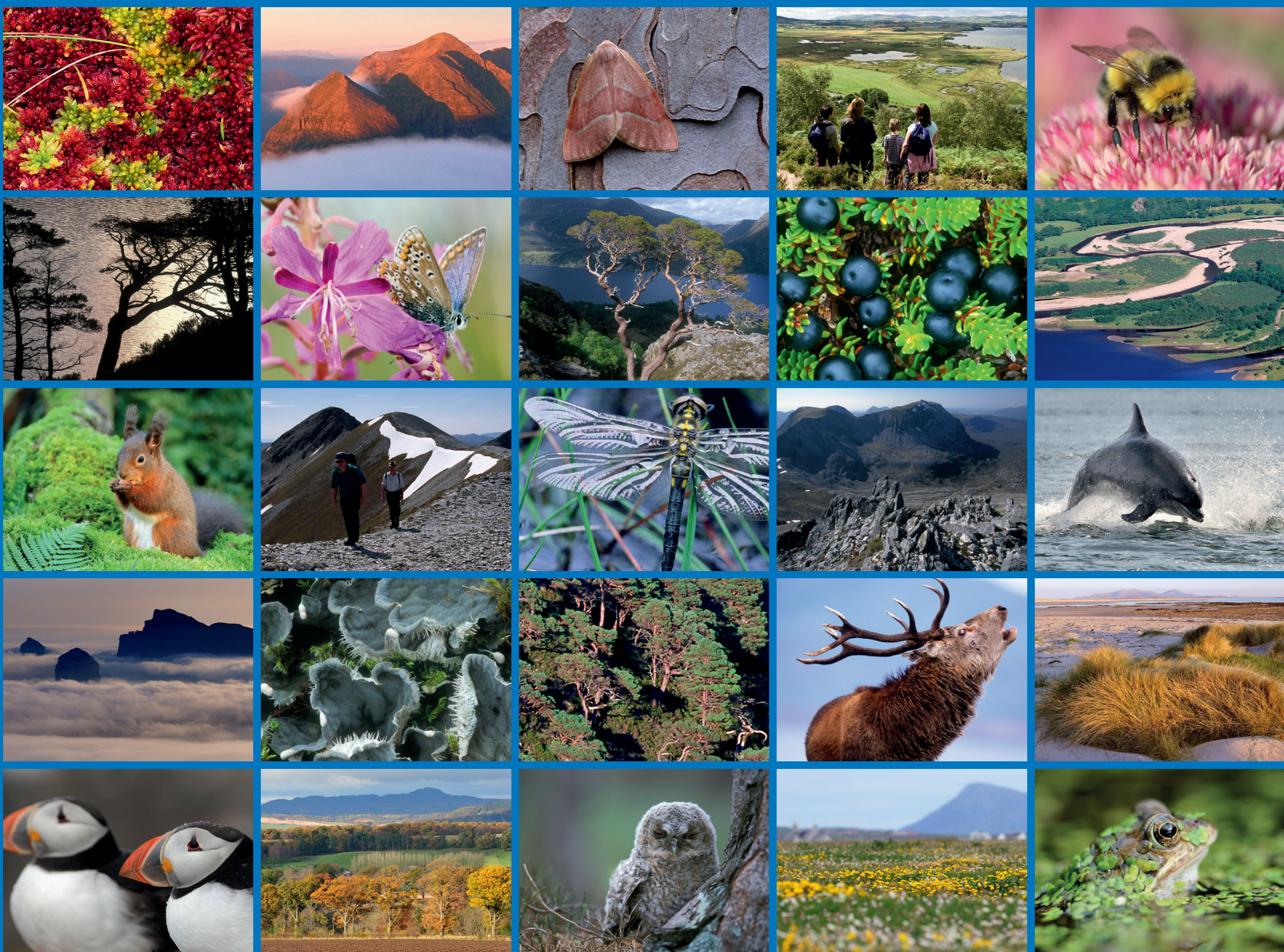
Scottish Natural Heritage
Research Report No. 1175

Developing FeAST for mobile marine species



RESEARCH REPORT

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Developing FeAST for mobile marine species

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RESEARCH REPORT

Summary

Developing FeAST for mobile marine species

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Keywords

sensitivity; tolerance; recovery; pressure; marine mammals; seals; basking shark

Background

The Feature Activity Sensitivity Tool (FeAST) is hosted on the Marine Scotland (MS) website and supported by Scottish Natural Heritage (SNH) and the Joint Nature Conservation Committee (JNCC). Its purpose is to enable high-level assessment of the sensitivity of features of conservation value, present in Scottish seas, to different pressures resulting from human activities. The overall aim of this project is to enable the FeAST methodology to be adapted for mobile marine species and to consider for which species sensitivity assessment at an individual level, as opposed to the population level, was more appropriate, and why.

Main findings

- Existing approaches to Sensitivity Assessment, including FeAST, Marine Evidence-based Sensitivity Assessment (MarESA) and Highly Mobile Species Sensitivity (HMSS) methods, entail the estimation of changes in population expressed as a percentage of the existing population. They assess the sensitivity of a hypothetical population and are not site-specific.
- It was difficult to define, categorically, when it is most appropriate to use an individual-based rather than population-based approach to sensitivity assessment. Accordingly, two sets of indicators were identified which tended to favour such an approach.
- We suggest that Individual-based Sensitivity Assessment (IBSA) should be applied in species where the loss of a single individual (or small number of individuals) has the potential to affect the survival of the population adversely or where legislation protecting the species is implemented on an individual level. Such species are likely to be K-strategists that are slow to reproduce with a long lifespan, slow growth rates, late reproduction, high parental investment in their young, low fecundity and, probably, small population sizes.
- We identified those species with legislative protection at an individual level, in Scotland, from criteria and species lists set out in the Wildlife and Countryside Act (W&C) 1981, the Habitats Directive and the Marine (Scotland) Act 2010.
- All the cetaceans, seals, marine reptiles, sharks and rays listed under W&C 1981 and as European Protected Species would be suitable for IBSA using this approach, together with the otter and notable fin-fish, i.e. the Atlantic sturgeon, Allis shad, Twaite shad and European river lamprey.

- In addition, the sharks and rays listed as mobile PMFs are also suitable, together with the Atlantic halibut, blue ling, European eel, orange roughy, and round-nose grenadier. A list of another seven fin-fish requires further consideration. The remaining fin-fish listed as PMFs are probably not suitable under our suggested indicators.
- However, the life history characteristics examined represent a short review of the characteristics that influence population recovery and do not take into account larval/juvenile mortality, recruitment, population dynamics, or restricted breeding sites such as nursery areas in fish or rivers and estuaries in anadromous fish. In addition, the cut-off values for life history characteristics are subjective rather than definitive.
- Further study is required to expand and test the application of the above list of indicators and the IBSA approach to a wider range of species than considered here.
- An individual-based tolerance scale is suggested. We avoided a binary scale (dead/alive) and suggested a scale from 'dead' through different levels of impairments due to physical injury and behavioural changes. We slightly amended the existing FeAST recovery scale to emphasize its application to the recovery of individuals rather than that of populations. The FeAST sensitivity matrix was also amended slightly to highlight the fact that no recovery was possible from direct mortality. The existing FeAST scales for 'confidence' and 'evidence' were adopted.
- The suggested individual-based approach was tested on two pilot species: Risso's dolphin and the harbour seal. Contrary to initial concerns, the suggested scales did not result in binary scores, that is, just mortality or no mortality. Both pilot assessments gave a range of scores for tolerance, recovery and, hence, sensitivity.
- Assessing on an individual level was found to simplify the assessment of tolerance. It was often very straightforward to assess whether an individual was likely to suffer injury or mortality from an impact.
- The suggested individual-based approach does not take the likelihood of the impact occurring or the extent of the impact into account at any point. Many of the pressures to which the assessed species are highly sensitive may be very unlikely to have a population level impact, due to their low likelihood of occurrence.
- It should also be noted that the revision of benchmarks and scales for highly mobile species in FeAST means that the resultant sensitivity assessment will differ from those generated under the MarESA and HMSS approaches, and that their sensitivity scores for the same species will not be directly comparable.

Overall, the suggested Individual-based Sensitivity Assessment (IBSA) approach was used successfully to assess the sensitivity of two highly mobile species. More species need to be assessed to test the approach fully and to develop examples and guidance on the application of the individual-based tolerance scale to other highly mobile species.

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1. INTRODUCTION & CONTEXT

The Feature Activity Sensitivity Tool (FeAST) is hosted on the Marine Scotland (MS) website (http://www.marine.scotland.gov.uk/FEAST/Index.aspx) and supported by Scottish Natural Heritage (SNH) and the Joint Nature Conservation Committee (JNCC). Its purpose is to enable high-level assessment of the sensitivity of features[1] of conservation value, present in Scottish seas, to different pressures resulting from human activities. Initially set up to inform Nature Conservation Marine Protected Area (MPA) consultations, FeAST presently contains detailed information and sensitivity assessments on seabed habitats and geomorphological / geological features. Limited information on some seabirds and a few fish species is also included but most mobile marine species, including marine mammals, are not currently covered. Twenty-nine discrete pressures and associated pressure benchmarks are identified and defined within FeAST, and the sensitivities of each feature to these pressures are assessed against the pressure benchmarks. The pressures are linked to activities so that users can interrogate the tool from a feature or activity perspective.

In the long term, it is planned that FeAST should incorporate sensitivity assessments for a broad range of nature conservation features in Scottish seas, including Priority Marine Features (PMFs), protected species and habitats within Nature Conservation MPAs, birds, Annex 1 habitats and Annex 2 species under the Birds and Habitats Directives, and earth science features.

Whilst some progress has been made in drafting initial assessments for mobile species, this has been hindered by difficulties in applying aspects of FeAST, specifically the sensitivity assessment and scoring methods, initially drawn up for benthic species and habitats, to mobile species. A thorough review of the FeAST tool and these methods, ensuring applicability to mobile marine species, was required by SNH before these assessments could be prepared and be made available online.

FeAST categorises a feature's sensitivity to a particular pressure by combining scores of that feature's **tolerance (resistance)** and **recovery (resilience)** to the pressure concerned, to derive an overall **sensitivity score**. This methodology is based on that described in Tillin *et al.* (2010) and has been subsequently adapted to reflect Scottish features and activities. New evidence has been included where available, and some pressure benchmarks altered in light of ongoing work. New category descriptions for tolerance and recovery have been developed for geodiversity (Brookes, 2013). None have yet been developed for mobile species, specifically for FeAST, though analogous descriptors for resistance and resilience, relating to birds, fish and marine mammals, were developed by Natural England (NE) for application in marine Special Areas of Conservation (SACs) in England (Perez-Dominguez *et al.*, 2016).

In spite of this recent progress, challenges remain in evaluating and scoring tolerance and recovery for many mobile species, and thereby in deriving appropriate sensitivity assessments. This is in part due to difficulties in defining local populations for the species concerned and also in quantifying the likely impact of a particular pressure on that population, in order to derive the sensitivity assessment as, for example, required under the NE approach cited above. At a FeAST project workshop in November 2017, SNH, JNCC, MS and the Scottish Association for Marine Science (SAMS) agreed that a more viable approach to deriving a sensitivity assessment for many mobile species, and cetaceans specifically, may be generated by considering the tolerance and recovery of **individual animals** to the pressures concerned, rather than **populations**.

[1] 'Features' in this context, relate to specified habitats, landforms and species, including birds, fish and mammals.

1.1 Aims and objectives

The overall aim of this project is to enable the FeAST methodology to be adapted for mobile marine species and to consider for which species sensitivity assessment at an individual level, as opposed to the population level, was more appropriate, and why.

The project will therefore result in the following outputs:

1. revised pressures and their benchmarks and tolerance and recovery scales that are suitable for application to mobile marine species within the FeAST tool,
2. criteria or indicators to determine whether a mobile marine species should be assessed at an individual or at a population level, and
3. six completed sensitivity assessments for inclusion into the FeAST tool.

The project consists of two phases.

Phase 1. To review existing approaches and develop an approach for the sensitivity assessment of mobile species (particularly cetaceans) based on individuals rather than populations.

The project:

- examines the suitability of individual-based vs. population-based assessments for mobile marine species;
- reviews existing tolerance and recovery scales in FeAST for benthic species and habitats, and those developed in other sensitivity assessment work for highly mobile marine species (fish, birds and marine mammals);
- reviews existing pressures and their benchmarks in the FeAST tool and their applicability to mobile marine species, especially cetaceans;
- develops four-point scales for relevant categories of tolerance (resistance), recovery (resilience) and sensitivity to the defined pressures list, while ensuring compatibility with existing FeAST scales as far as possible;
- examines how to incorporate the indirect effects of changes in prey into the assessment process;
- examines the suitability of the approach for other mobile species and makes recommendations; and
- tests (pilots) the suggested approach on one of the priority species (Risso's dolphin) and one from those listed in Annex 2 of the project specification (harbour seal).

The priority species for this project were:

- Risso's dolphin,
- Minke whale,
- Basking shark,
- Harbour porpoise, and
- Bottlenose dolphin.

The project was supported by a steering group of representatives from SNH Marine Scotland and the JNCC. The project team and project steering group (PSG) liaised closely on the development of the approach, through interim meetings and a series of review cycles.

Phase 2. Following the steering group review and approval of the suggested sensitivity assessment approach for mobile marine species, the approach will be applied to the remaining four priority species. The final sensitivity assessments for all priority species (in addition to the pilot studies of harbour seal and Risso’s dolphin from Phase 1) will be provided in the relevant sensitivity assessment Excel template for inclusion into FeAST.

This report forms the output of phase 1. The additional sensitivity assessments prepared under phase 2 will be uploaded onto FeAST in due course.

2. OUTLINE OF EXISTING SENSITIVITY APPROACHES

The concept of the sensitivity of receptors (such as birds, fish, mammals and habitats) and, hence, sensitivity assessment, has been developed over many decades. Numerous approaches have been developed, applied at a range of spatial scales, and to a variety of management questions (see Roberts *et al.*, 2010 for review). The different approaches fall into three main classes: 1) empirical techniques aimed at specific pressures or activities (e.g. fishing, aggregate dredging), 2) biological traits-based approaches, and 3) evidence–based and/or expert judgement-based approaches that enable broad coverage of both pressures and features (habitats or species) (Roberts *et al.,* 2010).

The sensitivity assessment of UK marine species and habitats developed from the initial concepts of Holling (1973) and oil spill sensitivity mapping (Gundlach & Hayes, 1978), through seminal work by Holt *et al.* (1995, 1997), MacDonald *et al.* (1996), and Hiscock *et al.* (1999). Sensitivity assessment was developed further by MarLIN (Marine Life Information Network) in liaison with the UK Statutory Nature Conservation Bodies (SNCBs[2]) and Government departments and agencies[3], and was applied to numerous marine species and habitats (as biotopes), in particular features of marine SACs, between 1999 and 2010 (Tyler-Walters *et al.,* 2001; Tyler-Walters & Hiscock, 2003, 2005; Hiscock & Tyler-Walters, 2006).

The UK approach to sensitivity assessments was further revised by the UK SNCBs and Government departments and agencies[4] in response to the need to identify and assess MPAs (under the MB0102 project) (Tillin *et al.*,2010). The FeAST approach was based on Tillin *et al.* (2010) and the MarLIN evidence base (1999-2010) for Features of Conservation Interest (FOCI), with subsequent amendment and expansion.

Tillin & Hull (2012-2013) expanded the MB0102 approach and incorporated an auditable evidence base, similar to the MarLIN approach. Recent work to examine the sensitivity of ecological groups and specified designated habitats (d'Avack *et al.*, 2014; Gibb *et al.*, 2014; Mainwaring *et al.*, 2014; Tillin & Tyler-Walters, 2014 a, b) incorporated the defined list of pressures resulting from human activities that was produced by the Oslo and Paris Commission (OSPAR) Intercessional Correspondence Group on Cumulative Effects (ICG-C) (OSPAR, 2011). Minor revision of the pressures and their benchmarks by the SNCBs[5], Defra, DAERA, MS, and MarLIN resulted in the Marine Evidence-based Sensitivity Assessment (MarESA) approach (Tyler-Walters *et al.*, 2018). Natural England also explored the application of sensitivity assessment to Highly Mobile Species, and developed an approach based on the MarESA methodology, but with separate scales of tolerance for fish, birds, and marine mammals, together with separate scales for recovery (the HMSS approach, Perez-Dominguez *et al.,* 2016). The MarLIN, MB0102, MarESA and HMSS approaches were developed specifically to support the management of designated sites.

The MarLIN, MB0102, FeAST and HMSS approaches are examples of evidence-based/ expert judgment-based approaches (*sensu* Roberts *et al.,* 2010). To date, MarLIN and MarESA approaches have been applied to species and habitats (as biotopes), while FeAST has been applied to geomorphological features and Priority Marine Features (PMFs), consisting of low/limited mobility species (e.g. feather stars), mobile species (e.g. birds), and seabed habitats.

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[2] The Joint Nature Conservation Committee (JNCC), English Nature (EN), Scottish Natural Heritage (SNH), and Countryside Council for Wales (CCW)

[3] Dept Environment, Transport and the Regions (DETR), and Dept. For Environment, Food and Rural Affairs (Defra) and Centre for Environment, Fisheries and Aquaculture Science (CEFAS)

[4] Isle of Man Government, Dept. of the Environment (Northern Ireland, now Department of Agriculture, Environment and Rural Affairs (DAERA)), Marine Scotland and Defra

[5] The Joint Nature Conservation Committee (JNCC), Natural England (NE), Scottish Natural Heritage (SNH), and Natural Resources Wales (NRW)

2.1 General concepts

The most common approaches define 'sensitivity' as a product of:

- the likelihood of damage (termed tolerance or resistance) due to a pressure;
- the rate of (or time taken for) recovery (termed recoverability, or resilience) once the pressure has abated or been removed.

Or in other words "a species (population) is defined as <u>very sensitive</u> when it is <u>*easily adversely affected by human activity*</u> (e.g. low tolerance) and <u>*recovery is only achieved after a prolonged period, if at all*</u> (e.g. low recoverability)" (Laffoley *et al.*, 2000; OSPAR, 2003;).

Sensitivity is an inherent characteristic determined by the biology/ecology of the feature (species or habitat) in question. But it is a relative concept as it depends on the degree (expressed as magnitude, extent, frequency or duration) of the effect on the feature. Therefore, sensitivity assessment uses a variety of standardized thresholds, categories and ranks to ensure that the assessments of relative sensitivity compare like with like. These are:

1. standard categories of human activities and natural events, and their resultant '**pressures**' on the environment;
2. descriptors of the nature of the **pressure** (i.e. type of pressure, e.g. temperature change, physical disturbance or oxygen depletion);
3. descriptors of the pressure (e.g. magnitude, extent, duration and frequency of the effect) termed the **pressure benchmark**;
4. descriptors of resultant change / damage (**tolerance**) (i.e. proportion of the species lost, area of habitat lost/damaged);
5. categories or scales of recovery (**recoverability**) thought to be significant, and
6. resultant scores of **sensitivity**.

2.2 Common terms and definitions

The concepts of **tolerance** (**resistance)** and **recovery** (**resilience)** have been widely used to assess sensitivity. The OSPAR Commission, for example, used these concepts to evaluate sensitivity as part of the criteria used to identify 'threatened and/or declining' species and habitats within the OSPAR region - the Texel-Faial criteria (OSPAR, 2003). These concepts are used in the sensitivity approaches within MarLIN (Hiscock & Tyler-Walters, 2006); project MB0102 (Tillin *et al.,* 2010), and subsequently adopted for FeAST, MarESA and HMSS. The definitions in common use are shown in Table 1.

Activities in the marine environment result in a number of **pressures**, which may result in an **impact** on environmental components that are sensitive to the pressure. Pressures have been defined as 'the mechanism through which an activity has an effect on any part of the ecosystem' (Robinson *et al.*, 2009). Pressures can be hydrological, physical, chemical, or biological. The same pressure can be caused by a number of different activities; for example fishing using bottom gears and aggregate dredging both cause abrasion (Robinson *et al.*, 2009). Impacts are defined as the consequences of these pressures on components of an ecosystem where a change occurs that is different to that expected under natural conditions. Different pressures can result in the same impact, for example, habitat loss and habitat structure changes can both result in the mortality of benthic invertebrates (Robinson *et al.*, 2009).

