Blunt Trauma Observed in a Common Dolphin Delphinus sp. Likely Caused by a Vessel Collision in the Hauraki Gulf, New Zealand

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While coastal cetaceans can become habituated to watercraft, that may not prevent their injury or mortality as a consequence of vessel strike. Here we report a case of a likely collision between a Common Dolphin *Delphinus* sp. and a recreational vessel in the Hauraki Gulf, New Zealand. Injuries sustained by the immature male dolphin were fatal. Recovery and subsequent post-mortem of the carcass revealed a transection of the spinal cord, with the vertebral column sustaining fractures between L17 and Cd7 and between Cd3 and Cd8 of the neural and transverse processes, respectively. Cd4 likely received the brunt of the impact given the vertebral body and epiphyses were also fractured. Paralysis of the lower truck and associated extensive internal injuries resulted in a live stranding and subsequent mortality. Injuries sustained were consistent of those of blunt force trauma, a consequence of an impact caused by a collision with a small watercraft, most likely a jet-ski. This incident reinforces the need for continued public education concerning safe water practices around marine mammals, which are protected under the New Zealand *Marine Mammals Protection Act 1978* and *Marine Mammals Protection Regulations 1992*.

Key words: mortality, collision, blunt trauma, management, New Zealand

INTRODUCTION

VESSEL collisions have been documented as a major source of human-related injuries and deaths in many marine taxa, notably reptiles (e.g., Hazel and Gyuris 2006; Grant and Lewis 2010), sirenians (e.g., Lightsey *et al.* 2006), and cetaceans (e.g., Wells and Scott 1997; Campbell-Malone *et al.* 2008). Collisions between vessels and cetaceans are a growing concern worldwide (e.g., Laist *et al.* 2001), with over 18 species affected by this issue (Van Waerebeek *et al.* 2007). Approximately 30% of worldwide collision reports include small cetaceans, challenging the assumption that only whales are affected (Van Waerebeek *et al.* 2007). Injuries resulting from direct contact between a boat and an animal's body range from minor physical disfigurations to extensive trauma and/or mortality (Andersen *et al.* 2008).

Within New Zealand, vessel collisions have been reported in several cetacean species including: Hector's Dolphins *Cephalorhynchus hectori*; (Stone and Yoshinaga 2000); Bottlenose Dolphins *Tursiops truncatus*; (Lusseau *et al.* 2002); Killer Whales *Orcinus orca*; (Visser 1999); several species of beaked whales *Mesoplodon* sp., *Ziphius cavirostris*, *Berardius arnuxii*; (Dalebout *et al.* 2004; Van Waerebeek *et al.*, 2007), Sperm Whales *Physeter macrocephalus*; (Van Waerebeek *et al.*, 2007), and several species of baleen whales *Balaenoptera* sp., (Van Waerebeek *et al.* 2007), particularly Bryde's Whales *B. brydei*; (Behrens and Constantine 2008; Stockin *et al.*, 2008a). Like most regions, marine mammals in New Zealand appear to be particularly susceptible in busy waterways (Stone *et al.* 2000; Behrens and Constantine 2008; Stockin *et al.* 2008a).

The Hauraki Gulf, on the east coast of the North Island, comprises one of the busiest ports and shipping lanes in New Zealand, as it is the primary sea access to Auckland, the country's largest city with over 1.4 million inhabitants. Movements of commercial and recreational vessels within the gulf transit through the habitat of several cetacean species, including Common Dolphins (referred to as *Delphinus* sp. given taxonomic ambiguity of the species within NZ waters, see Stockin *et al.* in press). *Delphinus* occur year-round within Hauraki Gulf waters (Stockin *et al.* 2008b), using these waters to feed (Stockin *et al.* 2009a), and nurse their young (Schaffar-Delaney 2004; Stockin *et al.* 2008b).

Here, we report on the extensive trauma present in a Common Dolphin examined ante and post-mortem following a likely collision with a small motorcraft in the Hauraki Gulf. Describing both ante- and post-mortem observations, we highlight the nature of injuries likely to be sustained by marine mammals involved in boat strike incidences.

