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Annex 2: 2018 options for monitoring UK seals

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Foreword

Yessica Griffiths and Dr Karen Webb, JNCC (2024)

This historical paper is part of an archival report series, produced between 2016 and 2018, which collectively presents options for monitoring UK marine biodiversity. These options for monitoring were evaluated at a series of workshops in 2017 and 2018, by scientific experts from the Healthy and Biologically Diverse Evidence Group (HBDSEG) and policy representatives from the four governments of the UK. The initial set of workshops provided a steer on political ambitions for monitoring specific aspects of marine biodiversity, while a final workshop garnered advice from scientific experts on the proposed monitoring across UK marine biodiversity. In 2019, the combined outcomes of these workshops formed advice for UK Governments on monitoring of UK marine biodiversity. The process for developing this advice is outlined in the summary paper (Webb *et al*. 2024).

Publication of this historical report series provides a publicly available audit of the information underpinning the 2019 advice to UK Governments on proposed marine biodiversity monitoring in UK waters. This information provides a solid foundation for developing updated future advice. At the time of publication (2024), many of the evidence gaps which have been highlighted remain and, in some instances, have increased.

This paper provides a snapshot in time of the UK seal monitoring landscape in 2017 and the collated viewpoints, on proposed monitoring, of HBDSEG and policy representatives in 2018. These viewpoints are historical and do not necessarily reflect viewpoints at the time of publication in 2024. All monitoring options developed and presented in this paper were dependent on the assumption that core UK monitoring programmes would continue at the same level of funding. However, in parallel with decreasing resources, inflation has significantly increased the costs of marine monitoring and as a result there has been ongoing, yearly erosion of core monitoring.

Greater understanding of seal populations is required to provide evidence for tackling the biodiversity loss and climate crisis. Monitoring seals provides valuable data on the overall ecosystem health and biodiversity, fulfilling legal obligations and informing decisions to ensure sustainable management and conservation of marine resources. Grey seals are among the rarest seals in the world. The British population of grey seals is of great international importance as the UK population represents about 40% of the world population and 95% of the EU population. The UK population of Harbour seals represents about 5% of the world population and approximately 50% of the EU population.

It should be noted that some of the legislative drivers which have been referenced in this report have been updated or superseded since 2017. In addition, new legislation and obligations have been introduced since 2017. For clarity, '[2017]' has been included alongside all occurrences of the term 'current' (and its derivatives) and within all table and figure captions and headings, throughout this paper.

Executive Summary

Current [2017] monitoring

Since the introduction of the Conservation of Seals Act (1970), the Wildlife (Northern Ireland) Order 1985 and, more recently, the Marine (Scotland) Act, 2010, the abundance and distribution of seals (grey and harbour, the latter also known as common) in UK waters has been investigated by the Sea Mammal Research Unit (SMRU). Funded by the Natural Environment Research Council (NERC), whose statutory duty it is to provide '*advice to government on the conservation and management of UK seals*' (NERC are the named authority in both the Conservation of Seals Act and the Marine (Scotland) Act) and by the Statutory Nature Conservation Bodies (SNCBs), the data and associated underpinning research are reviewed annually by the Special Committee on Seals (SCOS) who then report the findings to UK governments. The advice is then made widely available each year through the SMRU website or directly on request. Population trend data for grey seals, as pup production and total population size metrics, have been collected since the early 1980s, and for harbour seals as minimum population sizes (from the number of animals hauled out during the annual moult) since the late 1980s. The risks of not fulfilling these requirements or providing advice to SCOS would result in a failure of NERC in its UK statutory duties under the legislation and an inability to report on other policy obligations which rely on this advice (including the Habitats Directive and the Marine Strategy Framework Directive (MSFD)).

Under MSFD two abundance state indicators (grey seal pup production and seal population size) are now being taken forward in the 2017 Intermediate Assessment as indicators M3 and M5 Biodiversity Descriptors. This requires monitoring grey seal pup production, estimating total grey seal population size from the pup production data and monitoring harbour seal abundance during the annual moult. Distributional indicators, using spatial aerial survey data obtained during the seal counting surveys, is more problematic due, for example, to the mobility of the animals and the spatial coverage of the surveys and have, at this stage, only been recommended for 'surveillance' rather than for monitoring.

The power of the current [2017] monitoring programme to detect changes at an acceptable level of confidence is assessed. For grey seal pup production, the current [2017] biennial aerial surveys are sufficient, although only the major pupping sites are monitored. Pup counts for smaller colonies in, for example, southwest England and Wales are not undertaken regularly. The minimum change in pup production that is detectable is 12% over the 50 years of the study to date (with annual surveys until 2010). Over 10 years, surveying every 2 years (which is now the current [2017] regime), a minimum detectable change with 80% power would be 26%, which equates to a change of 3% per annum. The current [2017] regime for harbour seals is 5 yearly time intervals (due to the length of coastline and the cost of the air surveys) for the majority of the harbour seal moult sites surveyed to provide abundance estimates, particularly in Scotland, which gives a statistical power of ~ 20% to detect a rate of decline of 1% per year.

Funding for the continuation of all the seal monitoring work is reliant on NERC continuing to have a statutory duty under the Conservation of Seals and Marine (Scotland) Acts to provide scientific advice, which includes a requirement for regular information on seal abundance and distribution. The grey seal pup production surveys were reduced in 2010 from annual to biennial in response to a cut in funding from NERC. Harbour seal surveys in Scotland have been reliant on annual funding from NatureScot (formerly Scottish Natural Heritage) for the last 24 years.

In addition, there are two other long-term monitoring programmes that also provide data on seals. These are:

- The UK bycatch monitoring scheme in which bycaught seals are reported annually (by ICES subdivision) to the European Commission through EU Regulation 812/2004.
- The UK Cetacean Strandings Investigation Programme (CSIP) which aims to identify the causes of death in stranded marine mammals. In Scotland, the Scottish Marine Animal Stranding Scheme (SMASS) arm of the CSIP includes seals. Outwith Scotland, post-mortem investigations on seals are not routine. In recent years, Natural England has provided some funding for post-mortem examinations of seal carcasses on an *ad hoc* basis.

Overall funding at a UK level for these two additional programmes is largely governed by drivers for cetacean work as seals are a secondary aspect for both (outwith the additional funding from Scottish Government for the seal strandings in Scotland).

Enhanced monitoring

In addition, there are several longer term *research* projects which have provided datasets, whilst not primarily for monitoring purposes, would fulfil the role of pressure indicators for seals. However, further funding would be required for the continuation or expansion of this work to ensure its suitability for timely and effective monitoring as required by the legislative and policy drivers. These include:

- Population demography in terms of, for example, maternal post-partum mass, pup growth and survival. For grey seals this has only been carried out at two colonies around the UK and continued funding for this work is highly uncertain. Similar data for harbour seals from long-term studies would be important in determining population state for a species currently [2017] undergoing regional declines. Whilst some harbour seal population dynamics studies have been, or are currently [2017] being carried out, which could contribute information, the spatial extent and duration of these is again limited.
- Pathogen, contaminant, and toxin analysis in seals is currently [2017] only carried out on an *ad hoc* basis, where funding for research can be obtained, although historical data are available for baseline comparison. Toxins from harmful algae, now found regularly in seal faeces and urine samples, could be used to determine prevailing oceanographic conditions as well as indicate potential impacts of eutrophication and climate change on seal health.
- Long-term monitoring of seal diet would improve our understanding of the nutritive and energetic pressures on seals and assist in the interpretation of the changes in trends in abundance and distribution.
- At-sea distribution of seals is now possible to determine from combining seal haulout counts with movement data from telemetry studies, allowing for a greater understanding of the potential for interactions between seals and marine anthropogenic activities.

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1 Introduction

Monitoring options for marine biodiversity and surveillance in UK waters are being developed for various biota, under the auspices of the UK Marine Monitoring and Assessment Strategy (UKMMAS). The overall aim of the work is to provide details of the monitoring options for various species which are covered by policy and statutory obligations such as OSPAR, the Habitats and Birds Directives, Biodiversity 2020, and the EU Marine Strategy Framework Directive (MSFD).

In the UK, populations of the two species of seal, the grey seal (*Halichoerus grypus*) and the harbour (also known as common) seal (*Phoca vitulina*) are managed under the Conservation of Seals Act (1970) and the Marine (Scotland) Act 2010. Under both these pieces of legislation, the Natural Environment Research Council (NERC) is required to provide advice to UK governments on '*matters related to the conservation and management of seals*'. NERC has appointed a Special Committee on Seals (SCOS) to formulate this advice so that it may discharge this statutory duty. Formal advice is given annually, based on the latest scientific information provided to SCOS by the Sea Mammal Research Unit (SMRU). SMRU is an interdisciplinary research group at the University of St Andrews which receives National Capability funding from NERC to fulfil its statutory requirements and is a delivery partner of the National Oceanography Centre. SMRU also provides the Scottish Government with scientific reviews of all licence applications to shoot seals, information, and advice in response to parliamentary questions and correspondence. Each year questions are raised to SCOS by Marine Scotland (MS), the Department of the Environment, Food and Rural Affairs (Defra) and the SNCBs. In addition, other UK policy obligations that utilise the SCOS advice include the Habitats Directive and the MSFD.

The aim of this paper is to detail options for seal monitoring, the cost-benefit of which is evaluated in terms of how well it fulfils legislative requirements for seals and whether it provides timely and effective advice for the management of marine activities.

