Natural England Commissioned Report NECR263

Seal Necropsies in England

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Foreword

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

Background

The Cetacean Strandings Investigation Programme (CSIP, www.ukstrandings.org) have undertaken cetacean (whale and dolphin) necropsies in England for over two decades, but seals have not formed part of the routine surveillance and necropsy programme since the investigation of the last phocine distemper virus (PDV) epizootic in 2002/03.

Monitoring and reporting on harbour and grey seal status are required under the Habitats Directive, the MSFD and informs licensing under the Conservation of Seals Act. Necropsies allow information gains on seal status that cannot be achieved by existing monitoring schemes. For example, seal necropsies can:

- Identify cases of disease and potential disease epizootics (e.g. PDV and influenza A)
- Identify evidence for grey seal predation on other marine mammals
- Identify legal and illegal shooting
- Provide further information on marine debris entanglement/ingestion
- Provide further information on bycatch

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Further information
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Seal necropsies in England

(Contract number Marine SD-014)

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This report results from work conducted by the Institute of Zoology, Zoological Society of London (ZSL), part of the collaborative UK Cetacean Strandings Investigation Programme.

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CSIP
UK Cetacean Strandings Investigation Programme

Executive Summary

Between November 2015 and March 2016, 125 dead seals were reported around the English coast through existing monitoring programmes. These were comprised of grey seals (n=104), harbour seals (n=7) and indeterminate identity seals (n=14), representing a 100% increase in reported strandings in comparison to the mean number over the same period over the previous four years (n=62, 2011-2015).

Of these, 27 were recovered for post-mortem investigation, including 17 that were examined under the funding within this project. Of the 21 grey seals that were examined at post-mortem, the causes of mortality consisted of possible grey seal predation (n=6), infectious disease related mortality (n=6), by-catch (n=2), known by-catch (n=2), starvation (n=2), physical trauma of unknown origin (n=2) and extensive mandibular/oral trauma (n=1). Of the six harbour seals that were examined at post-mortem, the causes of mortality consisted of infectious disease related mortality (n=2), starvation (n=2), and by-catch (n=1). A cause of death was not established in one harbour seal.

By-catch was the only direct anthropogenic driver of mortality in both species. Several cases of probable grey seal predation were diagnosed in juvenile grey seals retrieved from National Trust, Blakeney Point in Norfolk, which exhibited extensive lacerations and associated tissue loss. Recently published research has suggested that a majority of seal carcasses in the UK bearing helical lacerations (or 'corkscrew' seals as they have been termed) are the result of grey seal predation, rather than impact from ducted propellers or shark predation as had been previously proposed.

No cases of shot seals were found during the period of this report. There was no evidence of either marine debris ingestion or entanglement. No cases of infectious disease mortality related to infection with phocine distemper virus or influenza A were noted.

This limited period of funding demonstrates that it is possible to use infrastructure from existing strandings programmes in the UK to run a basic, short-term seal mortality monitoring programme with relatively low levels of financial support. A longer-term monitoring programme would be valuable in enabling more systematic and effective surveillance across the English coastline and to detect new trends in mortality and/or emerging disease outbreaks and threats, but this would require lengthier and greater levels of support.

Contents **Page**

List of Figures and Plates

Introduction

The Cetacean Strandings Investigation Programe (CSIP, www.ukstrandings.org) undertake necropsies on UK stranded cetaceans under contract to UK government and the Devolved governments of Scotland and Wales, to learn more about the threats these species face in UK waters. However, although the investigation of seal mortality formed part of its initial remit in 1990, seals have not been part of the routine surveillance and necropsy programme in England since the investigation of the last phocine distemper virus (PDV) epizootic in 2002/03 (Lawson and Jepson, 2003), apart from a few *ad hoc* investigations for wildlife crime investigations etc. This situation contrasts with that in Scotland, where the Scottish Marine Animal Strandings Scheme (www.strandings.org, part of the wider CSIP consortium) examines stranded seals under contract to Marine Scotland. Without a comparable seal necropsy programme in other parts of the UK, it is difficult to ascertain causes of mortality and to ensure major and/or novel causes of mortality can be identified as early as possible.

There are numerous policy and legislation drivers that would support a more cohesive approach to seal mortality monitoring in England and across the UK, including, but not limited to;

- *Habitats Directive (and associated national legislation) – management measures in sites and seal monitoring for FCS (e.g. causes of changes in abundance, including bycatch, atypical traumatic injuries, disease, competition between seal species etc).*
- *MSFD – descriptors 1 and 4 indicators concerning abundance (as per Habitats Directive).*
- *Biodiversity 2020 – Priority Actions for the harbour seal.*
- *The Conservation of Seals Act (1970) – shooting incidences.*

In November 2015 and following discussion with the contractor, Natural England agreed to fund a short five-month monitoring programme in England (November 2015-March 2016), with the following aims;

- *to improve collation of records of dead stranded seals around the English coast*
- *to carry out systematic necropsies on a proportion of the seals stranded around the English coast during this period.*
- *to identify cases of disease and potential disease epizootics (e.g. PDV and influenza A)*
- *identify evidence for grey seal predation on other marine mammals*
- *identify legal and illegal shooting*
- *identify possible origin/s of atypical physical trauma ('corkscrew' injuries)*
- *marine debris entanglement/ingestion*

The contractor (Institute of Zoology, IoZ, lead partner in the CSIP consortium) used the existing cetacean strandings scheme infrastructure (reporting/transportation network/necropsy capacity), to facilitate a small-scale seal mortality monitoring scheme in England. The funding through this project enabled the recovery, storage, transportation and necropsy of a small number of seals at IoZ. Data generated from such necropsies would be integrated with data collected during a small number of other necropsies carried out in Cornwall, enabling wider reporting of English seal mortality.

Methods

Reporting of seal mortality and collection of carcasses

Strandings are defined by the CSIP as;

"*When an animal swims, is left by a receding tide or is deposited onto land (beach, mudflats, sandbank etc) dead or alive. Live animals that are prevented from stranding by human interaction from the shore, but would clearly have otherwise stranded without such intervention, may also be included.*"[1]

In relation to seals, the picture is more complex as they evidently spend a proportion of their time on land. If reports of a moribund or otherwise compromised seal are received, rescue networks such as British Divers Marine Life Rescue (www.bdmlr.org) will attempt to assess it under veterinary guidance for one of the following options; rescue; euthanasia; or rehabilitation as appropriate. Where reports of dead seals are received, the CSIP will record this information. If a seal has been in rehabilitation for longer than three days and then dies, it is not recorded by the CSIP in the UK database, as it is judged to be no longer representative of the wild population.

