Surface feeding birds; NONE, land birds; BA, Bony amphidromous fish; AA, Agnata amphidromous fish; M, Marine fish/crustacean;

Confidence scores for pressures resulting in likely direct effects were highly dependent on the HMS group (Figure 3). Among birds features sensitivity to the pressures of: visual disturbance, introduction of invasive species and removal of individuals (targeted removal or by-catch) resulted in the most confidence scores assessed as being “high”. Conversely sensitivity of birds to pressures of: noise, collision below the water surface, suspended solids, introduction of light and emergence regime were almost always associated with low confidence scores. For fish, sensitivity scores to pressures of: barriers to species movement and changes to water flow generally had high confidence scores, whereas sensitivity to the pressures: deoxygenation, genetic modifications and removal of target and not-target species pressures also frequently scored medium and low probably reflecting species-specific trends. Sensitivity to: wave exposure, introduction of microbial pathogens, electromagnetic changes, and visual disturbance all have low confidence scores (Figure 3). Finally for marine mammals, sensitivity to visual disturbance, removal or target and non-target species almost always had high confidence scores, sensitivity to introduction of microbial pathogens had high or medium confidence with sensitivity to the rest of the assessed direct pressures having medium confidence. Only sensitivity to collision below water was associated with low confidence scores in the group (Figure 3).

A
Birds



B
Fish and
crustacean



C
Marine
mammals

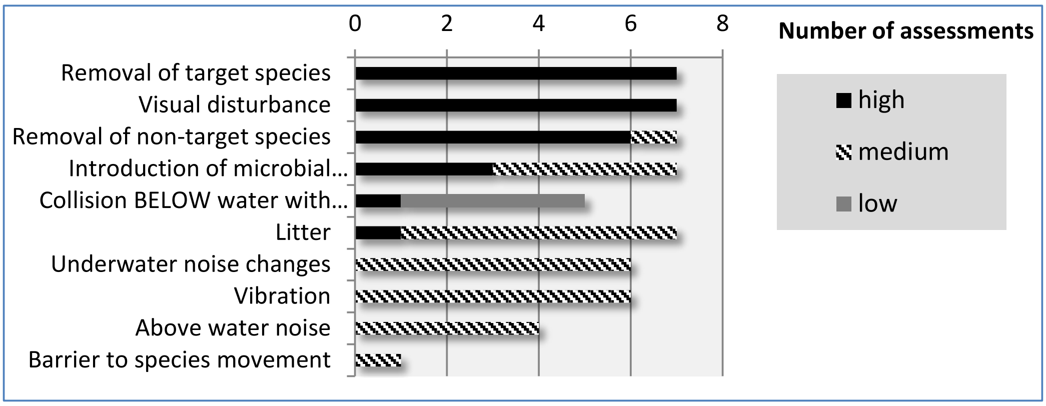


Figure 3 Pressure types ranked according to the distribution of the sensitivity confidence scores in each of the HMS groups: A, Birds; B, Fish (and Lobster); and C, Marine mammals (and Otter). The legend given in the figure indicates high, medium or low confidence score.

Overall confidence assessments scored as “high” were comparatively rarer for birds than for either fish or marine mammals (Figure 3, Table 6). Possibly the high proportion of “high” confidence assessments in the latter two groups is explained by there being very few mammals (5) and fish (13) features being assessed (in comparison with birds (88)), these generally being the subject of dedicated species-specific studies (in the case of mammals) and all being relatively similar in their basic ecology and use of habitats in comparison to the very large and diverse range of bird species being assessed.

Table 6 Numbers of sensitivity assessments by sensitivity rank, confidence assessment and feature type. Figure in parentheses refer to percentage of total assessments by feature type.

Feature type	Sensitivity rank	Confidence assessment			Total
		High	Medium	Low	Total
bird	High	50 (3.6)	371 (26.9)	228 (15.9)	649 (47.1)
	Medium	9 (0.7)	121 (8.8)	244 (17.7)	374 (27.2)
	Low	6 (0.4)	38 (2.8)	127 (9.2)	171 (12.4)
	Not sensitive	-	80 (5.8)	103 (7.5)	183 (13.3)
	Total	65 (4.7)	610 (44.3)	702 (51.0)	1377 (100)
Fish and crustacean	High	27 (15.6)	46 (26.6)	29 (16.8)	102 (59)
	Medium	-	12 (6.9)	16 (9.2)	28 (16.2)
	Low	1 (0.6)	19 (11)	7 (4)	27 (15.6)
	Not sensitive	9 (5.2)	6 (3.5)	1 (0.6)	16 (9.2)
	Total	37 (21.4)	83 (48)	53 (30.6)	173 (100)
Marine mammals mammals	High	15 (29.4)	9 (17.6)	4 (7.8)	28 (54.9)
	Medium	1 (2)	8 (15.7)	-	9 (17.6)
	Low	5 (9.8)	5 (9.8)	-	10 (19.6)
	Not sensitive	4 (7.8)	-	-	4 (7.8)
	Total	25 (49)	22 (43.1)	4 (7.8)	51 (100)

- no data

5 Technical workshops and audit trail

All four stages of the basic methodology were subject to external critique by scientific experts. The input of the technical advisors was provided in four dedicated one-day workshops and additional ad-hoc consultation with nature conservation practitioners, nature conservation agencies and researchers. Two workshops were dedicated to bird species, one to fish and one to marine mammals. Minutes and further technical outcomes of the workshops are provided in Annex 1. The workshops followed a common structure where the experts were invited to refine the functional group assignments, pressure definitions, benchmark levels, and to provide external technical input to the scoring methodology. Worked out examples to illustrate the application of the Resistance and Resilience scores were presented and scrutinised in the workshops. The main areas discussed by the technical advisors were:

- the relevance of the existing methodology to the HMS group;
- benchmark proposals;
- scoring table proposals;
- draft functional group assignments; and
- review and moderation of scores.

A brief summary with the main outcomes of the workshops, actions and the final HMS-pressure matrix was issued to the participating technical advisors to provide further comments on the method and used to provide an audit trail of the decisions made during the workshop (see Annex 1 for further reference). All phases of the method development were subject to internal and external audit, and records of the HMS-pressure decisions were kept for reference and to aid transparency in method development. Particular scrutiny was targeted towards the development of methods used to derive the sensitivity and confidence scores (recovery, resilience and benchmarks used) and that of the evidence base underpinning the draft assessments. All sensitivity and confidence assessments were subject to internal and external peer review before compilation into the final feature-pressure sensitivity assessments.

6 Method application and interpretation of the sensitivity assessments

Ecological vulnerability is widely assessed following a 2-step approach involving an initial high-level pre-assessment of theoretical tolerances to expected pressure type(s) (scoping phase), and a second site-specific assessment phase to integrate exposure, intensity and extent of pressure at the scale of the relevant management unit (ie individual MPA or network of MPAs). The initial scoping phase is used to identify sensitive receptors and route of impact(s). This is in fact, a pre-assessment of sensitivity to standardised activities or pressure benchmarks. Such an approach is likely to reduce uncertainty and, to some extent, eliminate personal bias early on in the evaluation process ensuring that potential threats are not overlooked or, equally important, that irrelevant interactions are consistently identified and not considered further.

Moreover, this high-level scoping phase is analogous to the standalone sensitivity exercise described in this report. However, impact assessment methods typically consider both direct and indirect effect pathways 24. Indirect effects, those impacting HMS indirectly through effects on supporting habitats or resources within habitats (eg availability or quality of spawning substratum, food resource, shelter, roosting/nesting habitat, etc.), are difficult to assess with precision by a high-level scoping exercise. It is important to note that this study focused on direct effect pathways on HMS. Therefore, only displacements, and lethal or sub-lethal effects on individuals that are likely to have population consequences were assessed. Indirect effects through direct effects on habitats, food resource or more complex biotic interactions (competition and predation) are likely to exist and cannot be ignored.

The initial literature review revealed that scientific evidence linking pressures and population effects are in most cases limited. Moreover, basic parameters required to assess sensitivity of some HMS have not previously been developed. Home ranges and distribution areas are normally vast and variable with food availability, predator incidence, seasons (eg spawning, breeding or calving periods), developmental stage and, occasionally, gender having a controlling influence. For example, for some fish species typical population size within a site is largely unknown due to the species' wide range and the potentially low numbers present in a location at any one time. In many cases there is not enough knowledge about the life cycle of these species or their habitat requirements to allow for an efficient assessment.

The mobile nature of HMS means that not all individual animals within a population are subjected to the pressure from an activity all of the time. This results in greater difficulty in determining a sensitivity assessment in comparison with doing so for less mobile, sedentary organisms or habitat features. For these features the proportion of a population within an affected area is more easily determined, as is the period of time for which that fraction of the population is subject to that pressure. This mismatch between the home range of the HMS and the scale of the typical pressures acting at the site level is likely to result in difficulties in defining benchmarks and scoring the sensitivity of HMS populations to pressures at those benchmarks. Likewise, using available site- and activity-specific evidence to inform theoretical sensitivity assessments is difficult simply because the degree of spatial and temporal interaction (ie exposure) is generally case-specific and not directly transferrable.

Highly mobile species have the ability to actively avoid harmful pressures. Thus, some pressures (eg visual or noise disturbance), may lead to displacement and relocation outside the MPA site boundaries and significant reductions in population numbers within that site without introducing mortality or reproductive failure. Nonetheless such pressures would reduce the ability of the site to support the feature in the numbers it otherwise would. On the other hand, some pressures which cannot be avoided will lead to direct mortality or reduced productivity of certain individuals in a population (eg fishing, collision or microbial pathogens). However, for most pressures, both displacement and mortality/fitness effect pathways are likely to contribute to local population declines. An important consideration is that their mobility may lead to a lower Resistance score via the displacement pathway than via the mortality pathway as individuals make use of their mobility to avoid a pressure source and reduce the associated direct mortality risk. On the other hand, that behavioural reaction may lead to a higher Resilience score via the displacement pathway in comparison with that via the mortality pathway as individuals which have not suffered mortality may readily return once the pressure is lowered or ceases – this being at a rate which will almost certainly be faster than that at which the population will replace individuals lost through mortality or reduced productivity. In a real situation a number of site-specific factors, and indeed the level of exposure to the pressure, will affect the degree to which a pressure acts on a feature via one or other pathway and hence the impact on the feature.

Due to the general paucity of direct recovery evidence, Resilience scores have comparatively lower confidence levels than Resistance scores. Expert judgement was used to produce an estimate of the recovery potential of a population in years given the expected severity of the impact and the effect pathway. Assessments were possible considering basic fecundity, adult mortality rate, age at first maturation and lifespan to assess recovery time for pressures resulting in mortality or fitness effects. Information on home range and dispersive capacity was used for pressures resulting in displacement effects.

7 Limitations of the sensitivity scores

It was clear that the outcomes of the HMS feature assessments are subjective in nature and depend heavily on the applicability of the evidence, selection of benchmark, scoring thresholds, confidence in the assessments and the level of experience of the technical specialists providing the final scoring. As such the assessment provides an indication of sensitivity rather than a precise evaluation. There was no easy way to capture with precision the ecology of all speceis within a functional group. Both scoping of relevant pressures by functional groups and the assignment of species to functional groups are in nature subjective and will require careful consideration and review before sesnsitivity scores are used.

It is also important to stress that the sensitivity assessments take no account of the indirect effects that pressures may have on these HMS mediated through significant effects on their supporting habitats or other resources on which they depend. It is important to note that these assessments are simplifications of functional responses which are necessarily assessed on hypothetical scenarios representing the average expected condition. They are generic, do not incorporate exposure in the scoring, are very dependent on the particular benchmark levels used, do not account for spatial or temporal scale, and are often based on limited scientific evidence of the precise magnitude of responses to pressures in terms of both immediate change in numbers in the face of a pressure (indicative of the level of resistance) and the time for any recovery to occur once a pressure is lessened or ceases (indicative of the level of resilience).

Clearly the sensitivity assessments will be applicable to multiple specific activities and areas (case work) as the assessments are based on generic pressure scenarios (benchmarks) acting on a hypothetical free-living population in a pristine environment and living within the optimal niche of the species. However, the sensitivity assessment is not an impact assessment and this sensitivity assessment should only be used as a guide to inform the site-specific assessments conducted on specific sites and activities. The magnitude of specific activities has not been assessed as the sensitivity assessment is based on theoretical benchmarks.

Nevertheless, the limitations implicit in the method are acceptable when the sensitivity outcomes are used sensibly to guide management decisions by trained technical advisers and biologists or alternatively to provide a high-level standardised screening and ensure consistency for scoping and assessment exercises. For example, scores can be interpreted by comparing the magnitude of the actual activity that will take place (case work) with the benchmarks to provide an indication of whether the HMS is likely to be more or less sensitive than the reported sensitivity assessment. Due to the relative simplicity of the approach the sensitivity outcomes can be easily reviewed and updated as new evidence becomes available.

Valid inferences are possible if the limitations of the approach are clearly understood and users pay careful attention to:

- The evidence provided and confidence assigned to each assessment;
- The benchmark used and how it compares with site-level pressures if scores will be used to inform management;
- The possibility of significantly greater sensitivity of local populations, eg those with low population numbers, reduced genetic diversity or having a strong social coherence which could greatly amplify population effects;
- The nature of the effect and understanding of the effects of pressures (eg, direct or indirect impacts);
- The main pathway of effect, typically displacement from preferred habitats or fitness related;
- The possibility of cumulative and in-combination effects;
- The functional group and scoping of relevant pressures for proxy assessments;

- The possibility of indirect effects; and
- The need to allow for an independent review by experienced practitioners and relevant stakeholders.

Overall, this study provides a robust sensitivity matrix which, when combined with an assessment of the magnitude of specific activities, assists in helping to determine potential impacts and appropriate conservation measures for HMS within the marine environment.

8 References

BROWN, C., HULL, S. & WARKEN, N. 2012. Accessing and developing the required biophysical datasets and data layers for Marine Protected Area network planning and wider marine spatial planning purposes. Report 26 Project code MB0102. March 2012.

BUSCH, M., BUISSON, R., BARRETT, Z., DAVIES, S., REHFISCH, M., 2015. Developing a Habitat Loss Method for Assessing Displacement Impacts from Offshore Wind Farms. JNCC Report 551, Peterborough. (ISSN 0963 8091). http://jncc.defra.gov.uk/page-6987

CHANIOTIS, P.D., CUNNINGHAM, S., GILLHAM, K. & EPSTEIN, G. 2014. *Assessing risk to Scottish MPA search features at the MPA regional scale.* Final report produced by the Joint Nature Conservation Committee, Scottish Natural Heritage and Marine Scotland for the Scottish Marine Protected Areas Project.

COLLABORATION FOR ENVIRONMENTAL EVIDENCE. 2013. *Guidelines for Systematic Review and Evidence Synthesis in Environmental Management*. Version 4.2. Environmental Evidence. URL: www.environmentalevidence.org/Documents/Guidelines/Guidelines4.2.pdf [Accessed May 2015].

COLLETER, M., GASCUEL, D., ECOUTIN, J.-M. & TITO DE MORAIS, L. 2012. Modelling trophic flows in ecosystems to assess the efficiency of marine protected area (MPA), a case study on the coast of Sénégal. *Ecological Modelling*, 232, 1-13.