2 Legislation in relation to monitoring of seals

Two species of seal live and breed in UK waters: grey seals (*Halichoerus grypus*) and harbour (also called common) seals (*Phoca vitulina*). Grey seals only occur in the North Atlantic, Barents and Baltic Sea with their main concentrations on the east coast of Canada and United States of America and in north-west Europe. Harbour seals have a circumpolar distribution in the Northern Hemisphere and are divided into five sub-species. The population in European waters represents one subspecies (*Phoca vitulina vitulina*). Other species occasionally visit UK coastal waters, including ringed seals (*Phoca hispida*), harp seals (*Phoca groenlandica*), bearded seals (*Erignathus barbatus*) and hooded seals (*Cystophora crystata*), all of which are Arctic species.

2.1 Legislative requirements for monitoring

The Grey Seal (Protection) Act, 1914, provided the first legal protection for any mammal in the UK because of a perception that seal populations were very low and there was a need to protect them. In the UK, seals are now protected under the Conservation of Seals Act 1970 (England and Wales), the Marine (Scotland) Act 2010, and The Wildlife (Northern Ireland) Order 1985.

2.1.1 Conservation of Seals Act (1970)

The Conservation of Seals Act prohibits taking seals during a close season (1 September to 31 December for grey seals and 1 June to 31 August for harbour seals) except under licence

issued by the Marine Management Organisation (MMO) in England and Wales. The Act also allows for specific Conservation Orders to extend the close season to protect vulnerable populations. Currently [2017] both grey and harbour seals on the east coast of England are protected.

2.1.2 Marine (Scotland) Act (2010)

The Marine (Scotland) Act 2010 (Section 6) prohibits the taking of any seals except under licence (so there is no close season as such in Scotland although seasonality may be taken into consideration in the licence conditions). Licences can be granted for the protection of fisheries, for scientific and welfare reasons and for the protection of aquaculture activities. NERC (through SMRU) provides advice on all licence applications and haulout designations.

The Marine (Scotland) Act allows for the designation of conservation areas to protect populations that are in decline. After consultation with NERC (through SCOS), year round protection for both species has been established in the Moray Firth and for harbour seals in the Outer Hebrides, Shetland, Orkney, and the east coast of Scotland (between Stonehaven and Dunbar, effectively protecting all the main concentrations of harbour seals along the east coasts of Scotland and England).

2.1.3 The Wildlife (Northern Ireland) Order 1985

The Wildlife (Northern Ireland) Order 1985 provides complete protection for both grey and harbour seals and prohibits the killing of seals except under licence. In Northern Ireland it is an offence to disturb seals intentionally or recklessly at any haulout site.

2.1.4 United Nations Convention of the Law of the Sea

The United Nations Convention on the Law of the Sea (2012) establishes rules governing all uses of the oceans and their resources. The Convention includes the statement that Contracting Parties "*shall cooperate with a view to the conservation of marine mammals*" and that signatories must take measures "*necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life*".

2.1.5 Bern Convention and the Habitats Directive

The Convention on the Conservation of European Wildlife and Natural Habitats (or the Bern Convention) protects some marine mammal species and allows exploitation of others if their population numbers are not jeopardised. For Member States of the European Community, these provisions are largely included in the 1992 Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC, the 'Habitats Directive'). Grey and harbour seals are listed in Annex II and V. Under Annex II specific areas to be designated for their protection. They are also listed on Annex V which are species of community interest whose taking, and exploitation may be subject to management measures if their favourable conservation status will be negatively affected.

Article 4 of the Habitats Directive requires where certain conditions are met, the protection of UK seals through the designation of protected sites. A coherent European ecological network of Special Areas of Conservations (SACs) is being established under Natura 2000, which is composed of sites with the habitat types listed in Annex I and the habitats of species listed in Annex II. These sites shall enable the habitat types and the species' habitats concerned to be maintained, or where appropriate, restored at a favourable conservation status in their natural range [Article 3(1)]. Article 4(1) states '*for animal species ranging over wide areas these sites shall correspond to the places within the natural range*

of such species which present the physical or biological factors essential to their life and reproduction. For aquatic species which range over wide areas, such sites will be proposed only where there is a clearly identifiable area representing the physical and biological factors essential to their life and reproduction'.

Article 11 of the Habitats Directive requires that "*Member States shall undertake surveillance of the **conservation status** of the natural habitats and species referred to in Article 2 with particular regard to priority natural habitat types and priority species.*" This includes both species of seal, although neither are *priority species*. For species, the conservation status (CS) was defined as *'the sum of the influences acting on the species that may affect the long-term distribution and abundance of its populations'*. A species status could be considered favourable if:

i. population dynamics data indicate that the species is maintaining itself on a long-term basis as a viable component of its natural habitats;

ii. the natural range of the species is neither being reduced nor is likely to be reduced in the foreseeable future; and

iii. will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

To date, 16 Special Areas of Conservation (SACs) have been designated specifically for seals, with a further seven where seals are features of qualifying interest. The SAC reporting cycle required formal status assessments for these sites, and these were completed in 2013 (SCOS 2015). Assessment of CS therefore requires consideration of range and population (including trends), habitat availability, the main pressures, and threats to the species (including bycatch), and prospects of the species.

Article 14 notes that '*in the light of the surveillance provided for in Article 11, Member States deem it necessary, they shall take measures to ensure that the taking in the wild of specimens of species of wild fauna and flora listed in Annex V as well as their exploitation is compatible with their being maintained at a favourable conservation statu*s' whilst Article 15 notes '*Member States shall prohibit the use of all indiscriminate means capable of causing local disappearance of, or serious disturbance to, populations of such species*'. Article 17 requires that Member States undertake an assessment of the favourable conservation status of all listed species every six years. In the last assessment of FCS (2007–2012) grey seal status was favourable and harbour seal was unfavourable bad (having declined from unfavourable inadequate in the previous round).

2.1.6 Convention on Biological Diversity (CBD)

The Convention on Biological Diversity (CBD) aims to promote biodiversity, balancing conservation with sustainable use and the sharing of economic benefits that are derived from biodiversity. CBD requires countries to prepare a national biodiversity strategy and to ensure it is incorporated into the planning and activities of all those sectors whose activities can have an impact (positive and negative) on biodiversity.

As a result of the CBD Strategic Plan for Biodiversity 2011–2020 (2012) the European Commission developed and, in 2011, adopted the EU biodiversity strategy (2012), a target of which is "*to halt the deterioration in the status of all species and habitats covered by EU nature legislation and achieve a significant and measurable improvement in their status so that, by 2020, compared to current assessments, 100% more habitat assessments and 50% more species assessments under the Habitats Directive show an improved conservation status*". The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) provides a framework to address issues associated with maritime

pollution. Additionally, OSPAR also covers the *'protection and conservation of the ecosystem and biological diversity of the maritime area'* (Annex V) and Annex IV is concerned with the nature of monitoring programmes to allow the assessment of environmental quality.

At the fifth North Sea Conference it was agreed that an Ecological Quality Element relating to seal population trends in the North Sea would be set. The original objectives were revised in 2005. The grey seal EcoQO was revised to: *"Taking into account natural population dynamics and trends, there should be no decline in pup production of grey seals of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of nine sub-units of the North Sea. These sub-units are: Orkney; Fast Castle/Isle of May; the Farne Islands; Donna Nook; the French North Sea and Channel coasts; the Netherlands coast; the Schleswig-Holstein Wadden Sea; Heligoland; Kjørholmane (Rogaland)."* The harbour seal EcoQO was reformulated as: *"Taking into account natural population dynamics and trends, there should be no decline in harbour seal population size (as measured by numbers hauled out) of ≥10% as represented in a five-year running mean or point estimates (separated by up to five years) within any of eleven sub-units of the North Sea. These sub-units are: Shetland; Orkney; North and East Scotland; South-East Scotland; the Greater Wash/Scroby Sands; the Netherlands Delta area; the Wadden Sea; Heligoland; Limfjord; the Kattegat, the Skagerrak and the Oslofjord; the west coast of Norway south of 62°N".* The performance of the EcoQos were evaluated in 2009, with the conclusion that for grey seals they had been met but for harbour seals they were not met for subunits Shetland, Orkney, east of Scotland, Greater Wash, Limfjorden and the west coast of Norway south of 62°N. SMRU, funded by Scottish Government, is undertaking studies into the causes of the decline in harbour seals on the east coast of Scotland and Northern Isles.

2.1.7 Marine Strategy Framework Directive (MSFD) and Good Environmental Status (GES)

The Marine Strategy Framework Directive (MSFD (2012)) requires Member States to develop marine strategies that apply '*an ecosystem-based approach to the management of human activities while enabling a sustainable use of marine goods and services, priority should be given to achieving or maintaining good environmental status in the Community's marine environment, to continuing its protection and preservation, and to preventing subsequent deterioration.... This approach should include protected areas and should address all human activities that have an impact on the marine environment*'.

Article 11 states that '*Member States shall establish and implement coordinated monitoring programmes for the ongoing assessment of the environmental status of their marine waters... Monitoring programmes shall be compatible within marine regions or subregions and shall build upon, and be compatible with, relevant provisions for assessment and monitoring laid down by Community legislation, including the Habitats and Birds Directives, or under international agreements....Member States sharing a marine region or subregion shall draw up monitoring programmes...and shall, in the interest of coherence and coordination, endeavour to ensure that:*

(a) monitoring methods are consistent across the marine region or subregion so as to facilitate comparability of monitoring results;

(b) *relevant transboundary impacts and transboundary features are taken into account*.'

