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SHORT COMMUNICATION

Short-term survival of severe propeller strike injuries and observations on wound progression in a bottlenose dolphin

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Until recently, vessel collisions with small cetaceans were presumed rare, mainly as a consequence of limited reporting. Observations on dolphin wound healing from propeller strike injuries also remain scarce. We present an extreme case of a bottlenose dolphin (*Tursiops truncatus*) with multiple propeller wounds, including a penetration to the bone, where survival was possible for at least 23 days post injury. We used photographic records in conjunction with field observations to describe wound progression in the absence of treatment. Considering the severity of the wounds, it was surprising that the injuries were not immediately fatal. A practical solution remains to be found for the problem of odontocete vessel collisions, in particular for small highly mobile species using neritic waters. In view of the ongoing problem in the Hauraki Gulf and, indeed, worldwide, we recommend continued evaluation of cases and reporting of incidents, in addition to investigations into mechanisms that may reduce the risk of occurrence of vessel collisions with cetaceans.

Keywords: vessel collision; propeller strike; bottlenose dolphin; *Tursiops truncatus*; New Zealand

Introduction

Vessel collisions with marine mammals manifest in the form of blunt trauma and/or propeller strike injuries (Andersen et al. 2007; Calleson & Frohlich 2007; Van Waerebeek et al. 2007; Byard et al. 2012), with the latter typically characterised by curvilinear parallel incised wounds and lacerations (Byard et al. 2012, 2013). Until recently, such vessel collisions with small cetaceans were presumed rare, mainly as a consequence of limited reporting and monitoring worldwide (Van Waerebeek et al. 2007). Observations on dolphin wound healing from propeller strike injuries also remain scarce (Bloom & Jager 1994; Elwen & Leeney 2010).

The documentation of vessel collision injuries and fatalities in cetaceans is challenged by the difficulties in observing injuries in the first instance and subsequently monitoring recovery or recording fatality in these highly mobile animals. The frequency of injuries and fatalities is unknown for most cetacean species for a number of reasons. These include inconclusive or unconfirmed necropsy findings due to decomposed carcasses (Moore et al. 2013), fatally-struck carcasses that are simply not recovered (Dolman et al. 2006; Van Waerebeek et al. 2007), a lack of visible evidence of blunt trauma for cases where necropsy is not performed (Dolman et al. 2006; Moore et al. 2013) and an overall problem of under-reporting when probable or definite collisions are witnessed (Byard et al. 2013). Consequently, the shortage of adequately documented cases is the main obstacle in accurately assessing for vessel collision (Van Waerebeek et al. 2007), and the primary reason for this report.

In New Zealand, vessel collision and propeller strike have been reported for a number of large and small cetacean species (see Martinez & Stockin 2013). In bottlenose dolphins (*Tursiops truncatus*),

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propeller strike scars have been reported for individuals of the Fiordland population (Lusseau 2002; Currey 2008), including one calf that was not resighted following an observed collision (Lusseau 2002). The likelihood of survival from vessel collision injuries can be difficult to ascertain in bottlenose dolphins due to their notable ability to heal from extreme injuries (Zasloff 2011). When assessment of visible external injuries in the field is possible, it is typically difficult to track survivorship of an injured free-ranging individual over time.

Under the New Zealand Threat Classification System (Hitchmough et al. 2007), bottlenose dolphins are classified as Nationally Endangered owing to declines in abundance in two of the three local populations, alongside reports of high calf mortality (Baker et al. 2010). Given that neonates, calves and juveniles appear to be particularly vulnerable to vessel collisions (Stone & Yoshinaga 2000; Laist et al. 2001; Dolman et al. 2006), documentation of any threats to survival is important for these populations.

From previously published records it appears that injuries that penetrate deeply through the muscle, and certainly through the bone, are likely to be fatal (Stone & Yoshinaga 2000; Byard et al. 2012, 2013). We describe herein the most severe propeller strike injuries we are aware of that have been reported for a living free-ranging bottlenose dolphin. We use photographic records in conjunction with field observations to describe wound progression in the absence of treatment.

Methods

The study site included the west coast of Great Barrier Island and all Inner Hauraki Gulf waters south of a line between Takatu Point on the mainland east coast and Kaiiti Point on the Coromandel Peninsula. Boat-based surveys were conducted on the research vessel *Te Epiwhania*, a 5.5 m Stabicraft powered by a 100 hp four-stroke outboard engine. Survey data were collected during all months of the year between January 2010 and January 2013, with Inner Hauraki Gulf Surveys commencing in January 2010 and Great Barrier Island surveys commencing in January 2011.

