# Visual health assessment of white-beaked dolphins off the coast of Northumberland, North Sea, using underwater photography

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The white-beaked dolphin (*Lagenorhynchus albirostris*) inhabits cold temperate to subpolar waters of the North Atlantic and is commonly found in the North Sea and off the west coast of the United Kingdom and Ireland (Galatius and Kinze 2016). The most recent available abundance estimates for these areas were generated from surveys conducted in 2005 resulting in 10,565 (CV = 0.29) *L. albirostris* in the North Sea and adjacent waters and 11,700 (CV >0.6) off the west of Scotland (Hammond *et al*. 2013). Dedicated and opportunistic surveys, including shore-based volunteer observations, off the Northeast coast of the UK have shown a relatively higher occurrence of *L. albirostris* during July and August (Brereton *et al*. 2010).

*L. albirostris* faces several conservation threats as well as other health concerns in the Northeast Atlantic Ocean and the North Sea. It is occasionally hunted in the Faroe Islands during the drive catches for long-finned pilot whale (*Globicephala melas*) (Bloch 1996, MacLeod 2013) and is known to be incidentally caught in purse-seine and trawl nets, though there are no quantitative assessments of bycatch rate (Couperus 1997, Kinze *et al*. 1997, Kirkwood *et al*. 1997, Kaschner 2003, Galatius and Kinze 2015, Alstrup *et al*. 2016). Non-lethal injuries likely resulting from anthropogenic interactions, mostly with fishing devices, were detected by photographic assessment in 15 of 90 photo-identified *L. albirostris* free-ranging off Iceland in 2004-2009 (Bertulli *et al*. 2012). Vertebral lesions, such as spondylosis deformans, spondyloarthritis and kyphosis, were also commonly observed in this species, some likely following traumata of anthropogenic origin (Slijper 1936, van Assen 1975, Kompanje 1995, 1999, Galatius *et al*. 2009, Bertulli *et al*. 2015). Cetacean morbillivirus repeatedly induced morbidity and mortality in *L. albirostris* along the shores of Germany and The Netherlands (Osterhaus *et al*. 1995, Wohlsein *et al*. 2007, Van Elk *et al*. 2014) and the Gram-negative bacteria *Brucella* spp. was isolated from multiple organs of an individual stranded on the coast of Scotland (Foster *et al*. 2002). These infectious agents are considered a serious risk to cetacean populations worldwide as they may trigger massive mortalities and/or affect reproduction (Van Bressem *et al*. 2009, 2014, Guzmán-Verri *et al*. 2012). Other threats to *L. albirostris* populations include over-fishing of prey species, habitat degradation, chemical and acoustic pollution, and climate change (MacLeod 2013).

Unlike conventional photo-identification that compares photographs of the dorsal fin taken from a platform above the surface, still and video high-definition underwater photography allow for matching and cataloguing of individuals using multiple body sections, as reported for spotted dolphins (*Stenella frontalis*) in the Bahamas (Brobeil and Dudzinski 2001), common bottlenose dolphins (*Tursiops truncatus*) in Belize (Campbell *et al*. 2002), and Peale's dolphin (*Lagenorhynchus australis*) in Chile (Sanino and Yañez 2012). It is especially useful when working with cetacean species that appear for short periods at the surface and generate much spray, such as *L. albirostris*. This technique also permitted to identify skin disorders in *L. australis* and Chilean dolphins (*Cephalorhynchus eutropia*) from southern Chile (Sanino *et al*. 2014), and body injuries in *T. truncatus* off the coast of Portugal (Martinho *et al*. 2015).

Boat-based opportunistic surveys conducted since 2011 identified the Farnes Deep, a glacial trench with high bio-productivity, 14-20 nm off the Northumberland coast, UK (Fig. 1), as an area where *L. albirostris* commonly occurs and can be reliably located between June and October. Insert Figure 1. Still and video high-definition underwater photography were used to collect data for individual identification and external health assessment of these dolphins in the Farnes Deep area in 2011-2016. Preliminary examination of the videos revealed skin disorders and traumata in several individuals. This led us to examine whether the general health status of *L. albirostris* could be evaluated using these underwater images, as is commonly done with images from photo-identification studies (Thompson and Hammond 1992, Wilson *et al*. 1997, Van Bressem *et al*. 2003, Murdoch e*t al*. 2008, Sanino *et al*. 2014, Pettis *et al*. 2017).