To determine Good Environmental Status (GES), 11 qualitative descriptors have been selected and indicators and targets are being derived within each. OSPAR is leading the international development of indicators and targets for determining GES in the relevant subregions. In November 2011, OSPAR brought together its Contracting Parties to discuss

proposed indicators and targets of GES for Descriptor 1: Biodiversity. OSPAR Contracting Parties in the Greater North Sea sub-region have adopted the following common indicators for seals:

M-3 Abundance of grey and harbour seals at breeding and haul-out sites, respectively

M-5 Grey seal pup production

The assessment sheets for the Intermediate Assessment in 2017 for these indicators have now been produced and were reviewed by ICES in February 2016 at the Working Group for Marine Mammal Ecology (ICES 2016) and OSPAR BDC February 2017.

2.1.8 Summary of parameters for monitoring to fulfil legislative requirements

As described above there is a considerable amount of overlap between the different legislative and policy requirements. These are consolidated into the list of ecological parameters to fulfil the needs of the drivers combined, including the pressures monitoring (Table 1).

The legal requirements and obligations all generally require the development of a monitoring programme capable of assessing trends in species' distribution and abundance over time, as well as the threats and pressures acting on those species. This requires:

i. undertaking wider surveillance and assessment of species to provide a robust understanding of the population (i.e. the context against which threats and pressures can be assessed);
ii. identifying and evaluating the risk of key threats and pressures, including detecting any novel ones;
iii. monitoring key threats and pressures; and
iv. implementing measures to reduce identified threats and pressure, including monitoring to assess the effectiveness of them.

The Habitats Directive and other European legislation generally define animal populations as those individuals that utilise national waters.

Table 1: Summary of legislative commitments and agreement obligations to monitoring. Dist. = Distribution; Pop. = Population [in 2017].

Primary Legislation/ Obligation	Article/ Annex	Requirement	Ecological Parameter to be monitored					
			Range	Dist. pattern	Pop. Abundance & trends	Pop. Demographic characteristics	Pop. health	Size and quality of habitat (protected areas & wider environment)
Conservation of seals Act and Marine (Scotland) Act	Section 6 MSA	*CSA – The Council shall provide the Secretary of State [F27, the Welsh Ministers and the Natural Resources Body for Wales] with scientific advice on matters related to the management of seal populations.* *MSA – Conservation of Seals Advice on seal populations – the Scottish Ministers must have regard to any advice about the management of seal populations which is given to them by the Natural Environment Research Council.*		Y	Y	Y	Y	Y
Habitats Directive	11	*Member States shall undertake surveillance of the conservation status of the natural habitats and species referred to in Article 2 with regard to priority natural habitat types and priority species.*		Y	Y	Y	Y	Y
Marine Strategy Framework Directive	11	*Member States shall establish and implement coordinated monitoring programmes for the ongoing assessment of the environmental status of their marine waters.*		Y	Y	Y	Y	Y

Primary Legislation/ Obligation	Article/ Annex	Requirement	Ecological Parameter to be monitored					
			Range	Dist. pattern	Pop. Abundance & trends	Pop. Demographic characteristics	Pop. health	Size and quality of habitat (protected areas & wider environment)
OSPAR	VI	*The Contracting Parties shall, in accordance with the provisions of the Convention, in particular as provided for the Annex IV:* *(a) undertake and publish at regular intervals joint assessments of the quality status of the marine environment and of its development, for the maritime area or for regions or sub-regions thereof;* *(b) include in such assessments both an evaluation of the effectiveness of the measures taken and planned for the protection of the marine environment and the identification of priorities for action.* *EcoQOs for seals to assess ecosystem health ad direct management actions.*		Y	Y			

3 The process used to develop monitoring options

Monitoring options need to consider what, how, when, and where to sample to collect the necessary data in a cost-effective way. The species' ecology, their interaction with human activities and what technologies exist to take measurements need to be taken into consideration.

3.1 Part 1 – What to monitor

There are two species of seal in UK waters, grey and harbour seals, whose trends in abundance and distribution have been monitored regularly since the early 1980s. However, other aspects of their ecology, population health and life history should also be regularly assessed to fulfil the legislative commitments listed in Table 1. These include estimates of demography such as maternal post-partum mass, pup growth and breeding habitat, estimates of population health such as exposure to pathogens, contaminants and toxins and movements and at-sea distribution, fisheries bycatch, and diet.

3.2 Part 2 – How to monitor

There needs to be a balance between the monitoring cost and its effectiveness in achieving an objective. For seals, the number of surveys (largely aerial), their frequency and geographic range comprises most of the monitoring costs. Developing the monitoring programme will also consider its effectiveness against the objectives and whether they are being met. The power of the programme to detect a specified amount of change and the level of statistical significance is critical. Since the seal monitoring programme (for both species) in terms of trends in abundance and distribution has been maintained for some years (largely with funding from NERC and NatureScot) it is possible to determine the current [2017] level of effectiveness. What is less clear is the effectiveness of any additional monitoring programmes (for example the Cetacean Strandings Investigation Programme's Scottish Marine Animal Strandings Scheme which now includes seals as well as cetaceans) and options outlined here which are not currently [2017] implemented.

3.3 Part 3 – Monitoring options

The options described here are based on previous considerations of what is important in terms of the additional ecological parameters (beyond trends in abundance and spatial distribution of the species, across the life cycle of the two seal species) that can be readily monitored within the context of the legislative drivers outlined above. Table 2 lists some of the key threats and pressures for both species.

Table 2: Key pressures potentially impacting seals in UK waters (NOT in order of priority) [in 2017].

Harbour seal (*Phoca vitulina*)	**Grey seal (*Halichoerus grypus*)**
Nutritional stress [1]	Nutritional stress [2]
Competition with grey seals and other marine mammals [3]	Competition with other marine mammals [4]
Disease (infectious, non-infectious and toxins) [5, 6]	Disease (infectious, non-infectious and toxins) [7]
Deliberate killing (shooting)[8]	Deliberate killing (shooting)
Predation [9]	Predation [9]
Bycatch (fisheries) [10]	Bycatch (fisheries) [10]
Prey availability (removal or target and non-target species) [1, 12]	Prey availability (removal or target and non-target species)
Trauma – Death or injury by collisions (with marine renewable energy developments) [13]	Trauma – Death or injury by collisions (with marine renewable energy developments) [13]
Pollution [14]	Pollution [15]
Loss of habitat [16]	Loss of habitat
Climate change [17]	Climate change [17]
Anthropogenic disturbance – including increased ocean noise, boat traffic, disturbance from haulout sites [18]	Anthropogenic disturbance – including increased ocean noise, boat traffic, disturbance from haulout sites [18]
Entanglement in marine debris [19]	Entanglement in marine debris

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4 PART 1: What to monitor

4.1 Choice of species to monitor

Whilst the abundance of grey and harbour seals in UK waters is regularly monitored, many of the ecological parameters of interest are not. There are no other seal species in UK waters that warrant monitoring. Some vagrant species such as hooded seals, harp seals, ringed seals and bearded seals are only very occasionally recorded in UK waters.

4.2 Ecological parameters relating to the monitoring options design

4.2.1 Ecological parameters

For both seal species there are several ecological parameters that can be measured and monitored to fulfil legislative requirements (Section 3.1).

These can be split into two groups:

i. State parameters: provide a measure of population state and tend to respond to a combination of factors, including climate change, as well as some pressures. Included here are direct measures of population size (e.g. abundance).

ii. Pressure parameters: provide a measure of the effect of a given pressure (e.g. fisheries bycatch estimates, contaminant levels). These are crucial to identify the

cause of an observed change in state, and to provide evidence for advice on the management of activities. There are various key pressures that have been identified as potentially impacting both species of UK seal (Table 2). However, it is not possible to undertake monitoring which will affectively identify the impact of all of these.

Ecological parameters that respond to pressures and which could be or are being monitored are given in Table 3. It should be noted that many of these are **not** included in the regular monitoring programmes for seals in the UK. However, various longer term research projects being carried out by particularly by SMRU and the University of Aberdeen, with *ad hoc* funding support can supply historical data for monitoring purposes.

Table 3 [2017]: List of parameters for consideration in the development of monitoring options for seals.

Ecological parameter	Description	Group	Legislation
Distribution pattern	Spatial arrangement of a population within its range	State[1]	Habitats Directive, Conservation of seals Act and Marine (Scotland) Act
Population size	Number of individuals within a population	State	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland) Act
Population demographic characteristics	Maternal post-partum mass, pup growth, pup mortality and habitat use by females.	State	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland) Act
Pathogens, contaminants, and toxins	Estimate of pathogen prevalence, contaminant concentrations (mainly persistent organic pollutants (POPs) and toxins from harmful algae	Pressure	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland) Act
Seal bycatch	Bycatch of seals due to fishing	Pressure	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland Act)
Seal diet	Seal diet estimates from the analysis of hard parts in faeces	Pressure	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland) Act
At-sea foraging distribution	At-sea foraging distribution from telemetry tagged seals	Pressure	Habitats Directive, MSFD, Conservation of seals Act and Marine (Scotland) Act

[1] Currently [2017] adopted as a surveillance indicator only under MSFD.