A related concept is that of **Vulnerability.** Though not addressed specifically in this contract, as not specified on FeAST, it can be confused with sensitivity; the following definition is provided to help clarify the distinction. Vulnerability is a measure of the likelihood of exposure of a feature to a pressure to which it is sensitive. For example, a species may be sensitive to a given pressure but it is only **'vulnerable'** if it is exposed to that pressure. It is usually expressed as a combination of the likelihood or degree of exposure and the likely sensitivity to the pressure of interest (Hiscock *et al.,* 1999; Oakwood Environmental Ltd., 2002). The concept of vulnerability has close similarities with the concept of '**risk'**, which is a combination of hazard (a probability of exposure) and consequence of exposure (a likely effect or sensitivity).

Table 1. Common terms and definitions

Term	**Definition**	**Sources**
Sensitivity	The likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience).	Tillin *et al.* (2010); Tillin & Hull (2012-13), Tillin & Tyler-Walters (2014a)
Resistance/ tolerance	Resistance characteristics indicate whether a receptor can absorb disturbance or stress without changing character.	Holling (1973)
Resilience/recovery	The ability of a receptor to recover from disturbance or stress.	Holling (1973)
Pressure	The mechanism through which an activity has an effect on any part of the ecosystem. The nature of the pressure is determined by activity type, intensity, and distribution.	Robinson *et al.* (2009)
Pressure benchmark	The standard descriptor of the pressure defined in terms of the magnitude, extent, duration, and frequency of the effect. Benchmarks may be quantitative or qualitative.	Tyler-Walters *et al.,* (2001)
Exposure	The action of a pressure on a receptor, with regard to the extent, magnitude, and duration of the pressure.	Robinson *et al.* (2009)
Vulnerability	Vulnerability is a measure of the degree of exposure of a receptor to a pressure to which it is sensitive.	Hiscock *et al.* (1999); Oakwood Environmental Ltd (2002)

2.3 Application

Sensitivity assessment involves a detailed literature review and compilation of the evidence on the effect of a given pressure on the feature (species or habitat) in question, at the pressure benchmark level of effect, on a pressure-by-pressure basis (Figure 1).

The MarLIN, FeAST, and MarESA approaches provide a systematic process to compile and assess the best available scientific evidence to determine each sensitivity assessment. The evidence used is documented throughout the process to provide an audit trail to explain each sensitivity assessment.

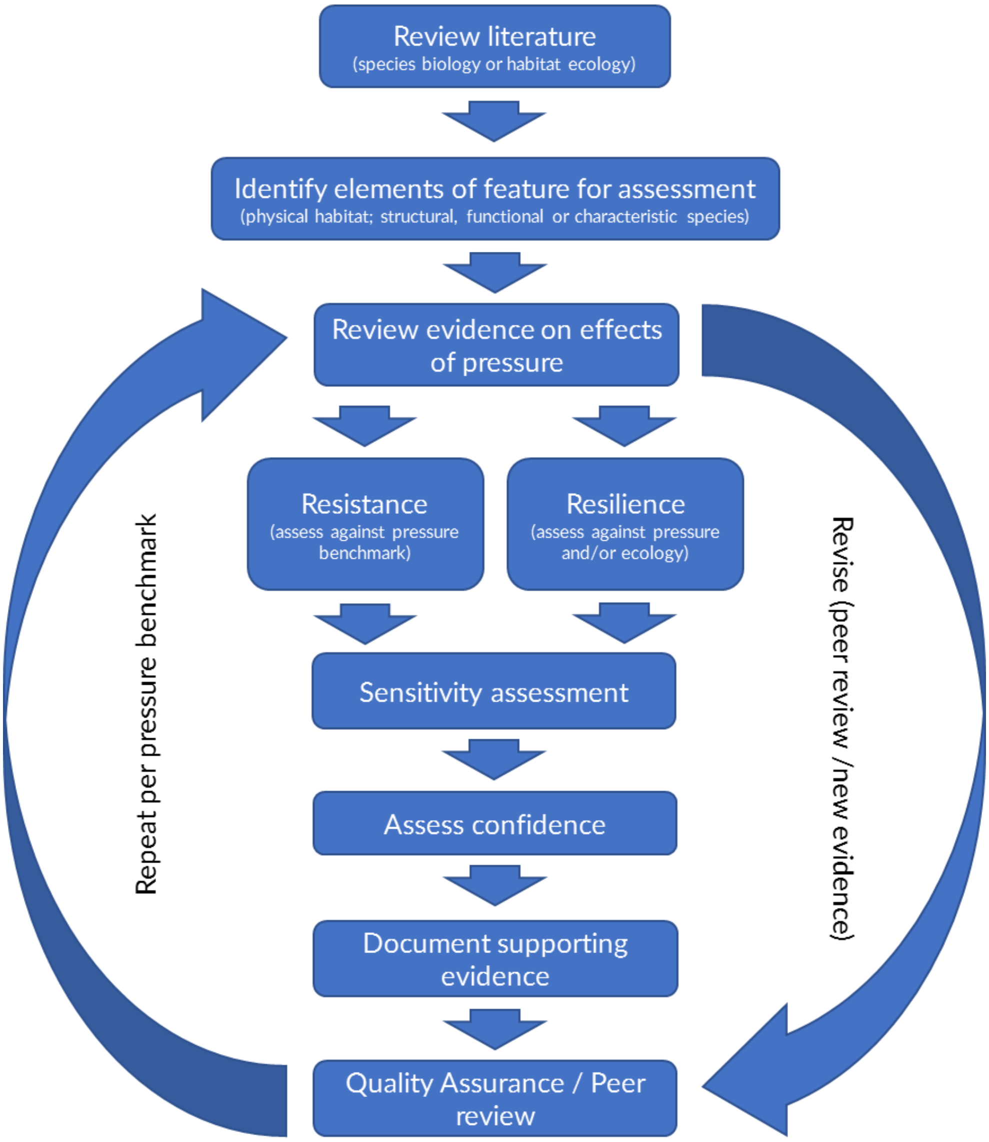

Figure 1. Generic outline of sensitivity assessment.

Literature review and critical appraisal of the evidence gained, and its comparison to the benchmark level of each pressure, are integral parts of the process. The resultant evidence-base is the most important output of each approach (MarLIN/FeAST/MarESA) and is documented carefully.

It is important to be mindful of the limitations and assumptions inherent in sensitivity assessment:

- the sensitivity assessments are generic and NOT site-specific; they are based on the likely effects of a pressure on a hypothetical population in the middle of its environmental range;
- the resulting sensitivity assessment scores are NOT absolute but are relative to the magnitude, extent, duration, and frequency of the pressure affecting the species or community and habitat in question; thus, the assessment scores are very dependent on the pressure benchmark levels used;
- sensitivity assessments are general assessments that indicate the **likely effects** of a given pressure (likely to arise from one or more activities) on species or habitats of conservation interest;

- the assessments are based on the magnitude and duration of pressures (where specified) but do not take account of spatial or temporal scale of the impact;
- there are limitations in the scientific evidence for the biology of features and their responses to environmental pressures, on which the sensitivity assessments have been based;
- the sensitivity assessment methodology takes account of both tolerance (resistance) and recovery (resilience). Recovery pre-supposes that the pressure was temporary or was alleviated. However, this will generally only be the case where management measures are implemented;
- recovery is assumed to have occurred if a species population and/or habitat returns to a state that existed prior to the impact of a given pressure, **not** to some hypothetical pristine condition.
- furthermore, sensitivity assessments assume recovery to a recognisable habitat or to a similar population size and composition, rather than presuming recovery of all species in the community and/or total recovery to prior biodiversity.

Where the evidence on the effects of a given pressure suggests a range of sensitivities, e.g. from a number of relevant activities, or variation in the habitat or community present, then the assessment is based on the **worst-case scenario** and the potential range of sensitivities is highlighted.

The resultant evidence collated during the sensitivity assessment process is the ultimate source of information for the application of the sensitivity assessments to management and planning decisions. The significance of impacts arising from pressures also needs to take account of the size or extent of the features. Users must always consult the evidence provided to determine the applicability of the sensitivity assessments to the site-specific effects or management issues in question.

Therefore, sensitivity assessment methods provide a systematic approach to the review of evidence on the likely effects of a range of pressures on marine species or habitats. The sensitivity scores (and hence tolerance and recovery scores) discriminate between species or habitats according to their relative sensitivity to any given pressure, in order to identify those species or habitats that require conservation action or are exposed to activities that require management.

The definition of pressures and their benchmarks allows the sensitivity assessments to be applied to the same level of effect throughout the given methodology so that the resultant assessments for individual pressures are relative and comparable (that is, they compare like with like), and discriminate between the most sensitive and least sensitive species or habitats. The pressures and benchmark also allow users to compare the likely effect and sensitivity to the predicted effect of any given development, action, or management measure.

3. REVIEW OF EXISTING METHODS AND SCALES

We have used three existing methods (FeAST, MarESA, and HMSS) as the basis for our review to ensure compatibility with FeAST but also examined information from the draft UK Dolphin and Porpoise Conservation Strategy (DPCS) (Marine Scotland, 2018).

The three methods outlined above differ in their scales of tolerance/resistance and recovery/resilience, how they combine these scales to determine an overall rank or score of sensitivity, how they assess the confidence in their assessment, and in some of their pressure and benchmark definitions. These differences in pressure and benchmark definitions or the relevant scales between methods make direct comparisons difficult.

For example, tolerance/resistance is determined from evidence of the direct effects of a pressure on the species, at the benchmark level, and compared to the tolerance/resistance scale developed by each approach for the relevant species group. The MarESA resistance scale focuses on the degree of mortality likely to occur directly or indirectly, while the HMSS scale focuses on both displacement and mortality from direct effects only. The different scales also differ in their definition of 'severe', 'significant,' and 'moderate' decline, e.g. HMSS defines 'severe' at >50% decline (birds/fish) or >10% (marine mammals) while MarESA and FeAST define 'severe' as >75% decline.

Similarly, MarESA defines resilience as the time taken for population regrowth, and recovery, recruitment, and possible migration of adults in sedentary species. The HMSS approach defines resilience as the time taken to return from displacement, or population recovery in the case of mortality-based impacts. Again, the resilience scales differ, e.g. 'High' resilience is defined as <2 years in FeAST and MarESA and <3 years in HMSS. The HMSS resilience (recovery) scale is apparently arbitrary (Perez-Dominguez *et al.*, 2016) based on the reporting schedule with Natural England site monitoring. The MB0102 resilience scale was based on the recovery scale as amended by the experts consulted during the MB0102 project. Both FeAST and MarESA adopted this MB0102 recovery scale.

The tolerance and recovery scales are then combined using a matrix in order to determine the overall sensitivity. Again, the matrices differ between methods in terms of how the different scores for tolerance and recovery are combined to achieve the final sensitivity score.

The differences in approaches (and the scales/ranks used) stem from differences in the questions the approaches were designed to answer, the range of pressures examined, and the range of features (species or habitats) to which they were applied.

The MarLIN approach was designed in liaison with SNCBs, Government agency (DETR/Defra, CEFAS) staff and academics to support the UK commitments under the Convention of Biodiversity, Biodiversity Action Plans and the management of European Marine Sites. Its emphasis was on benthic species and habitats and was influenced by prior work on benthic life cycles (Hiscock, 1999), fishing sensitivity (MacDonald *et al.*, 1999), and CCW's SensMap programme (Cooke *et al.*, 2001), and revised after the Review of Marine Nature Conservation (Laffoley *et al.*, 2000).

The MB0102 approach (Tillin *et al.,* 2010) was developed as part of a major project to collate the data layers to underpin the identification of marine protected areas in the UK. Its focus was benthic features of conservation interest and it was developed by SNCBs and Government agencies (Defra, MS, CEFAS). It was influenced by the further development of defined pressures and vulnerability assessment in marine status reporting under OSPAR (Robinson *et al.,* 2009). The resultant sensitivity assessments were based on expert judgement by panels of relevant habitat or species experts, where available, and expressed as a range of values in many cases.

The MarESA approach (Tyler-Walters *et al.*, 2018) was developed in liaison with SNCBs and Government agency (Defra, MS) staff to synthesise the work of MarLIN and MB0102 so that it could be applied to the management of marine designated sites (e.g. European Marine Sites and MCZs) with a focus on benthic habitats. It built on prior work by MarLIN, MB0102, and Tillin & Hull (2012-2013). The resultant evidence review updated the range of sensitivity assessments against individual pressure/feature combinations that resulted from the MB0120 sensitivity assessment approach.

The HMSS (Perez-Dominguez *et al.*, 2016) approach was developed by Natural England and focused on mobile species including birds, fish and marine mammals within English designated sites and Marine Protected Areas in liaison with relevant experts on those species groups.

The different approaches also reflect, to some extent, the differences in the views of the relevant experts on what constitutes ‘sensitivity’, and the biology of the species or ecology of the features examined. The strong similarity between MarLIN, MB0102 and MarESA approaches stems, in part, from the similarities in purpose of the assessments and features examined. In their review of fishing sensitivity approaches alone, Roberts *et al.* (2010) catalogued twelve separate types of approach.

Therefore, the scales and resultant sensitivity assessments (scores / ranks) cannot be compared directly. Similarly, any sensitivity assessments (scores / ranks) that result from a revised methodology will not be comparable to earlier methods.

4. INDIVIDUAL-BASED VS. POPULATION-BASED APPROACHES

The existing FeAST tool, the Perez-Dominguez *et al.* (2016) HMSS approach and MarESA all assess the sensitivity of species to pressures at a population level. The HMSS work was designed for use when examining MPAs and so an area, with a boundary and a defined population was always (at least theoretically) available. The problem with conducting a population-based assessment of sensitivity for many highly mobile species is that information on spatial extent and population sizes is often not available at the required scale.

Defined Management Units (MUs) exist for some highly mobile species, and can be used as a basis against which to assess sensitivity. An MU is a geographical area to which management of human activities is applied, though typically incorporates what understanding of species populations and sub-populations there may be. An MU can be smaller than the entire population or an ecological unit to reflect spatial differences in human activities and their management. The Inter Agency Marine Mammal Working Group (IAMMWG) defined MUs for cetacean species in UK waters (IAMMWG, 2015). For bottlenose dolphins in specific areas, these are relatively local and based on well-studied, known populations. For other species for which there may be fewer available data (Risso's dolphin, white-beaked dolphin, Atlantic white-sided dolphin, common dolphin, minke whale), the MU's encompass the entire North Sea, and Celtic and Irish Seas in a single Management Unit. It is considered that MUs of this scale may be too large to assess local scale pressures against. Seal Management Areas (SMAs) have also been defined for both grey and harbour seals in the UK (IAMMWG, 2013). However the boundaries between SMAs likely do not represent discrete populations, particularly for grey seals that are known to range widely between haul-outs and foraging sites and frequently travel over 100 km between haul-out sites (SCOS, 2017). Harbour seals generally feed within 40-50 km around their haul out sites (SCOS, 2017). However, individuals can display longer-term movements. For example, individual harbour seals tagged in the Moray Firth SMA have undergone large-scale movements to Orkney in a separate SMA (Graham *et al.*, 2016). Thus, SMAs may not be independent of each other and do not represent discrete local populations against which to assess sensitivity to pressures.

For other highly mobile species, even these large-scale MU population data are not available. For example, there is no abundance estimate for basking sharks for the North Atlantic. In the complete absence of any numerical context, it would be difficult to conduct a meaningful population-based sensitivity assessment for this species.

In practice, risk assessments for highly mobile species (e.g. marine mammals and seabirds), undertaken as part of the Environmental Impact Assessment (EIA) process, are in effect site-specific sensitivity assessments. The difference between those assessments and the more general sensitivity assessments considered in this report is that: for EIA, the risk assessments are conducted for a specified geographical area with a defined boundary; the pressures themselves are specific (e.g. the noise characteristics of a development are specifically modelled) and quantified in terms of both magnitude and duration; and tailored data collection may have been carried out in order to provide context for the site within the overall population of animals. As the predicted level of exposure and pressure (magnitude, extent, duration and frequency) are addressed, the 'sensitivity' assessment undertaken in EIA is similar to 'vulnerability' (or risk) assessment as defined above (Table 1). In addition, the locally surveyed population of animals and the number predicted to be impacted can then be put into context by comparing against the most relevant Management Unit (where available). The extra detail that is available when discussing site-specific sensitivities rather than general sensitivity means that population-based assessment becomes a more meaningful approach.

As a concept, sensitivity assessments are not designed as tools from which one should derive absolute measures, rather they are designed to compare relative scores and to provide high-level indication of relative sensitivity to prompt further, more detailed study. Whilst the scales developed in the HMSS approach refer to a '>10% reduction in the estimated size of the local population' (Table 2), the sensitivity assessments cannot be site-specific and the size of the local population is not considered when following the methodology and conducting the assessment. The scales provide a quantified but conceptual change in the state of a hypothetical population and allow the sensitivity assessment author to judge the likely 'tolerance/resistance' against the reported effect of any given pressure on a similar population of species or habitat(s).

Table 2. Taxon-specific resistance assessment scale for marine mammals (Perez-Dominguez et al., 2016), as used in Natural England's HMSS approach.

Resistance	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 (e.g. foraging effort) but these may be buffered from feeding through to changed rates of reproduction or mortality or local population best estimates.

Similarly, they provide a guide for the subsequent user of the sensitivity assessment, e.g. statutory agency staff, consultant or developer. When used in this way, the assessment is not hampered by a lack of site-specific detail, as the assessment is not specifically aimed at a particular location.

However, even in hypothetical terms, there is difficulty in defining local marine mammal populations against which to assess sensitivity. Therefore, this project has investigated whether a different approach to sensitivity assessment would be more applicable to marine mammals and other highly mobile species.

As they are currently defined, the existing FeAST definitions of tolerance are not ideally suited to marine mammals and other highly mobile species. For example, the definition of 'high' tolerance includes "may affect feeding, respiration and reproduction rates" (Table 3). In the case of highly mobile species such as cetaceans, these are not synonymous with 'high' tolerance. For example in marine mammal species, a pressure that has the ability to alter fertility rates can affect the population trajectory. Therefore, a definition of 'high' tolerance would seem inconsistent, particularly for a K-selected species that is slow-growing, long-lived, with high levels of maternal investment.

Table 3. The tolerance scale for sensitivity currently used in the FeAST tool and MarESA.

Resistance/Tolerance	Description
None	Key functional, structural, characterizing species severely decline and/or physico-chemical parameters are also affected e.g. removal of habitat causing change in habitat type. A severe decline/reduction relates to the loss of 75% of the extent, density or abundance of the selected species or habitat element e.g. loss of 75% substratum (where this can be sensibly applied).
Low	Significant mortality of key and characterizing species with some effects on physico-chemical character of habitat. A significant decline/reduction relates to the loss of 25%-75% of the extent, density or abundance of the selected species or habitat element e.g. loss of 25-75% substratum.
Medium	Some mortality of species (can be significant where these are not keystone structural /functional and characterizing species) without change to habitat type. The 'some mortality' relates to the loss of <25% of the species or element.
High	No significant effects to the physico-chemical character of habitat and no effect on population viability of key/characterizing species but may affect feeding, respiration and reproduction rates.

Given concerns, for many marine mammals and other highly mobile species, regarding the ability to define populations either at a local level or at the scale of the relevant management units, against which to assess impacts, and the fact that the existing FeAST tolerance definitions are not well suited to marine mammals, it is proposed that an individual-based sensitivity assessment approach is used instead. This requires no knowledge of the number of animals that would be subjected to a pressure, and no knowledge of the proportion of the population this would represent. The method for implementing an individual-based approach, its advantages and its limitations, is presented below.