Data were collected during 16 small boat surveys under good sea conditions (Beaufort 1–3) in July 2011, July-September 2013, August-September 2015 and 2016. High definition images of submerged animals were captured by a diver (without scuba tank) using a Sony HDV HC5E video camera (2011) and GoPro Hero 3&4 (2013-2016). VLC media (www.videolan.org/vlc) was used to “screen grab” high quality still photos from the video files. Still images were processed and organized using freeware Xnview (www.xnview.com). Individual dolphins were identified based on nicks, scarring, and pigmentation using images of the head, body, dorsal fin, and peduncle from both the left and right side of the animal. Images from each sighting were cropped and saved and further assessed for distinctive identification features. They were graded (Q 0-4) following recommendation in Urian *et al.* (2015) but adapted for underwater images of the whole body and head. Grading was based on focus, lighting, water transparency, and distance from camera. The highest quality (3-4) images were sharply focused, well-lit, taken in clear water and close to the camera, whereas medium quality (2) images where focused but further from the camera. Low quality (0-1) images were less sharply focused, taken in turbid water and at a greater distance from the camera. Angle was not considered in the grading process as different angles of the body and head were beneficial for the identification process. A photo-identification catalogue was created using only medium and high quality (Q 2-4) images to match distinctive individuals between sightings (Urian *et al.* 2015). Re-sightings of catalogued individuals were recorded and used to create an encounter history.

The health of 86 photo-identified dolphins was visually assessed using the Q 2-4 images, evaluating body condition and traumata. The body condition was considered abnormal when the ribs were prominent and/or when a concave depression occurred behind the head (Clegg *et al*. 2015). Traumata included fresh wounds, scars and amputation of miscellaneous origins. To determine if they were of anthropogenic origin we compared to similar, documented cases (Robbins and Mattila 2004, Andersen *et al*. 2008, Van Waerebeek *et al*. 2007, Slooten *et al*. 2013, Felix *et al*. 2017, Wang *et al*. 2017) and used the criteria and case definitions for serious injury and death of cetaceans from anthropogenic trauma as defined by Moore *et al*. (2013). An anthropogenic origin was considered 'highly likely' when at least two body conditions fitted the criteria for entanglement, vessel strike or other human-related interaction, and 'likely' when at least one body condition fitted those criteria. A subset of 73 dolphins with Q 3-4 images, *i.e*., close and focused enough to allow the detection of the characteristic stippled pattern of tattoo skin disease (TSD; Geraci *et al*. 1979; Van Bressem *et al*. 1993, 2009) lesions, was also examined for cutaneous disorders. The greatest diameter of the skin lesions was estimated photogrammetrically on the comparative basis of a dorsal fin height of 253 mm for *L. albirostris* from the Northeast Atlantic (Bertulli *et al*. 2012). The lesions were classified as small (<15 mm), medium-sized (15-55 mm), large (56-115 mm), and very large (>115 mm) (Van Bressem *et al*. 2017). The persistence of some skin disorders and traumata could be evaluated in five dolphins with between-year recaptures (dolphin ID numbers: 2011-05, 2013-03, 2013-17, 2015-09, and 2015-20). Prevalence levels of conditions should be considered as minimum, as the entire body could not be examined. Confidence intervals (95%, CI) for proportions were computed exactly using the Wilson method (Brown *et al*. 2001).

During the present study abnormal body condition, tattoo skin disease, and traumata were observed in 67 dolphins, of which 18 had multiple external body conditions (Fig. 2). Insert Figure 2.

**1. Body condition**. Individual (2013-11) was underweight, as evidenced by rib protrusion. The body condition of the other dolphins was good.