4.2.2 Choice of parameters for each species

Not all parameters are equally useful in achieving the monitoring objectives for seals in UK waters. Of the currently [2017] identified set of monitoring activities, many are already being used either for a monitoring or more commonly for the pressure parameters in underpinning, evidence based policy related research projects, and these are summarised in Table 4. It should be noted that the sensitivity of the different parameters to pressure changes will vary, and some will only be able to detect strong or higher magnitude changes, which may render them inoperable, depending on the conservation objective. It is therefore critical to undertake some form of power analysis before including additional parameters in any programme. Preliminary data is, however, required for this, so some research and development and shorter-term studies to provide trial data may be needed to determine the degree of variability and ability of the parameter to achieve any given conservation monitoring objective.

Table 4 [2017]: Assessment of applicability of methods to each combination of species & parameters. Y = has been/is used; N = not applicable to UK context; R&D = potential after relatively short-term R&D; R = potential after longer-term R&D, grey cells = eliminated parameters (see Appendix I).

Parameter	Method	Grey seal	Harbour seal
Distribution pattern	Aerial surveys (photographic and thermal imagery)	Y	Y
Population size	Aerial surveys (photographic and thermal imagery)	Y	Y
Population demographic characteristics	Photographic and marked individual identification	Y	Y
	Live capture release mass measurements	Y	Y
Pathogens, contaminants, and toxins	Live capture release biopsy and excreta sampling	Y	Y
	Faecal sample collection from haul out sites	Y	Y
	Post-mortem strandings	Y	Y
	Post-mortem seals shot under licence	Y	Y
Seal bycatch	Direct recording of bycatch on fishing vessels	Y	Y
	Post-mortem strandings	Y	Y
Seal diet	Faecal sample collection from haul out sites	Y	Y
	Post-mortem strandings		
	Post-mortem seals shot under licence	Y	Y
At-sea foraging distribution	Live capture release telemetry tagging	Y	Y

5 PART 2: How to monitor

5.1 Monitoring objectives

For each parameter (e.g. aerial surveys, tissue sampling), a monitoring objective needs to be defined. In general, monitoring objectives are concerned with identifying changes in parameters between repeated measures, within stated time periods. For some parameters, the objectives are already set for monitoring purposes under, for example, the MSFD (see Table 5). However, some of the objectives need further refinement, especially in determining what is a 'significant change'. The assessment of current [2017] monitoring activities and the levels of change in parameters that can be detected may inform decisions on what levels of change can be measured and what level of significance is acceptable. These objectives will need to be revisited before progressing and implementing additional monitoring activities.

Table 5 [2017]: Summary of monitoring parameters and objectives.

Group	Ecological Parameter	Objectives
State	Distribution pattern	Meaningful changes in seal distribution are currently [2017] difficult to detect and assess from abundance surveys, this aspect of the indicator will be considered as a 'surveillance indicator': the metric(s) will be described but not quantitatively assessed against a threshold value.
	Trend in population abundance	**Grey seal pup production** *Threshold 1:* No decline in *Abundance* of > 1% per year in the previous 6-year period (this is approximately 5% over 6 years). *Threshold 2:* No decline in *Abundance* of > 25% since the fixed baseline at the start of the Habitats Directive in 1992 (or closest value). **Harbour and grey seal abundance** *Threshold 1:* No decline in *Abundance* of > 1% per year in the previous 6-year period (this is approximately 5% over 6 years). *Threshold 2:* No decline in *Abundance* of > 25% since the fixed baseline at the start of the Habitats Directive in 1992 (or closest value).
	Population demographic characteristics	To detect a significant decrease in seal demography (e.g. post-partum maternal mass, pup growth rates, pre-weaning mortality or habitat use by females)
Pressure	Pathogens, contaminants, and toxins	To assess levels of contaminants with respect to known levels of toxicity for marine mammals. To determine prevalence of pathogenic organisms of known virulence in live and dead seals.
	Bycatch	Mortality due to fishing bycatch should be sufficiently low so as not to inhibit population size targets being met
	Seal diet	To detect a significant change in the proportion of different prey in the diet

Group	Ecological Parameter	Objectives
	At-sea foraging distribution	To detect a significant change in the at-sea foraging distribution

5.2 Amount of change to be detected for trends in abundance

To monitor trends in population abundance, the magnitude of change in abundance to be detected and the timescale of this change need to be defined. The seal indicators being used for MSFD have been assessed in this context, as described below.

5.2.1 Grey seal pup production (Descriptor 1, biological diversity – metric "M5")

- *Threshold 1*: To estimate the annual population growth rate within the previous 6-year reporting round a linear trend was fitted to the sum of all available data in each Assessment Unit (AU) for the round 2007:2012. Generalised linear models (GLMs) were fitted to count data with a quasi-Poisson error distribution and log link. Annual growth rate (%) and 80% confidence intervals were estimated for each Assessment Unit (AUs, Figure 1 harbour seal and grey seal pup production AUs. A single AU for grey seal total population size cover the whole UK coast was agreed because of the known large scale movements of this species). Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, α, equal to 0.20 or 20%.
- *Threshold 2*: To determine the change in abundance of pups since the baseline year, generalised linear models (GLMs) or generalised additive models (GAMs) were fitted to the sum of pup production data within an Assessment Unit with a quasi-Poisson error distribution and log link using all available annual survey data in the range 1992:2012. The percentage change in pup numbers since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were calculated from fitted values. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, α, equal to 0.20 or 20%.

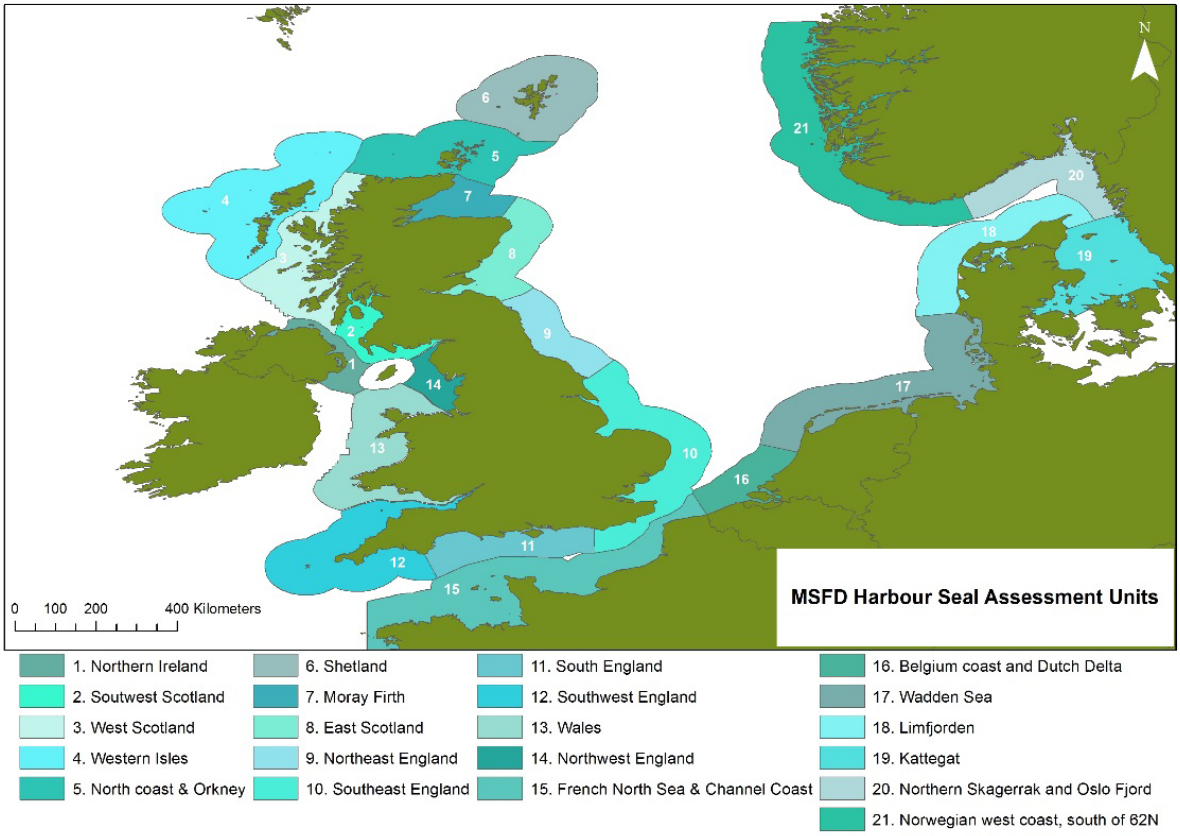

Figure 1 [2017]: Harbour seal and grey seal pup production assessment units (maps courtesy of JNCC). These grey seal pup production assessment units differ from the total grey seal population size assessment units as these areas are indicative of population condition based on pup production.

Grey seal pup production estimates were assessed in relation to a baseline set as the start of the Habitats Directive in 1992 (or start of the time series) and by calculating the average rate of annual population change within the last reporting round (2007-2012). Indicator metrics and associated confidence intervals were assessed against two thresholds; the average annual growth rate (%) and 80% confidence intervals within the last reporting round were less than -1% per year and the percentage change in abundance since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were less than -25%. If the 80% confidence intervals encompassed the threshold, the assessment was classified as 'inconclusive'.

Changes in grey seal pup production were above threshold levels within regional AU (Table 6). In Shetland, the short-term threshold assessment was inconclusive; Shetland is a difficult area to survey. Surveys are conducted by volunteers from the ground/sea when weather conditions permit. The numbers used in this assessment represent the best possible estimate for that year but do not normally represent a comprehensive, repeated, survey of all colonies on the islands.

