Collisions of sailing vessels with cetaceans worldwide: First insights into a seemingly growing problem

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ABSTRACT

Vessel-whale collisions are of growing concern worldwide, but information about collisions involving sailing vessels is especially scarce. This study represents the first global quantification of this kind. A total of 111 collisions and 57 near misses were identified, spanning from 1966 until 2010; 75% of cases was reported for the period from 2002–2010, suggesting an increasing trend. Reported collisions and near misses occurred on all oceans, often during ocean races and regattas, and were most frequent in the North Atlantic. Vessel type and speed as well as circumstances of the incident varied widely, but most often monohulls were involved, predominantly sailing at speeds between 5 and 10 knots. Most reports referred to 'large whales' as opposed to 'small whales' or 'dolphins'. The species could be identified in 54 cases. Most recognised animals were humpback or sperm whales. Injuries to the whales varied strongly from 'not visible' to 'dead after collision', but mostly could not be determined. Sailing crew members were hurt in several cases, including collisions occurring at low speeds, and collisions often damaged vessels, including major impairment and seven cases of vessel loss. The findings presented here suggest that elevated vessel speed contributes to a higher risk of collisions. Conversely, the outcome of a collision (e.g. injury to whale or crew, damage to vessel) appears not to be a direct function of vessel speed. Several measures are discussed which potentially can contribute to mitigating the problem, including placing watchposts, an open dialogue with regatta organisers, changes in the design of regattas and ocean races and public outreach initiatives.

KEYWORDS: CETACEANS; MORTALITY; SAILING VESSELS; SURVEY-ONLINE; SHIP STRIKES

INTRODUCTION

Collisions between vessels and cetaceans are of growing concern on a global scale. Historical records of collisions date back to the early 17th century, and the worldwide number of collisions appears to have increased steadily during recent decades (IWC, 2008; Laist *et al.*, 2001). Today, collisions may significantly affect the status of cetacean populations in certain areas of the world, namely where both cetaceans and shipping traffic are concentrated (ACCOBAMS, 2005; Carrillo and Ritter, 2010; Panigada, 2006; Pesante *et al.*, 2002). While the issue meanwhile has entered discussions at international levels, with the International Whaling Commission (IWC) playing a major role in raising knowledge and awareness, it is still not known how many whales and/or dolphins are hit each year, although it is widely accepted that collision numbers are mostly underestimated and generally increasing (IWC, 2008).

The types of vessels involved in collisions with whales include tankers, cargo or cruise ships, but also whalewatching vessels, navy ships, hydrofoils, high speed ferries and sailing vessels (Carrillo and Ritter, 2010; Jensen and Silber, 2004; Laist *et al.*, 2001; Van Waerebeek *et al.*, 2007). Information about collisions involving sailing vessels is especially scarce. Despite anecdotal accounts of collisions between sailing boats and cetaceans, no systematic investigation has been conducted. The present study is focused on instances where sailing vessels had a collision or near miss with a cetacean, the reports on which were obtained from a variety of sources.

Most cases where whales were known to be severely hurt or killed occurred at vessel speeds of 14 knots or more and were caused by large ships of 80m or more in length (Laist *et al.*, 2001). While sailing vessels usually are of smaller size, modern racing yachts including multihull vessels frequently reach speeds of more than 20 knots, thereby likely increasing both collision risk and probability of injuries for humans and cetaceans.

The aim of this study was to examine the issue with a focus on the circumstances under which collisions occur, the types of sailing vessels involved, the prevalence of collisions, possible trends in collisions and risks posed to animals, vessels and sailing crew.

METHODS

A variety of sources were used to collect collision cases. Initially, the internet was searched for vessel-whale strikes. Additionally, the Google Alert[1] function was used from June 2006 to 31 March 2010; this automatically delivers search results, i.e. links to websites, where defined search words 'collision whale' and 'Kollision Wal' were detected. This search resulted in regular references to websites (here termed 'internet reports') which subsequently were inspected for collision reports involving sailing vessels. Additionally, 16 international internet websites related to world sailing activities and five sailing magazines were contacted. Furthermore, through co-operation with one of the major worldwide sailing websites (*noonsite.com*), an online survey was established.

For this survey, a questionnaire was elaborated including questions about the most important features (based on the IWC ship strike database[2]) of a collision or near miss event. The questions included time, day and location of collisions or near miss events and factors like vessel size, hull type and speed. Enquiries were also made about species type ('large whale', 'small whale' or 'dolphin') and species identification. It was also asked if whales were seen before a collision (or, in the case of a near miss, before a potential

[1] *Google Alert* is a search engine based internet crawler obtaining keyword related search results from news, web, blogs, and groups.
[2] *http://iwcoffice.org/sci_com/shipstrikes.htm*.

impact), if any avoiding manoeuvres were taken, or if any injuries were observed on the animals after the collision. Other questions dealt with possible injuries to vessel crew, vessel damage, etc. The survey asked 19 questions about the actual incidents and additional information about the identity of the reporter. The questionnaire can be downloaded at *m-e-e-r.de/442.1.html.*

The survey was put online in June 2006 and simultaneously announced on *noonsite.com* and *m-e-e-r.org* and via a press release. Additionally, the MARMAM discussion group and the e-mail discussion group of the European Cetacean Society (ECS) were used to announce the online survey and to find out if members of the marine mammal researcher community were aware of any collision or near miss events. A near miss was defined as a close encounter of a vessel with a cetacean (i.e. animal within 30 metres or less) bearing a collisions risk but not leading to an impact.