Photo-identification of individual bottlenose dolphins was conducted for all groups encountered following standard methods (Würsig & Jefferson 1990) using a Canon 7D or 400D camera fitted with 100–400 mm and 70–300 mm lenses, respectively. Attempts were made to photograph all individuals in the group. Photographs included in analysis and in the subsequent Great Barrier Island Bottlenose Dolphin Catalogue (S. Dwyer, Massey University, unpubl. data) were selected based on four criteria described in Berghan et al. (2008), to account for angle, focus, relative size and contrast of the fin. All images were subject to a quality control procedure and were not included in analysis if more than two of the above criteria were compromised. Nicks and notches in the dorsal fin were used, in conjunction with secondary features (i.e. scarring, including tooth rake marks), to identify and match individuals (Würsig & Jefferson 1990). All matching of images was performed by the first author and cross-checked by two observers experienced in photo-identification. Sighting information was recorded in a database for each identified individual.

Results

Background

Individual TM007 was first recorded pre-trauma in the Hauraki Gulf on 17 May 2010 (Table 1). Based on size (approximately half the size of an adult bottlenose dolphin) and associated swimming in the infant position with adult TM009, TM007 was identified as a calf. This presumed mother-offspring association was recorded during four subsequent encounters at Great Barrier Island in 2011 and 2012. No external injuries or deformations were observed on TM007 during these encounters, the fourth of which was on 22 August 2012.

Injury observations

Observation day 1

On 19 September 2012, individual TM007 was photographed with one large open wound on the

Table 1 Sighting records with photographic evidence (✓) of bottlenose dolphins TM007 and TM009 pre- and post-trauma. Great Barrier Island is located approximately 50 km to the northeast of the Inner Hauraki Gulf and 170 km northwest of Tauranga.

TM007	TM009	Date	Location	Latitude	Longitude	Observer(s)
✓	✓	17/05/10	Inner Hauraki Gulf	−36.5094	174.9728	S Dwyer
✓	✓	24/10/11	Great Barrier Island	−36.2623	175.4337	S Dwyer
✓	✓	25/10/11	Great Barrier Island	−36.2628	175.4354	S Dwyer
✓	✓	18/02/12	Great Barrier Island	−36.1445	175.2959	S Dwyer
✓	✓	22/08/12	Great Barrier Island	−36.2526	175.4002	S Dwyer
✓	✓	19/09/12	Great Barrier Island	−36.2636	175.4330	L Kozmian-Ledward; S Dwyer
✓	✓	20/09/12	Great Barrier Island	−36.2621	175.4343	L Kozmian-Ledward; S Dwyer
✓	✓	10/10/12	Great Barrier Island	−36.3284	175.4764	B Kearney
✓	✓	11/10/12	Great Barrier Island	−36.3064	175.4862	S Dwyer
×	✓	01/01/13	Great Barrier Island	−36.1354	175.3103	S Dwyer
×	✓	27/02/13	Tauranga	−37.6085	176.1810	J Bradbury

caudal peduncle immediately caudal to the dorsal fin, and two smaller wounds along the midpoint of the peduncle and on the left tail fluke (Fig. 1). These three evenly spaced parallel wounds were consistent with propeller strike injuries (Byard et al. 2013). Additionally, evidence of blunt trauma in the form of bruising and swelling to the dorsal region of the thorax cranial to the dorsal fin was visible (Fig. 1A).

The largest incised wound (X2; Figs. 1–2) partially transected the caudal peduncle, and penetrated deeply through the skin, blubber, muscle and at least one spinal process of the lumbar vertebrae (Fig. 2A). The incised wound along the midpoint of the caudal peduncle (X3; Fig. 1) also penetrated the skin, blubber and muscle; however, it was not clear if damage was sustained to the caudal vertebrae due to difficulties in observing and photographing this wound. The laceration to the left tail fluke (X4; Fig. 1) was shallower than X2 and X3 and the fluke remained intact. A raised deformation of the dorsal region of the thorax just cranial to the dorsal fin (X1; Fig. 1) was evident and indicative of blunt force trauma. X2 was more deeply incised on the right side of the body (Fig. 2). No haemorrhage was evident from any of the wounds; however, the caudal open face of X2 appeared relatively fresh according to the clear demarcations of the respective layers of skin, blubber and muscle as well as the freshly peeling skin of normal dark grey colouration. The skin surrounding X2 and X3 was intact around the cranial aspects but was peeling away from the smooth blubber layer on the caudal margins and was completely absent in places. The cranial face of X2 was darker and showed an orange to red discolouration of the blubber layer with orange coloured tissue visible on the exposed muscle region (Fig. 2C). Given the apparent freshness of the wounds we suggest the dolphin was likely injured within the previous week.

