Fatal attraction: The death of a solitary-sociable bottlenose dolphin due to anthropogenic trauma in the Netherlands

Lonneke L. IJsseldijk[1*], Linde van Schalkwijk[1*], Annemarie van den Berg[2], Mariel T.I. ten Doeschate[1], Eligius Everaarts[2], Guido O. Keijl[3,4], Nienke Kuijpers[5], Elisa L. Bravo Rebolledo[6], Stefanie Veraa[5], Marja J.L. Kik[1+] & Mardik F. Leopold[4+]

[1] Division of Pathology, Department of Biomolecular Health Sciences, Faculty of Veterinary Medicine, Utrecht University, the Netherlands, e-mail: L.L.IJsseldijk@uu.nl
[2] SOS Dolfijn Foundation, Anna Paulowna, the Netherlands
[3] Naturalis Biodiversity Center, Leiden, the Netherlands
[4] Wageningen Marine Research, Den Helder, the Netherlands
[5] Diagnostic Imaging, Department of Clinical Sciences, Faculty of Veterinary Medicine, Utrecht University, the Netherlands
[6] Bureau Waardenburg, Culemborg, the Netherlands
*these authors contributed equally to this study
+joint last authorship

Abstract: The death and behaviour prior to death of a bottlenose dolphin (*Tursiops truncatus*) known by the name of "Zafar" created significant national and international public interest. The animal was first observed in the Netherlands on the 2nd of May 2020, closely following a boat from Brittany, France, all the way into the port of Amsterdam after passing the locks at IJmuiden. After a day of residency in the industrial port of Amsterdam, the animal was successfully lured back into the North Sea. The dolphin was observed lastly on the 5th of May following a fishing vessel heading north in coastal waters near Callantsoog. Seven days later, a dead bottlenose dolphin stranded at Wijk aan Zee and through photo-identification, the animal was identified to be Zafar. A post-mortem investigation was carried out with the aim of determining the animal's most likely cause of death, its health status, and an attempt was made to unravel the animals approximate whereabouts prior to death through stomach content analysis. The post-mortem investigation revealed that this subadult, 14 year old male had a moderate to good body condition, no sign of significant disease, and had been feeding shortly prior to death. Injuries on the animal fit with an anthropogenic source causing mortality, and the nature and severity of the lesions were most consistent with vessel collision. Based on the sightings and stranding location and the stomach content, the animal probably died within the Dutch coastal waters of Noord-Holland. This animal was first sighted in 2017 as a solitary-sociable dolphin. Such individuals have particular home-ranges, typically interact with people and little with conspecifics. It has been reported that solitary-sociable dolphins have a higher chance of suffering from human interference, and the case of Zafar clearly demonstrates this risk.

Keywords: post-mortem investigation, pathology, diet analysis, vessel collision, sharp trauma, blunt force trauma, *Tursiops truncates.*

Introduction

Bottlenose dolphins (*Tursiops truncatus*) have a cosmopolitan distribution and are found in temperate to tropical marine areas, where they occur in both coastal and offshore waters (Wells & Scott 2018, Wells et al. 2019). This species is known as highly social and typically, bottlenose dolphins are found in groups of 2-15 individuals, although larger pods have regularly been reported, particularly offshore (Shane et al. 1986, Wells & Scott 2018). Group composition changes frequently, with determining factors being sex, age, reproductive condition as well as familial relationships and affiliation histories (Wells 2014).

Despite being known as a highly social species, several "solitary-sociable bottlenose dolphins" have been identified in different parts of the world. These are individuals that live apart from their conspecifics and (start to) interact with people instead. Typically, these interactions follow an original period of isolation and intensify over time, which may result in situations where the welfare of the animal may be compromised (Wilke et al. 2005, Nunny & Simmonds 2019). Additionally, it has been reported that solitary-sociable dolphins have a higher risk of suffering from anthropogenic influences, which may include feeding on non-food items, deliberate injuries, entanglement in debris or fishing lines, and collisions with vessels or ships propellers (Lockyer 1978, Müller & Bossley 2002, Eisfeld et al. 2010, Nunny & Simmonds 2019).

Nunny and Simmonds (2019) described as many as 32 solitary odontocete records globally since 2008, of which 27 were bottlenose dolphins. One of these 27 solitary-sociable bottlenose dolphins was known by the name of ''Zafar'' (also called "Toto" by some). This individual's reported home range was the coast of Brittany (France), but the animal had also been sighted in Portsmouth and the Isle of Wight in the United Kingdom. The first confirmed sighting dates back to June 2017. Nunny and Simmonds (2019) considered this individual a 'stage 3-4' solitary-sociable dolphin, which reflects solitary animals in limited home ranges that actively approach boats and interact with humans who habituated them by deliberately swimming with them and touching them (Wilke et al. 2005, Eisfeld et al. 2010, Nunny & Simmonds 2019). As a result of media reports on these events, such dolphins become 'tourist attractions' and they may also exhibit dominant, aggressive and sexual behaviour (Nunny & Simmonds 2019). At the time that Nunny and Simmonds published their global reassessment of solitary-sociable dolphins in 2019, Zafar was alive and resided in Brittany.

