Prey that kill: Dover soles (*Solea solea*) causing fatal asphyxiation in seals in the southern North Sea

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Abstract: Along with the increase of harbour seals (*Phoca vitulina*) and grey seals (*Halichoerus grypus*) in the southern North Sea, the number of stranded dead and dying seals has risen sharply in recent decades. A selection of animals stranded in Belgium and the Netherlands is examined, with as one of the main objectives to collect information about the cause of death. One of the causes of death is suffocation from fish that enter the trachea, or from fish that are too large to be swallowed completely. In this contribution, eleven of such cases are discussed. It appears that Dover sole (*Solea solea*) is especially dangerous for seals.

Keywords: *Phoca vitulina*, *Halichoerus grypus*, mortality, suffocation, *Solea solea*, Belgium, the Netherlands.

Introduction

Two species of seal are indigenous to the southern North Sea: the harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*). The harbour seal population crashed several times during the 20th century, while the grey seal had been virtually absent in this area for centuries (Brasseur et al. 2015, 2018). However, numbers of both species have increased dramatically during the last decades. The number of harbour seals currently present in the French North Sea and Channel, the Dutch Delta area, the Wadden Sea and south-east England is estimated to amount to more than 35,000 animals (OSPAR 2023). In Belgium, only two haul-out sites exist, holding very few seals. In the Wadden Sea area and on Helgoland 2,214 grey seal pups were counted in the winter pupping season of 2021/2022, and in April 2022 8,948 grey seals were counted in the Wadden Sea (Schop et al. 2022). Estimates of the number of grey seal births at the colonies in eastern England amounted to more than 11,000 in 2019 (SCOS 2022, OSPAR 2023). Together with the increase in numbers present, the number of stranded dead and dying seals has increased. A selection of animals stranded in Belgium and the Netherlands is investigated, with as one of the main objectives identifying the cause of death. In this contribution we focus on the pathology and the occurrence of an unexpected cause of death: asphyxia due to the ingestion of Dover sole (*Solea solea*).

Material and methods

In Belgium, the Royal Belgian Institute of Natural Sciences (RBINS) is responsible for recording strandings and incidental catches of marine mammals and organising the col-

Table 1. Data of the seals used in this study; M: male, F: female; TL: total length; DCC: decomposition code; NCC: Nutritional Condition Code; ND: not determined; B: Belgium; NL: the Netherlands

Case no.	Species	Date	Location	Rehab. tag	Weight (kg)	TL (cm)	Sex	Age	DCC	NCC	Images available
1	*Halichoerus grypus*	25/09/2014	Oostende (B)	No	148	ND	M	Adult	3	5	Yes
2	*Halichoerus grypus*	21/04/2015	Middelkerke (B)	No	Approx. 200	230	M	Adult	3	1	Yes
3	*Halichoerus grypus*	14/03/2017	Middelkerke (B)	SEALIFE (B)	40	132	M	Juvenile	2	1	Yes
4	*Halichoerus grypus*	5/04/2018	Wenduine (B)	No	85	176	M	Subadult	2	1	No
5	*Halichoerus grypus*	1/05/2018	Burghsluis (NL)	Pieterburen (NL)	29.8	124	F	Juvenile	2	1	Yes
6	*Phoca vitulina*	8/11/2012	Texel (NL)	Pieterburen (NL)	18.5	116	F	Juvenile	2-3	1	No
7	*Phoca vitulina*	25/04/2013	Julianadorp (NL)	No	43.6	147	F	Subadult	2	2	Yes
8	*Phoca vitulina*	2/05/2013	Texel (NL)	No	104	184	F	Adult	3	2	Yes
9	*Phoca vitulina*	12/10/2013	Texel (NL)	No	61	145	F	Adult	3	3	No
10	*Phoca vitulina*	5/06/2014	Den Helder (NL)	No	72,5	158	F	Adult	3	1	Yes
11	*Phoca vitulina*	12/05/2017	Sint Maartensdijk (NL)	Chip FDXB	103.5	170	F	Adult	3	1	Yes

lection of a selection of stranded and bycaught animals. Selection is mostly based on decomposition and size, with limited decomposition as the most important driver for selection. Collected animals are submitted to a necropsy performed at the University of Liège or at the University of Ghent, or on-site in case of very large seals. A standardized necropsy protocol is used (Jauniaux et al. 2002, Pugliares et al. 2007).