Observation day 2

External changes in wounds appeared minimal between the first and second day of observations. Differences were only detected for the caudal edge of X2 where further deterioration of the skin was visible on the left side and cream coloured necrotic tissue was observed trailing outside the wound.

Observation day 23

Significant changes in wound appearance were recorded 23 days after first observing the injuries. By 11 October 2012, X2 was filled with granulation tissue across the full extent of the wound. Skin and underlying soft tissue caudal to X2 was necrotic.

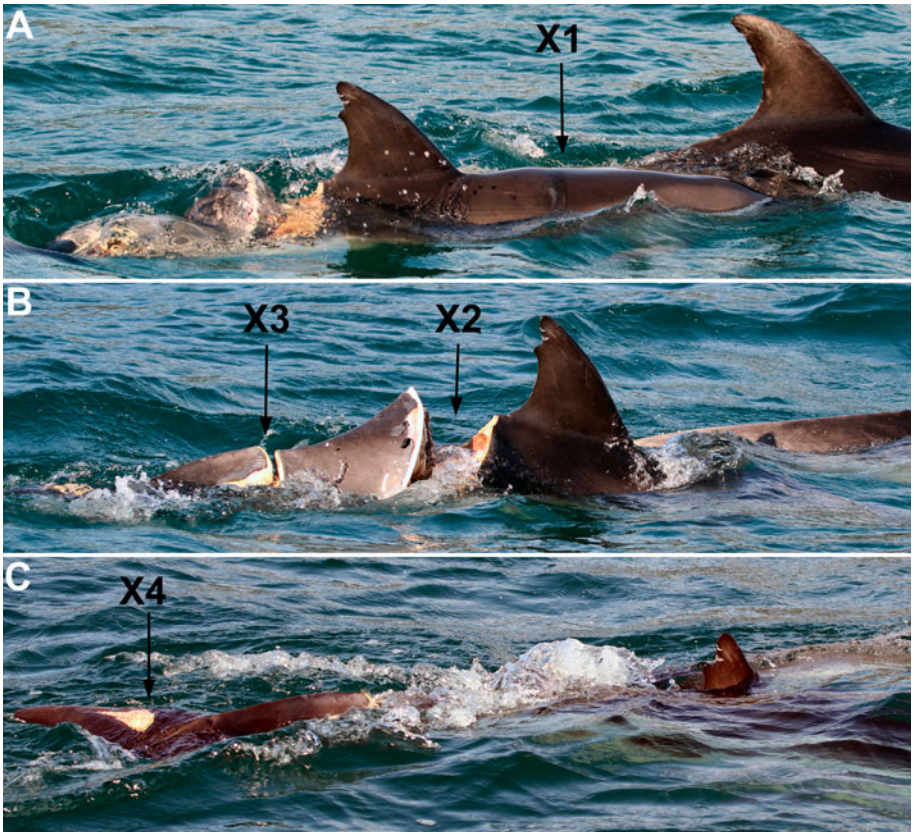

Figure 1 Locations of four externally visible injuries (X1–X4) on a free-ranging bottlenose dolphin *Tursiops truncatus*. Individual TM007 (the injured dolphin) is accompanied by presumed mother TM009. **A**, Evidence of blunt trauma (X1) to the dorsal region of the thorax cranial to the dorsal fin. **B**, Incised wounds X2 and X3 caudal to the dorsal fin. **C**, Wound X4 on the left tail fluke. Photographs by SL Dwyer.

Injuries X3 and X4 were only photographed through the water; therefore, descriptions of wound progressions are limited. X3 was open to a greater degree and both white and pink discolouration could be observed through the water. X4 appeared to be a similar size across all observation days. X1 was still present in the shape of a dorsal deformation and, furthermore, a region of skin was missing, exposing the underlying subdermal surface.

Field observations

During all post-injury encounters the dolphins stayed within a small area of each of the shallow bays at Great Barrier Island at a distance of less than 400 m from shore; therefore overall group movements were small. TM007 and TM009 were consistently observed swimming together in very close proximity (less than one body length apart; Figs. 1, 3) and frequently touching. TM007 was only recorded apart (greater than five body lengths) from TM009 twice; on 19 September 2012 when TM007 was observed alone at a distance of c. 200 m from the group for a period of less than 10 minutes and on 11 October 2012 when TM009 was observed alongside three other adults c. 150 m away from TM007. Following both of these spatial separations, TM009 re-joined TM007 and continued to maintain very close proximity for the remainder of the encounter.

