Report on recent seal mortalities in UK waters caused by extensive lacerations

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Dave Thompson¹, Steve Bexton², Andrew Brownlow³, David Wood⁴,
Tony Patterson⁵, Ken Pye⁶, Mike Lonergan¹ and Ryan Milne¹.

1. Sea Mammal Research Unit, Scottish Oceans Institute,
   University of St Andrews, Scotland

2. R.S.P.C.A. East Winch Wildlife Centre,
   Norfolk, England

3. Veterinary Investigation Centre, Scottish Agricultural College,
   Inverness, Scotland

4. National Trust, Blakeney Point Nature Reserve,
   Norfolk, England

5. Veterinary Sciences Division, Agri-Food and Biosciences Institute,
   Stormont, Belfast, Northern Ireland

6. K. Pye Associates
   Reading, England
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1. Summary

This report describes the occurrence of dead seals with characteristic spiral injuries reported from sites on the UK east coast and in Northern Ireland up to September 2010.

Severely damaged seal carcasses have been found on beaches in eastern Scotland (St Andrews Bay, Tay and Eden Estuaries and Firth of Forth), along the North Norfolk coast in England (centred on the Blakeney Point nature reserve), and within and around Strangford Lough in Northern Ireland (Figure 1). All the seals had a characteristic wound consisting of a single smooth edged cut that starts at the head and spirals around the body. In most cases the resulting spiral strip of skin and blubber was detached from the underlying tissue. In each case examined so far the wound would have been fatal. The extremely neat edge to the wound strongly suggests the effects of a blade with a smooth edge applied with considerable force, while the spiral shape is consistent with rotation about the longitudinal axis of the animal.

The injuries are consistent with the seals being drawn through a ducted propeller such as a Kort nozzle or some types of Azimuth thrusters. Such systems are common to a wide range of ships including tugs, self propelled barges and rigs, various types of offshore support vessels and research boats. All the other explanations of the injuries that have been proposed, including suggested Greenland shark predation are difficult to reconcile with the actual observations and, based on the evidence to date, seem very unlikely to have been the cause of these mortalities.

Figure 1. Harbour seal juvenile showing typical spiral wound. Collected in the Eden estuary in St Andrews Bay, July 2009.
2. Occurrence

To date (October 2010), examples of these characteristic spiral cuts have been confirmed on seal carcasses from south east Scotland, south east England and Northern Ireland (Figure 2). Details of species, timing and location of strandings are given in Tables 1 & 2.

- In south east Scotland, two adult female harbour seals (*Phoca vitulina*) were found in summer 2008 in St Andrews Bay. Two juvenile and two adult female harbour seals were found in summer 2009 and six adult female harbour seals (5 of which were in late pregnancy) and one adult female grey seal (*Halichoerus grypus*) were found in St Andrews Bay in June & July 2010 (Figure 3). A juvenile grey seal with similar wounds was also found in the Firth of Forth in December 2009.

- Eleven grey seals were discovered on the north Norfolk coast in the vicinity of Blakeney Point between October 2009 and March 2010. A total of 21 female harbour seals and 5 unidentified seals (thought most likely to have been harbour seals based on their description), were found in the same area between April and September 2010 (Figure 4). Two unidentified seals with similar injuries had also been reported at Blakeney in March 2009.

- Several seal carcasses examined in and around Strangford Lough since 2008 have had similar wounds, with the most recent example in the UK being a harbour seal collected from Strangford Lough on 25th September 2010.

There are also various older reports, of carcasses with wounds to the head and thorax, from these and other areas around the UK. Such animals have often been assumed to have died in fishing nets and sustained lacerations when being cut out of nets. However some of these wounds may be consistent with a rotating blade strike and warrant further investigation in light of our more recent observations.
Table 1. Spiral cut seals found in south east Scotland, mainly in St Andrews Bay and around the Fife coast between June 2008 and August 2010.