MATERIALS AND METHODS

Live stranding

On 13 February 2011, members of the public reported a dolphin in danger of live stranding at Toroa Point, Torbay, Auckland, New Zealand (36° 41' 46.65" S, 174° 45' 38.58" E; Fig. 1). This animal had earlier been observed swimming off the bay with other conspecifics, where jet-skis were reportedly operating (Watts, pers. comm., Department of Conservation). Rangers from both the Department of

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Conservation (DOC) and the Auckland Regional Council (ARC) first attended the scene and identified the species as a Common Dolphin (Fig. 2a). Initially the animal was observed exhaling regularly while floating motionless in the shallows (50 m from beach, < 1 m water depth). However, shortly after rangers entered the water to assist, the dolphin began to roll clockwise beyond normal equilibrium. While attempting to maintain an upright body position for the dolphin in order to keep the blow hole above water, approximately another four to five exhalations were witnessed prior to death. The last exhalation was recorded *c.* 10 min after rangers first entered the water to assist.

The carcass was kept in the water until a recovery vehicle was available for collection. The dolphin was then transported *c.* 15 min to Massey University, Auckland, where the carcass was refrigerated (4°C) until a subsequent necropsy was undertaken.

Necropsy protocol

On 14 February 2011, a necropsy was performed on the dolphin (identified as KS11-08Dd and locally referred to as "*Toroa*") using adapted standard necropsy protocols (Jefferson *et al.*, 1994). The procedure included recording external morphometric measurements (cm),

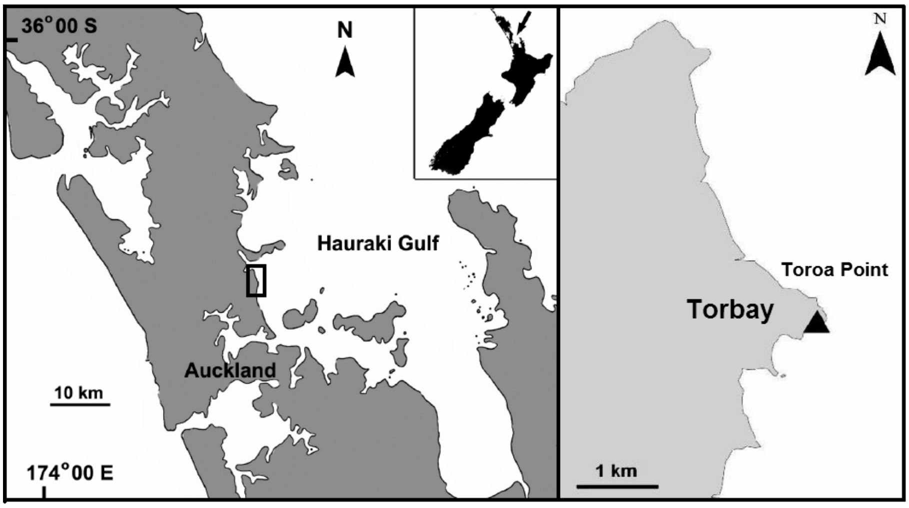

Fig. 1. Map showing the Hauraki Gulf, New Zealand and the location of the live stranding of a male Common Dolphin on 13/02/2011.