In England (excluding Cornwall), seal mortality reports are received by the Institute of Zoology, which maintains a UK wide database on all strandings. In Cornwall, the Cornwall Wildlife Trust Marine Strandings Network (CWTMSN, www.cwtstrandings.org/index.html) co-ordinates the collation of data on seal mortality around the Cornish coast. A small number of seals are retrieved and transported to the University of Exeter (Penryn campus) by CWTMSN volunteers each year for post-mortem investigation under a *de facto* local strandings scheme, with support from University of Exeter, Animal and Plant Health Agency (APHA) and Natural England. Seal strandings data collected by CWTMSN/Exeter University is made available to the CSIP for inclusion in the central UK database and in CSIP national reports. The CSIP also has a regional collaboration in place in the northeast of England with Dr Per Berggren at the University of Newcastle, whereby appropriate strandings in the area are retrieved and held frozen prior to retrieval for post-mortem examination by the CSIP.

The decision about whether to subject a carcass to post-mortem is based on the state of decomposition and whether it can be secured safely prior to collection and transportation to a laboratory for post-mortem examination. The relevant public health considerations of handling seal carcasses were stressed to those individuals and organisations that are involved with the day-to-day reporting and recovery of stranded animals. Appropriate carcasses were occasionally stored frozen in the vicinity of a stranding location, prior to retrieval in batches and/or at the same time as cetacean carcass retrieval, in an effort to reduce transportation costs.

Post-mortem examinations

Stranded seal carcasses were transported to one of two CSIP pathology labs in England:

[1] e.g. Deaville compiler (2016)

- Institute of Zoology (Zoological Society of London), Regent's Park, London, NW1 4RY
- University of Exeter, Penryn Campus, Truro, Cornwall, TR10 9EZ

All seal post-mortem investigations (including tissue sampling) were conducted using standard procedures (See **Appendices 3 and 4**). Essentially, organs were systematically examined and routine tissue samples were collected for virological, microbiological, histopathological, toxicological and other studies. Any observed lesions were also sampled for further diagnostic tests, depending on the suspected aetiology.

Assessing causes of death

Although it is often not possible to arrive at a definitive cause of death for any individual carcass, a most probable cause of death was ascribed wherever possible based on the collective findings from post-mortem and other diagnostic investigations. Oversight of the allocation of causes of death is conducted by Dr. Paul Jepson (CSIP lead scientist and pathologist). Criteria used to establish selected causes of death are described below.

- **By-catch (entanglement in fishing gear)** was ascribed as a cause of death in stranded seal carcasses, using pathological criteria partly derived from cetacean by-catch diagnosis
- **By-catch (known)**- ascribed as a cause of death in animals retrieved directly from fishing gear
- **Infectious Disease**- a broad category consisting of a number of causes of death of infectious origin
- **Starvation**- given as the cause of death in animals that were severely emaciated and, following post-mortem examination, ascertained to have no other significant disease processes that could explain the poor nutritional status
- **Grey seal predation**- ascribed as a cause of death in individuals presenting with pathology potentially consistent with grey seal attack, as recently described (Brownlow *et al.* 2016)
- **Physical trauma (boat/ship strike)**- physical trauma consistent with impact from a boat or ship. Includes blunt trauma to dorsal/lateral aspect of body wall and/or injuries consistent with propeller strike
- **Neoplasia**- where the cause of death is due to the formation of a tumour
- **Debris entanglement**- where the cause of death is associated with entanglement in marine debris leading to drowning or progressive starvation or infection with route of ingress through associated cuts. Sometimes leads to 'ring necking' (see Discussion).
- **Others**- a broad category covering causes of death that cannot be categorised using existing criteria

Tissue archiving

Tissue specimens collected for research were stored frozen at either -20˚C or -80˚C and fixed in either 10% neutral buffered formalin or 70% alcohol at the IoZ or sent to collaborating institutions for research purposes (also see **Appendix 2**).

Results

In the five-month period between 1st November 2015 and 31st March 2016, the CSIP and CWTMSN received reports of 125 dead seals in England, consisting of grey seals (n=104), harbour seals (n=7) and indeterminate identity seals (n=14) (**Figure 1**). These figures represent a 100% increase on the mean number reported during the same period over the preceding four years (**Figure 1** n=62, 2011-2015, data CSIP database). Please note, 2016 data is still being collated for the CSIP UK strandings 2016 annual report (Deaville compiler, 2017) and is subject to potential amendment.

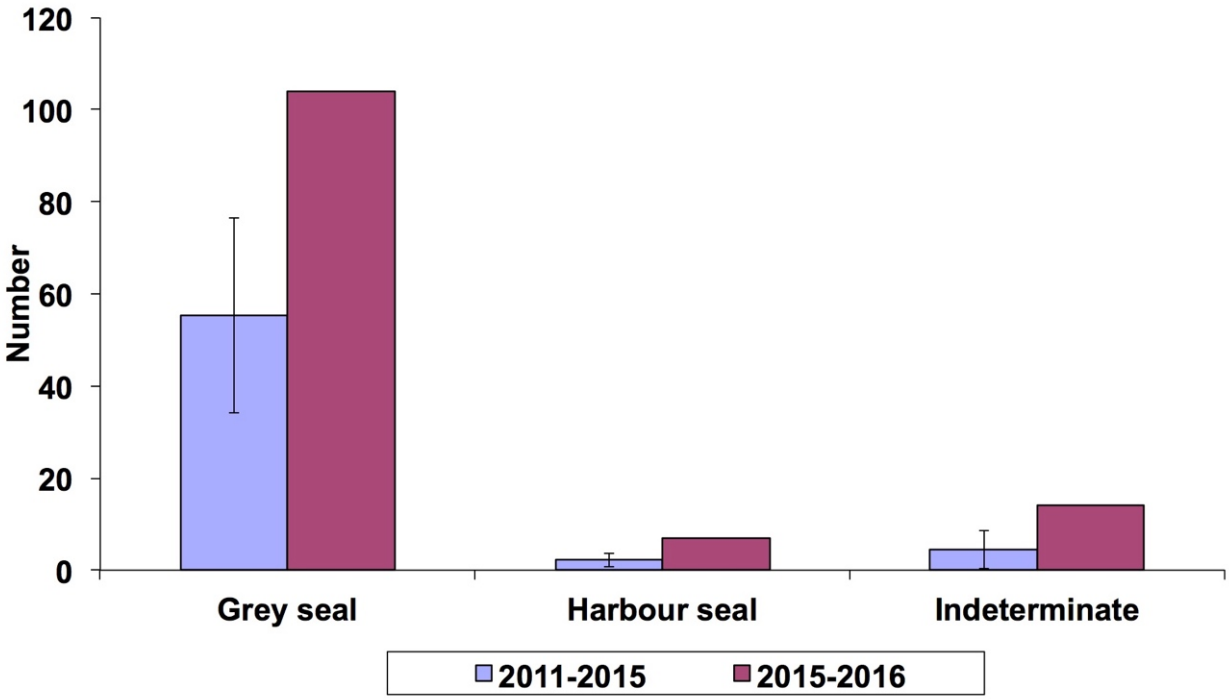

Figure 1 Mean number of dead seal reports received during November-March 2011-2015 and during the period of this report (2015-2016)