In the Netherlands, the University of Utrecht occasionally performs necropsies on stranded seals.

To the animals necropsied, a decomposition code (DCC) is attributed, with as DCC 2: freshly dead, intact animal; DCC 3: moderate autolysis, with organs still intact, moderate swelling due to gas, skin sloughing and discernible smell of decomposition, and DCC 4: advanced decomposition, with major bloating, skin peeling, and organs beyond recognition. For each animal also a nutritional condition code (NCC) was scored on a scale from 1 (very fat) to 6 (emaciated) (Pugliares et al. 2007).

The main objective of the necropsies was to establish the cause of death.

Results

During necropsies of seals washed ashore in Belgium and the Netherlands between 2012 and 2018, an obstruction of the airways by a fish was diagnosed in eleven cases: five grey seals and six harbour seals (Table 1). The fish was either obstructing the oral cavity, or it was partially or entirely stuck in the trachea. In all cases in which the fish was identified to species level (n=7), it turned out to be Dover sole (*Solea solea*), with an additional case in which the fish was suspected to be a Dover sole. Most of the animals in this study were found between March and June (n=8). An

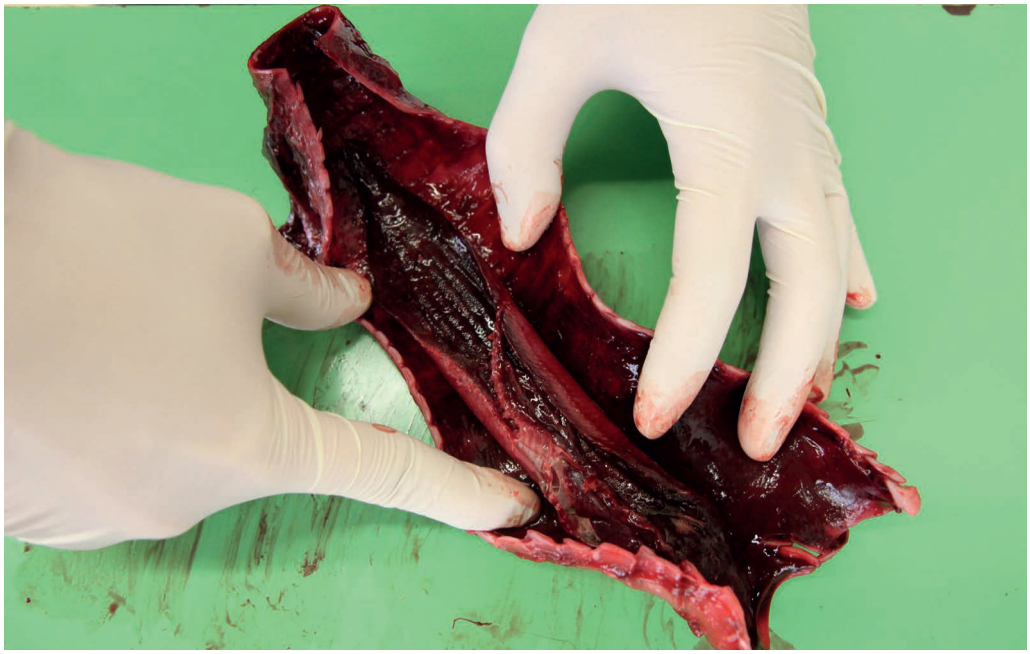

Figure 1. Dover sole present in, and blocking the trachea of a grey seal (case 1). *Photo: University of Ghent, Belgium, Faculty of Veterinary Medicine, dept. Morphology*.

additional animal (a grey seal that washed ashore at Westkapelle, the Netherlands, on 11 April 2017) that choked on a flounder (*Platichthys flesus*) is not discussed here, as it was not subjected to a necropsy.

Description of cases

The description of the cases, with a focus on the obstruction of the airways and the suspected cause of death, was extracted from the necropsy reports. Comments, not from these reports, are put in square brackets.

Case 1. The cranial part of the trachea of the animal was obstructed by an undamaged Dover sole, head down (Figure 1). According to the necropsy report, the stomach contained a lot of fish. [No stomach content analysis was performed.]