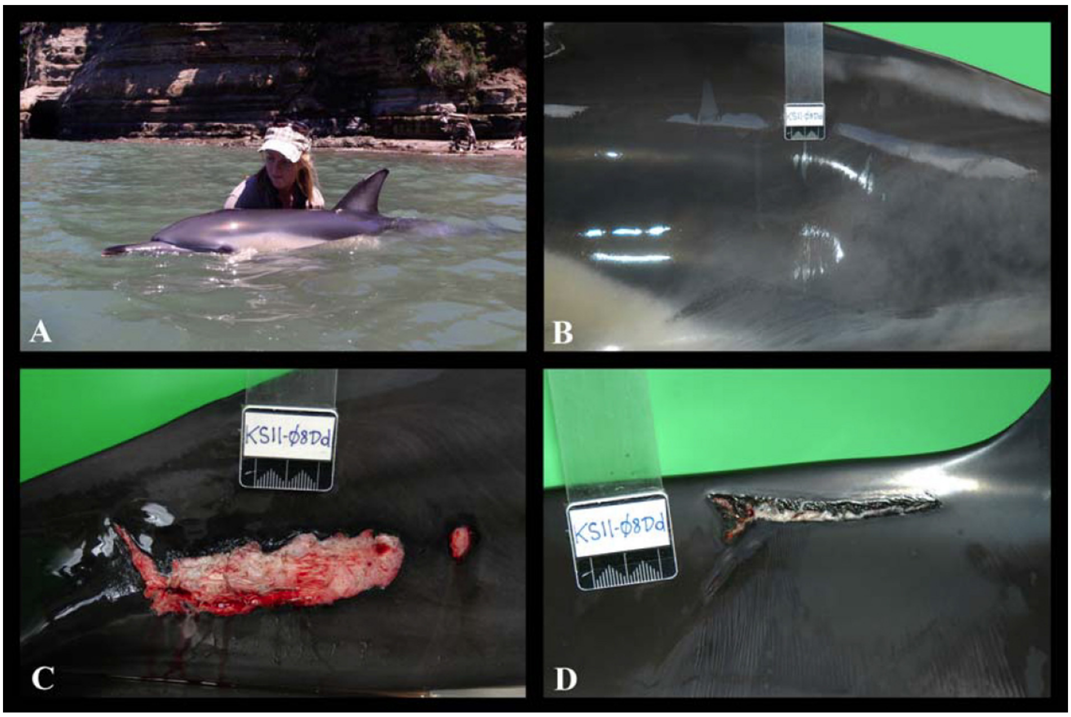

Fig. 2. A: DOC ranger Steph Watts attending fatally injured Common Dolphin KS11-08Dd ante-mortem. B: Concave indentation of the caudal left side of the body wall. C: Fresh linear wound along right side of the tail stock. D: Fresh linear wound on the right side caudal of the dorsal fin.

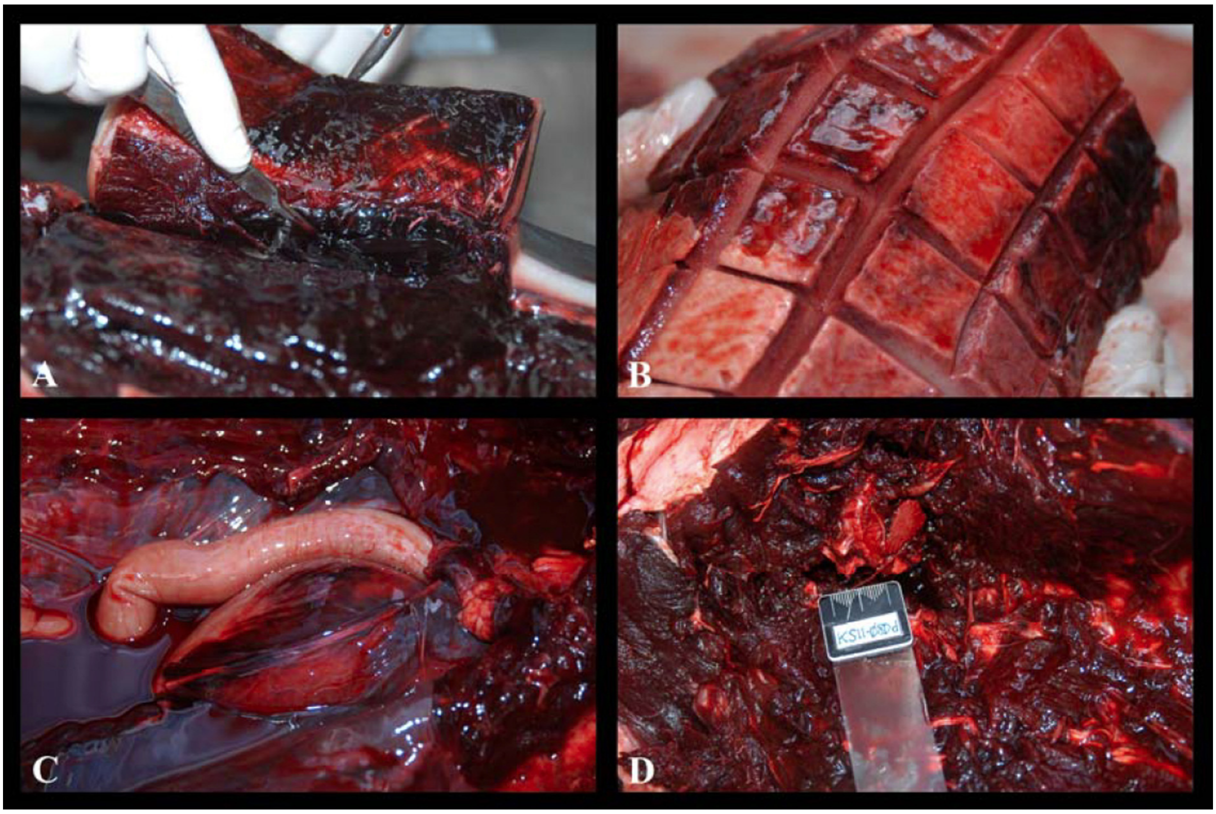

Fig. 3. A: Extensive trauma evident in the muscle and subcutaneous tissue of a male Common Dolphin KS11-08Dd. B: Extensive bruising of the blubber adjacent to indentation on the left flank. C: Severe bruising of the bladder wall. D: Fractured and dislodged caudal vertebra (Cd4) and associated epiphyses.

body weight (kg), and examination of the carcass for external lesions. Once the carcass was fully flensed, the subcutis was examined for evidence of trauma.