Of the 125 stranded seals, 17 were recovered for post-mortem examination at IoZ under funding within this contract and ten were recovered by the Cornwall Wildlife Trust Marine Strandings Network, for necropsy at the University of Exeter. The spatial distribution of animals necropsied during the period of this report are shown in **Figure 2**. Of the 27 seals that were necropsied during this five-month period, 21 were grey seals (13 females and eight males) and six were harbour seals (three males and three females). The causes of death of the grey seals comprised possible grey seal predation (n=6, see Discussion), possible by-catch (n=2), known by-catch (n=2), physical trauma of unknown origin (n=2), starvation (n=2, one of which was associated with right eye blindness, see **Plate 5**), generalised bacterial infection (n=2), parasitic pneumonia (n=1), peritonitis due to perforation of a large ulcer associated with ascarid worm infestation (n=1), osteomyelitis and flipper abscessation (n=1), hepatic abscessation (n=1) and extensive mandibular/oral trauma (n=1) (**Figure 3**). The causes of death of the harbour seals comprised starvation (n=2), by-catch (n=1), generalised bacterial infection (n=1) and parasitic pneumonia (n=1). A cause of death could not be established in one individual

(**Figure 3**). Causes of death and biological, spatial and temporal data on each seal are shown in **Appendix 1**.

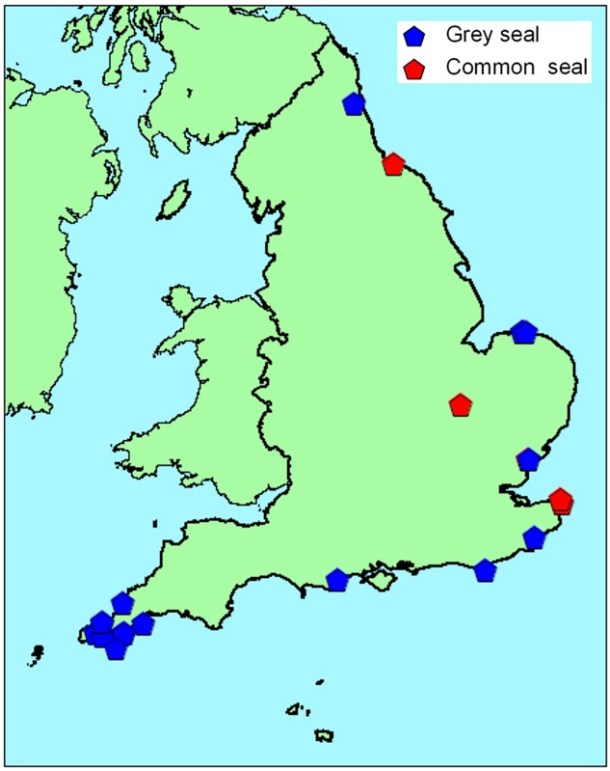

Figure 2 Location of seals necropsied in England during the period of this report (Nov 2015-March 2016)

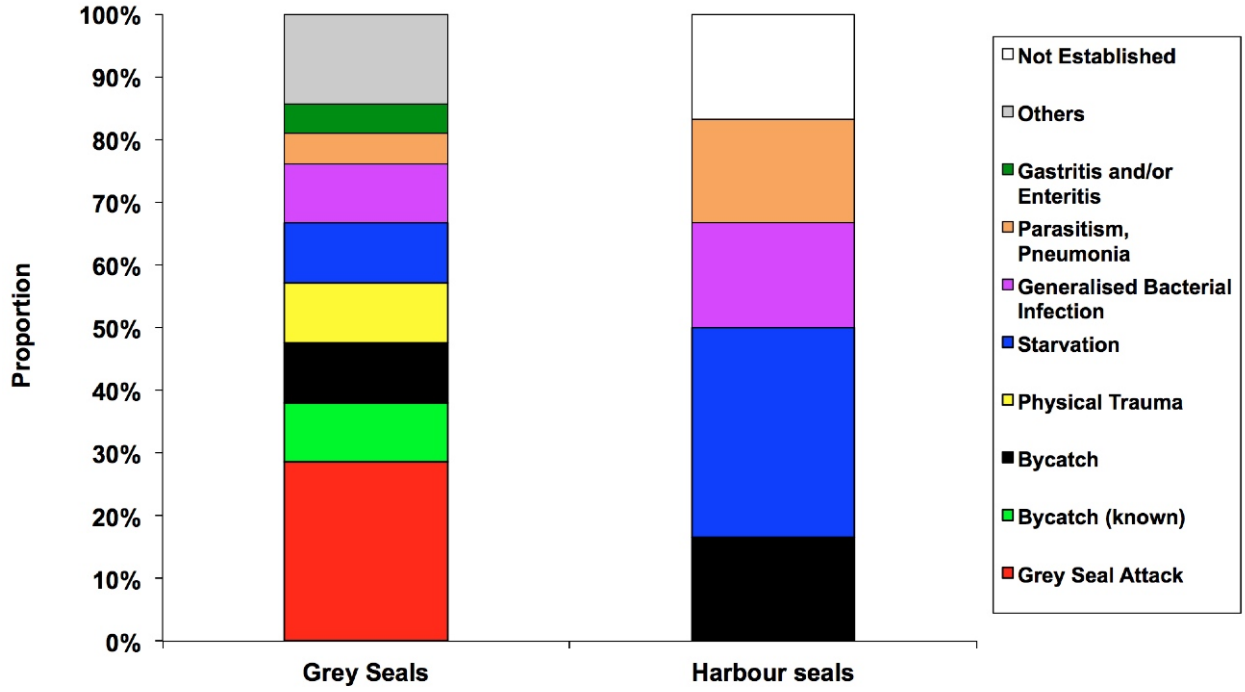

Figure 3 Causes of death in grey and harbour seals examined at necropsy between November 2015 and March 2016

Plate 1 Recovery of SS2016/98 from a lake in Cambridgshire. Image credit CSIP-ZSL

Plate 2 Seal necropsies conducted at Institute of Zoology. Image credit CSIP-ZSL

Plate 3 Lesion on the lateral aspect of the left hind flipper of SS2016/48.1, consistent with entanglement in fishing gear (by-catch) Image credit Exeter University-CWTMSN