EDGAR, G. J., STUART-SMITH, R. D., WILLIS, T. J., KININMONTH, S., BAKER, S. C., BANKS, S., BARRETT, N. S., BECERRO, M. A., BERNARD, A. T. F., BERKHOUT, J., BUXTON, C. D., CAMPBELL, S. J., COOPER, A. T., DAVEY, M., EDGAR, S. C., FÖRSTERRA, G., GALVÁN, D. E., IRIGOYEN, A. J., KUSHNER, D. J., MOURA, R., PARNELL, P. E., SHEARS, N. T., SOLER, G., STRAIN, E. M. A. & THOMSON, R. J. 2014. Global conservation outcomes depend on marine protected areas with five key features. *Nature*, 506(7487), 216-220. doi: 10.1038/nature13022

FENBERG, P. B., CASELLE, J. E., CLAUDET, J., CLEMENCE, M., GAINES, S. D., GARCÍA-CHARTON, J. A., GONÇALVES, E., GRORUD-COLVERT, K., GUIDETTI, P., JENKINS, S., JONES, P.J.S., LESTER, S., MCALLEN, R., MOLAND, E., PLANES, S. & SØRENSEN, T. K. 2012. The science of European marine reserves: Status, efficacy, and future needs. *Marine Policy*, 36(5), 1012-1021.

HOOKER, S. K., & GERBER, L. R. 2004. Marine reserves as a tool for ecosystem-based management: the potential importance of megafauna. *BioScience*, 54(1), 27-39.

ICES. 2013. *(Annex D) Report of the Joint ICES/OSPAR Expert Group on Seabirds (WGBIRD)*, 22–25 October 2013, Copenhagen, Denmark. ICES CM 2013/ACOM:78. 77 pp.

LAFFOLEY, D.D'A., CONNOR, D.W., TASKER, M. L. & BINES, T. 2000. *Nationally important seascapes, habitats and species. A recommended approach to their identification, conservation and protection.* Prepared for the DETR Working Group on the Review of Marine Nature Conservation by English Nature and the Joint Nature Conservation Committee. Peterborough, English Nature, 17 pp.

Marine.scotland.gov.uk 2015. Home Page. [online] Available at: http://www.marine.scotland.gov.uk/FEAST/ [Accessed 15 July. 2015].
Marlin.ac.uk 2015. MarLIN - The Marine Life Information Network -. [online] Available at: http://www.marlin.ac.uk/species/sensitivity [Accessed 19 December. 2015].

MORRIS, R. K. A., BENNETT, T., BLYTH-SKYRME, R., BARHAM, P. J., & BALL, A. 2014. Managing Natura 2000 in the marine environment - An evaluation of the effectiveness of 'management schemes' in England. *Ocean and Coastal Management*, 87, 40-51.

O'CONNELL, T. J., JACKSON, L. E., & BROOKS, R. P. 2000. Bird guilds as indicators of ecological condition in the central Appalachians. *Ecological Applications*, 10(6), 1706-1721.
OSPAR. 2011. *Intersessional Correspondence Group on Cumulative Effects– Amended 25th March 2011*. OSPAR Commission EIHA 11/5/3 Add.2-E.

PIANKA, E. R. 2011. Vital statistics of populations. In Evolutionary ecology. Eric R. Pianka. 7th Edition. eBook.

TILLIN, H.M., HULL, S.C. & TYLER-WALTERS, H. 2010. *Development of a Sensitivity Matrix (pressures-MCZ/MPA features)*. Report to the Department of Environment, Food and Rural Affairs from ABPMer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK. Defra Contract No. MB0102 Task 3A, Report No. 22.

TYLER-WALTERS, H. & JACKSON, A. 1999. Assessing seabed species and ecosystems sensitivities. Rationale and user guide, January 2000 edition. Report to English Nature, Scottish Natural Heritage and the Department of the Environment Transport and the Regions from the Marine Life Information Network (MarLIN). Plymouth, Marine Biological Association of the UK. (MarLIN Report No. 4.).

TYLER-WALTERS, H., HISCOCK, K., LEAR, D.B. & JACKSON, A., 2001. Identifying species and ecosystem sensitivities. Report to the Department for Environment, Food and Rural Affairs from the Marine Life Information Network (MarLIN), Marine Biological Association of the United Kingdom, Plymouth. Contract CW0826. [Final Report.]

WILLIAMS, S.E., SHOO, L.P., ISAAC, J.L., HOFFMANN, A.A. & LANGHAM, G. 2008. Towards an Integrated Framework for Assessing the Vulnerability of Species to Climate Change. *PLoS Biol*, 6(12): e325. doi:10.1371/journal.pbio.0060325.

9 Appendices

Appendix 1 Evidence search protocol to inform highly mobile species sensitivity assessments

The review started with the identification of the *main subjects* (marine pressures and HMS), *process under review* (direct sensitivity to marine pressures), and *outcome* (sensitivity assessments) of the study to enable a targeted search of the available evidence. The three main components of the search, subject, process or intervention, and outcome were subsequently broken down into specific feature- pressure- or process-focused search questions to identify available titles on each specific topic. The process followed the Guidelines for Systematic Review in Conservation and Environmental Management by Collaboration for Environmental Evidence (CEE) (2013).

Briefly, the above described main search question and terms were further defined using a series of search words that varied from:

- general (eg bird, fish, etc.);
- feature targeted (eg species common and Latin names or existing functional group names);
- pressure targeted (eg siltation, collision, etc); and
- management specific terms (eg environmental assessment).

These terms were used in isolation or combined into search strings with the relevance of the search assessed by the total number of hits returned and relevance of the search based on a systematic search for:

- relevant HMS feature by common and Latin names;
- relevant HMS life history traits and functional grouping;
- relevant marine pressure indicator(s) (or proxy activity); and
- relevant sensitivity-related work and proxy subjects.

The search strategy consisted in recording all search terms and relevance of the literature found after each search. Searches resulting in a large number or non-relevant hits were discarded and alternative search strings used. The preliminary screening of the relevance of the searches was based on number of relevant titles within the first 10 documents in each independent search (Busch and others 2015). All bibliographic records from relevant searches were tagged with the search strings used in the search to ensure all titles could be accessed using relevant keywords at any point during the search or later during the evidence appraisal. The original pool of potential titles was re-assessed by senior level scientists and a final search strategy adopted. This included the final identification of HMS functional functional groups after the workshops and preferred search strings for features, functional groups, and pressures. This approach was necessary to ensure a wide evidence base during the method development and sensitivity assessments.

The final step consisted in the assessment of the quality and relevance of the information found during the literature searches. This was done following a pre-screening protocol focused on:

1 Biology and ecology of the HMS features; and
2 HMS responses to pressures and sensitivity scoring methodologies.

All three HMS groups; birds, fish and marine mammals, were assessed independently and individual bibliographic lists kept for each feature group. The aim of this step was to assess from the abstract, or by a quick assessment of the full text, the more promising titles and to facilitate the review of information during the method development, and the sensitivity and confidence assessments. Life history traits and functional group-specific search terms (eg wading birds, coastal bird aggregations, migratory fish assemblages, functional group-characterising species, etc.) were refined in the search and pre-screening steps.

The final screening for direct pressure evidence, scientific quality (eg objectivity, experimental design and applicability of the evidence) was conducted during the development of the HMS-pressure matrix and sensitivity assessments. The selection of relevant titles on functional groups was similar to that employed to identify species-specific evidence. The selected final pool of studies was used to inform the method development as well as the Resistance and Resilience assessments. Key elements of the HMS-pressure associations were summarised in short reviews (including expert opinion where gaps existed) to support the scores given in the assessments.

Results

A total of 29,405 bibliographic records were identified by the initial searches. This number was reduced in a two-step relevance screening described above to a total of 1,318 documents. Peer reviewed journal articles, reports, conference proceedings, serial publication and books or book sections dated between 1948 and 2014 accounted for almost all of the records. However, the vast majority of records were from publications published since the 1990s. In recent years the number of natural resource management and assessment science publications has clearly increased which is likely to respond to a shift into evidence-based conservation initiatives (Figure A1.1).

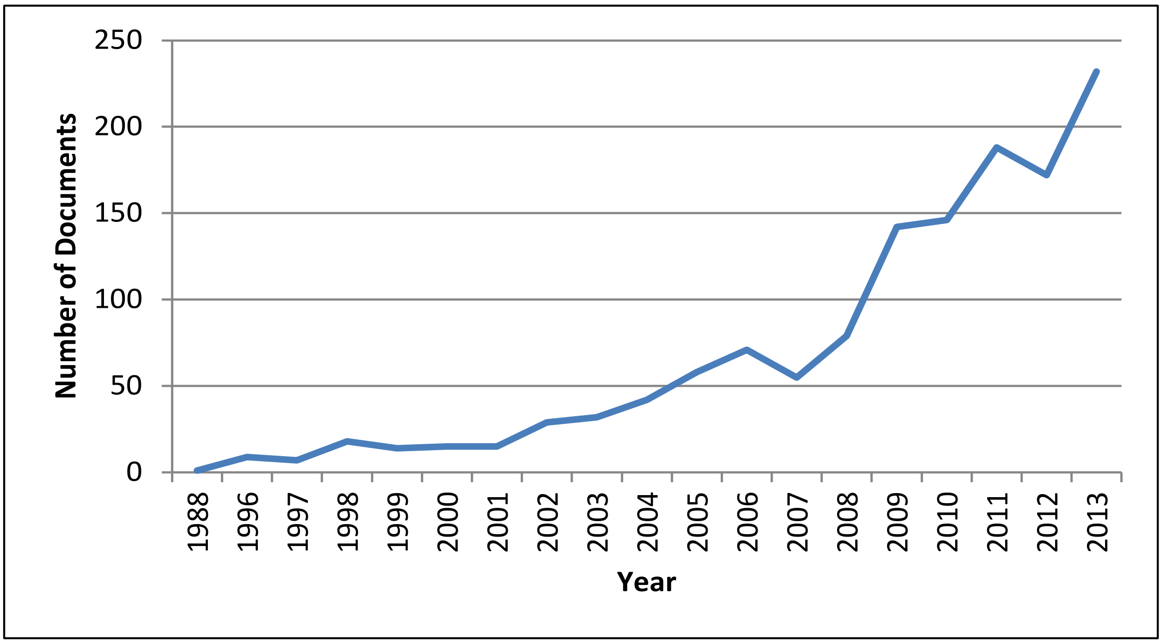


Figure A1.1 Number of studies by year of publication with direct relevance to management and conservation assessments for all environmental science disciplines combined. Based on a Scopus search query using the following search string: “sensitivity AND pressures AND assessment AND management OR conservation”.

Appendix 2 Species list and functional groups included in the assessments

Table A2.1 Features (a) birds, (b) fish and crustaceans and (c) marine mammals. The functional groups assigned under the heading 'ecology/taxonomy' (ie reproduction and habitat functional groups) were assigned according to the evidence found of Great Britain/Western European populations. The full functional group name and descriptor is provided in Table A2.2

Common name	Latin name	Functional groups 1 (ecology/taxonomy)	Functional groups 2 (feeding)
A Bird			
Aquatic Warbler	*Acrocephalus paludicola*	NONE ASSIGNED	NONE ASSIGNED
Arctic Tern	*Sterna paradisaea*	CBWB & SBS	SF
Avocet	*Recurvirostra avosetta*	CBWB & CnBWB	WB&IF
Balearic shearwater	*Puffinus mauretanicus*	SBS	WCF
Barnacle Goose	*Branta leucopsis*	CnBWB	H_GB
Bar-Tailed Godwit	*Limosa lapponica*	CnBWB	WB&IF
Bean Goose	*Anser fabalis*	CnBWB	H_GB
Bewick's Swan	*Cygnus columbianus*	CnBWB	HGB
Bittern	*Botaurus stellaris*	CBWB & CnBWB	WCF
Black-Headed Gull	*Chroicocephalus ridibundus*	CBWB & CnBWB	SF
Black-Necked Grebe	*Podiceps nigricollis*	CnBWB	WF
Black-Tailed Godwit	*Limosa limosa*	CnBWB	WB&IF
Black-Throated Diver	*Gavia arctica*	CnBWB	WCF
Common Scoter	*Melanitta nigra*	CnBWB	BDF
Common Tern	*Sterna hirundo*	CBWB & SBS	SF
Coot	*Fulica atra*	CnBWB	WF
Cormorant	*Phalacrocorax carbo*	CBWB & CnBWB	BDF
Curlew	*Numenius arquata*	CBWB & CnBWB	WB_IF
Dark-Bellied Brent Goose	*Branta bernicla bernicla*	CnBWB	H_GB
Dunlin	*Calidris alpina*	CnBWB	WB&IF
Eider	*Somateria mollissima*	CBWB & CnBWB	BDF
Fulmar	*Fulmarus glacialis*	CBWB & SBS	SF
Gadwall	*Anas strepera*	CBWB & CnBWB	SF
Gannet	*Morus bassanus*	CBWB & SBS	WCF
Golden Plover	*Pluvialis apricaria*	CnBWB	WB&IF
Goldeneye	*Bucephala clangula*	CnBWB	BDF
Goosander	*Mergus merganser*	CnBWB	WCF
Great Black-Backed Gull	*Larus marinus*	CBWB & SBS	SF
Great Crested Grebe	*Podiceps cristatus*	CnBWB	WCF
Great Northern Diver	*Gavia immer*	CnBWB	WCF
Great Skua	*Stercorarius skua*	CBWB & SBS	SF
Greater White-Fronted Goose	*Anser albifrons*	CnBWB	H_GB
Greenshank	*Tringa nebularia*	CBWB & CnBWB	WB_IF
Grey Plover	*Pluvialis squatarola*	CnBWB	WB&IF
Greylag Goose	*Anser anser*	CBWB & CnBWB	H_GB
Guillemot	*Uria aalge*	CBWB & CnBWB & SBS	WCF
Hen Harrier	*Circus cyaneus*	NONE ASSIGNED	NONE ASSIGNED
Herring Gull	*Larus argentatus*	CBWB & CnBWB	SF

Common name	Latin name	Functional groups 1 (ecology/taxonomy)	Functional groups 2 (feeding)
Kittiwake	*Rissa tridactyla*	CBWB & SBS	SF
Knot	*Calidris canutus*	CnBWB	WB&IF
Lapwing	*Vanellus vanellus*	CnBWB	WB_IF
Lesser Black-Backed Gull	*Larus fuscus*	CBWB & SBS	SF
Light-Bellied Brent Goose	*Branta bernicla hrota*	CnBWB	H_GB
Little Egret	*Egretta garzetta*	CBWB & CnBWB	WB&IF
Little Grebe	*Tachybaptus ruficollis*	CBWB & CnBWB	WF
Little Gull	*Hydrocoloeus minutus*	CnBWB/SBS	SF
Little Tern	*Sternula albifrons*	CBWB/SBS	SF
Long-tailed Duck	*Clangula hyemalis*	CnBWB & SBS	BDF
Mallard	*Anas platyrhynchos*	CnBWB	SF
Manx Shearwater	*Puffinus puffinus*	CBWB/SBS	WCF
Marsh Harrier	*Circus aeruginosus*	NONE ASSIGNED	NONE ASSIGNED
Mediterranean Gull	*Ichthyaetus melanocephalus*	CBWB & CnBWB	SF
Mew Gull	*Larus canus*	CBWB & CnBWB/SBS	SF
Montagu's Harrier	*Circus pygargus*	NONE ASSIGNED	NONE ASSIGNED
Mute Swan	*Cygnus olor*	CBWB & CnBWB	H_GB
Northern Shoveler	*Anas clypeata*	CBWB & CnBWB	SF
Oystercatcher	*Haematopus ostralegus*	CBWB & CnBWB	WB&IF
Pink-Footed Goose	*Anser brachyrhynchus*	CnBWB	HGB
Pintail	*Anas acuta*	CnBWB	WB&IF
Pochard	*Aythya ferina*	CBWB & CnBWB	WF
Puffin	*Fratercula arctica*	CBWB & SBS	WCF
Purple Sandpiper	*Calidris maritima*	CnBWB	WB_IF
Razorbill	*Alca torda*	CBWB & SBS & CnBWB	WCF
Red-Breasted Merganser	*Mergus serrator*	CnBWB	WCF
Redshank	*Tringa totanus*	CBWB & CnBWB	WB&IF
Red-Throated Diver	*Gavia stellata*	CBWB & CnBWB	WCF
Ringed Plover	*Charadrius hiaticula*	CBWB & CnBWB	WB&IF
Roseate Tern	*Sterna dougallii*	CBWB & SBS	SF
Ruff	*Philomachus pugnax*	CBWB & CnBWB	WB&IF
Sanderling	*Calidris alba*	CnBWB	WB&IF
Sandwich Tern	*Sterna sandvicensis*	CBWB & CnBWB & SBS	SF
Scaup	*Aythya marila*	CnBWB	BDF
Shag	*Phalacrocorax aristotelis*	CBWB & CnBWB/SBS	BDF
Shelduck	*Tadorna tadorna*	CBWB & CnBWB	WB&IF
Slavonian Grebe	*Podiceps auritus*	CnBWB	WCF
Smew	*Mergellus albellus*	CnBWB	WCF
Spoonbill	*Platalea leucorodia*	CBWB & CnBWB	WB_IF
Spotted Redshank	*Tringa erythropus*	CBWB & CnBWB	WB_IF
Storm Petrel	*Hydrobates pelagicus*	CBWB & SBS	SF
Teal	*Anas crecca*	CBWB & CnBWB	WB&IF
Tufted Duck	*Aythya fuligula*	CBWB & CnBWB	WF
Turnstone	*Arenaria interpres*	CnBWB	WB_IF
Velvet Scoter	*Melanitta fusca*	CnBWB	BDF
Water Rail	*Rallus aquaticus*	CBWB & CnBWB	WB_IF