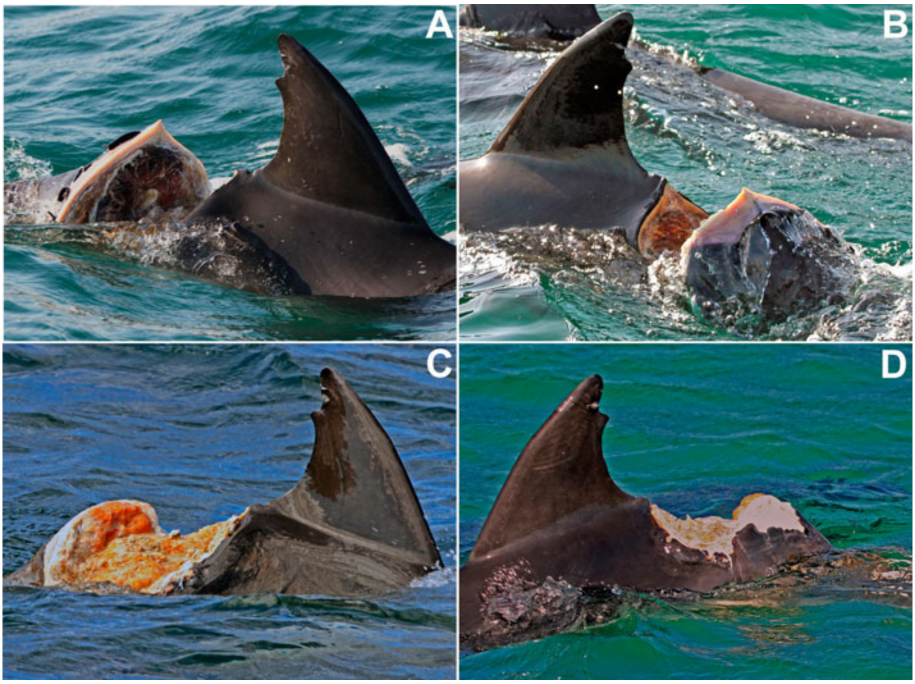

Figure 2 Progression of wound healing associated with the largest incised wound (X2) located immediately caudal to the dorsal fin. **A**, Right side aspect on 19 September 2012. **B**, Left side aspect on 19 September 2012. **C**, Right side aspect on 11 October 2012. **D**, Left side aspect on 11 October 2012. Photographs by SL Dwyer.

Surfacing behaviour of TM007 appeared non-typical, with hyperflexion of the spine beyond what is normally observed for bottlenose dolphins (Fig. 3). Although swimming appeared inhibited and relatively slow, TM007 could maintain spatial proximity to the group and at least shallow diving was possible. Although no photographic evidence could be obtained, TM007 was further reported south of Little Barrier Island on 2 October 2012 (T. Wilson, DOC, pers. comm. 2 October 2012) at a minimum distance of 30 km from the Great Barrier Island sightings. Foraging by TM007 was not observed during any of the post-injury encounters.

TM007 was last photographed on 11 October 2012 (Table 1); however, a sighting without photographic evidence was reported on 21 October

Figure 3 Surfacing behaviour of individual TM007 alongside presumed mother TM009 on 19 September 2012. Photograph by SL Dwyer.

2012 (B. Kearney, Chaos Charters, pers. comm. 24 October 2012). On 1 January 2013, TM009 was resighted at Great Barrier Island in an adult only group, where TM007 was not present. On 27 February 2013, TM009 was further photographed off Tauranga (170 km southeast of Great Barrier Island), where again TM007 was not observed (Table 1). Since a carcass has not been recovered, it cannot be completely ruled out that TM007 is still alive. However, given the historical associations of TM007 and TM009, where neither individual was previously sighted without the other (Table 1), and given that TM009 has since been sighted twice without TM007, we presume that TM007 did not survive the extensive injuries endured.

Discussion

The wound-healing process in dolphins is often considered remarkable in terms of the severity of wounds that can be survived as well as the speed of recovery (Orams & Deakin 1997; Zasloff 2011). We present an extreme case of a dolphin with multiple propeller wounds, including a penetration to the bone, where survival was possible for at least 23 days post injury. Considering the severity of the wounds, it was surprising that the injuries were not immediately fatal. It was also remarkable that the animal was still capable of swimming and maintaining group cohesion with conspecifics for at least three weeks post trauma.