Here we report several sightings and the eventual death of Zafar in spring 2020 in Dutch waters. The animal was seen interacting with humans and boats, but found stranded seven days after the last sighting. We provide the timeline and documented behaviour from the first to the last day that the animal was sighted in Dutch waters and describe the results of the extensive post-mortem investigation, which consisted of diagnostic imaging, gross and histopathological examination and microbiology, and subsequent life history and diet analysis. These results update and finalise the status of this particular solitary-sociable dolphin and conclusions may be used during risk assessments of human-dolphin interactions in the future.

Methods

Since the report of the bottlenose dolphin in Dutch waters, SOS Dolfijn Foundation monitored the animal and collected information on its position and behaviour, with photos of the animal regularly taken during observations. In the results section we present a timeline of the dolphin's presence in Dutch waters, which included a period spent in an industrialised area that was semi-enclosed from the North Sea and a subsequent rescue attempt to get the animal back into the open sea.

Post-mortem investigation

After the report of a stranded bottlenose dolphin on the Dutch coast, the carcass was retrieved and transported to Utrecht University (UU), Faculty of Veterinary Medicine for post-mortem investigation. Prior to the necropsy, a full-body computer tomography (CT) scan was attempted at the division of Diagnostic Imaging, Department of Clinical Sciences of UU following procedures as outlined in Willems et al. (2020). However, the midsection of the animal exceeded the scanners perimeter, resulting in loss image acquisition of the widest area of the animal, therefore additionally the entire vertebral column was scanned after dissection to allow proper evaluation of all vertebrae. The 64-slice sliding gantry CT scanner (Somatom Definition AS, Siemens AG, München, Germany) obtained data with an acquisition of 0.6 mm detector width, 120 kVp, reference mAs 370, 0.5 s rotation speed, 0.9 pitch and matrix size 512 x 512. Images were reconstructed to 3 mm slice thickness, 1.5 mm increment and soft tissue algorithm (B30f medium smooth) with a window width / window level of 300/50. Images were also reconstructed to 1 mm slice thickness and an increment of 0.7 mm using a bone algorithm (B60F) with a window width / window level 3000/600 and evaluated using the Picture Archiving and Communication System (Impax, version 6.6.1.3004, N.V., Agfa Healthcare, Mortsel, Belgium).

The post-mortem examination was conducted at the division of Pathology, Department of Biomolecular Health Sciences of UU, following an internationally standardised protocol (IJsseldijk, Brownlow & Mazzariol 2019). The animal was weighed, and its length, girth and blubber thickness were measured. The latter was measured immediately anteriorly to the dorsal fin at three locations (dorsal, lateral and ventral). All tissues were grossly inspected and subsequently, a standard set of samples was collected for histopathological evaluation, including: skin, muscle, lung, heart, thyroid, liver, adrenals, kidney, stomachs, intestine, pancreas, urinary bladder, reproductive tissue, eyes, brain and spinal cord, spleen, thymus and various lymph nodes, as well as all macroscopically identified lesions. Tissues were routinely fixed in 10% neutral buffered formalin and embedded in paraffin wax, sectioned at 5 µm, stained with haematoxylin and eosin (HE), and examined. Additional staining was performed, including periodic acid–Schiff (PAS) stain, to assess the presence of fungal organisms, and Ziehl-Neelsen (ZN) stain, to assess the presence of acid-fast mycobacteria, in respiratory tract tissue and in a mesenteric lymph node. In addition, microbiological examination was conducted on lung and brain tissues at the Veterinary Microbiological Diagnostic Centre of UU according to standard protocols. After the post-mortem examination and tissue sampling, the skeleton (i.e. those parts that were present) was cleaned for further assessment. It is part of the whale exhibition at Ecomare on Texel since October 2020 (Naturalis national reference number: RMNH.MAM.59783).

Life history analysis

Exact age was determined by assessing tooth growth layer groups (GLG). One mandibular tooth was collected during necropsy and subsequently analysed according to methods described in Hohn and Lockyer (1995) at the University of Veterinary Medicine, Hannover, Germany. The animal's reproductive status was evaluated by gross and histologic assessment of the reproductive organs.

Diet analysis

The entire gastro-intestinal tract (GIT) was collected during necropsy, sampled for histopathology, and subsequently stored frozen prior to further assessment at Wageningen

Figure 1. The bottlenose dolphin with the Tres Hombres in the Amsterdam Port. *Photo: Wouter Jan Strietman*.

Marine Research. These organs were cut open and all hard prey remains, particularly fish sagittal otoliths were assessed (full method in Leopold et al. 2015). The otoliths were used to identify fish species and to estimate fish length and mass, which were back-calculated following Leopold et al. (2001). Special attention was payed to non-food items present, such as stones or plastic.

Results

Timeline and behaviour prior to stranding

On its journey from the Caribbean to Amsterdam, the non-motorised cargo vessel "Tres Hombres" was accompanied by a bottlenose dolphin known by the name Zafar when it passed Brittany, France, late April 2020. The animal was first reported in the Netherlands in the port of IJmuiden on 2 May 2020, where it stayed close to the cargo vessel. Doing so, the vessel and animal entered through the harbour locks and made their way 20 km inland to the Suez port of Amsterdam where the cargo vessel docked to unload. The animal stayed within close proximity of the "Tres Hombres" (figure 1), but his behaviour varied, from logging at the water surface next to the vessel, to active foraging around the vessel. On occasion, the animal presented its penis towards the boat, which could indicate sexual behaviour.

