Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere; building a standardized database

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ABSTRACT

We compiled and reviewed 248 cases of reported vessel collisions with small cetaceans worldwide and with large cetaceans in the Southern Hemisphere. Difficulties were encountered with the comparison of highly variable data in terms of quality (evidence), sources, detail and degree of authentication. It is recommended that wide agreement be reached on a minimum dataset template. We propose 25 standardized parameters, including an essential 'probability tag' (confirmed, probable, possible and indeterminate) that categorizes likelihood of vessel strike as evaluated by the original observer(s). Since the time-consuming process of fact-checking and standardizing is ongoing, any elaborate quantitative analysis is premature. Among baleen whales in the Southern Hemisphere, ship collisions have definitely accounted for deaths of southern right, blue, sei, fin, Bryde's and humpback whales. In South Africa, an estimated 20% of mortality in *Eubalaena australis* is due to vessel strikes (Best *et al*., 2001). Accumulating evidence suggests the problem to be severe also in Argentina, Brazil and Uruguay, but small samples impede estimation of incidence. Odontocetes regularly affected include sperm whale, killer whale and common bottlenose dolphin. At least one or a few vessel strikes are documented for 19 species of small cetaceans (several for the first time): *Kogia breviceps*, *Orcinus orca, Globicephala melas, G. macrorhynchus, Tursiops truncatus, Sousa chinensis, Orcaella brevirostris, Cephalorhynchus hectori, C. commersonii, Lagenorhynchus australis*, *Stenella frontalis*, *Neophocaena phocaenoides, Phocoena spinipinnis*, *Phocoena phocoena*, *Lipotes vexillifer, Platanista gangetica*, *Ziphius cavirostris*, *Berardius arnuxii* and *Mesoplodon grayi*. Three species with suspected involvement in accidents include *Sousa plumbea*, *Mesoplodon hectori* and *M. bowdoini*. For some 11 small cetacean species the effect of collisions on populations is thought to be insignificant. Among estuarine species, at least two populations of each *S. chinensis* (Xiamen and Hong Kong/Pearl River) and *O. brevirostris* (Mahakam River and Chilika Lagoon) are significantly impacted. Mahakam population mortality is definitely not sustainable (2.9% minimum annual mortality). For *L. vexillifer* of the Yangtze river and *P. gangetica*, because of extremely low population numbers, even a very few mortalities may reduce likelihood of future survival. In Hong Kong's *N. phocaenoides*, 9.4% of carcasses showed blunt traumatic injury consistent with boat collisions. Two calves *C. hectori* were killed by boats near Banks Peninsula in 1999, a major concern considering its endangered status. Around 2% of *T. truncatus* in the Gulf of Guayaquil showed scars and mutilations of dorsal fins, caused at least partly by propellers. Boat based dolphin-watching, such as in Chile and Costa Rica may adversely affect local *T. truncatus* populations. Overall, considering the high incidence of injuries and mortality caused by propellers, a much wider use of propeller guards is advised.

Keywords: CETACEANS; WORLDWIDE; SHIP STRIKE; PROPELLER STRIKE; MORTALITY; SOUTHERN HEMISPHERE

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INTRODUCTION

Collisions between ever faster and larger vessels and unwary cetaceans have only recently been fully recognized as a source of anthropogenic mortality and injury, equivalent to bycatch, that needs to be assessed and quantified. Except for a very few areas and populations, the lack of a historical record compromises attempts of evaluating time series and trends. Even well-studied species like bowhead whales *Balaena mysticetus* were long unknown to occasionally be struck by vessels (see Reeves and Leatherwood, 1985), the first indications of which surfaced only about a decade ago (Philo *et al.*, 1993; George *et al.*, 1994; Finley, 1999). Further, the problem is often perceived as being largely constrained to the northern hemisphere, and particularly in the North Atlantic Ocean and the Mediterranean Sea. We suggest here that a positive bias in monitoring and reporting may explain this discrepancy, and we show that the impact is truly global. Another common perception implies that mostly large whales are affected, while emerging evidence demonstrates that many species of small cetaceans fall victim, or are hurt, by intense maritime traffic.

An urgent task then from a global management point of view, consists of verifying which species and populations may be suffering collision mortality and injuries to a degree as to potentially present a significant threat to population status. Alternatively, for which cetacean taxa do collisions (due to their rarity) likely exert only a negligible effect. This paper aspired to answer some of these basic but vital questions, however coinciding population data and ship-caused mortality are rarely available, and that at this point mostly qualitative appraisals are possible. Still, these constitute useful guidance for future research.

Small cetaceans are especially sensitive to disturbance and effects from high-speed boats (e.g. jet-skis). Possible effects of leisure boats and ships may include strong underwater noise, which disturbs the communication and acoustic navigation of small cetaceans, the risk of collision with high-speed boats, which can hardly be located, and disturbance causing permanent separation of mother and calf. Little direct evidence is published on the effects of vessel traffic on dolphins and porpoises, but collisions with motorized vessels can kill or seriously injure small cetaceans. The latter are not always able to detect and avoid oncoming traffic (Reeves *et al.*, 1997) or, if they do, are likely unaware of the danger posed by propellers for instance.

A proper assessment of the collision problem is thwarted by a number of inherent obstructions, some technical, others of regulatory nature. The most severe is the shortage of adequately documented cases. Non-reporting by ship crews is still the rule rather than the exception for, in most countries reporting obligation either does not exist or is not enforced. If recorded at all, information typically is buried in largely inaccessible ship's logbooks.

As to allow meaningful quantitative analysis or modeling, a second predicament needs to be tackled, which is the shortage of truly comparable datasets, the result of non-standardized data collecting. In this paper we propose to agree on a minimum set of necessary parameters to be recorded in a standardized way.

Finally, correct diagnosis of cause of death in, often decomposed, carcasses is difficult and sometimes impossible. Floating carcasses can be struck by vessels, possibly confounding interpretations of some traumatic lesions during necropsies. Criteria must be robust and limitations of present methodology recognized as to avoid 'collision' becoming a convenient default for unexplained mortality.

MATERIAL AND METHODS

The authors compiled and critically reviewed 246 confirmed and suspected cases of vessel collisions with small cetaceans world-wide and collisions with large cetaceans in the Southern Hemisphere according an agreed database template. The resulting initial 'Vessel Collision Database' (VCD) including 25 parameters (Table 1) is proposed as a precursor for a standardized global database, provisionally maintained and updated at the Museo de Delfines, Pucusana, Peru.

Definition of vessel strike applied here is a collision between any part of a watercraft and a *live* cetacean, often resulting in life-threatening trauma or death. While usually the impacting movement is the vessel's, in some cases a cetacean may bump into a vessel, or a combination of both. Impact, typically accidental, appears most commonly initiated by violent contact with the bow or propeller. Contact with fishing gear, sometimes equivocally referred to as 'collisions' must be considered bycatch.

