Fox scavenging mutilations on dead harbour porpoises *(Phocoena phocoena)*

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Cover photo: Harbour porpoise in the dunes, used for the experiment (Steve Geelhoed)

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Summary

Harbour porpoises (*Phocoena phocoena*) are nowadays common residents in Dutch waters, and stranding numbers of up to 6,000 individuals have been reported over the past 15 years. Post-mortem investigation has been carried out since 2008, and main causes of death found are bycatch, infectious diseases and grey seal attacks. The latter is a relatively new phenomenon, that has been studied extensively during the past three years. These studies resulted amongst others in a description of mutilations on porpoises induced by grey seals. However, sometimes mutilations are observed in stranded porpoises that do not match this description, indicating that certain mutilations could be induced by other taxa. In this study we investigate the appearance of mutilations induced by a common scavenger which is present in large numbers in the Dutch dune area: the red fox (*Vulpes vulpes*). We conducted a literature study and field-based experiments to describe fox scavenging marks. Also, we conducted a retrospective analysis of the available post mortem photo database of fresh to moderately fresh necropsied porpoises between 2008-2013 to assess the rate of occurrence of fox induced mutilations on porpoise carcasses.

The field experiments resulted in two interactions between foxes and the carcasses. During one of these interactions a fox tried to scavenge on one of the carcasses leaving distinct bite marks. Based on this result and another case study describing the likely scavenging by a red fox on a (live) stranded harbour porpoise, the appearance of fox induced mutilations was defined as: '*Multifocal injuries, extremities partly removed, with frayed edges (possible chewing); irregular, and relatively superficial scratches (possible by claws); deeper, focal injury where blubber is penetrated*.' The photo database was reviewed to assess the presence of mutilations on stranded porpoises fitting these criteria. Analysis suggests that 12% (N=52) of all carcasses (N=429) was 'probably fox scavenged'. This was 'possibly fox scavenged' for 46% (N=199) and 'unlikely fox scavenged' for 22% (N=96). The remaining carcasses (18%, N=81) were qualified as unknown, since they lacked images or were too decomposed making interpretation impossible.

No differences were found between gender and age class among the fox scavenging categories. However, we did find a peak in winter (Dec-Feb) for the category 'probably fox scavenged', with lowest occurrence in May-July. This pattern probably reflects the availability of other food sources for foxes, with a minimum in winter.

The retrospective analysis also revealed difficulties among the differentiation of mutilations on carcasses. Foxes only occur on the Dutch mainland and are absent on the Wadden Islands, but the 'probably fox scavenged' category included four carcasses which were found on the Wadden Islands (8%). This means that the criteria in the analysis are insufficient to differentiate between different scavengers, and could also mean that the lack of other included scavengers (e.g. birds and dogs) in this study poses problems. Further investigation can be done by new experiments including more species, or by DNA analysis of swabs taken from wounds/mutilations on fresh harbour porpoise carcasses.

The presence of mutilations in harbour porpoises has generated an increasing interest worldwide qualifying and quantifying these mutilations is essential. Unnatural causes of death, such as bycatch, should be distinguishable from natural causes of death, such as inter-species interaction. Furthermore, natural causes such as predation should be distinguishable from scavenging upon already dead animals, as for the latter another cause of stranding (and presumable death) should be found during post mortem investigation of these stranded porpoises. The results of this study are the first steps in defining mutilations induced by scavengers present along the Dutch coast.

Introduction

The harbour porpoise (*Phocoena phocoena*) is currently a common resident in the southern North Sea (Camphuysen & Peet, 2006; Geelhoed et al., 2013), after a period of disappearance between the 1960s-1980s (Camphuysen, 2004; Camphuysen, 2011; Haelters et al., 2011). An increase in sightings in the 1990s was noted and more or less in parallel an exponential increase in stranding frequency was recorded (Camphuysen & Siemensma, 2011), with almost 6,000 harbour porpoises found dead in the Netherlands over the past 15 years (www.walvisstrandingen.nl). Harbour porpoises are protected under several international agreements (e.g. ASCOBANS; European Union Habitats Directive; Marine Strategy Framework Directive and Common Fisheries Policy; OSPAR convention; Siebert et al., 2006; Peltier et al., 2013; Scheidat et al., 2013). To identify appropriate management measures, it is important to understand the factors underlying the observed population trends and shifts in distribution, including the causes of mortality for the stranded animals. Therefore, since the end of 2008 harbour porpoises were collected for post-mortem investigation at the Faculty of Veterinary Medicine of Utrecht University.

The main aim of the post-mortem research is determination of cause of death, but additional studies have been conducted also. One of these specific studies was on interspecies interaction, after large amounts of mutilated porpoises with presumed bite marks were found. These studies by van Bleijswijk et al. (2014) and Leopold et al. (2015) revealed the presence of grey seal (*Halichoerus grypus*) DNA in sampled bite marks, and conclude that the majority of the mutilated porpoises died of grey seal attacks (**Fig. 1**). This means that predation by grey seals is one of the main causes of death of porpoises in The Netherlands, amongst other causes such as bycatch, emaciation and infectious disease (Begeman et al., 2014). However, the mutilations observed in some stranded porpoises did not match the grey seal attack criteria proposed by Leopold et al. (2015), meaning that mutilations can also occur due to other causes or by interaction with other taxa. This however has not yet been investigated in The Netherlands.

Figure 1. Harbour porpoise with severe mutilation and bite marks, in which grey seal DNA was detected.

Inter-species interaction may originate from different causes, e.g. aggression, predation or scavenging. Aggression between marine mammal species is known for bottlenose dolphins (*Tursiops truncatus*) and harbour porpoises, in which bottlenose dolphin were observed chasing, attacking and eventually killing harbour porpoises (Ross & Wilson, 1996; Barnett et al., 2009). Externally, this shows teeth marks of the bottlenose dolphins on the porpoise skin. Distance between the teeth is species specific. Based on the findings of teeth marks, interactions between white-beaked dolphins (*Lagenorhynchus albirostris*) and porpoises were also described (Haelters & Everaarts, 2011), however there has not been any report of fatal interactions between these species. As mentioned above, fatal interaction related to predation was described between grey seals and harbour porpoises. Grey seal attacked mostly healthy juveniles, but older animals are taken occasionally (Van Bleijswijk et al., 2014; Leopold et al., 2015). External grey seal induced marks are defined as sharp-edged mutilations often with bite marks on the tailstock and other extremities.

