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Report of the Workshop on Predator–prey Interactions between Grey Seals and other marine mammals (WKPIGS)

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Middelfart, Denmark

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H. C. Andersens Boulevard 44–46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Executive summary

A one-day Workshop on Predator-prey Interactions between Grey Seals and other marine mammals (WKPIGS) focused on predatory behaviour of grey seals (*Halichoerus grypus*) towards other grey seals, harbour seals (*Phoca vitulina*) and harbour porpoises (*Phocoena phocoena*) in European waters was convened in April 2017. The workshop was chaired by Nora Hanson, UK, Abbo van Neer, Germany, Andrew Brownlow, UK, and Jan Haelters, Belgium. It was attended by 30 scientists from organisations in six nations across Europe, and the USA and aimed to define and harmonise the pathological indicators of grey seal predation events across nations and to collate data on the prevalence and distribution of such events. A further objective was to discuss methods to aid in detection of predation events and potential population-level consequences of reported incidences. The following report summarises the presentations and discussions held in each of four workshop sessions: pathological indicators, distribution and prevalence, population consequences and research priorities.

The challenge of ascribing grey seal predation as the cause of a mortality event from limited pathological evidence was discussed. In cases where the behaviour has been observed in pinnipeds, a straight-edged wound margin which spirals around the carcass is typical; however, most cases are not directly observed. Inferring grey seal predation as a cause of death from stranding reports, photographs and necropsies occurs by ruling out other potential causes of death and by examining the macroscopic and microscopic pathology. Decision-trees have been reported elsewhere and the workshop focused on the challenges of distinguishing grey seal predation from grey seal scavenging and from scavenging by other (terrestrial or avian) predators. New techniques examining the histopathology of wound margins and forensic (DNA) evidence can aid in detection of tearing of warm tissue (indicator of active predation) and in ruling out predators other than grey seals.

Reported cases of grey seal predation events in Europe were collated and summarised. The behaviour has been detected throughout much of the grey seal range, although information is lacking from some key areas. Seasonal trends of predation on pinnipeds peaked during their respective pupping/mating seasons while cases of predation on harbour porpoises peaked in spring months. A total of 737 cases were reported, peaking in 2016.

The implications of these findings for populations of grey seals, harbour seals and harbour porpoises were limited by the challenges of detecting the true prevalence of the behaviour in the grey seal population. The incidence of grey seal predation on other marine mammals steadily increased over the last 10 years although it is not known if this represents a true increase in prevalence, reflects the steady increase in European grey seal numbers over the same period or is due to an increase in effort and reporting. It was noted that if previously high rates of harbour seal mortality due to grey seal predation were sustained, they could potentially account for observed declines in some populations. Coupled with the rise in European grey seal numbers, this could become the most important driver of local harbour seal extinctions in populations already beyond natural recovery.

Future research priorities include continued standardisation of pathological indicators, development of affordable DNA screening techniques and possible targeted ground surveys of e.g. breeding sites where the behaviour has been detected to increase our understanding of prevalence. If possible, telemetry devices could be attached to grey seals exhibiting the behaviour to further study their movements at sea and gain an understanding of the ecological importance of the behaviour from both the individual and population level.

1 WKPIGS Terms of Reference

a) Define and harmonise the pathological indicators of a grey seal predation event.
b) Describe the known prevalence and if possible trends of grey seal predation on other seals and harbour porpoises across the North Atlantic, including spatio-temporal patterns, if any.
c) Identify potential environmental or demographic drivers of the behaviour and trends.
d) Discuss potential methods to quantify the impact of grey seal predation on harbour seal and harbour porpoise populations.
e) Identify knowledge gaps and develop a collaborative program of research to address these.

2 Opening of the meeting

The workshop was convened by co-Chairs Nora Hanson (University of St Andrews), Abbo van Neer (University of Veterinary Medicine Hannover), Andrew Brownlow (Scotland's Rural College), and Jan Haelters (Royal Belgian Institute of Natural Sciences) in response to a recommendation from the ICES Working Group on Marine Mammal Ecology (WGMME) in 2015. Workshop participants met during the European Cetacean Society Conference in Middelfart, Denmark, 30 April 2017. It was attended by 30 scientists from organisations across Europe and the USA. For a list of participants, see Annex 1.

3 Background information

Grey and harbour seals are sympatric predators throughout much of their distribution in the Northeast Atlantic. In some areas of Scotland, where ~ 30% of the European population is found, harbour seal populations are in steep decline. Over the past two decades, and at both sides of the North-Atlantic, there has been an increase in the number of dead seals with indications of acute trauma characterised by a single spiral laceration originating at the cranial end of the animal. Until recently, the causes were hypothesized to be predation by sharks, and/or mortality resulting from collision with ducted propellers on ships. However, direct observations have now been made in Germany (van Neer *et al.* 2015) and in the UK (Brownlow *et al.* 2016) of adult male grey seals causing similar injuries while catching, killing and preying upon young grey and harbour seals.

Additionally, grey seals have been shown to kill and predate upon harbour porpoises in Belgium, The Netherlands, France and the UK (Haelters 2012, Bouveroux *et al.* 2014, Leopold *et al.* 2015, Stringell *et al.* 2015). In the Netherlands, grey seals were identified as one of the main causes of death in stranded harbour porpoises (Leopold *et al.* 2015). Observations of the behaviour usually involve a single adult male grey seal, and distribution of carcass strandings may indicate the behaviour is restricted to a few specialised individuals. The true prevalence is however unknown.

Predation on harbour seals and porpoises by grey seals is an example of asymmetric intraguild predation whereby one predator species kills and perhaps eats another predator with which they are in competition for prey resources. Interactions between sympatric

predators can be modulated by resource limitations, habitat availability / space use, and the dynamics of other intraguild competitive interactions. Understanding the prevalence, and potential drivers, of intraguild predation in these protected marine predators will be critical to the continued work of the WGMME in order to provide sound scientific evidence of the ecological interations between marine mammals in the North Atlantic. National agencies responsible for the management of seals and harbour porpoises under the Marine Strategies Framework Directive, the Habitats Directive and other legislative instruments will also benefit from a concerted effort to collate and disseminate all available information and to develop a collaborative research plan.