**2. Skin disorders.** TSD, a disease caused by cetacean poxviruses (Bracht *et al*. 2006), was the main cutaneous condition observed during this study. Tattoo skin lesions ('tattoos') with a diagnostic stippled pattern were detected in 10 dolphins (Fig. 3). Lesions occurred on all parts of the body, ranging in size from small to large, numbered between one and 10+ and were sometimes superposed over tooth-rakes. A severe case, with tattoos covering *ca*. 10 % of the body, was seen in female 2013-17 on 7 August and again on 21 September 2013, demonstrating a minimum duration of clinical disease of 45 d without visible change in the size or number of tattoos during that period. Severe TSD has been reported in other odontocetes, free-ranging and captive, and may be associated with immune deficiencies (Van Bressem and Van Waerebeek 1996; Van Bressem *et al*. 2009, 2017). TSD affected 13.7% (CI 7.6% - 23.4%) of 73 *L. albirostris*. In comparison, TSD prevalence in harbor porpoises (*Phocoena phocoena*) and short-beaked common dolphins (*Delphinus delphis*) that died in 2004-2006 along the coasts of the UK following bycatch or other blunt traumas was 2.8% ($n$= 36) and 5.6% ($n$= 18), respectively (Van Bressem *et al*. 2009). Though prevalence of TSD in *L. albirostris* was apparently higher, this was not statistically significant ($Z$=1.78, $P$=0.075; and $Z$=0.949, $P$=0.34; respectively). Skin lesions reminiscent of TSD were also detected by visual assessment in six *L. albirostris* off the coasts of Iceland in 2004-2009 (Bertulli *et al*.

2012). Tattoo skin lesions should be examined by electron microscopy and molecular techniques to confirm the poxviral origin in stranded and bycaught *L. albirostris*.

**3. Traumata.** Sixty-six of the 86 dolphins (76.7%, CI 66.8%-84.1%) had at least one type of nonlethal injury in 2011-2015 (Table 1). Traumata of anthropogenic origin were considered likely in 13 (19.7%, CI 11.9%-30.8%) of the injured dolphins (Table 1). We distinguished three categories of traumata based on our own observations and the literature (Robbins and Mattila 2004, Van Waerebeek *et al*. 2007, Moore *et al*. 2013, Slooten *et al*. 2013, Bertulli *et al*. 2015, Felix *et al*. 2017, Wang *et al*. 2017).

*3.1 White marks*. White marks with regular or crater edges were seen in 53 of the 86 (61.6%, CI 51%-71.2%) dolphins photo-identified in 2011-2015 (Table 1). Insert Table 1. The marks seemed generally confluent with adjoining normal skin and occurred on the head, back, flanks, dorsal fin, flipper, and flukes and numbered between one and four (Fig. 4a, b). Their size ranged from small to very large, with large and very large marks observed in 25 of the 53 (47.2%, CI 34.4%-60.3%) dolphins. The more severe lesions appeared to deeply affect the dermis/hypodermis as evidence by blubber exposure. In four dolphins recaptured in 2013 (ID 2011-05 and 2013-17) and in 2016 (ID 2013-03, 2015-09 and 2015-20) the marks persisted for at least one to two years and likely were long-lasting scars (Fig. 4a,b). Insert Figure 4. In two other dolphins (2013-35 and 2013-16) the white marks represented lacerations and abrasions, respectively, with exposed blubber in individual 2013-35. Nine of the scarred dolphins had other injuries consistent with anthropogenic interactions, possibly the result of entanglement (Table 1). Cutaneous white marks resulting from entanglements in fishing gear, very similar to the marks observed during the present study, have been described in Taiwanese white dolphins (*Sousa chinensis taiwanensis*) (Slooten *et al*. 2013, Fig.4b), humpback whales (*Megaptera novaeangliae*) in the Gulf of Maine (Robbins and Mattila 2004, Fig 3d) and in

North Atlantic right whales (*Eubalaena glacialis*) (Moore *et al*. 2013, Fig. 19). The origin of the white marks in the other *L. albirostris* is unclear but contact with sharp underwater objects such as rocks is a possibility (Greenwood *et al*. 1974, Baker 1992).