Another interaction is scavenging of stranded animals by opportunistic feeders e.g. dogs and red foxes (*Vulpes vulpes*). The latter is an opportunistic feeder (MacDonald et al., 2008) and therefore possibly feeds on stranded marine mammals (dead or alive). Besides, the red fox population in the dunes along the Dutch mainland coastline increased over the past three to four decades (Mulder, 1985a; Bouwmeester et al., 1989; Van den Berghe, 1995; Vervaeke et al., 2005). Haelters et al. (2016) describe the finding of a live stranded harbour porpoise with severe injuries on its left side which did not match any injury described for attacks from delphinids and seals. They elaborate on possible scavengers, e.g. dogs and birds, and conclude that the mutilations on this harbour porpoises most likely must have been induced by a red fox. Evidence, however, was not enough to verify this. They also state that a description of the marks left by scavenging foxes does not exist in the literature and that more evidence, e.g. by using camera traps, should be gathered.

The presence of mutilations in harbour porpoises has generated an increasing interest worldwide (e.g. after Leopold et al. 2015). To qualify and quantify these mutilations, unnatural causes of death such as bycatch, should be distinguishable from natural causes of death, such as inter-species interaction. Furthermore, natural causes such as predation should be distinguishable from scavenging upon already dead animals. For the latter, it is important to be able to differentiate between bite marks of different carnivores. Grey seals have been identified as the cause of death of most porpoises found with bite marks (Leopold et al. 2015), while bite marks from scavengers (e.g. fox) on the beach will only be induced after an animal is beached due to other causes. This means that another cause of stranding (and presumable death) should be found in these individuals. Besides, marks from scavenging can make interpretation of other lesions more difficult. A correct interpretation of lesions is vital for biologists and veterinary pathologists working with stranded harbour porpoises, either dead or alive.

Assignment

The aim of this project is to characterize larger mutilations found on stranded harbour porpoises, focussing on the gap in knowledge on the differentiation of scavenging wounds of foxes from predator wounds caused by grey seals, as described in the original assignment of the Beleidsondersteunend Onderzoek program of the Ministry of Economic Affairs (EZ): Helpdeskvraag BO-11-018.02-052 'Expert-inbreng Interpretatie bijtwonden bruinvissen'. Research questions are:

1) How can scavenging lesions from foxes on the beach be defined?
2) How do those differentiate from grey seal induced lesions?
3) What is the frequency of occurrence/relevance of scavenging lesions induced by foxes?

The aim of this research is to assess the causes of the mutilations found on stranded harbour porpoises and to attempt to quantify the frequency of occurrence of fox scavenging. This research aims at a description of external fox scavenging marks and the distinction with grey seal predation/scavenging mutilations. The results are usable for biologists and veterinary pathologists working with stranded harbour porpoises to defining the origin of different types of external marks on these animals.

Material and methods

Fox scavenging experiments

For the experiments five intact harbour porpoise carcasses stored in a -20°C freezer, were used. The animals stranded in 2012, 2013 and 2014. Prior to the experiments, basic data was gathered from these animals, including body measurements to assess age class, gender, weight, strandings date and their decomposition condition code (DCC). The latter is assigned on a 1-5 scale, with DCC1 being a very fresh carcass and DCC5 carcass remains (cf. Kuiken & Garcia Hartmann, 1991). The animals were in fresh to moderately fresh condition (DCC 2-3) and fully intact (**Table 1**).

Table 1. Basic data on five harbour porpoises selected for the scavenging experiments.

Carcass	Age class	Gender	Weight (kg)	Strandingslocation	Strandingsdate	DCC
1	Juvenile	Female	14.4	Ameland	17-02-2014	2
2	Juvenile	Male	Unknown	Egmond aan zee	21-10-2013	2
3	Juvenile	Male	31.4	Julianadorp	27-02-2014	2
4	Adult	Male	37	Ameland	27-07-2012	3
5	Adult	Male	27.5	Ameland	21-07-2014	3

The experiments were conducted on three locations in the dunes of De Kennemerduinen, National Park Zuid-Kennemerland along the Dutch mainland coast (**Fig. 2**). In cooperation with the responsible nature managing body Puur Water Natuur (PWN), these locations were selected for two main reasons: 1) presence of a red fox population and 2) limited access for the public. The experiments were conducted in late winter/early spring (19 Feb- 20 Mar 2015) as food sources for foxes is limited in this period, theoretically increasing the chance of a fox scavenging upon a carcass (Dell'Arte et al., 2007; Gerritsen et al., 1988; Mulder, 1985b). On each position, one carcass at a time was placed, secured to a pole. The carcasses in De Wieringen and Spinnekoppenvlak were replaced 6 March. The number of days a carcass was exposed to potential scavenging varied between 14 and 29 days (**Table 2**), to allow red foxes to find the carcasses, also during the deterioration of the state of the carcasses.

Table 2. Experiment period and locations

Carcass	Location	Date	Period (days)
1	De Wieringen	19 Feb – 6 Mar	15
2	Spinnekoppenvlak	19 Feb – 6 Mar	15
3	Waterwinweg	19 Feb – 20 Mar	29
4	De Wieringen	6 Mar – 20 Mar	14
5	Spinnekoppenvlak	6 Mar – 20 Mar	14

The carcasses were under constant surveillance of two Reconyx R6 cameras per animal. The cameras have a night-function in order to record footage in the dark. The cameras have a movement sensor that triggered recording. The cameras were placed at ca 3 m distance from the carcass to get a broader range of view and to ensure that different sides of the carcasses could be observed. The carcasses were visited and photographed daily to document external features of the carcasses. Video footage and pictures of the carcasses were evaluated after the experiments.

After the experiments, the carcasses were transported to Utrecht University for a limited post-mortem investigation, according to a standardized protocol (Kuiken & Garcia-Hartmann, 1991). This included several body measurements (mentioned above), but also collection of life history samples (teeth and

DNA). The cause of death could not be investigated due to the advanced state of decomposition of the carcasses after the experiments.

Figure 2. Study area on the Dutch mainland coastline in National Park Zuid-Kennermerland with scavenging-experiment locations assigned in the red area. The locations are called 1) De Wieringen, 2) Spinnekoppenvlak and 3) Waterwinweg.

Retrospective study of post-mortem photographs

Red fox induced mutilations were characterized by the combination of the inflicted scavenging wounds during the video experiments together with the paper of Haelters et al. *(*2016*;* Appendix*)*. This allowed us to do a retrospective study of post-mortem pictures in the harbour porpoise photo database of the Faculty of Veterinary Medicine of Utrecht University. Aim of this study was to investigate the frequency of occurrence of fox induced mutilations. This database is composed of images of 876 cases of stranded porpoises (2009-2013). For this study only very fresh to moderately fresh carcasses (DCC1-3) were used. This dataset comprised pictures of 429 individuals.