The internal organs were examined systematically and tissues sampled for histopathology, toxicology (blubber, muscle), and genetics (skin). The heart, liver, spleen and kidneys were weighed (g) and sampled. The testes and adrenals were carefully excized, measured (mm), weighed (g) and stored in 10% neutral buffered formalin for subsequent histopathology. The stomach was removed *in situ* and stored (frozen) until contents could later be examined. Gross lesions were photographed with a Nikon D70 camera with an 18–55 mm Nikkor lens. Teeth were counted and graded based on degree of wear and/or damage.

Finally, after the post-mortem the vertebral column, from the atlas bones to the caudal vertebrae, was retained and cleaned for subsequent analysis. Initially, excess flesh and soft tissues were hand removed using forceps and a knife prior to the remaining structures being submerged in horse *Equus caballus* manure. This process took approximately 12 weeks and required regular aeration and hydration of the manure to facilitate decomposition. On disinterment, the bones were coded and labelled before drying and bleaching. The bones were then subsequently ordered, evaluated and photographed.

The definitions of cervical, thoracic, lumbar and caudal vertebrae are equivocal in cetaceans, in particular for the caudal region (Rommel 1990). The delimitation of the different regions of the vertebral column was based on De Smet (1977) criteria to facilitate comparisons with other Delphinids.

RESULTS

Ante-mortem observations

External injuries evident included a substantial concave indentation of the body wall on the left flank of the animal, a fresh superficial wound along the right side of the tail stock, and a further fresh injury just caudal of the dorsal fin, also on the right flank of the animal (Fig. 2b,c,d). The penis was extruded and had been from the first instant the animal was initially encountered.

