

VESSEL COLLISIONS WITH SMALL CETACEANS WORLDWIDE AND WITH LARGE WHALES IN THE SOUTHERN HEMISPHERE, AN INITIAL ASSESSMENT

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ABSTRACT: Collisions with vessels are a well-documented conservation problem for some populations of large whales (LW) in the Northern Hemisphere. Less attention has been given to incidents in the Southern Hemisphere or to small cetaceans (SC) worldwide, therefore an experimental database was compiled (N=256; 119 LW, 137 SC) to allow a rapid assessment. Confirmed collision records were identified for 25 species (7 LW, 18 SC) and unconfirmed but probable records for 10 other species (2 LW, 8 SC). Among LW, ship-caused mortality and traumatic injuries seem to affect primarily southern right (56 reported cases), humpback (15) and Bryde's whales (13), but also sperm (8), blue (5), sei (4) and fin whales (2) are involved, and probably Antarctic minke and dwarf minke whales. Southern right whale populations off South Africa and off eastern South America (Brazil, Uruguay and Argentina) suffer significant mortality. Incidence and potential population impact vary widely among the 26 small cetacean species for which collision records exist. Vessel strikes in at least two populations each of the Indo-Pacific humpback dolphin (Xiamen and Hong Kong/Pearl River, possibly western Taiwan), Irrawaddy dolphin (Mahakam River, Chilika Lagoon, possibly Laos) and finless porpoise (Yangtze River, Hong Kong) may directly compromise long-term survival. Annual vessel-caused mortality (min. 2.9% of population) for Irrawaddy dolphins in the Mahakam River may not be sustainable. The quasi-extinction of the baiji warns for a potential similar fate for the Yangtze River finless porpoise and Ganges river dolphin. Two calves of the endangered Hector's dolphin are known killed by boats. All highly impacted species have a neritic, estuarine or fluvial habitat, areas where vessel traffic is concentrated. Species that may receive a moderate impact from collisions but which may be sustainable at species level (because many strikes are non-lethal), include common bottlenose dolphins, killer whales, short-finned pilot whales and pygmy sperm whales. Almost 2% of common bottlenose dolphins in the Gulf of Guayaquil showed propeller-inflicted injuries and scars. Propeller guards should be made compulsory for all boat-based cetacean tourism, as habituation to boat traffic seems a contributing factor in accidents. Low impact occurs in 15 small cetacean species with only few reported vessel strikes. However, vast underreporting is thought to be the norm and there is a need for a global, standardised database.

RESUMEN: Las colisiones con barcos constituyen un problema de conservación bien documentado en el caso de ballenas grandes (BG) en el hemisferio norte. Menos atención se le ha brindado a los incidentes en el hemisferio sur y a los cetáceos menores (CM) alrededor del mundo. A fin de realizar una evaluación rápida de este problema se ha compilado una base de datos preliminar (N=256; 119 BG, 137 CM), la cual incluye registros confirmados de colisión para 25 especies (7 BG, 18 CM) y registros no confirmados pero probables para otras 10 (2 BG, 8 CM). Entre BG, la mortalidad causada por barcos e injurias traumáticas parecen afectar principalmente a las ballenas francas australes (56 casos reportados), ballenas jorobadas (15) y ballenas de Bryde (13), pero también se vieron involucrados cachalotes (8), ballenas azules (5), sei (4), de aleta (2), y probablemente ballenas minke antárticas y minke enanas. Ballenas francas australes costa afuera de Sudáfrica y de Sudamérica (Brasil, Uruguay y Argentina) sufren mortalidades significativas. La incidencia y el potencial impacto para las poblaciones varían ampliamente entre las 26 especies de cetáceos menores para las que existen registros de colisiones. En al menos dos poblaciones del delfín jorobado del Indo-Pacífico (río Mahakam, laguna Chilika, posiblemente Laos) y del delfín liso (río Yangtze, Hong Kong), las colisiones con barcos pueden directamente comprometer su sobrevivencia a largo plazo. La mortalidad anual causada por barcos para delfines del Río Irrawaddy en el río Mahakam (min. 2.9% de la población) puede no ser sostenible. La cuasi extinción del baiji es una advertencia de un potencial destino similar para el delfín liso del río Yangtze y para el delfín del río Ganges. Se conoce de dos crías del amenazado delfín de Hector muertos por botes. Todas las especies altamente afectadas tienen un hábitat nerítico, estuarino o fluvial, áreas donde el tráfico marítimo se concentra. Especies que pueden recibir un moderado impacto por colisiones con barcos pero que pueden ser sostenibles a nivel de especies (pues muchas colisiones no son fatales) incluyen a los delfines nariz de botella comunes, orcas, ballenas piloto de aleta corta y cachalotes pigmeos. Casi 2% de la población de delfines nariz de botella del golfo de Guayaquil mostraron heridas y cicatrices causadas por hélices. Se debería obligar el uso de dispositivos cubre hélice para todas las embarcaciones que realizan turismo de observación de cetáceos, pues la habituación al tráfico marítimo parece ser un factor que contribuye a los incidentes. Bajo impacto ocurre en 15 especies de cetáceos menores con solo unos pocos casos reportados de colisiones. Se estima que solo una fracción de las colisiones con cetáceos es reportada. Adicionalmente, se requiere una base de datos global estandarizada.

KEYWORDS: Cetaceans; worldwide; ship collision; propeller strike; mortality; Southern Hemisphere

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Introduction

Collisions between ever faster, larger, and increasing numbers of vessels and cetaceans have only relatively recently become recognised as a significant source of anthropogenic mortality and traumatic injuries (*e.g.* Kraus, 1990; Knowlton *et al.*, 1997; Wells and Scott, 1997; Visser, 1999; Knowlton and Kraus, 2001; Laist *et al.*, 2001; IWC, 2003; Jensen and Silber, 2004; Norman *et al.*, 2004; Silber *et al.*, 2004; de Stephanis *et al.*, 2005¹¹; Félix and Van Waerebeek, 2005; Weinrich, 2005; Panigada *et al.*, 2006; Van Waerebeek *et al.*, 2006). For purposes of management, lethal collisions with cetaceans are considered equivalent to bycatch. Except for a few areas and populations, mainly in the North Atlantic, the scarcity of documented records impedes any accurate assessment of the true collision prevalence and trend analyses (*sensu* Lammers *et al.*, 2007). The collision predicament is often perceived as largely confined to large whales in some ocean provinces, such as the North Atlantic Ocean, the Mediterranean Sea and the North Pacific (East Sea/Sea of Japan, Hawaii and southeast Alaska) and has been considered of little consequence in other oceans including all of those in the Southern Hemisphere (SH). However, opportunistic observations suggest that the scarcity of records from many regions may be an artefact of limited monitoring and reporting. Collision accidents follow the global expansion of major shipping and seaborne trade development, hence occur also in coastal waters of newly industrializing countries (NICs) and even developing countries (*e.g.* Félix and Van Waerebeek, 2005). A growing body of information also calls into question the widely held assumption that only whales, and not smaller cetaceans, are affected. Results presented here support the notion of a sampling or reporting bias and largely contradict the latter conjecture.

Assessments of impact on species and populations are thwarted by a number of obstacles. Foremost among these is the difficulty in obtaining adequately documented cases. Under- or non-reporting is a global norm. Useful information may be buried in largely inaccessible ship logbooks. Only a handful of countries have reporting requirements and, even there, the level of compliance remains untested. To carry out useful trends analyses and modelling, authenticated and standardised data are required. The IWC's Scientific Committee tasked a working group to compose a template for a global vessel strike database (Van Waerebeek and Leaper, 2007). In the meantime, a 2006 experimental database presented here allowed a rapid initial assessment of small cetaceans worldwide and

large whales in the SH that may be significantly impacted and therefore deserve attention.

Material and Methods

We compiled an experimental database with 25 parameters and 256 vessel-cetacean collision records, 137 (53.5%) involving small cetaceans worldwide and 119 (46.5%) involving large whales in the Southern Hemisphere (SH). Some 57% were considered confirmed collisions¹², 43% were unconfirmed but probable/suspected collisions. In small cetaceans most records consisted of documented sightings of free-ranging animals with diagnostic injuries or scars and a small sample of carcasses, while for large whales the majority were of stranded carcasses showing injuries congruent with vessel strikes. Information on the occurrence of ship collisions was gathered from various sources including published records, photographs of propeller wounds from aerial surveys of southern right whales in Argentina in the WCI/OA right whale database (Right Whale Program, Whale Conservation Institute), stranding records attributed to ship collisions from the New Zealand Whale Stranding Database, and reports of collisions from state authorities in Australia.

For purposes of this review, a vessel collision or strike is defined as a forceful impact between any part of a watercraft, most commonly the bow or propeller and a live cetacean, often resulting in death or physical trauma. Most collisions were attributed to the momentum of the vessel, but in rare cases cetaceans reportedly bumped into a boat, or involved a combination of both. Entanglement or violent contact with fishing gear sometimes leaves injuries that may inappropriately be referred to as evidence of a collision, while such events are rather a form of bycatch. Incidence rates of post-mortem collisions, relevant mostly as maritime navigation hazards, may however shed light on the possible frequency of false positives. Predisposing factors, such as disease, non-fatal entanglements in fishing gear, and prior injuries may hamper a whale's ability to avoid a vessel. For instance, a blue whale killed by a ship in New Zealand appeared to have been attacked by killer whales prior to the collision (New Zealand Stranding Database). Similarly, Ogden *et al.* (1981) argued that fractures in the radius and ulna of a fin whale probably predisposed it to an impact by a large vessel. Laist *et al.* (2001) cite a North Atlantic right whale that had parts of a gillnet entangled around its tail when it was hit and killed by a large vessel off Florida in March 1991.

¹¹ de Stephanis, R., Verborgh, P., Pérez Gimeno, N., Sánchez Cabanes, A., Pérez Jorge, S., Esteban Pavo, R., Séller, N., Urquiola, E., and Guinet, C. (2005) Impacts produced by the maritime traffic on cetacean populations in the Strait of Gibraltar (Spain). Current situation and future previsions. Dirección General para la Biodiversidad del Ministerio de Medio Ambiente. 35pp. (unpublished).

¹² Observed injuries and scars and their location were pathognomonic for vessel strikes: no other known causes of traumata, such as entanglement in fishing gear, bycatch, large-predator attacks or ice damage could explain them.

However, such deaths were still considered vessel kills because individuals, even if weakened by other causes, could have recovered.

The information gathered by many different observers widely varied in parameter definition, detail and authentication. Evidence ranged from meticulously documented cases supported by necropsies to-the-bone by expert scientists to, more commonly, reports of circumstantial accounts by casual observers. Most specimens, especially fresh ones that presented severe propeller wounds dorsally or massive haemorrhages and multiple unhealed bone fractures were considered killed by a vessel. Scars or injuries on fins following killer whale attacks show irregular borders that often can be differentiated from propeller trauma in which cut surfaces are more likely to be clean, often linear (see e.g. figure 2 in Kraus, 1990).

Uncertainty of each alleged collision event was estimated based on total available evidence, or absence of it. Cases considered here were either 'confirmed collision' or 'unconfirmed but probable collision'. The two most common uncertainties were: (a) whether a collision occurred ante- or post-mortem, and (b) whether a severe scar or traumatic injury was caused by a vessel, fishing gear, predation/aggression or morbidity. 'Unconfirmed but probable records' were believed to include many genuine collisions and their consideration allows the widest view of an underreported conservation problem and serves as guidance for future efforts.