4 Pathological indicators of predation

To assess the prevalence of grey seal cannibalism and predation on other marine mammals, it is first necessary to have robust indicators for detection of the behaviour. Several recent publications have documented the gross and histo-pathological indicators of known and likely grey seal predation and scavenging on harbour porpoises (Haelters 2012, Bouveroux *et al.* 2014, Leopold *et al.* 2015), harbour seals (van Neer *et al.* 2015) and young grey seals (Brownlow *et al.* 2016). We refer the reader to those publications for detailed descriptions of injuries that were known or suspected to be caused by grey seals. The cases described in these papers represent a small proportion of the total number of stranded carcasses that have been found with similar pathologies. A major question is thus how to determine if a mortality event was caused by a grey seal when the behaviour was not actually observed, or when only limited evidence is available, for example in a few photographs. Leopold *et al.* (2015) presented the first pathological decision-tree for grey seal predation on harbour porpoises and Brownlow *et al.* (2016) presented a scoring system based on gross pathology for assessment of grey seal predation on grey seal pups. A particular aim of the workshop participants was to discuss the challenges of ascribing grey seal predation as the cause of a mortality event.

4.1 Recognising predation

Some of the pathological indicators of predation by grey seals could potentially be produced by behaviours other than predation, for example scavenging, propeller damage or misdirected sexual aggression. There are two challenges related to scavenging. Firstly, the possibility that wound patterns ascribed to grey seals represent scavenging activity by grey seals rather than active predation. Secondly, the possibility that wound patterns ascribed to grey seals were inflicted by other terrestrial predators or scavengers, e.g. the red fox (*Vulpes vulpes*).

The first challenge has previously been addressed in Leopold *et al.* (2015). The presence of acute macro or microscopic haemorrhages associated with bite marks, good nutritive condition and the presence of food in the stomach (indicative of an animal in good health) were taken as evidence for predation rather than scavenging. Additionally, ruling out other causes of death can aid in discrimination. Brownlow *et al.* (2016) found no evidence for underlying disease or disability in 11 grey seal pup carcasses – some of which were observed killed by an adult male grey seal. The particular predation method of this male appeared to involve drowning the pup prior to tearing at the skin at the back on the neck causing significant haemorrhage. The adult male was then observed to tear at the

skin, producing the characteristic straight-edged wound which, if extended, spiralled around the body of the pup. The male was also observed to rake at the blubber with the incisor teeth, causing both an undermining of blubber oblique to the wound margin and several punctate lesions caused by canine teeth. With the observation of this behaviour, the authors were able to use indicators such as the morphology of the spiral wound, evidence of water, mud or silt aspiration or hypovolemeia to determine a similar cause of death for pups where predation was not directly observed. Most suspected predation events are not directly observed. This has led researchers to investigate wound patterns produced by tearing versus cutting in the laboratory in an attempt to reproduce the characteristic straight-edged wound pattern (Figure 1). Tearing the skin successfully reproduced the wound margins observed on carcasses (Brownlow, van Neer, *pers. comm.*) but one potentially important consideration is that the flesh will tear with less force applied if it is warm, i.e. if the animal is still alive or recently deceased. Future attempts to artificially reproduce such tears should try to do so under realistic thermal conditions.

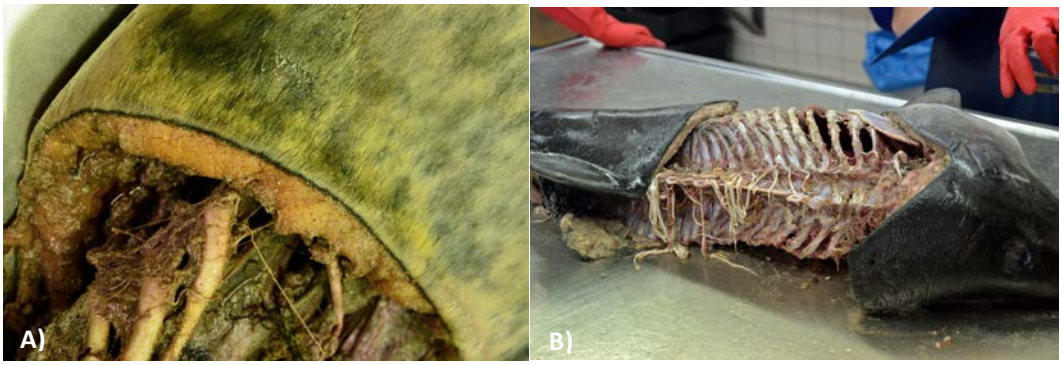

Figure 1. Straight wound margin on a A) grey seal and B) harbour porpoise most likely caused by grey seal predation (Pictures © by Abbo van Neer).

Across Europe, and at the east coast of the USA, there are several other terrestrial and avian predators known to scavenge on diseased, stranded or otherwise weak harbour porpoises and seals. Red foxes (*Vulpes vulpes*) have been observed or suspected to scavenge on harbour porpoises (Haelters *et al.* 2016) and seals, as well as to actively predate on young (often sick) harbour seals on Sylt (Germany) (van Neer, *pers. comm.*), and to be active at a UK mainland grey seal breeding colony (Culloch *et al.* 2012). Avian scavengers on seal carrion are commonplace, including gulls and corvids (Quaggiotto *et al.* 2016).

Figure 2. Avian scavenging on a harbour seal carcass potentially preyed on by a grey seal on Helgoland, Germany (Picture © by Abbo van Neer).