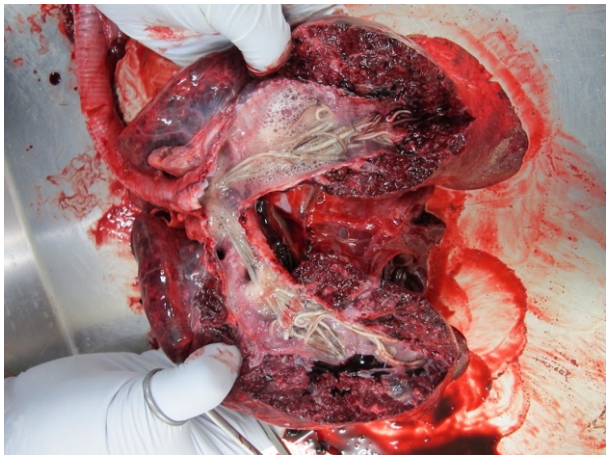

Plate 4 Lungworm burden in the primary bronchi of the lungs of SS2016/1. Image credit CSIP-ZSL

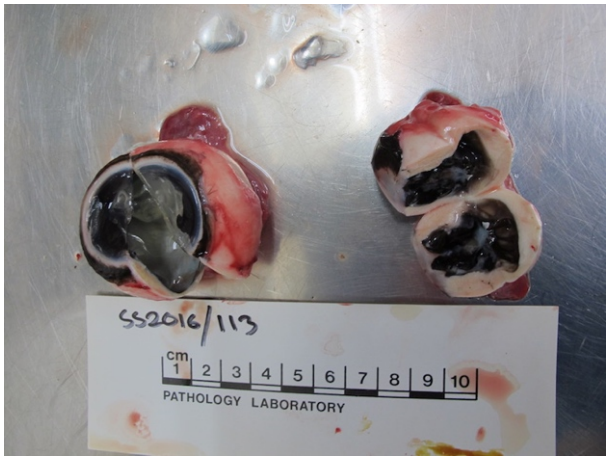

Plate 5 Excised eyes of SS2016/113, an adult male grey seal in poor nutritional condition. Note shrunken non-functional right eye (phthisis bulbi) causing blindness. Image credit CSIP-ZSL

Plate 6 Potential grey seal predation case from Blakeney Point, Norfolk (SS2015/432). Image credit CSIP-ZSL

Discussion

This five-month period of funding had several broad aims, as stated in the Introduction. These are discussed individually below.

- ***to improve collation of records of dead stranded seals around the English coast***

The 125 reports of dead seals received by the existing networks (CSIP and CWTMSN) during the period of this report, represents a 100% increase in reports over the same period during the preceding four years. This increase may have at least in part been driven by attempts to publicise the work programme of this contract and consequentially increase effort in seal mortality reporting around the English coast.[2] However, following the end of this project in April 2016, reported stranding numbers declined to levels comparable to previous years (data CSIP UK strandings database).

- ***to carry out systematic necropsies on a proportion of the seals stranded around the English coast during this period***

The post-mortem examinations of 27 seals took place during the five-month period of this report, 17 of which were directly funded by Natural England via this contract. A variety of causes of death were determined, with by-catch being the only direct anthropogenic driver of mortality that was recorded.

The known by-caught seals examined by colleagues in Cornwall (SS2016/48.1 and 48.2, see **Appendix 1**) are potentially useful cases, as they may help create diagnostic criteria for establishing the pathology of by-catch in pinnipeds. As Duignan and Jones (2007) point out, diagnosis of by-catch in pinnipeds is more difficult to determine than in cetaceans, as any net marks may be masked to some extent by the dense pelage and tougher keratinised epidermis of seals (also see **Plate 3**). In addition, the Sea Mammal Research Unit are also examining a small number of pinnipeds retrieved through their by-catch observer schemes and it is hoped that the data from these individuals may also aid in the future diagnosis of by-catch in any stranded individuals examined at necropsy (pers. comm. SMRU).

A broad range of samples were also collected during these necropsies and are held in the national marine mammal tissue archive maintained at IoZ (see **Appendix 3**). These samples may prove of use in future multi-disciplinary collaborative studies.

- ***to identify cases of disease and potential disease epizootics (e.g. PDV and influenza A)***

Since the last phocine distemper (PDV) epizootic between 2002-2003 (Jensen *et al.* 2002, Härkönen *et al.* 2006, Lawson and Jepson, 2003), populations of harbour seals are thought to have returned to pre-epizootic levels in many parts of Europe (including the east coast of England). The estimated inter-epidemic interval for PDV has

[2] e.g. https://www.zsl.org/blogs/wild-science/understanding-seal-strandings
http://www.edp24.co.uk/news/environment/new_study_launched_into_mysterious_seal_deaths_between_wells_and_blakeney_1_4346379

been proposed to be around 14 years (Harding *et al.* 2002) and it is expected that another PDV epizootic is likely to occur at some point in the near future (e.g. Bodewes *et al.* 2013). Epizootics of influenza A have also impacted harbour seal populations on the European North Sea coast in recent years (Zohari *et al.* 2014, Krog *et al.* 2015, Bodwewes *et al.* 2015).

No cases of PDV or of influenza A infection were diagnosed in any of the seals examined during the period of this report. However, outside of the period of this report, *Klebsiella pneumoniae* of suspected human origin was recently found in three free-living harbour seals on the east coast of England (Duff *et al.* 2016). A more cohesive approach to and longer term monitoring of seal mortality in England would help facilitate the early detection of any future disease outbreaks, including any PDV or influenza A epizootics.

- ***identify evidence for grey seal predation on other marine mammals***

Previous research has identified the grey seal as a potential predator of other marine mammals around Europe including harbour seals and harbour porpoises (van Neer *et al.,* 2014, Haelters *et al.* 2012, Leopold *et al.*, 2014, Bouveroux *et al.* 2014). Direct observations of predation events have also occurred in the UK more recently, involving grey seals predating on harbour porpoises (Stringell *et al.* 2015) and grey seals predating on grey seal pups (Bishop *et al.* 2016). The main driver for these events has been proposed to be interspecific resource competition as sympatric grey seal and harbour porpoise populations in parts of the North Sea increase (e.g. van Neer *et al.* 2014).