Survey entries and internet reports were collected until 31 March 2010. Survey entries that did not yield useful information were discarded. Only those cases were considered when a whale had been seen. Where assumptions were made on whether it could have been some other object, records were not taken into account for analyses. Where necessary, the following steps were taken to make data quantifiable: for vessel speed, to receive a more conservative value, the lower value of a given range was set as the travel speed of the vessel. Concerning species identification, the species status was categorised into: (1) *definite*, when there appeared to be no doubt about the species, sometimes with records of distinctive morphological features or behaviours of the animals observed; (2) *probable*, when there was little doubt about the species identity, sometimes with records of distinctive morphological features or behaviours observed; and (3) *possible*, when there was considerable doubt about the identity of the species. For analysis by species, only categories (1) and (2) were considered. The question regarding vessels being 'under sail' or 'motoring' sometimes was answered as 'motorsailing'. These cases were classified as 'motoring', because the crucial aspect here is the vessel engine running (as the potential predominant acoustic cue to the animals). Evidence of vessel damage was further classified into: (1) *minor*, when sailing could be continued without restrictions; (2) *major*, when sailing was only possible in a limited manner; and (3) *vessel loss*, when the vessel finally had to be abandoned or turned out to be irreparable.

RESULTS

The internet search resulted in 45 reports on collisions and two reports of near miss events. The online survey yielded a total of 66 reports on collisions and 55 reports of near miss events. Thus, a total of 111 collisions and 57 near misses were identified. The majority of internet reports delivered answers to only a fraction of the questions asked because they usually were relatively broad in scope. Likewise, many contributors to the online survey did not answer all questions.

The temporal distribution of incidents spanned from 1966 until 2010 for collisions and from 1979 until 2010 for near miss events. The annual number of reports ranged from 0 to 21 collisions and from 0 to 11 near miss events. 72 (75%) occurred in the period from 2002 until 2010 (see Fig. 1).

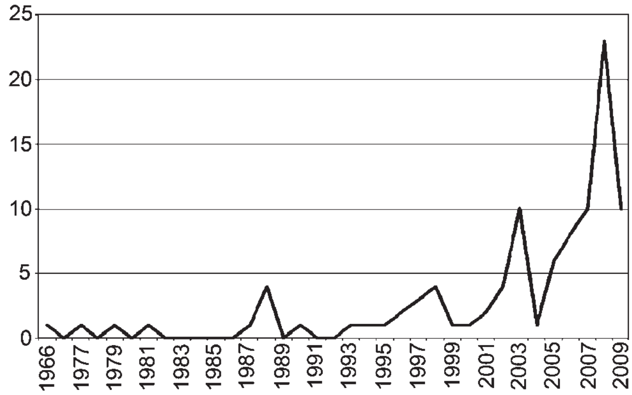

Fig. 1. Number of reported collisions (n = 98) between sailing vessels and cetaceans per year worldwide (1966–2009)

Due to the generic difference of collision and near miss events, especially in light of the dissimilarity of their outcomes, results will be presented separately here. Percentage numbers mostly refer to the numbers of cases for which information was available. Accordingly, missing percentages represent the fraction of survey entries without answers or where the answer was 'Not known', and absent information in internet reports, respectively.

Near miss events

Out of the total of 57, 55 incidents (96.5%) were reported by sailors directly involved and two were found on the internet. The majority of near miss events occurred in the Atlantic Ocean (n = 32; 56.2%), 29 in the North Atlantic including the Caribbean Sea and three in the South Atlantic. Eighteen incidents were reported for the Pacific Ocean (12 in the North and 6 in the South Pacific). The Mediterranean Sea accounted for two cases, the Indian Ocean for three, and two were reported from other areas (see Table 1).

A total of 75.4% vessels were monohulls (n = 43), and two catamarans. The majority of vessels were made of fibreglass (n = 39), followed by aluminium (n = 12) with a few vessels being made of wood (n = 2) or steel (n = 1). The size of the vessels ranged from less than 10m (n = 6) to more than 20m (n = 1). Most vessels were 10–15m (n = 36, 62.2%) and three were 15–20m long (see Table 2).

Forty-five near misses (78.9%) occurred during day time, 9 (15.8%) at partial light (dawn/dusk) and two at night time (darkness). 30 times, the animal were seen before the near miss (see Table 2).

During the incident, most vessels were under sail (n = 38, 66.7%), while 9 (15.8%) were either motoring or motorsailing. The speed of the vessels varied from 2 to 9 knots (n = 42). Most vessels travelled at 5–10 knots (n = 30), and 12 less than 5 knots (see Fig. 2).

Sixteen sailors reported that they took manoeuvres to avoid the collision (which otherwise they believed would have been very likely), and four reported that they saw the animals only when it was too late to take any action. In 36 cases, the animal was reported to be missed by only a few metres (<15m, most often much less). Four times it was apparently inquisitive behaviour, e.g. approaches by the animals that led to a near miss.