Common name	Latin name	Functional groups 1 (ecology/taxonomy)	Functional groups 2 (feeding)
Whimbrel	*Numenius phaeopus*	CBWB & CnBWB	WB_IF
White-Fronted Goose	*Anser albifrons*	CnBWB	H_GB
Whooper Swan	*Cygnus cygnus*	CnBWB	HGB
Wigeon	*Anas penelope*	CnBWB	HGB
B Fish and crustacean			
Spiny Lobster	*Palinurus elephas*	M	-
Allis Shad	*Alosa alosa*	BA	-
Atlantic Salmon	*Salmo salar*	BA	-
Black Seabream	*Spondyliosoma cantharus*	M	-
Couch's Goby	*Gobius couchi*	M	-
European Eel	*Anguilla anguilla*	BA	-
Long Snouted Seahorse	*Hippocampus guttulatus*	M	-
River Lamprey	*Lampetra fluviatilis*	AA	-
Sea bass	*Dicentrarchus labrax*	M	-
Sea Lamprey	*Petromyzon marinus*	AA	-
Sea Trout	*Salmo trutta*	BA	-
Short Snouted Seahorse	*Hippocampus hippocampus*	M	-
Smelt	*Osmerus eperlanus*	BA	-
Twaite Shad	*Alosa fallax*	BA	-
C Marine mammal			
Bottlenose Dolphin	*Tursiops truncatus*	Cetaceans	-
European Otter	*Lutra lutra*	Otter	-
Grey Seal	*Halichoerus grypus*	Seals	-
Harbour Seal	*Phoca vitulina*	Seals	-
Harbour Porpoise	*Phocoena Phocoena*	Cetaceans	-

Table A2.2 Functional groupd efinitions. For bird species, OSPAR common indicator and bird functional groups was followed as recommended for the implementation of bird indicators for the MSFD by ICES. Owing to the reduced number of species, marine mammal and fish functional groups were based on high-level taxonomical or ecological traits only.

Feature Group	Functional Group Name and Code	Functional Group Descriptor
A Birds		
Ecology	Coastal breeding waterbirds - CBWB	Species that breed on or near the coast in England.
Ecology	Coastal non-breeding waterbirds - CnBWB	Species that spend the non-breeding period on or near the coast in England.
Ecology	Seabirds at sea -SBS	Species which occur in the marine environment during any time of year (as distinct from their occurrence on the coast).
Feeding mode	Wading birds & intertidal feeders - WB&IF	Species that feed by wading in shallow water or on exposed (intertidal) substrates. Not in the taxonomic sense but as a functional feeding characteristic. Added "intertidal feeders" to allow for the inclusion of species like shelduck (*Tadorna tadorna*), but also teal (*Anas crecca*) and pintail (*Anas* acuta) feeding on exposed substrates and shallow water in intertidal area when occurring in coastal areas.
Feeding mode	Surface feeders - SF	Species feeding on resources available on the water surface or slightly below, that can be picked from the surface or gathered by shallow plunge dives.
Feeding mode	Watercolumn feeders - WCF	Species using the water column for extended dives in search for food resources.
Feeding mode	Benthicdemersal feeders - BDF	Species diving through the water column to the seabed where they search for food. To be clearly separated from eg wading birds also feeding on benthic prey when exposed or only covered by shallow water.
Feeding mode	Herbivorous & grazing birds - HGB	Species feeding mainly on coastal meadows/grassland or nearby agricultural land by grazing. At times those species will feed on shallow waters/lagoons too.
B Fish / crustacean		
Ecology	Bony fish amphidromous - BA	Teleost species that migrate from fresh to salt water or from salt to fresh water at some stage of the life cycle other than the breeding period.
Ecology	Agnatha amphidromous - AA	Superclass of jawless vertebrates that migrate from fresh to salt water or from salt to fresh water at some stage of the life cycle other than the breeding period.
Ecology	Marine species -M	Any species that lives in salt water and/or estuarine environment influenced by salt water.
C Marine mammals / Otter		
Taxonomy	Cetaceans	Marine mammals of the order Cetacea.
Taxonomy	Seals	Marine mammal of the order Carnivora, Suborder Pinnipedia.
Taxonomy	Otter	Marine mammal of the order Carnivora, Family Mustelidae.

Appendix 3 Pressures and Benchmark definitions used in the assessments

This appendix provides definitions of the pressures and benchmarks used in the assessment of feature sensitivity. Table A3.1 defines the pressures identified through the sensitivity assessment process. The process for identifying pressures is described in Section 3. Benchmarks were defined against which the sensitivity of features could be assessed. This process is described in Section 3 and 4 of the main report and the benchmarks used for birds, fish and marine mammals are defined in Table A3.2, Table A3.3 and A3.4 of this appendix.

Table A3.1 Pressure Definitions – The list of pressures have been divided in pressure themes which broadly corresponded to physical, chemical or biological classes. Pressure descriptions are based on 25and25. Identification of the existence of a direct pathway between each pressure and each guild reflects the views of those involved in the project and that these assessment are by nature subjective and should not be viewed as necessarily definitive.

Pressure theme & name	Pressure Description
Biological pressures	
Genetic modification & translocation of indigenous species	Genetic modification can be either deliberate (eg introduction of farmed individuals to the wild, genetically modified (GM) food production) or a by-product of other activities (eg mutations associated with radionuclide contamination). The former is related to escapees or deliberate releases eg cultivated species such as farmed ducks and geese, farmed salmon if GM practices are employed. Mutated organisms from the latter could be transferred with imports for aquaculture, aquaria, species traded as live food or 'natural' migration. Movement of native species to new regions can also introduce different genetic stock.
Introduction or spread of non-indigenous species	This pressure refers to the direct or indirect introduction of non-indigenous species, eg Chinese mitten crabs, slipper limpets, Pacific oyster and their subsequent spreading and out-competing of native species. Ballast water, hull fouling, stepping stone effects (eg offshore wind farms) may facilitate the spread of such species. This pressure could be associated with aquaculture, mussel or shellfishery activities due to imported seed stock imported or from accidental releases. Introduction of predators such as mink, weasels, rats, hedgehogs and domestic cats can result in predation of nesting birds.
Introduction of microbial pathogens	This pressure relates to the untreated or insufficiently treated effluent discharges and run-off from terrestrial and offshore sources and vessels. It may also be a consequence of ballast water releases. In aquaculture where seed stocks are imported, 'infected' seed could be introduced, or microbial pathogens could be introduced from accidental releases of effluvia. Escapees, eg farmed salmon, could be infected and spread pathogens to the indigenous populations. Aquaculture may release contaminated faecal matter, from which pathogens could enter the food chain.
Removal of target species	This pressure relates to the direct removal / harvesting of biota from the commercial exploitation of fish and shellfish stocks, including smaller scale harvesting, angling and scientific sampling. Ecological consequences include pressures on the sustainability of stocks, reducing / depleting feeding areas, impacting energy flows through food webs and the size and age composition within fish stocks. For birds, wildfowling and hunting has identical effects on targeted populations.
Removal of non-target species	This pressure addresses the effects caused by fishing, hunting or harvesting of marine resources including direct removal of individuals and physical resources (eg aggregates, cooling water, etc.). Ecological consequences include food web dependencies, population dynamics of fish, marine mammals, turtles and sea birds (including survival threats in extreme case). Includes entrapment in static fishing gear and power plants as a form of by-catch on aquatic fauna.
Hydrological changes	

Pressure theme & name	Pressure Description
Temperature changes - local	This pressure includes events or activities that result in increasing or decreasing local water temperature. This is most likely from thermal discharges, eg the release of cooling waters from power stations. This pressure could also relate to temperature changes in the vicinity of operational subsea power cables. This pressure only applies within the thermal plume generated by the pressure source. It excludes temperature changes from global warming which occur at a regional scale and cannot be managed at the local scale.
Salinity changes - local	This pressure includes events or activities that result in increasing or decreasing local salinity. This relates to anthropogenic sources/causes that have the potential to be controlled, eg freshwater discharges from pipelines that reduce salinity, or brine discharges from desalination plants or salt cavern washings that may increase salinity. This pressure could also include hydromorphological modification, eg capital navigation dredging if this alters the halocline, or erection of barrages or weirs that alter freshwater/seawater flow or exchange rates. The pressure may be temporally and spatially delineated as derived from the causal event/activity and local environment.
Water flow (tidal current) changes – local, including sediment transport considerations	The pressure relates to changes in water movement associated with tidal streams (the rise and fall of the tide, riverine flows), prevailing winds and ocean currents. The pressure is therefore associated with activities that have the potential to modify hydrological energy flows. For example, tidal energy generation devices remove (convert) energy and such pressures could be manifested leeward of the device, capital dredging may deepen and widen a channel and therefore decrease the water flow, canalisation and/or structures may alter flow speed and direction; managed realignment, and tidal barrages. The pressure will be spatially delineated. The pressure extremes are a shift from a high to a low energy environment (or vice versa). The biota associated with these extremes will be markedly different as will the substrate, sediment supply/transport and associated seabed elevation changes. The potential exists for profound changes (eg coastal erosion/deposition) to occur at long distances from the construction itself if an important sediment transport pathway was disrupted. As such this pressure could have multiple and complex impacts associated with it.
Emergence regime changes – local, including tidal level change considerations	The pressure relates to changes in water levels reducing the intertidal zone (and the associated/dependent habitats). The pressure relates to changes in both the spatial area and duration that intertidal species are immersed and exposed during tidal cycles (the percentage of immersion is dependent on the position or height on the shore relative to the tide). This relates to anthropogenic causes that may directly influence the temporal and spatial extent of tidal immersion, eg upstream and downstream of a tidal barrage the emergence would be respectively reduced and increased, beach re-profiling could change gradients and therefore exposure times, capital dredging may change the natural tidal range, managed realignment, saltmarsh creation. Such alteration may be of importance in estuaries because of their influence on tidal flushing and potential wave propagation. Changes in tidal levels will only affect the emergence regime in areas that are inundated for only part of the time. Foraging time for wading birds and fish using intertidal mudflats for example could produce direct effects on populations. The effects that tidal level changes may have on sediment transport are not restricted to these areas, so a very large construction could significantly affect the tidal level at a deep site without changing the emergence regime. Such a change could still have a serious impact. This excludes pressure from sea level rise which will be at a regional scale and cannot be managed at the local scale.

Pressure theme & name	Pressure Description
Wave exposure changes - local	This pressure refers to local changes in wave length, height and frequency. Exposure on an open shore is dependent upon the distance of open seawater over which wind may blow to generate waves (the fetch) and the strength and incidence of winds. Anthropogenic sources of this pressure include artificial reefs, breakwaters, barrages, and wrecks that can directly influence wave action or activities that may locally affect the incidence of winds, eg a dense network of wind turbines may have the potential to influence wave exposure, depending upon their location relative to the coastline.
Physical damage (Reversible Change)	
Habitat structure changes - removal of substratum (extraction)	This pressure is likely to only act indirectly on mobile species. Unlike the 'physical change' pressure where there is a permanent change in sea bed type (eg sand to gravel, sediment to a hard artificial substrate) the 'habitat structure change' pressure relates to a temporary and/or reversible change. For example, a reversible change occurs with marine mineral extraction where a proportion of seabed sands or gravels are removed but a residual layer of seabed is left which is similar to the pre-dredge structure and as such biological communities could re-colonise. Navigation dredging to maintain channels is another example where the silts or sands removed are replaced by non-anthropogenic mechanisms so the sediment typology is not changed. Other examples of this type of pressure include removal of structures required for spawning, shelter or roosting.
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	This pressure is likely to only act indirectly on mobile species. This pressure refers to the disturbance of sediments where there is limited or no loss of substrate from the system. This pressure is associated with activities such as anchoring, taking of sediment/geological cores, cone penetration tests, cable burial (ploughing or jetting), propeller wash from vessels, and certain fishing activities, eg scallop dredging, beam trawling (physical effects of fishing gear on seabed habitats). Agitation dredging, where sediments are deliberately disturbed and move by gravity and hydraulic dredging where sediments are deliberately disturbed and moved by currents could also be associated with this pressure type. Compression of sediments, eg from the legs of a jack-up barge could also fit into this pressure type. Abrasion relates to the damage of the seabed surface layers (typically up to 50 cm depth).
Changes in suspended solids (water clarity)	This pressure relates to changes in water clarity from changes in sediment and organic particulate matter concentrations. It is related to activities disturbing sediment and/or organic particulate matter thereby mobilising it into the water column. Anthropogenic activities such as all forms of dredging, disposal at sea, cable and pipeline burial, secondary effects of construction works, eg breakwaters all affect water clarity. Particle size, hydrological energy (current speed and direction) and tidal excursion are all influencing factors on the spatial extent and temporal duration. This pressure also relates to changes in turbidity from suspended solids of organic origin (as such it excludes sediments - see the 'changes in suspended sediment' pressure). Salinity, turbulence, pH and temperature may result in flocculation of suspended organic matter. Anthropogenic sources are mostly short lived and occur over relatively small spatial extents but could affect species that rely of underwater vision for hunting.