The port of Amsterdam is an industrial area with many human activities. The salty water of the North Sea is mixed with fresh waters coming from rivers and lakes, resulting in a brackish to fresh water environment. Media attention regarding the presence of this animal resulted in crowds on scene, both on shore and on the water, despite the strong advice by the local municipality and nature conservation parties to leave the animal in peace, to ensure its safety as well as to respect the Covid-19 measures that were in place at the time. Due to this situation, SOS Dolfijn Foundation composed a strategy to lure the animal back into open waters. In accordance with the local municipality and the Dutch government, a first attempt was conducted using a rigid-inflatable boat (RIB) from the local water police. The dolphin initially followed the RIB for several kilometres, but lost his interest and was therefore redirected to the "Tres Hombres", whilst a second rescue operation was developed by SOS Dolfijn. The following day and under the guidance of several nature conservation parties, the "Tres Hombres", set sail towards the locks of IJmuiden, aiming at guiding the animal back to open waters. The ship and the dolphin successfully entered the North Sea together, after which the vessel turned and again passed the locks to sail back to the port of Amsterdam, while the dolphin remained in open waters. Regular sightings of the animal were made the following two days (4 and 5 May[1]) in the Seaport Marine harbour of IJmuiden, where it frequently interacted with people and boats and was at one occasion observed "catching large fish"[2]. It was repeatedly observed to exit and re-enter the harbour, and was last seen on the evening of 5 May interacting with a beam trawler that was heading north in coastal waters, at 7pm near Castricum until 10pm (at dusk) near Callantsoog (timeline presented in table 1 and locations plotted in figure 2).

Stranding

On the evening of 12 May 2020, a dead, moderately fresh bottlenose dolphin was reported stranded at Wijk aan Zee (circa 3 km north of IJmuiden). It was immediately apparent that the animal had its fluke amputated. The animal was moved higher up the beach and out of the surf by local beach operators and animal rescue staff, to ensure that it would not wash

[1] For an overview see: https://waarneming.nl/species/422/observations/

[2] https://waarneming.nl/observation/190488805/

Table 1. Timeline of sightings and stranding of Zafar in Dutch waters.

Category	Description	Location	Date
Sighting	First sighting	Port of IJmuiden	2-5-2020
Sighting	The animal followed the Tres Hombres inland	Suez port of Amsterdam	2-5-2020
Sighting	Rescue attempt with Tres Hombres	Noordzeekanaal	3-5-2020
Sighting	Several sightings	Seaport IJmuiden	4-5-2020
Sighting	Several sightings	Seaport IJmuiden	5-5-2020
Sighting	Observed interacting with a beam trawler	Castricum	5-5-2020
Sighting	Observed interacting with a beam trawler	Callantsoog	5-5-2020
Stranding	Found dead	Wijk aan Zee	12-5-2020

away overnight. Pictures were taken from the animal for photo-identification purposes and the notches in the dorsal fin, as well as scarring on the head indicted that this animal was Zafar (Hoekendijk et al., in prep). The next morning, the animal was transported to the Faculty of Veterinary Medicine for post-mortem investigation.

Post-mortem investigation

The bottlenose dolphin was a male with a length of 253 cm, measured in a straight line from rostrum to the dorsal side of the amputation, and 285.5 cm from rostrum to the ventral side of the amputation, and weighed 290 kg. The most caudal part of the tailstock (estimated at a maximum of 45 cm, using the girth cranial to the dorsal fin (174 cm), according to Mallette et al. 2016) and fluke were missing (figure 3A). The animal appeared in moderate to good nutritional condition, with a blubber thickness of 21-28 mm. Decomposition was moderate (code 3 following IJsseldijk, Brownlow & Mazzariol 2019).

Externally, there was a spiral laceration extending from the left mid-side of the tailstock, where a clear and sharp-edged cut affected the blubber and the underlying muscle tissue, which deepened towards the dorsal side of the tailstock leading into the amputation (figure 3B-C). The wound edges were generally sharp, but softer tissue was protruding and signs of decomposition were apparent. The lumbar vertebra at the amputation side was fractured completely and the vertebral body consisted of multifocal, loose bone fragments (comminuted fracture) and appeared incomplete (figure 3B). This was confirmed upon assessment of the CT scan, with the vertebral body existing of multiple dislocated bone fragments (figure 4A). In addition, lateral parts of multiple lumbar vertebrae were fractured. Grossly, on its cut surface the wound edges presented mild amounts of oedema and haemorrhage, but histological examination could not confirm ante-mortem occurrence due to advanced decomposition of the tissues at this location.