On 35 occasions (61.4%) the animal was categorised as a 'large whale' and 11 times (19.3%) as a 'small whale' (see

Table 1

Locations of collisions and near miss events between sailing vessels and cetaceans (1966–2010).

Location	Collision (*n* = 106)	Near miss (*n* = 57)	Total (*n* = 165)	Total (%)
North Atlantic Ocean	43	26	69	41.8
Caribbean Ocean	5	3	8	4.8
South Atlantic Ocean	12	3	15	9.1
North Pacific Ocean	14	12	26	15.8
South Pacific Ocean	21	6	27	16.4
Northern Indian Ocean	1	2	3	1.8
Southern Indian Ocean	4	1	5	3.0
Mediterranean Sea	3	2	5	3.0
Baltic Sea	1	0	1	0.6
Other	4	2	6	3.6

Table 2

Collisions and near miss events between sailing vessels and cetaceans worldwide (1966–2010): vessel size, vessel type, light conditions and detection of whales.

		Collision	Near miss	Total	Total %
Vessel size	<10m	7	6	13	12.0
	>10m	43	36	79	73.1
	>15m	6	3	9	8.3
	>20m	6	1	7	6.5
	n	*62*	*46*	*108*	
Vessel type	Monohull	64	43	107	88.4
	Catamaran	8	2	10	8.3
	Trimaran	4	0	4	3.3
	n	*76*	*45*	*121*	
Light	Day time	53	45	98	71.5
	Dawn/dusk	9	9	18	13.1
	Night time	19	2	21	15.3
	n	*81*	*56*	*137*	
Whale seen before?	Yes	22	30	52	43.0
	No	54	15	69	57.0
	n	*76*	*45*	*121*	

Table 3

Collisions and near miss events between sailing vessels and cetaceans worldwide (1966–2010). (a) ID category and (b) species identification.

	Collision (*n* = 67)	Near miss (*n* = 46)	Total (*n* = 113)	Total (%)
(a) ID category				
Large whale	51	35	86	76.1
Small whale	12	11	23	20.4
Dolphin	4	0	4	3.5
	Collision (*n* = 32)	Near miss (*n* = 22)	Total (*n* = 54)	Total (%)
(b) Species				
Humpback whale	15	3	18	34.6
Sperm whale	9	9	18	34.6
Gray whale	3	3	6	11.5
Right whale	1	3	4	7.7
Fin whale	1	2	3	5.8
Blue whale	0	1	1	1.9
Pilot whale	1	1	2	3.8
Orca	1	0	1	1.9
Common dolphin	1	0	1	1.9

Table 3a). In 22 instances, the cetacean species was identified. These included sperm whales (*n* = 9), right whales (*n* = 3), gray whales (*n* = 2), humpback whales (*n* = 3) and fin whales (*n* = 2). One case each was reported for blue whales and pilot whales (see Table 3b). However, in 35 cases no species identification was provided. There were no reports about injuries to crew or vessel.

Collisions

Of a total of 111, 54 incidents (48.6%) were reported by the sailors directly involved and 52 (46.8%) were found on the internet. The majority of collisions occurred in the Atlantic Ocean (*n* = 60, 54.1%), 48 in the North Atlantic including the Caribbean Sea and 12 in the South Atlantic. 35 (31.5%) incidents were reported for the Pacific Ocean (14 in the North and 21 in the South Pacific). The Mediterranean Sea accounted for three cases, the Indian Ocean for five (one in the Northern Indian Ocean and four in the Southern Indian Ocean, see Table 1). Two collisions were caught on film[3].

Some 82.1% of vessels were monohulls (*n* = 64), 10.3% were catamarans (*n* = 8) and 5.1% were trimarans (*n* = 4). The size of the vessels ranged from less than 10m (*n* = 7) to more than 20m (*n* = 6). Most vessels were 10–15m (*n* = 43) and six were 15–20m long (see Table 2). The majority (*n* = 55, 76.3%) of vessels were made of fibreglass, with smaller numbers made of wood (*n* = 7), steel (*n* = 5) or aluminium (*n* = 2).

A total of 53 collisions (47.7%) occurred during day time, 9 (8.1%) at partial light (dawn/dusk) and 19 (17.1%) at night time (darkness). In 54 cases (48.6%), the animals were not seen before the collision (see Table 2). This was only the case for 22 incidents (see Table 2). However, in 63 cases (56.8%) the animals were seen after the collision.

Most vessels were under sail (*n* = 86, 90.5%) while 9 (9.5%) were either motoring or motorsailing. 38 (34.2%). Collisions were reported occurring during sailing regattas, most of these being ocean races.

