ABSTRACTS FOR THE IWC/ACCOBAMS WORKSHOP ON SHIP STRIKES REDUCTION

1 Overview of the issue with emphasis on the data needed to assess the impact of ship strikes at the population level

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Collisions between cetaceans and ships are one of the anthropogenic factors that has been receiving increasing attention in recent years; it is a problem that can have negative effects for both cetaceans and humans. While this is a problem for any individual cetacean struck, the focus on this talk is one of examining the problem at the population level i.e. does the level and severity of the interactions cause a problem for the conservation status of the cetacean population concerned? If the answer is yes then that population would be given high priority for developing appropriate mitigation measures in conjunction with the shipping industry.

Quantifying the issue and determining priorities for actions requires obtaining reliable information on two fronts:

1. the identity and status of the population(s) concerned (population abundance, structure and spatio-temporal distribution);
2. numbers of injured/killed animals from the population(s) concerned (see below).

The presentation will focus on the data required on whale populations and estimating mortality to allow an assessment of the conservation implications. There are several well established procedures for evaluating the impact of anthropogenic mortality against pre-determined management objectives. However, the difficulties in obtaining relevant data can be considerable. This is especially true with respect to estimating mortality due to ship strikes.. It is likely that all the methods used to establish whether a collision occurred including direct reporting from vessels, observations of carcases at sea and post-mortem examinations of carcases washed up on shore, will reveal only a fraction of the total numbers of incidents.

Given the large number of cetacean populations worldwide, some initial priorities for investigation will need to be set and the use of information on the co-occurrence of shipping traffic and cetaceans (GIS approaches can be valuable here), in conjunction with available information on vulnerability (e.g. from information included in the IWC's ship strikes database). This will require good spatio-temporal information on both vessels and animals. The inevitable uncertainties in data will require careful consideration to allow informed policy decisions to be made.

Where priorities for mitigation action can already be identified, then practical solutions need to be developed in co-operation with stakeholders. These can include separation of ships and cetaceans (e.g. via shipping lanes), management measures such as reduced speed to technological approaches (e.g. REPCET). The importance of monitoring to ensure that identified measures produce the intended results will be emphasised.

2 The IWC ship strikes database: lessons learned and future developments

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The need for a global database of incidents involving collisions between vessels and whales has been widely recognised by scientists, industry and management bodies, including the International Maritime Organization (IMO), ACCOBAMS and IWC. The IWC Scientific Committee initiated the development of a database in 2007 including historical data and systems for public data entry and review of incidents as they occur. The three main objectives were:

1. to allow use of all available data to generate larger sample sizes in order to investigate how factors such as speed and vessel type relate to collision risk – this should lead to better ways to model risk and identify high risk areas;
2. to improve ability to identify areas where the impacts of ship strikes may be of particular conservation concern at the population level, based on the numbers of reported incidents and/or modelling of risk;
3. to improve potential to develop the most effective mitigation measures.

Data sources for historical records included previous published datasets, and review papers by region or vessel type presented to the Scientific Committee meetings. More recent incidents involving large whales were summarised in National Progress reports submitted annually by IWC member states. The structure of the database was designed to allow linking of records from different sources to a single incident. For example, reports of the collision itself, observations of a carcass at sea and a subsequent stranded carcass ashore may all involve the same whale. A publicly available web based data entry questionnaire system was developed in 2009 to allow anyone with information to report it. Such information requires a careful validation and verification process since it cannot be assumed that the source is reliable.

The focus to date has been on data entry and developing a reliable data gathering system. Hence the database has not been available for general queries. However, there have been many more requests for data than those wishing to contribute data. Making data available raises a number of issues including the level of validation and confidentiality of certain information. It is critical that data cannot be used in a way that would discourage others from reporting incidents. The downloadable summary database prepared for the workshop is the first attempt to balance making data readily available while minimising the risks that these will be misinterpreted.

The database has been developed through work by individual members of the IWC Scientific Committee, the IWC Secretariat and small contracts for data entry and to a database consultant. These informal arrangements have allowed progress but will need to be kept under review, and appointment of a dedicated database co-ordinator may be required in the future.

3 Information on shipping density and demonstration of data integration on the web

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The talk will describe the potential sources of shipping position information that are currently available that are relevant to whale strikes and outline some of the revenant issues with the data. There are a number of potential sources of data, each with their own advantages/disadvantages.

- What types of shipping they cover
- Coverage, both spatially and temporally
- Value added services, e.g. alert systems
- Access and licensing
- Opportunities to work with partner organisations
- Producing meaningful maps of shipping and shipping density

In addition, a brief demonstration will be given to highlight how conservation-related datasets can be integrated using web-based GIS tools using a couple of the tools that UNEP-WCMC have developed.

4 Assessing the Potential Conflict between Shipping and Cetaceans in the ASCOBANS Region

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Northwest Europe contains some of the busiest waterways in the world. In order to reach a better understanding of the risk posed by shipping to cetaceans within the ASCOBANS Agreement Area, two alternative approaches to plotting vessel densities were examined, and then compared with information on the relative densities of various cetacean taxa (baleen whales, large toothed whales, dolphins & porpoises).