During the period of this report, colleagues at National Trust, Blakeney Point in Norfolk retrieved a number of juvenile grey seals for examination by IoZ. They were all found stranded between December 2015 and February 2016 and exhibited evidence of potential traumatic interactions (see **Plates 6 and 7**). The examination of these seals revealed a number of findings comparable with recently published literature describing grey seal cannibalism (Brownlow *et al.* 2016), including multiple linear to curvi-linear deep lacerations and tissue defects, extensive tissue loss, undermining of the blubber layer, separation of the skin and blubber layer from underlying subcutaneous tissue, evulsion of scapulae, punctate lesions consistent with grey seal bite marks in edges of remaining blubber/skin and little to no damage to the underlying skeletal structure (see **Plates 6 and 7** and **Appendix 1**). All the Blakeney point seals were broadly similar in size (113-126cm) and appeared to be in otherwise good nutritional condition and with broadly similar pathology, indicating a similar aetiology to the cases.

The National Trust team at Blakeney Point have documented a number of similar cases over the last 4-year period (2013-2016, n=47, *pers. comm.* National Trust, Blakeney Point), with a majority occurring during the winter months (n=44, Dec-Mar). In addition, direct observation of a grey seal predation event by a bull on a grey seal pup also occurred in the region during the period of this report in February 2016 (*pers. comm.* National Trust, Blakeney Point). Grey seal predation may therefore be a relatively common cause of mortality in some locations and at certain times of the year. However, the exact scale, extent and potential impact of this interesting phenomenon is currently unclear and further investigation is therefore warranted.

Plate 7 Panel of images from potential grey seal predation cases from Blakeney Point, Norfolk (images from SS2016/322, SS2016/323 and SS2016/324)

- ***identify legal and illegal shooting***

No evidence of shooting was identified in the necropsied seals examined during this study. However, numerous reports of shot seals are received each year in England, so this may just be a consequence of the relatively brief period of funding. Post-mortem examinations of suspect cases can not only help differentiate genuine shooting cases[3] from spurious reports, but can also potentially reveal whether any non-compliance with legislation may have taken place. For example, they can help reveal the calibre of bullet or type of firearm employed (e.g. use of shot guns rather than rifles), the potential orientation of the animal when shot (i.e. whether supine/hauled out) etc.

- ***identify possible origin/s of atypical physical trauma ('corkscrew' injuries)***

The discovery of dead seals with helical, circumscribing cuts around the body at various UK locations during the beginning of this decade, lead to speculation that these lesions may have been due to ship strike and more specifically due to impact from ducted propellers (Bexton *et al.* 2012, Onoufriou and Thompson 2014). Large numbers of dead seals found on Sable Island in Canada with similar 'corkscrew' type lesions had

[3] e.g. http://www.dailymail.co.uk/news/article-2122863/Mystery-seal-shot-dead-riverbank-anglers-blamed-eating-fish.html

alternatively been linked to predation by Greenland sharks (Lucas and Natanson 2010). Since the funding for this project was initiated in November 2015, direct observations of grey seal predation events on the Isle of May in Scotland[4] (Bishop *et al.* 2016) led to a pathological reassessment of these cases by Brownlow and colleagues (Brownlow *et al.* 2016), with the authors concluding 'that most of the seal carcasses displaying spiral lacerations in the UK are caused by grey seal predation'. The balance of probability is therefore that a large majority of the 'corkscrew' type lesions can in fact be explained by aggressive interactions from grey seals. See the preceding section '*identify evidence for grey seal predation on other marine mammals*' for more detail on work on this issue in England. An ICES workshop on this topic will be held at the forthcoming 2017 ECS conference in Middlefart, Denmark [5].

- ***marine debris entanglement/ingestion***

No cases of marine debris ingestion or entanglement were found during the period of this report. However, cases of chronic debris entanglement have been previously diagnosed in seal necropsies carried out elsewhere in England (for examples see Plate 8 below). Seals appear to be prone to entanglement in marine debris, as described in work previously conducted in Cornwall by the Cornwall Wildlife Trust Marine Strandings Network (CWTMSN 2015 and **Plate 8**) and elsewhere (NOAA 2014) and can pose a potentially significant welfare issue for affected individuals. The CSIP routinely records and reports on data on marine debris ingestion/entanglement in UK stranded cetaceans examined at necropsy, as this information can potentially help inform research and monitoring under Descriptor 10 of the Marine Strategy Framework Directive (marine litter). Collection of comparable data in seals during routine necropsies (both negative and positive) could also feed into the UK wide reporting and help further our understanding of the scale and extent of this issue. It may also be possible to provide a degree of monitoring of this issue, through the use of increased effort in seal mortality reporting, provision of digital imagery etc. Further study through additional and more extensive seal mortality monitoring is therefore warranted.

Plate 8 Grey seals examined with evidence of chronic entanglement resulting from discarded or other marine debris. Cases from Cornwall in 2014 and 2015 (left and middle image, credit Exeter University-CWTMSN) and Kent in 2015 (right hand image, credit Thanet council)

[4] Cannibalism by a male grey seal (*Halichoerus grypus*) in the North Sea (https://vimeo.com/154314167)
[5] Workshop on Predator-prey Interactions between grey seals and other marine mammals http://www.ices.dk/community/groups/Pages/WKPIGS.aspx

Conclusions

This five month contract has demonstrated that a basic and short term seal mortality monitoring programme can be set up in England fairly readily, using existing CSIP infrastructure and reporting processes and with relatively low levels of financial support.. However, the short-term nature of this monitoring programme could only ever reveal a relatively limited amount of information. Any longer-term monitoring programme would require greater and more continuous level of support. This would enable more systematic and effective surveillance across the English coastline and allow the early detection of new trends in mortality and/or emerging disease outbreaks and threats. The cost/s of any subsequent seal mortality-monitoring programme would be largely determined by the specific requirements and scope of any contract objectives.

Acknowledgments

Grateful thanks are due to Natural England for agreeing to fund this short term monitoring contract. As with the main outputs of the CSIP, the success of this project relied upon the efforts of a number of individuals and organisations, which have assisted with the reporting and collection of stranded seal carcasses for post-mortem examination during 2015-2016. These include staff of coastal local government authorities and landowners, as well as members of the public and our grateful thanks go to them all.

Many thanks in particular to the staff and volunteers at National Trust, Blakeney Point (particularly Victoria Egan, Graham Lubbock and Ajay Tegala) for their help with the recovery and storage of seal carcasses and helping us to explore the issue of grey seal predation. Julia Cable and Stephen Marsh at British Divers Marine Life Rescue also provided much support and advice during the period of this report. We'd also like to thank colleagues from the wider CSIP consortium, particularly Louise Allan and Rod Penrose for their assistance and advice.

We would also like to thank the staff and volunteers of the Cornwall Wildlife Trust Marine Strandings Network (CWTMSN), who have given endless and unstinting help with the coordination and reporting of seal strandings around the Cornish coast. In Cornwall, we would like to particularly thank and acknowledge the dedication and hard work of CSIP pathologist James Barnett (University of Exeter) who conducts necropsies at frequently inhospitable hours. We would like to thank Dr. Per Berggren and the staff at the University of Newcastle/Dove Marine Labs for all their much-valued assistance with the recovery and storage of strandings in the northeast coast of England.