Vessel speed at the time of the collisions varied from 2 to 25 knots (*n* = 65). Most vessels travelled at 5–10 knots (*n* = 39, 60.9%, see Fig. 2), 14 between 10–15 knots (21.9%) and four faster than 15 knots (see Fig. 2). Yet, for 46 incidents

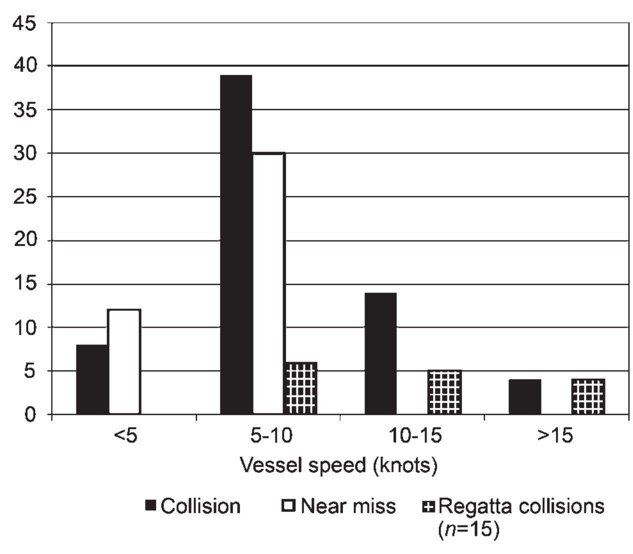

Fig. 2. Collisions (*n* = 65) and near miss events (*n* = 42) between sailing vessels and cetaceans in relation to vessel speed (1966–2010, numbers of chequered bars are also included in black bars).

[3] The video sequences can be watched on the internet at: *http://www.sailvalis.com/Pac%20Cup%2008/Images/Whale.mpg* and *http://www.youtube.com/watch?v=D21iF3N_cbY*, respectively.

(41.4% of the total), vessel speed remained unknown or was not provided. Four sailors reported that they took manoeuvres to try to avoid the collision. Collisions during regattas involved vessel speeds ranging from 7 to 25 knots with a mean of 12.7 (SD = 5.73; *n* = 15), including nine cases where speed was 10 knots or more (see Fig. 2).

On 51 occasions (45.9%) the animals were categorised as a 'large whale' and 12 times (10.8%) as a 'small whale' while four (3.6%) were dolphins (see Table 3a). For 44 accounts (39.6%), no categorisation was made or the answer was 'not known'. In 32 cases, the cetacean species was identified, these included: humpback whales (*n* = 15), sperm whales (*n* = 9), grey whales (*n* = 3), and one each of the following species: right whale, fin whale, pilot whale and orcas/killer whales, as well as one common dolphin (see Table 3b). Again, for the majority of descriptions (*n* = 77, 70.6%) no species identification was provided. For five situations, it was reported that juveniles or calves (= 'small animals') were seen, and in one of these cases it was reported that the young animal was hit.

The behaviour of the animals prior to the collision was described for 22 instances. Six times, the animals appeared to be sleeping/logging on the surface, one whale was seen travelling, and two showed inquisitive behaviour, e.g. by approaching the vessel and/or riding its bow wave (two bowriding cases both involved dolphins). Seven times, whales appeared to emerge from below and thus apparently hit the vessel while trying to surface. Three cases involved animals being described as 'attacking' the vessel and in two instances whales leapt onto a vessel. Where sailors described attacks (these involved one group of sperm whales, and one pod each of pilot whales and orcas), the animals' behaviour appeared to be intentional, with the animals actively ramming the vessel in all three cases. Finally, one whale was described as intentionally approaching the vessel and 'rubbing up and down the port side', thereby causing considerable damage. The two cases where large whales leapt onto vessels involved a humpback and a right whale. One of these cases was caught on film as well as on photographs. Finally, one whale was reported to be floating dead on the surface when it was hit.

Cetaceans reportedly were hit by different parts of the vessels, typically by the bow and parts of the keel. Some cases involved damage caused to the daggerboard, a movable keel which is potentially more vulnerable to damage than a fixed keel. Sometimes the collision was described as being relatively soft, felt as a bump or light shudder, but during 18 collisions the vessel came to an abrupt halt. Consequently, there were several reports of crew members being hurt (*n* = 9) including one instance of a crew member going overboard (and 7 out of 17 crew members being injured in that same incident). Crew members were hurt during collisions at vessel speeds ranging from 4–10 knots (*n* = 7), while 'no injury' was reported for collisions happening at speeds from 3–25 knots (*n* = 58, Mean 7.84, SD = 4.09).

There were 26 reports indicative of some kind of visible reaction of the whale after the strike. Nine whales were said to 'dive away', and six to 'swim away', both apparent evasive behaviours. Seven whales struck the water surface with either their flukes or flippers and two were observed defecating. One injured whale 'spied' at the vessel just after the strike. One dolphin hit by a vessel's rudder was described rolling on its side in the wake as if 'stunned or the breath knocked out of it'. Three times it was explicitly stated that there was no apparent reaction by the whale.

Injuries inflicted on the animals varied from 'no visible injury' to 'possibly dead'. In 20 cases (18.3%) blood was seen in the water after the collision, and four whales carried severe visible injuries. One animal supposedly was dead just after a strike with a monohull vessel travelling at 15 knots, a second one was suspected to have 'surely died shortly after the collision'. Six animals were seen to have minor visible injuries, described as e.g. 'minor scratches to the whale's skin', and in 10 cases an apparent injury could not be determined as being minor or severe (five of theses cases involved blood seen in the water). On 24 occasions (22.0%), there was 'no visible injury', while for 19 times (17.4%) the answer was 'Not known'.