First of all these individuals were scored on completeness. Animals lacking either one or more of the following body parts: dorsal fin, pectoral fin(s), head or fluke, were defined as incomplete. Incomplete porpoises were disregarded from further analysis. As a second step, the complete carcasses were scored on being either damaged or undamaged. Damage is defined as a defect larger than 5 cm cross section, anywhere on the body, affecting the epidermis and underlying tissue (blubber, and/or muscle) with an acute appearance and mild to no reaction of the surrounding tissue. This latter aspect will exclude all skin lesions with an inflammatory or virological appearance, which were most likely induced prior to the stranding and were therefore no scavenging or predation-related wounds. The third step was scoring if the damaged carcasses had tailstock defects. In a fourth step, the position of the defects was recorded for the following body parts: tailstock, genital area, dorsal fin, pectoral fin, fluke and rostrum. The final fifth step was scoring of the presence or absence of teeth marks or presumed chewing marks on dorsal fin, pectoral fin, fluke and rostrum (**Fig. 3**). Presumed chewing was scored when parts of the extremities were missing, with irregular and frayed edges, often accompanied with scratches/puncture lesions.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
U	D	compl	beschac	consisten	tailstock les	around gen	dorsal fin m	flippers m	fluke m	rostrum m	dorsal fin ch	flippers ch	fluke ch	rostrum cl	categ
608	3	Y	U												unknown
609	3	N													unknown
610	3	Y	Y	N	N	Y	Y	Y	Y	Y	N	N	N	N	maybe
611	3	Y	N												yes
614	3	N													unknown
617	3	N													unknown
618	2	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	N	N	maybe
622	2.5	Y	Y	N	N	N	N	N	N	N	N	N	N	N	no
623	2	Y	Y	N	N	N	N	N	N	N	N	N	N	N	no
624	2	Y	Y	N	Y	N	N	N	Y	Y	N	N	N	N	maybe
628	3	Y	Y	N	N	Y	Y	Y	Y	N	N	N	N	N	maybe

Figure 3. Screenshot of part of the Excel database showing the scoring system of this study.

All complete carcasses were divided into three categories:

1. 'unlikely fox scavenged' for undamaged carcasses or carcasses with only chronic lesions.
2. 'possibly fox scavenged' for damaged carcasses but without chewing marks on these body parts (tailstock, genital area, dorsal fin, pectoral fin, fluke and rostrum).
3. 'probably fox scavenged' when damaged carcasses also showed chewing marks on one or more of the body parts (tailstock, genital area, dorsal fin, pectoral fin, fluke and rostrum).

Photo scoring in the retrospective study was done by one person (LIJ). To test for observer bias in scoring of the photos, the retrospective study was repeated by a second person (SG), who independently scored every tenth animal.

The characterization was tested by defining the induced wounds in the stranded harbour porpoises, and by the comparison of the occurrence in relation to the stranding location. Two categories were used: 1. Carcasses stranded on the Wadden islands (Texel, Vlieland, Terschelling, Ameland and Schiermonninkoog) or found (afloat) offshore, and 2. Carcasses found on the Dutch mainland.

Finally, an overview of fox-scavenged carcasses in relation to gender, age classes and stranding season of these porpoises is given.

Results

Experiment and definition of fox-induced scavenging wounds

The fox-scavenging experiments resulted in the documentation of two interactions between the carcasses and a red fox. The first interaction occurred in the night of the 28th February, at 1.26 AM at carcass #1 in De Wieringen. Video footage of 64 seconds was recorded. The fox first tried to pull the carcass away by tearing at its fluke; biting in the right side of the fluke. The fox soon noted that the carcass was not moving, and then started biting on the carcass' right side of the head (**Fig. 4**). After a few bites, it gave up and left the carcass. No interaction was filmed the next day. The second interaction occurred on the evening of the 17th of March at 11.30 PM, at carcass #4 in Spinnekoppenvlak. The fox was filmed for 120 seconds, but did only sniff at and did not bite in the carcass, therefore not leaving any marks (**Fig. 5**).

Figure 4. Stills of the scavenging attempt by a red fox on carcass #1. Footage from 28 February, 1.26 AM. After an unsuccessful attempt to tow away the carcass (top left), the fox started biting on the carcass' right side of the head.

Figure 5. Stills from 17 March, 11.30 PM. Both cameras filming carcass #4 and showing a curious red fox checking out the carcass, but not scavenging on it.

Figure 6. Top image: picture of right cranial side carcass #1 before fox scavenging. Bottom image: picture of right cranial side carcass #1 after fox scavenging. The scratches seen in rectangle in the bottom image, cranial to the pectoral fin and caudal to the right eye, are induced by the red fox as shown on the video footage.

As the encounter on 17 March did not leave any marks, only the first observation can be used to identify fox induced bite wounds. On the morning of the 27th of February and the 28th of February, pictures were taken from the carcass. These show the scavenging lesions induced by the fox (**Fig. 6**). In carcass #1 the right side of the head, just caudal to the eye, was the most affected area. The fluke did not show any bite marks. The scavenging lesions observed in carcass #1 can be defined as multifocal, irregular and relatively superficial scratches, penetrating the epidermis into the blubber layer, without any parallel lesions. It was impossible to measure the distance between the canine teeth of this fox, due to the several bites it took (**Fig. 6**).
One paper describes a possible interaction between a live stranded harbour porpoise and a red fox on the beach, leaving distinctive mutilations on the stranded animal: Haelters et al. (2016*;* appendix). They define scavenging lesions as followed: '*Multifocal injuries, extremities partly removed, with frayed edges (possible chewing); irregular, and relatively superficial scratches (possible by claws); deeper, focal injury where blubber is penetrated'.* This definition corresponds mostly to our findings, with the exception of 'chewing'.

Retrospective study

The dataset included pictures of 429 harbour porpoises found on the Dutch coastline between 2009 and 2013. All animals were in a very fresh, fresh or moderate state of decomposition (DCC1-3). After the first assessment of the images, 37 individuals were excluded from the analysis due to incompleteness of the bodies. Another 45 individuals were excluded from further analysis, based on the lack of proper images or a too far-reached decomposition state making an assessment impossible. Scoring was done for N=347 cases.
The combination of the video footage gained in this study and the findings of Haelters et al. (2016) were used in the retrospective study to reveal fox interaction with porpoise carcasses. The video footage showed that scavenging lesions on the body can be seen as multifocal, irregular and relatively superficial scratches, penetrating the epidermis into the blubber layer, without any parallel lesions. Haelters et al. adds the presence of 'deeper, focal injury where blubber is penetrated' and 'chewing' which was observed on the extremities of the described porpoise in this study (pectoral fin and fluke). Within the retrospective study, presence of scavenging lesions was scored but also presence of chewing on extremities. As the results of Haelters et al. (2016) are used in this study as a tool to base the scoring within the retrospective upon, this paper is added in the appendix.