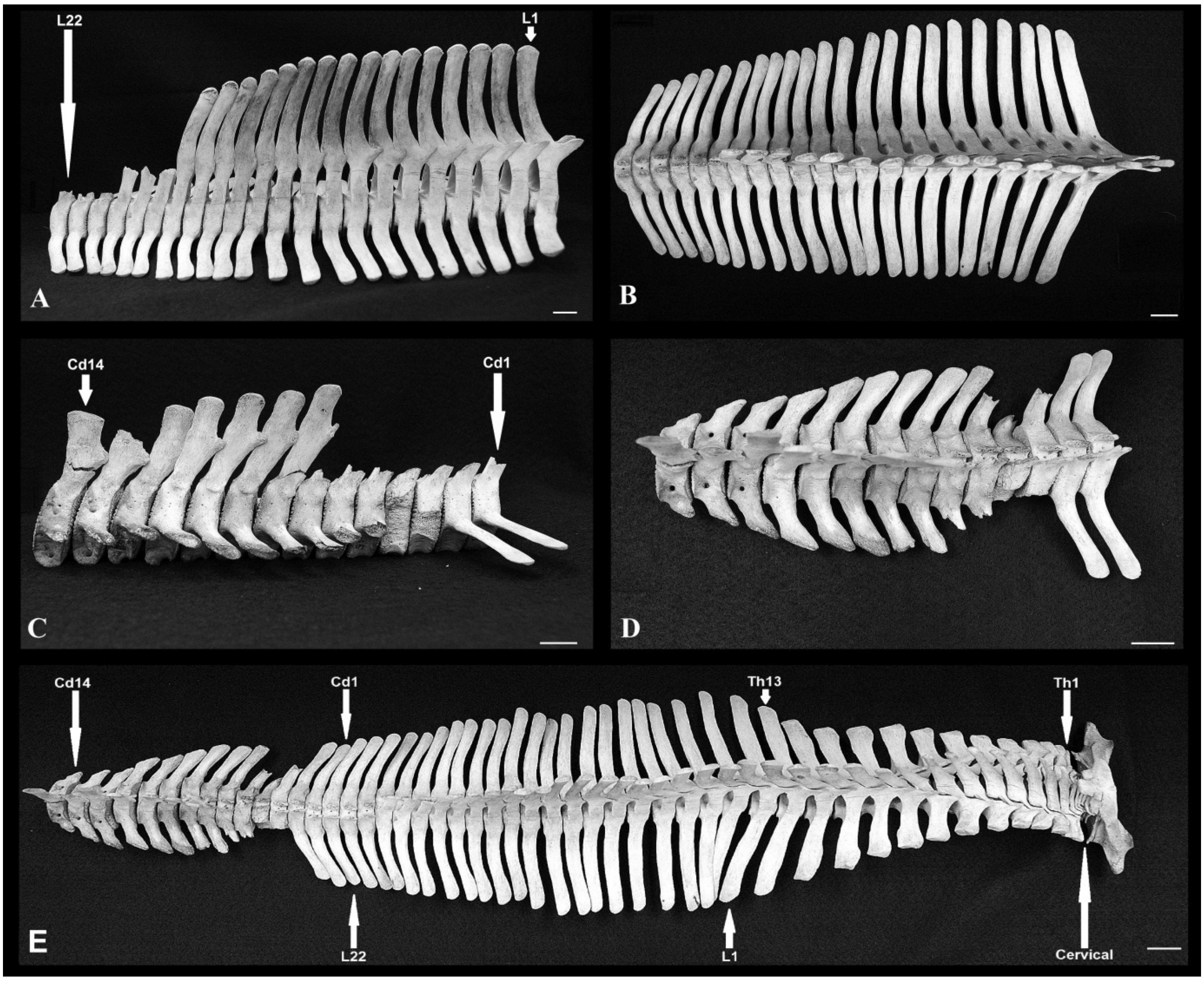

Fig. 4. A, B: Lumbar vertebrae (L1 to L22) of a male Common Dolphin KS11-08Dd. Note the fractures of the neural processes of L17 to L22. A: Right lateral view. B: Dorsal view. C, D: Caudal vertebrae (Cd1 to Cd14). Note the fractures of the neural processes from Cd1 to Cd7 and Cd13, fracture lines on Cd8 and Cd14. The transverse processes of Cd3 to Cd8 were also fractured. C: Right lateral view. D: Dorsal view. E: Dorsal view of the vertebral column from the cervical vertebrae to Cd14. All scale bars = 2 cm.

Post-mortem examination

Initial findings of the necropsy revealed that the male Common Dolphin weighed 71.0 kg and was 176.0 cm long, with an auxiliary girth measurement of 103.5 cm. The animal was in good body condition, with a recorded mean blubber thickness of 1.3 cm.

Body morphometrics and dentition fit the profile of a sub-adult, with all teeth fully erupted and little dentine wear evident. Examination of the reproductive tract indicated that this male was sexually immature, with no obvious testicular development. However, a vestigial post-anal hump or keel further suggested that this individual may have been at the onset of pubescence. Male Common Dolphins in New Zealand waters attain sexual maturity at an average length of 197.5 cm (Stockin *et al.* 2011).

Upon external examination, a substantial concave indentation of the body wall running perpendicular to the spine, just dorsum of the post-anal hump was clearly visible (Fig. 2b). Furthermore, along the lower right flank, just cranial of the tail stock, a fresh superficial linear laceration (9.7 × 2.1 cm) was detected (Fig. 2c), with a further fresh (7.2 × 0.8 cm) injury evident just caudal of the dorsal fin (Fig. 2d). In addition to an extruded penis, extensor rigidity of the pectoral flippers was also noted. Upon flensing, extensive internal trauma extending over subcutaneous tissue and the muscle beneath the blubber was also evident along the left caudal section of the body (Fig. 3a), with prolific bruising evident throughout the adjoining blubber (Fig. 3b). These findings support a live impact injury, concurring with the visible external trauma and observations of the animal ante-mortem.

Stomach contents revealed the dolphin was weaned, with a digested fraction of hard parts (primarily otoliths, eye lenses and miscellaneous bones) present in all three chambers of the stomach. Faeces were also evident in the intestine and anus, further supporting recent feeding activity. At gross examination, all organs,