Shipping was plotted using AIS (Automatic Identification Systems) and VOS (Voluntary Observing Ships Scheme). Each has its advantages and limitations. Because the VOS program is voluntary, some commercial shipping traffic is not captured by these data, and this may particularly underestimate high traffic locations. Furthermore, because ships report their location with varying distance between signals, ship tracks are estimates of the actual shipping route taken. Under the International Maritime Organization's International Convention for the Safety of Life at Sea (SOLAS), AIS is required on all vessels with a gross tonnage of 300 or more tons, and all passenger vessels regardless of size, giving it particular potential for mapping shipping densities. However, AIS receivers have finite range whilst this may vary with atmospheric conditions. The most important factor for better reception is the elevation of the base station antenna. The higher it is, the better. In optimal conditions this can detect vessels 200 nm away, but for many land-based stations, it is much less. This was tested further in waters around the British Isles.

Despite the limitations of the two methods, they both reveal similar patterns of variation in shipping density, with high traffic locations generally matching our knowledge from other information sources.

The relative densities of cetaceans were derived from dedicated offshore surveys, with numbers per unit effort (corrected for sea conditions) plotted on a grid cell basis for different cetacean groupings. These were then used to make some assessment of the relative risk of ship strike (taking account of average vessel speed which influences lethality) on a regional basis.

5.1 Regional case studies: Mediterranean Sea and Canary Islands

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Collisions between ships and cetaceans occur throughout the world, with the fin whale, *Balaenoptera physalus*, being the species most often involved. In the Mediterranean Sea, ship strikes with the two large Mediterranean cetaceans, the fin whale and the sperm whale, *Physeter macrocephalus*, are relatively common, due to the high volume of maritime traffic concentrating in areas and seasons in which these species occur in high densities.

In cooperation with ACCOBAMS and the IWC, a series of initiatives to investigate and suggest mitigation measures for the risk of collision in the Mediterranean, particularly in the Pelagos Sanctuary has been developed. One of the first aims of this initiative is to improve and increase the dataset for the Mediterranean basin and raise public and institutional awareness. A dedicated web site (www.tethys.org/collisioni/) presents latest updated information about ship strikes, helps disseminate awareness materials to inform ship crews and the general public and includes reporting forms.

This regional database is compatible with the global IWC database and the Mediterranean data will form an integral part of it. An important component is also the collaboration among shipping companies, port authorities and scientists, along with the provision of public information on reporting. The available information for the Mediterranean Sea is sparse. Reliable estimates of fatality rates and associated information are essential to assess impacts at the population level and design effective mitigation measures.

Preliminary qualitative maps to assess areas where ship strike risk may be high in the Mediterranean Sea have been produced, overlapping naval traffic - obtained from AIS data and from ferry routes - and large whale known preferred habitats.

5.2 Collisions between ships and whales in the Canary Islands. The case of Tenerife

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The monitoring and study of the stranded cetacean in the Tenerife island has been carried out in a systematic manner since 1991, when the stranding of two specimens of sperm whale *Physeter macrocephalus* was reported for the first time. The animals were two adult females with the bodies divided in halves. (Martín y Carrillo 1992). As a consequence of the social alarm that the collisions between the small fast ferries (jet-foil) and cetaceans caused, in 1993, the University of Las Palmas de Gran Canaria (ULPGC) was introduced to the research, with the financial support of the Transmediterranea Company, in order to determine the migratory patterns of the big whales in the Canary Islands. The results confirmed that the waters near the port of Santa Cruz de Tenerife are a high density area of cetaceans, emphasizing the presence of a resident population of sperm whale (André, M. 1998). However, the research provided little information about the distribution and seasonality of the sightings.

From 1999, coinciding with an increase of shipping traffic and the development of newer faster vessels, the situation changed remarkably. A notable increase of stranded cetaceans with clear signs of ship strikes has been reported (Aguilar *et al*. 2000, 2001, Herrera *et al* 2000). To this regard and with the aim to identify the potential risk of the collisions, a model of risk for the high shipping traffic areas in Tenerife was developed (Tregenza *et al*. 2000, 2002) as well as general tables for collisions for all the Canary Islands (Government of Canary Islands, ULPGC, Tenerife Conservation and SECAC 2009). The analysis of the different stranded animals clearly confirms that the most affected species by ship strikes is the sperm whale (Carrillo & Tejedor, 2006; De Stefanis & Urquiola 2006; Carrillo, M. 2007; Carrillo & Ritter 2008).

Complementary to the analysis of the collisions between vessels and cetaceans, we also go through all the mortality factors and the seasonality of 284 records of stranded cetacean in Tenerife, the island in the Canary's were not only most cases of stranded animals but also ship strikes are reported (Arbelo, M. 2007). The analysis of the stranded cetaceans during the period from 1991 to July 2010 shows that in 103 of the cases (36.3%) no signs of anthropogenic interactions were found, reporting these deaths as a natural factor. In 70 of the cases (24.6%) wounds, fractures, net marks, fishing devices or anomalous stomach contents (plastics) were observed, which could be associated to the death of the animal, thus, the mortality factor is related to anthropogenic interaction. In 111 of the cases (39.1%) the mortality factor has been classified as undetermined due to the difficulty to examine the specimens or as a consequence of the high level of decomposition.