<table>
<thead>
<tr>
<th>Species</th>
<th>No.</th>
<th>Age &amp; Sex</th>
<th>Date</th>
<th>Location</th>
<th>Comments</th>
</tr>
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<tr>
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<td>adult female</td>
<td>05.06.08</td>
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<td>01.07.09</td>
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<td>juvenile male</td>
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<tr>
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<td>juvenile male</td>
<td>06.12.09</td>
<td>Inchkeith</td>
<td>fresh</td>
</tr>
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<td>adult female</td>
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<td>Eden estuary</td>
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Table 2. Spiral cut seals found on the north Norfolk coast between March 2009 and August 2010. (Unidentified indicates that the carcass was of a seal the species was not determined.)

<table>
<thead>
<tr>
<th>Species</th>
<th>No.</th>
<th>Age &amp; Sex</th>
<th>Date</th>
<th>Location</th>
<th>Comments</th>
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Figure 2. Areas where seals with spiral laceration have been identified so far
Figure 3. Distribution of spiral cut seal carcasses in south-east Scotland in 2010 (RED=harbour seal, BLUE=grey seal). In summer 2008 and 2009 carcasses were restricted to the Eden estuary and West Sands in St Andrews Bay.

Figure 4. Distribution of seal carcass (marked by a red star) strandings in and around Blakeney in north Norfolk between 12th & 29th July 2010.
3. Pathology

A total 12 harbour seal carcasses from north Norfolk have been necropsied 11 at RSPCA East Winch Wildlife Centre and one at the Veterinary Laboratories Agency. Five harbour seals from St Andrews Bay have been necropsied by the Scottish Agricultural College (SAC). The estimated time between death and when carcasses were necropsied varied between individuals with several estimated to have been dead for only one to two days. Estimates of the time since death (TSD) are notoriously unreliable if carcasses are already showing advanced autolytic change, especially since some bodies may have spent undeterminable periods of time in and out of water. Some carcasses were definitely over 2 weeks old.

In Norfolk all necropsied harbour seals were female, 9 adults and 2 immature animals. Radiographs and close inspection ruled out shooting or other trauma to the head as the cause of death. The key pathological findings were consistent in all seals suggesting a common cause. All had a single continuous wound which started on the left lower jaw and then followed a spiral around the body. The wound ended at different points in different individuals, varying between the bottom of the ribcage and the pelvis. In all cases, the wound followed a clockwise spiral when viewed head-on.

The skin was cleanly cut in a smooth continuous arc in each case (Figure 5) and the blubber and connective tissue had been ripped away (caudally) from the body consistent with a powerful shearing force and with the animal being drawn head-first past the blade causing the laceration. There were no significant bone fractures but the muscular attachments of the scapulae had been torn free in all cases. The cut through the tissue slanted at approximately 35° towards the tail, suggesting the animal was moving forward relative to the cutting device. There was no evidence of cut hair on any of the wounds. This indicates that the cutting edge was not a sharpened blade such as knife or razor and suggests that a smooth edge must have been applied with significant force.

Smaller irregular puncture wounds were present on the muzzles of all the seals in Norfolk. In several cases these wounds appeared to be impressions of a regular serrated edge similar to the shearing blade of a propeller rope cutter attachment (Figure 6).
Figure 5. Photograph of the wound on a juvenile harbour seal. The smooth edged cut through the skin and tearing of the blubber by a lateral shearing force was common to all carcasses examined.

Five harbour seals from St Andrews Bay were necropsied by the Scottish Marine Mammal Strandings programme, two juveniles in 2009 and three pregnant adult females in June 2010. Pathological findings were consistent with those of the Norfolk seals. All cases exhibited corkscrew-shaped wounds, originating on the left hand side of the mouth and spiraling in a clockwise direction as a single, clean-cut continuous spiral around the head and neck, ending in the lumbar region. Unlike the Norfolk seals, few other cut marks were noted on the St Andrews Bay carcasses, but in the two yearling seals the wound cut through the top of the skull.

Figure 6. Facial wound on female harbour seal showing triangular shaped cuts consistent with contact with a propeller rope cutting device.