The extent to which these scavengers are capable of producing wound patterns on carcasses similar to those inflicted by grey seals is unknown. Distinguishing between avian and non-avian wounds may be relatively straightforward if carcasses are not too decomposed, but red foxes can produce skin damage and blubber scraping marks similar to those produced by grey seals (Figure 2; van Neer, *pers. comm.*). Lesions that might be typical for fox scavenging in porpoises, and that might discriminate between fox scavenging and grey seal predation, are unilaterally chewed fins and flippers (Figure 3; Haelters *et al.*, 2016).

Figure 3. Harbour seal scavenged on by a red fox on the island of Sylt, Germany (Picture © by Thomas Diedrichsen).

Figure 4. Harbour porpoise presumed scavenged upon by a red fox at the Belgian coast (Picture © by RBINS).

Collisions with vessels may also produce lacerations similar to those known to be caused by grey seals. When the characteristic spiral ('corkscrew') lesions on grey seal pups and harbour seals first appeared in larger numbers, the cause was thought to be propeller interactions (Bexton *et al.* 2012). Subsequent documentation of adult male grey seals causing the same, and more diverse, lesions on seals has shifted the weight of evidence towards grey seals as a natural predator of other seals and harbour porpoises. However, vessel collisions with harbour porpoises in particular may be a source of mortality, although thought to be rare (Waerebeek *et al.* 2007; van Neer, *pers. comm.*). The pathology of a suspected ship strike on harbour porpoises was characterised by a single strike / laceration causing also skeletal damage. One way of potentially ruling out anthropogenic causes is to distinguish between tissue that has been cut versus torn using microhistological methods (discussed in section 4.3).

Additionally, unsuccessful predation events may still ultimately cause death. For a number of cases of stranded porpoises, including live stranded porpoises, it is likely that they survived a predation attempt, to die later, directly from the lesions sustained or from the infection of wounds.

Figure 5. Infected leasion on harbour porpoise from suspected predation attempt (Picture © by RBINS).

4.2 Detection of predation from limited evidence

National marine animal strandings networks vary across Europe in several aspects; objectives, operating mandate, staff and resources. Schemes are usually opportunistic, relying on volunteers and members of the public to report stranded animals. Only a small proportion of those reported are eventually recovered for post mortem examination, with criteria for necropsy depending on taxonomy, decomposition state and accessibility. With increasing use of mobile technology and social media to encourage and facilitate reporting, photographs have become more frequent and can provide a wealth of information about the case if taken properly. In some cases, local volunteers or wildlife rangers have been trained to provide additional samples and measurements from a carcass without the need to relocate it to a lab for a full post-mortem (e.g. Scottish Marine Animal Strandings Scheme, www.strandings.org). Such citizen science is an efficient way of maximising information obtained from reported strandings which otherwise would remain unexamined. Volunteers can be trained to look specifically for, and to document, archetypal signs of seal predation as outlined in Brownlow *et al.* (2016). In future, these efforts will help to provide more evidence to accurately diagnose the prevalence of grey seal predation. Meanwhile, historical records of stranding events can be examined for indications of

pathologies associated with the behaviour. Below, we outline an 'evidence tree' to aid researchers in determining what information can be collected from limited evidence.

If the behaviour is directly observed, it can obviously be classed as a 'DEFINITE' case of grey seal predation. If not directly observed, can the carcass be collected? If so, gross and histo-pathological indicators and decision trees presented in Brownlow *et al.* (2016) and Leopold *et al.* (2015) will aid in classification of cases into likelihood categories. In addition, swabs of punctate wounds or wound margins could be taken for detection of grey seal DNA. Collection of a small section of the wound margin may aid in discrimination between cut and torn flesh by microhistopathological methods (see below). Whilst the 'gold-standard' for attributing a case to grey seal predation is through a detailed necropsy by experienced pathologists, cases can still be classified as 'LIKELY' given sufficient information can be identified from photographs or samples collected by non-pathologists. These might include swabs of punctate wounds or wound margins for genetic analysis and wound margin sample for microhistopathological analysis. 'Good quality' photographs are discussed in section 4.3 in more detail. With appropriately detailed photographs it is possible to achieve a 'LIKELY' classification with this level of evidence. Sometimes, especially for historical strandings reports, only a few photographs are available.

4.3 Potential tools to aid detection

Dedicated observation: The reported cases of direct observation of grey seal predation on a harbour seal (van Neer *et al.* 2015) and on grey seal pups (Bishop *et al.* 2016, Brownlow *et al.* 2016) occurred in areas and at times of high observer effort. At the time, observers were not expecting the behaviour; since the observations were made, teams at both sites have been on the lookout for the behaviour but no further attacks have been directly observed. However, archetypal canabalistic behaviour of a male grey seal towards young pups at a breeding site in the Shetland Islands, UK, was filmed by a BBC cameraman (available at: http://tinyurl.com/y7gxtd2c) and other eyewitness reports (including respective photographs) exist of male grey seal predatory behaviour towards harbour seals collected on Helgoland (Germany) (Figure 5; National Geographic, 2014; video available at: http://kunzgalerie.de/kegelrobbenattacke.html).

While increased awareness in the scientific community of grey seal predation on other seals and harbour porpoises has increased the likelihood of its detection in areas of good existing observer effort, e.g. seal breeding sites, the cost of a broad-scale dedicated observation is prohibitively high. Good detection, however, is vital to enable valid estimates of prevalence and identification of any population-level consequences grey seal predation may have on other marine mammals.

Citizen science apps: Several workshop attendees represented strandings networks. These have increasingly sought to use social media and other dedicated apps to record information from members of the public. Development of standardised reporting of carcasses via e.g. a dedicated app may increase detection of predation cases without increased dedicated observer effort.

Forensic detection: Detection of grey seal DNA on suspected predation carcasses of harbour seals or harbour porpoises, and / or detection of harbour seal or harbour porpoise DNA in the scat of grey seals are potential tools to aid in confirmation of predation.