There were some stranding- or post-mortem related changes such as sloughing of the epidermis on extremities, as well as tens of chronic, ante-mortem, parallel running, superficial and completely healed rake marks with inter-dental distance of approximately 12 mm; compatible with the inter-dental distance of conspecifics (Ross & Wilson 1996). There was a focal rectangle-shaped white scar with dark rim dorsally to the right eye and multifocal deeper scratches caudoventrally at this location, and an additional oval-shaped white discoloration with darker rim cranially to the left eye (scars also used for photo-identification matching). These skin lesions, which were morphologically consistent with viral infections (e.g. van Beurden et al. 2015), were deemed old and irrelevant in terms of the cause of death of the animal. No evidence, such as superficial nicks or encircling imprints on the rostrum, head or extremities or lack of teeth, that could indicate

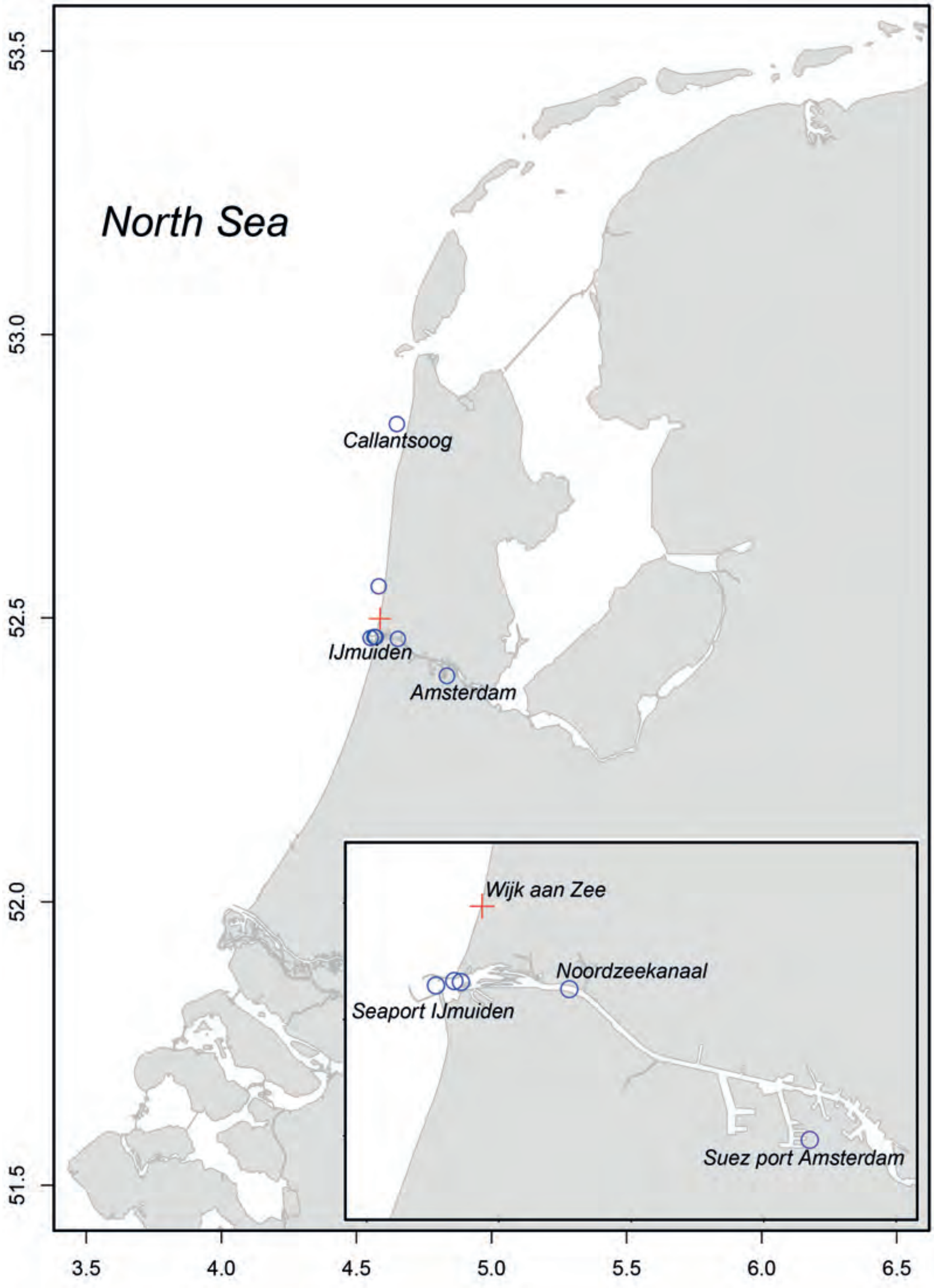

Figure 2. Map indicating sightings (open blue circles) and stranding (red cross) of Zafar. See table 1 for timeline.

Figure 3. Bottlenose dolphin with tail fluke amputated. (A) Ventral body side. (B) Caudal view of amputation lesion, with fractured spinous process (left arrow) and vertebral body (right arrow), the right side of the tailstock is facing upwards in this photo. (C) Left side of the tailstock, with rotational sharp edge wounds extending into the amputation.

entanglement in fishing gear were detected.

Subcutaneously, dorsolaterally on the left side at the height of the dorsal fin, there was a haemorrhagic and oedematous area of approximately 30x15x10 cm where the muscle (*M. longissimus dorsi*) had lost its structure completely. Externally at this location, the blubber was intact, but the epidermis was sloughed. The CT scan revealed fractures in multiple thoracic vertebrae (figure 4B). Histologically, acute and extensive intramuscular haemorrhage was confirmed (figure 5A).

Approximately 2 litres of blood was present in the abdominal cavity, suggestive of an haemoabdomen. The second stomach compartment was ruptured, which, based on histology, was likely a post-mortem artefact, resulting in the presence of a mild amount of stomach content in the abdominal cavity. The caudal part of the oesophagus and the forestomach were filled with partly digested and undigested prey and the intestines appeared well filled (see diet analyses for details). In all abdominal organs assessed grossly and histologically, no signs of significant infectious disease, parasitism, neoplasia or other abnormalities were detected. However, decomposition of the organs may have hampered the evaluation.