Pressure theme & name	Pressure Description
Siltation rate changes including smothering (depth of vertical sediment overburden)	Siltation rate changes are an indirect effect and refer to when the natural rates of siltation are altered (either increased or decreased). Siltation (or sedimentation) is the settling out of silt/sediments suspended in the water column. Activities associated with this pressure type include mariculture, land claim, navigational dredging, disposal at sea, marine mineral extraction, cable and pipeline laying and various construction activities. It can result in short lived sediment concentration gradients and the accumulation of sediments on the sea floor. If the sediments are physically different the effect would fall within the theme ‘physical loss’. Two different pressure benchmarks were included ‘High’ siltation rate and ‘Low’ siltation rate representing up to 30cm and 5cm of fine material added to the seabed in a single event within site, respectively.
Abrasion/disturbance of the substrate on the surface of the seabed	This pressure is likely to only act indirectly on mobile species. Damage to seabed surface features by activities associated with abrasion can cover relatively large spatial areas and include: - fishing with towed demersal trawls (fish & shellfish); - bio-prospecting such as harvesting of biogenic features such as maerl beds where, after extraction, conditions for recolonisation remain suitable or - relatively localised activities including: seaweed harvesting, recreation, potting, aquaculture. Abrasion and surficial damage to sediment structures may affect features if these structures are required for spawning, shelter or roosting (eg herring spawning grounds)
Physical loss (Permanent Change)	
Physical loss (to land or freshwater habitat)	This pressure relates to the permanent loss of marine habitats. Associated activities are: land claim; new coastal defences that encroach on and move the Mean High Water Springs level seawards; the footprint of a wind turbine on the seabed and the sea surface it covers; and dredging if it alters the position of the halocline. This pressure excludes changes from one marine habitat type to another marine habitat type.
Physical change (to another marine habitat type)	The permanent change of one marine habitat type to another marine habitat type, through the change in substratum, including to artificial (eg concrete) or water column habitat changes (ie a barrage increasing the water column volume and effects on pelagic food webs). This therefore involves the permanent loss of one marine habitat type but has an equal creation of a different marine habitat type. Associated activities include the installation of infrastructure (eg surface of platforms or wind farm foundations, marinas, coastal defences, pipelines and cables), the placement of scour protection where soft sediment habitats are replaced by hard/coarse substrate habitats, removal of coarse substrate (marine mineral extraction) in those instances where surficial finer sediments are lost, capital dredging where the residual sedimentary habitat differs structurally from the pre-dredge state, creation of artificial reefs, mariculture ie mussel beds, and the protection of pipes and cables using rock dumping and mattressing techniques. The placement of cuttings piles from oil and gas activities could fit this pressure type, however, there may be an additional associated pressures, eg ‘pollution and other chemical changes’ theme. This pressure includes dredging where the depth of sediment changes locally but the sediment typology is not changed.

Pressure theme & name	Pressure Description
Other physical pressures	
Litter	Marine litter is any manufactured or processed solid material from anthropogenic activities that are discarded, disposed of or abandoned once entering the marine and coastal environment including: plastics, metals, timber, rope, fishing gear etc. and their degraded components, eg microplastic particles. Ecological effects can be physical (smothering), biological (ingestion, including uptake of microplastics; entangling; physical damage; accumulation of chemicals) and/or chemical (leaching, contamination).
Electromagnetic changes	This pressure relates to the localised electric and magnetic fields associated with operational power cables and telecommunication cables (if equipped with power relays). Such cables may generate electric and magnetic fields that could alter behaviour and migration patterns of sensitive species (eg sharks, rays, lampreys, etc.)
Introduction of light	Direct inputs of light from anthropogenic activities, ie lighting on structures during construction or operation to allow 24 hour working; new tourist facilities, eg promenade or pier lighting; lighting on oil and gas facilities etc. Ecological effects may include the diversion of bird species from migration routes if they become disorientated by or attracted to the lights. Attraction to light sources can result in birds directly colliding with structures, or interfering with fish migration or spawning. It is also possible that continuous lighting may lead to increased algal growth resulting in other indirect effects.
Barrier to species movement	This pressure relates to the physical obstruction of species movements and including local movements (within and between roosting, breeding, feeding areas) and regional/global migrations (eg birds, eels, salmon, and whales). Both include up-river movements (where tidal barrages and devices or dams could obstruct movements) or movements across open waters (offshore wind farm, wave or tidal array devices, mariculture infrastructure or fixed fishing gears). The species affected are mostly birds, fish, and mammals. This pressure includes temporary physical discontinuities to migratory (or commuting) corridors such as DO sags (low dissolved oxygen concentration event).
Collision above or below water with static or moving objects not naturally found in the marine environment	This pressure relates to the injury or mortality of biota from collisions with both static and/or moving structures. Examples include collisions with: - rigs (eg birds) - screens in intake pipes (eg fish at power stations) - wind turbine blades (eg birds) - tidal devices (eg fish and mammals) and - shipping (eg fish and mammals). Activities increasing number of vessels transiting areas, eg new port development or construction works will influence the scale and intensity of this pressure. In the assessments the above and below collision risks were assessed separately as two independent pressure types.
Visual disturbance	This pressure relates to the disturbance of biota by anthropogenic activities, eg increased vessel movements, such as during construction phases for new infrastructure (bridges, cranes, port buildings, offshore platforms, offshore wind farms etc.), increased personnel movements, increased tourism, moving wind turbine blades, increased vehicular movements onshore and offshore disturbing bird roosting areas, rafting areas, feeding areas, seal haul out areas etc.
Above water noise	This pressure relates to any loud noise made onshore or offshore by construction, vehicles (including aircraft), vessels, tourism, mining, blasting etc. that may disturb birds and reduce time spent in feeding or breeding area.

Pressure theme & name	Pressure Description
Underwater noise	Increases over and above background noise levels (consisting of environmental noise (ambient) and incidental man-made/anthropogenic noise (apparent)) at a particular location. Species known to be affected are marine mammals and fish but could potentially include diving birds and crustaceans. The theoretical zones of noise influence are temporary or permanent hearing loss; discomfort and injury; response; and masking. In extreme cases noise pressures may lead to physical injury and death. The physical or behavioural effects are dependent on a number of variables, including the sound pressure level and frequency of the noise. High amplitude low and mid-frequency impulsive sounds and low frequency continuous sound are of greatest concern for effects on marine organisms. Some species may be responsive to the associated particle motion rather than the usual concept of noise (ie pressure wave). Noise propagation can be over large distances (tens of kilometres) but transmission losses can be attributed to factors such as water depth and sea bed topography. Noise levels associated with construction activities, such as pile-driving, are typically significantly greater than operational phases (ie shipping, operation of a wind farm).
Vibration	Aquatic animals are sensitive to particle motion therefore vibration alone will present a significant direct disturbance to some species. In addition to direct vibration sources (eg drilling, trawling, piling, etc.) energy from substrate vibrations can enter the water column as sound waves which are likely to produce pressure components of sound and cause similar effects as those discussed in ‘underwater noise’.
Pollution and other chemical changes	
Transition elements & organo-metal (eg TBT) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	This pressure relates to the increase in transition element levels compared with background concentrations, resulting from their input from land/riverine sources, by air or directly to sea. For marine sediments the main elements of concern are arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc. Organo-metallic compounds such as the butyl tins (tri butyl tin and its derivatives) can be highly persistent and chronic exposure to low levels has adverse biological effects, eg imposex in molluscs.
Hydrocarbon & Poly Aromatic Hydrocarbon (PAH) contamination. Includes those priority substances listed in Annex II of Directive 2008/105/EC.	This pressure relates to increases in the levels of these compounds compared with background concentrations. Ecological consequences include tainting and some hydrocarbons are acutely toxic resulting in carcinomas and growth defects. This pressure includes oil spills. Hydrocarbons are naturally occurring compounds, which are a complex mixture of two basic molecular structures: - straight chained aliphatic hydrocarbons (relatively low toxicity and susceptible to degradation) - multiple ringed aromatic hydrocarbons (higher toxicity and more resistant to degradation). These fall into three categories based on source (includes both aliphatics and polyaromatic hydrocarbons): - petroleum hydrocarbons (from natural seeps, oil spills and surface water run-off) - pyrogenic hydrocarbons (from combustion of coal, woods and petroleum) - biogenic hydrocarbons (from plants & animals).

Pressure theme & name	Pressure Description
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in Annex II of Directive 2008/105/EC.	This pressure relates to increases in the levels of synthetic compounds compared with background concentrations. Ecological consequences include physiological changes (eg growth defects, carcinomas). These compounds are synthesised from a variety of industrial processes and commercial applications. Chlorinated compounds include polychlorinated biphenols (PCBs), dichlor-diphenyl-trichloroethane (DDT) and 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD) which are persistent and often very toxic. Pesticides vary greatly in structure, composition, environmental persistence and toxicity to non-target organisms. They include: insecticides, herbicides, rodenticides and fungicides. Pharmaceuticals and Personal Care Products originate from veterinary and human applications which compose a variety of products including over-the-counter medications, fungicides, chemotherapy drugs and animal therapeutics, such as growth hormones. Due to their biologically active nature, high levels of consumption, known combined effects, and their detection in most aquatic environments they have become an emerging concern.
Introduction of other substances (solid, liquid or gas)	The 'systematic or intentional release of liquids, gases' (from the Marine Strategy Framework Directive Annex III Table 2) is being considered eg in relation to produced water from the oil industry. It should therefore be considered in parallel with contamination transition elements and organo-metals, hydrocarbons and PAH, and synthetic compounds.
Radionuclide contamination	This pressure relates to the introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea-based operations (eg oil platforms, medical sources). The disposal of radioactive material at sea is prohibited unless it fulfils exemption criteria developed by the International Atomic Energy Agency (IAEA), namely that both the following radiological criteria are satisfied: (i) the effective dose expected to be incurred by any member of the public or ships crew is 10 μSv or less in a year; (ii) the collective effective dose to the public or ships crew is not more than 1 man Sv per annum, then the material is deemed to contain *de minimis* levels of radioactivity and may be disposed at sea pursuant to it fulfilling all the other provisions under the Convention. The individual dose criteria are placed in perspective (ie very low), given that the average background dose to the UK population is ~2,700 μSv/a. Ports and coastal sediments can be affected by the authorised discharge of both current and historical low-level radioactive wastes from coastal nuclear establishments.
Nutrient enrichment	This pressure relates to the increased levels of the elements nitrogen, phosphorus, silicon (and iron) in the marine environment compared to background concentrations. Nutrients can enter marine waters by natural processes (eg decomposition of detritus, riverine, direct and atmospheric inputs) or anthropogenic sources (eg waste water runoff, terrestrial/agricultural runoff, sewage discharges, aquaculture, and atmospheric deposition). Nutrients can also enter marine regions from ‘upstream’ locations, eg via tidal currents to induce enrichment in the receiving area. Nutrient enrichment may lead to eutrophication. Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.
Organic enrichment	This pressure relates to organic enrichment resulting from the degraded remains of dead biota and microbiota (from land and sea); faecal matter from marine animals; flocculated colloidal organic matter and the degraded remains of sewage material, domestic wastes, industrial wastes etc. Organic matter can enter marine waters from sewage discharges, aquaculture or terrestrial/agricultural runoff. Black carbon comes from the products of incomplete combustion (PIC) of fossil fuels and vegetation. Organic enrichment may lead to eutrophication. Adverse environmental effects include deoxygenation, algal blooms, changes in community structure of benthos and macrophytes.

Pressure theme & name	Pressure Description
Deoxygenation	This pressure relates to any deoxygenation that is not directly associated with nutrient or organic enrichment. This pressure refers to the lowering, temporarily or more permanently, of oxygen levels in the water or substrate due to anthropogenic causes (some areas may naturally be deoxygenated due to stagnation of water masses, eg inner basins of fjords). This is typically associated with nutrient and organic enrichment, but it can also derive from the release of ballast water or other stagnant waters (where organic or nutrient enrichment may be absent). Ballast waters may be deliberately deoxygenated via treatment with inert gases to kill non-indigenous species.

Table A3.2 Benchmarks for Birds – Final list of pressures with benchmark definitions selected for inclusion in the pressures-features sensitivity matrix. Result of the scoping exercise for direct effects on highly mobile species (birds) are given; "y" indicates that the pressure is likely to impact directly the species included in the relevant functional group or taxonomic group.

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Genetic modification & translocation of indigenous species	Displacement/mortality-fitness	Translocation/displacement outside of a geographic area; introduction of farm/hatchery-reared individuals outside of geographic area from which adult stock derives.	y	y	y	y	y	y	y	y
Introduction or spread of non-indigenous species	Displacement/mortality-fitness	A significant pathway exists for introduction or spread of one or more non-indigenous invasive species; OR there is a potential for the introduction of highly invasive/impact species.	y		y	y	y	y	y	y
Introduction of microbial pathogens	Mortality-fitness	The introduction of relevant microbial pathogens to an area where they are currently not present (eg avian influenza virus, viral haemorrhagic septicaemia virus, etc.)	y	y	y	y	y	y	y	y
Removal of target species	Mortality-fitness	The number of individuals of a feature removed as target species equates to in excess of 10% of the rate of natural mortality of the population of the site under consideration eg increases annual mortality of that site's population of individuals from 10% to more than 11%.	y	y	y	y	y	y	y	y
Removal of non-target species	Mortality-fitness	The numbers of individuals of a feature removed as by-catch equates to in excess of 10% of the rate of natural mortality of the population of the site under consideration eg increases annual mortality of that site's population of individuals from 10% to more than 11%.	y	y	y	y	y	y	y	y

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Habitat structure changes - removal of substratum (extraction)	Mortality-fitness[3]	The extraction of sediment to 30 cm; OR removal of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within a site.	y	y	y	y	y	y	y	y
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within site.								
Changes in suspended solids (water clarity)	Displacement	A change in one Water Framework Directive (WFD) ecological status class for one year within site.					y	y		
Siltation rate changes (High), including smothering (depth of vertical sediment overburden)	Displacement/mortality-fitness	Up to 30 cm of fine material added to the seabed in a single event within site.								y
Siltation rate changes (Low), including smothering (depth of vertical sediment overburden)	NO DIRECT EFFECTS	Up to 5 cm of fine material added to the seabed in a single event within a site.								
Abrasion/disturbance of the substrate on the surface of the seabed	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including biogenic forming structures) within a site.								
Temperature changes - local	NO DIRECT EFFECTS	A short-term 5°C change in temp over species habitat areas, or 2°C for one year or more.								

[3] Included direct removal or damage to the feature by removal of substratum is removed (ie dredging) from preferred habitats.

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Salinity changes - local	NO DIRECT EFFECTS	An increase in salinity from 35 to 38 units over species essential habitat areas. Decrease in salinity by 4-10 units a year.								
Water flow (tidal current) changes – local, including sediment transport considerations	Displacement[4]	A change in peak mean spring tide bed flow velocity of between 0.1 m/s to 0.2 m/s .	y	y	y		y	y		
Emergence regime changes – local, including tidal level change considerations	Displacement	*Intertidal species and habitats not uniquely defined by intertidal zone*: A one hour change in the time covered or not covered by the sea for a period of one year. *Intertidal species and habitats (and landscapes) defined by intertidal zone*: An increase in relative sea level or decrease in high water level of 1 mm for one year over a shoreline length >1 km	y	y		y				y
Wave exposure changes - local	Displacement	A change in nearshore significant wave height of >3% but <5%.	y	y		y				y
Physical loss (to land or freshwater habitat)	Displacement	Permanent loss of existing saline habitat within a site.	y	y	y	y	y	y	y	y
Physical change (to another habitat type)	NO DIRECT EFFECTS	Change in one Folk class for two years or >10% habitat type change within site.								
Litter	Mortality-fitness	The introduction of manmade objects able to cause physical harm (surface, water column, sea floor and/or strandline).	y	y	y	y	y	y	y	y

[4] The effect of changes in flow was not consider enough to cause direct displacement effects in BDF birds as as benthic resources are likely to remain available on the seabed at the pressure benchmark.