A recent exciting development to rapidly and efficiently detect DNA on carcasses is the Loop-Mediated Isothermal Amplification (LAMP) assay. In trials the method was shown to efficiently detect grey seal and red fox DNA in porpoise carcasses. For grey seals this method was so far only tested under laboratory conditions whereas for fox DNA it could additionally successfully detect fox DNA in a carcass stranded on the island of Sylt (Germany) (Heers *et al.* 2017) Besides being highly sensitive, the LAMP method has the advantage that tests can be conducted in near real time directly in the field.

Microhistopathology: As highlighted above, discrimination between lesions caused by cuts or tears, e.g. a propeller strike or a case of grey seal predation, is difficult due to similarity of lesions macroscopically. Work is however underway to assess the possibilities of other diagnostic tools, such as the microhistopathological assessment of the wound margin. Direct observations of grey seal predation on marine mammals have so far indicated that lesions induced by grey seals represent torn tissue in contrast to cut tissue (Figure 5). Preliminary results of examinations conducted at the University of Veterinary Medicine Hannover have shown that there is the potential to discriminate between cut and torn tissue using this method.

Figure 6. Grey seal tearing the tissue of a harbour seal on Helgoland, Germany (Picture © by Sebastian Fuhrmann).

5 Prevalence and distribution

Information on the occurrence and distribution of grey seal predation on other marine mammals was collated as part of the workshop. The data presented below represent current and known cases from across European strandings schemes.

Stranding networks around the North Sea coast have been set up in different ways. Below we give a short overview of the organisation of stranding networks and the time frame considered for the analyses of geographical and seasonal distribution and number of cases of grey seal predation on marine mammals.

Belgium

The whole coast of Belgium is easily accessible and strandings are routinely reported by the public to local authorities. Carcasses are collected by the Royal Belgian Institute of Natural Sciences (RBINS) if still useful for further investigation.

Timeframe: 2005–2016

Denmark

The Danish stranding network is coordinated by the Natural History Museum of Denmark (University of Copenhagen). Strandings are reported by the public as well as local authorities and chosen carcasses (at least 25 porpoises and 25 seals per year) are collected for a thorough veterinary examination.

France

With over 20 000 entries, the stranding data base documented since the 1970s by the French stranding network (RNE) provides one of the largest datasets on cetacean strandings in Europe. This network is dedicated to the monitoring of marine mammal populations (biology, demography, ecology, and causes of mortality) and the effort is considered unchanged since the end of 1980s. Around 300 trained volunteers are currently taking an active part in the network. These volunteers make the complete coverage of French coastlines possible, from the southern North Sea to the Southern Bay oy Biscay and Mediterranean coast. Standardized training of volunteers by the Observatoire PELAGIS (UMS 3462, University of La Rochelle and CNRS) staff, which takes place each year, ensures the homogeneity, comparability and standardization of data and sample collection procedures in the field.

Timeframe: 2000–2016

Germany

In the state of Schleswig-Holstein the whole coast (North- & Baltic Sea) including the islands is covered by several trained volunteers and all stranded marine mammals are considered and reported. All areas are regularly monitored throughout the whole year. Cases that are regarded as being of interest due to decomposition status and/or circumstances are being collected for post mortem examination in the Institute for Terrestrial and Aquatic Wildlife Research. This stranding scheme is funded by the Schleswig-Holstein Ministry of Energy, Agriculture, the Environment, Nature and Digitalization. On the coast of Mecklenburg-West Pomerania volunteers as well as the public report carcasses of marine mammals also with the help of a publicly available smartphone app. Selected carcasses are collected by the German Oceanographic Museum for post mortem examination. Work is underway to conduct a retrospective analysis of the existing data assessing the frequency of grey seal predation on marine mammals in this area. For the coast of Lower Saxony there is no organised reporting of stranded marine mammals and carcasses are not routinely collected for post mortem examination.

Timeframe: 1990 (porpoises) and 1996 (seals) to 2016.

Netherlands

The entire coastline of the Netherlands is easily accessible and strandings of porpoises are reported by the public to the volunteers of the National Stranding Scheme and to local authorities. All porpoise strandings are collated in the database of Naturalis Biodiversity Centre (www.walvisstrandingen.nl) and cases in a fresh to moderate condition are collected for post mortem investigation. Necropsies are conducted at the Department of Pathobiology of the Faculty of Veterinary Medicine of Utrecht University. This research is funded by the Dutch government and approximately 50–100 cases are extensively investigated per year. Funding for seals is not available, thus seals are not routinely collected and examined.

Timeframe: 2003 until present

Republic of Ireland

The Irish Seal Sanctuary collates dead seal reports from across Ireland, with associated photographs, and are investigating the historic prevalence of 'corkscrew lacerations' in their database. This is a volunteer based operation and their records date back to 2012. Several 'Likely' cases have been confirmed however, the proportion of grey seal predation cases in their database remains unknown at present as investigation has only recently begun. It seems likely that grey seal predation and cannibalism is occurring in Ireland however the extent and regularity of cases is unknown.

Timeframe: 2012 until present.

UK

Scotland: The Scottish Marine Animal Stranding Scheme (SMASS) collates all reported data from stranded marine animals around Scotland. The scheme has been in operation since 1992 and receives funding from Scottish and Westminster governments to monitor and collate marine animal stranding data. Depending on the condition and location of the carcass, pathologists may collect the carcass for necropsy or arrange for samples to be taken for analysis. Between Jan 1992 and June 2017 there have been 5108 reports of dead stranded pinnipeds, of which 683 have been necropsied. Of those, 59 have been confirmed as having lesions consistent with grey seal attack with a further 193 were diagnosed as being likely or possible cases based on photographs. The incidence is possibly also increasing, with the first cases few being seen in 2007–2009, an average of 25 cases 2010–2015 and 76 cases being reported in 2017. It is not clear however if this is a true increase in incidence or the effect of increased observer effort. In terms of cetaceans, 28 harbour porpoise have shown lesion patterns consistent with seal predation. The first necropsied case was in 2010, and again the incidence appears to be increasing with 21/28 (75%) of these cases being reported since 2016.