No grey seal carcasses have been necropsied to date. However, examination of photographs suggests that the pathology is similar, with a single smooth edged
cut spiraling around the body. In those cases where the head can be seen on the photographs the wound appears to start further back on the head, at the back of the jaw or on the neck (Figure 7).

There was no evidence of any underlying disorder such as impaired vision or other disease process in any of the seals examined in Norfolk or St Andrews Bay. Blubber thickness was assessed in an unaffected part of the body and was normal for the time of year in all cases suggesting that these were otherwise healthy animals that had been feeding normally. Where present, the stomach contents also indicated recent successful feeding. Two out of 3 seals tested positive for Domoic acid exposure in the St Andrews animals but none of the 10 Norfolk animals tested showed signs of exposure. Domoic acid is an algal biotoxin known to have produced neuropathological symptoms in seals.

Blood loss from such severe injuries would be massive and unconsciousness and death would be very rapid. The impacts on the two juvenile harbour seals found in St Andrews Bay in 2009 caused instantaneous, massive head trauma that would
have been immediately fatal. All the seals would therefore have died
instantaneously and drifted to shore where they were stranded by the tide. It is
uncertain how far they may have drifted but models of currents in the vicinity
suggest they died close to shore.

4. Is this a continuing problem?
No new carcasses have been seen in either eastern Scotland or Norfolk since late
August. However there does seem to be a seasonal pattern in the findings,
particularly around St Andrews. On the 25th September 2010 a grey seal juvenile
with the same wound type was also discovered in Strangford Lough in Northern
Ireland.

5. Locations where animals died
In both St Andrews Bay and Norfolk a number of the carcasses were from animals
that had died very recently when examined and were estimated to have been in
the water for around one or two days. Others may have been floating for longer
or may have been ashore for some time before being found.

An analysis of the tidal and wave induced surface current in north Norfolk was
carried out by K.Pye Associates. For two seals the times of stranding were known
to within a few hours. Reasonably accurate TSD estimation was possible for two
of the freshly dead Norfolk seals based on a number of factors including gross and
histological evidence of autolysis in various tissues. A detailed analysis of the
effects of tidal and wave-induced surface currents on these seal bodies allowed a
prediction to be made of the likely area in which they died. Results suggest that
these two particular seals died within 5 km of the shore, somewhere between
Scolt (20km west of Blakeney Point) and Weybourne (12km east of Blakeney
Point) with the area between Holkham/Wells and Blakeney the most likely.
Furthermore, as the Norfolk seal bodies have all washed ashore along a relatively
small stretch of coast, it is reasonable to assume they may have died in the same
general area in close proximity to the shore.

A detailed description of the analysis and examples of the estimated drift tracks
for both seals can be found in the full report (contact K. Pye@kpal.co.uk). The
report also details a longer term analysis for the middle of July when several
animals stranded. This analysis also suggested that that the other seals found in
Norfolk probably also died within this general area and also suggests that they are
likely to have been killed relatively close to shore.

A similar analysis of the potential source for the St Andrews Bay seals is
underway. A preliminary investigation based on a simple tidal flow model without
wave and wind driven surface currents suggests that again the mortalities are occurring relatively close inshore. The stranding of two juvenile harbour seals in the Eden estuary at the same time and within a few metres of each other is a strong indication that they were killed relatively close to shore.

6. Geographical extent
So far in the UK, confirmed spiral cut seals have been seen in south east Scotland, north Norfolk and Strangford Lough. There are also reports of similar injuries to seals at sites on the Scottish west coast and on the North east English coast but the absence of photographs or poor quality of photographs means that these cannot be confirmed.

Seals with similar characteristic spiral or corkscrew injuries have been reported from Atlantic Canada for at least the last 15 years. For example, both grey and harbour seals with these types of injuries have washed ashore on Sable Island in Canada. Similar injuries were also seen on large numbers of juvenile harp seals in a single mass stranding along the shore of Prince Edward Island in the Gulf of St Lawrence in 1997. In addition, groups of grey seals with similar injuries stranded in Nova Scotia in 2009 and 2010.