When compiling information predating this study, it became clear that *a priori* collection and recording often meant comparing data heterogeneous in parameter definition, quantity (detail) and, most importantly, reliability. Some cases were documented under rigorous scientific standards while others, when original source was pursued, evidence resulted wanting or was misinterpreted. In fact, not the heterogeneity in itself was problematic, but the lack of a consistent quality or probability tag by originators, including some published sources. A renewed attempt to screen reported cases for consistency by checking original sources, is very time-consuming. With this standardizing process still ongoing, any elaborate quantitative analysis of the VCD database is premature.

'Evidence level' was introduced as the leading categorical variable to determine the usability of each record. Probability tags, estimated from best available evidence, were defined as: 'confirmed' (100%, authenticated), 'probable' (90-99% probability), possible (50-90%) or indeterminate. The latter covers the two most common uncertainties: whether a known collision occurred antemortem or postmortem; and whether a healed scar was caused by a collision, a net entanglement or some other cause. While 'possible' accounts in the database may be useful in assessing the widest potential scope of the problem, they cannot be considered good data.

Parameter	**syntax**
Evidence level	confirmed, probable, possible, indeterminate
Species	scientific name
Standard length	xx.xx metres
Sex	M/F
Collision type	bow bulb draping, propeller hit, collision (indeterminate)
Vessel type	fast ferry, container vessel, navy, whale-watching, tanker, sailboat, etc.
Vessel length	in metres
Vessel name	nominal
Vessel speed at collision	knots
Cruising speed	normal speed steaming (knots)
Ocean province	NE, NW, SE, SW Ocean
Nation EEZ	Exclusive Economic Zone
Large area location	general area name
Small area location	specific area name
Date of collision	xx.Month.Year
Date of reporting	xx.Month.Year
Latitude	xx°xxx.xx' N/S
Longitude	xx°xxx.xx' E/W
Circumstance	descriptive (at sea, stranded, in port, indeterminate, etc.)
Evidence of collision	descriptive
Lethal	yes, no, indeterminate
Postmortem type	complete PM, visual inspection, indeterminate, none, not applicable (NA)
Comments	descriptive
Vessel damage	descriptive
Source	data collector, reference

Table 1. Proposed 25 minimum required parameters for a standardized Vessel Cetacean Collision Database.

We identified four types of vessel strikes:

- *Collisions (indeterminate) with bow or hull*

Vessel collisions can leave characteristic blunt trauma from mostly bow impact, but any part of the hull may be involved. Major skull and postcranial bone fractures are common.

- *Bow bulb draping*

Balaenopterids, but apparently no other species, occasionally become wedged, draped across the bow, after colliding with large vessels with not fully submerged bow bulbs. Cases have been documented in varying detail for (in declining frequency) fin whale, blue whale, Bryde's whale and sei whale (e.g. Jensen and Silber, 2004; Norman *et al.*, 2004; Félix and Van Waerebeek, 2005).

- *Propeller hits*

Sergeant (1979) first recognized that injuries caused by boat propellers are often significant and may cause death. Vessel collisions can leave characteristic propeller slashes (Morgan and Patton, 1990; 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 speed of the boat, the size of the propeller, and the posture and speed of the animal when hit. These wounds typically have several to many 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 an individual and related to the size and pitch of the propeller. Location and appearance of a boat collision trauma can help determine if the collision occurred ante- or postmortem. Dolphins do not typically expose their underside to the surface where it would be vulnerable to propellers. Pre-mortem propeller wounds are not expected on the belly (Morgan and Patton, 1990). Kraus (1990) argued convincingly that whale carcasses with propeller marks on the dorsum, or with severed flukes, were most likely hit when alive. Dead whales floating due to positive buoyancy (right whales) or decomposition gases are typically belly-up with tail and flukes hanging down in the water column. In this spatial configuration it is unlikely for ship propellers to damage the aforementioned body parts.

- *Cetacean hitting vessel*

Some cetaceans may violently hit or push vessels. One particular case refers to a 'porpoise'[2] in Australia when it jumped on top of a launch to escape a killer whale attack (Australian Government, unpublished data).

Information on ship collisions with whales from Argentina is supported by aerial survey photographs in the WCI/OA right whale database (Right Whale Program, Whale Conservation Institute). Most records from New Zealand are listed in the New Zealand Whale Stranding Database (NZWSD) however in different formatting.

Confidence intervals (95%CI) for collision incidence (proportions) were estimated by the Normal Approximation rule to the Binomial.

RESULTS

Of the 248 vessel collision records in the VCD on 1 May 2006, 78 (31%) refer to small cetaceans of the world and 170 (69%) are large whales of the Southern Hemisphere. Although frequency distribution continues to fluctuate as additional information may 'solve' indeterminate accounts or uplist others (possible, probable), an approximate 54% are confirmed collision records, 19% are probable cases and 26% are possible cases.

[2] most probably a Delphinidae (not Phocoenidae)

1. Species with documented vessel strikes

Eubalaenidae

Southern right whale *Eubalaena australis*

A review of stranding records from 1963-1998 in South Africa (Best *et al.*, 2001) identified ship collisions as a known or possible cause in 11 of 55 of recorded deaths, or 20%. Fifty-five percent (6 of 11) of the ship strikes 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).

The lack of stranding records of southern right whales connected with shipping accidents in Australasian waters is thought to be explained because, presently, this species is rarely found in the major ports and main shipping channels of southern Australia and New Zealand; prior to the 1850's these areas were part of their range and were used as nursery/calving grounds (Richards, 2002; F. Michaellis, pers. comm.). Also, the species is only found on New Zealand's mainland coast between August and October, and is uncommon.

Off Uruguay, one whale was found near Portezuela, Maldonado, in September 2005 with three 2.0x0.1m cuts and without its tail. Another stranded specimen near La Barra, Maldonado, had its occipital bone parted in two (photo available by R. Garcia-Pingaro). Some 3nm from shore a pipeline buoy is present where large tankers anchor. This area is one of high density of southern right whales.

In Argentina, Rowntree *et al.* (2001) first revealed collisions: eight southern right whales presented injuries that seem inflicted by small boat propellers. More recently, two juveniles were sighted off Patagonia (18 Oct 2000 and 7 Oct 2001) with evident propeller scars on their back. Another individual off Caleta Olivia, Santa Cruz (reported 24 August 2003) showed extensive dorsal bruising.

Two propeller-slashed specimens washed ashore dead in Rio Grande do Sul State, Brazil, one a 12.5m male (Figure 1) and the second, a young specimen. Greig *et al.* (2001) suggest that several factors may explain the relatively high number of stranding events in this southernmost State compared with the major breeding ground in Santa Catarina. They believe to include: (1) increased use by whales, possibly as breeding ground; (2) exposed open coast that favours stranding events [seems an unlikely factor] and (3) greater probability of collisions with fishing and cargo vessels.

Fig. 1. Stranded carcass of 12.5m southern right whale in Rio Grande do Sul, Brazil, showing (inset) deep propeller slashes (Photos E. Secchi).