To gain a rough sense of relative incidence of lethal collisions in a species, some authors (e.g. Jefferson, 2000a; Best *et al.*, 2001) have applied an estimator for carcasses studied, namely the number of confirmed vessel-killed individuals versus the total number of specimens examined to the bone. While this relative incidence may not necessarily represent mortality from vessel strikes in the population as a whole, considering that it does not account for dead whales that failed to strand (such as animals that die in far offshore waters), it provides a useful estimate allowing comparisons between species. However, in this initial assessment such estimators could not be computed for lack of information on the total numbers of examined carcasses.

The prevalence¹³ of non-lethal collisions can be estimated by the number of recognizable live individuals with diagnostic injuries and scars versus the total number of photo-identified individuals in a population, although it could show a slight upward bias if scarring facilitates photo-identification. Total collision

rate would then be the sum of lethal and non-lethal rates.

Four types of vessel strikes were identified:

(1) *Indeterminate collisions with bow or hull* involve vessels, or appendages such as struts and foils, that collide with a cetacean and leave characteristic, usually massive, blunt trauma from direct accidental impacts. A model fitted to around 100 observations where vessel speed and the fate of the whale was known suggests that at vessel speeds above 15 knots almost all collisions are likely to be lethal (Vanderlaan and Taggart, 2006). Multiple, complete and comminuted fractures of post-cranial and cranial bones are common.

(2) *Bow bulb draping*. A direct bow hit in which balaenopterids become wedged (draped) across the bow of large vessels. Case studies in varying detail exist for fin, blue, Bryde's and sei whales (e.g. Jensen and Silber, 2004; Norman *et al.*, 2004; Félix and Van Waerebeek, 2005). In August 2006 a cruise ship reported a humpback whale draped on its bow, apparently struck just outside Disenchantment Bay near Yakutat, Alaska¹⁴, but otherwise humpback whales become rarely wedged. These five species are the only ones currently known to become stuck, presumably because whales of smaller size (e.g. minke whales) or marked body shape asymmetry along the caudal-cranial axis (e.g. right whales) causes these to become hydrodynamically unstable and drop off. An observational or modelled estimate of a 'draping rate' (percentage of struck animals ending up as 'draped') would allow documented cases, typically discovered when ships enter ports, to be used to estimate a minimum collision mortality for the balaenopterids involved.

(3) *Propeller hits*. Shane (1977) and Sergeant (1979) recognised that injuries inflicted by boat propellers can be severe and cause death. Vessel collisions often leave characteristic propeller slashes (Morgan and Patton, 1990¹⁵; Visser, 1999). Skeg marks, scrapes made from the propeller guard on some outboard engines, may also be present. Propeller slashes vary in appearance depending on the size of the propeller, the speed of the boat, and the posture and velocity of the animal when hit. Wounds typically consist of multiple parallel slashes of varying length in which the length of each slash is related to its depth. Distance between slashes tends to be constant in each case, related to the size and pitch of the propeller, vessel speed through the water and shaft rotation speed. Location and appearance of trauma can help determine whether a collision occurred ante- or post-mortem. Dolphins do not normally expose their undersides to the surface, hence propeller wounds are not expected on the belly (Morgan and Patton, 1990).

¹³ Prevalence represents new and pre-existing cases alive on a certain date, in contrast to incidence which reflects new cases of a condition diagnosed during a given period of time. Prevalence is a function of both the incidence of the condition and survival.

¹⁴ http://www.marineconnection.org/archives/marine_impacts_2006.html.

¹⁵ Morgan, M.A. and Patton, G.W. (1990) Human Dolphin interactions on the West Coast of Florida: Documentation from MML's Marine Mammal Response Program. Mote Marine Laboratory Technical Report 191. 9pp.

Carcasses with propeller marks on the dorsum or with cleanly severed flukes were most likely hit when alive (Kraus, 1990). Dead whales floating due to positive buoyancy or decomposition gases typically turn belly-up, with tail and flukes hanging down in the water column unlikely to be damaged by propellers (Kraus, 1990).

(4) *Vessel colliding with breaching cetacean and incidents where whales bump into vessels.* Although rare, boats navigating or drifting close to cetaceans may intercept a cetacean in mid-air when the animal breaches or jumps clear off the water. One particular case refers to an unidentified 3m long small cetacean ('porpoise') in Australia when it 'crashed on to the front of a launch, skidding across the top of the cabin six miles off Ulverstone' while fleeing from a killer whale attack (Tasmanian DPIW data). Cetaceans, mostly large whales, sometimes accidentally bump into or ram vessels, may injure themselves in the process and can cause major vessel damage.

A) LARGE WHALES IN THE SOUTHERN HEMISPHERE

Southern right whale *Eubalaena australis*

From stranding records of southern right whales in South Africa (1963-1998), Best *et al.* (2001) identified ship collisions as a known or possible cause in 20% (11 of 55) of recorded deaths. Of these, 55% (6 of 11) involved calves or juveniles. In five cases ship strikes were cited as a definite cause of death and in six cases they were considered a possible cause. Two of the five definite ship strikes involved known vessels, a hopper dredge and a ferry. Non-fatal collisions (n=5) involved two motor launches, a 6-m inflatable boat, a catamaran whale-watching boat, and a fisheries patrol boat (Best *et al.*, 2001).

In Uruguay, a right whale washed ashore near Portezuela, Maldonado, in September 2005 with three 2m x 0.1m cuts and without its tail. Another specimen stranded near La Barra, Maldonado, with the occipital bone parted in two (photographed by R. Garcia-Pingaro). Large tankers anchor at a pipeline buoy in an area with a high seasonal density of southern right whales, ca. 3nm from shore. Presumably these are the two cases also briefly referred to by Del Bene *et al.* (2006).

In Argentina, Rowntree *et al.* (2001) reported 19 confirmed and 3 probable collision cases with southern right whales, many with scars inflicted by small boat propellers. Since then, two juveniles were sighted off Patagonia (18 October 2000 and 7 October 2001) with positive dorsal propeller scars. Another individual off Caleta Olivia, Santa Cruz (reported on 24 August 2003) showed extensive dorsal bruising.

In Brazil, three propeller-slashed specimens washed ashore dead in Rio Grande do Sul state: a 12.5m male at 32°08'S, 52°08'W on 25 October 1993 (Greig *et al.*, 2001; Figure 1A), a young 7.5m male at 32°03'S, 52°08'W on 25 August 1989 (Secchi, 1994 and this paper; Figure 1B) and a 12.8m subadult male on 28 July 1998, some 5km

north of the Lagoa do Peixe (Virginia Petry, email comm. to ES, 3 Oct 2007). The latter stranded in fresh condition, with two parallel, 30cm deep cuts some 90cm distant, one cut reaching a lumbar vertebra. Greig *et al.* (2001) suggest that several factors may explain the relatively high number of stranding events in the southernmost state, Rio Grande do Sul, compared with the major breeding ground in neighbouring Santa Catarina state: increased use by right whales (possibly as breeding ground); exposed open coast that favours stranding events; and relatively high numbers of transiting fishing and cargo vessels. However, we believe that higher ship traffic or whale density may be the more likely factor. Stranding frequencies of cetacean carcasses are also determined by predominant currents and winds.

A calf observed for a long period with its mother in Golfo de Arauco (37°12'S, 73°35'W), Chile, stranded and died after it was wounded by propellers (Canto *et al.*, 1991) possibly by imprudent whale-watchers. This is the only case known from the SE Pacific Ocean.

Humpback whale *Megaptera novaeangliae*

In Bahía Drake, on the Pacific coast of Costa Rica, collisions with humpback whale calves occurred in 2002 and 2005 with boats 7-9m long (S. Goodman and P. Cubero-Pardo, *in litt.* to KVV, 24 Jan 2006). In Pacific Colombia, at least three fatal collisions occurred between 1986 and 2000 (Capella *et al.*, 2001). Photo-ID catalogues of humpback whales curated by research groups in Colombia and Ecuador (see Flórez-Gonzalez *et al.*, 2007) also revealed severe, albeit non-fatal, injuries. Figure 2 illustrates four possible cases of humpback whales with severed flukes (although killer whale attacks cannot be excluded as causes) in Ecuador and Figure 3 shows two cases of whales with deep cuts in the dorsum near the dorsal fin, as well as an adult female with three parallel, healed scars on the anterior dorsum. Cristina Castro (Pacific Whale Foundation, email comm. to KVV, 4 Oct 2007) sighted an adult humpback whale with two evident propeller scars near Isla de la Plata, on 3 August 2005. A young male of ca. 7m length, with severe trauma on its upper dorsum while intact ventrally, stranded in good condition near Punta Negra, south of Talara in northern Peru, on 4 December 2007 (in Peruvian daily *El Comercio*, 6 December 2007, with voucher photo by Susana Briceño; and A. García-Godos, pers. comm. to KVV, 8 Dec. 2007). It is considered a probable, but unconfirmed, case of collision. Unfortunately the specimen was buried without a detailed necropsy.

Some records from the NE Pacific were included in the database because humpback whales in these areas are known (Colombia) or possible (Costa Rica) members from the western South America Breeding Stock G (reviewed in Flórez-Gonzalez *et al.*, 2007).

An adult humpback whale with seven parallel, apparently healed, propeller slashes on its upper dorsum, was sighted in Gerlache Strait, Antarctic Peninsula, in January 2006 (Figure 4). Two other collisions with

humpback whales were reported from the Peninsula, one that was injured by a passenger ship and another hit by a zodiac inflatable, possibly without consequences (Jensen and Silber, 2004).

At least three confirmed and two probable collision accidents have been recorded in Australian waters. On 22 June 2001, one humpback whale was hit in the lower Hawesbury River, New South Wales (NSW), causing serious dorsal wounds. The animal remained in the vicinity of Sydney until 28 June before disappearing. In NSW two adult whales washed up dead with severe external traumas, *i.e.* gouging and propeller-cut tail fluke, respectively in Ulladulla on 27 Sept 2003 and Shoalhaven Heads on 5 Oct 2003 (NSW Dept. Environment & Climate Change). Two other humpback whales were involved in collision accidents, one near Port Douglas, Queensland (5 Aug 2004) that swam away (Queensland Environmental Protection Agency), and one in Exmouth Gulf, Western Australia (3 Oct 2002) (Department of Environment & Conservation, WA), but their fate is unknown.

An injured humpback whale beached at Assini Mafia, eastern Ivory Coast, on 23 August 2007, and died the next day, as supported by photographic evidence (photos taken by Kambou Sia). The whale had reportedly been hit by a propeller on the head and back. Humpback whales wash ashore with some regularity in Benin and ship strikes are the main suspect for this mortality. Although breeding in the northern Gulf of Guinea, north of the equator, these individuals form part of the IWC-defined Southeast Atlantic Breeding Stock B. The steep increase in shipping and the construction of new ports throughout the Bight of Benin are of concern for the future of this SH population (Van Waerebeek *et al.*, 2001; Van Waerebeek, 2003). On 27 July 1995, a 14.2m humpback whale

washed ashore dead at Mouille Point, Cape Town. Four diagonal slashes 1.1-1.3m apart, up to 2.9m in length and 35-44cm deep, along the animal's back, suggested marks from the propeller of a large ship (Best, 2007). We concur with the latter author that 'the reason for its death seemed pretty obvious', considering the propeller cuts were on the back, and not the ventrum.