Timeframe: 1992 until present

England: The UK Cetacean Strandings Investigation Programme (CSIP) collates reported data from stranded cetaceans, marine turtles and basking sharks. It has been in operation since 1990. Historically, incidents of stranded seal carcasses have not been considered in this scheme although recent incidents of seals with spiral lesions have been investigated further.

Timeframe: 1990 until present

Wales: Apart from a couple of isolated occasions there has been no strategic or systematic funding for reporting and recording seal strandings or post mortem examinations outside of the Phocine Distemper Virus outbreaks.

Timeframe: 1988 until present

5.1 Distribution of known cases in Europe

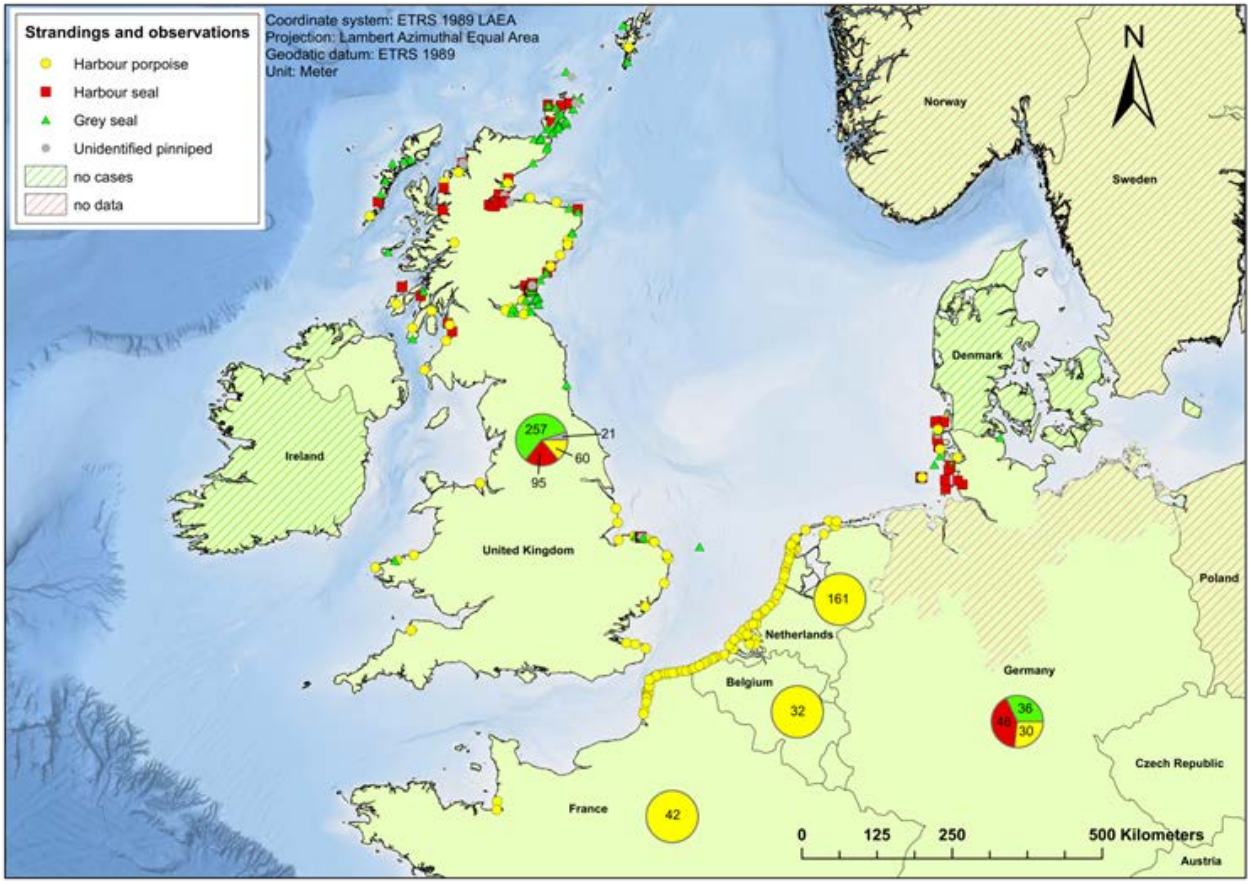

Figure 7. Distribution and number of known cases of grey seal predation on harbour porpoises (yellow circle), harbour seals (red square), grey seals (green triangle) and unidentified pinnipeds (grey circle). Shown data has been provided by the different stranding networks around the North Sea (for details on the respective stranding network see above). Data on bathymetry has been derived from data that is made available under the European Marine Observation Data Network (EMODnet) project (http://www.emodnet.eu/bathymetry), funded by the European Commission's Directorate-General for Maritime Affairs and Fisheries (DG MARE).

The map of the spatial distribution of known cases of grey seal predation on marine mammals (Figure 7) is the first collation of such data of the different states bordering the North and Baltic Sea. Assessment of the spatial occurrence of this phenomenon shows that it is not limited to single countries or regions but has been detected in the majority of areas of grey seal occurrence. It needs to be highlighted though, that the data has a high degree of heterogenity and in parts also resembles the objectives and set priorities of the

different stranding networks, as for example some stranding networks have no funding available for a systematic assessment of stranded pinnipeds.

Most of the known predation cases originate from stranded animals, with direct observation only available in a minority of cases. Severely mutilated animals are often considered as 'decomposed' by the public, as such reported and hence not further considered for further investigation. Also, sometimes small parts such as torn flipper on the beach might be the only remainder of a predation event (Figure 8), and as such may remain unreported. Thus this data set represents an underestimation of the true occurrence frequency of grey seal predation, given that also only an unknown percentage of the remains of a predation event would wash ashore.