Balaenopteridae

Humpback whale *Megaptera novaeangliae*

In Bahía Drake on the Pacific coast of Costa Rica, two incidents of collision between calf humpback whales and 7-9m boats, one each in 2002 and 2005, were mentioned by Sierra Goodman (pers. comm. to P. Cubero-Pardo; *in litt.* to KVW, 24.01.2006).

In Pacific Colombia, at least three fatal collisions with vessels were reported in the period 1986-2000 (Capella *et al.*, 2001). Catalogues of photo-identified humpback whales curated by several research groups in Colombia and Ecuador revealed defiguring but non-fatal accidents. For instance, Figure 2 shows four probable victims, three whales with an entire fluke missing and an adult female with three parallel healed scars on the anterior dorsum.

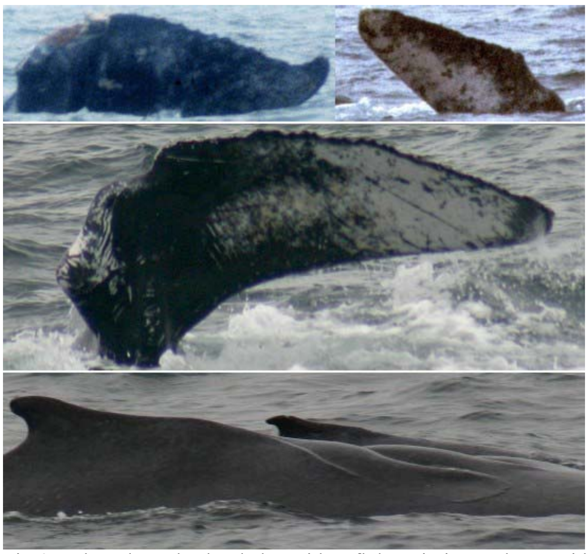

Fig 2. Three humpback whales with a fluke missing and one with parallel scars on the back recorded off Ecuador. (Photos courtesy of Pacific Whale Foundation [upper left] and Fundación Ecuatoriana para el Estudio de Mamíferos Marinos FEMM [others]).

E. Secchi sighted an adult humpback whale with apparent propeller scars on its upper dorsum in Gerlache Strait, Antarctic Peninsula, in January 2006 (Figure 3).

Fig. 3. Humpback whale with propeller scars on dorsum; Gerlache Strait, Antarctic Peninsula (Photo courtesy A.F. Azevedo)

Bryde's whale *Balaenoptera brydei*

Collisions with Bryde's whales have been considered uncommon -a NOAA database contains only three cases worldwide (Jensen and Silber, 2004). However, severe underreporting from (sub)tropical regions where Bryde's whales occur may explain this, considering that recent accounts suggest regular accidents.

Extensive haemorrhaging in a fresh Bryde's whale draped across the bow bulb of a container ship in Ecuador, demonstrated it collided alive (Félix and Van Waerebeek, 2005). In Brazil, two dead Bryde's whales were reported. A 4m fresh calf stranded in Bahía de Sepetiba, Rio de Janeiro, on 15 September 2005, with deep propeller gashes on its head (Salvatore Siciliano, pers. comm. to KVW) and another individual (Figure 4) was found dead with massive propeller injuries in the Patos Lagoon estuary, Rio Grande do Sul State (southern Brazil).

Bryde's whales have been struck by ships travelling to or from Auckland's busy commercial port, in the Hauraki Gulf, New Zealand (NZ Whale Stranding Database; Mike Donoghue, pers.comm.). Up to six confirmed and possible Bryde's whales may have been killed by vessels in New Zealand in 1999-2003.

One Bryde's whale was killed by a ship (confirmed by postmortem) in the Canary Islands in 2000 (Government of Spain, 2002).

Fin whale *Balaenoptera physalus*

Mortality is important in the North Atlantic, and especially in the Mediterranean Sea (Panigada *et al.*, 2006). Norman *et al.* (2004) report three fin whales stranded in Puget Sound, Washington, which had been struck by ships and were presumably carried into the sound. In the Southern Hemisphere, a single possible case is reported, from Quinteros, Chile, in 2004 (Sanino and Yañez, 2004).

Sei whale *Balaenoptera borealis*

Reports of ship strikes with sei whales are uncommon. The 2004 NOAA database contains only three cases world-wide (Jensen and Silber, 2004). A fourth sei whale was killed by a container vessel between the Canary Islands and Dakar (Félix and Van Waerebeek, 2005). Two dead sei whales were carried into the port of Auckland, New Zealand, on container ships' bow bulbs, one in 1993 and another in 2001, and another with suspected ship-caused injuries was found ashore in North Auckland in 1993 (NZ Whale stranding database). The global lethal count is therefore six sei whales.

Blue whale *Balaenoptera musculus*

Even world-wide, very few cases are known. There is one documented case of a bow-drape in the NE Pacific, a 16.2m female was carried along by a freighter, but the strike was theorised to have occurred off California along the freighter's route (Norman *et al.*, 2004). In Chile's Gulf of Corcovado, a collision between a 20m boat and a blue whale was reported by an anonymous salmon farm worker during February 2005 (Hucke-Gaete *et al.*, 2005). This incident is some cause of concern because of a projected increase in boat traffic in the area, including from whale-watching boats. The subspecific status of this specimen is unknown.

One blue whale, also of indeterminate subspecific status, that beached alive badly injured in Peru in 1997 was possibly hurt by a vessel (Van Waerebeek *et al.*, 1997).

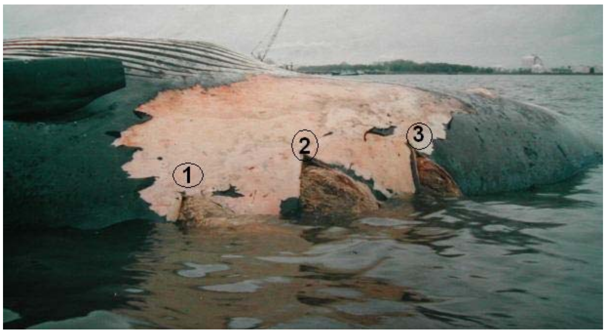

Fig. 4. Bryde's whale with three huge propeller slashes exposing epaxial muscles, Rio Grande, Brazil. (courtesy Lauro Barcellos, Museu Oceanográfico "Prof. Eliézer C. Rios").

Pygmy blue whale *Balaenoptera musculus brevicauda*

A male pygmy blue whale of 20.6m was brought into the port of Auckland, New Zealand in 1995. The intact epiderm, colouration, and baleen plates attached in palate indicated the whale was fresh when hit. The whale showed tooth rakes by killer whale on its flippers and flukes. Considerable damage to much of the postcranial skeleton needed repair when the specimen was put on display in the Museum of New Zealand. The whale was almost certainly hit at about the height of the right flipper, as the right radius was pulverised. Baleen (ratio of length/height) and dorsal fin placement was consistent with pygmy blue whale. Photos of the animal on the beach to which it was towed, as well as video of the animal wrapped around the bow are in the archives of one of us (AvH).