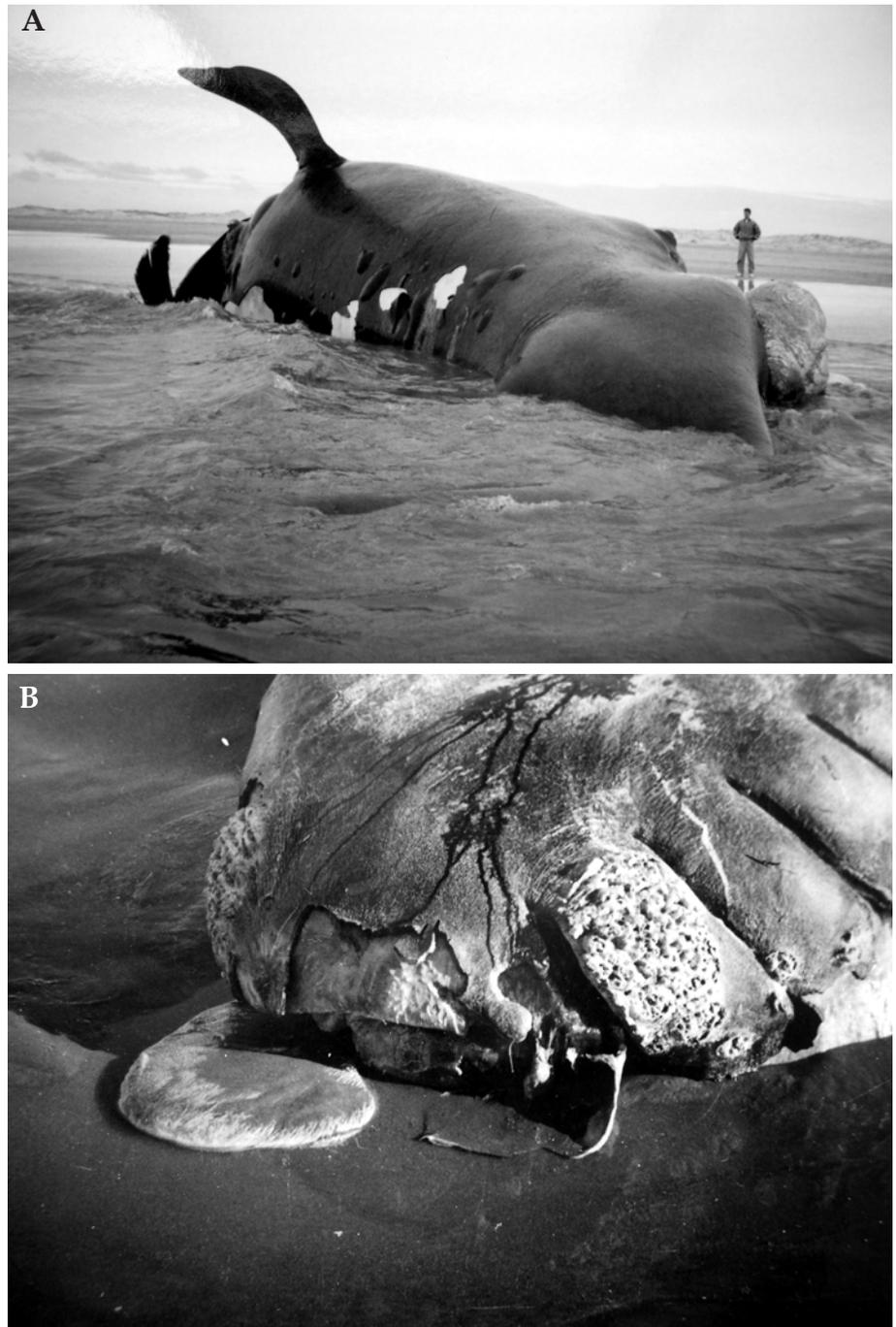


Figure 1. Carcasses of two southern right whales with evidence of propeller hits, stranded in Rio Grande do Sul state: [A] 12.5m specimen found on 25 October 1993; the largely intact epidermis and baleen plates attached to the palate demonstrate that the whale died shortly before it was found. Propeller marks are present on the tail stock; [B] remains of a 7.5m juvenile with deep propeller slashes on the head, found on 25 August 1989 (Photo by E. Secchi).



Figure 2. Four humpback whales with a missing fluke off Ecuador, consistent with possible propeller impacts although killer whale predation is also possible (Photos courtesy of Pacific Whale Foundation [upper left] and Fundación Ecuatoriana para el Estudio de Mamíferos Marinos, FEMM [others]).



Figure 3. Three humpback whales sighted off Ecuador with deep incisive traumas (two of these healed) attributable with high probability to vessel or propeller impacts (Photos by Fundación Ecuatoriana para el Estudio de Mamíferos Marinos, FEMM).



Figure 4. Humpback whale with mostly healed propeller scars encountered in the Gerlache Strait, Antarctic Peninsula in January 2006 (Photo by A.F. Azevedo, Projeto Baleias/Proantar).

Bryde's whale *Balaenoptera brydei*

Collisions with Bryde's whales have been considered rare. Although Jensen and Silber (2004) reported only three cases worldwide, their rarity may be an artefact of underreporting in (sub)tropical regions. Several new cases have been identified since. A ca. 16m specimen was reported in the Guayaquil harbour in 2004 draped across the bow of a container ship (Félix and Van Waerebeek, 2005). Two Bryde's whales also were found dead with propeller-inflicted traumas in Brazil. On 15 September 2005, a fresh 4m calf stranded, with deep propeller slashes on its head in Baía de Sepetiba, Rio de Janeiro (Salvatore Siciliano, pers. comm. to ES) and an adult with massive propeller trauma stranded in the Patos Lagoon estuary, Rio Grande do Sul state, in August 1989 (Figure 5).

Bryde's whales are struck regularly in New Zealand's Hauraki Gulf by ships travelling to or from Auckland's busy port (New Zealand Whale Stranding Database; Mike Donoghue, pers. comm. to ANB). Up to six Bryde's whales, both confirmed and probable cases, may have been killed by vessels in New Zealand between 1999 and 2003 (this paper). A Bryde's whale, identified from a DNA trace left on the vessel, in Twofold Bay, New South Wales, Australia reportedly "rammed a fishing boat" on 1 January 2001 (NSW Department of Environment & Climate Change).

Fin whale *Balaenoptera physalus*

Fin whales are the most commonly reported whale struck and killed by ships in the NH (Laist *et al.*, 2001; Jensen and Silber, 2004; Nelson *et al.*, 2007), especially in the

Mediterranean Sea (Panigada *et al.*, 2006) and in the NE Pacific (Norman *et al.*, 2004). In the SH, however, we are aware of only two cases, both in Chile. A 13.9m fin whale stranded in Quinteros (29°39'S, 70°59'W) on 9 July 2004 had a blunt trauma on its left pectoral region which was attributed to a vessel strike (Sanino and Yañez, 2005). A second collision, in which a fin whale lifted a kayak partially out of the water on its back, occurred north of Chañaral Island in January 1994 (G.P. Sanino, pers. obs.).

Sei whale *Balaenoptera borealis*

Reports of vessel traffic accidents with sei whales are infrequent worldwide: a 2004 database contains only three cases (Jensen and Silber, 2004) with an additional three reported from Senegal and the US (Félix and Van Waerebeek, 2005; Nelson *et al.*, 2007). As with Bryde's whales, underreporting is suspected. Two dead sei whales were carried into the port of Auckland on the bow of container ships in 1993 and in 2001. A third possible case exists for New Zealand in which an individual was found ashore in North Auckland in 1993 with suspected ship-caused traumas (New Zealand Whale Stranding Database).

Blue whale (Peru/Chile stock) *Balaenoptera musculus* subsp.

Only few collisions with blue whales have been published (Laist *et al.*, 2001; Norman *et al.*, 2004; Carretta *et al.*, 2007). On 31 January 1998, one of two blue whales sighted off Chañaral Island, Chile (29°01.59'S, 71°33.91'W) was photographed with half of its left fluke missing.

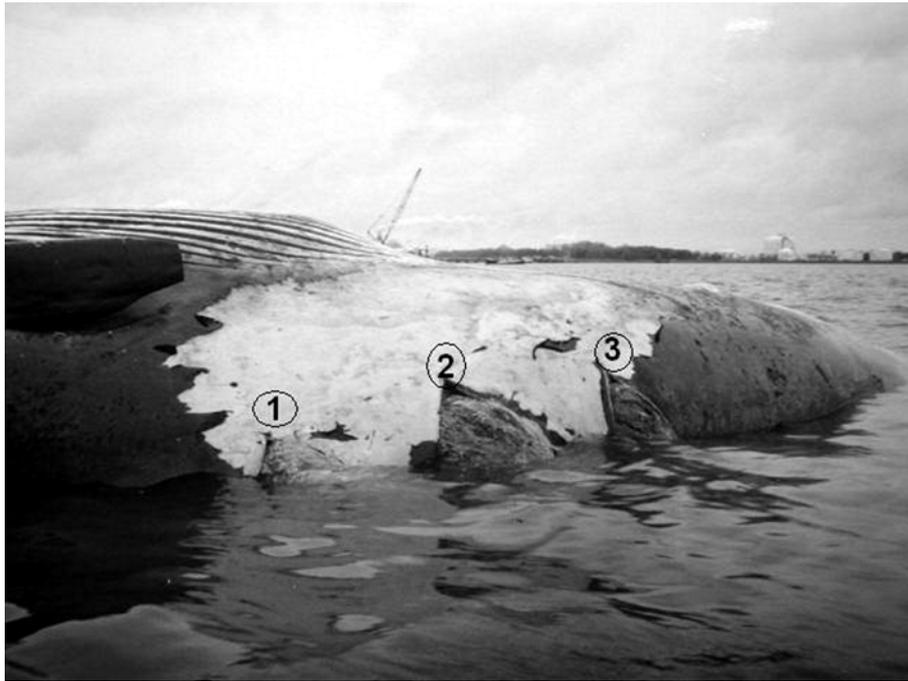


Figure 5. Bryde's whale with three gaping, equidistant propeller slashes exposing epaxial muscles stranded in Rio Grande, Brazil in August 1989 (Photo by Lauro Barcellos, Museu Oceanográfico "Prof. Eliézer C. Rios", Rio Grande).

The clean-cut surface was straight and parallel with the body axis indicative of a propeller strike from a large vessel. On 4 February 2005, a single blue whale sighted near the same island (29°01.14'S, 71°33.11'W), was seen with a healed, deep-cutting injury behind its left flipper, possibly the result of a lateral vessel collision (G.P. Sanino, pers. obs.). In the Gulf of Corcovado, southern Chile, the collision between a 20m boat and a blue whale was reported by a salmon farm worker in February 2005 (Hucke-Gaete *et al.*, 2005). The collision has raised concern about future accidents in view of a projected increase of boat traffic in the area, including from whale-watching boats. One injured, bleeding blue whale with morphological characteristics intermediate between an ordinary and a pygmy blue whale, run aground alive on a rocky island in Peru in 1997, possibly attributable to a vessel collision (Van Waerebeek *et al.*, 1997). Peru/Chile blue whales comprise an indeterminate but discrete management stock and probably a hitherto unrecognised subspecies *B. musculus* subsp. (Branch *et al.*, 2007).