Table 6 [2017]: Details of grey seal pup production rates of change and change in abundance since the baseline year.

Assessment Unit	**Abundance**		
	***Annual Percentage Growth rate*$_{2007\text{-}2012}$, n=No. years of data**	***Percentage change in abundance since baseline year ($\Delta_{baseline}$), n=No. years of data***	***Baseline year***
East Scotland	11 (9–12) n=5	347 (290–415) n=20	1992
Moray Firth	31 (20–42) n=4	476 (236–936) n=6	2005
North Coast & Orkney	4 (3–5) n=5	121 (105–138) n=20	1992
Northeast England	6 (5–7) n=6	54 (33–78) n=21	1992
Northern Ireland	d.d.	d.d.	n.a.
Republic of Ireland	n.s.	n.s.	n.s.
Shetland	-3 (-4–-1) n=6	-14 (-23–-4) n=9	2004
Southeast England	14 (13–14) n=6	1624 (1535–1719) n=21	1992
Southwest Scotland	n.a.	n.a.	n.a.
West England and Wales	d.d. n=1	25 (20–30) n=4	1992
West Scotland	4 (2–6) n=5	31 (23–39) n=20	1992
Western Isles	4 (3–5) n=5	13 (4–23) n=20	1992

n.s. = not submitted; d.d. = data deficient; n.a. = no data available; few or no seals

5.2.2 Harbour and grey seal abundance (Descriptor 1, biological diversity – metric "M3")

There are many ways in which the number of seals counted during any one year could vary, aside from representing true changes in population size, including adverse weather, or recent disturbance. It is therefore advisable to examine the variability in survey counts and incorporate this variability into trend or population size change estimates. ICES WGMME (ICES 2014) provided general advice on the need to understand the statistical power of current [2017] and proposed monitoring programmes. In the present context, statistical power is the percentage chance of *not* making a Type II error where a Type II error, or 'false negative,' would be concluding that no trend in abundance is occurring when in fact it is. Statistical power depends on the sample size (number of surveys), the level of statistical significance (α-level), variance in the counts, and the effect size – here, the threshold values described above. The ICES WGMME (ICES 2014) recommended that monitoring should achieve a minimum of 80% power – which equates to a 20% chance of making a Type II error. The same group also recommended that the threshold for detection of a 'significant' trend be relaxed from the traditional $\alpha = 0.05$ to $\alpha = 0.20$. The α parameter, or significance level, equates to the probability of concluding that a significant trend exists when in fact it does not (Type I error). An α value of 0.2 and power of 80% means there is equal probability

of making an incorrect conclusion (either Type I or Type II error) about the detection of a trend.

Current [2017] monitoring programmes vary in the level of statistical power achievable. In some regions the survey area is too large or complex to feasibly enable comprehensive and repeated surveys (e.g. many parts of the Scottish coast) and the power to detect change in these regions is reduced (SCOS 2014). However, even where replicated annual surveys are possible, within-year variance in the counts can be high and detection of small effect sizes may not be achievable with 80% power (Meesters *et al.* 2007; Teilmann *et al*. 2010).

While not usually recommended, it is possible to calculate the power of a study retrospectively (Thomas 1997). The effect size of interest – here, the threshold trend – is set *a priori* and the observed variance in the sample data is used to calculate power to detect an effect of that magnitude. Confidence intervals also provide a relevant measure of confidence in the assessment: where these encompass the threshold effect size the data do not provide conclusive evidence for calculated value being above or below the threshold value. Both above approaches to presenting uncertainty in the assessment were adopted here.

Harbour seals tend to undertake relatively short excursions from their favoured haul-out sites, often less than 50 km (although they may range over much larger distances) and there is little evidence of extensive seasonal migrations (Sharples *et al.* 2012; Jones *et al*. 2015). The AUs for this species are therefore much smaller than that prescribed for the grey seal. Grey seals range more widely at sea than harbour seals and may visit multiple distant haul-out sites (McConnell *et al.* 1999). Immigration of grey seals may account for as much as 35% of the observed population growth in the Dutch Wadden Sea (Brasseur *et al.* 2014) and hundreds of adults from the UK visit the area temporarily (SCOS 2015).

Quantitative assessment was only completed where enough annual data points were available (n = or > 4). Trends in the abundance of harbour seals counted during the annual moult (August) and of modelled total grey seal population size were assessed within each Assessment Unit.

Threshold 1: To estimate the annual population growth rate within the previous 6-year reporting round a linear trend was fitted to the sum of all available data in each AU for the round 2007:2012. GLMs were fitted to count data with a quasi-Poisson error distribution and log link. Annual growth rate (%) and 80% confidence intervals were estimated for each AUs. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, α, equal to 0.20 or 20%.

Power: Power to detect a rate of the magnitude specified in Threshold 1 (-1% per year) was calculated using the formulae from Thomas (1997) where λ (the non-centrality parameter) is a function of the specified effect size, the sum of squares and variance estimated from the fitted model. The total sample size was calculated as the product of the number of years of survey data and the typical number of replicate surveys performed in the AU.

Threshold 2: To determine the change in abundance of seals since the baseline year, GLMs or GAMs were fitted to the sum of count data within an AU with a quasi-Poisson error distribution and log link using all available annual survey data in the range 1992:2012. The percentage change in abundance since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were calculated from fitted values. Although no formal hypothesis testing was conducted, 80% confidence intervals were calculated to reflect the choice to set the significance level, α, equal to 0.20 or 20%.

Seal population size metrics were assessed in relation to a baseline set as the start of the Habitats Directive in 1992 (or start of the time series) and by calculating the average rate of

annual population change within the last reporting round (2007-2012). Indicator metrics and associated confidence intervals were assessed against two thresholds; the average annual growth rate (%) and 80% confidence intervals within the last reporting round were less than -1% per year and the percentage change in abundance since baseline year ($\Delta_{baseline}$) and 80% confidence intervals were less than -25%. If the 80% confidence intervals encompassed the threshold, the assessment was classified as 'inconclusive'. The statistical power to detect a harbour seal population rate of decline of 1% per year was also assessed and found to be ~20%.

5.2.2.1 Grey seal abundance

In the UK grey seal total population size (abundance) is estimated using a Bayesian population model from pup production, an approach that has now been adopted for the whole North Sea as well as the UK Celtic and Irish seas (and as submitted to OSPAR for the Intermediate Assessment, 2017).

5.2.2.2 Harbour seal abundance

Harbour seal populations were above the assessment thresholds in most AUs (Table 7). Counts in East Scotland, North Coast & Orkney and Northern Ireland were below the assessment threshold, or the results were inconclusive. Additionally, Shetland has seen a large decline in the abundance of harbour seals since 1993. The declines in these regions have been characterised and studied in greater detail elsewhere and are the subject of a major research initiative in the UK. Survey counts in the Western Isles were highly variable, resulting in an apparent decrease in the number of animals since 1992 count; however, confidence intervals for this estimate were wide (-35% to 21%). There are many harbour seals in the Western Isles AU and the population in this region is generally thought to be stable.

Table 7 [2017]: Details of harbour seal population rates of change and change in abundance since baseline year.

Assessment Unit	**Abundance**		
	***Annual Percentage Growth rate*$_{2007\text{-}2012,}$ n=No. year of data**	***Percentage change in abundance since baseline year ($\Delta_{baseline}$), n=No. years of data***	***Baseline year***
East Scotland	-12 (-15– -9) n=6	-69 (-77– -58) n=12	1997
Moray Firth	8 (3–12) n=6	-16 (-35–9) n=13	1994
North Coast & Orkney	-7 (-8– -5) n=5	-71 (-75– -66) n=9	1993
Northeast England	8 (7–9) n=6	27 (8–48) n=18	1997
Northern Ireland	-4 (-6– -3) n=4	-22 (-28– -15) n=6	2002
Shetland	d.d. n=1	-55 (-64– -44) n=5	1993
Southeast England	7 (5–9) n=6	62 (47–79) n=17	1995
Southwest Scotland	d.d. n=1	d.d. n=3	1996
West England and Wales	d.d.	d.d.	d.d.
West Scotland	0 (0–0) n=6	9 (-14–40) n=5	1997
Western Isles	d.d. n=2	-12 (-35–21) n=7	1992

n.s. = not submitted

d.d. = data deficient

n.d. = no subareas defined

n.a. = no data available; few or no seals

5.3 Harbour and grey seal distribution

Describing the (terrestrial) distribution of seals from surveys that are designed primarily to assess abundance is problematic and any distribution metric based on these data will have inherent limitations arising from three main areas:

- Spatial coverage: Seal abundance surveys necessarily census animals seen hauled out on land and do not address the distribution at sea. To estimate at-sea usage, long-term telemetry data are necessary (e.g. Jones *et al.* 2015).
- Sampling effort: Ideally in studies of distribution change, a complete and standardized survey is conducted repeatedly on the area of interest. The areas of interest for M3 are the AUs; these geographical areas are not all surveyed completely on an annual basis due to geographical and/or financial constraints. Limited resources for conducting surveys must be aimed at surveying those areas of known and high seal occurrence. Statistically, this could lead to a bias in seal distribution metrics due to *preferential sampling*. In addition, historical data is limited.

- Temporal coverage: the surveys cover narrow windows during key life-stages such as moulting, breeding and pupping seasons. The distribution of seals can be different between these stages.