Within the total dataset analysed (N=347), 76 individuals were undamaged and another 20 individuals were damaged but with only the presence of chronic lesions. These 96 individuals in total compromise the group 'unlikely fox scavenged' based on these results.

The remaining individuals were examined for the presence of area specific mutilations and presumed chewing marks, to assess the possibility of fox-scavenging. All cases which were externally damaged, from very mild damaging (wound larger than 5 cm, penetrating the epidermis into the underlying tissue) to severe damaging were 'possibly fox scavenged'. For these cases it was further defined for the presence or absence of chewing marks on one or more of the extremities. Presence of this latter differentiated between the categories 'possibly fox scavenged' and 'probably fox scavenged'. Chewing was observed in 52 cases, while this was not observed in the remaining 199 cases. To summarize, 27.7% of all cases analyzed during the retrospective study were qualified as 'unlikely fox scavenged', 57,3% 'possibly fox scavenged' and 15% 'probably fox scavenged' (**Fig. 7**).

Of the 52 porpoises of which there is a probable chance that these were scavenged by foxes according to our analysis, in the majority (N=40) presumed chewing marks on the fluke was observed. The other scored extremities, i.c. dorsal fin (N=23), pectoral fins (N=26) and rostrum (N=6), showed lower incidences of presumed chewing marks (**Fig. 8** for examples).

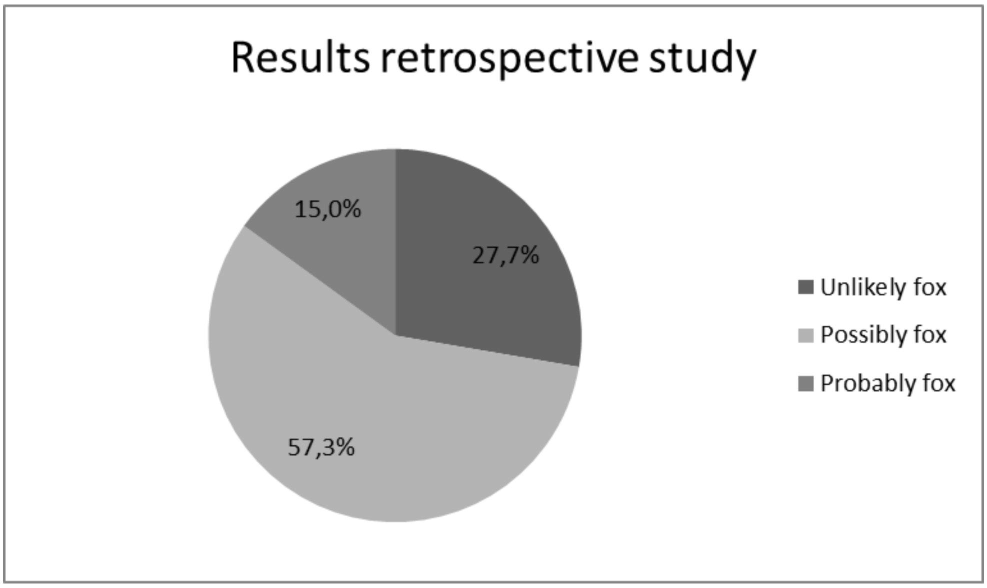

Figure 7. Fox scavenging of harbour porpoises found on the Dutch coastline, 2009-2013 (N=347), as found in the retrospective study.

Figure 8. Examples of presumed chewing marks on extremities; top left a fluke, top right a dorsal fin, bottom left a pectoral fin and bottom right a rostrum. All body parts show the irregular multifocal injuries with frayed edges, affecting the epidermis and underlying tissues, with parts of the body parts missing.

Fox scavenging versus grey seal predation

All photos were examined for defects on the tailstock. Tailstock lesions can be induced by grey seals as proven by van Bleijswijk et al. (2014). According to Leopold et al. (2015), the definition of tailstock marks induced by grey seals is: repetitive puncture wounds on the tailstock, present bilaterally, and running approximately dorsoventrally in two or more parallel lines.

No tailstock defect was observed in the group 'unlikely fox scavenged', as this group consist mainly of undamaged carcasses. Tailstock defects were however observed in the group 'possibly fox scavenged' in 96 cases, and 'probably fox scavenged' in 34 cases. The additional two cases in the 'unlikely fox scavenged' category had partly healed lesions on the tailstock, indicating that these lesions were induced prior to the stranding.
Tailstock defects were observed in 130 cases, of which 50 individuals has presumably died as a result of a grey seal attack according to the necropsy findings of these individuals (Database of post mortem research of Utrecht University). This leaves 62% of the tailstock marks undefined. Closer examination of these 62% (N=80) shows that in 56 cases the defects on the tailstock did not match the tailstock lesions description by Leopold et al. (2015). Within these 56 cases, tailstock defects with partly healed appearance (scars), and/or non-symmetric defects and unilateral defects were present. The origin of 10 cases remained unknown, as possible punctures lesions or bite marks were observed but the state of the carcasses or the quality of the images did not allow further assessment. In five cases, bilateral presumable bite marks were detected. Causes of death revealed anthropogenic causes (bycatch/trauma), but evaluation of these images of these five cases reveals likely grey seal mutilated carcasses, however this was not assigned as the cause of death.

This leaves nine highlighted cases in which tailstock defects were observed, but not immediately qualified as 'grey seal induced', as these did not match the description by Leopold et al. (2015). Four out of nine cases showed unilateral defects, and were therefore unlikely caused by grey seals. The additional five cases showed bilateral defects, but it was noted that rather than puncture lesions induced by canine teeth, chewing of the blubber was observed. It is possible that the tailstock defects in these animals, which lacked clear bite marks, were induced by foxes.

As an example, **Fig 9** shows one of these nine cases (UT469), clearly revealing a bilateral tailstock defect without parallel lines and repetitive punctures, making it unlikely that this lesions was induced by a grey seal (Leopold et al. 2015). In addition: this animal was live stranded. Besides the tailstock defect, also chewing on the fluke of this individual was observed.