Figure 9. Adult female harbour seal carcass stranded at Monifieth in the mouth of the estuary of the river Tay. Despite appearances, the carcass was relatively fresh and when repositioned, the skin and blubber showed the characteristic spiral cut.
It seems likely that the known geographical extent of this problem will increase as more researchers examine their photographic archives and identify similarly damaged carcasses. It is also likely that in the past, such carcasses have been seen but not identified. Figure 9 shows an example of the stranded carcase of a female harbour seals that suffered these injuries. The pattern of injuries was not obvious on initial inspection and could only be identified after the skin and blubber sections had been re-positioned.

7. Mechanism of Injury: Ducted Propellers

We believe that the most likely cause of death for the seals from the UK is associated with the seals being drawn through a ducted (or cowled) propeller, such as a fixed Kort or Rice nozzle or a ducted azimuth thruster.

The principal reasons for this conclusion are:

- The presence of a single, continuous, smooth edged cut appears to be the result of contact with a single blade. The absence of cut hair suggests that the blade was only sharp enough to cut the skin when applied with sufficient force but not razor sharp.

- To produce the spiral cut the seal must have rotated relative to the blade. Although a seal in contact with a large open propeller may rotate it will also be thrown out laterally away from the centre. The multiple rotations of the spiral cut suggest that the carcasses were prevented from being thrown out. This is consistent with the propeller being in some form of duct or cowling. In such a situation the carcass would be expected to roll around the inside of the cowling while being drawn past the blade by the movement of water through the duct.

- Simple trials using model seals with a solid core and a soft plasticine blubber layer showed that ducted propellers can produce such spiral wounds and that a propeller within a duct of approximately 1.6m diameter or larger would be needed to accommodate an adult female harbour seal.

- The spacing and number rotations of the cuts on the seals is consistent with the architecture of some ship drive systems. An adult harbour seal or juvenile grey seal can be approximated as a 0.4 m diameter by 1.6 m long cylinder. Drawing this through a cowling containing a 1.8m diameter propeller (i.e. approximately the size of propeller likely to be fitted on a 1000kw thruster) with a pitch of 1.0 to 1.7 times the diameter would produce a cut that spiralled round the cylinder between 2.2 and 3.7 times along the length of the object. The successive cuts would be approximately 0.4 to 0.7 m apart (Pearce
The force of water pushing the seal between the angled blades would be large, irresistible, and easily capable of forcing the skin/blubber layer off the underlying muscle and skeleton. The angle of the cuts is consistent with this architecture..

- The presence of patterns, matching the rope cutters that are present on these types of propeller systems, on the side of the head of several animals is also indicative of them being drawn through propellers.

- Ducted propellers and azimuth thrusters are used for the dynamic positioning of vessels. These boats maintain their position by altering the speed and direction of their thrust. This can involve an almost stationary vessel repeatedly starting or reversing its rapidly rotating propellers, a situation that used to be relatively rare. This may increase the opportunities for animals to approach propellers and be drawn into them.

8. Alternative explanations of the injuries

A large number of alternative mechanisms have been suggested by other research groups and the general public. All of these have been considered at length. In response to the wide public and press interest in some of these alternatives we have presented them along with a brief explanation as to why we do not think they are the causal mechanism in this situation.

8.1. Deliberate killing

- The cuts would have been very difficult to inflict manually. Necropsy results indicate that the seals were killed by the cuts, but it would be extraordinarily difficult to produce the single smooth edge cut by hand even on a dead seal and completely impossible on a conscious live animal. The force required to cut the skin with a blade that was not sufficiently sharp to also cut the hair would be well beyond the force that could be applied by a person or even a group of people working together. The consistent nature of the injuries also suggests that those carrying out the cutting would need to have been highly practiced.

- One recurring suggestion has been the existence of purpose built traps/underwater snares. Noting that such traps have not been found and are not known to exist, the mechanism of injury requires that any such device would need to be large, robust and contain a mechanically driven blade of some sort. It is hard to see how such a device could be built, deployed and operated in St Andrews Bay without being observed or detected. There is no evidence for such a device ever having been constructed or deployed.
anywhere. The simultaneous and secret deployment of similar devices in eastern Scotland, eastern England, Northern Ireland and Sable Island in Canada seems extremely unlikely.