On 31 January 1998, one of two individuals sighted off Chañaral Island, Chile (29º1.59'S, 71º33.91'W), presented half of the left fluke missing. The cut surface was straight, parallel with body axis and was attributed to a probable propeller hit from a large vessel. On 4 February 2005, a single individual was sighted nearby the same island (29º1.14'S, 71º33.11'W), presenting a healed deep cutting injury behind its left flipper, possibly attributable to a lateral vessel strike (G.P. Sanino, unpubl. data).

Minke whale *Balaenoptera acutorostrata*
We are unaware of any minke whale-ship accidents in the Southern Hemisphere, and very few elsewhere. One individual was reported killed in a ship collision in Spain (Duguy, 1983; Van Waerebeek *et al.* 1999). Though in most instances, studies have not found tourism related effects in survivorship, a common minke whale was killed after collision with a whale-watching vessel on Stellwagen Bank, Massachusetts (15 September 1998) (Yin, 1999).

Indeterminate minke whale *Balaenoptera sp.*
A single minke whale was found with cuts on head and flank at Westland, New Zealand, on 5 October 1991 (NZ Whale Stranding Database). The minke whale was not identified to species and both *B. acutorostrata* or *B. bonaerensis* are possible (see Baker, 1999).

Physeteridae

Sperm whale *Physeter macrocephalus*
André *et al.* (1994) first warned about threats to sperm whales in the Canary Islands. Later, authors recognized the sperm whale as the odontocete most commonly killed or injured by ships (Laist *et al*., 2001; Jensen and Silber, 2004) based on data mostly from the Northern Hemisphere. Lens *et al.* (2005) report on two sperm whales fatally struck (as determined from postmortems) off the Canary Islands in 2001.

Information from the Southern Hemisphere is very limited. Of 20 stranded sperm whales in Ecuador, one (5%) was a probable victim of a ship strike (Haase and Félix, 1994; Félix and Van Waerebeek, 2005).
A stranded lactating calf (female) was recorded on 23 September 2003 in Boyeruca, Chile, with propeller cuts of a smaller boat on its caudal peduncle. Locals described a live stranding on 21 September. A postmortem showed that it bled to death. Boyeruca is an area of high industrial and artisanal fisheries effort (G.P. Sanino, unpublished data).

Pygmy sperm whale *Kogia breviceps*
Lens *et al.* (2005) report two pygmy sperm whales killed in the Canary Islands, in 2002 and 2004 respectively. This oceanic species has not before been named as at least an occasional victim of ship traffic.

Delphinidae

Killer whale *Orcinus orca*
Killer whale struck by vessels has been discussed by several authors (Ford *et al.,* 1994; Visser, 1999; Visser and Fertl, 2000). In New Zealand many of the killer whales may be termed 'propeller positive' as they actively seek out the wash caused by propellers and have been seen to open their mouths around spinning propellers (Visser, 1999).

Playing in the turbulence of propeller wash of an idling 34m ocean-going tug, a lone killer whale got too close in Mooyah Bay, Canada, on 10 March 2006 and was killed (Rossiter, 2006).

Long-finned pilot whale *Globicephala melas*
Lens *et al.* (2005) listed a long-finned pilot whale of the Strait of Gibraltar in 2004 as a ship victim, however details are lacking.

Short-finned pilot whale *Globicephala macrorhynchus*
A short-finned pilot whale is listed as struck (no details) in the Canary islands in 2002 (Lens *et al.,* 2005).

Common bottlenose dolphins *Tursiops truncatus*
Lockyer and Morris (1990) first indicated small-boat propellers as causes of trauma in this species. Wells and Scott (1997) reported four cases of severe propeller cuts on dorsum and functional destruction of the dorsal fin in common bottlenose dolphin from Sarasota, Florida. Although none of these injuries was immediately fatal, long-term effects on survival were unknown.

In north-central Chile, careless and unregulated dolphin tourism from small boats resulted in repeated collision accidents with a resident (pod-R) common bottlenose dolphin community (Sanino and Yañez, 2000; archived video documentation by G.P. Sanino). Boat disturbance, including hits, are considered the major conservation problem for pod-R of less than 40 individuals. Homogeneity tests showed significant genetic differences with three other populations off Peru and Chile (Sanino *et al.*, 2005). This combined with a low nucleotide diversity (0.0069) and behavioural observations suggest that pod-R may be reproductively isolated. and active protection measures are recommended (Sanino *et al.*, 2005).

One of us (F. Félix) sighted 13 mutilated common bottlenose dolphins in the inner estuary of the Gulf of Guayaquil, Ecuador, over the period February 1990-October 1992 (Figures 5, 6). Such amount represents 2.04% of the estimated population in the studied area (Félix, 1994, 1997). Another case was recorded in 2005 in the northern part of the estuary. Several were definite cases (e.g. a complete fluke missing or parallel scars, Figure 6), most were probable and a few were possible[3] (cuts on the tip and base of the dorsal fin) propeller injuries from small open craft with outboard motors or small cargo/fishing vessels.
Social structure and ecology of this population is discussed by Félix (1994, 1997).

[3] a few may also have been caused by netting or longlines.

Fig. 5. Origin of some long scars may be difficult to interprete. The upper two are either from superficial propeller contact ("possible cases") or net marks. The lower two individuals have "probable" propeller-caused scars.

Fig. 6. Mutilated fluke and dorsal fins of common bottlenose dolphins in Gulf of Guayaquil, Ecuador. Except for one case (bottom left), all injuries appeared to have healed. Cases vary from possible to definite propeller strikes, indeed violent contact with fishing gear could also explain some of these.

On the Pacific coast of Costa Rica, in Golfo Dulce, C. Ovares reported on a dead bottlenose dolphin with a propeller cut in the neck region in 1999 (P. Cubero-Pardo, pers.comm. to KVW, 24.01.2006). In 2003, Mr. Alfredo Ruiz, the skipper of a local whale tourism boat commented that 'jet skis have hit dolphins and whales', without naming specific cases. Mr. Ruiz claimed to note a decrease in the number of dolphins in Bahía Culebra, Guanacaste (northwest coast) and blamed jet skis.

Samuels *et al.* (2000) reviewed tourism, pertaining to swimming with wild dolphins, which is mostly boat-based. The authors identified two 'well-documented cases of vessel strikes' (but no location given) in lone sociable bottlenose dolphins *Tursiops* sp. One probably subadult animal was injured after it became habituated to boats. Another, a juvenile, since 1992 received 37 boat-related injuries, of which eight life-threatening (Samuels *et al.*, 2000).

In 1999, Pace *et al*. (2000) found an adult individual dead near a fish farm on Italy's Lampedusa Island. It had 'evident lesions' near the rostrum from a possible collision with a boat.