These general limitations are applicable to most studies of animal abundance and distribution. Despite this, survey data may be useful to detect large-scale contractions in population distributions in terms of reduced use or abandonment of haulout sites or breeding areas, depending on the spatial resolution with which presence/absence data are reported.

To explore changes in seal distribution from available survey data, it was necessary to further subdivide the AU area into subunits or haulout areas. The borders of subunits were (arbitrarily) proscribed by the data provider, but with the intention to aggregate haulout sites by seaward proximity and likelihood that seals travel between sites rather than aligning with any pre-existing municipal boundaries. Using presence or absence of seals within these spatial units, two metrics of changes in distribution were calculated:

- *Distributional pattern* – percentage change in occupancy between two time periods for a given spatial unit:
- *Shift in occupancy* - an index to describe the overall shift in the distribution of grey seals between subareas or grid cells over time.

The index value is between 0 and 1: a value of 0 indicates that there has been a complete shift in the spatial units occupied; a value of 1 indicates there has been no shift.

Both distribution metrics are sensitive to the number of spatial units defined within each AU. In an AU with relatively few subdivisions, absence of animals in one subdivision will equate to a large change in occupancy ($\Delta_{occupancy}$) between the reporting rounds. However, the general direction of change in this metric is not sensitive to the number of AU subdivisions. Harbour seal occupancy of subareas has either increased or remained the same in most Assessment Units. A notable exception is East Scotland where the population has declined dramatically since the mid-2000s, and the number of occupied areas has decreased from seven out of a total of nine in the period 2001–2006, to five out of nine in the period 2007–2012. Changes in the number of colonies occupied by breeding grey seals were either stable or positive in all areas where the animals occur, and such data were available.

6 Overview and limitations of UK monitoring activities in relation to monitoring objectives

6.1 Current [2017] monitoring of UK seals

6.1.1 Grey seal abundance and distribution

Grey seals breed at traditional colonies, with females frequently returning to the same colony to breed in successive years (Pomeroy *et al.* 2000). Some females return to breed at the colony at which they were born. Habitual use by grey seals of specific breeding colonies, combined with knowledge of the location of those colonies, provides an opportunity for the numbers of pups born at the colonies to be monitored.

While grey seals breed at sites all around the UK coast, most (approximately 85%) breed at colonies in Scotland. Other main breeding colonies are along the east coast of England, in south-west England and in Wales. Most colonies in Scotland are on remote coasts or remote off-lying islands. Breeding colonies in south-west England and in Wales are either at the foot

of steep cliffs or in caves and are therefore extremely difficult to monitor in contrast to those in east England which are very accessible.

Until 2010, SMRU conducted annual aerial surveys of the major grey seal breeding colonies in Scotland to determine the number of pups born. The number of pups born at colonies along the east coast of England is monitored annually by counting on the ground by different organisations: National Trust staff count pups born at the Farne Islands (Northumberland) and at Blakeney Point (Norfolk); staff from the Lincolnshire Wildlife Trust count pups born at Donna Nook and the Friends of Horsey grey seal group count pups born at Horsey, on the east Norfolk coast. NatureScot staff count grey seal pups born in Shetland and on South Ronaldsay in Orkney.

Reductions in funding, combined with increasing aerial survey costs, have resulted in SMRU moving from monitoring grey seal breeding colonies annually to a biennial survey regime in Scotland. The first year with no survey was 2011. In 2012, a new digital camera system, funded by NERC, replaced the film-based large-format Linhof AeroTechnika system that has been in use since 1985. The numbers of pups born (pup production) at the aerially surveyed colonies in Scotland is estimated from a series of three or five counts derived from aerial images using a model of the birth process and the development of pups. The method used to obtain pup production estimates in 2012 was like that used in previous years. A lognormal distribution was fitted to colonies surveyed four or more times and a normal distribution to colonies surveyed three times.

Paired digital images are obtained from two Hasselblad H4D 40MP cameras mounted at opposing angles of 12 degrees from vertical in SMRU's modified Image Motion Compensating cradle. A series of transects are flown over each breeding colony, ensuring that all areas used by pups are photographed. Images are recorded directly onto hard drives, one for each camera.

All images are first adjusted for brightness and sharpness using Hasselblad's image processing software, Phocus. Individual images are then stretched from rectangular to trapezoid to closely match the ground area covered by oblique photographs taken at an angle of 12 degrees. All perspective-corrected images covering one survey of a particular colony are then stitched together to create a single digital image of the entire colony up to 15GB in size. Images are stitched and exported as PSB files using Microsoft's Image Composite Editor v1.4.4. In a few cases where the stitching software cannot stitch all images, such as with images of areas with large differences in ground elevation, images are stitched or adjusted manually using Adobe Photoshop CS5. The final composites are then saved as LZW compressed TIFF files (large images are split if TIFF's 4GB maximum file size is exceeded) and imported into Manifold GIS 8.0 for counting. The imported images are compressed within Manifold to reduce file size without losing too much image detail. Separate layers are created for marking whitecoat, moulted and dead pups. Pup production is then converted to total population size on a regional basis using a Bayesian state-space population model (SCOS 2015).

6.1.2 Harbour seal and abundance and distribution

Each year [2017] SMRU carries out surveys of harbour seals during the moult in August. Occasional pup counts are obtained but only at very limited locations, particularly the Wash. Given length of coastline it is impractical to survey the whole coastline every year and SMRU aims to survey the whole coastline across five consecutive years. Most of the English and Scottish east coast populations are surveyed annually, excluding the Northern Isles. Currently [2017] the Zoological Society of London also count seals in the Thames during the summer (both species).

Seals spend the largest proportion of their time on land during the moult and they are therefore visible during this period to be counted in the surveys. Most regions are surveyed using thermographic aerial photography to identify seals along the coastline. However, conventional photography is used to survey populations in the estuaries of the English and Scottish east coasts.

The estimated number of seals in a population based on these methods contains considerable levels of uncertainty. A large contribution to uncertainty is the proportion of seals not counted during the survey because they are in the water. We cannot be certain what this proportion is, but it is known to vary in relation to factors such as the time of year, the state of the tide and the weather. Efforts are made to reduce the effect of these factors by standardising the time of year and weather conditions and always conducting surveys within 2 hours of low tide. The current [2017] estimate for the proportion of time spent hauled out during the survey window is 0.72 (95% CI 0.54–0.88, (Lonergan *et al.* 2013) and this is used to estimate the total population size of harbour seals.

6.1.3 Bycatch monitoring scheme

Estimates of seal bycatch are reported annually to the European Commission in the UK "Report on the implementation of Council Regulation (EC) No 812/2004", which is produced by SMRU under contract to Defra and the Scottish Government. Seal bycatch estimates for static net fisheries are included in the Annex to that report by ICES subdivision but should be treated with caution as several caveats apply (for example they are only for static net fisheries in the Irish Sea, Celtic Sea, Bristol Channel and Western English Channel and do not include bycatch that occurs by fisheries operated by other countries in the area), and only point estimates are given.

6.1.4 Scottish Marine Animal Stranding Scheme

The Scottish Marine Animal Stranding Scheme (SMASS, part of the Cetacean Strandings Investigation Programme, CSIP) has additional funding [2017] from the Scottish Government to study the causes of death in stranded seals (http://www.strandings.org/). In England the CSIP scheme does not currently [2017] respond to seals. Between 2012 and 2015, 798 seals were reported to SMASS. The majority were grey seal strandings, with 17% being harbour seals. However, only 59 grey seals and 29 harbour seals were examined post-mortem (PME) due to several factors, the most important of which is advanced decomposition. Seal carcasses are often beyond PME state by the time they wash ashore. However, for those that are sampled, a range of tissues are taken and stored in an archive for use in potential future analyses. The scheme yields valuable information on the basic biology and pathology of UK seals and their causes of death. In recent years, identification of predation events by grey seals (cannibalism and predation on harbour seals and harbour porpoise [Brownlow *et al.* 2016]) has been invaluable and is now a major concern, particularly in the light of the declines in east coast harbour seal abundance.

6.2 Current [2017] long-term research

Two existing monitoring programmes for grey and harbour seals provide information on changes in pup production (grey seals), and numbers during their moult (harbour seals). Additional research programmes, such as grey seal demography studies may provide further information on population condition such as studying female body condition and pup growth rates. These statistics vary according to seals' response to conditions in their marine environment (such as food availability) and therefore can be used as indicators of the state of the marine environment and of seal population structure. These data could be used in future as state indicators.

Four additional indicators are suggested that would provide better information on the direct effects of a few pressures on seals. Three of these (seal diet, at-sea foraging distribution and seal bycatch) are closely connected and provide information on the relationship between seals, commercial fishing and the distribution and abundance of fish prey species. Development of all of these would improve our understanding of the relationship between seals and fisheries, would help to define important marine areas used by seals and would provide vital information on the response of seals to changes in abundance and distribution of prey populations.