The main bronchi were filled with moderate amounts of stable pink foam (oedema) and there were multiple dark red areas on the dorsal sides of the lung, compatible with haemorrhage, and congestion of pulmonary vessels, all of which were confirmed by histology. In addition, grossly several small nodules containing caseous exudate in both lungs were present. Histopathology revealed a local and mild granulomatous pneumonia. No parasites were observed either grossly or histologically, the periodic acid-Schiff (PAS) and Ziehl-Neelsen

(ZN) staining were negative and culture did not reveal a pure growth of a significant pathogen. The pneumonia was therefore considered to not solely have caused severe debilitation or death. In other thoracic organs assessed grossly and histologically, no signs of significant infectious disease, parasitism, neoplasia or other abnormalities were detected. However, decomposition of the organs may have hampered evaluation.

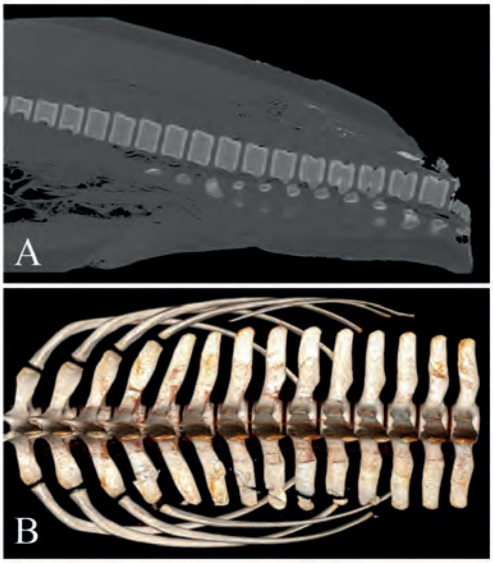

Figure 4. Sagittal CT-scan image of tailstock at the right side (A) and 3-D reconstruction of CT-scan of part of thoracic and lumbar vertebrae (B) both showing multiple fractures to the lateral parts as a result of severe trauma.

Both grossly and histologically, severe areas of hyperaemia and haemorrhage were observed in the central nervous system (CNS) (figure 5B). Additionally, the CT scan revealed a fracture in the right mandibular condyle. Histology showed that this had occurred antemortem, with extensive haemorrhage in the mandibular bone. Culture of brain tissue did not reveal a pure growth of a significant pathogen. No other abnormalities were observed in the head and neck region. However, decomposition may have hampered the evaluation and also prevented an assessment of the auditory system.

Maceration of the skeleton revealed irregularities in several costovertebral joints suggestive of a previous infection, and a post-traumatic deformity of the fifth rib on the right side of the ribcage, indicative of a previous trauma.

Life history

The animal was aged at 14 years, the testicles were ~11 x 2.5 cm bilaterally and no spermatozoa were observed histologically. Common

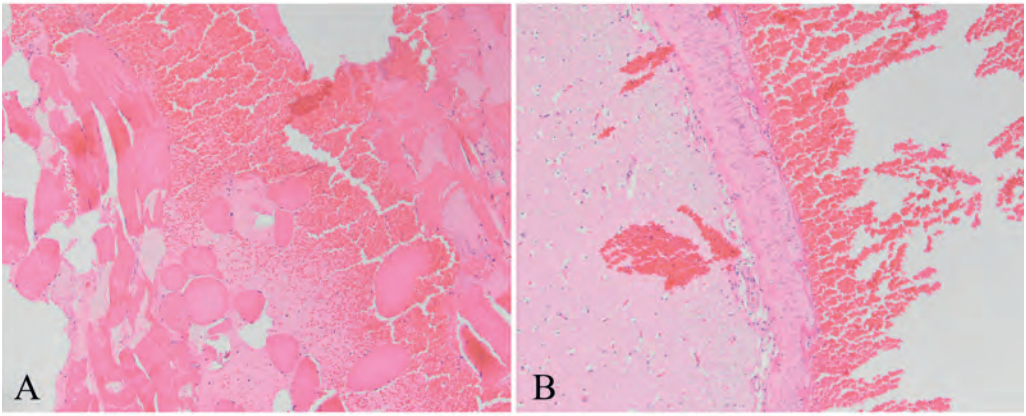

Figure 5. (A) Haemorrhage in M. longissimus dorsi (dark-red stained areas in muscle tissue, haematoxylin-eosin stain, 10x magnification) and (B) haemorrhage in cerebrum (dark-red stained areas in brain tissue, haematoxylin-eosin stain, 10x magnification) reveal acute, ante-mortem trauma.

Figure 6. Initial view of the stomach contents of the forestomach showed the partly digested body of the largest sea bass, the most intact and probably the last prey eaten. The most caudal part of the sea bass was positioned in the caudal part of the oesophagus.

bottlenose dolphins reach sexual maturity at ages between 9-14 (Wells & Scott 2018), and since there was no sign of sperm production we can consider this animal as sub-adult.