Indo-Pacific humpback dolphin *Sousa chinensis*

In China three populations of *S. chinensis* are affected by heavy ship traffic. The Hong Kong/Pearl River Estuary population is the most intensively studied, with documented collisions and other vessel disturbance (Jefferson, 2000a; Parsons and Porter, 1995; Jefferson and Hung, 2004). Blunt traumatic injuries consistent with boat collisions was seen in three of 28 (10.7%) necropsied *S. chinensis* carcasses from the Hong Kong Area (Parsons and Jefferson, 2000), however not all injuries result in death (Jefferson, 2005a). Several dolphins in a photo-identification catalog show scars of major injuries to the dorsal fin and back (see Jefferson, 2000c, p.31; and Figure 7), apparently caused by boat propellers, vessel collisions, or rope/net cuts. Between 1.2-1.8% of the dolphins show evidence of propeller scars (Jefferson, 2005).

Yamin Wang suggested (*in litteris* to KVW, 17 Nov 2005) that one of the key conservation problems of the (suspected isolated) Xiamen population in Fujian, eastern China, is ship strikes. Indeed, the Xiamen harbour is very busy. Subsequently at a Xiamen Workshop on *S. chinensis* conservation in March 2006 (Anonymous, 2006), dense ship traffic was recognized as a potential threat to the Xiamen population. Comparisons between 1994 and 2004 abundance estimates indicate that the population has halved in that time (Yang *et al*, 2006).

Detailed reports of specific cases are particularly useful. Two potential strike victims were documented from Zhuhai City, Guangdong Province, one 206cm male found on 16 Sept 2003 and a 270cm male examined on 28 Feb 2003 (Yamin Wang, unpubl. data).

In Taiwan, vessel collision was ranked as low to medium potential impact, primarily because of the possibility that high-speed ferries could eventually be used in western Taiwan and the fact that recreational use of personal water craft (eg. jet-skis) is increasing. Some of the scarring on humpback dolphins in Taiwan are suggestive of collision injuries (Wang *et al.*, 2004).

One individual in Queensland, Australia, was killed by a propeller, and washed ashore on Saunders Beach (Strandings Database, Queensland).

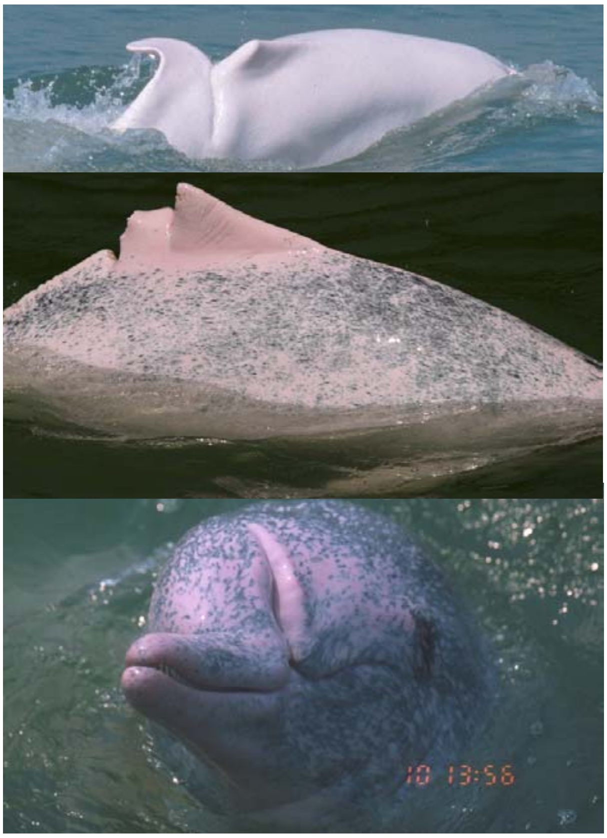

Fig. 7. Positive (above, centre) and probable (below) propeller scars in *Sousa chinensis* from Hong Kong waters (photos courtesy Hong Kong Dolphin Conservation Society and [upper] Tom Jefferson).

Irrawaddy dolphin *Orcaella brevirostris*

In Indonesia, during 1997-99, three deaths of Irrawaddy dolphin in the Mahakam River, Kalimantan, Indonesia, were attributed to vessel strikes (Kreb, 2000; Smith and Reeves, 2004). This small isolated population was most recently estimated at 34 individuals (Kreb, 2002). The estimated 2.9% (minimum) annual mortality rate from collision alone is clearly not sustainable.

In Laos, a juvenile dolphin died of injuries possibly incurred by a boat propeller in April 2002 (Perrin *et al.*, 2005). The population in coastal waters off northern Australia does not seem to be affected (Parra *et al.*, 2002).

Mortality reports of Irrawaddy dolphin from Chilika Lagoon, eastern India, list at least 54 deaths (1999-2006), of which five carcasses (9.3%) (all adults from 2004-05) are diagnosed by government researchers as dead from vessel collisions, four of these by propeller hits.

The engine boats in Chilika use longtailed outboard Lombardini engines of 9 and 12HP. Observations of dolphins (D. Sutaria, pers. observations) around approaching and passing by engine boats have shown that the animals avoid them and move away as soon as the boats come as close as 100m. It has also been observed that if the animals are feeding, the behaviour of the animal does not change if the boat is passing by or if the engine has been switched off. Boats have been observed to be chasing Irrawaddy dolphins that are traveling or socializing, and thus are a source of stress and risk of accidents. From carcasses diagnosed by D. Sutaria, primary mortality of Irrawaddy dolphins in Chilika are from shark nets, hook lines and seine nets, followed by decrease and obstruction of habitat and increased interaction with engine boats. Two live animals showed dorsal injuries thought to be from violent hits (Figure 8).

Boat traffic is heavy in Chilika's dolphin watching zone of Satpada. During the peak tourist season (October-February) anywhere between 250-280 tourist boats traverse the dolphin rich zone (Satpada) of 23km² between 8:30am-5pm, while in the non-tourist season about 75 boats a day operate. There are currently two community-run tourist associations in the Satpada region of Chilika. One is licensed and has 247 boats, while the other is not licensed but has 87 boats. These local associations are basically formed by fishermen who have taken up tourism as an additional source of income (increase is 3,000Rs-5,000Rs/month). The Orissa State Tourism Department has its own boat watching facilities, which uses 25HP inboard Yamaha engines and have nine boats. Occupancy is limited to seven persons per boat in both government and private boats. Another form of mechanized transport active in the region are the government-run ferries carrying buses and cars, that traverse a dolphin rich zone six times a day between 7am and 6pm. Lastly, there are local boat services across the water in the 23km² zone every hour between 7am and 5pm.

Collaboration both at the local and at the government level and between the two tourist associations is deficient, which is a major hindrance towards bringing about any management changes in tourist boat traffic and in environmental awareness. A positive change though is that the associations have realized that putting off engines around dolphins is a rule and chasing dolphins is punishable by law (D. Sutaria, personal observations).

Fig. 8. Probable boat/propeller-caused injury (inset: detail) on tail stock of Irrawaddy dolphin in Chilika Lagoon, India (photo D. Sutaria).