Like the population-based approach, the individual-based approach is also not entirely straightforward. There is the potential that individuals may not all be equally sensitive to pressures at all life-history stages. For example, studies of the contaminant burden of bottlenose dolphins resulting from the bioaccumulation of toxins in their blubber layers, have shown that levels tend to be higher in adult males than juveniles or adult females, due to the transfer of toxins from lactating females to their offspring (e.g. Fair *et al.,* 2010). In sensitivity assessment terms, therefore, breeding adult females could be considered as being less sensitive to this pressure than adult males. Conversely, breeding adult female whales (various species) may be the most sensitive to changes in foraging success compared to adult males and juveniles as breeding females will need to maintain their own body condition as well as gather sufficient provisions for gestation and lactation (e.g. Young & Keith, 2011). In this instance, breeding adult females would be considered as being more sensitive to changes in prey availability than adult males.

An expert elicitation[6] to assess the effects of disturbance from pile-driving activities, concluded that adult female fertility and weaned-of-the-year pup survival were the stages most vulnerable to the effects of disturbance in both grey and harbour seals, with mature female survival and juvenile survival considered unlikely to be significantly affected by

[6] A formal process used to ask experts for their judgements in a careful, structured way, where the uncertainty for a parameter is quantified along with the values for the parameters. The experts make probabilistic judgements expressing their uncertainty in their parameter estimate in the form of probability distributions.

disturbance from piling (Booth *et al.*, 2019). Likewise, the effects of disturbance from pile driving on harbour porpoise was considered to most likely result in changes to post-weaning calf survival and adult fertility, with juvenile and adult survival considered to be relatively robust and unlikely to be significantly affected (Booth *et al.*, 2019).

A further consideration of using individuals as the basic unit for the sensitivity assessment, rather than populations, is that individuals do not recover from mortality and the resultant sensitivity assessments will be skewed towards 'High' wherever a pressure could result in the mortality of an individual. As an example, consider a sensitivity assessment of the pressure 'Death or injury to mobile species by collision' for both harbour porpoise and the North Atlantic right whale assessed at both a population and individual level (Table 4). Collision is assumed to result in the death of the individual (no tolerance), from which there is no ability to recover. Consequently, when conducting an individual-based sensitivity assessment both species are assessed as highly sensitive. However, at a population level, the likelihood of the death of an individual harbour porpoise affecting the trajectory of the harbour porpoise Management Unit is low (the North Sea Management Unit is large and currently stable).

Table 4. Example population-based and individual-based sensitivity assessment for harbour porpoise and North Atlantic right whales to the pressure of 'death or injury to mobile species by collision'.

Species	**Approach**	**Tolerance**	**Recovery**	**Sensitivity**
Harbour porpoise	Population	Medium	High	Low
	Individual	None	None	High
Right whale	Population	Low	Low	High
	Individual	None	None	High

Conversely, for right whales, the population is so low that the loss of even a single breeding female could affect the population trajectory. This would result in a conclusion of 'Low' sensitivity for porpoise and 'High' sensitivity for right whales if assessed at a population level. Therefore, in this example, the individual-based sensitivity assessment for harbour porpoise exaggerates the resulting sensitivity score (High) compared to a population-based sensitivity assessment (Low). Individual-based sensitivity assessment thus captures all the evidence to provide a precautionary assessment of sensitivity. Further work (e.g. as part of EIA process), incorporating exposure and density estimates, can refine the risk to a specific population.

Most population-based assessments, such as the MarESA/HMSS assess the resistance of a population to a pressure using a scale of likelihood of population decline. However, as outlined above, there are very few marine mammal species for which there is a known and well defined local population, nor is it well understood how the impact of a pressure will result in changes to population trends. Using the example outlined above in Table 4, under a population-based assessment, the death of a single harbour porpoise will not affect the population trajectory of the large North Sea MU, and will therefore be assessed as having a 'low' sensitivity to the pressure. However since this species is a European Protected Species, and thereby protected at an individual level (making it an offence to kill, injure or disturb an individual) assessment at a population level will under-emphasise the significance of the pressure in regulatory terms.

If the end point of any sensitivity assessment is to indicate the significance of any pressure, in order to inform decision making and guide management efforts, then the population will need to be taken into account at some point and combined with a measure of the magnitude of exposure (i.e. a vulnerability assessment).

This approach has been adopted in the draft UK DPCS, which aims to identify and prioritise management actions for UK dolphins and porpoises, based on the pressures to which they are subject. The draft UK DPCS defines sensitivity as the likelihood of change when a pressure is applied to an individual animal. In order to assess sensitivity, the potential for mortality or an impact on fecundity or survival of an individual when exposed to a pressure was assessed. The definitions of individual animal sensitivity as adopted in the draft UK DPCS are presented in Table 5.

Table 5. The individual animal sensitivity scale used in the draft UK DPCS.

Sensitivity	Description
High	The pressure impacts the individual of a species directly and it would be unable to resist change and could not recover (e.g. direct mortality as a result of bycatch); OR the pressure acts indirectly (e.g. through prey consumption) but the consequence directly impacts survival/fecundity and it would be unable to resist change and could not recover (e.g. bioaccumulation of contaminants).
Medium	The pressure may impact the fecundity/survival of an individual of a species indirectly (e.g. the pressure elicits behavioural/physiological change that may have consequences on individual fitness); individuals may tolerate and/or recover (e.g. noise disturbance).
Low	The pressure does not impact survival or fecundity, directly or indirectly, of the individual of a species; it is resistant to the pressure.

The draft UK DPCS approach combines tolerance and recovery into a single scenario that removes the need for a matrix to combine the range of tolerance and recovery scales.

The next step of the draft UK DPCS assessment is an assessment of the exposure level where the individual sensitivity is considered in the context of the extent or exposure to the pressure. Consideration is given to the area over which the pressure extends, its magnitude and duration, and the proportion of the population experiencing the pressure, as judged from the total number and distribution of individuals within that population relative to the area affected by the pressure. This therefore places the individual sensitivity assessment in the context of the pressure extent and the effect on the population.

An exposure level (vulnerability) assessment is beyond the scope of this project, however it is envisaged that, where required, the results obtained from a FeAST individual-based sensitivity assessment (as developed within this project) would then be put into context in a separate exposure level (vulnerability) assessment that is specific to the site and activity in question e.g. through the EIA process.

4.1 Summary of pros and cons of the individual-based vs. population-based approaches

Sensitivity assessment approaches differ in the questions they are designed to answer and the features and pressures to which they are applied (Section 3), and all approaches have limitations that stem from their inherent assumptions and the evidence on which the assessments are based.

Population-based approaches (e.g. MarLIN/MB0102/MarESA/HMSS)

Pros

- applicable to a wide range of species populations and habitats;
- provides a relative assessment for species and habitats of their sensitivity to a range of pressures;
- can synthesize evidence from a wide range of sources, including quantitative and qualitative evidence, with varying degrees of confidence; and
- can be applied at a variety of scales from the biotope level to designated sites or marine landscapes.

Cons

- requires an appreciation of the scale or extent of the impacting pressure (the area of effect) against which to assess the likely effect on the species population or habitat;
- requires evidence of effects on the species populations or habitats; and
- is predicated on direct mortality; behavioural responses are not adequately accounted for in the methodology.

To date, most population-based approaches assess 'resistance' against reported changes in, for example, species abundance, biomass, distribution, extent, or range. Recovery rates or resistance assessments are based on evidence on population dynamics (recruitment, life history, growth rates and breeding method(s)), population size, distribution, and range or isolation. Hence, population-based assessment requires evidence at the population level. Lack of evidence is reflected in lack of confidence in the assessments.

Most importantly, MB0102/MarESA and HMSS do not include behavioural responses adequately. For most of the marine benthos and habitats assessed to date, behavioural responses **alone** result in a 'High' resistance by definition, and hence, 'low' sensitivity. Behavioural responses that result in long-term reduction in recruitment to the population are difficult to capture in the current population-based approaches, save where added as a caveat via expert judgement.

Individual-based approach

Pros

- the assessment is based on the individual not its resident population size nor the size of the area in which it resides or is impacted;
- the local, national, or regional scales of sites or the area of effect of the pressures are not relevant to the assessment;
- the lack of information on resident or impacted population size is not required for assessment;
- behavioural responses can be integrated into the assessment more easily; and
- the results are applicable directly to species that qualify for individual protection under relevant statutory protection.

Cons

- individual-based assessments may need to be placed in the context of the population in application to other assessments, e.g. environmental assessments or strategic environmental assessments; and
- It is not applicable to habitats.

An individual-based approach makes common sense when assessing species that require individual-based protection under statute (e.g. Wildlife & Countryside Act 1981[7] or Habitats Directive (1992; DIR 92 / 43 / EEC enacted by the Conservation of Habitats and Species Regulations 2017[8]).

The individual-based approach also has the advantage that it does not require evidence on the area of effect or extent of the pressure or the sites affected in the assessment. However, it does require information linking a behavioural response or physical injury to a species ability to recover, survive, and subsequently, breed and contribute to recruitment. Information on behavioural responses and their subsequent effect on reproduction or individual survival is lacking in many species of cetaceans, seals or shark species. In contrast such information is probably very limited or anecdotal in many sedentary benthic species that may respond by withdrawing from physical stimuli with some energetic cost but cannot otherwise respond to or avoid any given pressure. Similarly, mortality of a single individual within a population of many thousands (or more) of a polychaete or bivalve within any one site, is probably of little consequence to the population and, importantly, probably within natural levels of mortality. Accordingly, a population-based approach is more appropriate for these.

Therefore, the individual-based approach is relevant to the large, mobile species e.g. cetaceans, seals, turtles, sharks, and rays, especially those with documented behavioural responses, although any resultant impact on subsequent reproduction and recruitment is less well known and varies between species.

[7] Wildlife & Countryside Act (1981)(amended) http://www.legislation.gov.uk/ukpga/1981/69/contents
[8] Conservation of Habitats and Species Regulations 2017 http://www.legislation.gov.uk/uksi/2017/1012/contents/made

5. INDIVIDUAL-BASED METHODOLOGY

The main reason for exploring an individual-based approach for marine mammals was the inability to define both local level and Management Unit level population sizes for many marine mammals and other highly mobile species, and as a result quantify the level of decline that might result from application of a particular pressure. As a result, the quantitative criteria, based on a proportion of the local or affected population, used in the resistance scales developed by existing sensitivity assessment approaches could not be applied. However, it was unclear if marine mammals were the only highly mobile species for which an individual-based approach was the best method, and for which species a population-based approach would remain the most appropriate method.

5.1 Species that qualify for an individual-based sensitivity assessment (IBSA)

We suggest that individual-based sensitivity assessment (IBSA) could be applied to species where the loss of a single individual (or small number of individuals) has the potential to affect the survival of the population adversely, or that qualify for individual-based protection under legislation. Such species are likely to exhibit naturally small or restricted populations, have undergone significant population decline, and/or are K-strategists that are slow to reproduce and recover from loss of mature individuals slowly and are, hence, vulnerable to threats from human activities or natural events.

A preliminary review of species traits is presented in Annex 1 for the marine species listed as mobile Priority Marine Features in Scotland (PMFs) and marine protected species known to occur naturally in Scotland[9] and listed under the Wildlife & Countryside Act 1981 (W&C 1981) or Habitats Directive (1992; DIR 92 / 43 / EEC as enacted in Scotland by The Conservation (Natural Habitats, &c.) Regulations 1994[10]. The traits presented are based on readily available summary information but do not, necessarily, represent local or regional variations. They are presented to compare general traits between the separate groups of species under consideration (i.e. cetaceans, seals, reptiles, shark, rays, and fin-fish), and as such are not intended to provide the most comprehensive list of data available.

There are good or reasonable population size estimates for some marine mammal populations (e.g. bottlenose dolphins on the east coast of Scotland, harbour and grey seals). However, there is no accurate estimate of population size for some of the other marine mammal species nor for many of the fish species listed in Annex 1. Catch rates presented for commercially fished species provide information on trends in population size rather than actual population size. It is likely that we do not have an accurate estimate of population size for many marine species with perhaps the exception of benthic shellfish stocks, a few rare species, or a limited number of species that have dedicated long-term monitoring programmes (e.g. bottlenose dolphins and seal species).

However, even based on estimates, it is clear that population sizes for cetaceans are generally small when compared to those of, for example, fin-fish or benthic invertebrates. The estimates of most cetacean population sizes range from tens of individuals to few thousands in local waters to tens of thousands to many hundreds of thousands in regional or global waters. This compares with many thousands or millions of fin-fish, depending on species. Similarly, most benthic invertebrates probably reach populations of many thousands on a local shore (e.g. amphipods, barnacles and mussels).

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[9] List of protect species in Scotland https://www.nature.scot/sensitive-species-scotland-list

[10] Note – birds, lichen, stoneworts, vascular plants and freshwater fish are excluded.

There are international and national estimates of population status in the form of red lists (IUCN, 2019[11]) that address the concept that the population size, range or distribution is significantly reduced, restricted, or in decline and, therefore, captures information on the estimated **status** of the population. Most notably, the W&C 1981 and Habitats Directive include criteria that use these concepts to identify species that qualify for individual-based protection because they are 'endangered'. Therefore, we suggest that the criteria used to identify species that qualify for individual-based protection provide a useful proxy for population status where reliable estimates of population size, especially local and regional estimates, are missing. It also makes sense to apply an individual-based approach to sensitivity assessment to species that require individual-based protection so that results of the assessment can be used to support management. These criteria also identify species that are potentially 'vulnerable' to becoming 'endangered' in the future.

5.1.1 Indicators

Two sets of indicators are suggested to identify species that may be suitable for IBSA. The first set is based on the legislative criteria used to identify species that qualify for individual-based protection and addresses their population status. The second set of indicators address the potential vulnerability of species to human activities based on their life history characteristics.

Indicator 1 - Population status

The W&C (1981) lists a number of criteria to define 'endangered' species and species vulnerable to becoming endangered and, in so doing, helps indicate species that may qualify for individual-based protection based on population status. These are summarised below[12].

"One or more of the following criteria may indicate that a species is or may become 'endangered' (W&C 1981):

- it is included on recognised international IUCN Red lists (or GB Red Books[13]) as 'Extinct in the Wild', 'Critically Endangered', 'Endangered', or 'Vulnerable';
- it is known from a single locality;
- it is confined to a particularly threatened habitat (e.g. lagoons);
- it is rapidly declining in population, number of sites occupied, or range; or
- it is endangered or likely to become endangered due to targeted exploitation or killing for commercial reasons and/or collection".

The Habitats Directive (1992; DIR 92 / 43 / EEC) uses similar criteria to identify '**species of Community Interest**' (Article 1(g)) which can require protection on an individual-based level. The W&C 1981 includes additional criteria so that only species that would benefit from individual-based protection under the Act are scheduled. Species listed under the W&C 1981 (Schedules 1, 5, 7 and 8) and under the Habitats Directive (enacted in Scotland by The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), Schedules 2, 3 and 4)) are provided with individual protection in the United Kingdom and Europe. In Scotland, seals are further protected at the individual level under the Marine (Scotland) Act 2010.

Therefore, the W&C 1981 criteria and IUCN Red List assessments provide a useful set of indicators of population status and a proxy for population size, and provide a list of species for which protective legislation is assigned at an individual level.

[11] IUCN Red List of Threatened Species https://www.iucnredlist.org/
[12] Summarized from the 5th JNCC Quinquennial review http://jncc.defra.gov.uk/PDF/5qr.pdf
[13] GB Red Books are not updated and the IUCN Red List assessments are used here.

Indicator 2 - The species show 'K-selected' life history traits

These species are slow to reproduce and make a considerable investment in a small number of offspring.

They exhibit more than one of the following life history traits:

- are long-lived, slow-growing and late to reproduce (age of maturity is typically >5 years);
- have long gestation or egg development times (typically >6 months);
- produce small numbers of offspring (often one but typically no more than ca 100 per reproductive cycle);
- do not reproduce annually but typically rest between reproductive phases for one or more years, and have long generation times (>10 years).

In each case, a cut-off value (in brackets in the list above) for each indicator was used for guidance on the suitability of the species for IBSA under Indicator 2. It should be noted that the suggested cut-offs are based on the expert judgement of the authors and are considered to be indicative rather than prescriptive. They may, therefore, warrant further study outside the scope of this project.

5.1.2 Application of indicators

The suggested indicators were applied to highly mobile marine protected species known to occur naturally in Scotland[14] and species identified as priority marine features (PMFs) (as listed in the project specification). These species are listed in Table 6 together with the indicators.

Indicator 1 - Population status

All cetaceans are suitable for IBSA based on Indicator 1 due to their inclusion under the Habitats Directive as European Protected Species (EPS, Annex IV). It is an offense to deliberately or recklessly capture, injure, or kill an EPS, which includes obstructing an animal's access to breeding/resting/foraging sites or to disturb an animal such that its ability to survive, breed, and rear its young might be impaired. Other highly mobile marine species listed as EPS include five species of marine turtle, the European otter and the Atlantic sturgeon. Seals are protected under W&C 1981 under Schedule 7 (Protection of Certain Mammals, via The Conservation of Seals Act 1970) and, in Scotland, under the Marine (Scotland) Act 2010[15]. The basking shark is the only shark species (under W&C 1981) and only four fin-fish species (Allis shad, Twaite shad, Atlantic sturgeon and European river lamprey) suitable for IBSA based on Indicator 1.

Indicator 1 provides a common sense qualifier as it makes sense to apply an IBSA to those species that qualify for individual-based protection under the W&C 1981 and Habitats Directive (as above).

[14] List of protected species in Scotland https://www.nature.scot/sensitive-species-scotland-list
[15] Marine (Scotland) Act 2010 https://www.legislation.gov.uk/asp/2010/5/contents

Table 6. Designated highly mobile marine[16] species (known to occur naturally in Scotland) and indicators of individual-based vs. population-based assessment. Indicator cut-offs as follows: generation time >10 years, fecundity (litter size) ~<100, age at maturity >5 years, and gestation time >6 months.

Key: ✓= complies with indicator listed; ×= does not comply with indicator listed; ×/✓ = borderline compliance with indicator; ? = no information. Indicators of suitability are also highlighted in grey.

			Indicator 1: Population status			**Indicator 2: Life history**				
Taxon group	**Common name**	**Species name**	WCA 1981	HR 1994 Annex IV	IUCN (Global / Europe)[17]	Age at maturity (>5 yrs.)	Long gestation /egg development (>6 mo.)	Low fecundity (litter size ~<100)	Long generation time (>10 yrs.)	Not reproduce annually
Species suitable for IBSA under legislation										
Mammal Cetaceans	All -dolphins, porpoises, whales	Cetacea	×	✓						
	Atlantic white-sided dolphin	*Lagenorhynchus acutus*	×	✓	LC/LC	✓	✓	✓	?	?
	Bottlenose dolphin	*Tursiops truncatus*	×	✓	LC/DD	✓	✓	✓	?	?
	Fin whale	*Balaenoptera physalus*	×	✓	VU/NT	✓	✓	✓	✓	?
	Harbour porpoise	*Phocoena phocoena*	×	✓	LC/VU	✓	✓	✓	?	×
	Killer whale	*Orcinus orca*	×	✓	DD/DD	✓	✓	✓	?	?
	Long-finned pilot whale	*Globicephela melas*	×	✓	LC/DD	✓	✓	✓	?	?
	Minke whale	*Balaenoptera acutorostrata*	×	✓	LC/LC	✓	✓	✓	✓	×
	Northern bottlenose whale	*Hyperoodon ampullatus*	×	✓	DD/?	✓	✓	✓	?	?
	Risso's dolphin	*Grampus griseus*	×	✓	LC/DD	✓	✓	✓	?	✓
	Short-beaked common dolphin	*Delphinus delphis*	×	✓	LC/DD	✓	✓	✓	?	✓
	Sowerby's beaked whale	*Mesoplodon bidens*	×	✓	DD/DD	✓	✓	✓	?	?
	Sperm whale	*Physeter macrocephalus*	×	✓	VU/VU	✓	✓	✓	✓	?
	White-beaked dolphin	*Lagenorhynchus albirostris*	×	✓	LC/LC	✓	✓	✓	?	✓
Mammal - Seals	Bearded seal	*Erignathus barbatus*	×	✓	LC/NA	?	?	?	?	?
	Harbour seal	*Phoca vitulina*	✓	×	LC/LC	×	✓	✓	?	×

[16] Note – birds, lichen, stoneworts, vascular plants and freshwater fish are excluded from this table.
[17] IUCN categories listed as Global / Europe Assessments as follows; CR- Critically endangered; DD – Data deficient; EN- Endangered; LC- Least concern; NT –Near threatened; NA – Not applicable; NE- Not evaluated; VU –Vulnerable; ? – No assessment given.