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Barrier to species movement	Displacement	Disruption to >10% of local population of a migratory feature affected by permanent or temporary lack of continuity of parts of the commuting or migration corridor causing complete obstruction or an increase in travel distance around barriers to species movement.	y	y	y	y	y	y	y	y
Collision above water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	Mortality-fitness	The introduction of aerial structures or devices that introduce collision risk in areas used by features.	y	y	y	y	y	y	y	y
Collision below water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	Mortality-fitness	A change in 0.1% of tidal volume on average tide, passing through an artificial structure.	y	y	y	y	y	y		
Visual disturbance	Displacement	The daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature.	y	y	y	y	y	y	y	y
Introduction of light	Displacement	A change of 0.1 Lux in diffuse irradiation during period of site occupancy by the feature; >3 distant strobe and point light sources visible over a 90° azimuth arc.	y	y	y	y	y	y	y	y
Underwater noise changes	Displacement	Marine Strategy Framework Directive (MSFD) indicator levels (SEL or peak SPL) exceeded in areas used by features.						y	y	

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Above water noise	Displacement	The introduction of airborne noise above background levels during periods of site occupancy by the feature.	y	y	y	y	y	y	y	y
Vibration	Displacement	Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features.						y	y	
Electromagnetic changes	NO DIRECT EFFECTS	The introduction of a local electric field of 1 V/m or a local magnetic field of 10 µT within a site.								
Transition elements & organo-metal (eg TBT) contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	The introduction of non-synthetic substances and compounds (eg heavy metals resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs).	y	y	y	y	y	y	y	y
Hydrocarbon & PAH contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	The non-compliance with any AA EQS, non-conformance with any PELs, EACs/ER-Ls within a site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of petroleum hydrocarbons on designated sites could have direct effects on bird features.	y	y	y	y	y	y	y	y
Synthetic compound contamination (incl. pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in *Annex II* of	Mortality-fitness	The non-compliance with any AA EQS, non-conformance with PELs, EACs, ER-Ls within site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of	y	y	y	y	y	y	y	y

Pressure	Route of impact	Benchmark Birds	CBWB	CnBWB	SBS	WB&IF	SF	WCF	BDF	HGB
Directive 2008/105/EC.		synthetic compounds on designated sites could have direct effects on birds features.								
Introduction of other substances (solid, liquid or gas)	Mortality-fitness	The presence of exogenous substances (including oil films and slicks) in areas used by features.	y	y	y	y	y	y	y	y
Radionuclide contamination	Mortality-fitness	An increase in radionuclides of 10 µGy/h above background levels within site.	y	y	y	y	y	y	y	y
Nutrient enrichment	NO DIRECT EFFECTS	Non-compliance with Water Framework Directive (WFD) criteria for good status within a site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no effects on the features, the accidental introduction of large quantities of nutrients on designated sites could result in severe eutrophication and have indirect effects on birds features.								
Organic enrichment	NO DIRECT EFFECTS	A deposit of 100 $gC/m^2/yr$ or more.								
Deoxygenation	NO DIRECT EFFECTS	Non-compliance with WFD criteria for good status within site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no direct effects on the features, local acute anoxic events on designated sites could have direct effect on water breathing features (fishes, molluscs, etc.)								

Table A3.3 Benchmarks for Fish - Final list of pressures with benchmark definitions selected for inclusion in the pressures-features sensitivity matrix. Result of the scoping exercise for direct effects on highly mobile species (fish) are given; "y" indicates that the pressure is likely to impact directly the species included in the relevant functional group or taxonomic group.

Pressure	Route of impact	Benchmark Fish	BA	AA	M
Genetic modification & translocation of indigenous species	Displacement/mortality-fitness	Translocation/displacement outside of a geographic area; introduction of farm/hatchery-reared individuals outside of a geographic area from which the adult stock derives.	y	y	y
Introduction or spread of non-indigenous species	Displacement/mortality-fitness	A significant pathway exists for the introduction or spread of one or more non-indigenous invasive species; OR there is a potential for the introduction of highly invasive/impact species.	y	y	y
Introduction of microbial pathogens	Mortality-fitness	The introduction of relevant microbial pathogens to an area where they are currently not present (eg avian influenza virus, viral haemorrhagic septicaemia virus, etc.)	y	y	y
Removal of target species	Mortality-fitness	The extraction of features as a target species removes 10% of the individuals from the population of the site under consideration.	y	y	y
Removal of non-target species	Mortality-fitness	The extraction of features as a non-target species removes 10% of the individuals from the population of the site under consideration.	y	y	y
Habitat structure changes - removal of substratum (extraction)	Mortality-fitness	Extraction of sediment to 30 cm; OR removal of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within a site.	y	y	
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within a site.			
Changes in suspended solids (water clarity)	Displacement	A change in one Water Framework Directive (WFD) ecological status class for one year within a site.	y	y	y
Siltation rate changes (High), including smothering (depth of vertical sediment overburden)	NO DIRECT EFFECTS	An increase of up to 30 cm of fine material added to the seabed in a single event within a site.			

Pressure	Route of impact	Benchmark Fish	BA	AA	M
Siltation rate changes (Low), including smothering (depth of vertical sediment overburden)	NO DIRECT EFFECTS	An increase of up to 5 cm of fine material added to the seabed in a single event within site.			
Abrasion/disturbance of the substrate on the surface of the seabed	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including biogenic forming structures) within a site.			
Temperature changes - local	Displacement/mortality-fitness	A short-term 5°C change in temp over species habitat areas, or 2°C for one year or more.	y	y	y
Salinity changes - local	Displacement	An increase in salinity from 35 to 38 units over species essential habitat areas. A decrease in salinity by 4-10 units a year.	y	y	y
Water flow (tidal current) changes – local, including sediment transport considerations	Displacement	A change in peak mean spring tide bed flow velocity of between 0.1 m/s to 0.2 m/s over population areas or 50% of width of a water body for more than one year.	y	y	
Emergence regime changes – local, including tidal level change considerations	Displacement	*Intertidal species and habitats not uniquely defined by intertidal zone*: A one hour change in the time covered or not covered by the sea for a period of one year. *Intertidal species and habitats (and landscapes) defined by intertidal zone*: An increase in relative sea level or decrease in high water level of 1 mm for one year over a shoreline length >1 km	y	y	y
Wave exposure changes - local	NO DIRECT EFFECTS	A change in nearshore significant wave height of >3% but <5%.			
Physical loss (to land or freshwater habitat)	NO DIRECT EFFECTS	Permanent loss of the existing saline habitat within a site.			
Physical change (to another habitat type)	NO DIRECT EFFECTS	Change in one Folk class for two years or >10% habitat type change within a site.			
Litter	Mortality-fitness	The introduction of manmade objects able to cause physical harm (surface, water column, sea floor and/or strandline).	y	y	y
Barrier to species movement	Displacement	Disruption to >10% of local population of a migratory feature affected by permanent or temporary lack of continuity of parts of the migration corridor.	y	y	y

Pressure	Route of impact	Benchmark Fish	BA	AA	M
Collision above water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	NO DIRECT EFFECTS	The introduction of aerial structures or devices that introduce collision risk in areas used by features.			
Collision below water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	Mortality-fitness	A change of 0.1% of tidal volume on average tide, passing through an artificial structure.	y	y	y
Visual disturbance	Displacement	The presence of activity within the visual range of the feature.	y		y
Introduction of light	NO DIRECT EFFECTS	The change of 0.1 Lux in diffuse irradiation at the water surface at night during the period of site occupancy by the feature.			
Underwater noise changes	Displacement	Marine Strategy Framework Directive (MSFD) indicator levels (SEL or peak SPL) exceeded in areas used by features.	y	y	y
Above water noise	NO DIRECT EFFECTS	The introduction of airborne noise above background levels during periods of site occupancy by the feature.			
Vibration	Displacement	Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features.	y	y	y
Electromagnetic changes	Displacement	The introduction of a local electric field of 1 V/m or a local magnetic field of 10 µT within a site.	y	y	y
Transition elements & organo-metal (eg TBT) contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	The introduction of non-synthetic substances and compounds (eg heavy metals resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs).	y	y	y

Pressure	Route of impact	Benchmark Fish	BA	AA	M
Hydrocarbon & PAH contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	Non-compliance with any AA EQS, non-conformance with PELs, EACs/ER-Ls within site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of petroleum hydrocarbons on designated sites could have direct effects on bird features.	y	y	y
Synthetic compound contamination (including pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in *Annex II* of Directive *2008/105/EC*.	Mortality-fitness	Non-compliance with any AA EQS, non-conformance with PELs, EACs, ER-Ls within site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of synthetic compounds on designated sites could have direct effects on fish features.	y	y	y
Introduction of other substances (solid, liquid or gas)	Mortality-fitness	The presence of exogenous substances (including oil films and slicks) in areas used by features.	y	y	y
Radionuclide contamination	Mortality-fitness	An increase in radionuclides of 10 µGy/h above background levels within a site.	y	y	y
Nutrient enrichment	NO DIRECT EFFECTS	Non-compliance with WFD criteria for good status within site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no effects on the features, the accidental introduction of large quantities of nutrients on designated sites could result in severe eutrophication and have indirect effects on fish features.			
Organic enrichment	NO DIRECT EFFECTS	A deposit of 100 gC/m^2/yr.			

Pressure	Route of impact	Benchmark Fish	BA	AA	M
Deoxygenation	Displacement/mortality-fitness	Non-compliance with WFD criteria for good status within site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no direct effects on the features, local acute anoxic events on designated sites could have direct effect on water breathing features (fishes, molluscs, etc.)	y	y	y

Table A3.4 Benchmark for Marine Mammals – Final list of pressures with benchmark definitions selected for inclusion in the pressures-features sensitivity matrix. Result of the scoping exercise for direct effects on highly mobile species (marine mammals) are given; "y" indicates that the pressure is likely to impact directly the species included in the relevant functional group or taxonomic group.

Pressure	Route of impact	Benchmark Marine Mammals	Otter	Seals	Cetaceans
Genetic modification & translocation of indigenous species	Displacement/mortality-fitness	Translocation/displacement outside of a geographic area; introduction of farm/hatchery-reared individuals outside of geographic area from which adult stock derives.	y	y	y
Introduction or spread of non-indigenous species	Displacement/mortality-fitness	A significant pathway exists for the introduction or spread of one or more non-indigenous invasive species; OR there is a potential for the introduction of highly invasive/impact species.	y	y	
Introduction of microbial pathogens	Mortality-fitness	The introduction of relevant microbial pathogens to an area where they are currently not present (eg avian influenza virus, viral haemorrhagic septicaemia virus, etc.)	y	y	y
Removal of target species	Mortality-fitness	Removal of feature as a target species exceeds 10% of the rate of natural mortality	y	y	y
Removal of non-target species	Mortality-fitness	The introduction of bycatch risk in areas used by features	y	y	y
Habitat structure changes - removal of substratum (extraction)	NO DIRECT EFFECTS	The extraction of sediment to 30 cm; OR removal of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within a site.			
Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including water column habitat and biogenic forming structures) within a site.			
Changes in suspended solids (water clarity)	NO DIRECT EFFECTS	A change in one Water Framework Directive (WFD) ecological status class for one year within a site.			
Siltation rate changes (High), including smothering (depth of vertical sediment overburden)	NO DIRECT EFFECTS	Up to 30 cm of fine material added to the seabed in a single event within a site.			

Pressure	Route of impact	Benchmark Marine Mammals	Otter	Seals	Cetaceans
Siltation rate changes (Low), including smothering (depth of vertical sediment overburden)	NO DIRECT EFFECTS	Up to 5 cm of fine material added to the seabed in a single event within a site.			
Abrasion/disturbance of the substrate on the surface of the seabed	NO DIRECT EFFECTS	Structural damage of >10% area/volume of biologically relevant structures (including biogenic forming structures) within a site.			
Temperature changes - local	NO DIRECT EFFECTS	A short-term 5°C change in temp over species habitat areas, or 2°C for one year or more.			
Salinity changes - local	NO DIRECT EFFECTS	An increase in salinity from 35 to 38 units over species habitat areas. A decrease in salinity by 4-10 units a year.			
Water flow (tidal current) changes – local, including sediment transport considerations	NO DIRECT EFFECTS	A change in peak mean spring tide bed flow velocity of between 0.1 m/s to 0.2 m/s over population areas or 50% of width of water body for more than one year.			
Emergence regime changes – local, including tidal level change considerations	NO DIRECT EFFECTS	*Intertidal species and habitats not uniquely defined by intertidal zone*: A one hour change in the time covered or not covered by the sea for a period of one year. *Intertidal species and habitats (and landscapes) defined by intertidal zone*: An increase in relative sea level or decrease in high water level of 1 mm for one year over a shoreline length >1 km			
Wave exposure changes - local	NO DIRECT EFFECTS	A change in nearshore significant wave height of >3% but <5%.			
Physical loss (to land or freshwater habitat)	NO DIRECT EFFECTS	Permanent loss of existing saline habitat within a site.			
Physical change (to another habitat type)	NO DIRECT EFFECTS	Change in one Folk class for two years or >10% habitat type change within a site.			
Litter	Mortality-fitness	The introduction of manmade objects able to cause physical harm (surface, water column, sea floor and/or strandline).	y	y	y
Barrier to species movement	Displacement	The introduction of a permanent physical barrier in areas used by features.		y	y

Pressure	Route of impact	Benchmark Marine Mammals	Otter	Seals	Cetaceans
Collision above water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	NO DIRECT EFFECTS	The introduction of aerial structures or devices that introduce collision risk in areas used by features.			
Collision below water with static or moving objects not naturally found in the marine environment (eg, boats, machinery, and structures)	Mortality-fitness	The presence of propelled vessels (particularly ducted propelled vessels) and/or tidal power devices OR 0.1% of tidal volume on an average tide, passing through an artificial structure.	y	y	y
Visual disturbance	Displacement	The presence of activity within the visual range of the feature.	y	y	y
Introduction of light	Displacement	A change of 0.1 Lux in diffuse irradiation during period of site occupancy by the feature; >3 distant strobe and point light sources visible over a 90° azimuth arc.	y	y	
Underwater noise changes	Displacement	Marine Strategy Framework Directive (MSFD) indicator levels (SEL or peak SPL) exceeded in areas used by features.	y	y	y
Above water noise	Displacement	Introduction of airborne noise above background levels during periods of site occupancy by the feature.	y	y	
Vibration	NO DIRECT EFFECTS	Particle motion equivalent for MSFD indicator levels (SEL or peak SPL) exceeded in areas used by features.			
Electromagnetic changes	NO DIRECT EFFECTS	The introduction of a local electric field of 1 V/m or a local magnetic field of 10 µT within a site.			
Transition elements & organo-metal (eg TBT) contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	The introduction of non-synthetic substances and compounds (eg heavy metals resulting, for example, from pollution by ships and oil, gas and mineral exploration, atmospheric deposition, riverine inputs).	y	y	y

Pressure	Route of impact	Benchmark Marine Mammals	Otter	Seals	Cetaceans
Hydrocarbon & PAH contamination. Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	Noncompliance with any AA EQS, non-conformance with PELs, EACs/ER-Ls within a site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of petroleum hydrocarbons on designated sites could have direct effects on bird features.	y	y	y
Synthetic compound contamination (including pesticides, antifoulants, pharmaceuticals). Includes those priority substances listed in *Annex II* of *Directive 2008/105/EC*.	Mortality-fitness	Non-compliance with any AA EQS, non-conformance with PELs, EACs, ER-Ls within site. *Note:* Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of synthetic compounds on designated sites could have direct effects on marine mammal features.	y	y	y
Introduction of other substances (solid, liquid or gas)	Mortality-fitness	Presence of exogenous substances (including oil films and slicks) in areas used by features.	y	y	y
Radionuclide contamination	Mortality-fitness	An increase in radionuclides of 10 µGy/h above background levels within site.	y	y	y
Nutrient enrichment	NO DIRECT EFFECTS	Non-compliance with WFD criteria for good status within site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no effects on the features, the accidental introduction of large quantities of nutrients on designated sites could result in severe eutrophication and have indirect effects on marine mammals features.			
Organic enrichment	NO DIRECT EFFECTS	A deposit of 100 gC/m2/yr.			

Pressure	Route of impact	Benchmark Marine Mammals	Otter	Seals	Cetaceans
Deoxygenation	NO DIRECT EFFECTS	Non-compliance with WFD criteria for good status within site. *Note:* Although compliance with established WFD criteria for good ecological status (GES) or good ecological potential (GEP) is likely to result in no direct effects on the features, local acute anoxic events on designated sites could have direct effect on water breathing features (fishes, molluscs, etc.)			