Finally, we would particularly like to thank and acknowledge Rebecca Walker at Natural England for her endless patience and considerable efforts in supporting the work carried out under this contract.

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Appendix 1: Causes of death of seals examined at post-mortem in England (November 2015-March 2016)

NE	National Ref.	PM no.	Species	Sex	Length	Date	Location	County	Cause of death
No	*SS2015/265*	*EX/S15/15*	*Grey seal*	*F*	*118*	*06-11-15*	*Marazion*	*Cornwall*	*acute death (possible bycatch)*
Yes	**SS2015/417**	**EXTERNAL**	**Grey seal**	**M**	**111**	**13-11-15**	**Morpeth**	**Northumberland**	**starvation/hypothermia**
No	*SS2015/290*	*EX/S16/15*	*Grey seal*	*F*	*94*	*22-11-15*	*Hayle*	*Cornwall*	*osteomyelitis (maxilla) and flipper abscess*
No	*SS2015/315*	*EX/S17/15*	*Grey seal*	*F*	*94*	*06-12-15*	*Gorran Haven*	*Cornwall*	*mandibular lymph node abscessation (and possible terminal septicaemia)*
Yes	**SS2015/317**	**XT1567/16**	**Harbour seal**	**F**	**126**	**11-12-15**	**Broadstairs**	**Norfolk**	**not established**
Yes	**SS2015/316**	**XT1636/16**	**Harbour seal**	**M**	**172**	**14-12-15**	**Viking Bay**	**Kent**	**generalised bacterial infection (*Streptococcus* grp. F)**
Yes	**SS2015/318**	**XT973/16**	**Harbour seal**	**F**	**171**	**16-12-15**	**West Mersea**	**Essex**	**physical trauma, bycatch (possible)**
Yes	**SS2015/431**	**XT1819/16**	**Grey seal**	**F**	**114**	**20-12-15**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
Yes	**SS2016/1**	**XT056/16**	**Harbour seal**	**M**	**110**	**01-01-16**	**Marske-by-the-Sea**	**Redcar & Cleveland**	**gastric and pulmonary parasitism (heavy)**
Yes	**SS2016/2**	**XT104/16**	**Grey seal**	**F**	**165**	**04-01-16**	**Coopers Beach**	**Essex**	**generalised bacterial infection (*Streptococcus canis*) and physical trauma**
Yes	**SS2016/301**	**XT1635/16**	**Grey seal**	**M**	**150**	**08-01-16**	**near Dymchurch**	**Kent**	**hepatic abscess**
No	*SS2016/030*	*EX/S01/16*	*Grey seal*	*F*	*105*	*10-01-16*	*Fistral beach*	*Cornwall*	*bronchopneumonia (secondary to lungworm infestation)*
Yes	**SS2016/321**	**XT1818/16**	**Grey seal**	**F**	**113**	**11-01-16**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
Yes	**SS2016/322**	**XT1682/16**	**Grey seal**	**F**	**126**	**15-01-16**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
Yes	**SS2016/58**	**XT145/16**	**Grey seal**	**M**	**121**	**18-01-16**	**Sandbanks**	**Poole**	**physical trauma**
No	*SS2016/031*	*EX/S02/16*	*Grey seal*	*M*	*127*	*18-01-16*	*Maenporth beach*	*Cornwall*	*acute death (possible bycatch)*
No	*SS2016/032*	*EX/S03/16*	*Grey seal*	*F*	*110*	*21-01-16*	*Praa Sands*	*Cornwall*	*peritonitis (due to perforation of a large ulcer associated with ascarid worm infestation)*
Yes	**SS2016/323**	**XT1817/16**	**Grey seal**	**F**	**118**	**21-01-16**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
Yes	**SS2016/98**	**XT366/16**	**Harbour seal**	**M**	**119**	**02-02-16**	**Swavesey**	**Cambridgeshire**	**starvation/hypothermia**
Yes	**SS2016/75**	**XT311/16**	**Harbour seal**	**F**	**167**	**16-02-16**	**Botany Bay**	**Kent**	**starvation/hypothermia**

NE	National Ref.	PM no.	Species	Sex	Length	Date	Location	County	Cause of death
Yes	**SS2016/324**	**XT1700/16**	**Grey seal**	**F**	**123**	**19-02-16**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
No	*SS2016/048.1*	*EX/S04/16*	*Grey seal*	*M*	*125*	*19-02-16*	*Falmouth*	*Cornwall*	*bycatch (known)*
No	*SS2016/048.2*	*EX/S05/16*	*Grey seal*	*M*	*125*	*19-02-16*	*Falmouth*	*Cornwall*	*bycatch (known)*
No	*SS2016/100*	*EX/S08/16*	*Grey seal*	*F*	*107*	*27-02-16*	*Poltesco Beach*	*Cornwall*	*extensive mandibular/oral trauma (euthanised)*
Yes	**SS2016/325**	**XT1701/16**	**Grey seal**	**M**	**123**	**28-02-16**	**Blakeney Point**	**Norfolk**	**grey seal predation (probable)**
No	*SS2016/101*	*EX/S07/16*	*Grey seal*	*F*	*106*	*05-03-16*	*Godrevy*	*Cornwall*	*severe blunt trauma to the head, neck and shoulders (euthanised)*
Yes	**SS2016/113**	**XT403/16**	**Grey seal**	**M**	**227**	**22-03-16**	**Holywell beach**	**East Sussex**	**starvation/hypothermia and right eye blindness (euthanised)**

NB The necropsies of the individuals in **bold** were conducted under the Natural England funding enabled through this project (n=17). The remaining examinations were conducted by the local strandings network in Cornwall, supported by Exeter University, APHA and CWTMSN volunteers (n=10)

Appendix 2:

Samples collected and available for collaborative analysis

Material	Number	Analysis	Sto
Skin	17	Genetics/population structure	Froz
Blubber	16	Contaminants (POPs)	Froz
Liver	11	Contaminant analysis (trace metals)	Froz
Muscle	14	Archived	Froz
Kidney	6	Archived	Froz
Rib	3	Radionuclide analyses	Froz
Teeth	14	Ageing	Froz
Serum/pericardial fluid	9	Serology	Froz
Whiskers	15	Stable isotopes	Froz
Liver/urine/stomach wall	3	Algal toxins	Froz
Gastrointestinal tract (whole)	3	Microplastics	Froz
Stomach contents	5	Dietary studies	Froz
Lung-Kidney-Spleen-Brain	9	Virology (archive and APHA)	Froz
Gonads	6	Life history studies	Forr

Appendix 3:

GUIDELINES FOR THE POSTMORTEM EXAMINATION AND TISSUE SAMPLING OF SEALS

All structures must be examined visually and by palpation, making incisions into the organs. The minimum incisions are indicated below. A full post mortem record must be kept, if possible on the standard "seal post-mortem report" form (see Appendix 3).

a) EXTERNAL EXAMINATION

The species of seal should be ascertained and the sex noted.