			Indicator 1: Population status			Indicator 2: Life history				
Taxon group	**Common name**	**Species name**	WCA 1981	HR 1994 Annex IV	IUCN (Global / Europe)[17]	Age at maturity (>5 yrs.)	Long gestation /egg development (>6 mo.)	Low fecundity (litter size ~<100)	Long generation time (>10 yrs.)	Not reproduce annually
	Grey seal	*Halichoerus grypus*	✓	✗	LC/LC	✗	✓	✓	?	✗
	Harp seal	*Phoca groenlandica*	✗	✓	LC/NA	?	?	?	?	?
Mammal	Otter	*Lutra lutra*	✗	✓	NT/NT	✗	✗	✓	✗	✗
Reptiles	Green turtle	*Chelonia mydas*	✗	✓	EN/?	✓	✗	✗	✓	✓
	Hawksbill turtle	*Eretmochelys imbricata*	✗	✓	CR/?	✓	✗	✗	✓	✓
	Kemp's ridley turtle	*Lepidochelys kempii*	✗	✓	CR/?	✓	✗	✗	?	✓
	Leatherback turtle	*Dermochelys coriacea*	✗	✓	VU/?	✓	✗	✗	?	✓
	Loggerhead turtle	*Caretta caretta*	✗	✓	VU/?	✓	✗	✗	✓	✓
Sharks/Rays	Basking shark	*Cetorhinus maximus*	✓	✗	VU/EN	✓	✓	✓	✓	✓
Fin-fish	Allis shad	*Alosa alosa*	✓	✓	LC/LC	✗/✓	✗	✗	?	?
	Atlantic sturgeon	*Acipenser sturio*	✗	✓	CR/CR	✓	?	✗	?	✓
	European river lamprey	*Lampetra fluviatilis*	✗	✓	LC/LC	✗/✓	?	✗	?	?
	Twaite shad	*Alosa fallax*	✓	✓	LC/LC	✗/✓	✗	✗	?	?
Species suitable for IBSA based on population status										
Sharks/Rays	Common skate	*Dipturus batis*	✗	✗	CR/CR	✓	✗	✓	✓	✓
	Leafscale gulper shark	*Centrophorus squamosus*	✗	✗	VU/EN	?	?	✓	?	?
	Porbeagle shark	*Lamna nasus*	✗	✗	VU/CR	✓	✓	✓	?	✗
	Portuguese dogfish	*Centroscymnus coelolepis*	✗	✗	NT/EN	✓	?	✓	✓	✓
	Sandy ray	*Leucoraja circularis*	✗	✗	EN/EN	?	?	?	✗	?
	Spiny dogfish	*Squalas acanthias*	✗	✗	VU/EN	✓	✓	✓	✓	?
Fin-fish	Atlantic halibut	*Hippoglossus hippoglossus*	✗	✗	EN/VU	✓	?	✗	?	?
	Atlantic salmon	*Salmo salar*	✗	✗	LC/VU	✗/✓	?	✗	✗	✗
	Blue ling	*Molva dypterygia*	✗	✗	LC/VU	✓	?	?	✓	?
	European eel	*Anguilla anguilla*	✗	✗	CR/CR	✓	?	✗	✗/✓	?
	Orange roughy	*Hoplostethus atlanticus*	✗	✗	?/VU	✓	?	✗	✓	?
	Round-nose grenadier	*Coryphaenoides rupestris*	✗	✗	CR/EN	✓	?	✗	✓	✗

			Indicator 1: Population status			Indicator 2: Life history				
Taxon group	Common name	Species name	WCA 1981	HR 1994 Annex IV	IUCN (Global / Europe)[17]	Age at maturity (>5 yrs.)	Long gestation /egg development (>6 mo.)	Low fecundity (litter size ~<100)	Long generation time (>10 yrs.)	Not reproduce annually
Species that MAY be suitable for IBSA based on life history traits										
	Anglerfish	*Lophius piscatorius*	×	×	LC/LC	✓	?	×	?	?
	Cod	*Gadus morhua*	×	×	VU/LC	×/✓	?	×	?	×
	Greenland halibut	*Reinhardtius hippoglossoides*	×	×	?/NT	✓	?	×	✓	?
	Horse mackerel	*Trachurus trachurus*	×	×	VU/LC	✓	?	×	✓	?
	Ling	*Molva molva*	×	×	?/LC	✓	?	×	×/✓	✓
	Saithe	*Pollachius virens*	×	×	?/LC	✓	?	×	✓	×
	Sea lamprey	*Petromyzon marinus*	×	×	LC/LC	✓	?	×	?	?
Species that are NOT suitable for IBSA										
	Atlantic herring	*Clupea harengus*	×	×	LC/LC	×/✓	×	×	?	×
	Atlantic mackerel	*Scomber scombrus*	×	×	LC/LC	×	?	×	×	×
	Black scabbardfish	*Aphanopus carbo*	×	×	?/LC	×	?	?	?	?
	Blue whiting	*Micromesistius poutassou*	×	×	?/LC	×/✓	?	×	?	?
	Norway pout	*Trisopterus esmarkii*	×	×	LC/LC	×	?	×	?	×
	Sand goby	*Pomatoschistus minutus*	×	×	LC/LC	×	×	×	×	×
	Sandeels	*Ammodytes marinus*	×	×	?/LC	×	×	×	×	×
	Sandeels	*Ammodytes tobianus*	×	×	DD/DD	×	×	×	×	×
	Sea trout	*Salmo trutta*	×	×	LC/LC	×/✓	?	×	?	×
	Sparling	*Osmerus eperlanus*	×	×	LCLC	×	?	×	?	×
	Whiting	*Merlangius merlangus*	×	×	LC/LC	×	×	×	×	×

However, several additional species could be suitable for an IBSA based on Indicator 1 because they are considered ‘Endangered’ (i.e. Critically Endangered’, ‘Endangered’, or ‘Vulnerable’) in Europe, based on IUCN Red list assessment (Table 6). These species are:

- Common skate (*Dipturus batis*);
- Leafscale gulper shark (*Centrophorus squamosus*);
- Porbeagle shark (*Lamna nasus*);
- Portuguese dogfish (*Centroscymnus coelolepis*);
- Sandy ray (*Leucoraja circularis*);
- Spiny dogfish (*Squalas acanthias*);
- Atlantic halibut (*Hippoglossus hippoglossus*);
- Blue ling (*Molva dypterygia*);
- European Eel (marine part of life cycle) (*Anguilla anguilla*);
- Orange roughy (*Hoplostethus atlanticus*); and the
- Round-nose grenadier (*Coryphaenoides rupestris*).

No IUCN Red List assessment for Europe was found for the turtles, although they were considered suitable for IBSA under Indicator 1 as they qualify for individual-based protection under the Habitats Directive Annex IV as EPS (Table 6). The cod (*Gadus morhua*) and the horse mackerel (*Trachurus trachurus*) were considered ‘Vulnerable’ under a global assessment but ‘Least concern’ in Europe. Therefore, they are included in the list of those species that ‘may’ be suitable for IBSA (Table 6).

Indicator 2 - The species show K-selected life history traits.

Where estimates exist, many of the highly mobile marine species listed in Annex 1 have life spans >20 years, an estimated generation time[18] of >10 years, and most are late to reach maturity (>5 years) and so exceed the Indicator 2 cut-offs and should therefore be assessed at an individual level. For example, the maximum recorded lifespan for the sperm whale is 70+ years, the orange roughy (149 years) while the ocean quahog is 507 years (see Annex 1 for source references). Similarly, the estimated generation time of the fin whale is 25.9 years, the basking shark is 21-50 years, the orange roughy is 88 years and the ocean quahog is 83 years.

Table 6 identifies where each species does or does not meet Indicator 1 or Indicator 2 and therefore, whether or not they should be recommended for IBSA.

The age of maturity for all the cetaceans examined is greater than five years, except the harbour porpoise and perhaps the short-beaked common dolphin, while all the turtles, sharks and rays have estimated ages at maturity greater than five years, as do many of the fin-fish species.

The cetaceans, seals, turtles, sharks and rays, **stand out** in their investment in reproduction and their offspring. Cetaceans and seals are viviparous, and some shark and ray species are ovoviviparous. All the cetaceans, seals, turtles, sharks and rays exhibit internal fertilization, long gestation times (>6 months) or large yolky eggs with long development times, and produce one (rarely twins) (cetaceans and seals) or a small number of offspring (typically ≤500). In the case of the cetaceans and seals, the survival of the offspring is dependent on subsequent parental care for several months depending on the species. In

[18] Generation time = 1) the average duration of the life cycle between birth and reproduction or 2) the mean period of time between reproduction of the parent generation and the reproduction of the first filial generation (Lincoln *et al.,* 1998), or 3) “the age at which half of total reproductive output is achieved by an individual” (IUCN, 2004).

cetaceans, turtles, sharks and rays there may also be a delay between breeding periods to recover condition or wean young (in the case of cetaceans). Conversely, most fin-fish produce many thousands of eggs.

Few of the life history traits stand out as indicators alone. However, those species that are considered ‘endangered’ correlate well with a number of the life history traits selected, especially ‘age at maturity’. As expected, most of the species considered to be ‘endangered’ were K-strategists that cannot recover from exploitation or collection and fall into population decline.

Therefore, all of the cetaceans, seals, turtles, sharks and rays listed are suitable for an IBSA based on both Indicator 1 (Population status) and Indicator 2 (K-selected life history traits) as they are included under the W&C 1981 or Habitats Directive, or exhibit several of the life history characteristics selected (Table 6). In particular, age at maturity, long generation time, long gestation time, low fecundity and delayed reproduction contribute to the decision in most of the cetaceans, seals, sharks and rays. The turtles are less clear based on life history due to their fecundity that is higher than the cut-off suggested under Indicator 2.

However, the life history characteristics examined represent a short review of the characteristics that influence population recovery and do not take into account larval/juvenile mortality, recruitment, population dynamics, or restricted breeding sites such as nursery areas in fish or rivers and estuaries in anadromous fish. In addition, the cut-offs values for life history characteristics under Indicator 2 are subjective rather than definitive. Further study is required to expand and test the application of the above approach to a wider range of species than considered here.

A list of seven species that **may be suitable** for IBSA is provided in Table 6. The cod is included as it is considered ‘Vulnerable’ globally but only ‘Least concern’ in Europe (IUCN, 2019). However, the remaining species may be suitable due to their late age at maturity (> 5 yrs.). In addition, the horse mackerel and saithe have a long generation time (>10 years). Further information on the population dynamics and life histories of these species and their current population status is required before recommending them for IBSA.

5.2 Suggested individual-based approach

Two things determine the sensitivity of an individual to a pressure. Firstly, the organism’s ability to resist that pressure either physiologically or behaviourally (tolerance), whilst at the same time depending on the capacity of the organism to recover from an altered state once the pressure has been removed (recoverability) (Tillin *et al.,* 2010; Perez-Dominguez *et al.,* 2016; Tyler-Walters *et al.,* 2018).

When assessing sensitivity at an individual level, no tolerance (None) of an individual to a pressure (at the defined pressure benchmark) will result in the mortality of the individual, a condition from which, of course, there is no recovery, no matter how short the exposure time to the pressure. This means that any assessment of no tolerance (None), has to be combined with an assessment of no recoverability (None), and always leads to an assessment of ‘High’ sensitivity.

A variety of sub-lethal effects are also possible for individuals with a tolerance to the pressure. These include direct physical injury, increased energy expenditure, increased vulnerability to predation (in some species) and effects on reproductive capacity.

Following review of the tolerance and recovery categories used in previous sensitivity assessments, and incorporating experience from environmental impact and assessment work, the definitions proposed for assessing the tolerance of individuals of highly mobile species are provided in Table 7.

Table 7. Proposed tolerance scale to incorporate into FeAST for assessing individual highly mobile species sensitivity to pressures.

Tolerance	Description
None	**Mortality** of the individual
Low	**Significant** sub-lethal effects: Behavioural response resulting in e.g. **significantly** increased energy expenditure, **significantly** reduced food intake, **significant** increase in susceptibility to disease or **significant** increased vulnerability to predation. Physical impairment with **significant** energetic or health consequences. **Likely** effects on fertility rate. **Possible effects** on probability of individual survival.
Medium	Behavioural response resulting in **some** increased energy expenditure, **some** reduced food intake, **some** increase in susceptibility to disease or **some** increased vulnerability to predation. **Possible** effects on fertility rate. **Unlikely to affect** the probability of individual survival.
High	Behavioural response resulting in **little** increased energy expenditure, **little** reduced food intake, **little** increase in susceptibility to disease or **little** increased vulnerability to predation. No significant change to the reproductive rate of the individual. No impact on probability of individual survival.

Consideration was given to the different recovery scales that are available for the different methods. The MB0102 resilience (recovery) scale was based on the Robinson *et al.* (2009) recovery scale as amended by the experts consulted during the MB0102 project. Both FeAST and MarESA adopted this MB0102 resilience/recovery scale (Table 8).

Table 8. Assessment scale for resilience (recovery) currently used in MB0102, MarESA and FeAST.

Resilience/Recovery	Description
Very low	Negligible or prolonged recovery possible; at least 25 years to recover structure and function.
Low	Full recovery within 10-25 years.
Medium	Full recovery within 2-10 years.
High	Full recovery within 2 years.

The HMSS approach created another scale for resilience (recovery) but Perez-Dominguez *et al.* (2016) note that their scale was arbitrary, based on the reporting schedule for Natural England site monitoring (see Section 3). In the absence of evidence to the contrary, we have adopted the existing FeAST/MarESA recovery/resilience scale within the individual-based approach but with minor amendments to reflect the recovery of the individual rather than the population (Table 9).

The proposed tolerance scale should then be combined with the amended version of the existing FeAST recovery scale (Table 9) using the matrix (Table 10) in order to categorise the overall sensitivity of an individual to a pressure.

Table 9. Proposed recovery scale to incorporate into FeAST for assessing individual highly mobile species sensitivity to pressures (amended from that currently used in the FeAST tool).

Recovery	Description
Very Low / None	Negligible or prolonged recovery possible. At least 25 years to recover fertility and survival rates to pre-impact level.
Low	Full recovery of fertility and probability of survival to pre-impact level within 10 - 25 years.
Medium	Full recovery of fertility and probability of survival to pre-impact level between 2 - 10 years.
High	Full recovery of fertility and probability of survival to pre-impact level within 2 years.

Table 10. The proposed matrix used to combine tolerance and recovery scores to categorise sensitivity (amended from that currently used in the FeAST tool).

	Tolerance			
Recovery	None	Low	Medium	High
Very Low / None	High	High	Medium	Low
Low	(blank)	High	Medium	Low
Medium	(blank)	Medium	Medium	Low
High	(blank)	Low	Low	Not Sensitive

The existing FeAST sensitivity matrix was also amended because a tolerance score of 'None' has been defined as mortality, from which there is 'no possible' recovery. Therefore, all pressures to which the individual has a tolerance of 'None', result in a recovery score of 'None' and an overall 'High' sensitivity score (Table 10). As no other recovery scores are possible in this scenario (i.e. Tolerance is 'None'), the remaining fields in the matrix are left blank.

However, the existing FeAST definitions and scoring of confidence in the sensitivity assessment (Table 11) and evidence sources (Table 12) were adopted, to maintain consistency with the existing tool. The existing definition of 'Not assessed' was also retained.

Table 11. The sensitivity confidence scores currently used in the FeAST tool.

Confidence	Description
High	There is good information on the sensitivity of the feature to the relevant pressure. The assessment is well supported by the scientific literature.
Medium	There is some specific evidence or good proxy information on the sensitivity of the feature to the relevant pressure.
Low	There is limited or no specific or suitable proxy information on the sensitivity of the feature to the relevant pressure. The assessment is based largely on expert judgement.

It is important to note that the definitions for tolerance and recovery outlined in Table 7 and Table 9 do not match the draft UK DPCS since the FeAST tool has a four level approach to tolerance (None, Low, Medium and High), as well as recovery (Very low/None, Low, Medium and High) while the draft UK DPCS defines sensitivity on three levels (Low, Medium, High) directly, rather than basing it on a matrix of tolerance and recovery. Both approaches consider the effect of a pressure on the survival and fecundity and thus the fitness of an individual in the assessment of sensitivity but in slightly different ways. Therefore, there is the possibility that the resulting sensitivity score to the same pressure may differ between the FeAST and draft UK DPCS assessment approaches.

Table 12. The evidence scores currently used in the FeAST tool.

ID	Evidence Score	Description
1	Directly relevant peer reviewed literature	Evidence concerning the sensitivity of the feature to a given pressure has been used from published source and reviewed by scientists working in the same field e.g. a scientific journal.
2	Directly relevant grey literature	Published sources but generally not reviewed by external experts e.g. Government reports.
3	Inference from studies on comparable habitats species, gears or geographical areas	Evidence from comparable studies have been used to infer the likely effects using e.g. studies from similar features, or the same feature in other countries waters.
4	Expert judgement	Published evidence is not thought to be available, and so expert judgement has been used to make an assessment.

6. PRESSURE AND BENCHMARK REVIEW FOR MARINE MAMMALS AND BASKING SHARKS

Six of the existing pressures in the FeAST tool were scoped out as being 'not assessed' for all cetaceans, seals and basking sharks in Scottish waters. The reasoning for not assessing these pressures is outlined in Table 13. In addition, the pressures that were identified as having no direct impact on cetaceans, seals or basking sharks but which could have an indirect impact on prey species are highlighted in Table 13. We suggest that these indirect pressures are assessed separately under a new pressure 'Reduction in prey' (see Section 7). The scoping of existing pressures and benchmarks should be carried out for each mobile species individually when conducting an assessment, as the relevant pressures will vary on a species-by-species basis.

For the most part, the pressure descriptions/benchmarks that currently exist in the FeAST tool were considered to be applicable to highly mobile species. There were a few exceptions where it was judged that the pressure description/benchmark needed altering slightly for highly mobile species and, on the advice of the PSG, some extra pressures were added. These are summarised here and in Annex 2:

- the current description for 'Barrier to species movement' states that it is applicable to cetaceans, basking shark and black guillemot only – however this pressure will also impact seal species and other highly mobile species, therefore the specific species groups were removed from the description;
- the current description for 'Electromagnetic changes' states that it is applicable to basking shark and common skate only – however some fish species and invertebrates have been shown to respond to electromagnetic fields (EMF) and therefore the specific species were removed from the description;
- the current description for 'Introduction of microbial pathogens' states that it is applicable to native oysters only and specifies two particular pathogens. Since highly mobile species are susceptible to a variety of pathogens and diseases, this description was adapted to be more general;
- the pressure 'Physical loss' was amended so that it was not specific to a particular habitat type and included 'exclusion of species' from that habitat;
- the description of 'Removal of target species (lethal)' was amended slightly to specify that it did not include bycatch;
- the benchmark for the pressure 'Underwater noise' was amended to combine the EU Commission Decision on criteria and methodological standards on good environmental status of marine waters[19] with the temporal element of the MarESA definition;
- the benchmark for the pressure 'Visual disturbance' was amended to match that in MarESA;
- the previous pressure of visual disturbance was divided into 'Visual Disturbance' (see above) and a new pressure of 'Introduction of Light' with the benchmark descriptor taken from MarESA;
- a new pressure of 'Marine litter' was added;
- a new pressure of 'Reduction in prey' was added (see section 7 below);
- a new pressure called 'Radionuclides' was added, with the benchmark descriptor taken from MarESA;
- a new pressure called 'Introduction of Other Substances (Solid, Liquid or Gas)' was added, with the benchmark descriptor taken from MarESA.