Appendix 4 Resilience scoring for bird features

Resilience to pressures resulting in displacement effects was considered to be broadly independent of the magnitude of expected impacts (Resistance) while the pressure acted. However, for pressures likely to result in direct population mortality or reduced productivity, longer recovery times were expected after more severe impacts (low or no Resistance) such that resilience scores were made a function of both the species' recovery potential. The recovery potential criteria used are summarised in Table A4. 1.

Table A4.1 Resilience criteria for mortality and/or fitness-mediated impact on birds populations. The table describes the range of four key demographic characteristics likely to be consistent with low, medium or high recovery potential.

Species life history strategy			
Lifespan	Long- lived (10 years +)	Moderate lifespans (5-10 years)	Short-lived (up to 5 years)
Age at fist maturity	Deferred maturity (first breeds when more than 3 years old)	First breeds when 2-3 years old	First breeds at one year of age,
Adult mortality rate	Low natural mortality (<15%)	Moderate natural mortality rate (15-25%)	High natural annual mortality (>25%)
Fecundity / reproductive success	Low (<2 chicks per pair per annum)	Moderate reproductive output (2-5 chicks per pair per annum)	High reproductive output (>5 chicks per pair per annum)
Recovery potential	**LOW RECOVERY POTENTIAL**	**MEDIUM RECOVERY POTENTIAL**	**HIGH RECOVERY POTENTIAL**

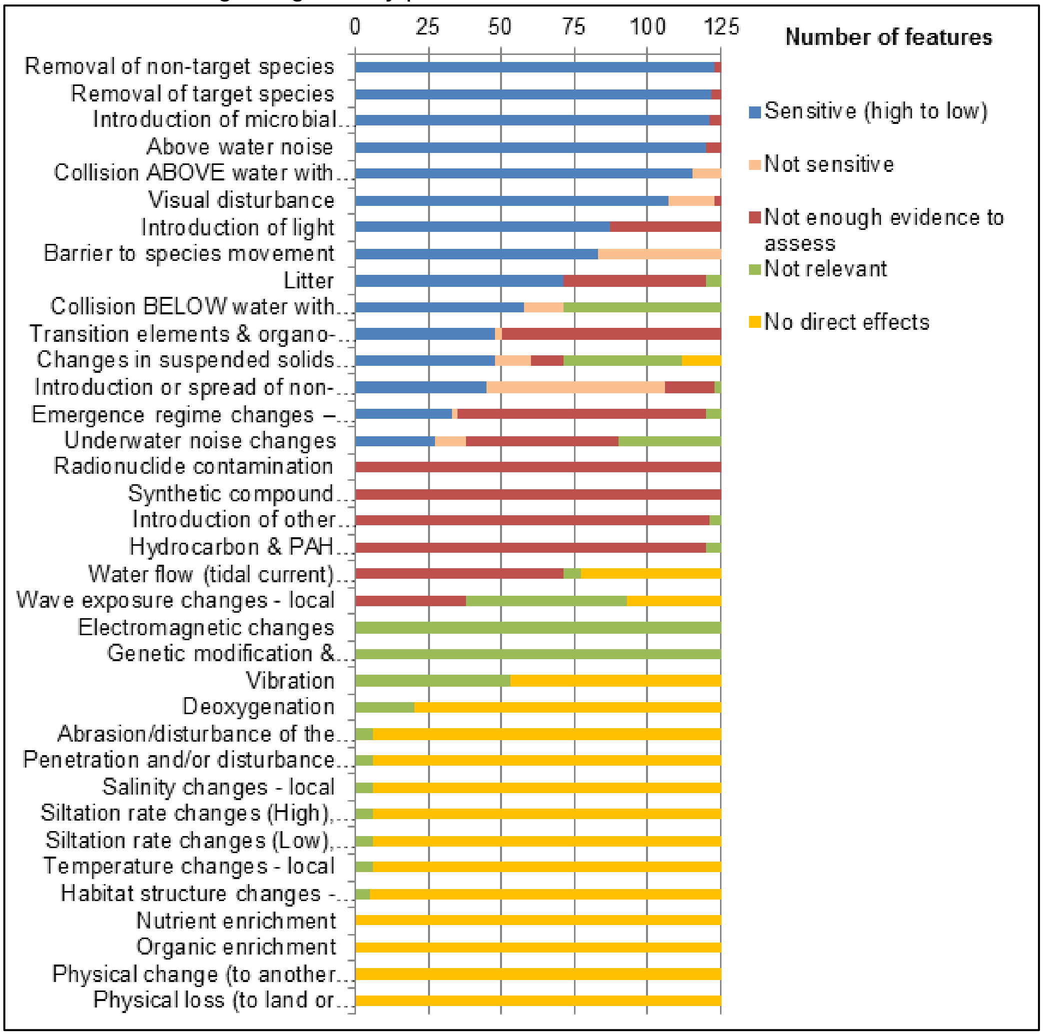
Appendix 5 Distribution of scoring categories by pressure

The annex provides a graphical representation of the distribution of scoring categories by pressure for: A, Birds; B, Fish; and C Marine mammals.

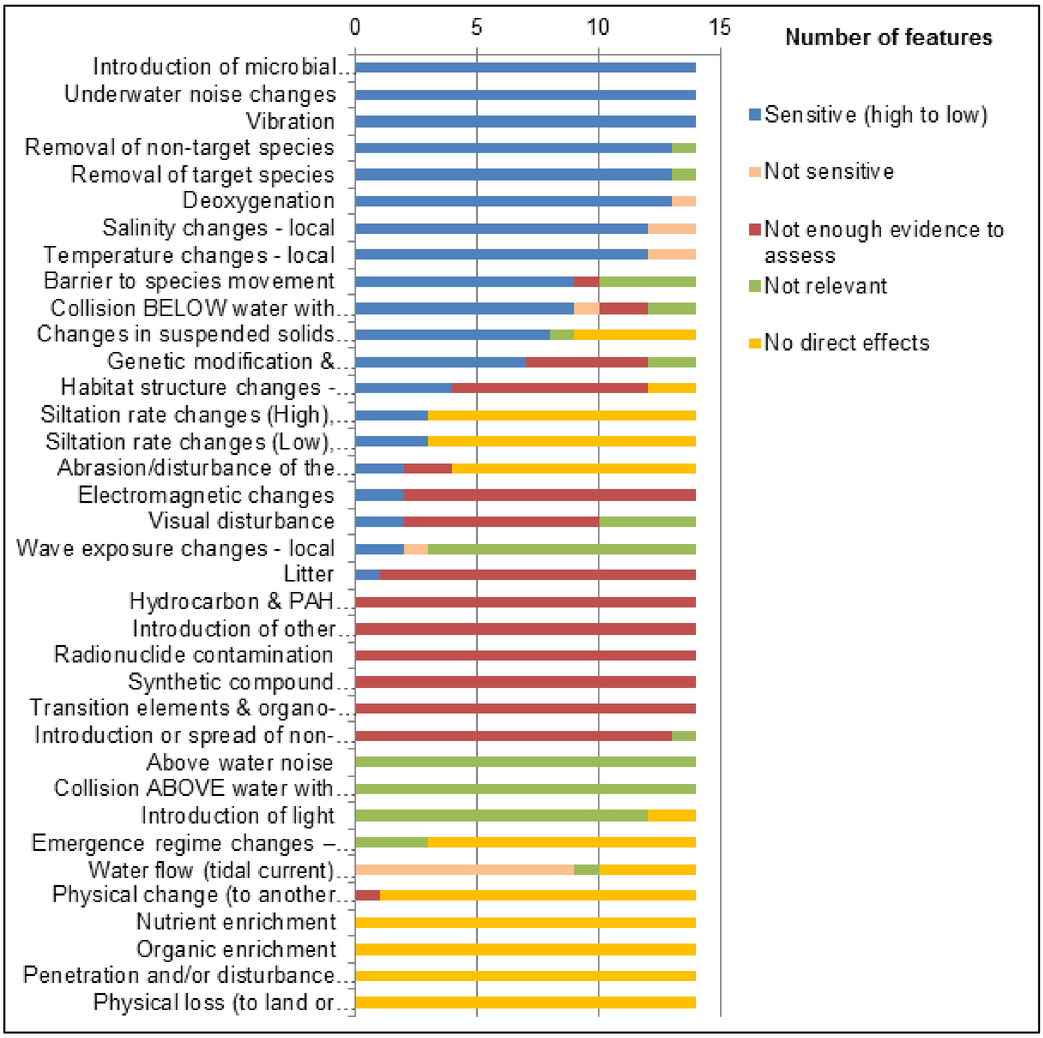
Table A5.1 Distribution of scoring categories by pressure

A

Birds

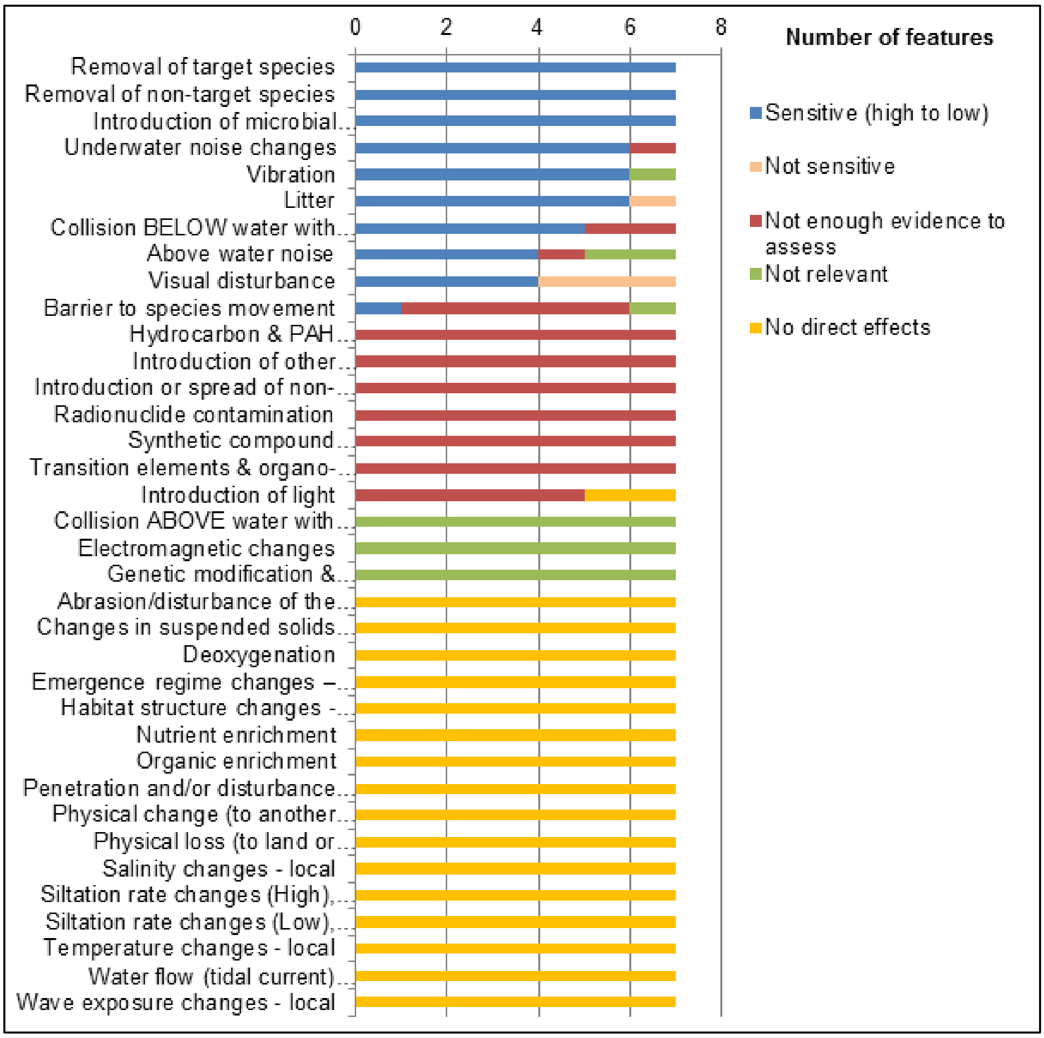


B
Fish

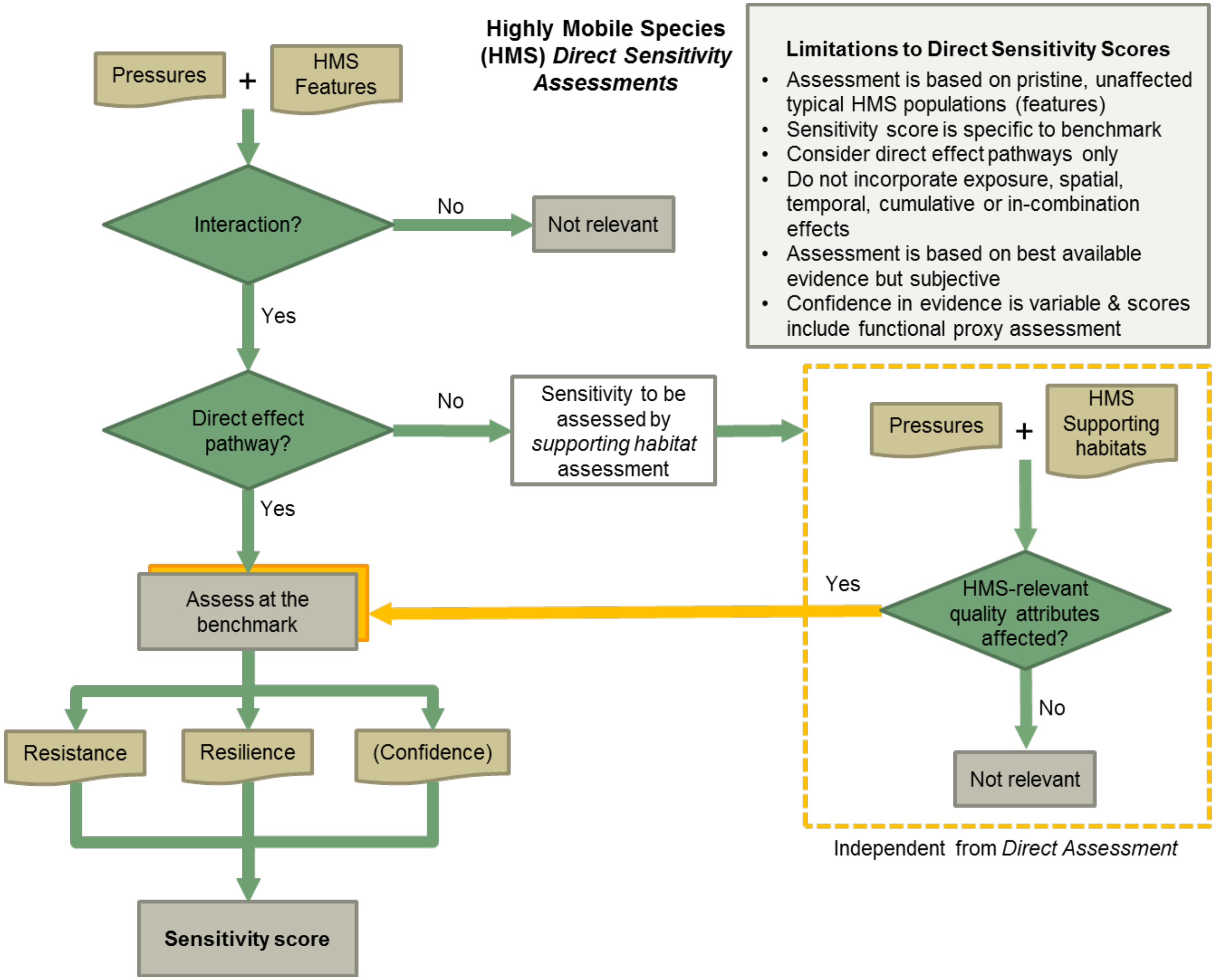


Number of features
0
5
10
15
Introduction of microbial…
Underwater noise changes
Vibration
Removal of non-target species
Removal of target species
Deoxygenation
Salinity changes - local
Temperature changes - local
Barrier to species movement
Collision BELOW water with…
Changes in suspended solids…
Genetic modification &…
Habitat structure changes -…
Siltation rate changes (High),…
Siltation rate changes (Low),…
Abrasion/disturbance of the…
Electromagnetic changes
Visual disturbance
Wave exposure changes - local
Litter
Hydrocarbon & PAH…
Introduction of other…
Radionuclide contamination
Synthetic compound…
Transition elements & organo-…
Introduction or spread of non-…
Above water noise
Collision ABOVE water with…
Introduction of light
Emergence regime changes –…
Water flow (tidal current)…
Physical change (to another…
Nutrient enrichment
Organic enrichment
Penetration and/or disturbance…
Physical loss (to land or…
Sensitive (high to low)
Not sensitive
Not enough evidence to assess
Not relevant
No direct effects