From the 70 cases of the specimens classified with a mortality factor of anthropogenic interaction, 43 of them showed serious injuries, massive traumas, fractures of hard bones or bodies divided in halves. These animals show clear signs of collision and have been reported as due to shipping traffic mortality factor. This represents 61.4% of the cases of anthropogenic interactions and 15.1% of all cases of stranded cetaceans in the island of Tenerife. The annual distribution of the different cases shows that until 1998, when jet-foils began to appear, 0.6 cases of collision were registered every year and from thereon (to present), the average has increased to 3.1 cases every year. Although cases are registered all year round, seasonality shows that the majority of collisions occur between June and July, with 8 cases registered in both months. In terms of affected species by ship strikes, at least 7 species have been reported: sperm whale (*P.macrocephalus*), short fin pilot whale (*Globicephala macrorhynchus)*, pygmy sperm whale (*Kogia breviceps*), dwarf sperm whale (*K. simus*), Cuvier's beaked whale (*Ziphius cavirostris*), Gervais's beaked whale (*Mesoplodon europaeus*) and fin whale (*Balaenoptera physalus*). The sperm whale, with 21 registered cases, is the most affected species and represents a 48.8% of the total cases of collision in the island of Tenerife. Furthermore, the sperm whale is listed as vulnerable in the Catalogo Nacional de Especies Amenazadas and in the IUCN Red List of Threatened Species (CNEA 1990, IUCN 2010). However, differently to other places where collisions are well documented (NMFS 2007; Tejedor *et al*., 2007), in Canary Islands nothing has been done to date in order to minimize the risk of ship strikes.

In order to better protect this species, it is essential to address and mitigate those human activities that result in mortality. In 2007, Tenerife Conservation carried out a revision of the available data of sightings, stranded cetacean and threat factors of the protected species of cetacean in the Canary's and developed a report for the government of the Canary Islands with the aim to establish a conservation plan for the sperm whale. Therefore, we propose the following measures:

1. To determine the distribution and estimate the size of the population of sperm whale and other cetacean in the areas of high vessel traffic (Tenerife-Gran Canaria and Tenerife-La Gomera, Red Natura 2000), in order to establish the relative probability of vessel and cetacean encounter.
2. The placement of dedicated on board observers (look-outs) on all fast and high speed vessels.
3. Experimental on-board application of technical mitigation measures to test their feasibility and effectiveness. Workshop on reducing risk of collisions between vessels and cetaceans.
4. The introduction of a mandatory reporting scheme for collisions, thereby making use of the database being developed by the IWC Vessel Strike Data Standardisation Group (Van Waerebeek and Leaper, 2007).
5. To propose to the vessel operators and crew an immediate recommendation to avoid causing injury or dead to cetacean.
6. It would be also important to improve the monitoring of floating dead cetacean that occasionally would not be recovered and might be cases of ship strikes.

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5.3 Regional case studies: Mediterranean Sea and Canary Islands

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Key areas for cetaceans in the Canary Archipelago: collision risk and mitigation strategies

With 29 species recorded, the Canary Islands (Spain), in the Lower North Atlantic, are a well-known hot spot for cetacean diversity. These waters constitute an important habitat for several species of deep-diving cetaceans such as beaked (fam Ziphiidae) and sperm whales (*Physeter macrocephalus*). Cetacean's mortality related to collisions is an increasing global conservation problem. This archipelago supports a high-density maritime traffic, with a high-speed vessels fleet that annually travels around 845,000 km between the islands. Some future lines of high-speed traffic are currently in consideration (e.g. west coast of La Palma, South-East of Fuerteventura islands, South of Lanzarote island). This archipelago has several Special Area for Conservation (SAC´s) for bottlenose dolphin (*Tursiops truncatus*) in the Canary Islands, which are mainly located in the SW portions of the main islands. They are sectors of waters protected from main currents and winds trades by the high relief of the islands, originating calm waters due to the "Island Mass Effect" that increase productivity locally. In these areas, a significant touristic growth in the last years has promoted synergic threats such as whale-watching, coast alterations, artisanal fishery, traffic of a variety of recreational boats and ferries and fast-ferries lines. Regarding the stranding data (Canary Islands Government, SECAC and IUSA's databases and published literature), two critical areas for collision with cetaceans exist in the archipelago: the SW of Tenerife and the North portion of the inter-islands channels between Tenerife and Gran Canaria islands. Since 1999, the Society for Study of Cetaceans in the Canary Archipelago (SECAC) has been involved in a number of projects to monitor the population of cetaceans in the islands. To date, 825 day-surveys, with 3.717 hour on effort, 21.319 nautical miles with 1.833 cetaceans sightings. In the last years a considerable effort has been realized in most oceanic waters of the oriental islands of the archipelago (Lanzarote and Fuerteventura) with a combination of visual and acoustic census with towed hydrophones, focusing on sperm whales. In these areas the collisions could be a potential threat for the conservation of the species. This presentation reveals the preliminary results about the frequency and distribution of these species in the Canary Islands, as well as the critical areas for collision.