Pygmy blue whale *Balaenoptera musculus brevicauda*

In 1995, a male pygmy blue whale 20.6m long was brought into the port of Auckland, New Zealand, on the bow of a ship. Its very fresh condition (*i.e.* intact epidermis and colouration, and baleen plates still inserted in the palate) indicate it was alive when hit. Tooth rakes by a killer whale also were visible on flippers and flukes. Considerable damage in the postcranial skeleton required repair when the specimen was assembled for display in the Museum of New

Zealand. Based on a pulverised right radius, the vessel impact site was inferred to have been at about the height of the right flipper. One of the authors (AvH) examined the carcass and concluded that the baleen length/height ratio and dorsal fin placement was consistent with that of a pygmy blue whale. Photos of the whale on the beach, as well as video of the animal wrapped around the bow, are archived in the New Zealand Whale Stranding Database. On 1 December 2006, after sighting blows and despite taking avoidance action, a military vessel collided with a whale in the waters off Perth, West Australia (Department of Environment & Conservation, WA). The species was unknown at the time. Blows were sighted minutes prior to a shuddering of the ship was felt as if it had hit something, then shortly afterward blood was sighted in the water. On 5 December 2006 a pygmy blue whale washed up on the beach approximately 30 miles north of Perth with injuries consistent with a ship strike.

Minke whales *Balaenoptera acutorostrata* and *B. bonaerensis*

Three probable but unconfirmed cases are reported for minke whales in the SH. An individual (see Baker, 1999) with injuries reminiscent of propeller cuts on head and flank was examined at Westland, New Zealand, on 5 October 1991 (New Zealand Whale Stranding Database). Deep bruising to the head and dorsum was apparent in a 3.4m calf Antarctic minke whale *B. bonaerensis* encountered at Victor Harbour, South Australia (C. Kemper and D. Stemmer, South Australian Museum, Adelaide, pers. comm. to JG). A calf dwarf minke whale

B. acutorostrata subsp. that stranded in Station Creek, north coast New South Wales, showed a propeller cut through a tail fluke which likely induced its stranding and subsequent death (source, New South Wales Department of Environment & Climate Change).

Sperm whale *Physeter macrocephalus*

The scant information on ship interactions with SH sperm whales may not be representative of true mortality. A suckling calf (female) live-stranded on 21 September 2003 in Boyeruca (34°41'S, 72°03'W), Chile, with small-boat propeller cuts on the caudal peduncle. A necropsy performed on 23 September by G.P. Sanino demonstrated that it had haemorrhaged to death. Boyeruca is situated south of Valparaiso, in an area with intense industrial and artisanal fisheries vessel traffic. Of 20 sperm whales stranded in Ecuador, one (5%) was a probable victim of a ship strike as was another that stranded in Paramonga, northern Peru (Haase and Félix, 1994; Félix and Van Waerebeek, 2005). In New Zealand, five sperm whales that stranded in the period 1985-2000 had cuts and other traumas that were consistent with ship collisions (New Zealand Whale Stranding Database) and are considered probable but unconfirmed records.

B) SMALL CETACEANS WORLDWIDE

KOGIIDAE

Pygmy sperm whale *Kogia breviceps*

At least six pygmy sperm whales were killed by probable ship strikes: four in the Canary Islands, one each in 2001 and 2004 and two in 2002 (Lens *et al.*, 2005)¹⁶, and two in South Australia. A 288cm male that stranded at Point Sinclair (5 Sept 2003), South Australia, presented both bruises on head and broken bones (C. Kemper and D. Stemmer, South Australia Museum, Adelaide, pers. comm. to JG) and can be considered a confirmed collision victim. Interestingly, no dwarf sperm whales *Kogia sima* have been reported killed. Barros *et al.* (1998)¹⁷ suggested, based on stranding data, that dwarf sperm whales off the southeast US coast may have a more pelagic distribution than pygmy sperm whales which, if confirmed, would render dwarf sperm whales less vulnerable to intense coastal shipping and less likely to strand if hit. However, indications are that in other areas, such as in Ecuador (F. Félix, pers. obs.) dwarf sperm whales may be more coastal. In South Africa (Ross, 1984), juvenile and immature *Kogia*, particularly *K. sima*, are thought to live closer inshore than adults, probably

inhabiting the outer continental shelf/slope area.

DELPHINIDAE

Killer whale *Orcinus orca*

Seven cases of killer whales struck by vessels in British Columbia, Canada, and New Zealand were discussed by several authors (Ford *et al.*, 1994; Visser, 1999; Visser and Fertl, 2000). An individual hit by a fishing boat propeller in Noutka Sound, Vancouver Island, resulting in a 15-20cm long x 3cm deep gash was reported by Orca Network News in August 2003. Visser (1999) termed many killer whales in New Zealand 'propeller-positive' for their tendency to actively seek out the wash produced by spinning propellers and even open their mouth around these. Such behaviour also was reported by a lone orca that was killed in Mooyah Bay, Canada, on 10 March 2006 when playing in the turbulence of propeller wash of an idling 34m ocean-going tug, and approaching too close (Rossiter, 2006).

Common bottlenose dolphins *Tursiops truncatus*

Small-boat propellers have long been recognised as a cause of traumas in common bottlenose dolphins (Doak, 1988; Lockyer and Morris, 1990; Fertl, 1994). In the Galveston Ship Channel, Texas, 10 of 240 (4.17%) photo-identified dolphins had obvious propeller cuts (clean, v-shaped marks); others had grotesquely bent or cut dorsal fins, or had white scarring on the top that indicated the possibility of a serious cut (Fertl, 1994). Propellers have been implicated in several other cases of dolphin mortality in Texas waters (Shane, 1977; Reynolds, 1985, Fertl, 1994). Three dead specimens from western Florida showed various traumas including propeller slashes, cleanly cut-off tail and extensive bruising (Morgan and Patton, 1990). Off Sarasota, Florida, four cases of severe propeller cuts on dorsum and functional destruction of the dorsal fin were documented (Wells and Scott, 1997). Although these injuries were not immediately fatal, long-term effects on survival and fitness are unknown, and fatal cases may go unrecorded. Reynolds (1985) recommended further studies to determine whether action should be taken to reduce dolphin mortality from propellers.

In north-central Chile, dolphin watching from small boats has resulted in repeated collisions with members of a genetically distinct group of resident coastal *T. truncatus*, named 'pod-R' (Sanino and Yañez, 2000; Sanino *et al.*, 2005; archived video documentation by

¹⁶ Lens, S., Asencio, C. and Urquiola, E. (compilers) (2005) Spanish Report November 2005 to IWC Ship Strikes Working Group. 4pp. (unpublished)

¹⁷ Barros, N. B., Duffield, D.A., Ostrom, P.H., Odell, D.K. and Cornish, V.R. (1998) Nearshore vs. offshore ecotype differentiation of *Kogia breviceps* and *K. sima* based on hemoglobin, morphometric and dietary analyses. Abstracts. World Marine Mammal Science Conference. Monaco. 20-24 January.

G.P. Sanino). Boat disturbance and collisions constitute a major conservation problem for pod-R, and rigorous protection measures have been urged (Sanino and Yañez, 2000; Sanino *et al.*, 2005).

One of us (FF) documented 11 common bottlenose dolphins with dorsal injuries, including severe mutilations, and three animals with deep cuts on the posterior dorsum, in the inner estuary of the Gulf of Guayaquil, Ecuador, between February 1990 and October 1992 (Figure 6). These injuries involved 2.2% of the estimated population size (Félix, 1994, 1997). Eight traumas were considered positively propeller-caused (*e.g.* a complete fluke missing with straight cut-surface or a series of parallel incisive scars on the posterior dorsum), while the other traumas were considered of indeterminate origin, possible the result of fishing gear (cuts at tip and base of dorsal fin). All vessel related traumas were likely caused by small outboard-powered craft and small cargo or fishing vessels.

In Australia at least six probable cases have been reported, some of which may relate to *T. aduncus*. Three carcasses stranded in Queensland, one in 1991 and two in 2004, bore slashes and cuts that were reminiscent of boat hits (Queensland Environmental Protection Agency). A propeller also injured the dorsum of an adult female in the Tweed River (New South Wales) on 16 February 1995. The fate of that animal was unknown (New South Wales Department of Environment & Climate Change).

Off Oostende, Belgium, in the southern North Sea, a common bottlenose dolphin was observed on 11 and 12 August 2007 with a large, freshly inflicted propeller wound on its left flank (Jan Haelters, pers. comm. to KVVW; Figure 7). The animal had been approached by several small boats.

Several cases, albeit probable vessel collisions, are poorly supported. In Golfo Dulce, Pacific Costa Rica, C. Ovares found a dead bottlenose dolphin in 1999 with a propeller cut in the neck region. In 2003, Alfredo Ruiz, skipper of a local whale tourism boat claimed that 'jet skis have hit dolphins and whales' (P. Cubero-Pardo, pers. comm. to KVVW, 24 Jan 2006). Samuels *et al.* (2000)¹⁸, in a review of tourism pertaining to swimming with wild dolphins, referred to two 'well-documented cases of vessel strikes' (no location) with lone sociable bottlenose dolphins. One animal was injured after it became habituated to boats. One juvenile received 37 boat-related injuries since 1992, of which eight were considered life-threatening (Samuels *et al.*, 2000).

In 1999, an adult bottlenose dolphin found dead near a fish farm on Italy's Lampedusa Island was attributed to

a collision because of 'evident lesions' near the rostrum (Pace *et al.*, 2000)¹⁹, however this cannot be verified. G. Lauriano of the Instituto Centrale per la Ricerca Scientifica e Tecnologica Applicata al Mare (ICRAM) (email comm. to KVVW, 2 December 2007) referred to another four stranding records of dead common bottlenose dolphins in Italy, reported between June 1991 and September 2000 by the Centro Studei Cetacei. All are considered probable cases of collision with boat propellers.

Indo-Pacific humpback dolphin *Sousa chinensis*

In China, at least three populations of Indo-Pacific humpback dolphins have suffered mortality and traumatic injuries from heavy maritime traffic. The Hong Kong/Pearl River Estuary population is the best documented (Parsons and Porter, 1995²⁰; Jefferson, 2000a; Jefferson and Hung, 2004). Traumata consistent with boat collisions were present in 10.7% (3 of 28) necropsied humpback dolphin carcasses from the Hong Kong area, however not all injuries result in death (Jefferson, 2000a; Parsons and Jefferson, 2000). A photo-identification catalogue (Jefferson, 2000c, p.31; and Figure 8) illustrates several individuals with major scars on the dorsal fin and dorsum, from boat propellers, vessel collisions and rope/net cuts. In a later survey, 1.2-1.8% of dolphins showed propeller scars (Jefferson *et al.*, 2006).

Yamin Wang suggested that collisions are an important conservation problem for the Xiamen humpback dolphin population in Fujian, eastern China due to intense vessel traffic in Xiamen harbour. At a 2006 workshop (Anonymous, 2006)²¹ Chinese scientists recognised it as a potential threat to the survival of the Xiamen population considering that abundance estimates declined by half between 1994 and 2004 (Yang *et al.*, 2006). Further, two potential victims were documented from Zhuhai City, Guangdong Province: one a 206cm male found on 16 September 2003 and the other a 270cm male examined on 28 February 2003 (Y. Wang, unpublished data).

On 3 October 1988, a male humpback dolphin washed ashore on Saunders Beach in Queensland, Australia, without tail and with dorsal propeller injuries (Queensland Environmental Protection Agency; unpublished data).

In Taiwan, collisions have been ranked as low to medium potential impact, primarily because of plans to introduce high-speed ferries into western Taiwan and increasing recreational use of personal water craft, such as jet-skis. Some of the scarring seen on humpback dolphins (two possible cases) in Taiwan were suggestive of collision injuries (J. Wang *et al.*, 2004a,b).