8.2. Fishing activity

- Fish lift/pump systems are used on large pelagic trawlers and seine net boats. These are known to have killed seals in the past by sucking them up into the pump mechanism. Extensive discussion with fisheries technologists, local fishery officers and coast guards confirmed that there were no large scale fishing operations in the inshore areas within 10 to 15 km of either Blakeney or St Andrews Bay.

- Long line fishing was highlighted as a potential source of spiral cuts. In order to cause such an injury, a line would need to wrap around the seal and then be pulled tight enough to cut through the skin. The suggested mechanism involved the seal taking the bait or a caught fish and itself becoming caught on the hook.
  - The consistency of the wound is unlikely to result from such a random event.
  - There were no apparent points where the blade cut deeper. A spiral line drawn tight might be expected to “bite” at certain points and produce cuts of different depth. Hooks are designed to grip rather than cut, and so would seem unlikely to produce clean cuts.
  - There are no longline fisheries near St Andrews Bay and we know of no long line fisheries near Blakeney.
  - There was no evidence of fishing line in any of the wounds

- Dredging for shellfish
  - Shell fish dredging is practiced in Norfolk, occasionally off St Andrews and around Sable Island. However, the gear employed does not contain any mechanism capable of producing the consistent spiral cut wounds

- Fishermen cutting seals from nets.
  - This is not feasible given the consistency and the smooth continuous nature of the wound.
  - Repeated references to fishermen removing seals heads and/or slicing them around the body to get them out of nets do not make sense. Such cuts would not help remove nets and would be extremely messy in terms of blood and oil discharge.
The absence of any large scale fishing operations in the fishery exclusion zone around St Andrews Bay and close to Blakeney means that there is no supporting evidence from the localities in which most of the dead seal have been found.

8.3. Self-inflicted injury during escape attempts

- Suggestions that seals are spinning in attempts to escape and cutting themselves on a blade are not feasible given the consistency and severity of the injuries. For example the two juvenile harbour seals in St Andrews Bay in 2009 suffered instantaneous, massive head trauma that was immediately fatal. All carcasses show that the body was dragged past a blade with sufficient force to remove the blubber and skin from underlying tissue. It would be impossible for a seal to maintain the swimming actions needed to inflict such an injury on itself.

8.4 Water Extraction and Dredging

- There are no known fixed mechanical devices with rotating parts large enough to cause these injuries in either area, and no dredging activity other than simple bucket dredging in the Tay and Wells harbours. Bucket dredges do not involve the use of any rotating devices other than the ship propellers on the dredgers themselves.

8.5 Predators

8.5.1 Killer whales

- Killer whales do not possess cutting teeth capable of inflicting cuts like those observed.
- Tearing seals apart would not produce the consistent spiral wounds observed in all seals.
- Although occasionally seen off the Fife coast, killer whales do not occur frequently enough in either St Andrews Bay or off north Norfolk to be responsible for even a small fraction of the seals found.

8.5.2 Greenland sharks

- There has been extensive speculation in the media that the spiral cuts are the result of predation by Greenland sharks. This stems from reports from Sable Island where the similar laceration injuries occur and researchers have suggested that they are inflicted by Greenland sharks. There does not appear to be any direct evidence from Sable Island that Greenland sharks are the principle cause of spiral lacerations to seals. We are
confident that shark predation is not the cause of these wounds in the UK and sceptical of the connection to Greenland sharks in the Canadian case.