Hector's dolphin *Cephalorhynchus hectori*

Hector's dolphins are positively attracted to, and regularly escort boats and bow-ride; even nudging the vessel and rubbing against the bow (Mörzer Bruyns and Baker, 1973; Slooten and Dawson, 1988). They are not attracted to fast boats and usually dive on their approach, surfacing after the boat has passed. However, Hector's dolphins do not seem to appear to leave areas of high boat traffic e.g. in locations where they are regulary accessed by dolphin watching tourist vessels (Slooten and Dawson, 1988).

Two calves Hector's dolphins were killed in boat strikes in Akaroa Harbour, Banks Peninsular Canterbury, on 26 and 27 January 1999 (pers.comm. to ANB, Al Hutt, Department of Conservation, Duvauchelles, New Zealand, December 2005). Stone and Yoshinaga (2000) also reported calf mortality and habituation to vessels.

Commerson's dolphin *Cephalorhynchus commersonii*

An individual with superficial propeller scars on its back and anterior of the dorsal fin was seen repeatedly in Bahia San Julián, Argentina, in January and February 2005 (M. Iñíguez, pers. observations). To tell from its colouration, the animal was a juvenile.
Commerson's dolphins are vulnerable, considering that they have been known to ride bow, stern and beam waves of boats of al sizes, from freighters and tugs to small motorized skiffs, a behaviour exploited to take them in breakaway hoopnets (Cornell *et al.* 1988; Leatherwood *et al*., 1988).

Peale's dolphin *Lagenorhynchus australis*

An adult Peale's dolphin, regularly sighted in the period 1990-2002 and member of a semi-resident group in the bay of Punta Arenas (Lescrauwaet, 1990), Chilean Patagonia, showed a characteristically sliced and bent dorsal fin (Figure 9), clearly result of a violent trauma (A.K. Lescrauwaet, pers.comm. to KVW, 13 Jan 2006), most likely a propeller slash. Killer whales are not known to cause such scars; also escape would be unlikely after suffering severe injuries. Peale's dolphins show a strong positive attraction towards moving vessels (Goodall *et al.*, 1997) which may increase risk of propeller injuries.

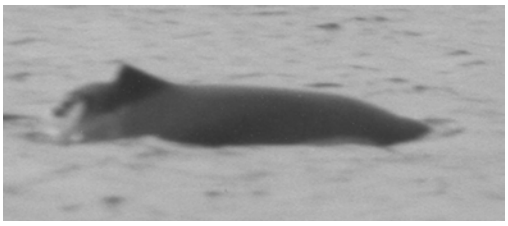

Fig. 9. First case of a probable propeller strike in Peale's dolphin, Punta Arenas, Chile (photo courtesy A.K. Lescrauwaet). The impact from a right-hand propeller would cut and bend the rear part of the dorsal fin to the left (see also Fig.7).

Atlantic spotted dolphin *Stenella frontalis*

A calf in a studied pod of Atlantic spotted dolphins in the Bahamas received life-threatening wounds, presumably from a boat propeller (Ransom, 1998; Samuels *et al.*, 2000). These dolphins are exploited for swim-with programmes. Ransom (1998) found that Atlantic spotted dolphins changed their behaviour 68% of the time when a boat approached, and responses in wich the dolphins closed in on the boat predominated. Increasing habituation puts individual dolphins in harms way, and this should be monitored.

Phocoenidae

Finless porpoise *Neophocaena phocaenoides*

Zhou K. *et al*. (1979, 1980) first warned that finless porpoises of the Yangtze River are occasionally killed by propellers, and provided a specific case of fatal collision. Reeves *et al*. (2000b) also listed 'collisions with powered vessels' as a threat to this particular population. The rate of killing or injury however is thought to be 'much lower' than in baiji (Zhou K. *et al*., 1979; Zhou, 1992).

Hong Kong is one of the busiest ports. A major fast ferry lane between Hong Kong and Macao also runs through important finless porpoise habitat just south of Lantau Island (Perrin *et al.*, 2005). Evidence of blunt traumatic injury, consistent with boat collisions, was found in 3 of 32 (9.4%) finless porpoise carcasses necropsied from the Hong Kong area in 1993-98 (Jefferson, 2000b; Parsons and Jefferson, 2000). Boat avoidance behaviour, including diving and leaping, was reported (Jefferson, 2000).

In Thailand a porpoise died as result of being run over by a water scooter (Chandropornsyl and Andersen, 1995).

Burmeister's porpoise *Phocoena spinipinnis*

A single potential case of collision is published. On 13 August 1986, a Burmeister's porpoise live-stranded on Playa Coloso, northern Chile, with deep, freshly inflicted, injuries on its head. It had moved erratically before stranding which led Guerra *et al.* (1987) to suggest it might have been hit by a boat. This case is the only documented live-stranding of a Burmeister's porpoise.

Harbour porpoise *Phocoena phocoena*

For harbour porpoises, a detailed assessment of boat collisions is not yet available due to limited knowledge. In Cardigan Bay, UK, one dead harbour porpoise showed lesions suspected to have been caused by a propeller (Kirkwood *et al*., 1997). A 150cm North Sea harbour porpoise carcass stranded on 13 January 2006 on the beach at 's Gravenzande, the Netherlands, with propeller gashes (Kees Camphuysen, unpublished data). However it was not possible to ascertain whether the porpoises were killed by propeller impact or were damaged postmortem.

Lipotidae

Baiji *Lipotes vexillifer*

Several authors pointed to baiji mortality from collisions, (Perrin and Brownell, 1989; Leatherwood and Reeves, 1994; Zhou, 1992), particularly in the lower reaches of the Yangtze River, where waterways contain high levels of large commercial vessel traffic (Zhou, 1992). Some warned that the rate of killing or injury, primarily by propellers, is high (Zhou K. *et al*., 1979, 1998; Zhou, 1992; Chen *et al.*, 1993). The increase in large ship traffic, resulting from improved navigation in the upper reaches of the Yangtze River after completion of the Three Gorges Dam will likely increase the incidence of ship strikes (Reeves *et al*., 2003).

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, 1996).

Ziphiidae

Cuvier's beaked whale *Ziphius cavirostris*
Three Cuvier's beaked whales stranded in the Canary Islands in 2000, 2002 and 2004 (Lens *et al.*, 2005) were potential victims of fatal vessel hits. A Cuvier's beaked whale washed ahore in Canterbury, New Zealand, in September 1992, with bruising and injuries that pointed to a vessel collision (NZ Whale Stranding Database).

Arnoux's beaked whale *Berardius arnuxii*
One of us (AvH) examined the anterior half of an Arnoux's beaked whale carcass stranded at Riverton, New Zealand, on 22 January 2006. The carcass was relatively fresh and the body probably sliced in two by a ship, with the trunk part missing. It is unclear whether this was the cause of death though.

Gray's beaked whale *Mesoplodon grayi*
The adult of a cow/calf pair sighted in Mahurangi harbour, New Zealand, exhibited a 'series of deep indentations ... along the back behind the dorsal fin. These 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).