Figure 8. Incomplete harbour porpoise remains on a Belgian beach (Picture © by RBINS).

5.2 Seasonal distribution of known cases

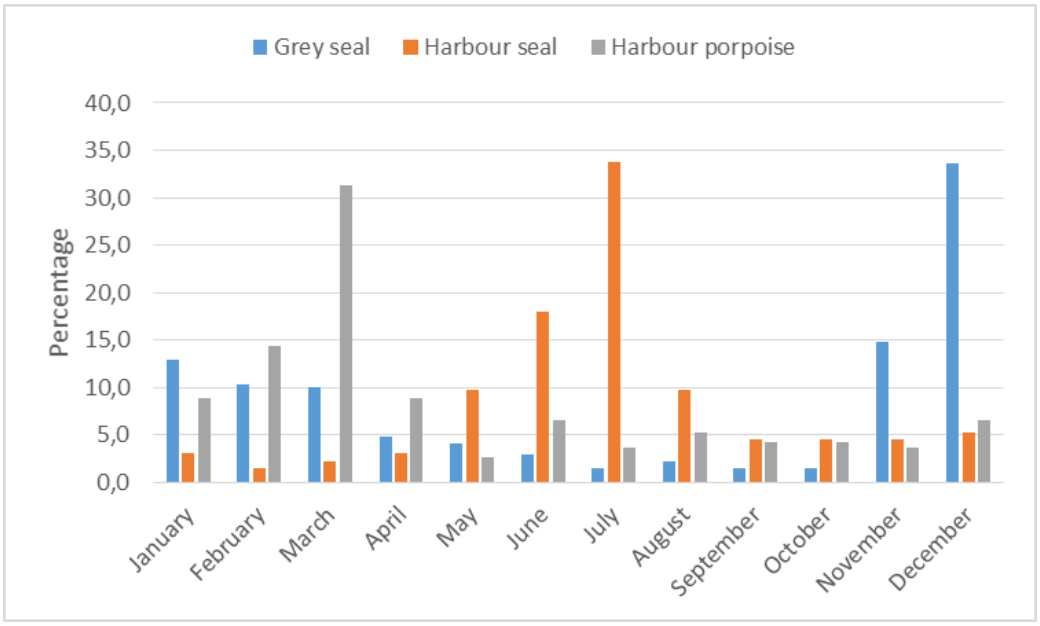

Figure 9. Seasonal distribution per species as a percentage of the total amount of cases found of respective species (n= 729).

Figure 9 shows the seasonal distribution of known cases of grey seal predation for the respective species. Seasonal trends are apparent; grey seals are preyed on predominantly in the winter months with a distinct peak in December whereas a higher percentage of harbour seals is preyed on in May – July. Harbour porpoises are preyed on mainly in the beginning of the year with a distinct peak in March. When comparing these data to the seasonal cycle of the respective species it becomes evident that grey seals' predate on other grey seals primarily during their pupping / mating season in winter months. Harbour seals are predominantly preyed upon during their pupping / mating season in summer months, whereas predation on harbour porpoises takes place during spring.

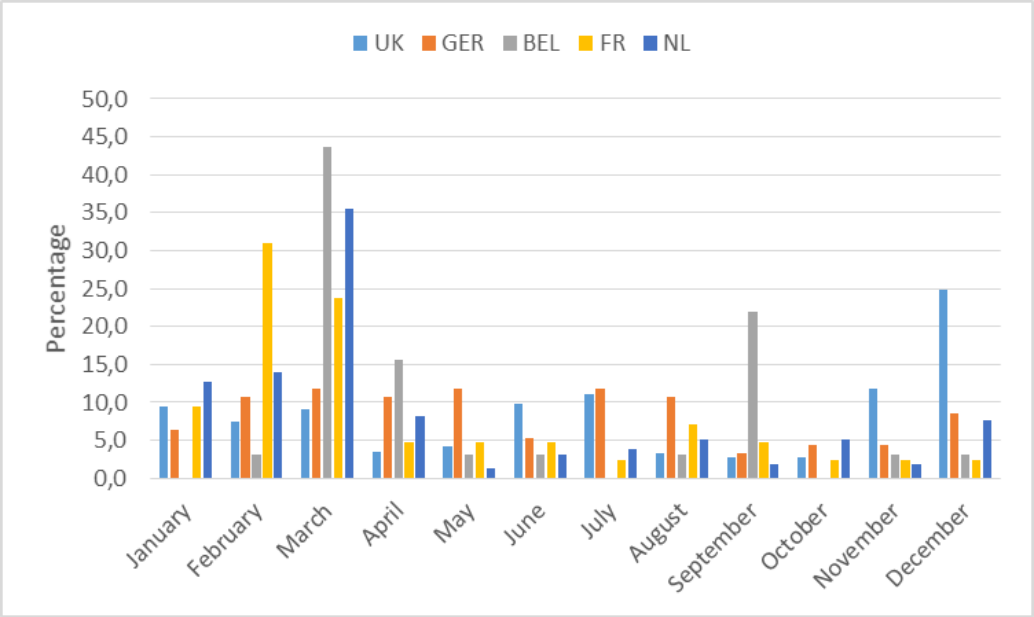

Figure 10. Seasonal distribution per region as a percentage of the total amount of cases (all species) found in the respective region (n= 729).