- The wounds observed in the UK are inconsistent with shark predation. It is a single smooth edged continuous cut. Although a smooth edged cut can be produced by the small cutting teeth in the lower jaw of a Greenland shark there is no indication that they are capable of producing a continuous spiral cut. There is no evidence at all that Greenland shark bites produce such wounds on carcasses of seals and no plausible mechanism for them to inflict such wounds. An alternative suggestion that Greenland sharks tear the skin by biting the faces of seals and then thrashing or spinning around is inconsistent with the wounds on UK seals (it requires that the razor sharp slicing teeth leave no marks during the violent thrashing) and implausible (the wounds are identical and clearly caused by a blade cutting in from the outside, in one seal at Blakeney the end of a fore flipper in line with the cut was crushed and cut). We also note that there is no direct observation of Greenland sharks involved in this behaviour. We can find no evidence to support the argument that the spiral tear results from some regular lattice structure in the collagen fibres of the skin and blubber in seals as suggested by some Canadian researchers.

- There are no known observations of Greenland sharks in inshore waters in the UK. They are primarily a cold water species and are thought to move into shallower waters in winter. They are not known from the shallow, relatively warm waters of the southern North Sea in July and August.

- There is no explanation for why any predator would kill large numbers of seals without eating any part of any of the carcasses. Video footage of Greenland sharks clearly shows them removing and swallowing large sections of skin, blubber and muscle from scavenged seal carcasses.

- The shark hypothesis at Sable Island was proposed in part because of a perception that there were few boats in the surrounding area. However this is not consistent with the construction, continued development and operation of an extensive network of gas rigs in the coastal waters off Sable Island, e.g. one rig is only 5km from the island’s shore. The development and maintenance of such an industry will have involved a wide range of shipping activity. The presence of these types of vessels appears to be a common feature of the UK and Canadian experiences of spiral cuts to seals.
8.6. Tidal turbines

- Spinning blades on tidal turbines were frequently suggested as likely culprits. They cannot be responsible for any of the seal mortalities on the Scottish or English east coasts because there are no tidal turbines in those regions. The closest operating devices are in the inner channels of the northern Orkney Islands, several hundred miles from the locations at which the, freshly killed, carcasses have been discovered.

8.7. Military activities

- The presence of submarines in the shallow water off Norfolk and within St Andrews Bay is very unlikely. For obvious reasons submarine do not operate normally within shallow waters and the regions concerned are not recognised naval exercise areas.

9. Is this level of mortality important?

The relatively small numbers of seals found would be unlikely to have a significant impact on large seal populations. However, we have no way of estimating what proportion of the casualties we are seeing and it is unlikely that all the mortalities are being recorded.

In St Andrews Bay and the Firth of Tay the harbour seal population has declined dramatically over the past decade. We do not know if the decline is related to this type of mortality but the current level of observed mortality due to this mechanism is unsustainable in this area.

It is not clear which breeding population the Blakeney harbour seals were from. The majority of the English harbour seal population breed in the Wash where pup production is approximately 1200 pups p.a. If we assume a high fecundity rate for this population, the observed mortality would represent approximately 2% of the breeding females. If fecundity is lower, then the observed mortality will represent a lower proportion of the total. Again, it is unlikely that we have seen all the casualties so this must be a minimum estimate of the impact.

We do not know the extent of the problem. We are seeing the carcasses because the seals are encountering the mechanism under a set of conditions that cause them to wash ashore. We do not know if these conditions are necessary for the mortality to occur or just that the particular conditions mean that we are seeing the results of what may be a more widespread but generally unobserved occurrence.
If it is the former, then the problem may be a local phenomenon with limited population scale consequences. However, we know that only a tiny proportion of the 30000+ seals that die each year in UK waters are washed ashore. The probability of observing a seal that dies at sea is therefore low. We cannot rule out the possibility that these stranded carcasses represent fortuitous observations of a more general and widespread process.

The problem may extend to other marine mammal species. Harbour porpoises (*Phocoena phocoena*) exhibiting large lacerations have stranded around the UK and southern North Sea in recent years. In the light of the seal strandings, photographic records of these harbour porpoise strandings are being re-examined.

**10. Future Research**

There are a large number of potential research questions and it is unlikely that we will be able to access funds to investigate most of them. It is therefore important to prioritise the issues and concentrate on those which are most likely to provide useful information.

Characterising the problem, identifying the mechanism and developing a useful mitigation strategy will require an integrated work programme involving specialists in seal pathology, seal diving and foraging behaviour, marine acoustics and coastal flow processes. They will need to interact with experts in marine technology, shipping and other marine industries. Some of the work has already been started and is reflected in this report.