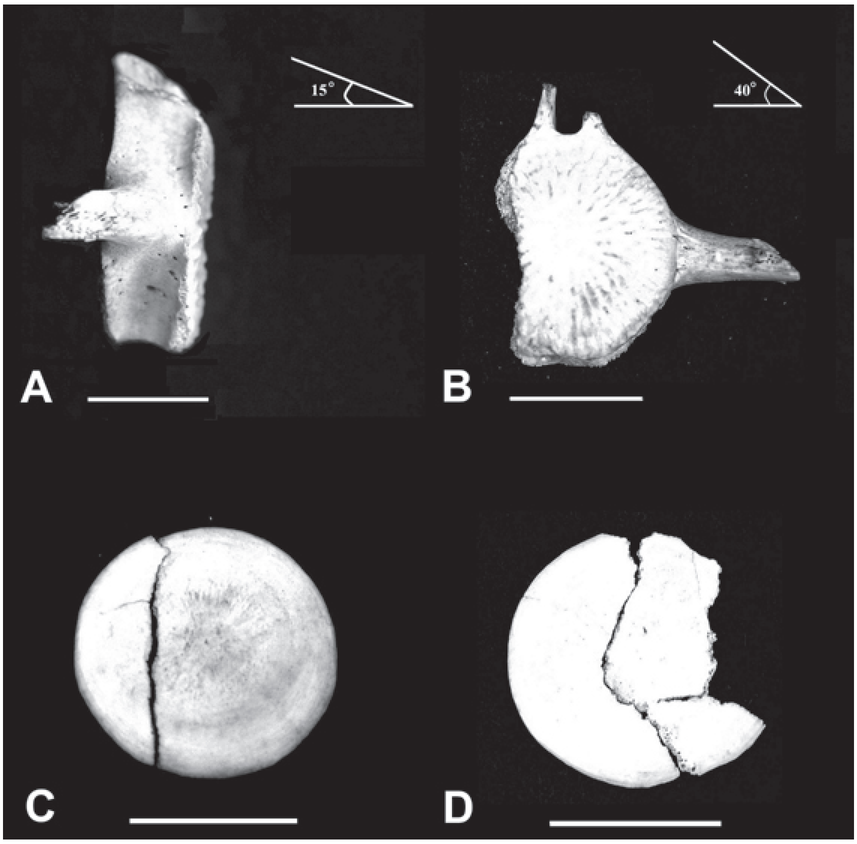

Fig. 5. Isolated caudal vertebra (Cd4) and associated epiphyses of a male Common Dolphin, KS11-08Dd. A: Ventral view showing fractures of the neural process, the left transversal process and vertebral body. B: Lateral view of Cd4. C and D: Cranial and caudal epiphyses with communited fractures, respectively. All scale bars = 2 cm.

glands and lymph nodes were unremarkable except for severe haemorrhage in the bladder wall (Fig. 3c), a likely consequence of acute blunt force. On dissection, additional bleeding was also evident within the bladder itself. Further evidence of extreme force was given by the complete fracture and displacement of the caudal vertebrae and epiphyses (Fig. 3d).

Subsequent examination of the vertebral column, post-flensing and cleaning, indicated oblique fractures of the neural processes on six lumbar (L17 to L22) and eight caudal (Cd1 to Cd7, Cd13; Fig. 4a,c) vertebrae. Fractures were primarily located at the level of the laminae or vertebral foramen (L18 to Cd8; Figs 4a,c,e), which protects the *medulla spinalis* (spinal cord). Simple fractures on the spinous processes of Cd8 and Cd14 were also apparent (Fig. 4c). In addition, the transverse processes of six caudal vertebrae (Cd3 to Cd8) sustained oblique fractures (Figs. 4d) both sides from Cd3 to Cd5 and on the right side only for the remaining three vertebrae. A closer inspection of the processes revealed that oblique fractures of the laminae on the left flank of the animal were closer to the vertebral body than those of the right flank and at 15° angle (Fig. 6a). Inversely, similar fractures on the transverse processes were in closer proximity to the vertebral body on the right flank (Fig. 4d). Furthermore, on Cd3 to Cd5 there was a 40° alignment between the fractures of the laminae and the transverse process when observed on a ventral view (Fig. 5b). The extent of the damage in this region is likely associated with the concave indentation previously described (Fig. 2b), which is consistent with blunt force trauma. None of the seven cervical and 13 thoracic vertebrae were affected (Fig. 4e).

Cd4 exhibited the most damage as a result of the probable blunt force sustained by the animal, with a longitudinal and oblique fracture of the vertebral body and dorsal/transverse processes, respectively, as well as a communited (i.e., bone is splintered or crushed into multiple pieces) fracture of the intervertebral discs (Fig. 5c,d). Excessive blunt force also likely contributed to a fracture-dislocation of the caudal spine at the level of Cd4. As a consequence, the animal sustained a transection of the spinal cord (Fig. 3d), which led to damage to the dorsal and ventral branches of the spinal nerve and nerve roots. Extensor rigidity of the pectoral flippers and the protruding penis suggests that there was likely spinal damage in the cervical area and/or at the brachial plexus level.

DISCUSSION

In New Zealand, like in the rest of the world, motorcraft have been reported to affect delphinids physically (e.g., Visser 1999; Stone and Yoshinaga 2000; Lusseau *et al.* 2002) and behaviourally (e.g., Lusseau 2003; Constantine *et al.* 2004; Stockin *et al.* 2008c; Markowitz *et al.* 2009; Martinez *et al.* 2011). There is growing concern regarding vessel-collisions, with *c*. 30% of all reported cases globally involving small cetaceans (Van Waerebeek *et al.* 2007).