Strait of Gibraltar

The Strait of Gibraltar is the second area with the most intense maritime traffic in the World, with around 103,000 ships passing every year. Collisions between ships and cetaceans in the area involve mainly three species, fin whales (Balaenoptera physalus), sperm whales and pilot whale (*Globicephala melas*).

Since 2007, the Spanish Government identified a critical area for sperm whale that recommends, between April and August, navigating with increased caution and at a speed lower than 13 knots in order to avoid collision. Land-based studies showed that the 13 knot-speed limit is not respected by a great majority of vessels, mean speed being 13.9 knots for cargo ships, 15.3 knots for regular ferries and 24.4 knots for fast-ferries, while a high number of fin and sperm whale sightings in winter suggests the need for an extension of the recommendation over the winter months.

The expansion of Tarifa harbour, with the opening of a new fast-ferry line from Tarifa to Tanger-Med harbour by the end of 2010, will increase once again the traffic and deliberately allow 30 knot-vessels to cross the entire critical area.

Dedicated surveys are carried out to investigate the movements of sperm whales as well as understanding the "boundaries" of the fin whale Mediterranean population.

A series of initiatives should be encouraged regarding the ship strike issue including training of the crew members, the presence of on-board observers, and passenger awareness, as well as increasing the collaboration with Morocco.

6.1 Reporting cetacean mortality related to ships strikes: the Italian experience

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In the recent years, the problems related to collisions with vessels in the Mediterranean basin have grown to a level of general concern because of the repetitive registered instances of animal harm. Evidences for death linked to collisions are largely due to well documented instances of large cetaceans (mostly fin whales) stricken by cruising vessels and photographed in the port. However a larger – and more worrisome – quantity of animals has been reported victim of accidental entanglement in fishing machineries in several areas of the Mediterranean. Our particular point of observation relays in the possibility of evaluating by-catch instances directly in the necropsy room when performing post-mortem investigations on stranded animas. The pathology service of the Faculty of Veterinary medicine of the University of Padova is closely linked to the Mediterranean marine mammal tissue Bank of the same Institution, and received animals recovered by the several local stranding networks that operate along the Italian shorelines. Additional to these regional opportunities, we have also been asked to express our opinion on animals recovered in other riparian countries facing the Adriatic. The definition of "stranded" here includes also those specimens that reached the shores long after long drifts in the open waters and show signs of mutilation due to engine parts and especially the rotor blades. To this list of animals, we may also add all the cetaceans that we have not examined directly either on the beach or in the necropsy room, but had the chance to see when specific puzzling pictures of the damaged animals were referred to our attention by third parties for a professional opinion.

In our presentation we will analyse all the issues and categories stated above as seen from our point of view, and will give an estimation of the phenomenon from this stand, suggesting the necessity to involve the national public veterinary service and the Coast Guard by a specific training, in order to have a capillary action and to understand the role of diseases and other spontaneous conditions in predisposing animals to vessels strikes. We hope our observations will contribute to reach a more general and widely shared evaluation of by-catch-related events in the Mediterranean area with special reference to the waters adjacent to the Italian peninsula.

6.2 Pathology of struck whales

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Collisions between large vessels and cetaceans have only recently been fully recognised as a source of anthropogenic mortality and injury, and they need to be assessed and quantified. A pathological diagnosis of the primary cause of death is not always easy, as most of the carcasses are found in a very advanced process of decomposition. Floating carcasses can have been stricken by vessels, making difficult to determine whether the collision had occurred pre- or post-mortem. Since some years ago, we have made efforts for the development of histochemical techniques that could help to differentiate those situations, allowing us to get a final diagnosis. A histochemical technique based on detecting fat emboli in the lung blood vessels has been set up, and it has been applied to whales suspected to have been killed by ship collision.

It is well known in human beings that after a significant trauma causing bone fractures or severe soft tissue damage, fat emboli can be found as a result of that. These fat emboli are found within lung mid size vessels and/or capillaries by using histochemical methods.

Forensic histopathologists have been using Osmium tetroxide postfixation and/or Oil Red O histochemical techniques to detect microscopically fat emboli in lung samples. These were previously, either frozen or formalin fixed. The second group is post-fixed in Osmium before being embedded in paraffin. During the last years, Unit of Histology and Pathology has been working on dead cetaceans suspected of having been traumatized by ships as well as with stranded dolphins and whales with and without external lesions in order to find out fat emboli in the lungs as a main sign to rule out "in vivo" trauma from postmortem changes. Our work will present the results of those studies, showing that this histochemical technique could be a valid forensic tool to demonstrate severe trauma occurred "in vivo" (especially in ship-collision cases), allowing us to rule out "postmortem" changes found during the necropsy.