Diet analyses

When the forestomach was initially opened on the necropsy table, it was immediately apparent that it was full of remains of recently consumed fish (figure 6). The fish remains were too far digested for direct measurements of fish lengths and prey species and sizes were therefore reconstructed from the otoliths found between the remains (table 2).

Remains of ten large sea bass were found, with reconstructed total lengths from 36.0 to 53.4 cm and a total (fresh) mass of 9848.5 gram. In addition, remains of 30 smaller prey were found: five fish species and three invertebrates (table 2). Together, these smaller prey amounted to only 2.4% of total reconstructed prey mass, and their relative small sizes suggest that these may all have been secondary prey, i.e., the prey of the sea bass taken by the dolphin. No prey hard parts that could be used for prey reconstruction were found in the other stomach compartments and intestine. No foreign objects (e.g. plastics) were detected.

Discussion and conclusion

The solitary-sociable bottlenose dolphin known as Zafar was observed alive in Dutch waters over a period of four days in the spring of 2020 and was found dead seven days after the last sighting. The post-mortem investigation revealed a moderate to good body condition, a lack of significant disease, and feeding shortly before death; all of which are consistent with an acute death. The injuries on the animal, including sharp and blunt force trauma, fit with a death due to an anthropogenic factor, and the nature and severity of the lesions, which included an amputation with multiple fractured vertebral elements, multifocal fractures elsewhere in the skeleton, and extensive subcutaneous, intramuscular and CNS haemorrhages, are most consistent with hull and propeller collision.

Both ship and propeller collision have been reported to induce blunt force trauma, sharp trauma, or a combination thereof (McLellan et al. 2013). The severity of the injuries is associated with the size and speed of the propeller or vessel, the nature or behaviour of the victim and angle of the impact (Byard et al. 2012, McLellan et al. 2013). Blunt force injuries result from contact with a non-rotating feature of a vessel, such as the bow or hull, and common injuries include the presence of a well-defined focal area of subcutaneous haemorrhage and oedema, physically disrupted muscle, fractured bones and disruption of organ systems (Martinez & Stockin 2013, McLellan et al. 2013, IJsseldijk et al. 2014). Collision with propellers are often associated with major injuries such as fractures, incised wounds and lacerations, and amputations, inflicted by heavy metal blades rotating at high speed (Lightsey et al. 2006, Byard et al.

Table 2. Prey found in the forestomach. Lengths and masses were reconstructed from the indicated prey hard parts. *For green crab, carapace width is given.

Prey nr	Prey species	Scientific name	Item	Length (cm)*	Mass (g)
1	Sea bass	*Dicentrarchus labrax*	2 otoliths	53.4	1408.5
2	Sea bass	*Dicentrarchus labrax*	2 otoliths	50.2	1171.6
3	Sea bass	*Dicentrarchus labrax*	2 otoliths	47.8	1010.5
4	Sea bass	*Dicentrarchus labrax*	2 otoliths	48.1	1028.9
5	Sea bass	*Dicentrarchus labrax*	2 otoliths	44.1	796.1
6	Sea bass	*Dicentrarchus labrax*	2 otoliths	48.7	1070.6
7	Sea bass	*Dicentrarchus labrax*	1 otolith	36.9	465.7
8	Sea bass	*Dicentrarchus labrax*	1 otolith	36.0	433.4
9	Sea bass	*Dicentrarchus labrax*	2 otoliths	48.7	1070.6
10	Sea bass	*Dicentrarchus labrax*	2 otoliths	53.2	1392.9
11	Great sandeel	*Hyperoplus lanceolatus*	1 otolith	19.8	19.96
12	Great sandeel	*Hyperoplus lanceolatus*	2 otoliths	12.9	5.66
13	Great sandeel	*Hyperoplus lanceolatus*	1 otolith	11.3	3.80
14	Sandeel spec.	*Ammodytes* sp.	2 otoliths	16.6	14.33
15	Sandeel spec.	*Ammodytes* sp.	1 otolith	19.1	23.16
16	Sandeel spec.	*Ammodytes* sp.	1 otolith	16.9	15.26
17	Sandeel spec.	*Ammodytes* sp.	2 otoliths	13.0	6.22
18	Sandeel spec.	*Ammodytes* sp.	1 otolith	14.1	8.24
19	Sandeel spec.	*Ammodytes* sp.	1 otolith	14.7	9.41
20	Sandeel spec.	*Ammodytes* sp.	1 otolith	13.9	7.66
21	Sandeel spec.	*Ammodytes* sp.	1 otolith	12.8	5.83
22	Sandeel spec.	*Ammodytes* sp.	1 otolith	13.3	6.58
23	Sandeel spec.	*Ammodytes* sp.	2 otoliths	11.6	4.19
24	Sandeel spec.	*Ammodytes* sp.	2 otoliths	11.0	3.43
25	Sandeel spec.	*Ammodytes* sp.	1 otolith	10.0	2.51
26	Sandeel spec.	*Ammodytes* sp.	1 otolith	18.4	20.46
27	Sandeel spec.	*Ammodytes* sp.	2 otoliths	9.5	2.04
28	Sandeel spec.	*Ammodytes* sp.	2 otoliths	7.9	1.08
29	Sandeel spec.	*Ammodytes* sp.	1 otolith	8.9	1.65
30	Sprat	*Sprattus sprattus*	2 otoliths	12.0	14.91
31	Sprat	*Sprattus sprattus*	2 otoliths	11.6	12.98
32	Sprat	*Sprattus sprattus*	1 otolith	11.6	13.30
33	Sprat	*Sprattus sprattus*	2 otoliths	11.3	11.89
34	Sprat	*Sprattus sprattus*	1 otolith	10.7	9.89
35	Herring	*Clupea harengus*	2 otoliths	7.0	2.07
36	Sand goby	*Pomatoschistus minutus*	1 otolith	7.8	4.06
37	Sand goby	*Pomatoschistus minutus*	1 otolith	8.3	4.81
38	Green crab	*Carcinus maenas*	carapax	2.3	2.97
39	Brown shrimp	*Crangon crangon*	tail	5.4	1.89
40	Slender ragworm	*Nereis pelagica*	jaw	6.2	0.23