No relation was identified between the gravity of the injury and the size nor the speed of the vessel. There were severe injuries and/or blood seen in water at speeds ranging from 4 to 25 knots (Mean 9.0, SD = 5.7, *n* = 15) involving 14 vessel sizes ranging from 10 to more than 20 m length, including 11 cases with monohulls and two cases with catamarans.

Vessel damage also varied widely from superficial effects (e.g. paint or antifouling ripped off the hull, scratches or small cracks, broken or bent steel poles, dents) to severe rudder, keel or daggerboard damage and major hull cracks or leaks. Five times, the collision caused the vessel to sink. In another incident, crew and vessel were rescued, but the vessel turned out to be not functional anymore. During the 2010 case when a right whale lept onto a vessel, the vessel suffered total loss, too. Additionally, several whales performed abrupt body movements at the time of the strike, thus forcefully hitting the vessel and causing damage.

Of the 63 collision events where damage was reported, 29 (46.0%) were classified as minor damage while 27 (42.9%) were considered to have resulted in major damage, where sailing could only be continued with some restriction. As described above, seven strikes (11.1%) resulted in vessel loss.

DISCUSSION

This study constitutes the first attempt to quantitatively assess collisions involving sailing vessels on a global scale. The internet was found to be an effective means to collect collision reports. However, the number of collision events reported on the world wide web, particularly near misses, is (and probably will remain) restricted. It is clear that only the more spectacular cases will enter news coverage and internet reports in general. Moreover, the information given in internet reports usually is not extensive and generally covers only the most basic aspects of an incident.

Conversely, a large number of collision and near miss reports were collected via the dedicated online survey, which thus was the more efficient way to collect data for this study, especially because survey entries by their nature yielded more detailed information. A considerable interest in the issue on behalf of the 'sailing scene' was noticed, as expressed through a number of e-mails by sailors and sailing website administrations and, of course, through the establishment of the online questionnaire initiated by a major sailing website. Nevertheless, in numerous cases not all questions of the survey were answered, and thus information repeatedly was limited, too. Moreover, many sailors around the world may have no access to the internet and therefore were not aware of the online survey. Although the online questionnaire could be answered anonymously, there might generally be a certain reluctance to report a collision at all, as in addition to the fact that it may have been an unpleasant experience, sailors may also be unsure if there will be (legal or other) consequences when they report an incident (IWC, 2003; Lammers *et al.*, 2007).

The temporal distribution of collisions and near miss events showed that this is not a new phenomenon. The earliest cases reported occurred in 1966 (collision) and 1974 (near miss), respectively. However, most of the incidents were reported to have happened during the past few years (see Fig. 1). Although this may be a reflection of a true increase in collisions with sailing vessels in recent years, it may also reflect reporting rate. Several factors may potentially lead to an underestimation of collision rates in earlier years. In particular, cases that date back years or decades may not be reported because the details are not clearly remembered. The internet was used as a primary source of data, thus reports in newspaper archives and other written media referring to more historical accounts would have been missed. For example, collision accounts involving sailing vessels are a rarity in the scientific literature (see Table 4), while this study showed that the phenomenon is quite widespread.

Ocean sailing has become a diversion or profession for an increasing number of people around the world. Hence there are many more vessels sailing on the oceans today, which inevitably increases the likelihood of collisions with marine mammals. Although it is assumed that collisions with sailing vessels are less frequent than with motorised vessels (see Lammers *et al.*, 2007), they may not be as rare as previously thought. Yet, this study has to be considered as a first glimpse at how widespread sailing vessel-whale collisions are and how often they occur. While the increase in collision and near miss events during recent years reported here may be interpreted as a representative reflection of a growing number of sailing vessel-cetacean collisions, it is too early to make any assumption about 'true' numbers; this is in fact a feature of research on all vessel-whale collisions. It is also likely that no near misses were reported by vessels travelling at high speeds (10 knots or more) because they would typically have been in rougher seas and so less likely to see a whale or been aware of having almost hit it. Quantifying sailing traffic clearly requires further research but is essential to enable solid estimation or quantification of collision risk.

Although collisions between sailing vessels and cetaceans may occur in any ocean, reports are most common for the Atlantic. This in line with the geographical distribution of current entries in the IWC ship strike data base (Russell Leaper, pers. comm.) and the fact that there is generally more sailing traffic in the Atlantic with the largest proportion of sailing yachts crossing the North Atlantic (Jeremy Wyatt, Noonsite, pers. comm.). It is worth noting that sailing yachts tend to sail in 'trade wind zones' at particular times of year – i.e. when wind speed and direction are favourable; future investigations may highlight such geographical areas.

The large proportion of reports from monohull sailors, generally with fibreglass vessels, reflects the fact that this is by far the most abundant vessel type worldwide. Most large scale ocean races and regattas are conducted with monohull vessels.