¹⁸ Samuels, A., Bejder, L. and Heinrich, S. (2000) A review of the literature pertaining to swimming with wild dolphins. Report to Marine Mammal Commission, Bethesda, MD, USA. 58pp. (unpublished).

¹⁹ Pace, D.S., Pulcini, M. and Triossi, F. (2000) Interactions with fisheries: modalities of opportunistic feeding for bottlenose dolphins at Lampedusa island (Italy). Unpublished document at www.oceanomare.info/pdfs/16-publ.pdf

²⁰ Parsons, E.C.M. and Porter, L.J. (1995) The threats to Hong Kong's Indo-Pacific humpbacked dolphin population. Pages 101-117 in The Third Symposium on Cetacean Ecology and Conservation, Taipei, Taiwan, June 15-16, 1995.

²¹ Anonymous. (2006) Xiamen International Workshop on Conservation of *Sousa chinensis*. Journal, Xiamen, China 25-26 March 2006. 40pp.

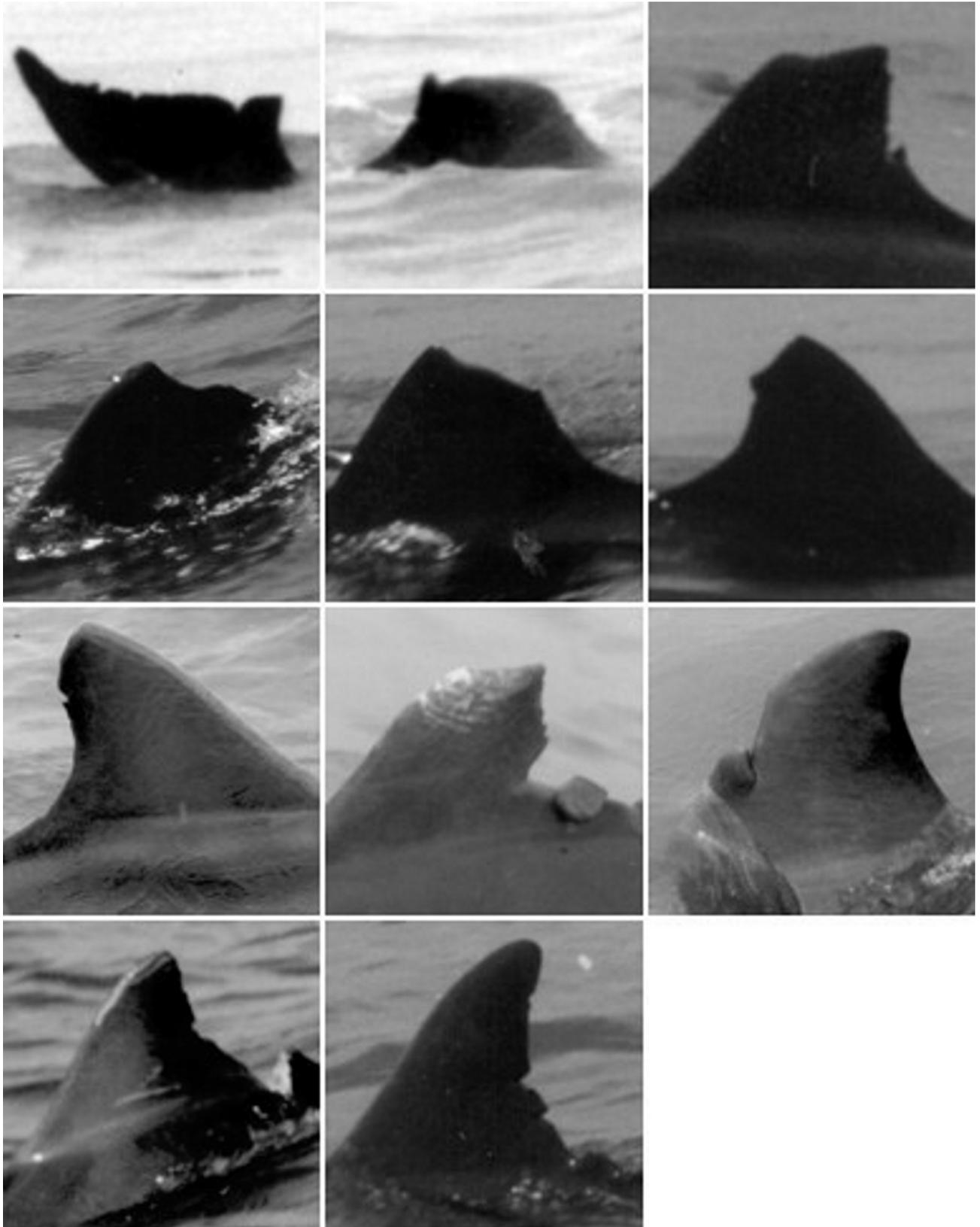


Figure 6. Partially mutilated fluke and dorsal fins of common bottlenose dolphins in the Gulf of Guayaquil. Except for one case (bottom left), all injuries appeared to have healed. Traumas vary from possible to definite propeller strikes, as entanglement in fishing lines or nets may also have caused some of these (Photos by F. Félix).



Figure 7. Lone common bottlenose dolphin seen off Oostende, southern North Sea (first case reported in the area), in August 2007, showing one deep and several superficial, vertical propeller cuts on the left flank (Photo provided by Jan Haelters).

Irrawaddy dolphin *Orcaella brevirostris*

At least three populations of Irrawaddy dolphin are affected by boats. Three deaths in Indonesia's Mahakam River, Kalimantan, were attributed to vessel strikes between 1997 and 1999 (Kreb, 2000; Smith and Reeves, 2004). For an isolated population of *ca.* 34 individuals (Kreb, 2002), the minimum mortality estimate of 2.9% per year from strikes alone is not sustainable. In Laos, a juvenile Irrawaddy dolphin died of injuries possibly caused by a boat propeller in April 2002 (Perrin *et al.*, 2005). The population in coastal waters off northern Australia is not known to be affected (Parra *et al.*, 2002).

Mortality reports of Irrawaddy dolphin from Chilika Lagoon, eastern India, list at least 45 deaths (2002-2006) of which 16 (35.6%) were diagnosed as vessel strikes and propeller injuries (Pattanaik *et al.*, 2007)²². Circumstances in Chilika lagoon can be summarised as follows (D. Sutaria, pers. obs.). The motorised boats use longtailed outboard engines of 9 and 12HP. Irrawaddy dolphins appear to avoid boats that come within 100m. Socialising and travelling animals show immediate changes in behaviour when boats are within 100m, while feeding animals are less likely to change their behaviour. Boats have been observed chasing travelling or

socialising Irrawaddy dolphins and thus are a source of disturbance, stress and risk of collisions. From carcasses examined between 2004 and 2006, the primary source of mortality for Irrawaddy dolphins in Chilika Lagoon was interactions with shark nets, hook lines and seine nets, followed by habitat deterioration and increased interaction with engine boats. Two live animals showed dorsal incisive injuries attributed to impact with propellers (Figure 9). Boat traffic is heavy in Satpada, Chilika's dolphin watching zone. During the peak dolphin watching season from October through February, anywhere between 250-280 tourist boats traverse the 23km² dolphin rich zone from 8:30am-5pm, while in the low season the number of boats drops to about 75/day. Two community-run tourist associations operate in the Satpada region, one with 247 boats is licensed and the other with 87 boats is unlicensed. The associations are formed by fishermen who have taken up tourism to supplement their income. The Orissa State Tourism Department has nine dolphin watching boats that use 25HP inboard engines. Occupancy is limited to seven persons per boat in both government and private boats. Government-run ferries carrying buses and cars also cross the prime dolphin habitat six times a day, from 7am-6pm. Lastly, there are local boat services that travel through the dolphin's habitat every hour between 7am and 5pm.

²² Pattanaik, A., Sutaria, D., Khan, M. and Behera, B. (2007) Review of the status and conservation of Irrawaddy dolphins *Orcaella brevirostris* in Chilika Lagoon of India. Pages 41-49 in Smith, B.D., Shore, R.G. and Lopez, A. (Eds) *Status and Conservation of Freshwater Populations of Irrawaddy Dolphins*. WCS Working Paper Series # 31. <http://www.wcs.org/science>.



Figure 8. Positive (above, centre) and probable (below) propeller scars in *Sousa chinensis* from Hong Kong waters (Photos courtesy Hong Kong Dolphin Conservation Society and [upper] Tom Jefferson).



Figure 9. Probable propeller-caused incisive injuries (inset: detail) on the tail stock of an Irrawaddy dolphin sighted in Chilika Lagoon, India, in November 2005 (Photo by D. Sutaria).

Common understandings at the community and governmental level and coordination between these institutions is a prerequisite for management in tourist boat traffic. Efforts by the Orissa Forest Department, Chilika Development Authority and local youth guides to manage tourist vessels have brought about some positive changes in 2006-2007. The associations have realised that turning off engines around dolphins gives better viewing; chasing dolphins is punishable by law, and using propeller guards while dolphin watching is legally required (D. Sutaria, pers. obs.).

Hector's dolphin *Cephalorhynchus hectori*

Two Hector's dolphin calves were killed by boat strikes in Akaroa Harbour, Banks Peninsula, Canterbury, on 26 and 27 January 1999 (Al Hutt, Department of Conservation, Duvauchelles, New Zealand, pers. comm. to ANB, December 2005). Stone and Yoshinaga (2000) also reported calf mortality and habituation to vessels. Hector's dolphins regularly escort boats and bow-ride, and even nudge vessels or rub against the bow (Mörzner-Bruyns and Baker, 1973; Slooten and Dawson, 1988). While Hector's dolphins are not attracted to fast boats and usually dive at their approach, they do not appear to leave areas with high levels of boat traffic or *dolphin watching* (Slooten and Dawson, 1988).

Commerson's dolphin *Cephalorhynchus commersonii*

A juvenile Commerson's dolphin with healed, shallow propeller scars on its anterior dorsum (Figure 10) was repeatedly sighted in Bahía San Julián, Argentina, in January and February 2005 (M. Iñíguez, pers. obs.). Commerson's dolphins are known to ride bow, stern and beam waves of boats of all sizes, from freighters and tugs to small motorised skiffs. This behaviour makes them vulnerable to collisions.

Guiana dolphin *Sotalia guianensis*

Marcos C. O. Santos (pers. comm. to ES) first noted propeller scars on the flank of a Guiana dolphin in Brazil in 2005 (Figure 11). A photo-identified adult female has been resighted several times in the waters near Cardoso Island (25°07.4'S, 47°51.7'W), southern São Paulo state. Cardoso Island was designated a state park in 1962 and has become a popular site for dolphin watching and watersports. On 19 June 2007, a second Guiana dolphin was seen with propeller scars from an outboard engine in Parati Bay (23°18'S, 44°30'W), Rio de Janeiro state (L. Flach, pers. comm. to ES). These comprise the first reports of vessel collisions with Guiana dolphins.

Peale's dolphin *Lagenorhynchus australis*

A semi-resident group of Peale's dolphins in the bay of Punta Arenas, Magallanes, Chile often accompanies small craft going back and forth to waiting ships (Lescrauwaet, 1997; Van Waerebeek, pers. obs., December 1997). An adult individual with a vertically bisected dorsal fin, the rear-half bent to the left, was regularly sighted between 1990 and 2002 by A.K. Lescrauwaet (pers. comm. to KVW, 13 Jan 2006; Figure 12). The fin may have been slashed by a right-hand propeller (compare with Figure 8, bottom photo), the most common type. On impact, blades may have bent the more flexible trailing part of the dorsal fin to the left side, assuming dolphin and boat headed in the same direction. Peale's dolphins are strongly attracted towards moving vessels and will accompany them (Goodall *et al.*, 1997), incurring evident risk. This is the first documented case of propeller trauma in a Peale's dolphin.