6.3 Stranding networks: proposals to enhance their effectiveness and streamline ship strike data reporting

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Ship strikes have been identified as a significant cause of mortality for large whales. The incidence of ship strikes has increased in the past decades because of an increase in shipping volume, but also in vessel speed. Nevertheless, ship strikes are underreported because of a range of complicating factors: most struck whales are in an advanced stage of decomposition when detected, determining the ante- or post-mortem timing of the strike is very difficult, carrying postmortems on large whales is not always possible, evidence of a strike is often only present at a skeletal level, and dead whales often drift towards the open sea. This presentation aims at providing criteria for improving the attribution of the cause of death to a ship strike by reviewing the most common lesions and signs present in case of a ship strike, and setting up a triage to assist stranding networks in increasing the detectability of ship-strike cases. In addition, suggestions are given in order to facilitate the integration of data submitted into the database.

7 Contribution of modelling to risk assessment and evaluation of mitigation measures

Russell Leaper *et al.*

Understanding the importance of different factors related to collision risk and hence designing the most effective mitigation strategies has been constrained by the lack of data. Models can play a useful role in integrating data on collision incidents collected globally, and also in relating shipping and whale density distributions to estimate risk. Simulation models may also be useful in evaluating mitigation strategies and the sensitivity of their effectiveness in risk reduction to the assumptions that have been made.

We briefly review examples of previous modelling studies including relating collision risk to vessel speed through analysis of reported collision data, relating risk to vessel type through hydrodynamic modelling, and simulation studies of the likely ability of vessels of different types to make avoidance manoeuvres in response to sightings.

The main focus of the presentation is on overlaying shipping and whale distribution patterns to assess risk and examine potential routing options to reduce risk. Factors to consider include the temporal variability in whale distribution and whether either short (dynamic) or long term (e.g. moving Traffic Separation Schemes) changes in routing would be effective risk reduction measures for case study areas. Data on shipping density can be derived from AIS transmissions but need careful analysis to generate unbiased estimates. Whale data are derived from surveys that represent a snapshot of distribution patterns. Sequences of survey data can be related to habitat variables to obtain information on the likely persistence over time of areas of high whale density.

8 1998 – 2010. From collisions to cetaceans reporting: the REPCET system

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1998, in the north west mediterranean sea, two collisions with fin whales occurred on two different ships "Monte Cinto" and "NGV Asco" with some damage on the HSS. These events were followed by the establishment of partnerships that lead to scientific studies 2001, a study on the detectability of large cetaceans from high speed vessels demonstrated the importance of having an observer specialising in the detection of large cetaceans. The study also developed a training course for crew members at the French National Merchant Marine School of Marseilles. 2004 test of a system for reporting the position of large cetaceans, foreshadowing the system REPCET who will be in function in 2010. REPCET, REaltime Plotting CEtacean is simple and is based on the following: every sighting of large cetaceans by crew on watch aboard a vessel equiped of REPCET is transmitted by satellite in real-time to a server located on land. The server then centralises the data and sends out an alert to all equipped vessels likely to be concerned. The alerts are displayed cartographically on a dedicated screen on board. The collaborative nature of the system means it relies on the density of maritime traffic. Other vessels are also welcome to contribute voluntarily to the system by reporting cetacean sightings, especially any scientists at sea, whale watching operators, or even pleasure boaters.

Designed to evolue with technology, REPCET will be also capable of providing seagoing personnel with results from prediction models of whale presence, and of integrating systems of automatic detection. All data collected through REPCET will be placed at the scientific community’s disposal as part of the work of Pelagos Sanctuary and ACCOBAMS.

9 Assessing Technological Approaches to Reduce Ship Strikes of Cetaceans

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Introduction

Vessel collisions are a worldwide threat to marine mammals. Vessel collisions ('ship strikes') occur with large whale species (Best *et al*., 2001; Knowlton and Kraus, 2001; Laist *et al*., 2001; Jensen and Silber, 2003; Vanderlaan and Taggart, 2007), small cetaceans (Van Waerebeek *et al*., 2006), and sirenians (i.e. manatees and dugongs) (Greenland and Limpus, 2006; Calleson and Frolich, 2007). Records indicate that nearly all large whale species are vulnerable to ship strikes (Laist *et al*., 2001; Jensen and Silber, 2003; Van Waerebeek and Leaper, 2008) including, but not limited to, blue (Balaenoptera musculus), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), right (*Eubalaena* spp.), sei (*B. borealis*), and sperm (*Physeter macrocephalus*) whales. Van Waerebeek and Leaper (2008) reported that a number of small and mid-sized cetaceans occurring in the Southern Hemisphere are involved in vessel collisions. Strikes involving sirenians and small water craft are an ongoing problem in locations where these species occur (U.S. Fish and Wildlife Service, 2001; Greenland and Limpus, 2006).