Collisions between cetaceans and boats can result in mortality from blunt trauma or severe propeller wounds (Andersen *et al.* 2008). Such incidents can be identified by prominent external parallel lacerations caused by propellers or blunt force impact. External characteristics of the latter can include massive bruising and deformities, which might not immediately be detected on physical examination (Laist *et al.* 2001). Internal blunt force trauma injuries, which are usually concealed, comprise but are not limited to, haemorrhaging, oedema, organ damage, and often, a concomitant ante-mortem fracture or displacement of skeletal elements (Lightsey *et al.* 2006; Andersen *et al.* 2008; Campbell-Malone *et al.* 2008). Andersen *et al.* (2008) developed an approach for differentiating between serious and non-serious injury in marine mammals and identified body trauma, in particular detectable fractures, as one of the serious injuries criteria.

Using the descriptions presented in Andersen *et al.* (2008), the Common Dolphin examined herein, suffered from acute serious injuries caused by blunt force trauma, including transection of the spinal cord and contusions. In Humans (*Homo sapiens sapiens*), pure dislocation is common in the cervical spine but rarely occurs in the lumbar spine given the amount of flexion necessary to disengage the large articular processes (Holdsworth 1963). Furthermore, as expected, human patients who sustained vertebral fractures and concurrent abdominal injury were more severely injured than those without abdominal injury (Rabinovici *et al.* 1999). This possibly reflects the increased force necessary to produce multiple injuries, given that the majority of such patients were involved in a motor vehicle collision.

In Common Dolphins, the lumbo-caudal region of the vertebral spine has a higher intervertebral joint stiffness compared with other parts of the column (Long *et al.*,1997) and is subject only to minor shear and torsion (Boszczyk *et al.* 2001). This region appears to function as a rigid base of support for the muscles for propulsion through sagittal strokes of the fluke (Long *et al.* 1997; Buchholtz and Schur 2004). In cetaceans, rotational movement of the vertebral spine is minimal (Buchholtz and Schur 2004). This indicates that an excessive amount of force must have, therefore, been applied to generate the extent of musculoskeletal and deep subdermal trauma observed in this particular Common Dolphin, including a completely severed caudal vertebra (Cd4) and fractures of spinous and/or transverse processes on 14 vertebrae.

Vessel size and speed are generally considered key determinants of the risk of collision and the severity of injuries sustained (see Laist *et al.* 2001; Vanderlaan and Taggart 2007; Andersen *et al.* 2008). Studies on whales have indicated that as speed increases, cetaceans are less likely to be detected (e.g., Best 1982) and consequently, the probability of a collision causing fatal or serious injury rises (e.g., Laist *et al.* 2001; Jensen and Silber 2003). At speeds exceeding 15 knots, chances of a lethal injury for whales increase asymptotically toward 100% (Vanderlaan and Taggart 2007). However, other variables such as cetacean species, age, size, mass, behaviour as well as vessel type, size, and angle of impact, are likely to affect those estimates. Nonetheless, vessel speed is regarded as a reasonable predictor of lethality (Laist *et al.* 2001; Vanderlaan and Taggart 2007). Given the extent of fatal internal injuries sustained and the absence of propeller marks on the carcass, it appears this individual was hit at a speed exceeding the recommended five knots (or no wake speed) under the *Marine Mammal Protection Regulations* (1992) and likely above 15 kts with the hull of the vessel.

Almost all types of vessel are known to be involved in collisions with cetaceans (e.g., Ritter 2009). This includes jet-skis (e.g., Chantrapornsyl and Andersen 1995; Beck 2011), which, if not handled with caution, can present a threat to cetaceans. In the case reported herein, circumstantial evidence points toward one of the jet-skis present at the scene (Watts, pers. comm.). Jet-skis with their high manoeuvrability and speed in conjunction with quieter underwater acoustics, are a vessel type more difficult to detect and avoid for cetaceans.

In Florida, Wells and Scott (1997) reported a seasonal occurrence of vessel-collisions on Bottlenose Dolphins, which were also positively correlated with periods of higher-than normal boating activity. The authors suggested several possible reasons as to why some animals were more likely to be struck: a) the conditions and/or age of the dolphins; b) a seasonal shift in the distribution of the animals; and c) an increase in boat traffic during summer holidays. All three reasons proposed by Wells and Scott (1997) may be applicable here.