White-beaked dolphin *Lagenorhynchus albirostris*

Jepson (2005) reported one white-beaked dolphin stranded in the UK between 2001 and 2004 that died of acute physical trauma of unspecified origin with a high probability that this was due to impact with a vessel.

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11



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Figure 10. A Commerson's dolphin with four parallel, healed propeller scars (arrow) on the anterior dorsum, photographed in Bahía San Julián, Argentina, on 18 January 2005 (Photo courtesy Fundación Cethus). **Figure 11.** A Guiana dolphin *Sotalia guianensis* with five propeller scars on its right flank, sighted near Cardoso Island, Brazil (Photo by Marcos C.O. Santos). **Figure 12.** A Peale's dolphin exposing a bisected dorsal fin in Punta Arenas bay, Magallanes, Chile (Photo by A.K. Lesrauwaet).

Atlantic spotted dolphin *Stenella frontalis*

Free-ranging Atlantic spotted dolphins are subject to tourism in the Bahamas by tour operators offering opportunities to swim with the dolphins in the wild. A calf in one pod received life-threatening wounds, apparently from a small boat propeller. The injuries were noted because this pod was intensively studied. Problems with unmonitored pods may go unreported (Ransom, 1998; Samuels *et al.*, 2000). Spotted dolphins changed their behaviour 68% of the time when a boat approached, with a closing-in response predominating (Ransom, 1998). Increasing habituation to motorised boats puts individual dolphins at a higher risk.

Spinner dolphin *Stenella longirostris*

On 26 April 2006 a live spinner dolphin was observed inside a cove of Fernando de Noronha Archipelago (03°51'S, 32°25'W) off Brazil, with severed upper and lower jaws and two parallel incisive injuries on its flank indicating it had been hit by a boat propeller (Camargo and Bellini, 2007). Since the dolphin looked very emaciated, feeding apparently had been impaired and its survival seemed unlikely. Because the spinner dolphin population in this area is subject to intense boat-based tourism (Camargo and Bellini, 2007), it was thought the strike likely was from a dolphin-watching boat not equipped with a propeller guard.

Striped dolphin *Stenella coeruleoalba*

G. Lauriano of ICRAM (email comm. to KVV, 2 December 2007) provided published references for seven stranding records of dead striped dolphins on the Italian coasts, indicating injuries consistent with vessel collisions. Strandings occurred both in the Ligurian and Adriatic Seas, were year-round and covered the period February 1987 until December 1995. They affected animals ranging from 109cm to 206cm in length. For four cases propeller damage was explicitly mentioned (Anonymous, 1988; 1992; 1996; 1997). Data were collected by Italy's national stranding network (Centro Studi Cetacei) and the seven cases are sufficiently supported to be considered 'probable collisions'.

Short-snouted common dolphin *Delphinus delphis*

In an analysis of strandings around the UK between 2001 and 2004, Jepson (2005) reported one short-snouted common dolphin with injuries consistent with a fatal impact from a boat strike and a further three common dolphins that died of acute physical trauma of unspecified origin. There are two other probable collision cases in New Zealand, one from Coromandel (June 1989) and one from Whangaparoa (March 1994) (New Zealand Whale Stranding Database). Another recent case in New Zealand involved a common dolphin jumping onto a runabout, badly injuring a passenger (ANB unpublished data). The dolphin bounced on the passenger, went over the side

and kept going. Presumably the skipper was speeding into an active pod, so it was effectively a ship strike rather than a dolphin strike.

Short-finned pilot whale *Globicephala macrorhynchus*

In Tenerife, Canary Islands, Heimlich-Boran (1990) and Carwardine (1994) highlighted the dangers posed for short-finned pilot whales by the high-speed, private launches and hydrofoil ferries. Several adult whales have damaged dorsal fins and deep propeller wounds on their backs. In one group, identified by an individual named 'Split-fin', all members of this group had propeller scars. The Tenerife short-finned pilot whale population is subject to an intense whale-watching industry which increases the risk of vessel collisions (Heimlich-Boran, 1990; Carwardine, 1994). Almost 10% of all short-finned pilot whales observed off Tenerife have been damaged by human activities (Heimlich-Boran, 1990).

Six individuals were reported collided with by various watercraft in the Canary Islands, two of these struck by a fast ferry off Tenerife on 10 July 1999 (Lens *et al.*, 2005¹⁶; Tregenza *et al.*, 2002). De Stephanis and Urquiola (2006) report three incidents with pilot whales around the Canary Islands, but it is unclear whether they are identical to these reported by Lens *et al.* (2005)¹⁶.

Long-finned pilot whale *Globicephala melas*

A ca. 5m female long-finned pilot whale stranded alive near Punta Arenas, Chile, on 31 December 2004 with injuries consistent with a lateral boat strike. It was refloated and helped to head to open waters of the Magellan Strait by Mr. Rafael Olivares and a Chilean Navy inflatable boat, until it crossed the kelp barrier. It is not known whether it survived (G.P. Sanino archives). On an unspecified date in 2004, a long-finned pilot whale *Globicephala melas* was found dead in the Strait of Gibraltar and diagnosed as a collision victim; supporting documentation, however, is currently lacking (Lens *et al.*, 2005¹⁶; de Stephanis and Urquiola, 2006). The Strait of Gibraltar is an area of high-density maritime traffic and a known hotspot for vessel strikes.

PHOCOENIDAE

Finless porpoise *Neophocaena phocaenoides*

Finless porpoises in China's Yangtze River occasionally die or are injured after colliding with powered vessels and their propellers. Such collisions are considered a significant threat to the survival of the Yangtze River population (Zhou *et al.*, 1979, 1980; Reeves *et al.*, 1997, 2000a,b). Rates of mortality and injury have been suggested to be 'much lower' than in baiji (Zhou *et al.*, 1979; Zhou, 1992), but no estimates exist. In southern China, a major fast ferry route between Hong Kong and Macao just south of Lantau Island runs through the habitat of another finless porpoise population (Perrin *et al.*, 2005).

Evidence of blunt traumatic injury consistent with boat collision has been diagnosed in 9.4% (3 of 32) porpoise carcasses necropsied in Hong Kong between 1993 and 1998 (Jefferson, 2000b²³; Parsons and Jefferson, 2000). Boat avoidance behaviour, including diving and leaping, is common (Jefferson, 2000b²³), but clearly not always effective. In Thailand, a finless porpoise died as the result of being run over by a "water scooter" (Chandropornsyl and Andersen, 1995)²⁴, presumably a jet ski.

Burmeister's porpoise *Phocoena spinipinnis*

The only documented live-stranding of a Burmeister's porpoise was considered a potential victim of a boat collision. On 13 August 1986, this animal beached at Playa Coloso, Antofagasta, northern Chile, with freshly inflicted, deep-cutting injuries on its head. It had moved erratically before stranding and Guerra *et al.* (1987) suggested then that it may have been hit by a boat.

Harbour porpoise *Phocoena phocoena*

Baker and Martin (1992) examined 41 stranded harbour porpoises on British coasts but did not find evidence of trauma related to shipping. However, a dead harbour porpoise from Cardigan Bay, UK, showed suspected propeller-caused lesions (Kirkwood *et al.*, 1997). Jepson (2005) reports on one harbour porpoise stranded in the UK between 2001 and 2004 with injuries consistent with a fatal boat strike. Twenty-six other harbour porpoises died of acute physical trauma of unspecified origin and Jepson (2005) suggested that a high proportion of these unidentified trauma cases were probably fatal impacts from watercraft, although some could also be undiagnosed bycatches or bottlenose dolphin attacks. The carcass of another harbour porpoise 150cm long stranded with propeller gashes on a beach at 's Gravenzande, The Netherlands, on 13 January 2006 (Kees Camphuysen, unpublished data); however, researchers could not confirm that it died from a propeller strike.

LIPOTIDAE

Baiji *Lipotes vexillifer*

Mortality of baiji due to vessel collisions has long been recognised as a significant threat, particularly in the lower reaches of the Yangtze River where high levels of traffic by large commercial vessels occurs (Perrin and Brownell, 1989; Zhou, 1992; Leatherwood and Reeves, 1994). Chinese scientists also warned that the rate of killing and injury by collisions, primarily by propellers, has been high (Zhou *et al.*, 1979, 1998; Zhou, 1992; Chen

et al., 1993). The increase in large ship traffic resulting from improved navigation on the upper reaches of the Yangtze River after completion of the Three Gorges Dam, is esteemed to have increased the risk (Reeves *et al.*, 2003). An intense river-wide survey in late 2006 failed to sight a single baiji, leading to the conclusion that the species had possibly become extinct (Guo, 2006; Turvey *et al.*, 2007). Besides bycatch, shipping traffic is one of two main causes that led to the baiji's demise.

PLATANISTIDAE

Ganges River dolphin *Platanista gangetica*

A Ganges river dolphin (susu) was reported by fishermen to have been killed by the propeller of a cargo boat in the Brahmaputra River near the India Bangladesh border (Mohan, 1996²⁵, cited in Reeves *et al.*, 2000a). It is plausible that the same anthropogenic factors, including heavy shipping, that drove the baiji to disappear from the Yangtze River (Guo, 2006) may turn out to be critical for the susu as well.

ZIPHIIDAE

Cuvier's beaked whale *Ziphius cavirostris*

A Cuvier's beaked whale stranded in Canterbury, New Zealand, in September 1992, with bruises and injuries pointing to a vessel collision (New Zealand Whale Stranding Database). Three other Cuvier's beaked whales, all of which washed ashore in the Canary Islands between 2000 and 2004 have also been considered possible victims of fatal vessel hits (Lens *et al.*, 2005)⁶. One animal stranded in May 1992 had propeller cuts in its flukes (Tregenza *et al.*, 2002). De Stephanis and Urquiola (2006) report one collision in the Gulf of Cadiz, Mediterranean, and four events around the Canary Islands but some of the latter may be identical to those reported by the aforementioned authors.

Gray's beaked whale *Mesoplodon grayi*

The adult of a cow/calf pair sighted in Mahurangi harbour, New Zealand, showed a 'series of deep indentations' along the back behind the dorsal fin. The scars, attributed to propeller gashes, appeared to have fully healed. Swimming movement was fluid and did not appear to be affected by this old injury (Dalebout *et al.*, 2004).

Andrew's beaked whale *Mesoplodon bowdoini*

An Andrew's beaked whale stranded in the Chatham Islands in October 1999 with a large impact trauma behind

²³ Jefferson, T.A. (2000b) Conservation biology of the finless porpoise (*Neophocaena phocaenoides*) in Hong Kong waters: Final Report. Final contract report to the Agriculture, Fisheries and Conservation Department, Hong Kong (Special Administrative Region) Government. 285pp.

²⁴ Chandropornsyl, S. and Andersen, M. (1995) The small cetaceans in Thai waters - a national review of their status. Unpublished report by Marine Mammals of Indochina Research project, Thailand.

²⁵ Mohan, R.S.L. (ed). (1996) River dolphin news. Newsletter of the Ganges River Dolphin Protection Committee. No.1.

the eye that was considered a probable vessel collision injury (New Zealand Whale Stranding Database).