The animal should be weighed and the following measurements taken:

- length from tip of nose to tip of hind flipper
- length from tip of nose to end of tail (both in a straight line)
- girth just behind front flippers
- the mid-sternal blubber depth (after making a small incision)

The skin should be examined and any alopecic areas or other abnormalities should be noted and a sample preserved in formalin.

Examine the eyes especially for conjunctivitis, corneal opacity or ulceration.

Examine the mouth looking particularly for tongue ulceration, missing teeth and diseased teeth. Feel along both mandibles for osteomyelitis due to tooth root infection.

b) EVISCERATION

Make a longitudinal incision along the ventral surface of the animal from the symphysis of the mandible to the anus or vulva and reflect the skin from the sides of the animal noting the appearance of the mammary tissue in females and the milk in lactating animals. Two full thickness blubber samples should be taken from the sternal region, the samples should be about 20 g each and should be placed in aluminium foil and stored at -20^{0}C. Open the abdominal cavity by removing the lower part of the abdominal wall- as you do so, note if there is a persistent urachus. Open the chest by removing the lower part of the chest wall using bone shears.

If the carcass is reasonably fresh the liver, spleen, one kidney and one lung should be sampled for both bacterial culture and virus isolation.

Remove the stomach and intestine from the carcass by severing the oesophagus, root of the mesentery and the rectum. In females remove the ovaries and the entire reproductive tract. Remove the liver and kidneys and adrenals, preserving a section of one adrenal gland in formalin. Loosen the tongue from between the mandibles and work down the neck to remove the oesophagus and trachea (with the tongue attached) and work into the chest to

remove the heart and lungs. Examine the pharynx and the back of the nasal chambers for the presence of mites.

Open the bladder and note the appearance of the urine. Take a sample of bladder in 10% formalin for histopathology.

c) EXAMINATION OF ORGANS OF HEAD, NECK AND THORAX

Once the viscera have been removed from the carcass start examining them. It is probably best to do this in the order given below.

Note the appearance of the thyroid and place a sample in formalin. Open the oesophagus along its entire length, any nematodes found should be preserved in ethanol. Open the trachea and its major branches and make several incisions into the substance of the lungs, any nematodes should be placed in ethanol. Preserve in formalin the left bronchial lymph node and a piece of lung (about 1 cm^3) from the upper posterior border of the left and right apical lobe.

Examine the thymus, if present and place 1 cm^3 in formalin.

Collect approximately 5-10ml of serum present in the heart lumen (or elsewhere), even if it is haemolytic, and freeze. Alternatively, collect a similar volume of pericardial fluid as a proxy for heart blood.

Separate the heart from the lungs and holding the right side of the heart in the left hand cut the left ventricle open parallel to the coronary groove and about 1 cm from it. Open the origin of the aorta by incising under the relevant valve cusp. Open the right side of the heart by incising the same distance from the coronary groove but on the other side, extending this incision into the origin of the pulmonary artery. Returning to the apex of the heart make a second incision about halfway between the two coronary grooves to go through the right atrio-ventricular valve. Join the two incisions in the right ventricle close to the apex of the heart. Examine both chambers of the right side of the heart for nematodes, these may well be intertwined with the bundles of the myocardium and a little difficult to see, any present should be preserved in 70% ethanol.

d) EXAMINATION OF ABDOMINAL ORGANS

Remove the spleen from the stomach and examine it. Seals' spleens usually have a number of clefts in them. Preserve a piece of the ventral tip of the spleen (about 1 cm^3) in formalin.

Examine the liver making numerous grooves into the substance looking particularly for areas of fibrosis and thickened bile ducts. After examination place two cross-sectional samples of liver tissue (about 20) in aluminium foil and freeze. Place 1 cm^3 of liver tissue in formalin.

Incise and examine the kidneys. After examination place two cross-sectional samples of liver tissue (about 20) in aluminium foil and freeze. Place 1 cm^3 from a kidney in formalin.

Examine the ovaries and incise the vagina, cervix and the uterine horns along their entire length looking particularly for evidence of uterine stenosis and occlusions. If these are found place the affected portion in formalin. Any foetus and its placenta should be frozen in aluminium foil. The ovaries should be preserved in formalin.

In males incise the testes, examine the cut surface and then place the entire organs (or a cross-sectional slice about 0.5cm thick after weighing the whole organs) in formalin.

Separate the stomach from the intestines and open it along the greater curvature. Any nematodes should be placed in 70% ethanol; look for the ulcers that they frequently cause. Examining the mucosa closely, especially between the mucosal folds- remove any prey species, squid beaks, fragments of shellfish/shells, otoliths, and other food material and store frozen. Examine the stomach for any evidence of marine debris ingestion. If any is present, photograph and store frozen.

Straighten out the entire intestine and examine it along the full length. Collect otoliths and any other recognisable food remains in 70% ethanol (or alternatively freeze). Acanthocephalid worms (most likely to be found in the lower jejunum and ileum) and cestodes should be placed in 70% ethanol. Very small trematodes have also been found in the intestines of seals. A full thickness sample from the middle of the mesenteric lymph node should be put in formalin.

e) SAMPLES FOR VARIOUS STUDIES

Take a 4 cm^2 piece of skin from between the digits and freeze.

Remove approximately six whiskers and store frozen (for stable isotope analysis).

Remove one lower canine or a sample of the lower jaw including the teeth and its root and preserve frozen. It is not unknown for both lower canines to be missing, in this case take one of the upper ones.

In addition to the samples mentioned above, lesions in any other organs should be preserved in formalin after taking a sample for bacteriological examination from any purulent material. If a viral infection is suspected samples from the relevant organs should also be frozen at -70^{0}C for virus isolation. Any abnormalities should also be photographed, preferably with a scale where possible.

Appendix 4

SEAL POSTMORTEM REPORT

When this report has been completed, please send a copy to: Marine Mammal Strandings Project, Veterinary Science Division, Institute of Zoology, Regent's Park, London NW1 4RY. Tel: 020 7449 6672 Fax: 020 7483 2237
email: rob.deaville@ioz.ac.uk or paul.jepson@ioz.ac.uk

SS NO. :..... ....PM NO. : ....