The contaminant pressures e.g. 'Non-synthetic compounds' and 'Synthetic compounds' have benchmarks set at 'compliance with all relevant environmental quality standards'. As a

[19] https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2010:232:0014:0024:EN:PDF

result, all species are technically considered to be ‘Not sensitive at the benchmark level’. However, this interpretation does not take into account the possibility of accidental spills or other pollution incidents. It also does not take into account the possibility of bioaccumulation of contaminants up the food chain in top predators, such as most cetaceans. Also, we note that FeAST labels species and habitats as ‘Sensitive’ to ‘contaminant’ pressures but does not ‘rank’ the ‘sensitivity’. Therefore, we have applied the individual-based assessment to each of these pressures based on the available evidence of the effects of contaminants on each of the pilot species tested.

Table 13. Pressures scoped out or considered as having indirect effects on prey for marine mammals and basking sharks.

Pressure name	**Cetaceans**	**Seals**	**Basking shark**	**Justification**
De-oxygenation	Change to prey	Change to prey	Change to prey	Cetaceans and seals are air breathing mammals that breathe at the surface. Consequently, oxygen concentration of the water has not been assessed for these species. In-direct changes to some prey species may occur – but those are considered separately under that specific pressure.
Electromagnetic changes	Change to prey	Change to prey	Unknown	There is no evidence of local electro-magnetic changes having an impact on cetaceans or seals. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure. Basking shark are an exception, and are attracted to electromagnetic fields but no evidence of adverse effects has been found, at present. Basking shark and other sharks and rays warrant assessment.
Emergence regime changes - local	None	None	None	The pressure description specifies Intertidal species only, which does not include marine mammals and basking sharks. Cetaceans and basking sharks are not reliant on the intertidal zone, at any point in their life-history stages, and a change in the exposure period of this zone will not have any impact. Seal species do utilise the intertidal zone for hauling out at low tide, however the benchmark of a change in 1 mm in the high water level will not impact on haul out availability to seals.
Genetic modification & translocation of indigenous species	None	None	None	The pressure description specifies aquaculture species only, and this does not include marine mammals or basking sharks. Since these species are not being reared in an aquaculture environment, there is no risk of translocation or introduction of captive reared juveniles via this mechanism for basking sharks or marine mammals.
Introduction or spread of non-indigenous species & translocations (competition)	Change to prey	Change to prey	Change to prey	Marine mammals and basking sharks regularly make long movements, to other territorial waters and other water bodies. This is not considered as an issue for these species directly. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.
Nitrogen & phosphorus enrichment	Change to prey	Change to prey	Change to prey	Cetaceans and seals are air breathing mammals that breathe at the surface. Consequently, nitrogen and phosphorous concentration of the water has not been assessed for these species. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure. Basking shark and other sharks and rays will probably avoid areas of nutrient or organic enrichment.

Pressure name	Cetaceans	Seals	Basking shark	Justification
Organic enrichment	Change to prey	Change to prey	Change to prey	Cetaceans and seals are air breathing mammals that breathe at the surface. Consequently, levels of siltation and dissolved organic matter in the water has not been assessed for these species directly. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure. Basking shark and other sharks and rays will probably avoid areas of nutrient or organic enrichment.
Physical change (to another seabed type)	Change to prey	Change to prey	Change to prey	Cetaceans, seals and basking sharks are highly mobile, pelagic organisms that are not linked to a particular seabed type. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.
Physical removal (extraction of substratum)	Change to prey	Change to prey	Change to prey	Cetaceans, seals and basking sharks are highly mobile, pelagic organisms that are not linked to a particular seabed type and do not utilise the sediment. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.
Removal of target species (lethal)	None	Direct Impact	None	Removal of target species for basking sharks and cetaceans is strictly prohibited under the EU Habitats Directive (cetaceans) and the Wildlife and Countryside Act (basking sharks). Whilst exposure to this pressure would result in death of the individual, the pressure does not exist in UK waters, and so it has not been assessed for cetaceans and basking sharks.
Siltation changes (low)	Change to prey	Change to prey	Change to prey	Cetaceans, seals and basking sharks are highly mobile, pelagic organisms that are not linked to a particular seabed type and do not utilise the sediment. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.
Sub-surface abrasion/ penetration	None	None	None	The pressure description specifies species living within the seabed. Marine mammals and basking sharks are pelagic species which make use of the water column, but not the seabed.
Surface abrasion	None	None	None	The pressure description specifies species living within the seabed. Marine mammals and basking sharks are pelagic species which make use of the water column, but not the seabed.
Water flow (tidal current) changes - local	Change to prey	Direct impact	Change to prey	Cetaceans and basking sharks are highly mobile species which regularly encounter a range of tidal flows across their known species ranges. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.

Pressure name	Cetaceans	Seals	Basking shark	Justification
Wave exposure changes - local	Change to prey	Direct Impact	Change to prey	Cetaceans and basking sharks are pelagic species which are not customarily inhabiting the zone affected by wave height. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.
Siltation changes (high)	Change to prey	Change to prey	Change to prey	Cetaceans, seals and basking sharks are highly mobile, pelagic organisms that are not linked to a particular seabed type and do not utilise the sediment. In-direct changes to some prey species may occur – but those are considered separately under a separate pressure.

7. INDIRECT EFFECTS: REDUCTION IN PREY

Highly mobile species are sensitive to impacts on their resources (prey species / key habitat such as seal haul-out sites) as well as to direct impacts on their behaviour and physiology. Unlike many of the other pressures, these indirect pressures are ones that they may not be able to avoid by moving to a new location.

The HMSS approach uses an *a priori* screening process to exclude pressures where no direct effect pathway is likely to exist, based on the functional group of the species in question.

For mobile species, pressures such as, 'emergence regime changes', 'physical change to another seabed type' and 'surface abrasion' are not going to have a direct impact (as detailed in Table 13). However, it is possible that they will have an indirect impact via changes in the availability of prey.

The mechanisms by which these indirect effects may occur are myriad and complicated. Many highly mobile species may be generalist feeders, able to exploit a wide variety of food resources, with different diet preferences being exhibited in different parts of their range, for example, harbour seals (Tollit & Thomson, 1996, and Wilson & Hammond (in review)). However, others may be quite specialised and feed on only one or two key prey species (e.g. basking shark, see Sims & Quayle, 1998). Even generalist mobile species that are able to exploit a certain species as prey in one part of its range may not necessarily do so in an alternative location. There may be different levels of geographically local specialisms (e.g. Santos & Pierce, 2003), age specific specialisms and local prey preferences (e.g. Spitz *et al.,* 2012) and it is unclear how these would be affected in cases of removal of prey species.

Whilst there are few examples where any marine mammal species is reliant on single prey species, it is not necessarily true that marine mammals will thrive eating any prey types in sufficient quantities. Differences in the quality of prey are likely to be as important to marine mammal species as the quantity of prey (Spitz *et al.*, 2012). Consequently, indirect effects are likely to be complex and potentially difficult to assess using typical sensitivity assessment methodologies.

Conducting a species-specific sensitivity assessment for each of the prey species known to be exploited by the five priority species (Annex 3) identified for this contract will require time and expertise outside that available for this report. The impact on these priority species may also vary by season and location. Therefore, the proposed approach is to add 'Reduction in prey' as a direct pressure in its own right. The 'loss of critical habitat' is addressed under the existing pressure 'Physical loss', which has been amended to include 'exclusion from habitat'. Once the assessments for the various prey species have been completed, it is envisaged that the FeAST tool can link to those with the highest importance for highly mobile species to provide additional context.

8. WORKED PILOT EXAMPLES

Annex 4 and Annex 5 provide the full draft individual-based species sensitivity assessment for both Risso's dolphins and harbour seals.

Prior to conducting the assessment, there was concern that assessing on an individual level would result in a binary assessment for the vast majority of impacts, where the result was either no impact, or death. However, the suggested individual-based approach, resulted in a range of different sensitivities.

In the example, Risso's dolphin was assessed as being highly sensitive to:

- 'Death of injury to mobile species by collision';
- 'Introduction of pathogens (disease)';
- 'Contamination (both synthetic and organic pollutants)';
- 'Removal of non-target species (bycatch)', and
- 'Marine litter'.

These are pressures that, in a worst case scenario, have the potential to result directly in the death of an individual, from which there is no possible recovery.

Harbour seals were found to be highly sensitive to a similar list of pressures but with the addition of high sensitivity to deliberate 'Removal of target species'.

Assessing on an individual level was found to simplify the assessment of tolerance. It was often very straightforward to assess whether an individual was likely to suffer injury or mortality from an impact. The suggested approach does not take the likelihood of the impact occurring into account at any point. Many of the pressures to which the assessed species are highly sensitive may be very unlikely to have a population level impact, due to the low likelihood of the pressure occurring.

The existing FeAST recovery (Table 9), confidence (Table 11), and evidence (Table 12) scales were also found to be applicable in the examples examined.

9. OVERALL CONCLUSIONS AND DISCUSSION

The primary motivation for the project was the difficulty in applying sensitivity assessment methods, especially the tolerance/resistance scale, to Highly Mobile Species and especially cetaceans in the absence of information on the existing local population size in any particular study area.

- Existing approaches to Sensitivity Assessment, including FeAST, MarESA and HMS Sensitivity (HMSS) entail the estimation of changes in population expressed as a percentage of the existing population. They assess the sensitivity of a hypothetical population and are not site-specific.
- For many highly mobile species there is little or no information available on the population either at a local level or at the scale of the relevant management units, against which to assess impacts.
- This review of pressures and benchmarks identified 17 pressures that could be excluded from the assessment for marine mammals and basking sharks, because they were unlikely to cause a direct impact.
- Most of the remaining 11 FeAST pressures were felt to be applicable to highly mobile species. However, minor amendments were made to eight benchmarks and pressure definitions to make them more applicable to cetaceans, in particular.
- 'Reduction in prey' was added to the list of pressures as the most practical approach to dealing with the potential effects of numerous activities on prey availability.
- 'Marine litter', 'Introduction of other substances (solid, liquid, gas)', 'Radionuclides' and 'Introduction of light' were also added to the list of pressures.
- The 'Contaminants' pressure benchmarks do not take into account accidental spills nor bioaccumulation. Therefore, we have assessed the 'contaminant' pressures based on what we expect levels in the environment to be, notwithstanding accidental spills etc. .
- It was difficult to define, categorically, when it is most appropriate to use an individual-based rather than population-based approach to sensitivity assessment. Accordingly, two sets of indicators were identified which tended to favour such an approach.
- We suggest that Individual-based Sensitivity Assessment (IBSA) should be applied in species where the loss of a single individual (or small number of individuals) has the potential to affect the survival of the population adversely or where legislation protecting the species is implemented on an individual level. Such species are likely to be K-strategists that are slow to reproduce with a long lifespan, slow growth rates, late reproduction, high parental investment in their young, low fecundity and, probably, small population sizes.
- We identified those species with legislative protection at an individual level, in Scotland, from criteria and species lists set out in the Wildlife and Countryside Act (W&C) 1981, the Habitats Directive and the Marine (Scotland) Act 2010.
- All the cetaceans, seals, marine reptiles, sharks and rays listed under W&C 1981 and as European Protected Species would be suitable for IBSA using this approach, together with the otter and notable fin-fish, i.e. the Atlantic sturgeon, Allis shad, Twaite shad and European river lamprey.
- In addition, the sharks and rays listed as mobile PMFs are also suitable, together with the Atlantic halibut, blue ling, European eel, orange roughy, and round-nose grenadier. A list of another seven fin-fish requires further consideration. The remaining fin-fish listed as PMFs are probably not suitable under our suggested indicators.
- However, the life history characteristics examined represent a short review of the characteristics that influence population recovery and do not take into account larval/juvenile mortality, recruitment, population dynamics, or restricted breeding sites such as nursery areas in fish or rivers and estuaries in anadromous fish. In addition, the cut-off values for life history characteristics are subjective rather than definitive.

- Further study is required to expand and test the application of the above approach to a wider range of species than considered here.
- It is worth examining the few sedentary invertebrate PMFs to see if they are suitable for IBSA (e.g. the fan mussel, and the ocean quahog).
- An individual-based tolerance scale is suggested. We avoided a binary scale (dead/alive) and suggested a scale from 'dead' through different levels of impairments due to physical injury and behavioural changes.
- We slightly amended the existing FeAST recovery scale to emphasize its application to the recovery of individuals rather than that of populations.
- The FeAST sensitivity matrix was also amended slightly to highlight the fact that no recovery was possible from direct mortality.
- The existing FeAST scales for 'confidence' and 'evidence' were adopted.
- The suggested IBSA approach was tested on two pilot species: Risso's dolphin and harbour seal. Contrary to initial concerns, the suggested scales did not result in binary scores, that is, just mortality or no mortality. Both pilot assessments gave a range of scores for tolerance, recovery and, hence, sensitivity.
- Risso's dolphin was assessed as being highly sensitive to collision; pathogens, contamination (both synthetic and organic pollutants); removal of non-target species (bycatch), and marine litter. These were all pressures that, in a worst case scenario, had the potential to result directly in the death of an individual from which there is no possible recovery.
- The harbour seal was assessed to be highly sensitive to the same list of pressures but with the addition of high sensitivity to deliberate 'removal of target species'.
- Assessing on an individual level was found to simplify the assessment of tolerance. It was often very straightforward to assess whether an individual was likely to suffer injury or mortality from an impact.
- The suggested individual-based approach does not take the likelihood of the impact occurring or the extent of the impact into account at any point. Many of the pressures to which the assessed species are highly sensitive may be very unlikely to have a population level impact, due to their low likelihood of occurrence.
- It should also be noted that the revision of benchmarks and scales for highly mobile species in FeAST means that the resultant sensitivity assessment will differ from those generated under the MarESA and HMSS approaches, and that their sensitivity scores for the same species will not be directly comparable.

Overall, the suggested Individual-based Sensitivity Assessment (IBSA) approach was used successfully to assess the sensitivity of two highly mobile species. More species need to be assessed to test the approach fully and to develop examples and guidance on the application of the individual-based tolerance scale to other highly mobile species.

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ANNEX 1: SPECIES TRAITS

List of selected traits for the priority species, the Annex 2 species identified in the project specification and selected long-lived invertebrates. The data presented was collated from readily available online resources (MarLIN[20], FishBase[21], Shark trust[22] (factsheets), Encyclopaedia of Life[23] the IUCN Red list[24], the NOAA Fisheries Species Directory[25], SCANS III[26] and the Encyclopaedia of Marine Mammals (Würsig et al., 2017) and does not take local or regional variation into account. The maximum lifespan is recorded, although the typical lifespan may be lower. Age at maturity is presented as a range of min. to max. values for males and females or from different sources. Fecundity is also presented as a range of min. to max. values from different sources. Indicator cut-offs are shaded as follows: lifespan (max) >20 years, generation time >10 years, fecundity ~<100, age at maturity >5 years, and gestation time >6 months.

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
Cetacean	Atlantic white-sided dolphin	*Lagenorhynchus acutus*	2.7	27		Internal	1	6-12	viviparous	11	2,187 all SCANS III survey blocks	
	Bottlenose dolphin	*Tursiops truncatus*	4	57		Internal	1	9	viviparous	12	195 Coastal East Scotland MU 45 Coastal West Scotland and the Hebrides MU[27] 19,201 all SCANS III survey blocks	

[20] MarLIN (Marine Life Information Network) – www.marlin.ac.uk
[21] FishBase – www.fishbase.org
[22] Shark Trust factsheets - https://www.sharktrust.org/en/factsheets
[23] Encyclopaedia of Life (EoL) - https://eol.org
[24] IUCN Red list - www.iucnredlist.org
[25] https://www.fisheries.noaa.gov/species-directory
[26] Hammond *et al.*, (2017)
[27] IAMMWG (2015)

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
	Fin whale	*Balaenoptera physalus*	22.5	80-90	25.9	Internal	1	6-8	viviparous	11	79,000 N. Atlantic	
	Harbour porpoise	*Phocoena phocoena*	2	>20		Internal	1	5	viviparous	11	345,373 North Sea MU 424,245 all SCANS III survey blocks	Calve once/ years
	Killer whale	*Orcinus orca*	9	F:80-90 M: 50-60		Internal	1	12-14	viviparous	15-18	50,000 Global	
	Long-finned pilot whale	*Globicephala melas*	6.3	F: >60 M: 45	?	Internal	1	8-12	viviparous	12-16	5,121 all SCANS III survey blocks	Calve once / 3-6 years.
	Minke whale	*Balaenoptera acutorostrata*	10.7	50	23	Internal	1	9	viviparous	10	13,101 all SCANS III survey blocks	Calve once/v year
	Northern bottlenose whale	*Hyperoodon ampullatus*	9.8	37+		Internal	1	7-11	viviparous	12	40,000 NEA	
	Risso's dolphin	*Grampus griseus*	4.3	35		Internal	1	8-12	viviparous	12	11,069 all SCANS III survey blocks	Calve once / 2.4 years.
	Short-beaked common dolphin	*Delphinus delphis*	2.6	30		Internal	1	2-12	viviparous	11.5	268,540 all SCANS III survey blocks	Calve once/ 1-3 years.

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
	Sowerby's beaked whale	*Mesoplodon bidens*	5.5	Unknown but long-lived		Internal	1	7	viviparous	12	Unknown	
	Sperm whale	*Physeter macrocephalus*	20.5	>50	27.3 / 27.5	Internal	1	9	viviparous	14-16	100,000s Global	
	White-beaked dolphin	*Lagenorhynchus albirostris*	3	Unknown but long-lived		Internal	1	7-12	viviparous		36,287 all SCANS III survey blocks	Calve once/ 4-20 years
Seals	Common or harbour seal	*Phoca vitulina*	2	20-30		Internal	1	4	viviparous	10.5 (incl. delayed implantation)	315,000 global; 60-65,000 Atlantic 43,500 in the UK in 2016[28]	Calve once/ years; Specific breeding areas (haul-out)
	Grey seal	*Halichoerus grypus*	2.3	F: >30 M: >20		Internal	1	5	viviparous	12 (incl. delayed implantation)	110,000 UK; 2,000 Ireland 141,000 in the UK in 201628	Calve once/ year; Specific breeding areas (haul-out)
	Harp seal	*Pagophilus groenlandicus*	1.8	30	15.7	Internal	1	4-8	viviparous	11.5 (incl. delayed implantation)	7.5 million in the Northwest Atlantic stock	Calve once/ year; Specific breeding areas (haul-out)

[28] Special Committee on Seals (SCOS, 2017)

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
Mammal	Eurasian otter	*Lutra lutra*	1.1	17	7.6	Internal	1-5	1.5-2	viviparous	63-65 days	10,395 (UK, 2004)	
Reptiles	Green turtle	*Chelonia mydas*	1.2	>60	35.5-49.5	Internal	2-5 (clutches) of 80-120	26-40	oviparous	60 day	Decreasing	Reproduce once every 2-4 years.
	Hawksbill turtle	*Eretmochelys imbricata*	0.9	Unknown but long-lived	35-45	Internal	2-5 clutches of eggs per season of 120-200 eggs per clutch	20-40	oviparous	60 day	Decreasing	Reproduce every 2-4 years
	Kemp's Ridley turtle	*Lepidocelys kempii*	0.7	Unknown but long-lived	?	Internal	1-3 clutches of 90-130 eggs per clutch	10-15	oviparous	60 day	?	Reproduce every 1-3 years
	Leatherback turtle	*Dermochelys coria cea*	1.8	Unknown but long-lived	?	Internal	4-7 clutches of 50-90 eggs per clutch	26-32?	oviparous	60 day	Decreasing	Reproduce every 2-4 years
	Loggerhead turtle	*Caretta caretta*	1.0	Unknown but long-lived	Up to 45	Internal	2-5 clutches of 80-120 eggs per clutch	20-30	oviparous	60 day	36,000-67,000 nesting females, global, estimated	Reproduce every 2-4 years

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
Sharks & rays	Basking shark	*Cetorhinus maximus*	12	21-100	21-50	Internal	2-10	12-20	ovoviviparous	12-42	?	Rest 2-3 years between mating
	Common Skate	*Dipturus batis*	3	21-100	10-20	Internal	Up to 40 eggs	11	oviparous	2-5 (egg)	?	Spawn annually every second year
	Leafscale gulper shark	*Centrophorus squamosus*	1.64	70	?	Internal	5-8 young in a litter	?	ovoviviparous	?	Decreasing	
	Porbeagle shark	*Lamna nasus*	3.65	30		Internal	1-5 pups	5-18	ovoviviparous	8-9	?	Reproduce annually
	Portuguese dogfish	*Centroscymnus coelolepis*	1.2	60	37.5	Internal	8-19 pups	ca 15	ovoviviparous	?	?	
	Sandy ray	*Leucoraja circularis*	1.2	12	9.7	Internal	?	?	oviparous	?	?	Life history poorly understood
	Spiny dogfish	*Squalus acanthias*	1.6	75	25-35	Internal	1-21 pups	7-15	ovoviviparous	18-24	100,000-600,000 NEA, in 2000	
	Thornback ray	*Raja clavata*	1.05	15	11-20	Internal	48-150 eggs	5-9	oviparous	?	?	Annual spawning
Fin-fish	Allis shad	*Alosa alosa*	0.8	10	?	External	50,000-600,000	2-9	oviparous	4-8 days	Unknown	Anadromous
	Anglerfish	*Lophius piscatorius*	2	24	?	External	1 M + over eggs	6-14	oviparous	?	?	