*3.2. Non-linear incisive injuries*. Injuries including amputation, cuts, nicks, and notches were seen in 14 of 86 (16.3%, CI 10%-25.5%) dolphins (Table 1, Fig. 5a,b,c). They affected the dorsal fin (*n*= 8), back and tailstock (*n*= 7) and pectoral fins (*n*= 1). An anthropogenic origin was deemed likely in eight (57.1%) of the injured dolphins (Table 1, Fig. 5a,b). Two cases were remarkable: *ca*. 40% of the dorsal fin of individual 2015-23 sighted on 19 September 2015 had been severed but healed (Fig. 5a), possibly following forceful contact with fishing gear or a boat propeller. A large, transverse, healing wound was present on the back behind the dorsal fin of dolphin 2015-30 filmed on 4 October 2015. This individual also presented kyphoscoliosis, a combination of vertical and lateral curvature of the vertebral column, at the level of the lumbar-caudal region just behind the wound (Fig. 5b). Insert Figure 5. Interestingly, a similar case was described in a juvenile male *L. albirostris* stranded in Bridlington, England, in 1995 (Bertulli *et al*. 2015, Fig. 2). In this individual there was a clear association between a chronic wound caudal to the dorsal fin, kyphoscoliosis and osteomyelitis. Anthropogenic interaction was deemed the most likely origin, as the flukes of this dolphin had also been partially severed (Bertulli *et al*. 2015). Another juvenile male stranded on Terschelling, The Netherlands, in January 1999, also presented a wound behind the dorsal fin together with deformation of the vertebral column and skin marks and lacerations suggestive of a fishery interaction (Bertulli *et al*. 2015). As deep oblique incisive wounds on the back of small cetaceans are often of anthropogenic origin (Visser 1999, Van Waerebeek *et al*. 2007, Dwyer *et al*. 2014), it seems likely that the injury and kyphoscoliosis seen in 2015-30 also resulted from a vessel strike or from entanglement in fishing gear, though we cannot exclude that the vertebral deformation was congenital.

In the remaining six dolphins the injuries were of indeterminate origin though a violent interaction with a seal was suspected in one case. A five-digit scratch mark evoking claw lesions was present on the anterior body of dolphin 2015-40 in October 2015 (Fig. 5c). The spaces between the marks measured between 1 and 1.5 cm, matching the inter-digital spacing of juvenile gray seals (*Halichoerus gryphus*) (1.4 ± 0.14 SD cm; Lockyer and Morris 1985). Gray seals are abundant in the *L. albirostris* home range off Northumberland and antagonistic interactions may occur during feeding activities.

*3.2. Linear mark***s.** Marks including linear impressions[1], lacerations and scars were seen in 17 (19.8 %, CI 12.7%-29.4%) of 86 dolphins, occurring on the back, flanks and flippers (Fig. 1b). According to the criteria and case definitions defined by Moore *et al*. (2013) these marks were likely the result of nonlethal net entanglement in seven of the 17 cases (41.2%) (Table 1). All seven individuals had also other traumata likely from accidents with fishing gear (Table 1). In dolphin 2013-16 the linear lacerations may have occurred shortly before it was filmed on 7 August 2013. There are two seasonal gillnet fisheries operating in Northumberland waters targeting salmon (*Salmo salar*) and sea trout (*Salmo trutta*); beach nets between 26 March to 31 August and driftnets between 1 June to 31 August (Browne 2010). Anecdotal information from interviews with fishermen using these nets indicate that interactions occur between dolphins and the gillnets and further that dolphins break through the nets rather than get caught (P. Berggren, unpubl. data). Such nonlethal encounters could explain the linear lacerations observed in dolphin 2013-16. Linear impressions and scars were seen in nine additional dolphins but, though contact with fishing gear was deemed possibly

[1] A linear impression occurs when a line, net, or other form of debris leaves an indentation, but does not lacerate or abrade the skin (Moore *et al*. 2013)

causative in three of them, this could not be ascertained. Linear impressions and lacerations of likely anthropogenic origin have also been reported in three *L. albirostris* free-ranging in Faxaflói Bay, Iceland, in 2007-2009 (Bertulli *et al*. 2012).