Seeking a technological solution to the problem of ship strikes (e.g. sonar, radar, enhanced remote visual detection), in addition to or in lieu of changes to vessel operations, has been proposed by maritime industries, resource managers, businesses, and government agencies alike. Some authors, corporations, or inventors indicate that a particular technology has direct application to addressing the problem, but not all claims are supported by studies or empirical test results. Further, relatively few studies have attempted to compile information on applicable technologies or assess the effectiveness of their use (Anonymous, 1999; NMFS, 2002).

In July 2008, NOAA's National Marine Fisheries Service (NMFS) convened a workshop to identify and assess technological approaches to reducing vessel collisions with large whales (Silber *et al*., 2009). Information contained in this paper is derived almost entirely from that workshop. A summary of key workshop conclusions is provided.

The July 2008 workshop identified and considered the advantages and disadvantages of the following technologies (Table 1 [- to be inserted -]):

1. marine mammal visual detection
2. telemetry and tagging
3. passive acoustics
4. active acoustics
5. infrared
6. radar
7. predictive modeling

Overview of Workshop Conclusions

Participants concluded that the problem of ship strikes is complex, with no obvious or simple technological 'fixes' immediately available for wide scale use. Thus, no single technology now exists, or is likely to be developed in the foreseeable future that will eliminate, or reduce to zero the chances of, ships striking large whales. Reducing the spatial overlap of both whales and vessels is likely to remain the best means of reducing ship strikes – a solution not feasible or practicable in many settings.

Use of remote sensing technologies may provide a more effective means to reduce ship strikes if used effectively and also allow certain maritime commerce and other activities to proceed with limited biological and economic impact. However, studies should be required to confirm that any technology developed and used for this purpose is clearly capable of reducing strikes and would not introduce added environmental impacts. Also, development, installation, and/or operation may be cost prohibitive (Anonymous, 1999).

If tested and used, several technologies (e.g. predictive modelling, passive acoustics, and active acoustics) employed in concert could provide information for far- and near-field detection capabilities to aid voyage planning, as well as immediate avoidance reactions. Some workshop participants proposed using multiple systems and technologies to best mitigate ship strikes. For example, they envisioned use of predictive modeling of regional whale occurrence, refined use of passive acoustics to determine local (10s to 100s of km out) occurrence, with yet further detail on whales in the vessel's immediate vicinity provided by active acoustics.

This hypothetically provides better bases for voyage planning and relatively near-field evasive actions, leaving mariners with the freedom to determine the best means of avoiding whales. However, such a network of systems might be costly to maintain and would still rely on potentially hurried last minute evasive action by a large vessel. With regard to some technologies, new, complex, or expensive ship-board systems may need to be developed and maintained, e.g. screen monitoring watch standers.

Mariner response and vessel reaction times

Technologies applicable for reducing ship strikes are focused almost entirely on enhancing whale detection. Enhanced detection capabilities can and should be pursued; however, reaction times of both whales and mariners remain important and challenging components of the problem. Several technologies used together would increase the chances of detection at ranges both near and far from a vessel, improving the likelihood of providing warnings to mariners.

However, knowledge of whale locations, regardless of how thorough or timely the information provided, only partly addresses the equation: mariners must still have sufficient time, the desire and wherewithal, and the capability to take Aevasive action@. Workshop participants emphasized that the mariner must have the capabilities (e.g. adequate communication systems and adequate response times) to take evasive action to avoid a detected whale. Responses to such information may vary amongst mariners and vessel types. Even the most diligent and conscientious mariner will require substantial distances to avoid, alter course, slow down, or react at all to an object directly in his/her path, particularly at higher speeds. Because most large, traditional hull vessels have very long reaction times and distances, workshop participants concluded that thousands of meters are needed to significantly alter the course of a large vessel in most conditions (Fig. 1). While executing such a manoeuvre, the vessel has limited options for evasive actions, is vulnerable to reduced manoeuvrability throughout the action, or may inadvertently veer toward undetected whales in avoiding those observed. In addition, responding to whales may put undue burden on responsible mariners who alter course or speed when others do not (thereby increasing the risk of collision with another ship, for example), thus affecting navigational safety.

In quite a number of records of large whale ship strikes, the whale suddenly surfaced under or immediately in front of the vessel and was never seen by the ship's crew (Laist *et al*., 2001; Jensen and Silber, 2003). This suggests that a strike may not have been precluded under any circumstances - even those in which the mariner might have been armed with good information that whales were in the vicinity.

High-speed vessels (e.g. some passenger ferries) represent exceptions to general manoeuvrability rules. Many possess unique hull configurations, propulsion systems, better manoeuvring capabilities, and shorter stopping distances. However, even with greater manoeuvrability than conventional hulls, such vessels may not be able to react to an observed whale in less time due to their faster speeds.

Alarm devices

Of the technologies considered, alarm devices that frighten or deter animals from a particular location were dismissed with minimal discussion in the workshop because repeated or chronic exposure to alarm or alerting stimuli may result in whales and other marine species abandoning a desired feeding, socializing, or migrating area that could result in significant adverse effects on the population. Further, no evidence exists that large whale species would, in fact, respond to such a sound signal by moving away. In the only study of alarm sound playback experiments involving right whales, Nowacek *et al*. (2004) found that right whales exposed to the alarm sounds immediately rose to the surface and remained motionless, where they are more vulnerable to being struck.