Figure 9. *Examples of presumed chewing marks on tailstock of UT469; This individual is part of the 'probably fox scavenged' category, and reveals a tailstock defect which does not fit with the description of tailstock lesions induced by grey seals. The lesion is bilateral with frayed edges, and accompanied by puncture marks. Besides, this animal revealed chewing on the fluke (with parts of the fluke tips missing) and was live stranded.*

Stranding locations of fox scavenged carcasses

Of the entire dataset (N=429), 25.9% of the carcasses came from the Wadden Islands or were found offshore (N=111), whereas 74.1% came from the Dutch mainland (N=318). The majority of the 'unlikely fox scavenged' carcasses (N=96) was found on the Dutch mainland (N=74) and the remainder on the Wadden Islands/offshore (N=22). Carcasses in the 'possibly fox scavenged' category (N=199) were also found in both location categories, with 129 individuals found on the mainland and 70 cases from the Wadden Islands/offshore. In the 'probably fox scavenged' category (N=52), the majority of cases came from the mainland (N=48), however four animals were found on the Wadden Islands (8%). Two of these animals (UT204 and UT289) were assigned in the cause of death category 'grey seal attack', while the other two cases (UT290 and UT379) died as a result of bycatch (possible) and infectious disease, respectively. These four cases revealed signs of chewing on the flukes, while one cases (UT204) also showed chewing on the rostrum and flipper(s).

Additional findings

Finally, it was investigated whether the possibility of scavenging by foxes showed any differences between gender, age classes and stranding season. Due to the different sample size per category, the figures reflect percentages of the total number of each category, including the entire dataset ('All'). In the entire dataset juvenile harbour porpoise carcasses are the most numerous age class, followed by adults. This age distribution is also present per fox scavenging categories (**Fig. 10**). No differences are seen between these categories. The same accounts for gender (**Fig. 11**). In general (category 'All'), slightly more males than females are present in the dataset. The fox scavenging categories did not differ from this distribution.
The fox scavenging categories show a seasonal pattern. In the winter months (Dec-Feb) more 'probably fox scavenged' carcasses were found than in other months. Significant less were found in late spring and summer (May-Jul) (**Fig. 13**).

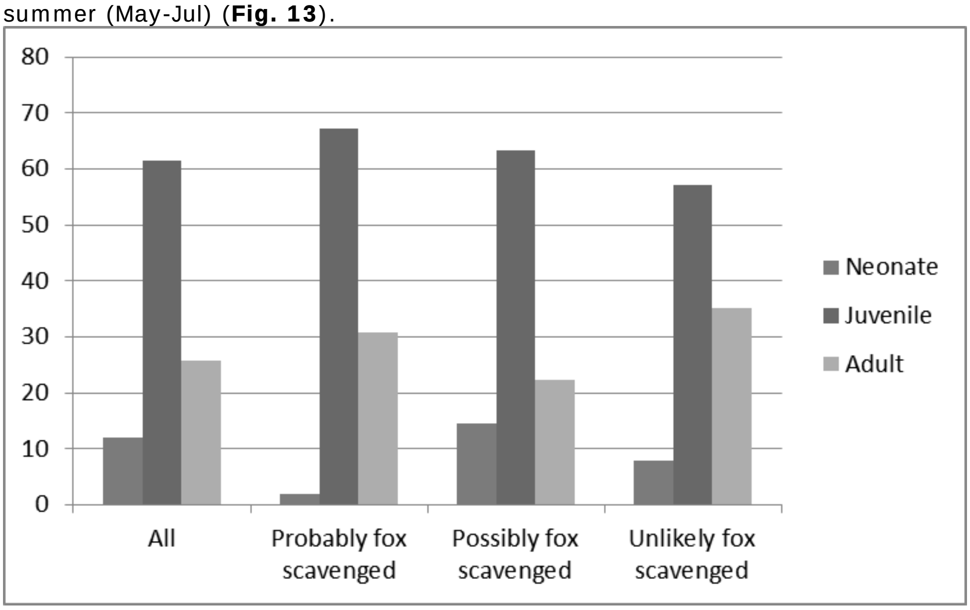

Figure 10. Age classes 'Neonate', 'Juvenile', and 'Adult', per category of harbour porpoise carcasses. Categories are 'All' including the entire dataset (N=429), 'Probably fox scavenged' carcasses that showed signs of fox scavenging (N=52), 'Possibly fox scavenged' carcasses that showed possible signs of fox scavenging (N=199), and 'Unlikely fox scavenged' carcasses that showed no signs of fox scavenging (N=96).

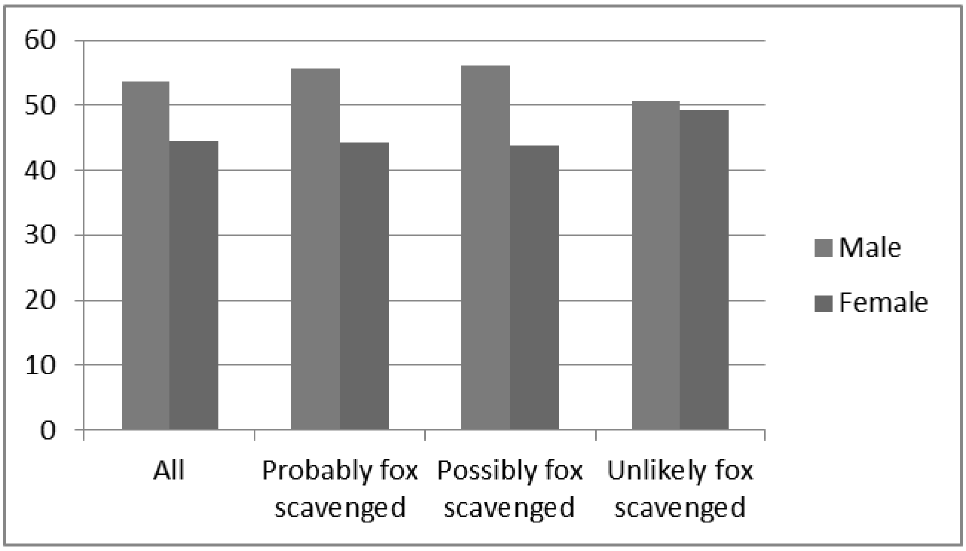

Figure 11. Gender per category of harbour porpoise carcasses. Categories are 'All' including the entire dataset (N=429), 'Probably fox scavenged' carcasses that showed signs of fox scavenging (N=52), 'Possibly fox scavenged' carcasses that showed possible signs of fox scavenging (N=199), and 'Unlikely fox scavenged' carcasses that showed no signs of fox scavenging (N=96).