Data from vessel collisions suggest that most dolphins are either immature animals (calves to juveniles) or mothers with neonates (e.g., Wells and Scott 1997; Stone and Yoshinaga 2000; Laist *et al.* 2001; Lusseau *et al.* 2002). Younger animals tend to be more vulnerable to collisions for several reasons: a) they are slower swimmers; b) they have limited diving capabilities; c) they spend more time at the surface and in shallower waters; and d) they are more inquisitive and less cautious of vessels (e.g., Constantine 2001; Laist *et al.* 2001). The latter reason is the most plausible in this case because the male Common Dolphin was considered immature. Play is important in many young developing mammals to help learn social and behavioural skills (Pagel and Harvey 1993). Play activity can involve a novel object such as a boat.

Within Hauraki Gulf waters, Common Dolphins are observed year-round (Stockin *et al.* 2008b). However, occurrence is affected by month, latitude and depth, with peak sightings reported around February (Stockin *et al.* 2008b). Furthermore, during the austral summer, between December and February, Common Dolphins are recorded more typically in shallower waters (Stockin *et al.* 2008b). This is consistent with other observations around New Zealand, where *Delphinus* move inshore during what appears to be the main reproductive season (Bräger and Schneider 1998; Neumann 2001).

Most collisions reported worldwide occur on the continental shelf or shelf slope, reflecting high usage by both vessels and cetaceans (Laist *et al.* 2001). This is particularly true for busy vessel routes or areas with a high concentration of vessels in a shallow and confined area. The Hauraki Gulf, which is adjacent to Auckland, the largest city in New Zealand (Statistics New Zealand 2012), has three major shipping channels. In addition to commercial ships, marine traffic in the region consists of a wide variety of vessels from both commercial and recreational fishing vessels to ferries, cruise liners, tour boats, motorboats, yachts and kayaks. Auckland is popularly known as the "City of Sails" with more vessels per capita than any other city in the world, with *ca.* one in three Auckland households owning a boat (NZ Herald 2010). During weekends and public holidays, there is a marked increase in vessel traffic, in particular sailing vessels, personal watercrafts (including jet-skis) and recreational fishing boats (Stockin *et al.* 2008c). It is not surprising, therefore, that vessel collisions with cetacean species using those waters occur. Free-ranging Common Dolphins (Massey University, unpublished data) and Bryde's Whales (Wiseman 2008; Behrens and Constantine 2008) exhibit scars likely caused by propellers. Furthermore, the Hauraki Gulf has been identified as a high-risk collision area for Bryde's whales (Behrens and Constantine 2008; Stockin *et al.* 2008a; Wiseman 2008).

The incident reported herein occurred in February, during the austral summer, when recreational boat activity in the Hauraki Gulf can be at its busiest. It is also plausible that ambient ocean noise could have masked the noise of the approaching vessel. Furthermore, given that the gulf is an area of high vessel traffic, this incident could have further been exacerbated by the possibility of tolerance or habituation to vessel traffic and/or noise, an issue highlighted in other species (Richardson *et al.* 1995; Nowacek *et al.* 2007, Bejder *et al.* 2009).

The frequency of vessel-collisions on this population is difficult to ascertain because the paucity of accurate vessel strike data. Incidents can go unrecorded as carcasses sink, wash out to sea, or wash up in remote locations (Behrens and Constantine 2008; Williams *et al.* 2011). Nonetheless, collisions between vessels and cetaceans can be expected to increase in the future, in line with Auckland's growing population.

The incident reported herein highlights potential ignorance by the New Zealand public to current legislation and, therefore, the need to improve education for boaters on how to behave and handle their vessel in the vicinity of cetaceans. Marine mammals in New Zealand waters are legally protected under both the *Marine Mammal Protection Act* (1978) and the *Marine Mammal Protection Regulations* (1992). Although this statutory framework mainly applies for commercial whale- and dolphin-watching activities, they also apply to any incidental recreational interaction. Under the regulations, vessels must avoid rapid changes in both speed and direction (regulation 18e) and not exceed speeds faster than the slowest mammal within a vicinity of 300m (regulation 18m). Education of the boating public has been emphasized as a preventive measure for vessel-collisions (Visser 1999). This is particularly recommended for vessel speed, an important factor in vessel-collisions (e.g., Laist and Shaw 2006).

In summary, the risk of collision is inherent in this population. However, compliance with the current legislation appears to be the best approach to reducing incidents, particularly during austral summer months when boat traffic peaks. Finally, despite the laborious process, the extraction and preparation of vertebral columns has clear merit when examining for visible evidence of vessel collision. This is especially pertinent is cases were external injuries are less indicative of blunt force trauma.

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