2. Species with suspected impact from vessel strikes

This category includes species that due to their known behaviour, including attraction to moving vessels, are potentially at risk from strikes, and species for which propeller damage is documented but cause of death is uncertain.

Indian Ocean humpback dolphin *Sousa plumbea*
Boat traffic, particularly in the Arabian Gulf, is thought to be one of the threats to *S. plumbea* (Baldwin *et al*., 2004), however no case studies are available.

Andrew's beaked whale *Mesoplodon bowdoini*
An Andrew's beaked whale stranded on the Chatham Islands, New Zealand, in October 1999 was injured with a large trauma behind the eye, and should be considered a possible vessel collision victim (NZ Whale Stranding Database).

Hector's beaked whale *Mesoplodon hectori*
A young 3.1m male Hector's beaked whale stranded in Waikawau Bay, Hauraki Gulf, New Zealand, on 21 April 1992 (NZ Whale and Stranding Database) had a propeller gash on its back anterior to the dorsal fin. It is possible that the injury contributed, or even caused the animal's death., although the location in the inner Hauraki Gulf is well inshore of the usual deepwater habitat of beaked whales, and the animal may have been already ailing when hit.

DISCUSSION

Range of affected species
This preliminary study shows that considerably more cetacean species are affected by vessel collisions than has hitherto been suggested. Laist *et al.* (2001) and Jensen and Silber (2003) listed 21 species. We found records for at least 31 species, 8 large whale species and 23 small cetaceans.

Among baleen whales, world-wide only four species, the North Pacific right whale *Eubalaena japonica*, the Antarctic minke whale *Balaenoptera bonaerensis* (but 1 possible case exists) the pygmy right whale *Caperea marginata* and the dwarf Bryde's whale *Balaenoptera cf. edeni* have not yet been definitely implicated. Our review shows that at least 18 species of small cetaceans are at least occasionally affected and another three species are suspected victims.

Three of six phocoenids including *Neophocaena phocaenoides, P. phocoena,* and *P. spinipinnis*, as well as two river dolphins (*L. vexillifer, P. gangetica*) are reported at least occasionally hit.

While it seems *Sousa chinensis* is heavily impacted, the lack of incidents for *S. teuszii* is explainable because this humpback dolphin is extremely wary of boats and reporting of mortality is next to non-existent (Van Waerebeek *et al.*, 2004).

We are unaware of any published incidents for the Amazon river dolphin (bouto) *Inia geoffrensis*, freshwater tucuxi *Sotalia fluviatilis*, or the Franciscana dolphin *Pontoporia blainvillei*, but non-reporting is believed to be problematic. Neither were cases encountered for typical pelagic dolphins such as *Stenella attenuata, S. longirostris, Delphinus delphis, Lagenodelphis hosei, Peponocephala electra, Feresa attenuata, Pseudorca crassidens* and *Grampus griseus* amongst others. However, many of these species are (sub)tropical, and potential accidents may go unrecorded.

Somewhat surprisingly, at least three and possibly five beaked whale species have been involved.

Incidence of strikes highly variable
Limited information is available on incidence of mortality from vessel collisions within populations, for the simple fact that long-term postmortem studies that provide such figures are few. Incidences vary approximately one order of magnitude, but part of variability is the result of differences in definitions :

- The highest known incidence is for *Eubalaena glacialis.* Of 30 mortalities of adults and juveniles in 1970-2002 for which cause of death was determined, the primary cause was 14 human–induced trauma from ship collisions (46.7%; CI 28.8-64.5%)[4] versus 4/30 from fishing gear entanglement (Moore *et al.*, 2004).
- An estimated 20% (CI 9-31 %) of mortality in South African *Eubalaena australis* is due to vessel strikes (Best *et al.*,2001), however this include several 'possible' cases. Several recent incidents suggest the problem may become more severe also in Argentina and Brazil, but samples are too small to permit quantification.
- Panigada *et al.* (in press) analyzed ship collision records for the relatively isolated population of fin whales in the Mediterranean Sea from 1972 to 2001. Out of 287 carcasses, 46 individuals (16.0%, CI 11.7-20.3%) were certainly killed by boats. The minimum mean annual fatal collision rate increased from 1 to 1.7 whales per year from the 1970s to the 1990s.
- Three of 28 *S. chinensis* carcasses (10.7%, CI 0-22.1%) from the Hong Kong Area showed blunt traumatic injuries consistent with boat collisions.
- Evidence of blunt traumatic injury, consistent with boat collisions, was found in 3 of 32 (9.4%, CI 0-19.5%) finless porpoises necropsied from the Hong Kong area in 1993-98 (Jefferson, 2000b).
- Of 20 stranded sperm whales in Ecuador, one was a probable collision victim (5%; CI 0-14.6%) (Haase and Félix, 1994; Félix and Van Waerebeek, 2005).

Another useful relative measure of collision frequencies is the prevalence of injuries and scars from non-lethal encounters.
- *ca*. 2% of common bottlenose dolphins in the Gulf of Guayaquil showed cuts in dorsal fin or scars along the dorsal part of the body, but a few may also have been from fishing gear.
- Two of 117 photo-identified killer whales (1.71%; CI 0-4.1%) off New Zealand had deep scars referrable to boat propeller hits (Visser, 1999).
- Between 1976 and 1992, three ship-strike injuries were documented out of a total of 236 bowhead whales (1.27%, CI 0-2.7%) examined from the Alaskan subsistence harvest (Shelden and Rugh, 1995). The threat will rise with increased shipping, especially if and when the Northwest Passage becomes a regular pathway following reduced ice cover.
- Baker and Martin (1992) examined 41 harbour porpoises stranded on British coasts and none (0%) showed evidence of trauma related to shipping.

Wide range of potential impact

Population impact by collisions cannot be quantified for most species due to a general lack of both population abundance estimates and population-level incidence of mortality from collisions. However, based on preliminary evidence we suggest that the relative impact on conservation status may widely vary depending on the species, and even the population. The low impact end of the spectrum, with only one or a few vessel strikes documented (several for the first time) in non-endangered species (IUCN Red List of Threatened Species status), applies to some 11 odontocete species for which the effect may be negligible: pygmy sperm whale (LR/lc)[5], Peale's dolphin (DD), Commerson's dolphin (DD), Atlantic spotted dolphin (DD), short-finned pilot whale (LR/cd), long-finned pilot whale (LR/lc), Burmeister's porpoise (DD), harbour porpoise (VU), and three Ziphiidae including Cuvier's beaked whale (DD), Arnoux's beaked whale (LR/cd) and Gray's beaked whale (DD). However, the net effect from all aggregated forms of disturbance resulting from heavy vessel traffic (and including direct hits), may still be significant.

At the high impact end of the spectrum with frequencies of reported cases considered high relative to estimated population size or IUCN Red Data status, it may constitute an immediate and direct threat to the taxon's long-term survival. For instance, collisions with vessels and net entanglements are the primary source of anthropogenic mortality in the North Atlantic right whale. The species is critically endangered and declining (Kraus, 1990; IWC, 2001; Knowlton and Kraus, 2001; Moore *et al.*, 2004); similarly, long-term survival of the western Pacific stock of gray whale *Eschrichtius robustus* may become compromised by ship traffic.