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
	Atlantic cod	*Gadus morhua*	2	25		External	2.5-9M eggs	2-15	oviparous	?	catch ca >1M tons	
	Atlantic halibut	*Hippoglossus hippoglossus*	4.7	50	?	External	1.3-3.5M eggs	7-11	oviparous	?	?	
	Atlantic herring	*Clupea harengus*	0.45	25	?	External	10,000-60,000 eggs	2-9	oviparous	3 weeks	SSB = 199,610 tons - catch	Limited/ traditional spawning grounds
	Atlantic mackerel	*Scomber scombrus*	0.6	18	3.5/6.5	External	155,000 - 1.98M eggs	1-3	oviparous	?	527-572K tons - catch	
	Atlantic salmon	*Salmo salar*	1.5	13	6	External	8-25K eggs	3-10	oviparous	?	ca 3.6 M Europe	Specific breeding areas (rivers)
	Atlantic sturgeon	*Acipenser sturio*	0.6	100	?	External	2K-2.5M	7-20	oviparous	?	20-750 adults in wild (IUCN)	Spawning – males every 2 years, females every 3-4 years.
	Black scabbardfish	*Aphanopus carbo*	1.5	?	?	External	?	3	oviparous	?	?	Limited spawning/nursery grounds
	Blue ling	*Molva dypterygia*	1.5	20	12.4	External	?	8-11	oviparous	?	18-19 M ICES 2013	
	Blue whiting	*Micromesistius poutassou*	0.55	20		External	6,000-150,000 eggs	2-7	oviparous	?	?	

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
	Eel (European)	*Anguilla anguilla*	1.33	88	2-50	External	2-3 M eggs	5-20	oviparous		Catch only	Die after spawning
	European river lamprey	*Lampetra fluviatilis*	0.5	10	?	External	650-42,500 eggs	4-9	oviparous	?	?	Die after spawning
	Greenland halibut	*Reinhardtius hippoglossoides*	1.1	30	13	External	5,800-300,000 eggs	7-12	oviparous	several months		
	Horse mackerel	*Trachurus trachurus*	0.7	40	11-18	External	12,700-860,000 eggs	2.5-4	oviparous	?	SSB = 0.84 M tons - catch	
	Lesser sandeel	*Ammodytes marinus*	0.25	10	3.8	External	2,700-25,000	1-3	oviparous	1-2 (egg)	?	Habitat dependent, annual spawning
	Ling	*Molva molva*	2	25	8-12	External	20-60M eggs	5-6	oviparous	?	TAC 2,428 in North Sea	Specific spawning/nursery grounds
	Norway pout	*Trisopterus esmarkii*	0.35	5		External	27,000-374,000 eggs	1-2	oviparous	?	?	Short life span, variable recruitment
	Orange roughy	*Hoplostethus atlanticus*	0.75	149	88	External	10,000-350,000	5-32	oviparous	?	?	Grows very slowly (IUCN)
	Round-nose grenadier	*Coryphaenoides rupestris*	1.1	54	30-37	External	2,489-68,780	9-11	oviparous	?	SSB=40,000 2010 Scotland	slow-growing, long-lived (IUCN) / batch spawner, 4000-70,000/batch

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
	Saithe	*Pollachius virens*	1.3	25	7-13	External	220,000 - 8.9M	4-10	oviparous	?	?	forms large aggregations
	Sand goby	*Pomatoschistus minutus*	0.1	3	1-2	External	2,383-5,603	0.7-1	oviparous	10 days (egg)	"common" European Atlantic	Nests, guarding
	Sea lamprey	*Petromyzon marinus*	1.2	11	?	External	152-304k eggs	5-12	oviparous	?	"unknown but large"	Larval life span = up to 5 years.
	Sea trout	*Salmo trutta*	1.4	38	?	External	120 - 10,000 eggs	1-6	oviparous	?	"abundant"	Spawn for 2-3 seasons
	Small sandeels	*Ammodytes tobiannus*	0.2	7	?	External	?	2-3	oviparous	?	?	Habitat dependent, annual spawning
	Sparling / European smelt	*Osmerus eperlanus*	0.45	10	?	External	6,500-50,000 eggs	1-2/3-4	oviparous	?	"abundant"	Most die after spawning
	Twaite shad	*Alosa fallax*	0.6	25	?	External	?	2-7	oviparous	2-8 days	Stable	Anadromous
	Whiting	*Merlangius merlangus*	0.9	20	5-6	External	83,900-1M eggs	1-4	oviparous	?	e.g. ca 621,00 tons (catch) North Sea +Eastern Channel	

Group	Common name	Species name	Body size (max) (m)	Lifespan (max) (years.)	Generation time (years.)	Fertilization	Fecundity (no. eggs or litter size)	Age at maturity (range) (years.)	Breeding type	Gestation (or egg development) (mo.)	IUCN/SCANS population estimate	Notes
Invertebrate	European spiny lobster	*Palinurus elphas*	0.2	25	9 [29]	External	23,000-202,000	4-5 (♀)	oviparous	2-8 days	Decreasing	Poor recruitment / 30+ year
	Icelandic cyprine / ocean quahog	*Arctica islandica*	0.13	507+	ca 83	External	unknown >10,000	5-15	oviparous	?	?	
	Horse mussel	*Modiolus modiolus*	0.2	50+	5-10	External	ca 1M	3-8	oviparous	?	?	
	Fan mussel	*Atrina fragilis*	0.48	32	?	External	?	?	oviparous	?	?	
	The tall sea pen	*Funiculina quadrangularis*	2.1	15-40	?	External	40K?	5-6?	oviparous	?	?	

[29] IUCN estimate

ANNEX 2: BENCHMARKS

The following table presents the list of pressures considered to have a direct impact on marine mammals and other highly mobile species. Impacts that are likely to have an indirect effect, for example through reduction in prey availability (e.g. physical change to seabed type) are not considered here. Instead, a specific pressure for reduction in prey availability has been included as a proxy for the indirect effects. All suggested changes to the existing FeAST benchmarks are in red text.

ID	Pressure name	Cetaceans	Seals	Basking shark	Pressure Description
1	Barrier to mobile species movement	Direct Impact	Direct Impact	Direct Impact	~~Cetaceans, basking shark and black guillemot only -~~ The physical obstruction of species movements including local movements (within & between roosting, breeding, feeding areas) and regional/global migrations (e.g. birds, eels, salmon, whales). Includes up river movements (where tidal barrages & devices or dams could obstruct movements) or movements across open waters (offshore wind farm, wave or tidal device arrays, mariculture infrastructure or fixed fishing gears). It is acknowledged that aquaculture and fixed fishing gears represent very low scale barriers. Note: entanglement is included under 'Removal of non-target species' pressure.
2	Death or injury to mobile species by collision	Direct Impact	Direct Impact	Direct Impact	Mobile species only - Injury or mortality from collisions of biota with both static &/or moving structures. Examples include: collision with rigs (e.g. birds) or screens in intake pipes (e.g. fish at power stations) (static) or collisions with wind turbine blades, fish & mammal collisions with tidal devices and activities involving shipping (moving).
3	De-oxygenation	Change to prey	Change to prey	Change to prey	Pressure refers to water column de-oxygenation, and is closely related to the N and P enrichment pressure. However, the water column immediately above the sea bed can have lower oxygen levels than the general water column, and this is closely linked to the 'Organic enrichment' and 'Siltation pressures'. Compliance with WFD criteria for good status. In offshore waters oxygen status can be assumed to be high as there are no significant pressures. For fully saline waters, the WFD standard for good status is 4mg/l, compared to a suggested level of 5mg/l in WQTAG 088e. However, all fully saline waters already meet high status (>5.7mg/l). Within estuaries, the WFD standard for good status is 5-(0.028xsalinity) compared to a suggested level of 6-(0.028xsalinity) in WQTAG088e. The latter standard is more precautionary as it also seeks to protect migratory fish, which are likely to be the most sensitive element. Note1: where deoxygenation is being considered for features present within estuaries or in relation to mobile species, additional consideration should be given. Note 2: Assume existing EQS will ensure Not Sensitive unless evidence to suggest otherwise, however if the standards were breached then this pressure would need to be reconsidered.

ID	Pressure name	Cetaceans	Seals	Basking shark	Pressure Description
4	Electromagnetic changes	Change to prey	Change to prey	Unknown	~~Basking shark and common skate only -~~ Local electric field of 1 volt per meter; Local magnetic field of 10 tesla (µT).
5	Emergence regime changes - local	None	None	None	Intertidal species only - A 1 hour change in the time covered or not covered by the sea for a period of 1 year. 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.
6	Genetic modification & translocation of indigenous species	None	None	None	Aquaculture species only - Translocation outside of geographic area or introduction of hatchery-reared juveniles outside of geographic area from which adult stock derives. Note that issues of salmon or halibut escapes are not included as these do not pose any impacts on MPA protected features.
7	Introduction of microbial pathogens (disease)	Direct Impact	Direct Impact	Unknown	~~Applicable to native oysters and habitats with native oysters only - The introduction of microbial pathogens Bonamia and Martelia refringens to an area where they are currently not present.~~ Diseases (pathogens or parasites) reported to result in significant effects to species of interest.
8	Introduction or spread of non-indigenous species & translocations (competition)	Change to prey	Change to prey	Change to prey	A significant pathway exists for introduction of one or more Invasive non-indigenous species (INS). Hyperlink to Annex I gives details of the INS considered.
9	Nitrogen & phosphorus enrichment	Change to prey	Change to prey	Change to prey	Compliance with WFD criteria for good status. Ideally, the pressure would be assessed in terms of increases in nutrient loading over background. However, such information is not readily available. As a surrogate, it could be possible to use information from WFD and CEMP assessments in relation to winter concentrations of DIN (a measure of state) and compare these to WFD standards and status classification outputs. Note: closely linked with de-oxygenation pressure.
10	Non-synthetic compound contamination (inc. heavy metals, hydrocarbons, produced water,)	Direct Impact	Direct Impact	Unknown	Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls. Water column annual average (AA) environmental quality standards (EQS) provide high levels of protection for all living organisms. Canadian interim sediment quality guidelines (ISQG) Probable Effects Levels (PELs) provide an indication of sediment risks. OSPAR Environmental Assessment Criteria (EACs) and Effects Range- Low (ER-Ls) criteria provide guidelines for sediment risks. There are also some OSPAR EACs for biota.

ID	Pressure name	Cetaceans	Seals	Basking shark	Pressure Description
11	Organic enrichment	Change to prey	Change to prey	Change to prey	A deposit of 100 gC/m2/yr. This pressure is referring to particulate organic matter and is therefore closely associated with the Siltation pressures. Dissolved organic matter is not covered directly by other pressures, but N and P enrichment pressure addresses the key enrichment factors.
12	Physical change (to another seabed type)	Change to prey	Change to prey	Change to prey	The permanent change of one marine habitat type to another marine habitat type, through the change in substratum. For instance a change from sediment to solid substrate including artificial (e.g. concrete mattresses, rock dumping, and moorings), or from one type of sediment to another. This pressure concerns disposal or the deposit of material, whilst the removal of material is covered under abrasion pressures.
13	Physical loss of or exclusion from habitat ~~(to land or freshwater habitat)~~	Direct Impact	Direct Impact	Direct Impact	Permanent loss of or exclusion from existing marine habitat ~~e.g. from coastal defence and land reclaim~~. Coastal features assumed to be highly sensitive to loss of their habitat.
14	Physical removal (extraction of substratum)	Change to prey	Change to prey	Change to prey	Extraction of sediment to 30 cm
16	Removal of non-target species (lethal)	Direct Impact	Direct Impact	Direct Impact	Removal of features through pursuit of a target fishery at a commercial scale, or through entanglement with nets or ropes e.g. aquaculture nets or mooring lines.
17	Removal of target species (lethal)	None	Direct Impact	None	Removal of target species that are features of conservation importance or sub-features of habitats of conservation importance at a commercial scale. The species under assessment is the 'targeted' species. Bycatch is assessed under 'non-targeted' removal.
18	Salinity changes - local	Change to prey	Change to prey	Change to prey	Increase from 35 to 38 units for one year or decrease in salinity by 4-10 units for a year.
19	Siltation changes (low)	Change to prey	Change to prey	Change to prey	5 cm of fine material added to the seabed in a single event, or the deposition of fine material over the lifetime of the development.
20	Sub-surface abrasion/penetration:	None	None	None	Damage to species living within the seabed. For geological/geomorphological features, the pressure relates to the indirect removal of surface sediment via accelerated flow (e.g. from scour around foundations or from propeller jets) or penetration by structures/equipment (e.g. fishing gear)

ID	Pressure name	Cetaceans	Seals	Basking shark	Pressure Description
21	Surface abrasion	None	None	None	Damage to species living on the seabed or damage to geological and geomorphological structures at the seabed surface
22	Synthetic compound contamination (inc. pesticides, antifoulants, pharmaceuticals)	Direct Impact	Direct Impact	Unknown	"Compliance with all AA EQS, conformance with PELs, EACs, ER-Ls. Water column annual average (AA) environmental quality standards (EQS) provide high levels of protection for all living organisms. Canadian interim sediment quality guidelines (ISQG) Probable Effects Levels (PELs) provide an indication of sediment risks. OSPAR Environmental Assessment Criteria (EACs) and Effects Range- Low (ER-Ls) criteria provide guidelines for sediment risks. There are also some OSPAR EACs for biota.
23	Temperature changes - national	Change to prey	Change to prey	Change to prey	1.5-4ºC change in sea temperature by 2100 (from UK Climate Impacts Project 2009 predictions).
24	Temperature changes - local	Change to prey	Change to prey	Change to prey	A 5ºC change in sea temperature for a one month period, or 2ºC for one year e.g. from thermal discharges
25	Underwater noise	Direct Impact	Direct Impact	None	Over 20% of days within a calendar year, over 20% of the habitat occupied by the individual, in which anthropogenic sound sources exceed levels that elicit a response from an individual, in terms of movement away, or cessation of feeding (for disturbance) or exposure which leads to auditory injury.
27	Water clarity changes	None	None	None	A change in one rank on the WFD scale, e.g. from clear to turbid for one year (ranks are mean suspended particulate matter in units of mg/c: >300 - very turbid; 100-300 - medium turbidity; 10-100 - intermediate; <10 - clear.)
28	Water flow (tidal current) changes - local	Change to prey	Change to prey	Change to prey	Peak mean spring tide flow change between 0.1 m/s to 0.2 m/s over an area >1 km^2 or 50% of width of water body for > 1 year
29	Wave exposure changes - local	Change to prey	Change to prey	Change to prey	A change in mean annual nearshore significant wave height >3% but <5% (sig wave ht =the average height of the highest one third of waves. This considers wind fetch, wind strength, duration of wind, and topography; generally significant wave height is <1.2 m but can be up to 3 m around UK coast
31	Siltation changes (high)	Change to prey	Change to prey	Change to prey	30 cm of fine material added to the seabed in a single event or the deposition of fine material over the lifetime of the development.

ID	Pressure name	Cetaceans	Seals	Basking shark	Pressure Description
37	Visual Disturbance	Direct Impact	Direct Impact	None	Daily duration of transient visual cues exceeds 10% of the period of site occupancy by the feature. The disturbance of biota by anthropogenic activities, e.g. increased vessel movements, such as during construction phases for new infrastructure (bridges, cranes, port buildings etc.), increased personnel movements, increased tourism, increased vehicular movements on shore etc. disturbing bird roosting areas, seal haul out areas etc. Note, in some instances it may be difficult to disentangle visual disturbance from underwater noise. For example, disturbance by vessels may be as a result of the physical presence of the vessel itself and/or the underwater noise that the vessel produces.
##	Marine litter	Direct Impact	Direct Impact	Direct Impact	Introduction of man-made objects able to cause physical harm (surface, water column, sea floor and/or strandline).
##	Reduction in prey	Direct Impact	Direct Impact	Direct Impact	Reduction in prey availability due to effects of other pressures on prey species.
##	Radionuclides	Direct Impact	Direct Impact	Direct Impact	An increase in 10 µGy/h above background levels. Introduction of radionuclide material, raising levels above background concentrations. Such materials can come from nuclear installation discharges, and from land or sea-based operations (e.g. 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 ship's crew is 10 µSv or less in a year; (ii) the collective effective dose to the public or ship's crew is not more than 1 man Sv per annum. The individual dose criteria are placed in perspective (i.e. very low), given that the average background dose to the UK population is ~2700 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.
##	Introduction of Light	Change to prey	Direct Impact	Change to prey	Direct inputs of light from anthropogenic activities, i.e. lighting on structures during construction or operation to allow 24 hour working; new tourist facilities, e.g. promenade or pier lighting, lighting on oil & gas facilities etc. Ecological effects may be the diversion of bird species from migration routes if they are disorientated by or attracted to the lights. It is also possible that continuous lighting may lead to increased algal growth.
##	Introduction of Other Substances (Solid, Liquid or Gas)	Direct Impact	Direct Impact	Direct Impact	Compliance with all AA EQS, conformance with PELs, EACs/ER-Ls. The 'systematic or intentional release of liquids, gases ' (from MSFD Annex III Table 2) is considered e.g. in relation to produced water from the oil industry. It should, therefore, be considered in parallel with the other chemical contaminants.

ANNEX 3: PREY SPECIES

Prey species known to be utilised by the five priority species: Risso's dolphin, minke whale, basking shark, harbour porpoise and bottlenose dolphin.

Priority Species: **Risso's dolphin (*Grampus griseus*)**			
Identified prey species	**Common name**	**Geographical location**	**Reference**
Sepia spp.	Cuttlefish	Bay of Biscay	Spitz *et al.*, 2011
Octopodidae spp.	Octopus spp.	Bay of Biscay	Spitz *et al.*, 2011
Eledone cirrhosa	Benthic octopus	UK waters	MacLeod *et al.*, 2014
Todarodes sagittatus	Flying squid	Faroe Islands	Bloch *et al.*, 2012
		UK waters	Clarke & Pascoe, 1985; Zonfrillo *et al.*, 1988 (both cited in Bloch *et al.* 2012)
Loligo forbesi	Veined squid	Faroe Islands	Bloch *et al.*, 2012
Todaropsis eblanae	Demersal lesser flying squid	Faroe Islands	Bloch *et al.*, 2012
		UK waters	Clarke & Pascoe, 1985 (cited in Bloch *et al.* 2012)
Octopus vulgaris	Common octopus	Galician Coast	Santos *et al.*, 1994 (cited in Bloch *et al.* 2012)
Sepia officianalis	Common cuttlefish	UK waters	Clarke & Pascoe, 1985 (cited in Bloch *et al.* 2012)
Loligo sp.	Myopsid squid spp.	Bay of Biscay	Desportes, 1985 (cited in Bloch *et al.* 2012)
Loligo vulgaris	European squid	Galician Coast	Santos *et al.*, 1994 (cited in Bloch *et al.* 2012)
Illex coindetii	Broadtail shortfin squid	Galician Coast	Santos *et al.*, 1994 (cited in Bloch *et al.* 2012)
Ommastrephidae	Squid spp.	Galician coast	Santos *et al.*, 1994 (cited in Bloch *et al.* 2012)
Gonatus steenstrupii	Gonatus squid	UK waters	Zonfrillo *et al.*, 1988 (cited in Bloch *et al.* 2012)

Priority Species: **Minke whale (*Balaenoptera acutorostrata*)**			
Identified prey species	**Common name**	**Geographical location**	**Reference**
Ammodytidae	Sandeels	Information from animals stranded in Scotland	Pierce *et al.*, 2004
		North Sea	Olsen & Holst, 2001.
		Iceland	
Clupea harengus	Herring	Information from animals stranded in Scotland	Pierce *et al.*, 2004
		Northern Norway	Skaug *et al.*, 1997; Sivertsen *et al.*, 2006, Olsen & Holst, 2001.