Case 2. A Dover sole was present, head down, in the cranial part of the trachea, completely blocking it (Figure 2). The stomach contained only Dover soles, 14 in total, in different stages of digestion (Figure 3).

Case 3. A 37 cm, 0.5 kg Dover sole was stuck, head down, in the oesophagus. Its head region had penetrated the oesophagus up to a depth of 7 cm; the rest of the fish's body was partly present in the oral cavity, blocking it completely, and partly sticking out of it (Figure 4). The seal stomach contained four undamaged Dover soles of 15 to 18 cm long, with a total weight of 0.45 kg. The animal had a flipper tag indicating that it had been born in fall/winter of 2016 and had been admitted for care at Sealife Blankenberge, Belgium.

Case 4. A Dover sole was stuck in the trachea, completely blocking it. The stomach contained 2 kg of Dover soles. [No further stomach content analysis was performed.]

Case 5. A Dover sole of 33 cm was stuck in the oesophagus, compressing the larynx (Figure 5). The stomach was filled with fish and with anisakid nematodes (*Contracaecum osculatum*). The animal had a tag indicating that it had been taken care of at Zeehondencentrum Pieterburen, the Netherlands. [No

Figure 2. Dover sole present in, and blocking the trachea of a grey seal (case 2); the fish was cut in two during the necropsy. *Photo: Jan Haelters / RBINS.*

Figure 3. Stomach content of a grey seal: Dover soles in various stages of digestion (case 2). *Photo: Jan Haelters / RBINS.*

Figure 4. A large Dover sole partly present in the oral cavity of a grey seal (case 3). *Photo: Jan Haelters / RBINS*.

Figure 5. A dover sole blocking the oral cavity of a grey seal (case 5). *Photo: Jooske IJzer, Utrecht University*.

further information could be obtained about the stomach content.]

Case 6. The animal had a subcutaneous haemorrhage of 10 by 5 cm in the neck at the level of vertebrae C2–C3 and was diagnosed as a possible bycatch. A small fish, headfirst, was found in the trachea. The animal had an internal chip indicating that it had been in care at Zeehondencentrum Pieterburen, the Netherlands. [No further information could be obtained about the fish in the trachea.]

Case 7. A Dover sole of 13 cm long and 2.6 cm wide was present in the cranial part of the trachea. The stomach contained several fish. [No further information could be obtained about the stomach content.]

Case 8. The animal suffered a broken neck at the first cervical vertebra, leading to a separation between the spinal cord and the brainstem. A haemorrhage was present at the ventral side of the neck, from the mandibula to the cranial part of the scapula. According to the necropsy report, the severe neck trauma was possibly sustained during agony. In the oesophagus, a fish was present, completely blocking the nasopharynx. The animal was pregnant with an almost fully-grown foetus of 7.1 kg. [No further information could be obtained about the fish blocking the nasopharynx.]

Case 9. A 10 cm long, 4 cm wide flatfish, probably a Dover sole, was present at the bifurcation of the trachea. The stomach contained many fish, and the oesophagus contained bony remnants of fish. [No further information could be obtained about the fish in the oesophagus, given their state of digestion most probably the result of regurgitation, or stomach.]

Case 10. Postpartum, lactating animal. A 15 cm long fish was present in the nasopharynx and trachea. The oesophagus was filled with fish as well. The blubber in the neck was very red, with many 3-5 mm round haemorrhages and pooling of blood [indicative of a peri-mortem lesion]. [The species of fish in the nasopharynx and trachea remained unidentified and its size was not mentioned in the necropsy report.]

Case 11. The cranial part of the trachea was completely obstructed by a 15 cm long Dover sole; its tail was present in the oropharynx on top of the epiglottis. The stomach was filled with 5 kg of flatfish, consisting predominantly of Dover soles. The animal was pregnant with an almost fully-grown foetus of 8 kg. The animal had an internal chip indicating it had been in care at a rehabilitation facility, but no further information could be obtained. [No further information on the presence of other species than Dover soles in the stomach could be obtained from the necropsy report.]

Discussion

Suffocation due to fish in marine mammals

The respiratory system of marine mammals is well adapted to life in the water. As in other mammals, systems exist that try and prevent communication between the nasopharynx and the oropharynx (Reidenberg 2007). Seals evolved an upper aerodigestive tract valving mechanism adapted to a marine environment, with the larynx acting as a valve to assure the separation of the respiratory and digestive pathways during swallowing to prevent the aspiration of food into the trachea and lungs (Adams et al. 2020).