SPECIES : ....SEX :... ....

LOCATION FOUND : . ...

DATE FOUND : ....FOUND BY : ... .

....

PATHOLOGIST : ....DATE OF PM : ....

FROZEN?: Y / N

CARCASS CONDITION:

BODY CONDITION USING CONDITION CODE :. . . . .

Condition code:

1) **live** (becomes code 2 at death)
2a) **extremely fresh** (as if just died, no bloating, meat is considered by most to be edible)
2b) **slight decomposition** (slight bloating, blood imbibition visible)
3) **moderate decomposition** (moderate bloating, skin peeling, penis may be extended in males, organs still intact, excluding postmortem damage)
4) **advanced decomposition** (major bloating, skin peeling, penis extended in males, organs beyond recognition, bones exposed due to decomposition)
5) **indeterminate** (mummified carcass or skeletal remains, no organs present)

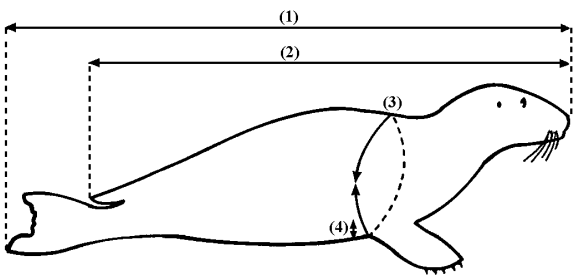
1. BASIC MEASUREMENTS

PHOTOGRAPHS TAKEN
-lateral views of whole body, both sides: Y / N
-other photographs (list):
- -

BODY WEIGHT (kg):

LENGTH, GIRTH AND BLUBBER THICKNESS:

-tip of nose to tip of hind flipper (cm) (1):
-tip of nose to end of tail (cm) (2):
-girth behind front flippers (cm) (3):
-mid-sternal blubber thickness (mm) (4):



2. GROSS POSTMORTEM

Encircle the appropriate category:

NE = not examined
NAD = nothing abnormal detected
A = abnormal (describe fully overleaf)

EXTERNAL EXAMINATION

-nutritional state (describe)
NE NAD A -body orifices (mouth, eyes, ear openings, nose anus, genital slit)

NE NAD A -ectoparasites
NE NAD A -flippers

INTEGUMENT

NE NAD A -skin
NE NAD A -blubber
NE NAD A -subcutaneous tissue
NE NAD A -mammary glands (describe)

MUSCULOSKELETAL SYSTEM

NE NAD A -skull
NE NAD A -other bones
NE NAD A -back muscle mass
NE NAD A -other muscles

NERVOUS SYSTEM

NE NAD A -brain
NE NAD A -spinal cord
NE NAD A -peripheral nerves

CARDIOVASCULAR SYSTEM

NE NAD A -pericardial sac
NE NAD A -myocardium
NE NAD A -valves
NE NAD A -arteries, veins

RESPIRATORY SYSTEM

NE NAD A -nasal cavity
NE NAD A -sinuses
NE NAD A -trachea, bronchi
NE NAD A -lungs
NE NAD A -pleura

ABDOMINAL CAVITY

NE NAD A -liver
NE NAD A -peritoneum/peritoneal cavity

ALIMENTARY TRACT

NE NAD A -mouth
NE NAD A -oesophagus
NE NAD A -stomach
NE NAD A -duodenum/jejunum/ileum
NE NAD A -large intestine
NE NAD A -anus

UROGENITAL SYSTEM

NE NAD A -ovaria/testes (describe)
NE NAD A -uterus
NE NAD A -vagina/penis
NE NAD A -kidneys
NE NAD A -ureters
NE NAD A -urinary bladder
NE NAD A -urethra

LYMPHATIC/ENDOCRINE SYSTEMS

NE NAD A -adrenals
NE NAD A -pancreas
NE NAD A -thyroids
NE NAD A -spleen
NE NAD A -thymus
NE NAD A -lymph nodes
NE NAD A -tonsils

DESCRIPTION OF ABNORMALITIES GROSS POSTMORTEM (add extra pages if necessary)**:**

PRELIMINARY DIAGNOSIS (in order of importance):

a.

b.

c.

d.

e.

3. RESULTS OF HISTOLOGY (add extra pages if necessary)

4. RESULTS OF BACTERIOLOGY

5. MISCELLANEOUS RESULTS

6. FINAL DIAGNOSIS (in order of importance)

a.

b.

c.

d.

e.

7. CHECKLIST SAMPLES

For sending samples, please contact Paul Jepson, Department of Veterinary Science, Institute of Zoology, Regent's Park, London NW1 4RY, UK, Tel: 020 7449 6672 Fax: 020 7483 2237 email: rob.deaville@ioz.ac.uk or paul.jepson@ioz.ac.uk

a) STANDARD SAMPLES

In each square, enter: ✓ *= sample taken*
Blank = sample not taken or not present
Record any extra samples taken in section b.

Weights
left testis (g):. . . . . .
right testis (g):. . . . . .

Ethanol

☐ food remains from:	all
☐ parasites from:	pref. all

Freeze at -20^{0}C

☐ blubber	2 x 20g
☐ canine teeth	2
☐ epidermis	4 cm^2
☐ foetus/placenta	whole
☐ kidney	2 x 20 g
☐ liver	2 x 20g
☐ muscle	2 x 20g
☐ rib (fifth left)	15 cm
☐ scapula	whole
☐ serum (also haemolytic)	up to 20 ml
☐ skull	whole
☐ whiskers	~6

Bacteriology

☐ kidney	swab/block
☐ liver	swab/block
☐ lung	swab/block

10% Formalin

☐ abnormalities female reproductive tract	all
☐ adrenal glands	both
☐ brain	whole
☐ bronchial ln. (left)	1 cm^3
☐ heart	1 cm^3
☐ kidney	1 cm^3
☐ liver	1 cm^3
☐ lung	4 x 1 cm^3
☐ lung (for morb.)	4 x 1 cm^3
☐ mesenteric ln.	1 cm slice
☐ bladder	1 cm^3
☐ ovaries	both
☐ spleen	1 cm^3
☐ testes	both/slices
☐ thymus	1 cm^3
☐ thyroid	1 cm^3

Virology (freeze at -70 ^{0}C)

☐ brain	1 cm^3
☐ bronchial lymph node	1 cm^3
☐ spleen	1 cm^3
☐ lung	1 cm^3

b) EXTRA SAMPLES

Extra samples of lesions taken for histological examination (list):

- -
- -
- -
- -
- -

Extra samples of lesions taken for bacteriological examination (list):

- -
- -
- -

Other extra samples taken (list):

- -
- -
- -
- -
- -