		North Sea	Olsen & Holst, 2001.
		Iceland	
Sprattus sprattus	Spratt	Information from animals stranded in Scotland	Pierce *et al.*, 2004
		North Sea	Olsen & Holst, 2001.
Scomber scombrus	Mackerel	Information from animals stranded in Scotland	Pierce *et al.*, 2004
		North Sea	Olsen & Holst, 2001.
Trisoterus spp.	Norway pout and / or poor cod	Information from animals stranded in Scotland	Pierce *et al.*, 2004
Gobiidae	Gobies	Information from animals stranded in Scotland	Pierce *et al.*, 2004
Mallotus villosus	Capelin	Northern Norway	Skaug *et al.*, 1997; Sivertsen *et al.*, 2006
Thysanoessa sp	Krill	Northern Norway	Skaug *et al.*, 1997; Sivertsen *et al.*, 2006
Gadus morhua	Cod	Northern Norway	Skaug *et al.*, 1997
Melanogrammus aeglefinus	Haddock	North Sea	Olsen & Holst, 2001.
		Iceland	Vikingsson *et al.*, 2014

Priority Species: **Basking shark (*Cetorhinus maximus*)**

Identified prey species	**Common name**	**Geographical location**	**Reference**
Calanus helgolandicus	Copepod	UK waters	Sims and Merrett, 1997
Calanus finmarchicus	Copepod	UK waters	Sims and Merrett, 1997
Pseudocalanus elongatus	Copepod	UK waters	Sims and Merrett, 1997
Temora longocornis	Copepod	UK waters	Sims and Merrett, 1997
Centropages typicus	Copepod	UK waters	Sims and Merrett, 1997
Acartia clause	Copepod	UK waters	Sims and Merrett, 1997
Euphausiid species	Krill	UK waters	Speedie & Johnson, 2008

Priority Species: **Bottlenose dolphin (*Tursiops truncatus*)**

Identified prey species	**Common name**	**Geographical location**	**Reference**
Cepola macrophthalma	Red bandfish	Northeast Atlantic	Spitz *et al.*, 2006.
Clupea harengus	Herring	Scotland	Santos *et al.*, 2001
Crangon crangon	Brown shrimp	Northeast Atlantic	Spitz *et al.*, 2006.
Dicentrarchus labrax	Sea bass	Northeast Atlantic	Spitz *et al.*, 2006.
Engraulis encrasicolus	European Anchovy	Northeast Atlantic	Spitz *et al.*, 2006.
Gadus morhua	Cod	UK	Santos *et al.*, 2001
Melanogrammus aeglefinus	Haddock	UK	Santos *et al.*, 2001
Merluccius merluccius	Hake	Northeast Atlantic	Spitz *et al.*, 2006.
Merlangius merlangus	Whiting	Scotland	Santos *et al.*, 2001
Pollarchius vurens	Saithe	Scotland	Santos *et al.*, 2001
Salmo salar	Atlantic salmon	Scotland	Santos *et al.*, 2001
Sardina pilchardus	Sardine	Northeast Atlantic	Spitz *et al.*, 2006.
Spondyliosoma cantharus	Sea bream	Northeast Atlantic	Spitz *et al.*, 2006.
Mugilidae	Mullets	Northeast Atlantic	Spitz *et al.*, 2006.

Trisopterus luscus	Pout	Northeast Atlantic	Spitz *et al.*, 2006.
Sprattus sprattus	Spratt	Scotland	Santos *et al.*, 2001
Molva molva	Ling	Scotland	Santos *et al.*, 2001
Myoxocephalus Scorpius	Bull-rout	Scotland	Santos *et al.*, 2001
Taurulus bubalis	Sea scorpion	Scotland	Santos *et al.*, 2001
Tracharus tracharus	Scad	Scotland	Santos *et al.*, 2001
Pleuronectes platessa	Plaice	Scotland	Santos *et al.*, 2001
Limanda limanda	Dab	Scotland	Santos *et al.*, 2001
Hippoglossoides plalessoides	Long rough dab	Scotland	Santos *et al.*, 2001

Priority Species: **Harbour porpoise (*Phocoena phocoena*)**

Identified prey species	**Common name**	**Geographical location**	**Reference**
Clupea harengus	Herring	UK	Santos *et al.*, 2006
Merlangius merlangus	Whiting	UK	Santos *et al.*, 2006
Sardina pilchardus	Sardine	Northeast Atlantic	Spitz *et al.*, 2006
Trachurus trachurus	Scads	Northeast Atlantic	Spitz *et al.*, 2006
Ammodytidae	Sandeels	UK	Santos *et al.*, 2006
Gobiidae	Gobies	Northeast Atlantic	Santos *et al.*, 2006 Spitz *et al.*, 2006
Meganyctiphanes norvegica	Northern krill	Northeast Atlantic	Spitz *et al.*, 2006
various	Shrimps	UK	Santos *et al.*, 2006
Sprattus sprattus	Spratt	UK	Santos *et al.*, 2006

ANNEX 4: RISSO'S DOLPHIN INDIVIDUAL-BASED SENSITIVITY ASSESSMENT

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Barrier to mobile species movement	Physical barriers could potentially prevent/inhibit the ability of individuals to reach foraging areas. Risso's dolphins are a widespread and wide-ranging species, however, and do not appear to have specific feeding grounds or migration routes. Hence, they are not thought to be sensitive on an individual basis to barriers to movement.	High	High	Not sensitive	Low	4 (expert judgement)
Death or injury to mobile species by collision	Whilst the likelihood of collision of an individual Risso's dolphin with either a tidal turbine blade or ship propeller is low, such a collision could well prove to be fatal, resulting in mortality from either blunt trauma or propeller wounds (Andersen, *et al*. 2002). Large, slow moving marine mammals are thought to be those most at risk from collision with large ships, but jet-skis and other small craft are known to cause injuries to at least 26 different species of small cetaceans (Van Waerebeek *et al.*, 2007). Not all of these injuries are fatal, with likelihood of mortality depending on the severity and location of the injuries (Wells *et al.* 2008), however small cetacean mortality is known to result from injuries caused by collision (e.g. bottlenose dolphins (Byard *et al*., 2012), so this possible outcome cannot be discounted.	None	None	High	Medium	3 (inference from proxy sp.)
De-oxygenation	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Electromagnetic changes	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Emergence regime changes – local	Not assessed as a direct impact to Risso's dolphins.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Genetic modification & translocation of indigenous species	Not assessed as a direct impact to Risso's dolphins.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Introduction of pathogens (disease)	There are a wide variety of pathogens that infect cetaceans. These may be both specific (e.g. morbillivirus, and papillomavirus) or opportunistic (bacteria / fungi) (Van Bressem et al. 2009). The ability of an animal to recover will depend on the pathogen, the severity of the infection and the overall health of the animal. However, in many of the cases listed above, diseases were thought	None	None	High	Medium	1 (direct evidence)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	to be the cause of death (Van Bressem *et al.*, 2009). Emerging infectious diseases (EIDs) (Bengis *et al.*, 2004) is the term for newly recognised diseases or those which may be showing an increase or changes, perhaps due to modification in host / pathogen ecology which may have been influenced by anthropogenic factors. The most significant EIDs for cetaceans are thought to be *Morbillivirus*, *Herpesvirus*, *Brucella ceti* and *Toxoplasma gondii* (Mazzariol *et al*., 2018). Risso's dolphins do not regularly occur as part of mass stranding events and are relatively infrequently recorded as stranded individuals. Hence, diseases in this species are not often studied. However, stranded animals have been found with evidence of parasitic infection (e.g. Cornaglia *et al.,* 2000, Zucca *et al.,* 2005), toxoplasmosis (Resendes *et al.,* 2002), bacterial infection linked to fatal haemorrhagic-necrotizing pneumonia and sepsis in a stranded neonate Risso's dolphin (Pérez *et al.,* 2015) and two different strains of cetacean morbillivirus (Sierra *et al.,* 2018). Recoverability from these pathogens is unknown, but in stranded animals it is often the suspected cause of death.					
Introduction or spread of non-indigenous species & translocations (competition)	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Nitrogen & phosphorus enrichment	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Non-synthetic compound contamination (inc. heavy metals, hydrocarbons, produced water)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species. Even so, indicative scores for tolerance, recovery and sensitivity are provided, along with supporting evidence, to inform situations where, for example, EQS may be exceeded, compounds are accidentally spilled or where bio-accumulation occurs.* Dolphins are known to accumulate extremely high levels of heavy metals through the food chain. Due to the lack of stranded animals of this	None	None	High	Medium	3 (inference from proxy sp)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	species, there are fewer examples for Risso's dolphin than for other dolphin species, however examples of Risso's dolphins stranding with extremely high levels of mercury in the liver, lung, kidney and muscle do exist, with levels high enough to cause damage (e.g. Storelli *et al.*, 1999, Capelli *et al.*, 2008). Evidence for contaminant accumulation in the UK population of Risso's dolphins is currently limited (Marine Scotland, 2018). Severe exposure to non-synthetic compounds may occur as a result of oil spills. The most serious acute health threat for cetaceans is thought to be respiratory damage via the inhalation of highly toxic aromatic compounds of oil (Helm *et al.,* 2015). They will likely also aspirate, ingest, and/or adsorb oil (Takeshita *et al*., 2017). The oil spill from Deepwater Horizon caused mortality, adverse health effects and reproductive failure in bottlenose dolphins (Kellar *et al.,* 2017, McDonald *et al.,* 2017, Schwacke *et al.,* 2017, Smith *et al.,* 2017). Although the likelihood of encountering an oil slick in UK waters is low, the likely result of encountering one is death of an individual. This pressure has been given a tolerance and recovery score of 'None'.					
Organic enrichment	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Physical change (to another seabed type)	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Physical loss of or exclusion from habitat	There is a lack of information on how short-term displacement/exclusion from habitat may manifest in terms of effects on individual fitness. For example, it could be assumed that the displacement/exclusion of an animal from a foraging area could result in increased energy expenditure to move away in addition to decreased foraging opportunities if the animal is displaced to an area that is of lower quality for foraging. The amount of displacement that is required to impact an animal's fitness is unknown, however, as Risso's dolphins are widespread, wide-ranging and do not have specific feeding grounds, coupled with the fact that they are able to store reserves in their blubber in order to compensate for short term changes in food intake; it is likely that they would be able to compensate for exclusion from a foraging	High	High	Not Sensitive	Low	4 (expert judgement)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	area by moving to another area. It is likely that this would incur only a little increased energy expenditure, and a little reduced food intake with no significant change to the reproductive rate or probability of individual survival. Risso's dolphins are a widespread and wide-ranging species and do not appear to have specific feeding grounds or migration routes. Hence, they are not thought to be sensitive on an individual basis to loss of or exclusion from habitat. (Please note that 'Reduction in prey' is assessed as a separate pressure).					
Physical removal (extraction of substratum)	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Removal of non-target species (lethal)	Risso's dolphins have been recorded as accidental catch, but not frequently (Deaville & Jepson, 2011; Northridge *et al.,* 2013). If caught, the result for an individual is highly likely to be mortality, rendering this species highly sensitive to non-targeted removal at an individual level. There are also likely to be sublethal effects from bycatch for individuals who survive, including the potential for behavioural alterations, physiological and energetic costs, and associated reductions in feeding, growth, or reproduction (Wilson *et al.,* 2014).	None	None	High	Medium	1 (direct evidence)
Removal of target species (lethal)	Not assessed as a direct impact to Risso's dolphins.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Salinity changes - local	There does not appear to be any published literature on the salinity preferences of Risso's dolphins. However, they are regularly sighted in the Mediterranean Sea (e.g. Bearzi *et al.,* 2011), which routinely has a recorded salinity of 38 ppt. As Risso's dolphins are more routinely sighted in deeper waters (200-1000 m, Hartman, 2018), records and information regarding their presence in estuarine or other low salinity habitats are limited. Consequently, the physiological impacts of low salinity waters on this species is unknown. Even in the event of local changes, it is not anticipated that this species would encounter these in its more offshore environment. In the event it does, other dolphin species are known to survive in estuarine environments, and bottlenose dolphins are found in waters with salinity as low as 11 ppt (Hornsby	High	High	Not sensitive	Low	4 (expert judgement)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	et al., 2017). Consequently, it is not expected that the local salinity changes described by this benchmark are likely to have a direct effect on individual Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).					
Siltation changes (low)	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Sub-surface abrasion/penetration	Not assessed as a direct impact to Risso's dolphins.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Surface abrasion	Not assessed as a direct impact to Risso's dolphins.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Synthetic compound contamination (inc. pesticides, antifoulants, pharmaceuticals)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species. Even so, indicative scores for tolerance, recovery and sensitivity are provided, along with supporting evidence, to inform situations where, for example, EQS may be exceeded, compounds are accidentally spilled or where bio-accumulation occurs*. Species specific information for Risso's dolphin in the Atlantic area is lacking. However, studies of the common dolphin have shown the bioaccumulation of synthetic compounds (e.g. Borrell *et al.*, 2001), although it is not clear what implications these may have in terms of individual survival (e.g. Rotander *et al.,* 2012), or what levels may be considered toxic (Ross *et al.,* 2000). In some populations of bottlenose dolphins, health concerns have been linked with PCB exposure (Schwacke *et al.*, 2011). Females typically have lower levels than males, suggesting that contaminant burden may be transferred during lactation. Studies from Japan showed that Risso's dolphins accumulate Butyltin trichloride (BT) in the liver and that there was no difference between males and females, which suggests that BTs were less transferable to offspring than other organochlorine compounds (Kim *et al.* 1996). Varying levels of PCBs and PCB metabolites have been documented in the blubber of Risso's dolphins in the Irish Sea (Troisi *et al.*, 1998).	Low	Low	High	Med	1 (direct evidence)
Temperature changes - national	Risso's dolphins prefer waters of 12˚C or warmer, and are not found in polar regions (Hartman, 2018). A 1.5-4˚C change in sea temperature described by this benchmark is unlikely to have a	High	High	Not sensitive	Medium	1 (direct evidence)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	direct effect on individual Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).					
Temperature changes – local	Risso's dolphins prefer waters of 12˚C or warmer, and are not found in polar regions (Hartman, 2018). A 5˚C change in sea temperature for a 1 month period (or 2˚C for one year) described by this benchmark is unlikely to have a direct effect on individual Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	High	High	Not sensitive	Medium	1 (direct evidence)
Underwater noise	There are a wide variety of sources of underwater noise including, for example: vessel noise, dredging activity, pile driving, seismic activity, acoustic deterrent devices and explosives. Marine mammals use sound for a variety of reasons (foraging, orientation and navigation, communication, detection and predator avoidance) and are therefore potentially susceptible to elevated levels of anthropogenic noise. Extremely high levels of noise can cause physical damage as a result of barotrauma, due to a high intensity of noise within a short period of time. Elevated anthropogenic noise can cause physical damage to the hearing systems of marine mammals, in addition to disrupting normal behaviour and masking auditory cues used for foraging, navigation and communication. There is limited empirical data available to confidently predict the extent to which animals may experience auditory damage although there is a growing evidence base to support predicted behavioural responses to noise. It is likely that factors other than noise levels alone will also influence the probability of response and the strength of response (e.g. previous experience, behavioural and physiological context, proximity to activities, characteristics of the sound other than level, such as duty cycle and pulse characteristics). There is also a lack of information on how observed effects (e.g. short-term displacement) manifest themselves in terms of effects on individual fitness. For example, it could be assumed that the displacement of an animal from a foraging area could result in increased energy expenditure to move away, in addition to decreased foraging opportunities if the animal is displaced to an area that is of lower quality for foraging. This could ultimately result in a reduction in energy gain which has the potential to lead	Medium	Medium	Medium	Medium	3 (inference from proxy sp)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	to reductions in fecundity. However, the amount of disturbance and displacement that is required to impact an animal's fitness is unknown. While there is a lack of information on the responses of Risso's dolphins to the various underwater noise sources, there is evidence in other dolphin species of responses to various noise sources. For example: pingers/ADDs (e.g. Sparling *et al.,* 2015), vessel activity (e.g. New *et al.,* 2013), pile driving (e.g. Brandt *et al.,* 2011, Dähne *et al.,* 2013, Brandt *et al.,* 2016), dredging (e.g. Pirotta *et al.,* 2013), seismic activity (e.g. Stone *et al.,* 2006) etc. In the absence of species-specific information on responses to different noise sources, it is expected that Risso's dolphins will respond in a similar way to other cetaceans such as bottlenose dolphins. Guidelines on the thresholds for temporary and permanent threshold shift (TTS and PTS) in mid-frequency cetaceans are available for both impulsive sounds (such as drilling or shipping) and non-impulsive noise sources (such as pile driving or controlled explosions of UXOs) (NMFS, 2018).					
Water clarity changes	Increased turbidity, or loss of water clarity may impact the visual range at which prey can be detected. Risso's dolphins routinely feed at depths where light levels are low, and like all odontocetes are able to use echolocation to locate prey. There is no evidence in the literature that turbidity has a negative impact on cetaceans' ability to forage effectively (Todd *et al.*, 2014)	High	High	Not sensitive	Low	4 (expert judgement)
Water flow (tidal current) changes - local	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Wave exposure changes - local	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Siltation changes (high)	Not assessed as a direct impact to Risso's dolphins. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Visual Disturbance	Disturbance of cetaceans from small boats, including tourist and other recreational boats, has been well documented, although how much this is associated with acoustic disturbance versus other forms of disturbance is unclear (e.g. Neumann & Orams, 2006; Bejder *et al.*, 2006; Stockin *et al.*, 2008). Risso's dolphins have been shown to spend significantly less time resting and socializing when in the presence of whale watching vessels, which has the potential to have negative impacts on the build-up of energy reserves and on reproductive success (Visser *et al.* 2011). In an incident in the Central Mediterranean, harassment of Risso's dolphins from pleasure boaters has been documented as resulting in high-speed erratic swimming, collisions with each other, spinning and swimming in circles with short inter-blow intervals all of which suggest signs of distress (Miragliuolo *et al.,* 2004).	Medium	Medium	Medium	High	1 (direct evidence)
Marine litter	Like all marine organisms, Risso's dolphins are susceptible to marine litter, which may be ingested or may cause the individual to become entangled. As a species which primarily feeds on cephalopods such as squid or octopus, Risso's dolphins are perhaps more susceptible to ingesting macro-plastics than other species as plastic bags may be ingested when mistaken for squid. Stranded Risso's dolphins have been found with plastic bags in their stomachs (e.g. Shoham-Frider *et al.,* 2002; Bearzi *et al.,* 2011). Direct mortality to cetacean species has been documented as a result of obstruction of the digestive tract by ingested plastic (Bearzi *et al.,* 2011). Plastic ingestion may not always directly result in the death of the individual but may contribute to overall poor condition and continuing deterioration over time if the individual is not able to offload the plastic burden through excretion (as evidenced by the presence of plastic in the intestines of cetaceans (Nelms *et al.,* 2019).	None	None	High	Medium	1 (direct evidence)