Our study indicates that a high proportion (76.7%) of the 86 *L. albirostris* photographed off the coast of Northumberland in 2011-2015 had some kind of nonlethal injuries. Fisheries related activities and vessel strikes may have been the causative agents in 19.7% of the 66 injured specimens, or 15.1% of the 86 dolphins examined in this study. The Farnes Deep area has been heavily fished by trawl fisheries targeting langoustine (*Nephrops norvegicus*) (Baily *et al*. 2012). Pelagic trawler operations in the North Sea are thought to lead to substantial mortalities among several Delphinidae species, including *L. albirostris*, in the English Channel and the Celtic Shelf (Kaschner 2003). However, no quantitative assessments of bycatch rate have been made for the North Sea and the impact on *L. albirostris* remains unknown (Galatius and Kinze 2016). Bycatch led to the death of four of nine *L. albirostris* stranded along the coasts of the UK in 1990-1995 (Kirkwood *et al*. 1997) and of two of 11 *L. albirostris* found dead along the coasts of Denmark in 2008-2014 (Alstrup *et al*. 2016). Further, two additional *L. albirostris* stranded in the UK in 1990-1995 showed physical traumata not inconsistent with bycatch (Kirkwood *et al*. 1997). Though interactions with fishing gear are not always lethal, the inflicted external injuries may affect fitness, longevity and reproduction (Wells *et al*. 2008). Nonlethal injuries of anthropogenic origin are increasingly reported in small cetaceans worldwide and are considered a threat to the survival of endangered species and populations (Berggren *et al.* 2002, Van Waerebeek *et al*. 2007, Bertulli *et al*. 2012, Luksemburg *et al*. 2014, Slooten *et al*. 2013, Wang *et al*. 2017, Felix *et al*. 2017). The high prevalence of such injuries in *L. albirostris* from Northumberland is of concern from a health and welfare perspective.