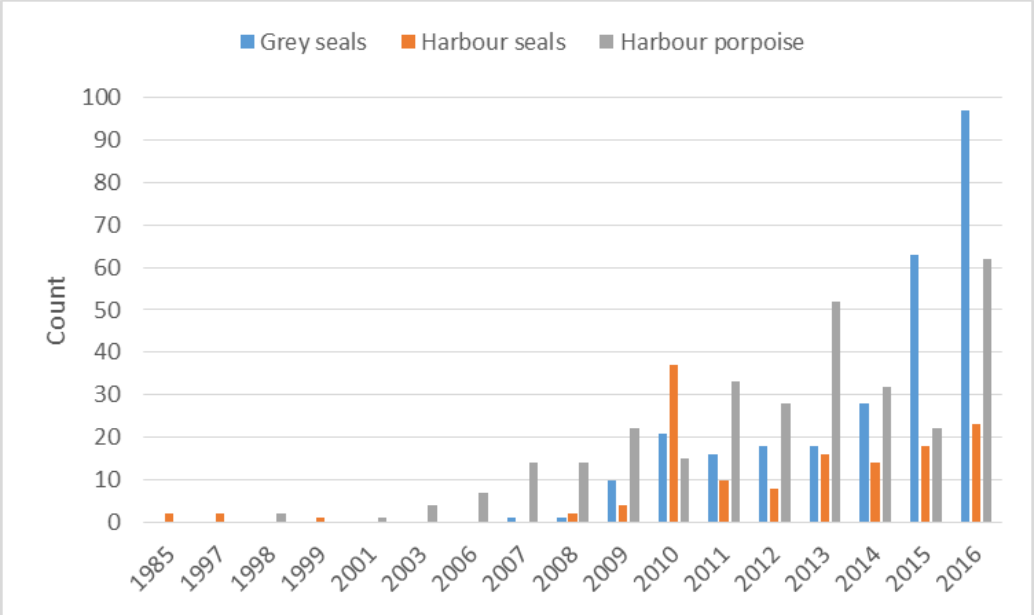

Figure 11. Absolute number of predation cases per species per year (n= 737).

Figure 11 shows the absolute number of known cases of grey seal predation as sum accros the different countries. There is a clear increase in detected cases over the last years with the peak of 186 (97 grey seals, 23 harbour seals, 62 harbour porpoises) in 2016. Whether this increase resembles a real increase in predation events or simply reflects an increase in awareness and effort is unclear. Potentially a part of this increase can be attributed to the substantially increasing abundance of grey seals e.g. in the Netherlands or in Germany which in turn increases the chance of detecting a case of predation as well as

potentially raising the number of cases even if the percentage of animals in the population showing this behaviour is constant.

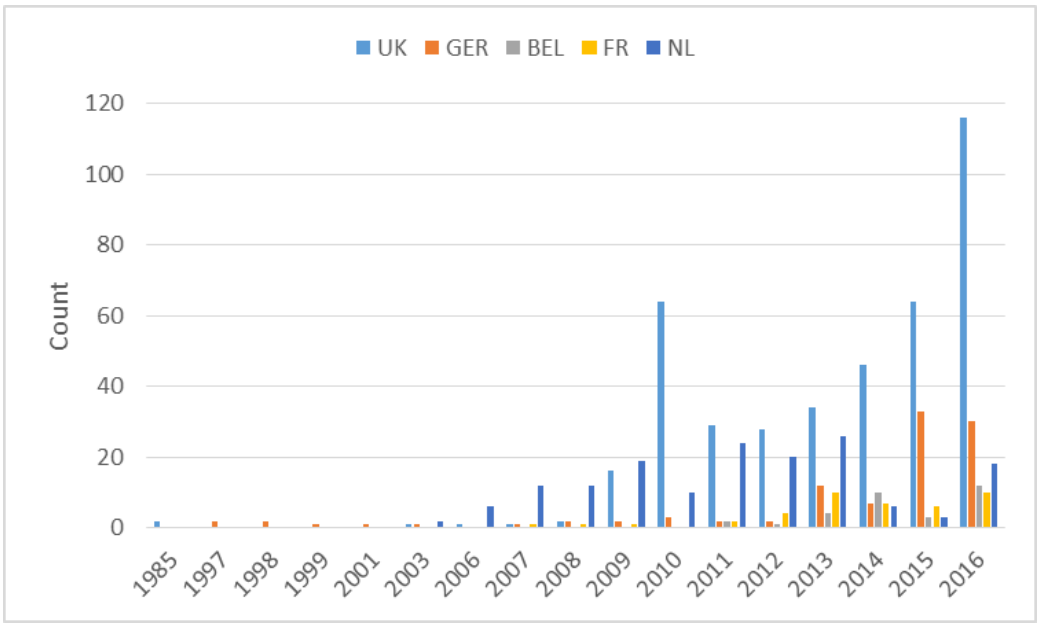

Figure 12. Absolute number of cases per region per year (n= 737).

A similar pattern as in Figure 11 can be seen in Figure 12 with increasing numbers of cases in the respective countries throughout the years. To date the majority of cases reported have been from the UK (Figure 12), primarily due to the large number of harbour seals reported in 2010 and large numbers of grey seal pups and juveniles in recent years. However there is a higher degree of variability present with some countries registering a high number of predation cases also in earlier years.

Table 1. Percentage of females and males of grey seal predation cases where the sex was determined (n= 288).

	Female [%]	Male [%]
Grey seal	58.6	41.4
Harbour seal	47.2	52.8
Harbour porpoise	44.8	55.2
Overall	*46.5*	*53.5*

Considering the data shown in Table 1, there is no clear indication that either males or females are taken as preferred prey by grey seals regardless of species.

6 Population consequences

It is clear that predation on harbour seals and porpoises is recorded throughout the North Sea basin and has continued over time. The group discussed possible population level effects. The main feature of seal populations relevant to the issue is seen as the rapid increase in grey seal populations in the southern North Sea, where both pup produc-

tion and summer haulout counts are increasing. The rapid increase in breeding and spring haulout numbers of grey seals in the Netherlands and Germany are also seen as a potential cause for concern.

It is notable that no repeat of the large scale mortality of harbour seals in S.E England since 2010 (Figure 12) has been detected, but simple modelling exercises show that even relatively small scale removals of adult female harbour seals could lead to population declines in the Wash (S.E. England) population. At present recorded predation levels in the southern North Sea seem to be too small to have a detectable effect on the populations of harbour seals in S.E. England or in the Wadden Sea. However it is recognised that the true extent and scale of such predation is not known.