2012, Costidis et al. 2013). The bottlenose dolphin described here presented a combination of these features, with substantial evidence of ante-mortem and severe trauma in the skeleton, CNS and subcutaneously / intramuscular haemorrhage. We consider that the most likely sequence of events was that the impact of vessel collision occurred on the left dorsolateral side of the animal, resulting in multiple vertebral fractures and severe subcutaneous contusion, and that the rotational energy of the propellers may have sucked the animal into the propeller blades, as is reported to occur in both humans and animals (Ihama et al. 2009, Byard et al. 2012), resulting in the rotational tailstock lesion and subsequent amputation of the fluke. It should however be noted that the presence of mild oedema and haemorrhage observed grossly in the amputation site could not be confirmed histologically, likely as a result of decomposition, and although considered less likely, it can therefore not fully be excluded that the amputation occurred post-mortem and/or in a separate event.

Some of the necropsy findings in this bottlenose dolphin are also consistent with another common, acute, anthropogenic cause of death in marine mammals: underwater entrapment (Cox et al. 1998, Jepson et al. 2013, Moore et al. 2013). Reported features in bycaught small cetaceans partly overlap with those seen in animals dying as a result of vessel collision, like oedematous lungs and fractures with associated haemorrhage in the mandible. However, the most reliable indicator of underwater entrapment is the presence of acute linear skin lesion and nicks (netmarks) in or around the rostrum or extremities (Kuiken 1994, Jepson et al. 2013, IJsseldijk et al. 2020). Although post-mortem and stranding related artefacts may have hampered detection, no fresh linear encircling imprint on the rostrum, head and neck regions, nor obvious, acute and characteristics cuts in the edges of the fins where detected and no teeth were damaged or dislocated. Physical traumas including amputations are occasionally also reported in bycaught or entangled individuals. This is either induced following a gradual process as chronic entanglement (Urbán et al. 2004) or during post-mortem disentanglement of an animal from a net (Kuiken 1994, Jepson et al. 2013, Peltier et al. 2020). Amputations lesions are often reported in small cetaceans stranded in France and Cornwall, and allocated to bycatch only when there are additional (partial) encircling impression marks (Clear et al. 2017, Peltier et al. 2020). These lesions appearing as clear-cut amputations through inter-vertebral discs or (partial) amputations of fluke tips. It is uncommon to find skeletal fractures in the amputation site (H. Peltier, personal communication). Amputations are also generally not commonly reported in bycaught cetaceans from the (southern) North Sea (Cox et al. 1998, Jepson et al. 2013, IJsseldijk et al. 2020), however, stranded animals with such lesions are sometimes found. In 2003, a humpback whale (*Megaptera novaeangliae*) calf was sighted off the coast of Scheveningen and later found stranded with its fluke and part of the right flipper "cut-off". Public and people involved in the stranding event concluded "that this was likely done by fishermen after drowning in fishing tackle" (Camphuysen & Peet 2007), but one should be careful with drawing conclusions since no necropsy was conducted. A proper description of the (external) lesions was not available and comparison with our case unfortunately therefore not reliably possible. In 2017, several harbour porpoises with clear-cut tailstock amputations stranded at Texel. One animal was collected for necropsy, which concluded that this animal probably died following underwater entrapment, with the amputation likely representing post-mortem disentanglement (IJsseldijk et al. 2018). More recently, a Northern bottlenose whale (*Hyperoodon ampullatus*) was found stranded at Terneuzen (September 2020), with an amputation cranial to the dorsal fin, with severe haemorrhage and multiple ante-mortem fractures. A necropsy was conducted concluding that propeller injury was the most likely cause of death (unpublished data). Comparison among these cases shows that the cut-edge of amputations in combination with skeletal damage aids in the differentiation between low-force knife-cuts (most likely post-mortem disentanglement from a net) and high-force mechanical, rotational trauma (most likely propeller). Therefore, and in the case of Zafar, we conclude that the amputation was more likely a propeller injury than human-induced knife cuts.

Establishing a time and location of death is highly challenging in marine mammal species. Decomposition is affected by numerous variables, including temperature, species and cause of death (IJsseldijk, Brownlow & Mazzariol 2019, Moore et al. 2020), and therefore there is uncertainty when it comes to establishing a time and associated location of death when animals are not observed dying. The case of Zafar however allows some speculation. Seeing the proximity of the stranding compared to the last sighting (~40 km in a straight line), it is most likely that the bottlenose dolphin resided within this approximate area. The animal probably swam at least some distance from shore as due to media attention, it is likely that sightings would have been reported if they were possible from land. An estimation based on decomposition of the dolphin carcass indicates that the animal was likely dead for at least 48 hours. The stomach contained a variety of prey species that all commonly occur in North Sea coastal waters, including port entrances and these provide no further clue about the exact location where the dolphin had died. The dolphin's (main) prey, sea bass, is a highly prized fish species that would unlikely be discarded by e.g. the trawler last seen being accompanied by the dolphin. Sea bass are also fast swimmers, indicating that Zafar was an agile hunter.