High-definition underwater photography provided a useful non-invasive tool to investigate the body condition, skin disorders, and traumata affecting *L. albirostris* off Northumberland. Tattoo skin disease and traumata could be positively recognized and, in some individuals, followed over months and years. Continued health monitoring of *L. albirostris* in the North Sea should provide important information on the progress and potential consequences of skin diseases and a variety of injuries, including those generated by human activities. This technique could also contribute to general health assessments in other odontocete species worldwide.

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**Figure captions**

Figure 1. Map of the Farnes Deep area, Northumberland, UK, where images were collected to test underwater photography as a non-invasive tool for health surveillance of white-beaked dolphins (*Lagenorhynchus albirostris*).

Figure 2. Multiple body conditions in dolphin 2013-33 observed in September 2013: (A) right side: tattoo skin disease (symmetric, black arrows), a large white cutaneous mark (narrow, black arrow) on back and incisive injuries (gray arrows) on the dorsal fin; (B) linear impressions on the back and neck (double, black arrow) and a white mark on back (narrow, black arrow).

Figure 3. Typical tattoo skin lesions (arrows) on the back of dolphin 2015-08 in July 2015.

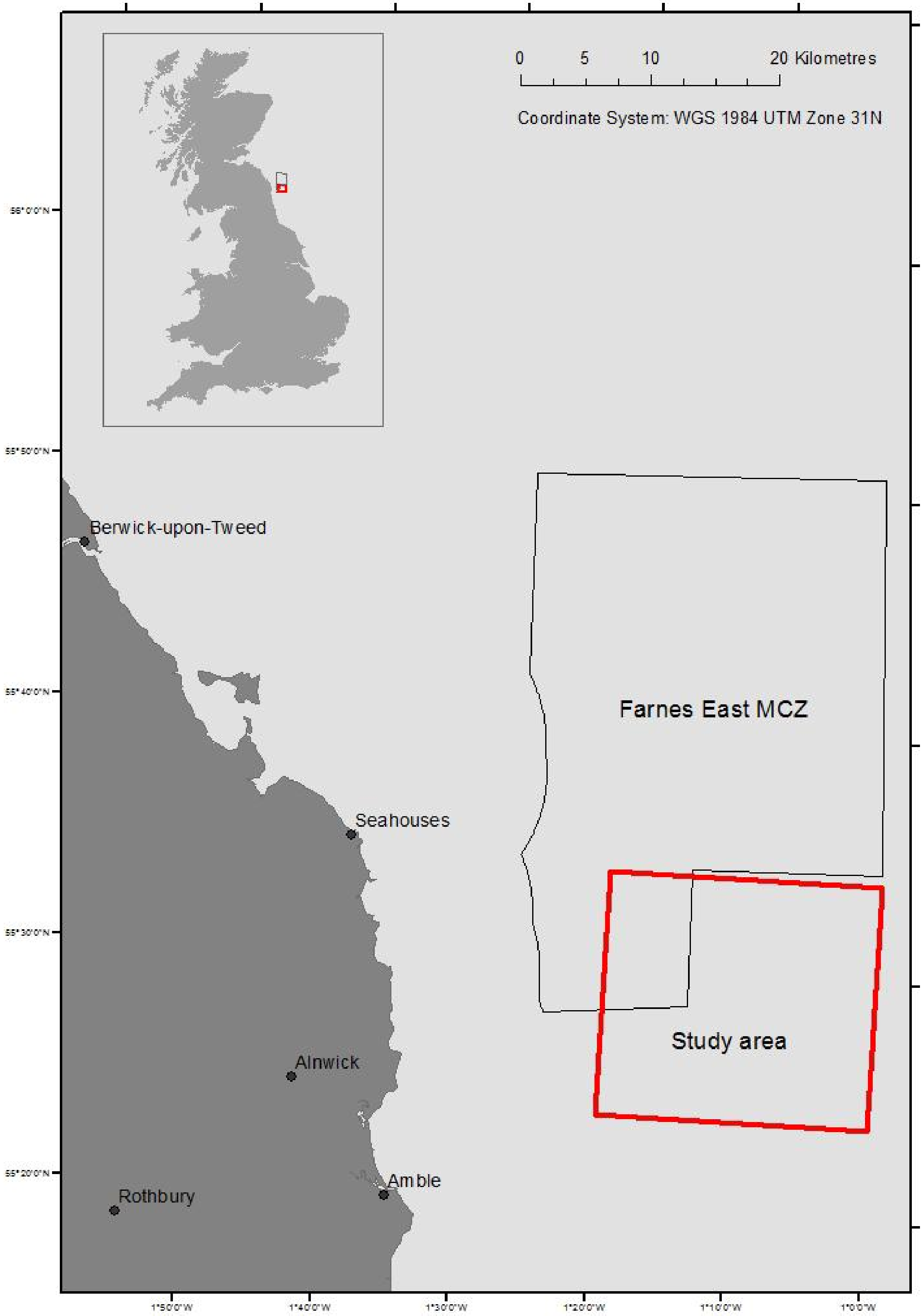
Figure 4. Very large white mark in dolphin 2011-05 in July 2011 (A) and in July 2013 (B).