C
Marine
mammals



Appendix 6 Method graphical outline



10 Annexes

Annex 1 Workshop reports, participants and minutes extracts

APEM Mobile feature sensitivity to pressures. 1st Workshop meeting

Agenda

Date 24th February 2014	**Start time** 10:30	**Finish time** 16:00
Location APEM Cambridge office	APEM Limited Suite 2, Ravenscroft House 59-61 Regent Street Cambridge CB2 1AB Tel: 01223 346 809	Dial in details Dial: 0800 783 6753 Chairperson passcode: 71659017 then # Participant passcode: 50340059 then #

Participants list	**Organisation**	**Notes**
Rafael Perez-Dominguez (RPD)	APEM - Principal Marine Ecologist	Chair & Project Manager
Lucy Wright (LW)	BTO - Senior Ornithologist	Confirmed
Robert Enever (RE)	NE-- Senior specialist	Confirmed
Richard Caldow (RC)	NE-- Senior marine ornithologist	Confirmed (dial in)
Julie Black (JB)	JNCC - Senior ornithologist	Confirmed
Claudia Stauss (CS)	NE-- Lead Advisor Conservation Advice	Confirmed

Summary of discussions and actions

Item	**Action**	**Time**
Lit search, EndNote, pre-screening, uncertainty scoring	RPD continue with the bibliographic search	ongoing
Functional group (guild) & Species Assessments RE- Table confusing as presented. Suggested to split up (breeding / non-breeding features (i.e. Tern) Reason to assign species to different guilds not clear. RC & LW- Red flagged breeding features not in marine UK Ramsar or SPA sites	RPD Keep multiple guild entries on the table but adjust the guild assignments to Remove species flagged red and update file (Priority1_Species guilds_v1)	asap
Benchmarking		
Visual disturbance: RE- add a temporal frame to the benchmark; level (proposed 20%) need to be relevant and supported by evidence; set at a relevant value for marine activities (RE- activity focus); LW suggested 10%	RPD Revise benchmark def.	By Wednesday
Genetic modification & translocation of indigenous species: RC – quantification not required remove 20%; JB- revert to original benchmark	"	"

Introduction or spread of non-indigenous species: RE benchmark need to define a time component; non-edible alternatives mediated by food availability and indirect effects; simplify the definition; LW aggressive NIS can cause big problems at low numbers (i.e mink); case for use presence/absence benchmark; consider different groups	"	"
Introduction of microbial pathogens: Revert to Tilin benchmark –presence/absence but naming specific infectious diseases 'relevant' to mobile species	"	
Removal of target species & Removal of non-target species: different meaning for different groups case for a dual benchmark (i.e. fisheries vs. wildfowling); RE-effect of removal of supporting habitat maybe relevant; not direct pressures as likely mediated by food availability; water column habitat will capture sensitivity to indirect routes (as with sandeels); Remove MSY and use 1% of natural mortality to capture more sensitive birds.	"	
Habitat structure changes – removal of substratum (extraction) & Physical change (to another *seabed* type); RESSURE NEEDS REDEFINING to make it relevant for non-seabed Hab. Structure changes, Physical loss to freshwater habitat and Physical change to other marine habitat type. Proposed to change to *habitat type* so is relevant to water column habitat and seabed habitat	"	
Emergence regime changes – local, including tidal level change considerations [possibly split emergence regime & tidal level changes]: Not a relevant pressure likely to have direct effects on mobile species; RC can have direct effect on roosting area; indirect effect linked to food availability; Revert to former baseline		
Underwater noise: Only impulsive noise relevant to mobile species. Use existing MSFD based reference		
Death or injury by collision (including corkscrew death): remove 0.1% and use a presence/absence criteria		
Nutrient enrichment & Organic enrichment: Only indirect effects; use Tilin benchmark		
Resistance and Sensitivity tables		
APEM MS tables_v1		
Add biological parameters and remove essential habitats. 75% level not universally relevant; can use as example of change of the population level to indicate what constitutes a severe decline;		

Generation time not best. Resilience in time so best to use time. Back to Tilin definition but using 1, 3, and 6 years to reflect the reporting periods. Resilience to be measured after the pressure is removed;		
Sensitivity table		
Need a more precautionary table; Need text to state the rationale of the different sensitivity categories; resilience is surrogated to resistance (need to have an impact before recovery can take place). The outcomes on the table should be defined with this in mind. Sensitivity is more directly defined by resistance.		

APEM Mobile feature sensitivity to pressures. 2nd Workshop meeting: Marine Mammals

Agenda

Date 30th April 2014	**Start time** 12:30	**Finish time** 17:00
Location Natural England Bristol office	Natural England, First Floor, Temple Quay House, 2 The Square, Bristol, BS1 6EB Tel: 0300 060 2065	

Participants list	**Organisation**	**Notes**
Rafael Perez-Dominguez (RPD)	APEM - Principal Marine Ecologist	Project Manager & Chair
Marc Hubble (MH)	APEM – Marine Technical Specialist	Confirmed
Nicola Quick (NQ)	SMRU - Principal Scientist	Confirmed
Robert Enever (RE)	NE- Senior Specialist	Confirmed
Claire Ludgate (CL)	NE	Confirmed
Tom Hardy (TH)	NE	Confirmed
Claudia Stauss (CS)	NE	Confirmed
Documents	By attachment	

Summary of discussions and actions

Item	**Action**	**Time**
Introductions and project update.		
Methods –Resistance and Resilience tables		
NQ – thresholds not relevant for marine mammals. MH- Different thresholds have been tested and have resulted in variations of the sensitivity scores.		asap
RPD- A calibration exercise to make it relevant for marine mammals would be a way to make scores relevant.	RPD to Revise Resistance table thresholds	
NQ- Highlighted a potential problem so the method as it does not consider exposure in the scoring process.		
RE- The intention for the table is to provide a realistic approach to assess hypothetical sensitivity for initial scoping purposes. Exposure will be considered later in the process.		
CL & TH pointed out the lack of reliable population estimates. NQ concurred. Using population numbers in the description of the resistance bands would results in lack of relevance and misunderstanding. RPD suggested to add “best estimates” to the descriptions. RE suggested further editing and simplifications.	RPD to Revise Resistance table band descriptions	asap

Methods –Benchmarking		
NQ- Noise benchmark not relevant difficult to apply as no exposure is implied. The use of a period of time in the description could cause problems. MH- suggested keeping MSFD base but modifying to overcome these problems. All agreed.	MH to revise benchmark	
Species assessments examples		
Bottlenose dolphin		
All- new benchmark for visual disturbance needed.		
TH- Barriers to species movements only relevant as permanent physical barriers (ie. barrages) for marine mammals. Other pressures capture the temporary or partial barriers (eg. Noise).		
RE- suggested splitting the pressure between permanent and temporal barriers. Temporal/partial barriers are not that relevant for dolphins, probably some relevance for seals (access to haul out sites) but likely not a main subject of concern. The discussion led to an agreement to just consider permanent barriers and update the pressure description to reflect this.		
CL- explained the likely cause of collisions and effect of ducted propellers (**seals** in particular are vulnerable). RE- benchmark fish specific and will need updating.		
All- new benchmark required. RPD- suggested a presence –absence approach for the benchmark “ducted propeller boats present in the area used by the feature”.		
MH & NQ highlighted the issues of bioaccumulation of PCBs. As these substances are banned they should not be an issue for case work. CL- enquired how the bioaccumulation issue was approached for the bird assessments.		
RPD- it was an issue of concern and was included as direct effect.		
TH- Introduction of other substances an issue for operations involving crude oil transfer at ports.		
Otter		
Underwater noise, not enough evidence to assess.		
Recovery probably faster that in other species.		

APEM Mobile feature sensitivity to pressures. 3rd Workshop meeting: Bird Features

Agenda

Date 12th June 2014	**Start time** 10:00	**Finish time** 15:00
Location DEFRA (London)	Nobel House Ground Floor, G22 17 Smith Square London SW1P 3JR	

Participants list	**Organisation**	**Notes**
Rafael Perez-Dominguez (RPD)	APEM - Principal Marine Ecologist	Project Manager & Chair
Robert Enever (RE)	NE- Senior Specialist	Confirmed
Claudia Stauss (CS)	NE	Confirmed
Lucy Wright (BTO)	BTO	Confirmed
Julie Black (JB)	JNCC	Confirmed (remote)
Richard Caldow (RC)	NE	Confirmed

ITEM	**ACTION**	**TIME**
Introductions- RPD	-	
Project progress update	-	
Second workshop, RPD summarised the work done to date including an update on the marine mammal s and fish features.		
Methodology review		
Benchmarking B1 Visual disturbance; Visual disturbance could occur during day and night. Aggregate makes the benchmark unclear. New definition proposed. O7 Above water noise; A number of stakeholder issues have been raised. These are the quoted levels in the IECS report; the inclusion of a exposure reference (& why >50% was proposed), responses mostly not clear to assess quantitatively, noise probably always associated with other disturbance (i.e. visual). JB suggested the inclusion of an “user guide” to allow interpretation of the benchmarks and scores. RPD suggested adding two extreme examples to the benchmark. Also to default to a presence e absence benchmark. LW suggested adding background noise in the benchmark to account for naturally noisy locations. H4 Emergence regime changes; RE pointed out at indirect effects that might not be covered by the habitat assessment. Direct vs. indirect (supporting habitat) is clear but indirect effects can be due to quality attributes that are relevant to birds (i.e. roosting space) or other mobile species but not captured as part of a standard habitat quality assessment. Need to think an approach. JB enquired about issues with Water Column Habitat. NOTE: For e.g. the habitats feature Mudflats and sandflats not covered by seawater at low tide (& sub-features), MarLIN includes structure (physical and chemical integrity) and functioning (processes) in the	RPD to update Revisit the dB levels and rationale Simplify the benchmark definition RPD to loot at the habitat-related pressure pathways (see note in red, I will appreciate feedback on this please)	Next draft ASAP

characterisation and importance assessment for management of this feature. Moreover, favourable condition tables for this feature include topography as an Attribute, with tidal elevation and shore slope as Measures, and a no change from established baseline as Target. So ANY habitat condition assessment should assess changes in exposure and sea level as a fundamental quality aspect of this feature (habitat). Which I think it is a strong case to consider that the assessment will cover all indirect effects linked to emergence regime changes that could be of relevance to wading birds. So the emergency regime is assessed and the information will allow to make a judgment of how this will affect the habitat value for waders	All to provide feedback	End of June
LW stated that Red Shank maybe especially susceptible to the pressure (emergence regime) as they show high site fidelity. Others may be able to move to alternative habitats, including freshwater habitats.		
All agreed that emergence regime changes are a key threat for waders. The recommendation was to revisit the assessments, add general background for the guild and reassess the sensitivity scores according to species plasticity (1-food resource and 2- use of alternative freshwater habitat)	APEM ornithologists to revise assessments	End of June
B5. Removal of target species. SC the definition of the benchmark was not clear, 10% over the rate of natural mortality is ambiguous with an example. RPD suggested revising the definition. Adding a quantitative threshold will always be a problem. I suggest simplifying the definition and using 'commercial exploitation' to introduce a qualitative level in the benchmark. The benchmark proposed for fish is "Removal of feature as a target species at a commercial (recreational) scale" I suggest to use something similar for birds.	RPD to revise benchmark definition (See note in red) All to provide feedback	ASAP End of June
B6. Removal of non-target species. Similar problems as B5. Suggested to add examples and/or revise benchmark. Suggest same benchmark agreed for fish "The introduction of bycatch risk in areas used by features from the pursuit of a commercial (recreational) activity (including power generation)"	RPD to revise benchmark definition (See note in red) All to provide feedback	ASAP End of June
P1-P4 Pollutants. RC introduced the approach of setting very low thresholds to spark discussion. There are general problems with the EQS (and other standards) in the benchmark. It is not possible to score high sensitivity if the benchmarks are compliant. For example, for RTD, there is evidence of high sensitivity to oil silks but low sensitivity (or complete resistance) to the actual EQSs. This will be true for all bird features. The particular case of large spills is not contemplated in the benchmark but likely to cause direct effects (toxic and physical). Suggested to add a note for the direct introduction of oil in large quantities (oil spills).	APEM ornithologists to revise assessments RPD to revise benchmark definition (See suggested note in red)	

Note: Although compliance with established EQSs is likely to result in no direct toxic effects, the accidental introduction of large quantities of petroleum hydrocarbons on designated sites could have direct effects on bird features. Finally, the possibility of bioaccumulation/bio-augmentation was discussed. Final problems to assess these pressures are the lack of direct species information resulting in low confidence assessments. The suggested approach was to present the <u>general</u> evidence available adding the fact that no <u>direct</u> species-specific evidence is available and give a "not enough evidence to assess" score. JB suggested adding to the guidance document a note on the interpretation of not assessed features so they are not neglected if effects are possible but the evidence is not developed enough to make an assessment.	All to provide feedback All to provide feedback	End of June End of June
LUNCH		
Resistance and Sensitivity tables		
LW/JB. Always difficult to detect 10% against natural variability. Precision is not a factor to consider; the population effect level is hypothetical, reflects what could happened to the population given the benchmark intensity		
LW suggested removing 'background' from the definition of high resistance. Very minor declines is not required, suggest rewording. A very minor effect in key functional and physiological attributes of the species. Sub-lethal effects may be detectable (e.g. foraging effort) but these are buffered from feeding through to changed rates of reproduction or mortality.	RPD to revise High Resistance definition (See suggested definition in red) All to provide feedback	ASAP End of June
The thresholds are not rates but actual population declines (it is an indication of impact). Need to clarify this for the marine mammal's assessments. Would a population where 90% of the individuals survive be considered to have no Resistance? The likely response is no.	RPD to ask SMRU	ASAP
RC, High and None resistance categories make general sense. All in agreement with the resistance banding for Medium (loss of up to 10%)) and Low (>10 and ≤50%) Resistance.	RPD to make the Resistance table final	To be issued with minutes
Additional points for users -Changes of population size at the site not the whole range of the species (conservation objectives are assessed by numbers within site). -Population changes are not only mortality, a 50% change in abundance within site due to displacement is enough to score None Resistance		
Species assessment example -		
Guillemot Breeding		