6.2.1 Population demographics characteristics

Grey seal demography has been studied at two breeding sites in Scotland by SMRU (Pomeroy *et al.* 2000). Both colonies are National Nature Reserves and Special Areas of Conservation for breeding grey seals. Demographic studies focus on the breeding success of individually recognised females, between-years differences in maternal post-partum mass, differences in pup growth rate (within and between years,) pre-weaning mortality, and habitat use by breeding females (Pomeroy *et al.* 1999, Pomeroy *et al.* 2010). Maternal post-partum mass, pup growth rate and pre-weaning survival are dependent on the condition of females returning to the colony to breed. Female condition is determined by her foraging success over the preceding months and will determine the rate at which her pup grows and whether it will survive or not. Demography studies for harbour seals are more challenging due to their intertidal breeding behaviour and our inability to recapture known individuals. However, a database of greater than 900 animals containing morphometric data collected by SMRU and the University of Aberdeen, as well as historical data from dead animals spanning over 50 years could provide useful body condition data that may be related to prevailing environmental conditions and prey variations. In addition, a long-term study of harbour seals in Loch Fleet by the University of Aberdeen provides a sentinel site where changes in fecundity and survival (Cordes *et al.* 2011; Mackey *et al.* 2008; Cordes & Thompson 2014) using mark-recapture methods is continuing that could be utilised in a wider monitoring programme.

6.2.2 Pathogens, contaminants, and toxins

Recent inclusion of seals into the Scottish Marine Animal Stranding Scheme means that changes in the prevalence of certain pathogens in stranded seals can be monitored. Whilst there may be some bias in this approach, it was clear from the outbreaks of phocine distemper in 1988 and 2002 that this is a valid approach in determining the impact of viral epidemics. Surveillance has also been very important in identifying the causes of infectious disease in seals and the land to sea transfer to pathogens, particularly those that are of human origin (Baily *et al.* 2016).

Contaminants (POPs and heavy metals) concentrations have sporadically been determined in UK seals since the late 1980s (Hall *et al.* 1992, 1997, 1999; Hall & Thomas 2007; Debier *et al.* 2003; Pomeroy *et al.* 1996). These have used samples collected during live capture release studies and blubber and tissue samples from stranded dead seals. In general concentrations have declined in these species although hot spots for polychlorinated biphenyl (PCB) contaminant exposure exist in some regions.

More recently, toxins from harmful algae have been reported in UK seals (Jensen *et al.* 2015; Hall & Frame 2010) and research into the impact of domoic acid, saxitoxin and okadaic acid exposure is being carried out by SMRU. Since 2009 samples of seal excreta have been regularly screened for the presence of these toxins. However, as with the contaminant studies, this has been related to specific research objectives rather than for monitoring purposes.

Samples are easily obtained from live-caught seals but Home Office Licensing regulations state that samples cannot be taken from live animals unless they will be processed as part of an existing programme of work. This means that samples of blubber (contaminants) and urine (toxins) cannot be collected in perpetuity and archived for future analysis. The absence of a continuous study or monitoring programme has resulted in many seals being captured for other purposes (such as movement studies) but not sampled.

6.2.3 Seal diet

Seal diet is usually determined through examination of hard parts (bones and otoliths) extracted from seal faeces. Digestion coefficients have been calculated for many prey species and studies of grey seals have shown changes in diet over time. Seal diet all around the UK has been determined by SMRU in three major studies, 1985, 2002 and 2012 (Hammond & Prime 1990; Hammond & Grellier 2006; Wilson 2014). Although the first two studies focused exclusively on grey seals, the most recent project compared the diet of the two species.

Thus, although there have been several specific studies assessing the diet of grey and harbour seals around the UK, there is no formal monitoring programme that routinely identifies regional differences or changes in prey consumption by either grey or harbour seals over time.

A monitoring programme of grey and harbour seal diet at key locations would provide information on seasonal changes in seal diet and, in time, provide information on longer-term changes. Changes in diet would reflect alterations in fish distribution and abundance that might be a consequence of changes in sea temperature around the UK. Regular studies of seal diet could provide information on where commercially important fish species were being consumed. This information could be used to define where fishing operations were exerting pressures on seal populations and, conversely, where seal populations were exerting pressure on commercially important fish stocks. Diet studies would also show which non-commercial prey species were important in their diet.

6.2.4 At-sea foraging

At-sea foraging distribution of UK seals can be determined using telemetry devices attached to seals. These devices locate the areas where seals spend more time (presumably foraging) and the routes they take to reach foraging grounds (e.g. Russell *et al.* 2013). Combined with aerial survey data on seal distribution, telemetry data have been used to create at-sea usage maps (Jones *et al.* 2015). These usage maps can highlight areas where interactions between seals and marine activities may conflict. However, as with many other datasets obtained during research projects, movement and at-sea foraging has limited spatial and temporal coverage. In addition, technological developments such as the inclusion of noise dosimetry sensors and conductivity, temperature and fluorimetry detectors into the telemetry tags could assist in obtaining critical information about noise in the ocean and the prevailing oceanographic conditions (see Boehme *et al.* (2009) for details about animal-borne sensors).

6.2.5 Summary of power of current [2017] UK seal monitoring activities

The statistical power to detect a harbour seal population rate of decline of 1% per year was assessed and found to be ~20%. In addition, a power analysis found it is not possible to detect a 10% decrease over 10 years with the current [2017] survey regime. The annual surveys with a CV of 0.15 and a power of 0.8 give a minimal detectable rate of change of 2% per annum (Hanson & Hall 2015).

For the annual grey seal pup production surveys, a CV of 0.105 is estimated from the state-space model which results in a minimum detectable change of 12% over the 50 years of the study (with annual surveys until 2010). Over 10 years, surveying every two years, a minimum detectable change with 80% power would be 26%, which equates to 3% per annum.

7 Options for monitoring

7.1 Option 1 – Continuation of current [2017] monitoring activities

The UK's current [2017] seal monitoring activities provides population abundance estimates for the two species every ~ five years for harbour seals and every two years for grey seals. Pressure monitoring, through SMASS is adequate for detecting changes in the causes of death for seals only in Scotland. However, targeted bycatch monitoring focuses on certain gears and areas with known bycatch or risk of bycatch and in the areas of most risk (i.e. not in Scotland).

The **average annual** cost [as of 2017] to maintain existing monitoring **abundance and distribution** of the two seal species is approximately £300–500k per year. The funding is currently [2017] provided by the Natural Environment Research Council's National and Public Good, National Capability funding to SMRU. Funding for harbour seal surveys is currently [2017] provided by the SNCBs (particularly NatureScot) and other interested parties. The long-term future of both sources is uncertain. For example, funding for seal counts in the Thames during the summer is not ongoing and there is no regular survey of seals in SW England or Wales.

7.1.1 Abundance and distribution

The main areas of concern within the current [2017] programme is the inadequacy of data to detect trends in abundance with sufficient power. For grey seal pup production, the current [2017] biennial round of monitoring all major pupping sites is adequate. However, for harbour seals the survey frequency is approximately once every five years, although this may vary according to the demand for information from different areas. There is no overall assessment of harbour seal pup production for most of the UK. This is because harbour seals tend to be more dispersed when breeding, newborn pups do not have a white coat and new pups can, and do, swim with their mothers within hours of birth. While information on pup production would be very useful, it would be difficult and extremely time consuming to collect these data over large areas. Instead, harbour seal pups are monitored in the Moray Firth and in Lincolnshire and Norfolk, around The Wash (SCOS 2015).

7.1.2 Occurrence of bycatch

Current [2017] monitoring of the occurrence of bycatch is sufficient to meet the requirements of Regulation 812/2004 which only covers cetaceans although the UK reports seals as other Protected, Endangered and Threatened Species to the ICES Working Group on Bycatch (ICES 2015) and seals are included in the Annex to the cetacean report. However, as with the cetaceans being monitored under this scheme, current [2017] levels of observer coverage are insufficient to generate precise bycatch estimates for the UK fleet which prevents an assessment of whether bycatch is having a significant negative effect at the UK population level.

7.1.3 Strandings and post-mortem examinations

The collation of strandings in Scotland is carried out through the Scottish Marine Animal Stranding Scheme which only covers seals in Scotland (SMASS 2015). Dead seals in England and Wales are only responded to on an *ad hoc* basis or when major disease issues are a potential problem. Both strandings response in the UK, whilst instigated following the PDV outbreak in seals, are set up primarily for the recording of cetacean strandings to allow the UK to meet its obligations to ASCOBANS, and for the Habitats Directive Article 17 reporting. As the strandings scheme also provides the opportunity for the collection of carcasses for post-mortem examination it can alert us to the potential for disease outbreaks (such as PDV and influenza) that could have major impact on seal population abundance and distribution.

7.2 Option 2 – Extend current [2017] monitoring

7.2.1 Occurrence of bycatch

Currently [2017] bycatch monitoring does not focus on seals. Whilst the bycatch of seals in some regions may be high there is no systematic scheme for monitoring the level. Robust and current [2017] estimate of total bycatch are not available. One option would be to extend the current [2017] cetacean scheme to seals.

7.2.2 Strandings and post-mortem examinations

The CSIP in England and Wales is not funded to carry out routine post-mortem examination on seals. Extending this to include all marine mammals would clearly increase our understanding of the disease burden, pathogen, and contaminant exposure as well as other causes of death and interactions with human activities that could affect seal populations to across the whole of the UK.

7.3 Option 3 – Enhanced monitoring: achieving monitoring objectives that underpin core legislation requirements

7.3.1 Population demography

Grey seal population demography in terms of maternal post-partum mass, pup growth and survival are currently [2017] only carried out at two colonies around the UK and continued funding for this work is uncertain. Similar data for harbour seals from long-term studies would be important in determining population state for a species undergoing regional declines (Pomeroy *et al*. 2010; Lonergan *et al.* 2007). Longer term harbour seal research has been carried out at one site in Scotland by the University of Aberdeen (Loch Fleet) where survival and fecundity estimates have been obtained from photo-id studies (Cordes & Thompson 2014). Current [2017] studies funded by Marine Scotland to SMRU are adding similar data for two additional sites in Scotland with different population trajectories.