Species affected

Laist *et al.* (2001) and Van Waerebeek *et al*. (2007) name a variety of cetacean species affected by vessel collisions, including large whales and small cetaceans. Carrillo and Ritter (2010) note that certain large whale species are especially vulnerable, namely those ones staying at the surface for longer periods of time, for example right whales (Eubalaena spp., see also Knowlton and Kraus, 2001) and sperm whales during resting periods (Physeter macrocephalus, see also Ritter, 2010). In 2011, the database contained a total of 452 cases where the species was positively identified and the judgement at the time was that it was a definite ship strike (see summary data from IWC database at *http://www.iwcoffice.org/sci_com/shipstrikes.htm*). The majority were fin, humpback and right whales. In the Mediterranean Sea, fin whales are at highest risk to be hit by vessels (Panigada, 2006). Fin and humpback whales were also the most common species in the US Large Whale Ship Strike Database (Jensen and Silber, 2004). While the high proportion of humpback whales (and large whales in general) corresponds to the findings presented here, there are otherwise considerable differences in the frequency of different species being struck. It is unclear why sailing vessels apparently tend to collide less often with fin whales than with sperm and humpback whales, but one explanation may be the degree of familiarity of sailors with these latter species due to their more obvious morphological and/or behavioural features. However, it may also reflect the behaviour of the species. For example, the relatively high proportion of near miss events involving sperm may be

Table 4

Collisions between sailing vessels and cetaceans: cases identified in the scientific literature (n = 8).

Date	Location	Vessel type	Species	Source
Jan. 1897	Mediterranean Sea, France	Yacht	Not known	Panigada *et al.* (2006)
Jun. 1972	Pacific Ocean	Schooner	Orca	Notarbartolo di Sciara (1977)
Apr. 1973	Mediterranean Sea, Italy	Yacht	16m whale	Panigada *et al.* (2006)
Feb. 1981	North Pacific Ocean, Hawaii	Trimaran	'Whale'	Lammers *et al.* (2007)
Feb. 1995	North Pacific Ocean, Hawaii	65ft sailing vessel	'Whale'	Lammers *et al.* (2007)
Oct. 1996	Pacific Ocean, Ecuador	Not known	Possibly sperm whale	Félix and Van Waerebeek (2005)
Dec. 1997	Caribbean	Yacht	'Whale'	Koschinski (2003)
Jul. 2005	North Atlantic Ocean	Not known	North Atlantic right whale	WDCS (2006)

attributed to their distinctive behaviour of frequently logging on the surface. In addition, sperm and humpback whales were also more approachable by open boat whalers. Whale behaviour clearly warrants further investigation. Given the high prevalence of a lack of species identification, it would be valuable if sailors were encouraged to collect skin or other samples after a collision, where feasible, to facilitate later species identification.

The minority of cases reported in this study relates to animals classified 'small whales' or 'dolphins'. This corresponds to the general knowledge about ship strikes (see Van Waerebeek and Leaper, 2008). The apparent low risk of dolphins colliding with vessels requires further investigation, however, since Van Waerebeek (2007), reported 31% of worldwide collision reports related to small cetaceans. Personal observations of the author in the Canary Islands (unpublished data) provides a similar picture.

Causes of collisions

The reports revealed that animals were hit by different parts of the vessels, most as expected however were hit by the bow and the keel. Some stated that the daggerboard was also damaged. In ultra-light, high speed boats sailing faster than hull speed, there is minimal hull in the water and the main contact is likely to be the keel or daggerboard. This part of the vessel strongly protrudes from the hull downwards, sometimes by several metres.

Little is known about the sound generated by sailing vessels, but it seems possible that cetaceans may hear an approaching sailing vessel, at least under 'ideal' conditions. Sailing vessels produce faint sounds by the flow of the water along the hull (Richardson *et al.*, 1995 cited in Koschinksi, 2003), and daggerboards may contribute their own frequencies. However, under less than ideal circumstances it may be difficult for whales to detect the faint sound of sailing vessels ship noise, due to a variety of biological and physical factors (ACCOBAMS, 2005) or masking through ambient sounds generated by wind, rain and shipping noise (WDCS, 2006). Nonetheless, some collisions occurred while the vessel was motoring or motorsailing. Koschinski (2003) reported that many sailors put on diesel generators when whales are seen to make the vessel more audible. Hence, there is some belief among sailors that cetaceans can be surprised by 'silent' vessels. Of course, running a propeller creates much more noise than either the boat's engine or generator.

The seven reported cases of whales colliding with a vessel from below, assumingly while trying to surface, suggests that these whales were not aware of the vessel. Whales also may be unaware of ships because they are distracted or asleep (WDCS, 2006). This may be especially true for sperm whales which recently were found to perform apparent deep rest close to the surface, not reacting to approaching vessels at all (Miller *et al.*, 2008).

Vessel speed

For motorised vessels, speed is generally thought to be a major factor concerning the number of collisions (see Laist *et al.*, 2001; Vanderlaan and Taggart, 2007). The reports presented here suggest the same for sailing vessels: Although the majority of collisions occurred at speeds of 5–10 knots (see Fig. 2), the vast majority of sailing vessels cannot go faster than 8–9 knots which is the displacement hull speed for boats up to about 20m overall length. The fact that 28% of collisions happened at faster speeds despite very few boats sailing at these speeds suggest that speed probably has an effect; collisions during regattas on average occurred at faster speeds than in other contexts.