Zafar expressed great interest in people, vessels and other items in and on the water since he was first sighted in 2017 as well as during his time in the port of Amsterdam. Several media outputs described his behaviour previously as violent and sexual towards swimmers[3,4,5]. One would think that since this animal was used to being around people and objects like boats with propellers, this may have reduced its risk of collision. While it has been reported that some cetaceans learn to avoid boats after a negative experience (such as a biopsy or capture), most studies show that injuries do not necessarily lead to behavioural changes and that avoidance of vessels does not occur, with the risk of collision persisting (Elwen & Leeney 2010, Nunny & Simmonds 2019). This was also demonstrated in the case of Zafar, given there were signs that the animal might have had boat collision experience based on the older skeletal lesions. Our results demonstrate that despite a possible previous trauma and habituation, Zafar continued to be attracted to people and vessels with a final fatal outcome.

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3 http://zafarledauphin.blogspot.com

4 https://www.telegraph.co.uk/news/2018/08/27/swimming-banned-french-beach-sexually-frustrated-dolphin-named/

5 https://www.washingtonpost.com/news/morning-mix/wp/2018/08/28/a-lonely-dolphins-sexual-behaviors-toward-humans-caused-a-french-town-to-ban-swimming/

gis (La Rochelle), who provided us with information on, and photos of stranded cetaceans in France with amputation lesions for comparison with our case. The skeleton of the animal is part of the National collection of Naturalis (RMNH.MAM.59783) and exhibited at Ecomare on Texel. Age determination was conducted at the Institute for Terrestrial and Aquatic Wildlife Research in Büsum, Germany. The investigation of this case was commissioned by the Ministry of Agriculture, Nature and Food Quality under project reference number 1400011072. The funding source had no role in the study design, data collection and analysis, and preparation of the manuscript. We also thank two anonymous reviewers for their helpful comments and suggestions on a previous version of the manuscript.

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Samenvatting

Fatale aantrekkingskracht: de dood van een solitair-sociale tuimelaar door antropogeen trauma in Nederland

De dood en het gedrag voorafgaand aan de dood van een tuimelaar (*Tursiops truncatus*), bekend onder de naam “Zafar”, zorgden eerder dit jaar voor aanzienlijke nationale en internationale publieke belangstelling. Het dier werd voor het eerst in Nederland gezien op 2 mei 2020, toen hij een boot vanuit Bretagne (Frankrijk) helemaal tot in de haven van Amsterdam volgde. Hierbij hadden boot en dier de sluizen van IJmuiden gepasseerd, waarna de tuimelaar een dag in de industriële haven van Amsterdam verbleef. De tuimelaar werd met succes terug de Noordzee in gelokt na een reddingsactie onder leiding van Stichting SOS Dolfijn. Hij werd voor het laatst waargenomen op 5 mei in de kustwateren bij Callantsoog, terwijl hij een vissersschip volgde dat naar het noorden voer. Zeven dagen later strandde een dode tuimelaar bij Wijk aan Zee en middels foto-identificatie kon worden vastgesteld dat het om Zafar ging. Er werd postmortaal onderzoek verricht met als doel de meest waarschijnlijke doodsoorzaak en de gezondheidstoestand vóór het overlijden vast te stellen. Ook werd er een poging gedaan om de geschatte plaats van overlijden van de dolfijn te achterhalen door middel van analyse van de maaginhoud. Uit het postmortaal onderzoek bleek dat het om een subadulte, 14 jaar oude, mannelijke dolfijn ging in een middelmatige tot goede voedingstoestand, die kort voor zijn dood nog goed gegeten had en geen tekenen van significante ziekte vertoonde; bevindingen die passen bij een acute doodsoorzaak. De dolfijn had ernstige externe en interne verwondingen als gevolg van zowel scherp als stomp trauma. Gezien de locatie en ernst van de verwondingen lijkt een aanvaring met een schip, zowel de boeg als de scheepsschroef, de meest waarschijnlijke doodsoorzaak. Uit de analyse van de maaginhoud bleek dat het dier zich in de Noordzeewateren heeft gevoed. Op basis van de locatie van de laatste waarneming en de stranding wordt het zeer waarschijnlijk geacht dat het dier stierf in de Nederlandse kustwateren van Noord-Holland. Deze tuimelaar werd voor het eerst waargenomen in 2017 en door anderen aangeduid als een solitair-sociale dolfijn. Dergelijke dieren hebben een leefgebied dat zich meestal dicht bij mensen en uit de buurt van soortgenoten bevindt. Hier hebben ze regelmatig contact met iets of iemand, in of op het water. In andere studies is vastgesteld dat solitair-sociale dolfijnen een grotere kans hebben om verwondingen op te lopen door dit menselijk contact en de dood van Zafar bevestigt dit risico.

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