There are four distinct but interrelated aspects to the investigation. For each of these aspects we present the main questions and suggest a specific work programme to address each:

1. **Assessing the scale and extent of the problem**
   a. **Determine the true geographical extent of the problem,**
      i. all seal carcasses washed ashore in the UK should be examined for signs of these wounds. Where possible wounds should be documented and photographed and where appropriate and practicable the carcasses should be collected and necropsied.
      ii. All available information on seal mortality in UK waters should be collated. In the first instance pathology records from the Strangford Lough strandings scheme should be included in the analysis and compared with the records from Norfolk and St Andrews.
iii. an international collaborative effort should be established to identify other examples of the same problem.

b. **Characterise the geographical, biological and oceanographic features of the locations where it occurs.**
   i. An in-depth analysis of wind, wave and tidal current induced movements of carcasses, should be completed for all locations with confirmed corkscrew wounds.
   ii. Further analysis of the ship movement patterns around both North Sea sites should be carried out in light of the wave and tidal current modelling work for both sites.
   iii. information on the distributions of seal haulouts and foraging patterns, bathymetry and boat/industrial usage characteristics should be compared across sites to identify common features.

c. **Assess the intensity of the problem, i.e. assess the number of animals involved**
   i. Methods for estimating the intensity of the problem will be developed in light of information from a & b above

2. **Identifying and then testing the most likely causal mechanisms.**
   a. **Use literature, expert advice and presence/absence to identify candidate mechanisms**
      i. Continue the current investigations and expand the network of researchers/engineers contributing information and suggestions.
   b. **Test the candidate mechanism**
      i. Scale models of seals (using ballistic gel and semi-rigid cores) should be tested in scale models of ducted propellers and other candidate mechanisms of injury.
      ii. Full scale carcass tests should be carried out on those mechanisms identified by scale tests
         1. intact/suitably fresh carcasses of both grey and harbour seals should be collected and stored in a freezer facility.
         2. industrial partners/government departments should be encouraged to supply vessel time for testing.
   c. **Use ship and industry records to identify specific devices where possible.**
      i. Use AIS ship tracking software and shipping /offshore industry records to determine the locations and operation patterns of vessels with candidate mechanisms.
3. Determining the conditions under which the mechanisms become lethal to seals

It is clear that the seals are responding inappropriately to some aspect of the operation of these devices. The localisation in space and time of these events makes it unlikely that the seals are being hit as a result of random coming together of swimming animals and fast moving vessels. The concentration of carcasses in each locality suggests that the vessels must be either stationary or slow moving but operating their propellers, such as when using motors for dynamic positioning. This suggests that some aspect of the operation of these devices is attracting the seals to within a danger zone from which they do not appear to be able to escape. Developing any mitigation measure will require that we identify and understand the attractive mechanism.

Two possible/likely mechanisms would be attraction to concentrations of food associated with the vessel and an inappropriate response to an acoustic signal from the motor/ship/propeller. An acoustic cue is suggested by the fact that all seals killed during summer month have been female harbour seals which are thought to be attracted by underwater calls of breeding males. Juvenile grey seals which are the main victims during winter months in Norfolk and Scotland have also been shown to be attracted by conspecific calls with a pulsing rhythmic pattern.

a. Characterise the acoustic signatures of the potential causal mechanisms

i. Collaborate with industry to obtain a comprehensive set of recordings of acoustic signals from candidate mechanisms identified above. Use a combination of captive animal studies and tests on wild free ranging seals to identify which if any of these signals are strongly attractive to seals.

ii. Collaborate with fisheries scientists and technologists to determine the likelihood that specific mechanisms or the vessels themselves may act as fish concentration devices.

4. Identifying and testing potential mitigation measures.

It would be premature to suggest the development of specific mitigation measures before the research projects detailed above have identified the causal mechanism and the conditions under which these events become more likely. However, it is essential that appropriate actions are taken as soon as we have sufficient information.