The number of regattas and ocean races has steadily grown during the past decades, both with monohull and multihull vessels, and there have been significant increases in speed of the vessels in long distance sailing races. There are also increasing numbers of transocean speed record attempts and round the world record attempts in monohulls and multihulls (Oliver Dewar, Global Ocean Race, pers. comm.). Many of these events seem to have at least one account of a collision. Given the scarcity of multihulls, it appears that this vessel type has at least a higher rate of collision reporting, if not a higher rate of strikes. This could be due to their generally higher speed, their involvement in high profile races with good media coverage, their greater vulnerability to damage due to lightweight construction, or a combination of these. It is not clear what percentage multihull vessels represent globally compared to monohulls. Such data are practically non-existent, although the percentage surely is believed to be small (Oliver Dewar, Global Ocean Race, pers. comm.).

Although in half of the collisions (49.5%, n = 76), the animals were not seen prior to the impact, a number of sailors who had seen the whale reported that they took steps to circumvent a collision. In 12 cases, this actually helped to avoid a strike, although in four it did not. This underlines that collisions might be prevented if a whale is seen early enough to take action. Obviously, this is dependant on someone being on the helm, which for solo sailors will not always be feasible. A high degree of effectiveness to avoid collisions has been attributed to dedicated look-outs on larger vessels (Weinrich and Pecarcik, 2007) and thus where there are larger sailing crews it might be beneficial to establish a permanent watch-post, at least while sailing in areas where cetacean abundance is known or expected.

Behaviour of the animals

Some whales hit were recorded as logging on the surface which may be resting or slow travelling behaviours. While floating behaviours might be expected to be particularly risky, the relatively high number of whales being described as surfacing from a dive (i.e. colliding with the bottom/keel of the vessel) is perhaps surprising. It appeared common for animals to surface without noticing an approaching vessel, perhaps due to an unfavourable combination of the ship's speed and the low sound level it produces. In some cases, animals may also actually have been attracted to the vessel before colliding (four near miss events were preceded by apparent 'inquisitive' behaviours on behalf of the animals, two times bowriding behaviours resulted in a collision).

There were reports of collisions being initiated by the cetaceans through apparent aggressive behaviour. Cetaceans attacking vessels have been described before, albeit rarely (but famously), e.g. Philbrick (2000). Van Waerebeek *et al.* (2007) also noted that some cetaceans may violently hit or push vessels. An interesting case involving orcas/killer whales was described by Notarbartolo di Sciara (1977). Some have speculated whether the right whale which leapt onto a sailing vessel in 2010 did so deliberately. However, such events are beyond the scope of this study, which is focussed on accidental and unintentional strikes.

Injuries to sailing crew or cetaceans; vessel damage

Collisions with whales can pose a serious threat to vessels (IWC, 2008; Jensen and Silber, 2004; Laist *et al.*, 2001), and sailors and ferry passengers (de Stephanis and Urquiola, 2006; Jensen and Silber, 2004). This study also received reports of crew members being hurt during collisions even at rather low speeds (the minimum found was 3 knots). On the other hand, high speed may not automatically lead to injured crew. In fact, no sailors were reported hurt in any of the collisions that occurred at speeds of 15 knots or more. This contrasts with findings by Jensen and Silber (2004) and Vanderlaan and Taggart (2007), although their investigations mainly involved motor vessels. This suggests that factors other than vessel speed have a greater influence, e.g. the whereabouts of crew members and the nature of the collision (‘softly’ or with an abrupt halt). In particular, sailing vessels are only likely to be travelling fast in sufficient wind. Thus unlike powered vessels which travel fastest on flat water, the motion of the vessel is likely to force the crew into positions where they are braced against the motion of the boat.

Similar considerations may apply for vessel damage. While Jensen and Silber (2004) found that all collisions where the speed was known and resulting in vessel damage took place at speeds of 10 knots or more, this study produced different results. The question is how can collisions at low speed lead to substantial damage. In some cases, whales were observed hitting the surface with their flukes or other body parts when the collision occurred. Startle reactions such as bending the body or slamming the tail fluke may be natural responses to a strike, and in at least some instances this had a greater influence on the degree of vessel damage than vessel size or speed. Factors including the size of the animal, its swimming speed as a function of its behaviour, the angle at which it is hit, its immediate (startle) reaction all can play a major role for the outcome of a collision.

Finally, the seven reports of vessels sinking after a collision are alarming. They underline the potential great threat to the life of a sailor when hitting a whale. A similar scenario was described in IWC (2006, p.13). Again, speed was not a major factor for the vessel loss: one of the instances occurred when a 10–15m monohull hit a sperm whale at a speed of 7 knots. The crew were uninjured in all instances and were rescued safely, but there may have been similar cases without such a happy end.

Similar aspects as described for injured crew may be true for the injuries inflicted to the animals. These varied strongly from ‘no visible injury’ to ‘possibly dead’. One of the cases for which the animal probably died involved a monohull vessel travelling at 15 knots (in the other case vessel speed is unknown). While this case corresponds to the general finding that most collisions causing severe injuries or death occur at greater speeds than 14 knots (Laist *et al.*, 2001), there were several cases where blood was seen in the water involving small vessels (<10m) hitting whales at slow speeds (4–5 knots). This is contrary to the assumption that collisions with sailing vessels only cause minor injuries (Laist *et al.*, 2001).