Constant irrigation of a wound with salt water has been cited as a possible aid to wound healing (Corkeron et al. 1987), although in this case the flow of water over X2 may have in fact hindered recovery since the force of the water flow would likely have caused the wound to remain open or even gape further as a consequence of the dolphin's movement through the water. This was evident in the degree of skin loss at the wound peripheries. The skin on the cranial edges of the wounds remained intact compared with the skin at the caudal edges of the wounds, which peeled away in the direction of the water flow over the caudal peduncle. Much of the open wound cavity of X2 had filled in with granulation tissue by observation day 23 and therefore appeared to be healing.

While we acknowledge that survival cannot be completely ruled out due to the absence of carcass retrieval, we presume TM007 did not survive the assumed vessel collision injuries in the long term, based on the strong social bond of the mother-offspring pair that was evident over two and a half years of sighting records. Neither individual was sighted separately prior to the vessel collision event and up to the last known sighting record of TM007. A combination of nurturant and succorant behaviour (Caldwell & Caldwell 1966) was displayed by TM009 towards TM007 in the form of repeated touching and what appeared at times to be a supporting position of TM007 at the surface. A high level of epimeletic care has been documented for bottlenose dolphins, to the extent of mothers carrying the decomposing remains of their dead calves for extended periods (e.g. Harzen & dos Santos 1992; Fertl & Schiro 1994). Considering this, and the social bond between a mother and her calf that typically lasts for several years (Wells et al. 1987), we believe TM009 would have unlikely abandoned her injured offspring if still alive. Since the injuries sustained were a combination of blunt and sharp force trauma and not immediately fatal, factors contributing to the presumed death may have included emaciation and/or dehydration, infection at the site of the propeller wounds, internal injuries caused by blunt trauma or a combination thereof (Byard et al. 2012; Martinez & Stockin 2013).

Fatal vessel collisions in the Hauraki Gulf region have been reported previously for common dolphins (*Delphinus* sp.; Martinez & Stockin 2013) and Bryde's whales (*Balaenoptera brydei*; Stockin et al. 2008; Behrens 2009). The probability of fatality for a vessel strike with a large whale has been shown to decrease by reducing the speed of shipping traffic (Vanderlaan & Taggart 2007), and rerouting shipping traffic outside of critical areas is also being proposed to reduce risk (Vanderlaan et al. 2008; Conn & Silber 2013; Redfern et al. 2013). Resolving the problem of odontocete vessel collisions remains challenging for small highly mobile species using neritic waters. Boat speed restrictions show evidence for reducing deaths in manatees (*Trichechus* sp.; Laist & Shaw 2006) and crocodilians (*Caiman crocodilus*; Grant & Lewis 2010); however, for species that are not territorial or are widely dispersed this may simply not be practical or enforceable. Another problem is that risk of collision according to vessel type is unknown. A study of propeller wounds on manatees (Beck et al. 1982) found that the lengths of the longest incised wounds varied greatly, likely due to variation in the torque of the motor, the position of the manatee in the water and vessel speed. The results of that study suggested larger vessels (over 7.3 m long), mainly powered by inboard engines, were responsible for most of the manatee fatalities attributed to propeller strike. Since the length, spacing and depth of the wounds could not be measured in this study, we cannot draw any conclusions about the type of vessel involved. Furthermore, many small cetaceans may be classified as 'propeller positive', a term used by Visser (1999) for describing cetaceans that actively seek out the wash caused by propellers. The use of propeller guards has therefore been suggested as a mitigation measure (Visser 1999; Van Waerebeek et al. 2007). Experiments with loggerhead sea turtles *Caretta caretta* did not show any significant improvement in animal safety when propeller guards were used (Work et al. 2010); however, their effectiveness is not known for dolphins.

Although legislation (Marine Mammals Protection Regulations [MMPR 1992]) is in place regarding the appropriate manner to operate a vessel around marine mammals, it is clear that these rules alone are not sufficient to protect cetaceans from boat strikes. A number of reported incidents have shown a peak in vessel collisions at times of the year when recreational vessel traffic is at its maximum (Wells & Scott 1997; Martinez & Stockin 2013). In this case, however, the incident occurred at the end of the austral winter when vessel traffic is typically at its lowest. The risks are therefore present year round and increased mitigation efforts at particular times of the year may not be effective.

This case further supports previous evidence that suggests it is unlikely a free-ranging cetacean can survive an injury that has penetrated to the bone. It also demonstrates that such injuries may not be immediately fatal. In view of the ongoing problem of vessel collisions with cetaceans in the Hauraki Gulf and indeed worldwide, we recommend continued evaluation of cases and reporting of incidents. Further discussion and investigations into the mechanisms to reduce the risk of occurrence (e.g. the effectiveness of propeller guards for small cetaceans) are clearly required.

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