Among delphinids, most stricken species and populations are characterized by an inshore, estuarine or neritic habitat. Among estuarine species, at least two populations of each *S. chinensis* (Xiamen and Hong Kong/Pearl River) and *Orcaella brevirostris* (Mahakam River and Chilika Lagoon) may be significantly impacted.

In two river dolphin species, *Lipotes vexillifer* (CR)[6] and *Platanista gangetica* (EN)[4], because of extremely low population numbers, a few or even a single mortality event may exert a serious impact on future survival.

Need for standardization

When compiling and reviewing raw data for this paper, great variation was found in the type and quality of information, degree of detail, authentication, qualifications of recorder and verification status. Some data were found hardly comparable with other datasets. Before modelling is attempted, a critical effort is needed towards standardizing parameters, lest it may yield unreliable results infused with noise and bias.

Some factors co-determining collisions and modelling needs

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[4] High value partly explainable because whales of indeterminate mortality were not included in ratio.

[5] 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.

[6] CR (critically endangered); EN (endangered).

Buoyancy - Positive buoyancy in right whales may pose added risks. Such buoyancy may impede diving responses to oncoming vessels and right whales may have a reduced ability to manoeuvre during free ascents. These risk factors can inform efforts to avoid collisions.

Habitat - Ferry crossings, commercial ports, and primary fishing grounds in Asian rivers are generally located downstream of convergent channels or sharp meanders, which are also the preferred habitat of river dolphins, with increased risk. River dolphins are often observed in areas with high vessel traffic, that includes small boats, motorized ferries, and in some location large container ships and oil tankers, with no visible damaging effects (Reeves *et al.*, 2000).

Habituation - Chronic swim-with-dolphin activities in open waters may increase tolerance of humans and vessels, disrupt natural behaviour and/or increase the animals' vulnerability to vessel strikes (e.g. Samuels and Bejder, 2004). Dolphins are more capable of avoiding collision from a vessel if the vessels' course is predictable and if there is adequate room or depth for escape. Each dolphin tourism programme must be individually assessed for risk, as much variability seem to exist. Also whales may become habituated to boat noise, then limit avoidance manoeuvres and even approach watercraft. With closer distance, contact accidents inevitably become more probable.

Age and sex - Cetaceans may be more vulnerable to collisions during calving and nursing periods. Also, it has been suggested that due to inexperience, calves, juveniles (and perhaps subadults) might be more prone to accidents with ships. For instance, maritime vessels are urged to use special caution while cruising along the US southeast coast during the right whale winter calving season (15 November – 15 April), when mother/calf pairs approaching shore are more exposed to accidents. Whether variation is significant awaits testing for each species separately, but far better primary data will be required.

Propeller hits - The evidence that boats often hurt small cetaceans by their propellers comes from tell-tale scars and injuries observed in an alarming number of dolphins. The commonly seen left-leaning trailing edge of bisected dorsal fins in dolphins (Figures 7, 9) may be caused by a direct hit of the modal right-handed propeller[7] when the dolphin travels grossly in the same direction of a moving boat. While clearly often not lethal, it would be hard to deny a reduced overall fitness through blood loss, opportunistic infections, hampered movements -at least initially- resulting in less foraging efficiency, etc.

Installing propeller guards on boats that are in regular contact with cetaceans have been recommended (e.g. Visser, 1999; Sanino and Yañez, 2000) and we vocally reiterate that recommendation. Commercial whale/dolphin watching platforms should not be allowed to operate without propeller guards.

Collision predisposing factors - A compounding factor when estimating or comparing mortality incidence from collisions are sick or injured animals that are killed while largely immobilized. For instance, one blue whale in New Zealand, appeared to have been attacked by orca prior to collision.

We still recommend these cases to be classified as vessel-caused mortality because there is no way to know whether the weakened animals were moribund or might have survived; the strike can be a certainty. Other pre-disposing factors may be discovered, including the individual's social condition.

Postmortem strikes - An oft-mentioned technical difficulty is the positive diagnosis of cause of death. Floating carcasses can be struck by vessels, potentially confounding interpretations of traumatic lesions, especially with necropsies of greatly decomposed (state 4 or 5) carcasses. However most cetaceans, with the exception of the Balaenidae, sink upon dying and resurface only after bloating sets in from gas production in step with progressive decomposition. It is less likely for a ship to run into such a floating, bloated carcass since often they can be readily spotted by naked eye, sometimes by radar, from a great distance, and be avoided. If postmortem run-ins occur nonetheless, the damage can be differentiated from antemortem traumas especially in relatively fresh specimens. Massive haemorrhaging is indicative of antemortem trauma (e.g. Félix and Van Waerebeek, 2005) as are fat emboli in the *lumina* of pulmonary vessels (Fernández *et al.*, 2005). Improved awareness and new histological techniques like the latter might help ensure that a higher percentage of carcasses are correctly diagnosed.

Recording bias - The ubiquitous, and often systematic, non-reporting by maritime stakeholders is a major obstruction for an integral, global assessment of the collision predicament. To date, reporting regulations exist only in Australia, Belgium, Canada, New Zealand and USA.

Regulatory issues - e.g., Colborn *et al.* (1998) describe strategies to avoid collisions with right whales.

Crowding and high-density shipping lanes

Boat activity in the vicinity of dolphins may result in inadvertent injury or death. The probability of collisions (typically low) increases with the density of cetaceans and vessels and their proximity to each other. Studies that analyse spatial and temporal overlap, correlate cetacean distribution with areas of dense vessel traffic and high collision incidence may yield novel insights. The IWC Ship Strike Working Group (SSWG) could provide suggestions as how such areas are optimally identified and profiled. Below we offer an example for such a profile, provided by R. Baldwin.

Strait of Hormuz Profile

Apart from fishing vessels, in the lanes of the traffic separation scheme in the gateway between the Arabian Gulf and the wider Indian Ocean, four main types of vessels use the Straits of Hormuz as detailed below:

- Large tankers using the traffic separation scheme. It is estimated that there are 40-50 vessel movements per day.

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

- Container vessels to and from Dubai and Abu Dhabi leaving and joining the traffic separation scheme. The track of these vessels runs parallel with the west coast of Musandam. There are estimated to be 15-20 such vessel movements per day.
- Small vessels (less than 20m) using the area. Generally these are coastal cargo vessels including wooden cargo dhows that ply between Dubai, Ra's Al Khaimah, Bandar Abbas, Charbahar and other regional ports. Such vessels use the inshore traffic zone that extends from the coast of Musandam to the international shipping lanes 15km offshore.
- Iranian traders operating between Oman and Iran. Although the main route from Khasab to Qeshm Island lies to the west of the prospect, there are a few other traders that target the eastern coast of Musandam and beyond. (WS Atkins International, 1999)

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