Figure 5. Non-linear incisive injuries: (A) partial amputation of the dorsal fin (white arrow) of dolphin 2015-23, September 2015; (B) large, healing wound on the back (narrow, white arrow) of individual 2015-30 together with kyphoscoliosis (white arrow), October 2015; (C) possible seal claw lesions (double arrow) in dolphin 2015-40, October 2015.

**Table 1: Injuries from anthropogenic interactions in white-beaked dolphins (*Lagenorhynchus albirostris*) off the coast of Northumberland in 2011-2016. Abbreviations are: DF = dorsal fin, R = right, L = left. An anthropogenic origin was considered "highly likely" when at least two body conditions fitted the criteria for entanglement, vessel strike or other anthropogenic interaction, and "likely" when at least one body condition fitted those criteria.**

| ID code | Date of sighting | | White scars | Non-linear incisive injuries | Linear marks | Anthropogenic origin | Suggested cause |
|---|---|---|---|---|---|---|---|
| | month | year | description | description | description | | |
| 2011-02 | Jul | 2011 | 1 medium-sized, oval scar at the basis of DF | 1 deep nick on DF trailing edge | 3 parallel, wide lacerations on R.flank | Highly likely | fisheries |
| 2013-01 | Jul | 2013 | 1 large scar on tailstock | Minor round nick in DF trailing edge | 3 linear, curved impressions on R.flank | Likely | fisheries |
| 2013-16 | Aug | 2013 | 1 medium abrasion (white) on DF leading edge | None | 2 linear, parallel lacerations on R.flank | Likely | fisheries |
| 2013-22 | Aug | 2013 | 2 small & medium scars on DF | Medium notch in DF (trailing edge base); small notch in tailstock | None | Likely | fisheries |
| 2013-26 | Aug | 2013 | None | 2 notches on back behind DF | Healed linear cuts on flank | Likely | fisheries |
| 2013-29 | Sept & Oct | 2013 | 1 small laceration on trailing edge of DF | 2 small nicks in tailstock (dorsally) | None | Likely | fisheries |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2013-33 | Aug & Sept | 2013 | 1 large oval scar behind DF | 2 fresh cuts on DF leading edge, notches in back | 2 long, parallel linear impressions on neck | Highly likely | fisheries |
| 2013-35 | Sept | 2013 | 1 large laceration on leading edge of DF | 3 small cuts on L.pectoral | None | Highly likely | fisheries, visible in September, not yet in August 2013 |
| 2015-02 | Jul | 2015 | 1 large scar on DF | Notch in tailstock | Long linear impression on R.flank | Likely | fisheries |
| 2015-09 | Aug Sept | 2015, 2016 | 3 large and very large scars on R.flank, tailstock and DF tip | None | None | Likely | indeterminate |
| 2015-23 | Sept | 2015 | 1 oval, medium-sized scar on top of severed DF | Severed DF, 40% missing (healed) | None | Highly likely | fisheries |
| 2015-28 | Sept | 2015 | 1 medium scar on flukes | Deep cut on leading edge of R. fluke; 1 cut in tailstock | Several linear lacerations, 1 healing on L.flank | Highly likely | fisheries |
| 2015-30 | Sept & Oct | 2015 | None | Deep injury behind DF and kyphoscoliosis | None | Likely | indeterminate |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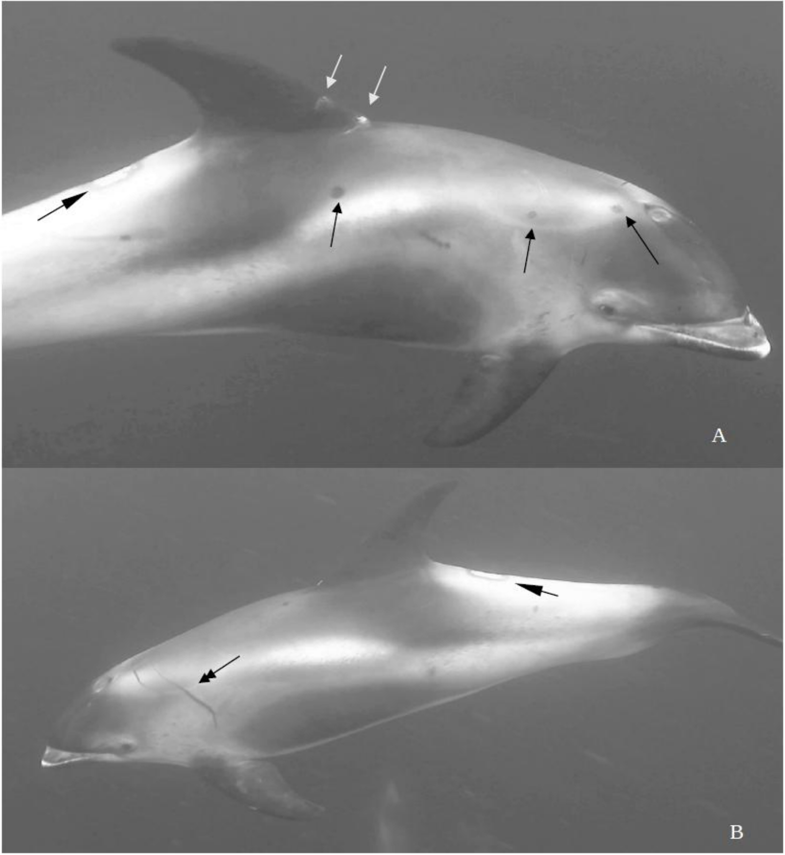
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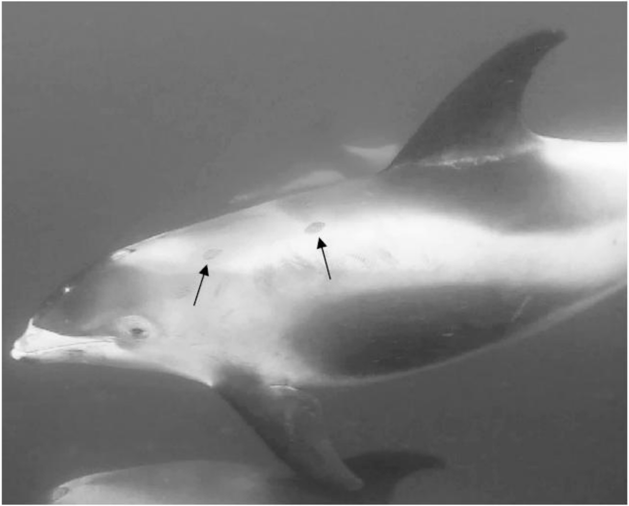


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