7.3.2 Pathogen, contaminant, and toxin levels

Pathogen, contaminant, and toxin analysis in seals is currently [2017] only on an *ad hoc* basis and where funding can be obtained although historical data are available for baseline comparison. Samples from stranded and live-captured animals could be used to determine changes in contaminant burdens over time and determine the response of seals to pollutants (Hall & Thomas 2007). Toxins from harmful algae could be used to determine prevailing oceanographic conditions for MSFD as well as indicate impacts of eutrophication and climate change on seal health.

7.3.3 Diet

Long-term monitoring of seal diet would improve our understanding of the pressures on seals and assist in the interpretation of the changes in trends in abundance and distribution. Specific sentinel sites could be chosen for each species.

7.3.4 At-sea foraging

At-sea distribution of seals is now possible to determine from combining seal haulout counts with movement data from telemetry studies. The body of data collected by SMRU and in conjunction with other research groups in the UK and Europe under various research projects has built up a large dataset that has been used by Marine Scotland and developers in understanding the potential for interactions between seals and marine spatial planning conflicts. However, the movement data are only available for specific areas and uncertainty bounds around the at-sea distribution maps are very wide. Recent data for grey at-sea distribution is also lacking (Jones *et al*. 2015).

Summaries of options 1, 2 and 3 are given in Tables 8 and 9.

8 Consideration of monitoring options by the Special Committee on Seals (SCOS)

This paper was considered by the Special Committee on Seals (SCOS) at their meeting in September 2017. The full response to the question relating to the seal monitoring options can be found in the SCOS Advice Document 'Scientific Advice on Matters Related to the Management of Seal Populations: 2017' (available at http://www.smru.st-andrews.ac.uk/research-policy/scos/). In summary SCOS discussed the current [2017] monitoring of seals (abundance, distribution, bycatch and strandings) and the legislative drivers for this work, as well as the enhanced monitoring options. A number of long-term research projects were highlighted that could form the basis of future options, particularly to identify population pressures, including: estimating population demography metrics; pathogen, contaminant and toxin analyses; monitoring seal diet; and at-sea seal distribution. However, considerable further work would be required to design and carry out robust and appropriate monitoring programmes. The current [2017] abundance and distribution monitoring is undertaken in response to the questions on trends in population dynamics received from UK government each year under the provisions of the Conservation of Seals Act (1970) and the Marine (Scotland) Act, 2010, and is therefore a statutory requirement. Expanding the other current [2017] monitoring programmes (bycatch and strandings) to seals across the UK would provide additional desirable information, therefore monitoring option 2 was considered the preferred option.

9 Review of monitoring options by the Special Committee on Seals (SCOS)

The preferred option selected by SCOS was reviewed by HBDSEG, alongside the remaining biodiversity components, at a two-day workshop 27 to 28 March 2018. Participants provided advice on whether an adequate level of evidence would be achieved by the policy option preferences and, if inadequate, what it would take to bring the option to a level of adequacy that would fulfil the following monitoring objectives:

- Understanding the natural variability of the biodiversity component and its role within ecosystem processes and functions.

- Understanding pressure-state relationships and facilitating the development of pressure-based monitoring to enable the sustainable management of human activities.
- Undertake robust assessments of conservation status and site condition at required scales and temporal frequencies to fulfil national and international reporting obligations.

HBDSEG concluded that the option preference selected by SCOS for monitoring UK seal populations would provide an adequate evidence base to fulfil our monitoring conservation and legislative commitments. However, HBDSEG did note that:

- grey seal pup surveys, although majority funded by the Natural Environment Research Council (NERC), are also funded by a variety of additional sources. This is particularly true of the smaller breeding colonies which are counted from the ground. These are funded by various partners and agencies including Natural England, the Friends of Horsey Seals, the National Trust, and Natural Resources Wales. It should be clear that these funds and this support needs to continue to complete the UK wide coverage for grey seal pup production. The figures in the options are not currently [2017] broken down by funding source.
- the amount estimated for including seals in the England and Wales stranding scheme (the CSIP) should be reduced, it should probably be nearer £50K. It should also be noted that the harbour seals surveys are largely funded by NatureScot and Natural England and there is no long-term guarantee of the continuation of this funding.

Table 8 [2017]: Summary of Option 1 and 2 – continuation or extension of current [2017] monitoring activities and their pros and cons.

Parameters	Activity/ method	Approach	Estimated £	Pros	Cons	Specific legislation	Reporting required	Risks
Abundance (and distribution)[1]	Aerial surveys	Largely UK wide grey seal pup production and harbour seal moult counts	300–400K p.a. This accounts for the data provision and the total population model run for grey seals but no development work. It thus accounts for the fact that grey seal pup production is a two-year cycle. This is therefore the average annual cost.	Precise estimates of abundance for MSFD, currently [2017] being implemented as M3 and M5 indicators.	Poor precision for harbour seals.	Conservation of Seals Act, Marine Scotland Act, Habitats Directive; MSFD;	Annually to SCOS; MSFD	Funding uncertainties.

Parameters	Activity/ method	Approach	Estimated £	Pros	Cons	Specific legislation	Reporting required	Risks
Occurrence of bycatch	Direct recording on fishing vessels	Bycatch monitoring scheme	Currently [2017] approx. 224K pa funded directly by Defra and the DAs	Sufficient monitoring of relevant fisheries at a regional level.	Insufficient sampling throughout areas/fisheries of concern for precise population level assessment.	Habitats Directive, MSFD	MSFD - common indicator/target; Habitats Directive Article 17 - pressures	Mandatory monitoring is prescribed under Regulation 812/2004 only for cetaceans.

Parameters	Activity/ method	Approach	Estimated £	Pros	Cons	Specific legislation	Reporting required	Risks
Cause of death	Strandings	CSIP of which SMASS provides coverage of seals	Volunteer reporting. Recording minimal costs in current [2017] scheme but that does not supply cause of death, in England no post-mortem exams carried out routinely. In Scotland additional funding provided by Marine Scotland for seals (~80K p.a. for 40–50 seals per year)	Drive for scheme currently [2017] cetaceans so adding seals is cost effective.	Not effort related which limits interpretation of number of strandings, decomposition and lack of seals washing ashore causes bias, only carried out in Scotland		Habitats Directive	Strandings scheme funding uncertain No routine coverage outside Scotland

[1] Current [2017] monitoring, minimum to fulfil legislative requirements.

Table 9 [2017]: Summary of Option 3 – enhanced approach to monitoring.

Parameters	Activity/ method	Approach	Estimated £	Pros	Cons	Specific legislation	Reporting required	Risks
Population demography	Live capture release	Two long-term study sites for grey seals, Isle of May, and North Rona	~100k annually	Precise estimates of female condition, pup growth and survival	Only two colonies monitored, one declining which has not been studied since 2013	Conservation of Seals Act, Marine Scotland Act	Annually to SCOS	Funding highly uncertain and requirement for licences from the Home Office and Marine Scotland, skills, and expertise for the live capture release studies.
Pathogens, contaminants, and toxins	Strandings and live capture release	Determine changes in pollutant burdens over time	3k per sample.	Trends in POPs in regional seas as indicators of pressure (especially in males that do not depurate during lactation)	POP analyses are expensive, requires live capture release studies to reduce bias in sampling and condition issues that arise from strandings.	Conservation of Seals Act, Marine Scotland Act MSFD	SCOS when data available	Inter-laboratory comparison and QA/QC issues to ensure data comparable with existing baselines, requirement for licences from the Home Office and Marine Scotland, skills, and expertise for the live capture release studies
Diet	Faecal samples	UK wide studies for both species but sentinel sites also an option	~100K annually	Determine changes in prey uptake that reflect changing environmental conditions	Sampling labour intensive, need large samples to ensure comparable datasets	Conservation of Seals Act, Marine Scotland Act	SCOS when data available	Sampling bias

Parameters	Activity/ method	Approach	Estimated £	Pros	Cons	Specific legislation	Reporting required	Risks
At sea foraging	Live capture release	Spatial model incorporating movement with haulout count data	Tag costs ~4k each plus costs for deployment	At-sea distribution estimates important for spatial interactions with anthropogenic activities and determining impact of pressures.	Use of camera systems instead of observers will mean biological samples cannot be collected. Requires maintenance and regular visits to vessel to provide clean hard drives for data storage.	Conservation of Seals Act, Marine Scotland Act	SCOS when data available	Sampling bias, requirement for licences from the Home Office and Marine Scotland, skills, and expertise for the live capture release studies

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Appendix 1 - Acronyms

Acronym	Description
CBD	Convention on Biological Diversity
CMS	Convention on Migratory Species
COBAM	Intercessional Correspondence Group: Coordination of Biodiversity Assessment and Monitoring
Defra	Department for Environment, Food and Rural Affairs
EcoQO	Ecological Quality Objective
GES	Good Environmental Status
ICES	The International Council for the Exploration of the Sea
MSFD	Marine Strategy Framework Directive
NERC	Natural Environment Research Council
OSPAR	Convention for the Protection of the marine Environment of the North-East Atlantic
PME	Post-mortem examination
SAC	Special Area of Conservation
SCOS	Special Committee on Seals
SMASS	Scottish Marine Animal Stranding Scheme
SMRU	Sea Mammal Research Unit
SNCBs	Statutory Nature Conservation Bodies
WGMME	ICES Working Group on Marine Mammal Ecology