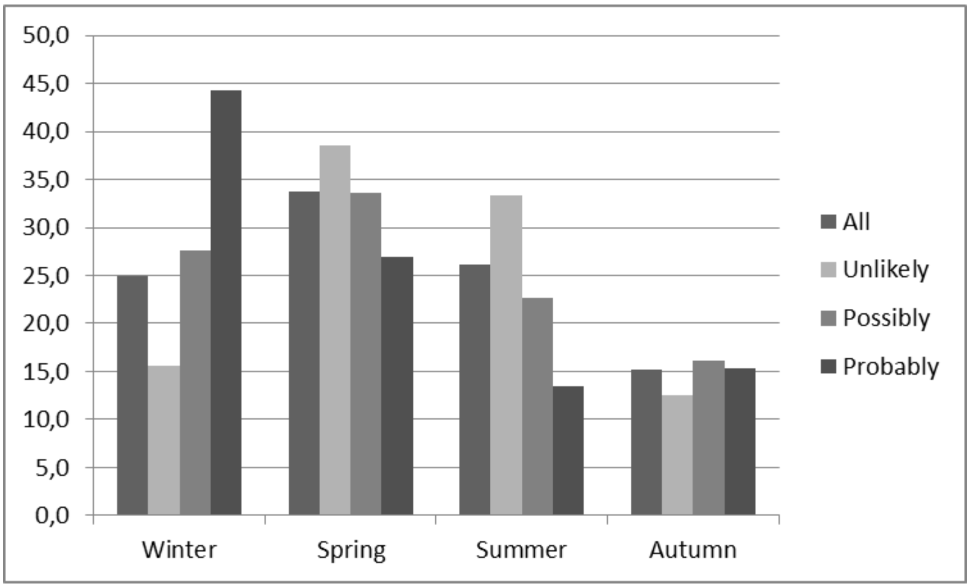

Figure 12. Season of carcasses found per category. Categories are 'All' including the entire dataset (N=429), 'Probably fox scavenged' carcasses that showed signs of fox scavenging (N=52), 'Possibly fox scavenged' carcasses that showed possible signs of fox scavenging (N=199), and 'Unlikely fox scavenged' carcasses that showed no signs of fox scavenging (N=96).

Discussion

In this study, we conducted field experiments and a literature review to identify red foxes as probable scavengers on harbour porpoise carcasses. We tried to document this occurrence and define scavenging lesions induced by foxes as follows: '*Multifocal injuries, extremities partly removed, with frayed edges (possible chewing); irregular, and relatively superficial scratches (possible by claws); deeper, focal injury where blubber is penetrated.'* Analysis of the available photo database of necropsied porpoises between 2009 and 2013 at Utrecht University suggests that 12% (N=52) of all carcasses (N=429) were 'probably fox scavenged'. This was 'possibly fox scavenged' for 46% (N=199) and 'unlikely fox scavenged' for 22% (N=96). The remaining carcasses (18%, N=81) were qualified as unknown, since they lacked images or were too decomposed making interpretation impossible.

We also investigated whether stranding location of the carcasses can aid in differentiating fox induced mutilations from grey seal induced mutilations. Foxes only occur on the Dutch mainland and are absent on the Wadden Islands (Broekhuizen et al., 1992), whilst grey seals can be found anywhere along the Dutch coast. In the 'probably fox scavenged' category (N=52) four carcasses were found on the Wadden Islands (8%). These four cases revealed signs of chewing on the flukes, while one cases (UT204) also showed chewing on the rostrum and flipper(s). As foxes do not occur on the Dutch Wadden islands it is highly unlikely that foxes scavenged on these carcasses. Chew marks on the fluke, apparently are not fox specific. Missing pieces of the fluke, and possibly of other extremities could also be found in grey seal attacked porpoises or could be induced by other scavengers then fox (e.g. birds and dogs). The combination of bite marks and chew marks indicate scavenging by a mammal rather than a bird. This error could have influenced our results, and it is likely that the mutilations qualified as fox induced are overestimated in this study. This could be further investigated by new experiments, or by DNA analysis of swabs taken from wounds/mutilations on fresh carcasses, cf. van Bleijswijk et al. (2014).

In the paper of Leopold et al. (2015), tailstock marks are assigned to be induced by grey seals, as also proven by van Bleijswijk et al. (2014). However, this study revealed cases with tailstock defects, potentially induced by foxes. In the majority of all cases, the tailstock defects observed did not match the description by Leopold et al. (2015), e.g. they were unilateral defects. Also, in some chewing of the blubber was observed, with lacking clear bite marks, which was also not reported by Leopold et al. (2015) as grey seal related. Therefore we assume that foxes also scavenge upon the tailstock, however we prove that the differentiation between grey seals attack wounds on the tailstock, and the presumable fox induced defects can be identified based on the characteristics of the wounds.

A comparison of the 'probably fox scavenged' carcasses showed no major differences between age class and gender of the porpoises. A seasonal pattern was found for the category 'probably fox scavenged' with a peak in winter (Dec-Feb), and lowest occurrence in May-July. This pattern probably reflects the availability of other food sources, with a minimum in winter (Gerritsen et al., 1988; Mulder, 1985b). During this period foxes are probably more catholic in their prey choice. Another explanation is the habit of foxes to translocate their food to another place and cache it to feed on it later. For beached birds this phenomenon has been described by Roersma (1995) who found an oiled guillemot (*Uria aalge*) with fox marks away from the beach. The seasonal pattern of 'probably fox scavenging' suggests that the field experiments were conducted slightly too late. It would have been better to start early January and finish the end of February at the latest, to increase the chance of scavenging on the carcasses.

The field experiments were successful in documenting one occasion of fox scavenging. The observed interaction with a porpoise carcass by only one fox was less than we expected. Reasons for this could be that foxes did not need to search for alternative food, since the availability of other food sources was sufficient. Or that porpoise carcasses are not known to all foxes as food source Individual foxes can have different food preferences, and not all foxes search for food on the beach. Foxes with territories further away from the beach could not visit beaches or frequent then less often than foxes with territories adjacent to the beach. In other words some foxes might not recognize a porpoise as a potential food source.

Scoring of the images for the retrospective study was done by one observer (LIJ). To test the observer bias in scoring of the photos, the retrospective study was repeated by a second person (SG), who checked every tenth score, covering 10% of the entire dataset. This did not reveal any difference and therefore it was assumed that scoring by the first observer was done in an objective matter. However, to validate our finding it is recommended to always use a second and third observer to conduct the same task, to verify or falsify the outcomes.

Final remarks

This study provides the following answers to the research questions:

1) How can scavenging lesions from foxes on the beach be defined?

Based on the results of the field experiment and literature we define scavenging lesions from red fox as follows: multifocal injuries, extremities partly removed, with frayed edges (possible chewing); irregular, and relatively superficial scratches (possible by claws); deeper, focal injury where blubber is penetrated.

2) How do those differentiate from grey seal induced lesion?