Pressure	Justification/Evidence	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Reduction in prey	Throughout their range Risso's dolphins feed on cephalopods such as squid or octopus. In Scottish waters they are thought to feed primarily on one species, the curled octopus (*Eledone cirrhosa)* (Pierce *et al.,* 2007). Hence, any changes in availability of this species in Scottish waters is likely to have a considerable impact on the survival of individuals.	Low	Medium	Medium	Low	4 (expert judgement)
Radionuclides	*This pressure is not assessed but the following summary of evidence is provided for information.* There is a lack of species-specific information available on the effects of radionuclides on Risso's dolphins. However, studies on other species have all shown that marine mammals do accumulate radionuclides, particularly in their muscles (Born *et al.,* 2002). However, whilst its presence in marine mammals is well documented, it is not known what the long-term effects of these contaminants might be, hence there is insufficient evidence to conduct an assessment.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Introduction of Light	Numerous studies with captive animals have shown that dolphins have excellent vision, and so are certainly physically able to perceive visual changes. From the structure, it appears that the cetacean eye is highly sensitive to light, although likely to lack colour vision (Griebel & Peichl, 2003). However, there is no evidence in the literature that Risso's dolphins are disturbed by the introduction of light or other visual factors. Prey species of Risso's dolphins (primarily squid) are known to be attracted to light, so there may be some alterations to prey. (Please note that 'Reduction in prey' is assessed as a separate pressure).	High	High	Not sensitive	Low	4 (expert judgement)
Introduction of Other Substances (Solid, Liquid or Gas)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species.* No information on the effects of produced waters, or similar contaminant sources was found. Therefore, there was not enough evidence on which to base an assessment.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed

ANNEX 5: HARBOUR SEAL INDIVIDUAL-BASED SENSITIVITY ASSESSMENT

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Barrier to mobile species movement	Physical barriers could potentially prevent/inhibit the ability of individuals to reach foraging areas, pupping areas, or haul-out areas. Telemetry studies of harbour seals at a tidal turbine in Northern Island (Sparling *et al.,* 2017) have demonstrated that a single tidal turbine does not cause a barrier to movement but that animals did avoid the immediate vicinity of the operational turbine. Telemetry studies (Russell *et al.,* 2016) have also shown that whilst harbour seals will avoid an offshore windfarm during pile-driving construction, displacement was limited to piling activity; and within 2 hours of cessation of pile driving the seals were distributed as per the non-piling scenario. There was no evidence of avoidance of the windfarm once operational, and data have been collected that show grid-like patterns of movement of tagged harbour seals within operational wind farms, which suggest that these structures were used for foraging and the directed movements show that animals could effectively navigate to and between structures (Russell *et al.,* 2014). Harbour seals can exhibit high levels of site fidelity when hauling out (Härkönen & Harding, 2001), and so obstruction of a preferred haul-out site may have deleterious effects upon an individual.	Medium	High	Low	Medium	1 (direct evidence)
Death or injury to mobile species by collision	Pinnipeds are known to succumb to collision with vessels, particularly smaller boats which may move in a more erratic manner (Costidis *et al.,* 2013), however the number of individuals affected is unknown. Telemetry studies have shown that some harbour seals display a certain level of avoidance of operational tidal turbines, thus reducing their risk of collision. This has been seen at an operational tidal turbine (e.g. Sparling *et al.,* 2017; Joy *et al.,* 2018) and, as a result of acoustic playbacks of tidal turbine sound (Hastie *et al.,* 2018). Whilst the likelihood of collision of an individual harbour seal with either a tidal turbine blade or ship propeller is low, there is the potential for a collision to be fatal. However, field trials using grey seal carcasses (Thompson *et al.,* 2015; Onoufriou *et al.*, 2019) have shown that slow speed collisions with the tips of tidal turbines (<5.1 m/s) are unlikely to produce serious or fatal injuries in grey seals. Therefore, it is	None	None	High	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	expected that a significant proportion of impacts would not be fatal, given the range of speeds tested and the speeds with which wild seals will be exposed to when interacting with tidal turbines. To date similar data for harbour seals are not available.					
De-oxygenation	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Electromagnetic changes	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Emergence regime changes – local	Not assessed as a direct impact to Harbour seals.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Genetic modification & translocation of indigenous species	Not assessed as a direct impact to Harbour seals.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Introduction of pathogens (disease)	Harbour seals are susceptible to Phocine Distemper Virus (PDV), which is caused by a morbillivirus and has been responsible for two mass mortalities of this species in the UK, one in 1988 and one in 2002 (Härkönen *et al.,* 2006). A different, as-yet unknown, virus was also responsible for a mass mortality of harbour seals in Danish and Swedish waters in 2007 (Härkönen *et al.,* 2008). The Influenza A virus was responsible for mass mortality events in 1979-80 and 1982 in Cape Cod, Massachusetts, US (Siebert *et al.*, 2010). Other smaller mortality events in the US have been linked to the bacteria *Erysipelothrix rhusiopathiae*, the *Orthopoxvirus* and the bacteria *Pseudomonas aeruginosa* (Siebert *et al.*, 2010). In addition, harbour seals are also susceptible to parasitic and bacterial infection of the lungs and *Escherichia coli* and *Clostridium perfringens infections resulting in* bronchopneumonia, gastroenteritis, polyarthritis, dermatitis and septicaemia (Siebert *et al.,* 2007).	None	None	High	High	1 (direct evidence)
Introduction or spread of non-indigenous species & translocations (competition)	Not assessed as a direct impact to Harbour seals.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Nitrogen & phosphorus enrichment	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Non-synthetic compound contamination (inc. heavy metals, hydrocarbons, produced water)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species. Even so, indicative scores for tolerance, recovery and sensitivity are provided, along with supporting evidence, to inform situations where, for example, EQS may be exceeded, compounds are accidentally spilled or where bio-accumulation occurs.* Harbour seals accumulate contaminants mainly through their diet. When seals reduce their food intake during lactation, moulting and breeding, they mobilise fat stores in order to meet energy demand. Contaminants that had been stored deep in the lipid layer are then mobilised along with the fat stores, resulting in suddenly increased contaminant levels. These may also be passed to offspring via both transplacental and lactational means, potentially affecting pups at crucial stages of development (Frouin *et al.,* 2010). Mercury and cadmium have been found in seals, and accumulate strongly with age, particularly in the liver (Das *et al.,* 2003). In mammals, methylmercury toxicity is manifested primarily as central nervous system damage, including sensory and motor deficits and behavioural impairment (Das *et al.,* 2003). Known effects of heavy metal contaminants include reduced reproductive capacity (e.g. Reijnders, 1980) and immuno-suppression (e.g. Ross *et al.,* 1996), which may exacerbate susceptibility to virus infection, resulting in mass-mortality events (Van Loveren *et al.,* 2000). Severe exposure to non-synthetic compounds may occur as a result of oil spills. The most serious acute health threat for seals is thought to be respiratory damage via the inhalation of highly toxic aromatic compounds of oil, although mucous membranes, eyes, ears, external genitalia and internal organ systems exposed to oil would also be negatively affected (Helm et al. 2015). They will likely also aspirate, ingest, and/or adsorb oil (Takeshita *et al.,* 2017). Approximately 300 harbour seals were estimated to have died as a result of the *Exxon Valdez* oil spill (Frost *et al.,* 1999) so there is a direct mechanism for mortality. Although the likelihood of	None	None	High	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	encountering an oil slick in UK waters is low, the likely result of encountering one is death of an individual.					
Organic enrichment	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Physical change (to another seabed type)	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Physical loss of or exclusion from habitat	Exclusion from key habitat such as foraging areas, breeding haul-outs or resting haul-outs could affect the energetics and vital rates (survival and fertility) of individual harbour seals. There is a lack of information on how short-term displacement/exclusion for habitat may manifest in terms of effects on individual fitness. For example, it could be assumed that the displacement/exclusion of an animal from a foraging area could result in increased energy expenditure to move away in addition to decreased foraging opportunities if the animal is displaced to an area that is of lower quality for foraging. There are likely to be more sensitive times of year. For example, a recent expert elicitation on the effects of disturbance on marine mammals concluded that the main mechanism by which missed foraging events would lead to any fitness effects on individual harbour seals was if lost foraging limited the ability for an adult female to produce a pup and to lactate through the weaning period (Booth *et al.,* 2019). Harbour seals exhibit high levels of site fidelity when hauling out (Härkönen & Harding, 2001), and so obstruction or loss of a preferred haul-out site may have deleterious effects upon an individual. However, movements between haul-out sites have been observed, for example, between the Moray Firth and Orkney (Graham *et al.,* 2016), which demonstrate that harbour seals are not strictly tied to a specific site.	Medium	Medium	Medium	Medium	1 (direct evidence)
Physical removal (extraction of substratum)	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Removal of non-target species (lethal)	Studies of the Norwegian gillnet fishery revealed levels of harbour seal bycatch that were high enough to be considered unsustainable in conjunction with the local hunting quotas (Moan, 2016).	None	None	High	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	Numbers of bycaught harbour seals in the UK are thought to be much lower. Northridge *et al.* (2017) report only two bycaught harbour seals for the 2016 UK reporting period. Despite the low numbers, bycatch is likely to result in the death of the individual concerned.					
Removal of target species (lethal)	Marine Scotland issues seal management licenses to shoot harbour seals for "protection of health and welfare" of farmed fish or the "prevention of serious damage" to fisheries or fish farms (see https://www2.gov.scot/Topics/marine/Licensing/SealLicensing). Therefore, targeted removal is fatal.	None	None	High	High	1 (direct evidence)
Salinity changes - local	There does not appear to be any published literature on the salinity preferences of harbour seals. However, they are regularly found in estuarine environments covering a range of fluctuating salinity variations. Harbour seals are resident in the Baltic Sea which has a very low salinity of just 8 ppt or less. Hence, it is not expected that the local salinity changes described by this benchmark will have a direct effect on individual harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	High	High	Not sensitive	Low	4 (expert judgement)
Siltation changes (low)	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Sub-surface abrasion/penetration	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Surface abrasion	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Synthetic compound contamination (inc. pesticides, antifoulants, pharmaceuticals)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species. Even so, indicative scores for tolerance, recovery and sensitivity are provided, along with supporting evidence, to inform situations where, for example, EQS may be exceeded, compounds are accidentally spilled or where bio-accumulation occurs*. Harbour seals accumulate contaminants mainly through their diet. When	Low	Low	High	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	seals then reduce their food intake during lactation, moulting and breeding, they mobilise fat stores in order to meet energy demand. Contaminants which had been stored deep in the lipid layer are then mobilised along with the fat stores, resulting in suddenly increased contaminant levels. These may also be passed to offspring via both transplacental and lactational means, potentially affecting pups at crucial stages of development (Frouin *et al.,* 2010). Known effects of contaminants include reduced reproductive capacity (e.g. Reijnders, 1980) and immuno-suppression (e.g. de Swart *et al.,* 1996) which may exacerbate susceptibility to virus infection, resulting in mass-mortality events (Van Loveren *et al.,* 2000). There are indications that levels of thyroid hormone and vitamin A are affected in grey seal pups exposed to chronic, low-levels of PCBs and DDTs (Jenssen, 1996).					
Temperature changes - national	In other parts of the range of this species, such as the Baltic Sea, sea temperatures can vary annually from just 1˚C to 16˚C. Since they are not dependent on ice to breed and are able to withstand a 16˚C temperature differential as part of normal annual fluctuations, it is not expected that national temperature changes described by this benchmark will have a direct effect on individual harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	High	High	Not sensitive	Low	4 (expert judgement)
Temperature changes – local	In other parts of the range of this species, such as the Baltic Sea, sea temperatures can vary annually from just 1˚C to 16˚C. Since they are not dependent on ice to breed and are able to withstand a 16˚C temperature differential as part of normal annual fluctuations, it is not expected that local temperature changes described by this benchmark will have a direct effect on individual harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	High	High	Not sensitive	Low	4 (expert judgement)
Underwater noise	There are a wide variety of sources of underwater noise including, for example: vessel noise, dredging activity, pile driving, seismic activity, acoustic deterrent devices and explosives. Marine mammals use sound for a variety of reasons (foraging, orientation and navigation, communication, detection and predator avoidance) and are therefore potentially susceptible to elevated	Medium	Medium	Medium	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	levels of anthropogenic noise. Extremely high levels of noise can cause physical damage as a result of barotrauma due to high intensity of noise within a short period of time. Elevated anthropogenic noise can cause physical damage to the hearing systems of marine mammals, in addition to disrupting normal behaviour and masking auditory cues used for foraging, navigation and communication. There is limited empirical data available to confidently predict the extent to which animals may experience auditory damage, although there is a growing evidence base to support predicted behavioural responses to noise. It is likely that factors other than noise levels alone will also influence the probability of response and the strength of response (e.g. previous experience, behavioural and physiological context, proximity to activities, characteristics of the sound other than level, such as duty cycle and pulse characteristics). There is also a lack of information on how observed effects (e.g. short-term displacement) manifest themselves in terms of effects on individual fitness. For example, it could be assumed that the displacement of an animal from a foraging area could result in increased energy expenditure to move away in addition to decreased foraging opportunities if the animal is displaced to an area that is of lower quality for foraging. This could ultimately result in a reduction in energy gain which has the potential to lead to reductions in fecundity. However, the amount of disturbance and displacement that is required to impact an animal's fitness is unknown. Studies have concluded that harbour seals are displaced both at sea and from haul-out sites by pile driving (e.g. Russell *et al.*, 2016), and that seals tagged in the vicinity of pile driving were estimated to receive noise levels high enough for a Temporary Threshold Shift in hearing (TTS) (and a Permanent Threshold Shift (PTS) in some cases) (Hastie *et al.,* 2015). In addition, the spatial co-occurrence of harbour seals and vessels show that predicted cumulative sound exposure levels from vessel activities can be above TTS thresholds (Jones *et al.*, 2017). Both TTS and PTS may lead to sub-lethal effects. Harbour seals do sometimes, but not consistently, respond to acoustic deterrent devices/pingers (e.g. Harris *et al.,* 2014; Sparling *et al.,* 2015).					

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Water clarity changes	There is direct experimental evidence that the visual acuity of harbour seals is affected by increased turbidity (Weiffen *et al.*, 2006). However, it is likely that seals are also able to utilise other senses to locate prey as studies of blind grey seals have found no significant reduction in foraging ability when compared to fully-sighted con-specifics (McConnell *et al.*, 1999).	High	High	Not sensitive	Low	4 (expert judgement)
Water flow (tidal current) changes - local	In some locations, there is evidence that seals preferably forage at specific tidal states and habitat corridors where water currents can be used to ambush prey. For example, Hastie *et al.* (2015) have shown that harbour seals at Kyle Rhea (Scotland) spent a high proportion of their time around the narrowest point of the channel with more sightings of seals in the water during the flood tide. As a consequence, changes in tidal current may have a significant impact on both the hunting strategy and energy intake of individuals (e.g. Zamon, 2008). However, given their generalist diet and range of feeding methods, it is expected that they will be able to compensate from loss of foraging opportunities linked with certain water current characteristics.	Medium	High	Low	Medium	1 (direct evidence)
Wave exposure changes - local	Harbour seals usually haul-out on rocky shores or beaches to rest and give birth. Studies in Norway found that seals hauled out more during calm wind and low tide than during rough wind and high tide (Bjørge et al., 2002). There are, however, limited numbers of studies on the specific effect of wave exposure on seal haul-out locations. Schneider & Payne (1983) examined the effects of wave intensity, disturbance and wind chill on haul out behaviour of harbour seals, and found that no single factor appeared to have a pre-eminent effect, and that in likelihood, several factors were operating simultaneously to determine haulout behaviour. Montgomery *et al.* (2007), found other seals selecting haul-our sites based on other factors (proximity to prey, proximity to disturbance, substrate and proximity to deep water) rather than wave exposure, which was included in the analysis. There is a lack of information on how short-term displacement/exclusion for habitat (such as may result from increased wave exposure) may manifest in terms of effects on individual fitness. For further information, please see pressure 'Physical loss of or exclusion from habitat'.	Medium	Medium	Medium	Medium	4 (expert judgement)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Siltation changes (high)	Not assessed as a direct impact to Harbour seals. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Visual Disturbance	Studies have shown that harbour seals can be disturbed from haul-out sites by the presence of people, kayaks, canoes and small boats in the vicinity (e.g. Henry & Hammill 2001; Anderson *et al.*, 2012). Response varies depending on the time of year, with responses being less severe during the breeding season, suggesting a trade-off between the desire to flee and to maintain nursing of pups (Anderson *et al.,* 2012). Disturbance at haul-outs can result in animals fleeing the haul-out site, resulting in stampedes that can cause injuries, particularly to pups. Repeated disturbance and fleeing from haul-out sites can have energetic consequences that may negatively impact on breeding success. It is for this reason that Marine Scotland have designated 147 seal haul-outs around Scotland, under the Marine (Scotland) Act 2010, to provide additional protection for seals from intentional or reckless harassment when hauled-out to rest, moult or breed.	Medium	High	Low	Med	1 (direct evidence)
Marine litter	Like all marine organisms, harbour seals are susceptible to marine litter, which may be ingested or may cause the individual to become entangled. Macroplastics and marine debris are a recorded cause of death for harbour seals, and has been recorded as entangling animals, and being ingested. Harbour seals are known to ingest plastic, which has been found in both stomachs and intestines of autopsied seals (Rebolledo *et al.*, 2013). The long-term effects of this ingestion are unknown as all seals in this sample had died from PDV, however it will likely affect the long term health of individuals, potentially resulting in death. Microplastics have also been detected in the scats of various seal species (e.g. Donohue *et al.*, 2019; Nelms *et al.*, 2018; Eriksson, 2003) which demonstrates that at least a proportion of the microplastics consumed are able to be passed. Other injuries associated with marine debris included lesions, suppurative ulcerative dermatitis, perforation of the digestive tract, abscesses, suppurative peritonitis and septicaemia (Unger *et al.,* 2017).	Low	Low	High	High	1 (direct evidence)
Reduction in prey	Harbour seals in Scotland eat a variety of different prey species,	Medium	Medium	Medium	Medium	1 (direct

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
	including sand eels, octopus, whiting, flounder, cod, pout, saithe, plaice, gobies, dragonets and many others (Tollit & Thomson, 1996; Wilson & Hammond, 2016), although the diversity of the diet varies depending on both geographical location and time of year. Observed changes in prey are broadly consistent with both the selection of energy-rich prey and with predicted changes in the availability of preferred prey (Pierce *et al.*, 1991). Whilst seals are able to feed on a variety of species, removal or depletion of an energy-rich prey species may result in impacts to an individual.					evidence)
Radionuclides	*This pressure is not assessed but the following summary of evidence is provided for information.* Concentrations of radionuclides vary considerably depending on location and proximity to source (Yoshitome *et al.*, 2003), but marine mammals are known to accumulate levels of these over time. A study of stranded seals around the UK coast (Watson *et al.*, 1999) analysed samples for radionuclides: ^{134}Cs, ^{137}Cs, ^{238}Pu, ^{239}Pu and ^{240}Pu. Concentrations did not depend on species or gender, however they increased with body weight, and decreased with distance from Sellafield nuclear site. Levels of radiocaesium were found to be higher in the muscles than in the liver, and 3-4 times higher than found in fish. The seals were found to have concentrated radiocaesium from their environment by a factor of 300 relative to the concentration in local seawater (Watson *et al.*, 1999). The long-term effects of these burdens in seals are not known. However, whilst its presence in harbour seals is well documented, it is not known what the long-term effects of these contaminants might be, hence there is insufficient evidence to conduct an assessment.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed
Introduction of Light	Pinniped vision is adapted to function both in air and water and studies have shown that they have sharp vision in both environments (e.g. Hanke *et al.,* 2009). Harbour seals have been shown to display predator-prey relationships that are dependent on light. For example, Yurk & Trites (2000) recorded harbour seals congregating under artificial lights to eat juvenile salmonids, and noted that turning off the lights resulted in reduced predation levels. (Please note that 'Reduction in prey' is assessed as a separate pressure).	Medium	High	Low	Medium	1 (direct evidence)

Pressure	Justification	Tolerance	Recovery	Sensitivity	Confidence	Evidence
Introduction of Other Substances (Solid, Liquid or Gas)	*In practice, the benchmark for this pressure assumes compliance with all AA EQS and conformance with PELs, EACs and ER-Ls which, if achieved, will prevent harm to this species*. No information on the effects of produced waters, or similar contaminant sources was found. Therefore, there was not enough evidence on which to base an assessment.	Not Assessed	Not Assessed	Not Assessed	Not Assessed	Not Assessed

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