The working group discussed the population declines of harbour seals in the Tay and Eden Special Area of Conservation (east Scotland; Hanson *et al.* 2017) and at Sable Island (Canada; Bowen, Ellis, *et al.* 2003) during periods of rapid grey seal population growth (Bowen, McMillan, *et al.* 2003, Brasseur *et al.* 2014, SCOS 2016). Both sites show concentrations of harbour seals, predominantly adult females with grey seal predation-type wounds. Both sites suffered catastrophic collapses in harbour seal numbers.

The rapid increase in numbers of grey seal pups being recorded may be due to increased reporting or could represent increased levels of predation. At present the numbers of predation events involving grey seal pups recorded is not thought to be significant in terms of population status.

7 Future research priorities

Several key research questions were identified during the discussions. These essentially fall into three work areas.

1) Improve the technical, clinical and pathological tools available to more reliably attribute seal predation as a primary cause of death.

2) Establish if predation behaviours are a specialist and/or emergent in a small proportion of individuals or a longstanding generalised phenomenon. To what extent is the increase incidence of reported cases a function of increased observer effort?

3) Assess what effect this phenomenon may be having at a group or population level, for example by incorporating seal predation as a factor in existing population dynamic models.

Specific priorities discussed included:

Integration and sharing of data on mortality, pathology and observed predation behaviour with researchers throughout the North Atlantic basin, in specific researchers in Eastern USA and Canada working on populations in Cape Cod, Sable Island and Gulf of St Lawrence.

Development of reliable and robust molecular tools for rapid and inexpensive identification of low levels of grey seal DNA from suspected bite wounds on harbour seal and porpoise carcasses, e.g. Loop mediated isothermal amplification (LAMP) techniques.

Telemetry tagging of known individuals to identify fine-scale behaviour of those individuals identified as exhibiting cannibalistic predation behaviour. This would enable assessment of foraging behaviour, distribution and potentially inform on hotspots for active monitoring of carcases. One aim would be to identify the potential number of predation events a single individual may be responsible for in a given area.

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Annex 1: List of participants

NAME	ORGANISATION	EMAIL
Ann-Isabel Algera		Isabel_algera@hotmail.com
Michael Bakker Paiva	Pieterburen Zeehondencentrum	Michael.bakkarpaiva@zeehondencentrum.nl
Andrew Brownlow	Scottish Marine Animal Strandings Scheme	Andrew.brownlow@sruc.ac.uk
Nick Davison	Scottish Marine Animal Strandings Scheme	Nick.davison@sruc.ac.uk
Mariel Doeschate	Scottish Marine Animal Strandings Scheme	Marielten.doeschate@sruc.ac.uk
Julie Eistrup-Esplat		Julie.esplat@hotmail.fr
Søs Engobe		Soeng11@student.sdu.dk
Miguel Grilo	University of Veterinary Medicine Hannover	Miguel.grilo@tiho-hannover.de
Jan Haelters	Royal Belgian Institute of Natural Sciences	jhaelters@naturalsciences.be
Kirstin Scheme	University of Southern Denmark	Kirstinhansen@biology.sdu.dk
Nora Hanson	Sea Mammal Research Unit, University of St Andrews	nnh@st-andrews.ac.uk
Lonneke Ijsseldijk	Utrecht University	l.l.ijsseldijk@uu.nl
Margarita Mendez	Pieterburen Zeehondencentrum	Margarita.mendez@zeehondencentrum.nl
Misty Niemeyer	International Fund for Animal Welfare	mniemeyer@ifaw.org
Joe Onifriou	Sea Mammal Research Unit, University of St Andrews	Jo26@st-andrews.ac.uk
Yann Planque	University of La Rochelle	Yann.planque@univ-lr.fr
Beatriz Rapado	Pieterburen Zeehondencentrum	Beatriz.rapado@zeehondencentrum.nl
Andrea Ravignani	Pieterburen Zeehondencentrum	Andrea.ravignani@gmail.com
Brian Sharp	International Fund for Animal Welfare	bsharp@ifaw.org
Ursula Siebert	University of Veterinary Medicine Hannover	Ursula.siebert@tiho-hannover.de
Nicole Smialek		n.smialek@gmx.de
Dave Thompson	Sea Mammal Research Unit, University of St Andrews	dt2@st-andrews.ac.uk
Abbo van Neer	University of Veterinary Medicine Hannover	Abbo.van.neer@tiho-hannover.de
Cecile Vincent	University of La Rochelle	cvincent@univ-lr.fr
Linda Westphal	University of Rostock	Linda.westphal@uni-rostock.de
Willem & Emily Zwamborn		emilyzwamborn@gmail.com

Annex 2: Agenda

Grey seal predation workshop (WKPIGS) agenda

9:00 – Welcome (Nora Hanson)

9:15 – 11:15 PATHOLOGY SESSION **Chair: Andrew Brownlow**

Gross and microhistopathology (Abbo van Neer)

Predation cases in Belgium

General discussion & agreement on pathology decision-tree

11:15 – 11:30 Coffee break (provided)

11:30 – 13:00 PREVALENCE & DISTRIBUTION **Chair: Abbo van Neer**

Summary of cases around Scotland (Andrew Brownlow)

General discussion

13:00 – 14:00 Lunch break (not provided)

14:00 – 15:30 POPOULATION CONSEQUENCES **Chair: Jan Haelters**

Grey seals' potential impact on harbour seals in Scotland (Dave Thompson)

General discussion

15:30 – 15:45 Coffee break (provided)

15:45 – 17:15 FUTURE RESEARCH PRIORITIES **Chair: Nora Hanson**

General discussion: top research priorities, funding sources, future collaboration

17:15 – 17:30 Closing remarks