Based on the results of the experiments and the retrospective study, it appeared highly difficult to differentiate between the mutilations induced by different scavengers. Carcasses in the categories ‘possibly fox scavenged’ and ‘probably fox scavenged’ were found on the Wadden Islands, where foxes are lacking. This could have influenced our results, and it is likely that the fox induced mutilations are overestimated in this study. Therefore, the results of this study must be treated with caution.

3) What is the frequency of occurrence/relevance of scavenging lesions induced by foxes?

To summarize the results: 28% of the included cases in this study were unlikely fox scavenged, 57% are possibly fox scavenged while the remaining 15% were probably fox scavenged. **Note**: The results of this study must be treated with caution. The analysis revealed difficulties in differentiation between the mutilations induced by different scavengers, and therefore the results are likely an overestimate of ‘probably fox scavenged’ carcasses.

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Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Mardik Leopold
Researcher

Signature:

Date: 30 March 2016

Approved: Tammo Bult
Business Unit Manager

Signature:

Date: 4 April 2016

Appendix : A Suspected Scavenging Event by Red Fox (*Vulpes vulpes*) on a Live Stranded Harbour Porpoise (*Phocoena phocoena*)

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At about 0900 h on 15 February 2014, members of the public found a live harbour porpoise (*Phocoena phocoena)* on the beach of Koksijde, Belgium. The stranding occurred on a sandy beach, with no mussel or oyster banks, wooden structures or rocks in the vicinity. It was unknown at what time the animal stranded, but it was likely between 0120 h (high tide) and well before 0900 h, given its position on the beach relative to the high water mark. The male porpoise was 1.08 m long (from rostrum to tail fluke), indicating it was a juvenile, likely 6 to 8 months old adjudged by the well documented breeding period (June-August) of harbour porpoise in this region (Lockyer, 1995; Lockyer & Kinze, 2003). The animal seemed to be in an average to good nutritional condition: there was no depression behind the head as seen in emaciated porpoises and the dorsal muscle area had a convex shape. The most prominent pathological features of the animal were a number of acute, irregular and multifocal injuries (Figure 1). The distal third part of the left pectoral fin was missing; the injury presented frayed (jagged) edges. The distal part (3 cm) of the left side of the fluke presented a similar injury as the left pectoral fin, but only a small part was missing. On the left flank, part of the blubber and skin was missing in an injury that penetrated into the thoracic muscle layer; this injury was triangular, with edges of 8 cm, and was surrounded by puncture wounds and by numerous dorso-ventral, irregular scratches of which some crossed each other. Posterior to this injury, similar superficial scratches, penetrating only the epidermis or the epidermis and the blubber layer, extended from the dorsal to the ventral side, as such covering almost half of the left flank of the harbour porpoise. There was also a superficial, 2 cm long, sharp-edged cut on the melon, penetrating only the epidermis. No injury was observed on the right side of the animal.

Figure 1. The harbour porpoise just admitted to the rehabilitation centre, showing severe injuries on its left flank and pectoral fin (top), pectoral fin (bottom left) and fluke (bottom right); pictures taken on day of stranding after arrival at SOS Dolfijn

There were no signs of penetrating wounds extending into the thorax or abdominal cavity and, therefore, it was assumed that no vital organs were damaged. No blood spilled from the animal nor was bleeding observed when the local stranding coordinator first saw the animal; therefore it was assumed that blood loss had been minimal. The animal was admitted for care at the SOS Dolfijn rehabilitation centre at Harderwijk, The Netherlands, where in May 2014, part of the left pectoral fin was amputated (a small part of the left side of the fluke had been removed earlier). The harbour porpoise is still alive as of 1 November 2015, with its lesions fully healed (Figure 2).

Figure 2. Healed lesions on the left flank (left), and healed left pectoral fin after surgery (right); both pictures taken approximately 6 months after arrival at SOS Dolfijn

There are a number of animals known to interact aggressively with harbour porpoises or to scavenge on carcasses, all leaving specific traces (Table 1). In the southern North Sea, aggression towards harbour porpoises by white beaked dolphins (*Lagenorhynchus albirostris*) (Haelters & Everaarts, 2011) and bottlenose dolphins (*Tursiops truncatus*) (Ross & Wilson, 1996; Patterson et al., 1998; Jepson, 2005; Barnett et al., 2009) is known, and at least the latter of these two delphinids can cause severe injury and even death. In the North Sea and other areas, grey seals (*Halichoerus grypus*) are known to predate on harbour porpoises (Haelters et al., 2012; Bouveroux et al., 2014; Jauniaux et al., 2014; Leopold et al., 2015a, 2015b; Stringell et al., 2015). The characteristics of the lesions left by delphinids and by grey seals have been described and illustrated in detail. The injuries on the harbour porpoise in this study did not match with any of these described injuries.

The acute nature of the injuries, and the fact that they were only present unilaterally, makes aggression, or a predation attempt at sea highly unlikely. In contrast, it is plausible that the porpoise was scavenged while it was lying on the beach, on its right side. However, there were no witnesses to the stranding and neither the individuals who found the porpoise, nor the firemen who removed the animal from the beach, reported traces or evidence of a scavenger (although their focus was on the animal itself, not on the search for such evidence). On the beach, possible scavengers are red foxes (*Vulpes vulpes*), dogs and birds. The red fox has returned to Belgium and The Netherlands during the past three to four decades, and has extended its range to coastal dune areas (Mulder, 1985; Bouwmeester et al., 1989; Van den Berghe, 1995; Keijl & Arts, 1998; Vervaeke et al., 2005), with the first report of fox presence in coastal dunes in Belgium dating from 1991 (Van Gompel, 1992). It now commonly occurs in the area where the harbour porpoise described in this study was found: tens of red fox road-kill carcasses are collected each year in the coastal community of Koksijde, and inhabitants often report instances of red foxes killing poultry (Milieudienst Koksijde, pers. com., 31 August 2015). Occasionally, dead red foxes are found on the beach of Koksijde (Rosseel, 2014), and the presence of red foxes on the beach along the Belgian coastline was considered a main factor contributing to the decrease of intact carcasses of washed-ashore seabirds (Stienen et al., 2014). Foxes are opportunistic feeders (Dell'Arte et al., 2007; Macdonald & Reynolds, 2008) and as such, they have been reported feeding on stranded animals (dead and alive) (A. van Neer, pers. com., 25 March 2015; Schlacher et al., 2013, 2015; Stienen et al., 2015), as well as scavenging on seal placentae and dead or moribund seal pups at mainland seal breeding colonies (Culloch et al., 2012). In contrast to red foxes, free-ranging dogs are rarely observed, and if they are reported they are caught as soon as possible and taken to an animal shelter (Milieudienst Koksijde, pers. com., 31 August 2015). We cannot exclude that a person taking a dog for a walk on the beach, let it cause extensive injury to a live stranded cetacean, although this seems very unlikely. The injuries described in the case presented here were also different from the marks commonly left by birds (e.g., gull species) on stranded harbour porpoises (personal observations by J. Haelters and L. IJsseldijk on tens of porpoises between 2010 and 2015; Table 1).