Hector's beaked whale *Mesoplodon hectori*

A young 3.1m male Hector's beaked whale washed ashore in Waikawau Bay, Hauraki Gulf, on 21 April 1992 (New Zealand Whale Stranding Database) with a propeller gash on the anterior dorsum which likely contributed to, if not caused, the animal's death. The inner Hauraki Gulf is well inshore of the usual deepwater habitat of mesoplodonts and the beaked whale may have been ailing when struck.

Arnoux's beaked whale *Berardius arnuxii*

One of us (AvH) examined the anterior half of an Arnoux's beaked whale, with the trunk and caudal part missing, at Riverton, southern coast of South Island, New Zealand, on 22 January 2006. The animal was found in a relatively fresh state (days before being photographed, Figure 13) and it had apparently been sliced in two ante-mortem by a large vessel. The likely negative buoyancy of a freshly dead Arnoux's beaked whale would have sunk it out of reach of vessels.

Discussion

This initial assessment summarises vessel collision records for 35 species. Of these, records were confirmed for 25 species (7 large whales, 18 small cetaceans) and unconfirmed but probable records were identified for 10 other species (2 large whales, 8 small cetaceans), an appreciable increase from earlier reports. Together, Laist *et al.* (2001) and Jensen and Silber (2004) reported collision records for 21 species. Few incidence rates of vessel-caused mortality are available partly because comprehensive stranding networks and long-term necropsy programmes are scarce in the SH.

Optimal assessments should be obtained for populations and areas where comprehensive photo-identification studies are combined with total coverage stranding networks. Several other biases may have to be adjusted for in models, but observational datasets necessary to support correction factors are currently not available. For example, a blunt impact by a ship's hull causing sub-lethal internal injuries could easily escape detection only if the whale would die during offshore migration.



Figure 13. The anterior body of an Arnoux's beaked whale at Riverton, New Zealand. When stranded it was in fairly fresh condition. A. van Helden took this photograph several days later when the body condition had deteriorated through decomposition and scavenging. The whale is thought to have been cut in half by a ship.

INCIDENCE IN SOUTHERN HEMISPHERE LARGE WHALES

In large whales of the SH, populations of three species, namely southern right, humpback and Bryde's whales suffer regular collisions with ships, but also sperm, blue, sei and fin whales are at least occasionally affected (Table 1). In blue whales both *B. musculus breviceauda* and a distinct stock, possibly *B. musculus* [Chile/Peru] subsp., are involved (see Van Waerebeek *et al.*, 1997; Branch *et al.*, 2007). Probable lethal cases exist for two other species, i.e. *B. bonaerensis* and *B. acutorostrata* subsp. [dwarf].

Except for the southern right whale off South Africa, in which an estimated 20% (CI 9-31%²⁶; including several 'possible' cases) of documented mortality in stranded and examined specimens is due to ship strikes (Best *et al.*, 2001), incidence rates cannot be estimated for other populations due to inconsistent and limited stranding response efforts. Indeed, awareness and reporting is very patchy in most areas. Recent deaths of *E. australis* due to ship collisions point to a potentially significant problem developing in coastal waters of Argentina, Uruguay and southern Brazil. Regulatory measures similar to those being developed in the NW Atlantic to reduce collision risks for North Atlantic right whales (*e.g.* Colborn *et al.*, 1998) may be needed. Only a single strike record is known for the Chile-Peru population, congruent with the scarcity of sighting records of southern right whales off western South America (Guerra *et al.*, 1987; Van Waerebeek *et al.*, 1998).

²⁶95% CI of incidence, estimated by normal approximation rule to the binomial.

Table 1. Species composition of the experimental database of vessel collision records (N= 256) used in this study, covering large whales of the Southern Hemisphere and small cetaceans worldwide.

	Total records	Conf	Unconf	Large areas
Large whales of Southern Hemisphere				
<i>Balaenoptera acutorostrata</i>	2	0	2	Australia, New Zealand
<i>Balaenoptera bonaerensis</i>	1	0	1	Australia
<i>Balaenoptera bonaerensis/acutorostrata</i>	1	0	1	New Zealand
<i>Balaenoptera borealis</i>	4	2	2	New Zealand
<i>Balaenoptera brydei</i>	13	5	8	Australia, Ecuador, New Zealand
<i>Balaenoptera musculus</i>	5	2	3	Australia, New Zealand, Peru
<i>Balaenoptera physalus</i>	2	1	1	Chile
<i>Balaenoptera</i> sp.	2	1	1	Chile
<i>Eubalaena australis</i>	56	48	8	Argentina, Australia, Brazil, Chile, South Africa, Uruguay
<i>Megaptera novaeangliae</i>	15	9	6	Australia, Antarctic Peninsula, Costa Rica, Ecuador, Peru, Ivory Coast, South Africa
<i>Physeter macrocephalus</i>	8	1	7	Chile, Peru, Ecuador, New Zealand
Unidentified large whale	10	10	0	Australia, Chile, Ecuador, Peru
subtotal	119	79	40	
Small cetaceans worldwide				
<i>Berardius aruxii</i>	1	0	1	New Zealand
<i>Cephalorhynchus hectori</i>	2	2	0	New Zealand
<i>Cephalorhynchus commersonii</i>	1	1	0	Argentina
<i>Delphinus delphis</i>	4	2	2	New Zealand, UK
Dolphin (unidentified)	4	3	1	Australia
<i>Globicephala macrorhynchus</i>	6	5	1	Canary Islands (Spain)
<i>Globicephala melas</i>	2	0	2	Chile, Spain
<i>Kogia breviceps</i>	6	0	6	Australia, Canary Islands (Spain)
<i>Lagenorhynchus albirostris</i>	1	0	1	UK
<i>Lagenorhynchus australis</i>	1	1	0	Chile
<i>Lipotes vexillifer</i>	1	1	na	China (Yangtze River)
<i>Mesoplodon grayi</i>	1	1	0	New Zealand
<i>Mesoplodon bowdoini</i>	1	0	1	New Zealand
<i>Mesoplodon hectori</i>	1	1	0	New Zealand
<i>Phocoena phocoena</i>	3	1	2	The Netherlands, UK
<i>Phocoena spinipinnis</i>	1	0	1	Chile
<i>Platanista gangetica</i>	1	0	1	India/Bangladesh border (Brahmaputra river)
<i>Orcaella brevirostris</i>	18	2	16	India
<i>Orcinus orca</i>	8	6	2	Canada, New Zealand
<i>Neophocaena phocaenoides</i>	4	4	0	Hong Kong, Thailand
<i>Sotalia guianensis</i>	2	2	0	Brazil
<i>Sousa chinensis</i>	6	4	2	Australia, China, Hong Kong
<i>Stenella frontalis</i>	1	1	0	Bahamas
<i>Stenella longirostris</i>	1	1	0	Brazil
<i>Stenella coeruleoalba</i>	7	0	7	Italy
<i>Tursiops</i> sp.	4	4	0	Australia
<i>Tursiops truncatus</i>	41	23	18	Australia, Chile, Belgium, Costa Rica, Ecuador, Italy, USA
<i>Ziphius cavirostris</i>	7	2	5	Canary Islands, New Zealand, Spain (Gulf of Cadiz)
Ziphiid (unidentified)	1	0	1	Spain
subtotal:	137	67	70	

The humpback whales reported from Ivory and Costa Rica belong to SH populations. Although no specific cases were identified, vessel collisions are widely reported to be a main threat to the baiji *Lipotes vexillifer*. This was recognised by allocating a single positive record for this species. Records from Italy were summarized from published national stranding records provided by G. Lauriano (ICRAM).

The lack of stranding records of southern right whales connected with shipping accidents in Australasian waters is likely due to the fact that presently this species is rare and its aggregation grounds lie primarily outside the major ports and shipping channels of southern Australia and New Zealand.

With only two documented collision records for SH fin whales, collision mortality might be small compared to that for the Mediterranean fin whale, where 16% of 287 carcasses (CI 11.7-20.3%) were attributed to ship strikes (Panigada *et al.*, 2006). However, only few stranded fin whales have been examined by scientists in the SH, and at least some of 12 unidentified struck *Balaenoptera* sp. or 'large whale' (Table 1) may have been fin whales. Only four collision records involving minke whales were identified in the SH, none fully confirmed, which is consistent with the scarcity of reports also in the NH.

The sperm whale is the large odontocete most commonly killed or injured by ships in the NH (Laist *et al.*, 2001; Jensen and Silber, 2004) and the Canary Islands may represent a particular problem area (André *et al.*, 1994, 1997; Tregenza *et al.*, 2002; Lens *et al.*, 2005⁶). Shipping lanes have been re-routed in the Strait of Gibraltar to reduce the risk to sperm whales (de Stephanis and Urquiola, 2006). In the SH, possible collision cases were reported from Ecuador and Peru (Haase and Félix, 1994; Félix and Van Waerebeek, 2005).

INCIDENCE IN SMALL CETACEANS

Vessel collisions have been confirmed for 18 small cetacean species: killer whale, short-finned pilot whale, common bottlenose dolphin, Indo-Pacific humpback dolphin, short-beaked common dolphin, Irrawaddy dolphin, Hector's dolphin, Commerson's dolphin, Guiana dolphin, Peale's dolphin, Atlantic spotted dolphin, spinner dolphin, finless porpoise, harbour porpoise, baiji, and Cuvier's, Hector's and Gray's beaked whales. Collision records for eight other species are considered probable.

Inshore, estuarine and riverine species are the most commonly and most severely affected, up to a degree that amounts to a significant threat to species survival. The combined pressure of collisions and bycatches has driven *L. vexillifer* to virtual extinction (Guo, 2006), which should serve as a warning for any management and conservation strategy of the Ganges river dolphin even though only one collision has been documented. The same may be true for the Indus river dolphin *Platanista gangetica minor* although no documented cases are available.

Finless porpoises of the Yangtze River are thought to be significantly impacted, as are at least two populations of Indo-Pacific humpback dolphins in China (Xiamen and Pearl River/Hongkong). Evidence of blunt traumatic injury, consistent with boat collisions, was found in 3 of 32 (9.4%, upper CI 19.5%) finless porpoises

necropsied from the Hong Kong area between 1993 and 1998 (Jefferson, 2000b). Also, 3 of 28 *S. chinensis* carcasses (10.7%, upper CI 22.1%) from the same area showed such trauma (Jefferson, 2000a; Jefferson *et al.*, 2006). Baldwin *et al.* (2004) expressed concern about Arabian Gulf humpback dolphins *Sousa plumbea* given the high level of shipping traffic in the Gulf. Unfortunately there is no monitoring system in place for that area.

Marked boat-aversion may offer some protection even in neritic habitats. No confirmed incidents exist for three species that exhibit vessel avoidance behaviour, *i.e.* Atlantic humpback dolphin *Sousa teuszii* (Van Waerebeek *et al.*, 2004), franciscana dolphin *Pontoporia blainvillei* and Burmeister's porpoise. Limited reporting and incomplete necropsies may account for the absence of records for vulnerable, river-dwelling species such as *Platanista minor*, the Amazon river dolphin (boto) *Inia geoffrensis* and tucuxi *Sotalia fluviatilis*.

Boat-based tourism is an established hazard to dolphins, and impacts on commercially 'watched' populations of inshore common bottlenose dolphins, Irrawaddy dolphins (*e.g.* Chilika Lagoon), spinner dolphins (*e.g.* Fernando de Noronha Archipelago) and Guiana dolphins must be closely monitored.