Suffocation due to a fish blocking the airways is well known in marine mammals. The problem may be caused by either a spiny fish that got stuck in the throat, an unusual prey, or a very agile fish. Additionally, overenthusiastic feeding on overly large prey can result in asphyxiation. In cases described earlier, the fish either blocked the cranial part of the oesophagus, concurrently leading to an obstruction of the airways, it dislocated the larynx and impeded its re-articulation, or it directly blocked the trachea.

Published cases of death of marine mammals due to spiny fish or fish that were too large to be swallowed concern bottlenose dolphins (*Tursi-*

ops truncatus) and Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) (Nash 1974, Byard et al. 2003, Watson & Gee 2005, Mignucci-Giannoni 2009, Byard et al. 2010, Stolen et al. 2013), harbour porpoises (*Phocoena phocoena*) (Orr 1937, Scheffer 1953, 1980, Ryan & Bolin 2014, Haelters et al. 2017, Elliser et al. 2020), a beluga whale (*Dephinapterus leucas*) (Rouse et al. 2017) and a northern elephant seal (*Mirounga angustirostris*) (Stroud & Roffe 1979).

In many other cases, asphyxiation was caused by sole (Soleidae), fish that are usually not too big nor too spiny for marine mammals and are probably a normal part of the diet. Soles are relatively narrow-bodied flatfish that are very agile compared to many other flatfish. Soles have flexible bodies: they can bend longitudinally into a circular shape, and laterally into the form of a cigar. Additionally, they have a rough skin which, together with gill covers and short fin rays, prevents fish returning once lodged. Cases of suffocation by Dover sole are known in common bottlenose dolphin (Perkins et al. 2015), long-finned pilot whales (*Globicephala melas*) (IJsseldijk et al. 2015) and in harbour porpoises (Benke et al. 1998, Siebert & Frese 1993, Siebert et al. 2001). Nine cases of fatal pharyngeal entrapment of Dover sole in harbour porpoises were described from the island of Sylt (North Sea, German waters) between April and July 2016, but in a retrospective evaluation in total 48 cases were identified between 1990 and 2019. In all but one case, the fish concerned were flatfish (Gross et al. 2020). Live sole have even been identified as having caused suffocation in humans by blocking the trachea, after they made their way into the mouth of fishermen while being handled by the teeth or while being kissed goodbye before release (Roper 2012, Pinheiro et al. 2013, Horton 2017).

Analysis of the cases described here

It is likely that in a number of the cases described here (cases 1, 2, 4, 6, 7, 9, 10 and 11), fish movement in the seal's mouth, in an attempt to escape, interfered with the system to separate the seal's digestive and respiratory tracts, and caused the fish to enter the trachea. Perhaps assisted by inhalation by the seal, the fish even entered the trachea completely, blocking the airways. It should be noted that it is possible that the fish outlived the seal and that its position observed during the necropsy could have changed since the death of the seal (Gross et al. 2020). In other cases (cases 3, 5 and 8), a relatively large ingested fish had caused a compression of the pharynx. This probably led to a laryngospasm and/or a physical blocking of the flow of air into the lungs. Either mechanism could result in a severe impairment of the ventilation to the lungs, followed by a hypoxia-induced loss of consciousness and death. It thus seems that Dover soles pose a risk to seals, both through their agility (entering the trachea) and size/roughness (irreversibly blocking the airways).

We noted haemorrhages in the cervical spine area in three cases (6, 8 and 10). In one of these (case 8), the cervical damage was immediately lethal by itself. It is likely that the stimulation of the larynx by aspirated food produced a strong cough reflex to protect the lungs. This, combined with violent head movements and strong muscle contractions before loss of consciousness (McEwan 2016), could have produced self-inflicted internal damage. Also Byard et al. (2010) suggested this for a bottlenose dolphin that choked on a fish. It should be added that in animals consciousness is maintained longer following tracheal occlusion compared to e.g. in people (McEwan 2016), and this may be the case in seals that can hold their breath for a relatively long time. It is notable that in the case of the animal with the fractured neck, the fracture occurred at the C1 vertebra, which is also the level of the pharyngeal isthmus between nasopharynx and oropharynx. During agony, vomiting could occur, which would explain the remains of partly digested fish remains in the oesophagus in several cases.