Approximate position of Table 1

To confirm that red foxes had scavenged on the harbour porpoise in this study, we investigated if red fox mitochondrial DNA was present in its injuries. Van Bleijswijk et al. (2014) showed that DNA of a predator in its prey is likely better preserved in relatively small and deep wounds, or in punctures that are closed quickly after the bite by overlying epidermis. To increase the chance of finding the perpetrator's DNA, wounds fitting this description were sampled. We took 11 dry-cotton swabs of several wounds immediately after the arrival of the porpoise at the rehabilitation centre: one swab of a puncture wound on the left pectoral fin; one swab of a puncture wound on the left side of the tail fluke; five swabs of deeper scratches on the flank which still had overlying epidermis; two swabs of a puncture lesion on the left flank which still had overlying epidermis; one swab of the cut on the melon; and one additional swab of undamaged skin to function as a negative control sample. A positive control was obtained from a saliva swab of a freshly dead red fox. We investigated the occurrence of red fox mitochondrial DNA in DNA extractions of the swab samples using Easymag DNA isolation (bioMerieux) according to the manufacturer's instructions. A Quantitative Polymerase Chain Reaction (QPCR) was performed with a set of primers targeting the mitochondrion genome of *Vulpes vulpes* (NCBI Reference Sequence: NC_008434.1) according to Berry et al. (2007). In short, DNA was amplified using forward primer (5'attcatcgaccttcccgcaccatcaaatat-3') and reverse primer (5'actatacatctgacacagctactgctttct-3'). The thermal profile of the QPCR, carried out in a Lightcycler 480 II (Roche diagnostics), consisted of a denaturation step of 94 °C for 2 min, 30 cycles of 94 °C for 30 s, 58 °C for 20 s, 72 °C for 15 s, and a final extension step at 72 °C for

2 min. Amplification data were analysed using the Lightcycler 480 software SW 1.5.1. (Roche diagnostics); however, the QPCR revealed no evidence of the presence of red fox DNA in the swabs taken from the harbour porpoise's wounds.

We assume that the red fox is the prime suspect causing the injuries seen in the stranded harbour porpoise described here, although we acknowledge that we do not present evidence. We argue that the dorso-ventral scratches could have been made by fox claws, while the larger injury on the flank, extending into the muscle, and the injuries on the pectoral fin and the fluke were probably scavenging lesions caused by red fox biting the porpoise. Although the QPCR analysis found no evidence of the presence of red fox DNA, this does not exempt the red fox as the perpetrator. DNA could have been absent, or lost from the injuries; e.g., due to bleeding, their open nature, DNA degradation as a result of the timespan between the scavenging and the time the swabs were taken, and/or washing out of DNA during initial care and transport of the animal, during which it was kept wet at all times. This highlights the importance of taking such samples, *in situ*, as quickly as possible.

Harbour porpoises from the North Sea are protected by the ASCOBANS Agreement. Parties to this Agreement endeavour to establish an efficient system to carry out necropsies to reveal, amongst others, possible causes of death (ASCOBANS, 2003; Camphuysen & Siemensma, 2011). For researchers attempting to identify the cause of ante- or post-mortem defects on a carcass, characteristic marks as seen on this animal help relate the damage back to a possible cause and estimate the relevance of the defects to the ultimate cause of death. As far as we are aware, a description of the marks left by scavenging foxes does not exist in the literature. To prove that foxes are scavenging on harbour porpoises (and potentially other marine mammals) that have stranded, a number of other methods could be used, including the use of camera traps or IR video on the beach next to stranded carcasses (Culloch et al., 2012).

Traces of fox paws or fox excrement in the sand around the carcass could be searched for (Stienen et al., 2014), although such trace evidence might disappear with incoming tides, wind or collection or displacement of the animal by members of the public or trained professionals. Furthermore, the frequency of fox scavenging could be revealed by investigating available photo-databases of stranded marine mammals and autopsy reports, which may also provide insight into the potential historical, temporal and spatial extent of this phenomenon. If certain characteristics of wounds could definitely be attributed to red fox, it would assist future post-mortem examiners of marine mammals to distinguish scavenging injuries that occurred on the beach from scavenging or predation injuries that were inflicted at sea. Finally, if feral animals are scavenging upon stranded animals then rehabilitation centres should consider the potential for cross-species zoonoses, including rabies (although currently eradicated from foxes in Belgium) (Odegaard & Krogsund, 1981; Brochier et al., 1994; Van Gucht & Le Roux, 2008), Brucellosis (Nielsen & Duncan, 1989), and Tuberculosis (Gavier-Widén et al., 2012).

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Table 1. Well-documented injuries on harbour porpoises left by other species occurring in the southern North Sea and along its coastline, in comparison with the current case (suspected red fox)

	Interacting species			
	Delphinidae	Grey seal	Bird	Suspected red fox
Description	Rake marks: parallel scratches, distance between scratches consistent with inter-teeth distance of the aggressor; bruising	Puncture injuries left by teeth and claws, strips of blubber removed or hanging loose, sometimes muscle partly removed	Multifocal, relatively small, superficial injuries penetrating through the skin into blubber layer, triangular in shape (beak); sometimes deeper penetration injuries with irregular edges	Multifocal injuries, extremities partly removed, with frayed edges (chewing?); irregular, and relatively superficial scratches (claws?); deeper, focal injury where blubber is penetrated
Position on the body	Anywhere on the body	On all sides of the body; punctures specifically on melon and tailstock	Often unilateral as a result of a floating or stranded carcass, and centred at softer tissue (around the eyes or genital split)	Unilateral on exposed side; lesions on extremities starting at the distal part
Pathology	Possibly internal bruising, damaged organs, broken bones; trauma inflicted by dolphin attack identified as cause of death in the majority of cases	Mostly healthy animals, recent feeding; haemorrhages in underlying tissue of puncture wounds (ante-mortem occurrence); trauma inflicted by grey seal attack identified as cause of death in the majority of cases	No haemorrhages in underlying tissue (post-mortem occurrence); lesions not identified as cause of death	Haemorrhages of underlying tissue (with no haemorrhages expected in cases of post-mortem occurrence)
References	Ross & Wilson, 1996; Barnett et al., 2009	Haelters et al., 2012; Bouveroux et al., 2014; Jauniaux et al., 2014; Leopold et al., 2015a, 2015b	Personal observations by J. Haelters and L. IJsseldijk	
Example image