At least three, and possibly five, beaked whale species are documented to have been struck. Despite spending a short proportion of their time close to the surface, repeated ventilation after surfacing from long, deep dives may put ziphiids at risk. Anaerobic physiological stress could compromise avoidance capabilities including evasive fast diving. Similarly, the highest risk to right whales is also thought to occur when emerging under a vessel from a dive (Nowacek *et al.*, 2001). Beaked whales have a low probability of being detected visually, compromising any potential avoidance manoeuvres by the vessel (Barlow and Gisiner, 2006).

No incidents are reported for a number of oceanic and pelagic dolphin species (*e.g.* *Lagenodelphis hosei*, *Peponocephala electra*, *Feresa attenuata*, *Pseudorca crassidens*, *etc.*) Given dispersed vessel traffic in pelagic areas, if collisions do occur they are likely to be infrequent and pose a negligible risk.

Sublethal encounters with cetaceans have infrequently been estimated, although existing photo-identification catalogues may be good data sources. Estimates are best obtained from long-term photo-identification studies and monitoring of bycatches or directed takes. Three of 236 bowhead whales (1.27%; upper CI 2.7%) in the Alaskan subsistence harvest of 1976-1992 had ship-caused injuries (Shelden and Rugh, 1995). This interaction may rise with increased shipping, for example if the Northwest Passage becomes a regular maritime corridor as ice cover retreats with global warming (Hansen, 2007). Three of 150 (2.0%) critically endangered western gray whales showed scars indicating that they had survived at least one vessel collision (Bradford *et al.*, 2007). Circa 2% of common

bottlenose dolphins in the Gulf of Guayaquil showed severed or otherwise mutilated dorsal fins, flukes or had large scars along the dorsum. Both damage from propellers and fishing gear are possible causes and distinguishing injuries is often difficult. In New Zealand, 1.71% (2/117; CI 0-4.1%) of photo-identified killer whales had deep scars attributed to boat propeller hits (Visser, 1999).

WIDE RANGE OF POTENTIAL IMPACT

In the NH, the North Atlantic right whale appears to suffer the highest collision incidence in relation to population size. Of 50 documented *E. glacialis* mortalities between 1990 and 2006, 22 (44%) were caused by ship collisions versus 6 deaths (12%) from fishing gear entanglement (Marine Mammal Commission, 2007). The NW Pacific stock of gray whale *Eschrichtius robustus* is also threatened (Brownell *et al.*, 1999; Moore and Clarke, 2002).

In SH large whales, population level impact from collisions cannot be currently assessed with any precision because of the uncertainty about incidence of vessel-caused mortality and in some cases also the lack of recent abundance estimates. Evidence does suggest that impacts may vary widely depending on the species and population. This study identified 56 collision reports (many lethal) for the southern right whale in six range states, suggesting that this species is the most severely impacted SH large whale. This situation should be carefully monitored taken into account that the long-term survival of the North Atlantic right whale is directly compromised by collisions (Kraus, 1990; IWC, 2001; Knowlton and Kraus, 2001; Moore *et al.*, 2004). Concern should be raised also for SH humpback and Bryde's whales (each with 13 collision reports) and sperm whales (8 reports) and their status in relation to ship traffic should be closely monitored.

In small cetaceans, at the high end of the possible impact range are populations whose distribution includes areas of high levels of ship traffic and where collisions can directly compromise long-term survival. In this paper we suggest that at least two populations of each Indo-Pacific humpback dolphin (Xiamen and Hong Kong/Pearl River), Irrawaddy dolphin (Mahakam River and Chilika Lagoon), finless porpoise (Yangtze River and HongKong/Pearl River), as well as an inshore common bottlenose dolphin population in Chile (Sanino and Yañez, 2005; Sanino *et al.*, 2005) and Hector's dolphin are likely impacted significantly. For endangered dolphin species like the Ganges river dolphin *P. gangetica* (EN)⁴, a few mortality events may exert a significant negative impact on future survival. This understanding comes too late for the baiji, now practically extinct (Guo, 2006). All highly impacted

species have a nearshore, neritic, estuarine or fluvial habitat, areas where vessel traffic is concentrated due to the presence of ports.

Species that may receive a moderate impact from collisions but which may be sustainable at species level because many strikes are non-lethal, include common bottlenose dolphins (LR/lc)²⁷, killer whales (LR/cd), short-finned pilot whales (LR/lc) and pygmy sperm whales. At the low end of the impact range are 16 non-endangered small cetacean species with only few reported vessel strikes: Peale's dolphin (DD), white-beaked dolphin (LR/lc), short-beaked common dolphin (LR/lc), Guiana dolphin (DD), Commerson's dolphin (DD), Atlantic spotted dolphin (DD), spinner dolphin (LR/cd), striped dolphin (LR/cd), long-finned pilot whale (LR/lc), Burmeister's porpoise (DD), harbour porpoise (VU), Cuvier's beaked whale (DD), Gray's beaked whale (DD), Andrew's beaked whale (DD), Hector's beaked whale (DD) and Arnoux's beaked whale (LR/cd).

Three general caveats, however must be noted. First, the current levels of collision incidence, and impact potential, may change abruptly with modifications in traffic patterns and intensity. Second, the aggregated effect from all forms of disturbance resulting from vessel traffic (*e.g.* high-amplitude underwater noise, permanent separation of mothers and calves, etc., in addition to collisions) may still be significant. Third, available data and stranding monitoring efforts are still vastly insufficient for most species to allow any reliable assessment.

GLOBAL STANDARDISED DATABASE

Despite increased research in a few NH species, including North Atlantic right whale (*e.g.* Nowacek *et al.*, 2001, 2004), humpback whale (Wiley *et al.*, 1994; Laist *et al.*, 2001; Lammers *et al.*, 2007) and fin whale (*e.g.* Panigada *et al.*, 2006), a general lack of understanding of the circumstances and factors that cause vessels to collide with cetaceans can at least in part be traced back to a shortage of authenticated datasets. In addition, small cetaceans and nautical information for the colliding vessels are rarely addressed, and information is limited to the few areas where reporting systems exist, and even there is considerable underreporting suspected.

During the compilation of the experimental database we encountered a vast heterogeneity in parameters, terminology, observer expertise, details, and authentication in both published and unpublished sources. Difficulty with comparative analysis led to a proposal for a comprehensive upgrade towards a fully standardised global database that clearly identifies the level of uncertainty for individual records (IWC, 2007).

²⁷ IUCN Red List of Threatened Species status: LR/lc (lower risk/least concern), LR/cd (lower risk/conservation dependent), DD (data deficient), VU (vulnerable). See <http://www.redlist.org/search/search-expert.php>.

Since management measures considered by the International Whaling Commission require estimation of all sources of human-induced mortality, its Scientific Committee (specifically, the Vessel Strike Data Standardization Group) was requested to take steps to set up a global data repository. A draft template was presented in May 2007 at the 59th Annual IWC Meeting (Van Waerebeek and Leaper, 2007) and was agreed upon with minor modifications.

A consistent, comprehensive worldwide database combining both biological and vessel data should ultimately lead to more accurate estimates of the incidence of mortality and injuries, help detect trends, allow better modelling of risk factors including vessel type and speed, point to causative or predisposing factors and reveal unsuspected collision 'hot spots'. The relational database which consists of five separate raw data tables²⁸ is designed to function as a global standard for archiving ship strike data. It is envisioned that once fine-tuned and widely available the template (or a simplified version) will allow observers, mariners and researchers to submit new records in a format that can then be screened and validated. The database will also be populated with 'historical' information from publications, reports and other unpublished sources. Primary sources may be contacted to retrieve previously unreleased, archived information.

Some key factors that would benefit from species-specific analysis of variation may include the following:

Effects of age and sex. Species that use neritic waters for calving and nursing may be more vulnerable to collisions during these periods. For instance, vessels are urged to use special caution while transiting the southeast US coast during the North Atlantic right whale winter calving season (15 November–15 April), when mother/calf pairs are present in the proximity of shore (Knowlton *et al.*, 1997). Partly due to inexperience, calves, juveniles and perhaps subadults, as well as nursing females, might be more prone to accidents (Laist *et al.*, 2001).

Effects of habituation. Recurring swim-with-dolphin activities in open waters and whale/dolphin watching are thought to increase tolerance of humans and vessels, disrupt natural behaviour and increase the animals' vulnerability to vessel strikes (*e.g.* Samuels *et al.*, 2000; Samuels and Bejder, 2004; Camargo and Bellini, 2007). Dolphins may be more capable of avoiding collision if a vessel's course is predictable and if there is adequate room or depth for escape. Such conditions are often violated by dolphin-watching platforms. Dolphin tourism programmes should be assessed individually for risk, allowing for considerable variability. Whales also may become habituated to boat noise, forgo

avoidance manoeuvres and even approach watercraft making accidents far more probable (*e.g.* Visser, 1999; Samuels *et al.*, 2000; Samuels and Bejder, 2004). Thus, habituation linked to boat-based cetacean tourism could be a significant anthropogenic factor for collisions.

Impact of sublethal traumata. The clean-cutting traumata and multiple parallel incisive injuries and scars encountered in increasing numbers of free-ranging small cetaceans is diagnostic evidence that boat propellers may be a major hazard. The left-leaning trailing part of bisected dorsal fins (Figures 8 and 12) suggests the slashing by a right-handed propeller²⁹ when a dolphin travels in the same direction as the boat. Sublethal injuries would reduce fitness through a number of negative health consequences. These may include weakness from haemorrhage and opportunistic infections, stress-induced immunity impairment and hampered movements resulting in compromised foraging efficiency, predator avoidance and reproductive fitness. Adequate datasets should shed light on the relative importance of such factors. Strikes that appear sublethal may eventually lead to death (*e.g.* Camargo and Bellini, 2007). We reiterate the recommendation of others that propeller guards should be installed on boats that are in regular contact with cetaceans (Visser, 1999; Sanino and Yañez, 2000), and should be made compulsory for all commercial dolphin watching or swim-with platforms, coupled with research to investigate the most effective designs for such guards.

Post-mortem strikes. A delicate technical predicament concerns the positive diagnosis of death from collision. Floating carcasses may be damaged, potentially confounding interpretations of traumatic lesions, especially when in advanced decomposition (state 4 or 5). However with the exception of Balaenidae (Slijper, 1979; Nowacek *et al.*, 2001), most cetaceans sink immediately after death and resurface, belly-up, only after bloating sets in. The likelihood for a ship to collide with a floating carcass that, if significantly bloated can be spotted by naked eye or radar from a great distance, needs to be evaluated. If a post-mortem collision occurs, the damage can often, but not always, be differentiated from ante-mortem traumata. Post-mortem damaged carcasses (again, Balaenidae excepted) would rarely strand in fresh state because bloating and floating require some degree of decomposition. Massive dorsal injuries, haemorrhaging and fat emboli in the lumina of pulmonary vessels are indicative of *in vivo* impact trauma (Hare and Mead, 1987; Félix and Van Waerebeek, 2005; Fernández *et al.*, 2005³⁰). Improved awareness, necropsies-to-the-bone, new histological techniques and standardised data recording should further help ensure that a higher percentage of carcasses are correctly diagnosed.

²⁸ Including a Record Manager, Specimen on Shore, Specimen at Sea, Incident at Sea and Whale Stuck on Bow.

²⁹ A right-handed propeller (the most common type) in forward motion turns clockwise when viewed from astern.

³⁰ Fernández, A., Arbelo, M., Sierra, E., Castro, P. and Méndez, M. (2005) Cetaceans, ship collisions and histopathology. Abstract presented in Ship Collision Workshop, Monaco (unpublished).

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