Overall, this review suggests that the number of whales that appeared uninjured after the collisions may be overestimated while the severity of an injury may be underestimated (see also IWC, 2003; Lammers *et al.*, 2007; WDCS, 2006). The fact that many sailors had no chance to have a closer look at the animal after the collision (if at all) because the animal is out of sight within seconds, makes it unlikely to detect injuries or to classify them correctly (see e.g. IWC, 2005).

CONCLUSIONS

A variety of measures has been discussed to mitigate the risk of vessel-whale collisions, including speed limitations, on board observers, re-routing and technical modifications or tools (ACCOBAMS, 2005; IWC, 2008; 2011; Pesante *et al.*, 2002). Technical measures up to now mostly have failed to prove their efficacy (ACCOBAMS, 2005; IWC, 2011). Only a fraction of these options will be applicable on sailing vessels. However, there are a number of potential solutions that might contribute to a higher awareness of the issue and the prevention of collisions, respectively.

The most obvious is to keep a sharp lookout during daylight hours. Some collisions reported could probably have been prevented after a whale was seen if avoiding action had been taken. Dedicated observers on board have proven to be an effective means to detect whales in the path of a ship (ACCOBAMS, 2005; Weinrich and Pecarcik, 2007), and combined with a general knowledge about where and when to expect cetaceans, this measure may also be helpful for participants of ocean races and regattas. However, permanent lookouts will only be practical with larger crews and reasonable sighting conditions. Reducing speed as a voluntary measure should be considered anywhere sailors enter important cetacean habitats. Protected areas or regions where cetaceans are known to be abundant should be avoided whenever possible.

Speed limitations by their nature will not be easy to implement for regattas and ocean races (although they are recommended for prime cetacean habitats) but other measures can usefully be considered. Gill (1997) has proposed to shift regatta routes away from the continental shelf, as these are known to commonly be inhabited by cetaceans. A development of this idea would be for other types of habitats and marine protected areas to be avoided by regattas and races (see Tejedor *et al.*, 2007). Important areas for many humpback, right and sperm whale populations are reasonably well known which would make it possible to identify overlaps of regatta routes with high risk areas e.g. migration corridors, areas of seasonal aggregation and prime habitats.

Gill (1997) also suggested conducting acoustic or aerial surveys just prior to a sailing event. This may help determine whether there are cetaceans present or to be expected and if so, to modify routes around as was the case for the Volvo Ocean Race in April 2009[4].

A final idea might be to start the engine/propeller while under sail in areas of known high cetacean abundance in an

[4] See *http://www.nytimes.com/2009/04/25/sports/othersports/25sailing.html?_r=1&ref=sports*.

attempt to make vessels more likely to be detected by cetaceans. The effectiveness of this is unknown but in any case, manoeuvrability will be improved. Experimental investigations are essential to evaluate this or other measures. So far, there are few scientific accounts of cetaceans reacting to acoustic stimuli; and one study showed that right whales returned to the surface after exposure to artificial sounds, making them more vulnerable to ship strikes than before (Nowacek *et al.*, 2004). Future research also should relate species distribution to certain vessel types and contexts (e.g. sailing regattas, etc.).

Education is clearly a major component of minimising collision risk. Sailors must be aware of (a) the risk of colliding with cetaceans; (b) where they are likely to encounter cetaceans; and (c) what can be done to avoid a collision. Without such knowledge, little change will be achieved. This study has shown that there is considerable interest in the issue on behalf of the sailors. Thus it seems realistic to raise further interest and to develop dedicated websites or website sections highlighting the issue. Existing websites thereby should explicitly mention sailing vessels as a potential cause of concern. An intensified dialogue between managers, scientists, NGOs and sailing event organisers is both necessary and feasible. Information campaigns run by regatta organisers' prior to regatta events, or during sailing fairs, could also include training of cetacean identification, mapping areas of high cetacean abundance and producing information materials to provide sailors with simple measures such as 'if you see one whale, the likelihood to encounter more will usually increase' and 'notify other sailors about the presence of whales'. Encouraging sailors to participate in sighting schemes (and even collect skin or other samples for scientific purposes) could further increase co-operations between sailors, scientists and conservationists. In fact, such a co-operation between an NGO and regatta organisers[5] was started during the 2011 Global Ocean Race (Jennifer Londsdale, pers. comm.).

Given that the IMO is dealing with the issue of vessel-whale collisions, and the International Sailing Federation has consultative status at the IMO, it is recommended that the IMO also address the issue of sailing vessels-whale strikes (see also IWC, 2011).

In addition, if a collision has happened, sailors and regatta administrations must be encouraged to report it, and be informed where to direct such information to, especially the IWC ship strikes database (*http://www.iwcoffice.org*)[2]. The permanent establishment of an online survey such as that developed for this study could play an important role. This review suggests that a precautionary approach is warranted on this issue with the final goal to make sailing safer, both for animals and humans.

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[5] *http://www.eia-international.org/new-alliance-seeks-to-make-sailing-greener*.

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