Dover sole in the diet of seals

Dover sole has been identified as prey of grey seals, and even as constituting an important part of the diet in certain areas (Prime & Hammond 1990, Hammond et al. 1997, Brasseur et al. 2004, Ridoux et al. 2007, Brown et al. 2012, Gosch et al. 2014, Smout et al. 2014, Aarts et al. 2018; own observations). Also in harbour seals, Dover sole forms, seasonally, an important part of the diet (Hall et al. 1998). Most of the animals in this study were found in spring. In this period of the year, Dover soles aggregate in shallow coastal waters to spawn. Dover sole in the diet of harbour seals in the south-western North Sea peaks in spring, probably related to availability in terms of distribution, abundance and size, and/or the (in)availability of other species (Hall et al. 1998). Dover sole is one of the most common flatfish species in the southern North Sea. It is striking that also in harbour porpoises in Germany, most cases of asphyxia due to Dover sole occurred between April and July (Gross et al. 2020).

Out of eleven of the seals investigated here, four had been, at one point in their life, taken from the beach given they were considered in need (very young, diseased, injured) and they were released after being treated at a rehabilitation facility. This is probably only illustrative of the high percentage of seals that is taken care of, mostly as pups, and any relationship between this and their fate, described in this study, remains speculative. In any case, Dover sole, or any other flatfish, is not on the menu in rehabilitation facilities.

Suction feeding vs. grip and tear feeding

The mechanism of feeding could partly explain why suffocation by sole occurs. Stomachs of grey seals often contain large quantities of undamaged or almost undamaged Dover soles (personal observations; this study). Although most pinnipeds are considered as biters (Kienle et al. 2018), the soles causing problems must have been consumed whole through suction feeding (Hocking et al. 2017). Grip and tear feeding is a strategy often used with prey that is too large to be swallowed (personal observations; Hocking et al. 2017). However, studies on feeding strategies of harbour seals suggest that suction feeding is the primary feeding strategy (Marshall et al. 2014, Kienle et al. 2018) and it appears that seals may consider soles as prey they can simply suck in.

Conclusions

Suffocation of seals due to Dover sole blocking the airways can occur due to fish entering the trachea or due to fish, too big to be swallowed, becoming stuck in the oesophagus and oral cavity. Consuming Dover sole, seasonally the most favoured prey for at least some seals, apparently comes with a risk. Given that also other flatfish species occur in the same area, and similarly sized fish are also consumed by seals, the problem for seals lies with (1) the mechanism of feeding – probably suction feeding rather than bite-and-tear feeding, and (2) the species of fish. This cause of death might have become more noticeable recently because seals became more common in the southern North Sea and nowadays more stranded seals are subjected to a necropsy.

As a mechanical obstruction of the airways is easily recognizable, even in the case of a decomposed animal and in animals that never make it to the necropsy table, we recommend even a very limited necropsy on stranded dead seals to provide more insight into the general importance of this cause of death and to assess trends.

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Samenvatting

Prooien die doden: verstikking door tong (*Solea solea*) bij zeehonden in de zuidelijke Noordzee

In de zuidelijke Noordzee komen twee soorten zeehonden voor: de gewone zeehond (*Phoca vitulina*) en de grijze zeehond (*Halichoerus grypus*). De populatie gewone zeehonden is in de 20e eeuw meermaals ingestort, terwijl de grijze zeehond eeuwenlang vrijwel afwezig was in dit gebied. De aantallen van beide soorten zijn de afgelopen decennia echter sterk toegenomen. Samen met deze toename is ook het aantal gestrande dode en stervende zeehonden sterk gestegen. Een selectie van in België en Nederland gestrande dieren wordt onderzocht, met als een van de belangrijkste doelstellingen het achterhalen van de doodsoorzaak. Een verrassende doodsoorzaak is verstikking door vissen die in de luchtpijp terechtkomen, of door vissen die te groot zijn en de mondholte volledig blokkeren. In deze bijdrage worden elf dergelijke gevallen besproken. Het blijkt dat vooral de zeer lenige tong (*Solea solea*) gevaarlijk kan zijn voor zeehonden.

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