B1 Visual disturbance. Duration so the disturbance should be part of the assessment; Resilience score too pessimistic; likely to show faster recovery. Stakeholders comments suggested daylight is not relevant. A further simplification to a presence/absence benchmark possible (used for fish and marine mammals) Presence of activity (or visual cues) within visual range of the feature	RPS to suggest new benchmark (in red) All to provide feedback	All End of June
B2-B3,		
B5 Removal of target species; Issues with applying the Resistance table with the current benchmark (i.e. 10% killing on to of natural mortality). The new proposed bechmark"Removal of feature as a target species at a commercial recreational) scale" probably easy to assess given current evidence. Not sensitive score need change to low sensitivity (medium resistance; high resilience)) to reflect potential issues Comparatively resilience in Fulmar should be very low (low confidence) In general the recommendation is to use a more precautionary approach (at least low sensitivity) with a low confidence score	APEM Ornithologists All to provide feedback on benchmark	End of June End of June
B6, as before; the new proposed benchmark "The introduction of bycatch risk in areas used by features from the pursuit of a commercial (recreational) activity (including power generation)" Probably easy to assess.	All to provide feedback on benchmark	End of June
D1, D2, no direct effects, all habitat mediated effects		
D3 Changes in suspended solids (water clarity) & D4/5 Siltation rate changes; Related pressures but sometimes may act independently. No comments		
D6, H1, H2, H3, H4, H5, L1, & L2, all indirect & not assessed.		
O1 Litter. Litter cause entanglements, effect of lost gear should be assessed here (lost gear=litter). Suggested to change Resistance to High; comparatively Fulmar shows greater vulnerability but there are no studies demonstration a damaging effect of litter on the population; suggested Medium Resistance and low Resilience with medium to low confidence.	APEM Ornithologists	End of June
O2 no effect ok		
O3 Underwater noise changes. Effect on breeding colonies expected to be larger than non-breeding aggregations. The Netherland case probably non-breeding evidence due to the lack of breeding birds (no suitable habitat for breeding colonies). Species-specific evidence but a proxy feature assessment hence should be low confidence. However, some sensitivity is expected so suggest change to Medium resistance. The evidence is not conclusive as it cannot be directly related to the benchmark (as cause-effect & dose level)		

as this must be clear on the text. Also adding a generic statement in the guidance document. In general there are no studies that present conclusive evidence of population effects at the level of MSFD noise indicators (still not fully defined).		
O4, Introduction of light. Suggest high resistance with low confidence (resilience low or medium). Same for most features that lack direct evidence. Fledging puffins are known to be attracted at nigh t by light. NOTE. 0.1 lux is about 10-40% of the expected max light intensity for a full moon night.	APEM Ornithologists to revise assessment.	End of June
RE, a number of errors are apparent and this will need to be corrected first.		
O5 Barrier to species movement. New Marine Scotland Science publication on modelling displacement effects on Auks. Not available on website 16/06/2014	All, please if you have a copy please forward to RPD	
O6 Death or injury by collision. Diving birds are exposed to collision risks with underwater structures. The benchmark should capture this. The use of death in the description of the pressure is not appropriate. Only used as such fro the removal of feature (direct or by-catch). Death is (could be) the consequence of collision but not a pressure. The pressure is best described using area increase of underwater structures. Introduction of underwater structures or devices that introduce collision risk in other than trivial amounts in areas used by features	RPD to propose a new pressure definition (in red) All to provide feedback on benchmark	 End of June
O6 Death or injury by collision. For the Guillemot assessment (and other Auks) the risk of collision is mainly associated with underwater structures (entanglement with gear is by-catch and with lost gear is Litter). The text need to reflect no sensitivity to aerial structures (delete all but the evidence relevant to Auks) and add a section on collision with underwater structures (tidal devices) as relevant and different to entanglements in fishing gear (already assessed under different pressures). Reference to large gulls is not relevant	APEM Ornithologists to revise assessment.	End of June
Review of main points, recommendations & Next steps		
1. revise benchmarks & pressure definitions and produce a new draft 2. revise resistance tables and produce a new draft 3. send all revised method documents to reviewers for comments and agreement on final method 4. revise the assessments using the finalised method 5. Send 4-6 revised feature complete assessments for expert evaluation and QA 6. Revise the feedback and update all assessments (priority 1 and 2) 7. Compile all information in the database and release a new draft.	As required	New pressure/ benchmark document to be issued with minutes Mid July
End of meeting		

APEM Mobile feature sensitivity to pressures. 4th Workshop meeting: Fish

Agenda

Date 13th June 2014	**Start time** 10:00	**Finish time** 16:00
Location DEFRA (London)	Nobel House Ground Floor, G22 17 Smith Square London SW1P 3JR	

Participants list	**Organisation**	**Notes**
Rafael Perez-Dominguez (RPD)	APEM - Principal Marine Ecologist	Project Manager & Chair
Robert Enever (RE)	NE- Senior Specialist	Confirmed
Claudia Stauss (CS)	NE	Confirmed
Adrian Fewings (AF)	EA	Confirmed
Randolph Velterop (RR)	NE	Confirmed
Mario Lepage (ML)	IRSTEA	Confirmed
Adam Waugh (AW)	EA	Confirmed (remote)
Steve Coates (SC)	SLR	Confirmed
Steve Colclough (SC2)	SC2	Confirmed

ITEM	**ACTION**	**TIME**
Meeting set up, apologies & Introductions		
RE presented the wider context for these exercises, the intention and future use within Natural England statutory obligations	-	
RPD introduced the aim of the workshop and produced a brief update of the project progress across highly mobile feature groups (birds, marine mammals and fish)		
SC2 commented on linkages with similar work done in the past by the EA SC made a note on problems with data quality and proxy species during the EA work. ML commented on the work done by IRSTEA and the availability of unpublished data (i.e. Shad low oxygen exposure trials)		
Benchmarking		
RPD reiterated the intended scope of the sensitivity assessment exercise, the problems with data and the intention of this work to be a high-level flagging exercise to avoid overlooking potential threats on features and ensure a more consistent advice. The benchmarks are key to set a standardised level of pressure in order to conduct the assessments.		
RR noted the use of risk models tuned to specific life stages and exposure information to provide final advice. SC2 liked the two-step approach (flagging + detailed advice), a more flexible		
Methodology review		
RPD briefly introduced the method and scoring tables before moving into the pressures and proposed benchmarks for direct effects of marine pressures on fish features.		

D1 & D2, Habitat structure changes & disturbance below substrate. RR pointed out that direct and indirect effects often occur at the same time, i.e. habitat structure changes may result in fish trapped in dredges causing direct mortality of benthic dwelling fish. Species like sea lamprey, smelt and some shad population spawn at the top of estuaries and could be affected.	RPD to include direct effects when relevant	
D3 Changes in suspended solids (water clarity). ML pointed out the need to consider species tolerances but also the estuary typology. There is evidence suggesting that this pressure cause changes in fish assemblages in clear water estuaries. AW suggested to base assessments on the more sensitive scenario (i.e. clear water estuary) but adding a statement for more turbid conditions where effect are unlikely. SC suggested to specify the WFD reference relates to ecological status class	ML to provide reference RPD to consider effect on assessments	End of June
D4 & 5 Siltation rate, probably of relevance to benthic spanners (smelt, black bream, shad…). RE smothering of eggs would require independent assessment (i.e. not captured by the supporting habitat assessment). An aggregate extraction activity may affect back bream in two ways: 1-removing spawning/nesting habitat, and 2-smothering of eggs. ML pointed out that natural processes could cause such effect (storms)		
D6 Abrasion of substrate. Water flow causes abrasion which could lead to scouring and direct effect on fish. This is probably captured by the supporting habitat assessment and/or water flow as pressure. SC2 abrasion may lead to habitat discontinuity and the creation of barriers to species movements. RE pointed out that it is necessary to identify all possible relevant interactions. ML some of these interactions are only apparent after there is a change (example of new jetty and drastic changes in bathymetry through water flow changes – clear cascade effect not anticipated before). ML also difficult to consider direct impacts in isolation; great uncertainty on pathways.	RPD to include notes on cascade effects between direct pressure pathways when relevant	
Lunch		
H1 Temperature changes. Thermal changes standard. SC introduced the WFD work on temperature standards and identified a SNIFER report on the subject. ML identified 5°C change and up to 33°C max temp as the current standards in France. Some activities take heat from the water (gas works) resulting in a different pressure worth mentioning in relevant assessments.	SC to provide full reference/copy of the SNIFFER report RPD to consider cooling in assessments	
H3 water flow. ML would be necessary to specify bed velocity as more relevant to fish. Use of flows at the set level of the benchmark (0.1m/s to 0.2m/s) not really relevant for selective tidal transport. ML noted that at the surface wind can produce speeds greater than the benchmark. Are levels of the benchmark relevant? Tidal currents can reach over 3m/sec (6 knots) in certain estuaries and moderate currents of 0.5-1.5m/s are common (including the coastal zone). ML noted that disruption of the velocity class (water body typology) can have deep effect son fish assemblages and this could	RPD to consider local effects when relevant for the assessments (migratory fishes)	

be a NEW pressure not included in the current list. RPD, suggested that most activities are not likely to affect entire water bodies (that is no effect on water body typology). Site-specific effects could result in localised fast flows (greatly over the benchmark) but sensitivities are (probably) already covered by the pressures introduction of underwater structures or barrier to species movement. ML/RR, high flows could produce barrier effects, fish may avoid such flows resulting in a barrier effect.		
H4 emergence regime. The benchmark is probably close to what would be expected from sea-level rise.		
H5 wave exposure. No direct effects on fish expected. Wind could produce changes in wave regime to the level of the benchmark. However, much larger waves could have impacts; eg. Interaction of fast moving vessels and shoreline defences. Indirect effects due to erosion could have effects.		
L1 &L2 habitat change; probably no direct effects hence not relevant		
O1 Litter. Accidental entanglement with lost gear could be a problem.		
O2 Electromagnetic changes. RR, new evidence available from Marine Scotland Science report. RPS evidence exists indicating that, under laboratory conditions, most fish are sensitive to the benchmark level. Some data on behavioural reactions exist in semi-natural conditions (mesocosms experiments). RPD indicated that evidence on behavioural effects is weak and no information on population effects was found.	RR to share MSS report with the group	ASAP
O3 Underwater noise changes. Benchmark is considered relevant		
O5 Barrier to species movement. Suggested to change 'commuting corridor' to 'migratory corridor'. Width of the corridor is not the only controlling aspect, flows, bathymetry and even bank orientation are important. The percentages quoted for the benchmark intensity may or may not be relevant and/or easy /possible to apply. A simplification to 'lack of continuity' would be better. >10% permanent change in available width of migratory corridor; OR permanent or temporary lack of continuity of the migratory corridor	RPD to propose a new benchmark definition (see benchmark in red, I will appreciate feedback on this please)	
O6 New pressure definition "The continuous presence of static or moving objects not naturally found in the marine environment (e.g., boats, machinery, and structures)" and benchmark proposed "Introduction of underwater structures or devices that introduce collision risk in other than trivial amounts in areas used by features; OR 0.1% of tidal volume on average tide, passing through artificial structure". Moving structures (vessels, tidal turbines), or static structures in areas of high flows (power station screens) introduce risk of collision for fish. Larger (and elongated) fish more vulnerable.	New pressure and benchmark definition (see text in red, I will appreciate feedback on this please)	

P1, P2, P3 & P4. Contaminants. CS confirmed that all substances are included within the 4 pressures. All agreed that EQS thresholds are generally not directly associated with acute toxic effects on fish. ML has evidence that fish can be sensitive to much lower concentrations as those given in the standards as well as to cocktails of different chemicals, and finally noted they have a study that shows a correlation between estuarine fish assemblages and pollutants in water. SC noted that fish may not be good indicators (the EQS are not designed to work with fish). Benthic fauna (non-mobile) probably better suited and suggested not to assess or to give a very low confidence. There is evidence for a negative correlation of fish and heavy metals concentrations within compliant levels (Marine Pollution Bulletin). A number of issues are relevant to these assessments and it was clear that the direct evidence may be lacking, as such; having a consistent approach is probably the best that could be done for these pressures. A 'not enough evidence to assess' score was the final recommendation. The special case of oil spills was briefly discussed, ML has done exposure experiments on sole and the fish developed ulcerations and tumours.	ML to provide further reference to the French study & circulate MPB paper	
P5 Radionuclide. Not relevant to fish		
P8 Deoxygenation. SC has published this information in a Marine Pollution Bulleting. All agree that oxygen cannot be separated from temperature and to a lesser extent salinity. Low Do and high temperatures are often lethal.	SC to circulate the MPB paper	
Resistance and Sensitivity tables		
Resistance: All agree on High and None Resistance categories. ML questioned the need for medium and low resistance. RE indicated that this is in the original method and shared across mobile species groups. RPD suggested adding this information to the user guide. The proposed threshold, up to 10% for medium, 10 to 50 for low and greater than 50% for none resistant were agreed for fish.		
Resilience: PRD current proposal based on reporting cycles relevant to most fishes. ML/SC noted that notable exceptions are long lived fish such as sturgeons. In general resilience will be determined by life history strategies in particular size, fecundity and age at first maturation but also population structure an connectivity (metapopulation centres). A problem with the confidence with resilience scores is the huge recruitment variability/uncertainty typical of fish populations. In general the ability to bounce back is high in fish as healthy populations are not limited by reproductive potential.		
Species assessment example. Allis Shad.		

Visual disturbance. Not assessed but RR indicated it could be relevant to a specific population using spawning grounds in the Tamar estuary (Hillman R (2002). The distribution, biology, ecology and conservation of allis and twaite shad (Alosa alosa and Alosa fallax Lacépède) in Southwest England. Environment Agency R&D Technical Report W1-047/TR)	RR to confirm reference	
Genetic modification & translocation of indigenous species. Update reference to the captive breeding work in the Rhine.	ML to provide a better reference	
Introduction or spread of non-indigenous species; Chinese mitten crabs could be potential problems. Catfish also a problem (footage exists of catfish eating migrating shads). Suggested to change assessment to not enough evidence to assess.	ML to provide a better reference/link to YouTube	
Removal of target species. Twaite shad fisheries exist in the south coast. It is relevant to mention the risk of post release mortalities for fish caught in targeted recreational fisheries. Assess to high sensitivity		
Removal of non-target species. In addition to the by-catch in seabass fisheries, ML is aware of a report by the French Marine Protected Area Agency about diadromous fish by-catch at sea in trawls. RR mentioned that CEFAS has similar evidence.	ML/RR to circulate evidence	
Habitat structure changes. Not relevant for Allis shad, probably relevant to Twaite shad. Water column (habitat) changes are complex, turbidity and hypoxia is often linked. Loss of spawning habitat a possible relevant marine pressure for the Tamar population. Not clear relevance ad direct effect on the feature as all are habitat related effects?		
Temperature. Climate change evidence available paper by Lassalle et al. Climate change is not relevant as cannot be managed at the local scale. Only relevant to assess change in species ranges. Suggested to change resistance to medium	RR/ML to circulate evidence on climate change and fish	
Wave exposure. Agree with not sensitive score, but suggest adding a note about scenarios way above the benchmark as these may result in direct impacts.		
Collision. Suggested high sensitivity		
Contaminants. Suggest ‘not assessed’ as the evidence in not develop enough to allow assessment		
Deoxygenation. Suggest changing to low resistance as juveniles cannot scape areas of low DO and are generally more sensitive.		
Species assessment example. Short Snouted Seahorse		
Visual disturbance. New evidence on flash photography suggest to effects.		
Removal of non-target species. ML has new evidence on by-catch.	ML to circulate evidence on by-catch	
Habitat structure changes - removal of substratum. Suction by dredges could be a problem as seahorses are poor swimmers. Suggest to asses high sensitivity with low confidence		

Changes in suspended solids (water clarity). Suggest low confidence		
Wav exposure.		
Barrier, consider habitat fragmentation		
Collision risk. High in power plans intakes.		
Next steps		
Review of main points, recommendations & Next steps		
1. revise benchmarks & pressure definitions and produce a new draft 2. send all revised method documents to the reviewers for comments and agreement on final method 3. revise the assessments using the finalised method 4. Send revised feature complete assessments for expert evaluation and QA 5. Compile all information in the database and release a new draft.	As required	New pressure/ benchmark document to be issued with minutes Mid July
End of meeting		

Annex 2 Sensitivity matrix structure and Data Base