Even if the whales initially responded in a way that might indicate a type of avoidance, workshop participants noted that whales may become habituated to such alarm signals. Acoustic deterrent or harassment devices have been used in certain situations to warn small cetaceans and pinnipeds away from commercial fishing gear and aquaculture operations by emitting loud sound pulses. Their use has received mixed success because some marine mammals grow accustomed to the stimuli (see Reeves *et al*., 1996).

Voyage planning

Workshop participants concluded that carefully considered voyage planning that anticipates the potential for whale interaction is more desirable than attempting to react to the presence of whales in the near field. That is, knowledge about where whales occur, either historically or with some predictability (e.g. through predictive modelling, see description below) may allow mariners to plan in advance to avoid or carefully transit through a particular area.

Feasibility

In all cases, efficient and reliable means to provide information to mariners that can be used to effectively respond is the best course to avoid whale strikes. Therefore, some technologies hold promise and may have application to this problem in the relatively near term, perhaps when used in combination. Others will require continued research and development before wide scale application is feasible. Whereas mariners expect to avoid whales when forewarned and all wish to avoid hitting them, most technologies have limitations in providing detection ranges adequate to allow mariners sufficient time to respond. Given the severity of the problem for a number of endangered species and the relative paucity of foolproof solutions, technological approaches are worthy of, and should be the subject of, ongoing pursuit.

Assessment of Technologies

Summary of conclusions regarding various types of technologies (refer to Silber *et al*., 2009 for complete discussions).

Marine mammal visual detection

Although used extensively in some areas, visual surveys can be expensive, logistically complex, and are limited by poor weather, low-light conditions that vary by time of the year. Even in the best of conditions, only a fraction of the whales actually present may be detected (Fig. 2). Most of these points also can generally be applied to the posting of dedicated lookouts.

Marine mammal tagging and telemetry

Telemetry is highly useful for studies of whale natural history and movement, and the field is advancing rapidly, particularly in regard to increasing power supplies and decreasing costs to transmit data. However, this approach faces challenges in the attaching of devices to whales and in the logistics of deploying devices to a sufficient number of individuals to make it a viable means to reduce ship strikes.

Passive acoustics

Passive acoustic technologies are becoming commonplace in many locations for studying whale occurrence and distribution. Due to the amount of data returned for cost investment relative to other technologies, this approach may be one of the most promising for addressing ship strikes. However, these devices will only detect vocalizing whales and determining specific location is not always possible unless multi-unit arrays are used.

Active acoustics

Active sonar devices can be effective in detecting whales within hundreds of meters (perhaps up to one thousand in certain cases and circumstances) of a vessel, although this range may be extended as technology improves. Wavelengths of sound that work best for detecting whales are also audible to other marine mammals and fish, and may produce undesirable effects on other organisms and parts of the ecosystem while reducing risks for large whales. Depending on the eventual system designs used, costs can be relatively high and false positives could be problematic.

Infrared

Thermal imaging devices have proved promising in detecting whale blows in Antarctic waters and elsewhere at ranges greater than one kilometer but are less effective in warmer climates where blows and ambient temperature differences are less.

Radar

Radar devices can be used from ship or shore and have the advantage of operating in poor weather. False positives are a potential problem, though, and more performance data will be needed before commercialization can be contemplated. Ranges are also limited to line-of-sight, which for a small vessel might be 5-8 km (about the same or slightly better than ideal visual detection ranges). The higher the antenna above the water's surface, the farther a radar can detect objects, with shore-based systems providing detections at ranges exceeding 10 km.

Predictive modelling

Predictive models using oceanographic data from satellites or other sources are a relatively low-cost means to predict where whales may occur. Like all models, including weather forecasts, there is an inherent amount of uncertainty in the predicted outcome, but fairly reliable models can be applied now to provide information on large scales. Coverage potentially can be regional in scale, but resolution (and therefore utility) is greatest at scales on the order of 100s of meters.

Some Additional, Miscellaneous Considerations

The workshop also made note of a number of additional observations not specifically discussed at length in the workshop deliberations. These included:

1. Any technology employed should introduce no, or minimal, co-occurring negative effects to marine organisms or habitat.
2. Use of technologies should involve minimal impact to normal bridge operations, i.e. least amount time involvement from the mariner while underway.
3. Some of the technologies considered require considerable training for the operators and could involve significant costs (including maintenance).
4. Technologies that can be incorporated with existing systems are more likely to be accepted by maritime industry than those that require autonomous equipment and dedicated staff to use them effectively.
5. Finding technological solutions is a multi-part process; there is no one measure to fit all situations.
6. Large vessels pay about $700/ton of fuel. Any hull changes or other devices added will increase fuel consumption. Environmental footprint will increase with physical solutions. It is highly undesirable to transfer one biological problem for another environmental problem.
7. Ideally, applicable technologies can be dovetailed with multiple detection systems and can be situation or context specific, e.g. can be fine-tuned to area or vessel type.
8. Ideally, a viable technology operates in real-time, but with sufficient time to react.
9. With regard to active acoustics technologies:
    a. the issue of underwater noise is an international concern (ship noise, sonar noise, etc.). Active acoustic technologies would involve increasing noise levels in the ocean; and ensonifying large areas of ocean would require significant power. Power requirements of some moored systems present technological challenges. Power requirement are not a limiting factor for ship-mounted forward-looking SONAR devices.
10. Small craft are also involved in whale collisions, but have operating characteristics that differ from large, oceanic vessels; and thus have a different range of technologies that may be appropriate to them.
11. If technology use or research were proposed for waters of the United States, it would:
    a. Likely require permits under the Marine Mammal Protection Act and possibly the Endangered Species Act. Any tagging of large whales would require MMPA and possibly ESA permits.
    b. Likely need to develop operational standards for any of the technologies and phase in any requirements for their use; and
    c. Likely need to develop key metrics for determining the standards of any technologies and the way they would be used, including feedback loops of the information gathered and communication systems to assure that information collected was widely disseminated.

In the course of discussions and during a ‘brainstorming’ session, the workshop participants also identified several other potentially applicable technologies to address ship strikes, but were not assessed. These were:

1. tactile alarm in front of ships, e.g. water cannon;
2. satellite- or unmanned aircraft-based hyperspectral imaging (i.e. detection of electromagnetic spectra, such as ultraviolet);
3. tomographic profiling of the water column;
4. physical technologies such as prop guards and hull designs; and
5. wake detection and other indicators of whale presence as detected from the air.

Conclusions

[- to be added -]

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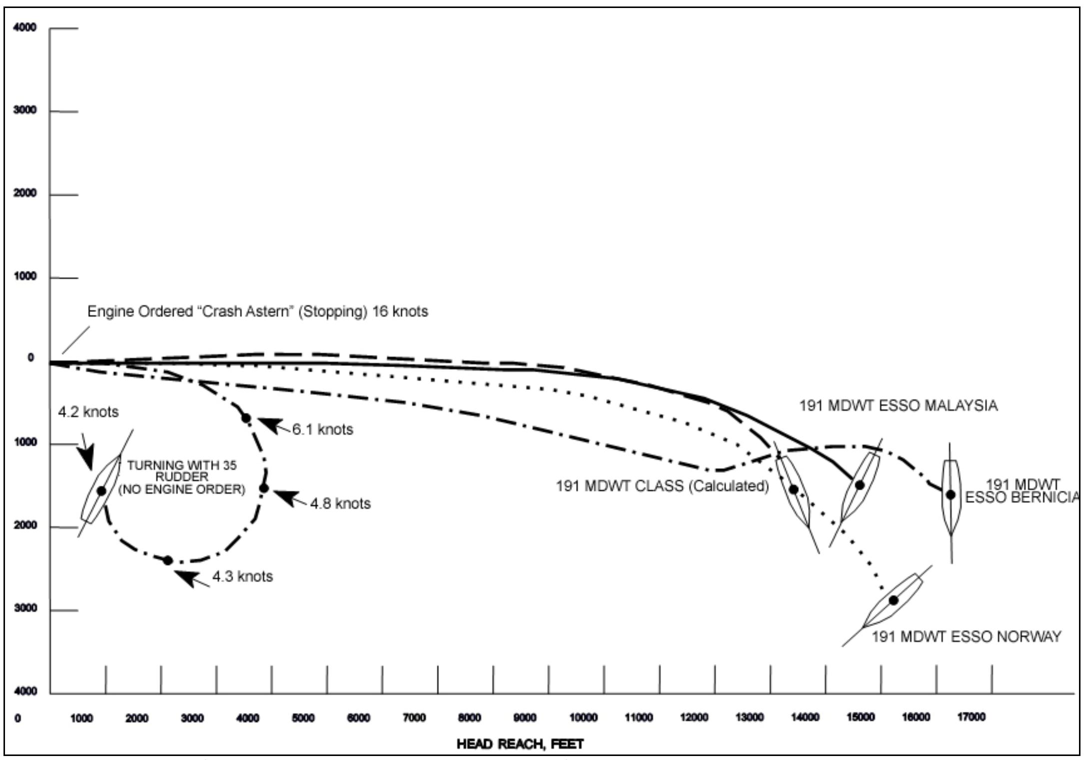

Figure 1. Comparison of calculated "crash astern" maneuvers with full-scale trial results (Exxon 191,000 dwt tankers, loaded condition). Please note, these comparisons are hypothetical and are intended for illustrative purposes only given the variables for any given situation such as wind and current forces, vessel size, weight and windage play significant roles in the curves presented here. It may not be possible to generalize them to other situations, hull types, etc. Graphic courtesy of Maritime Institute of Technology and Graduate Studies (MITAGS), provided by Robert Becker. (Silber *et al*., 2008)

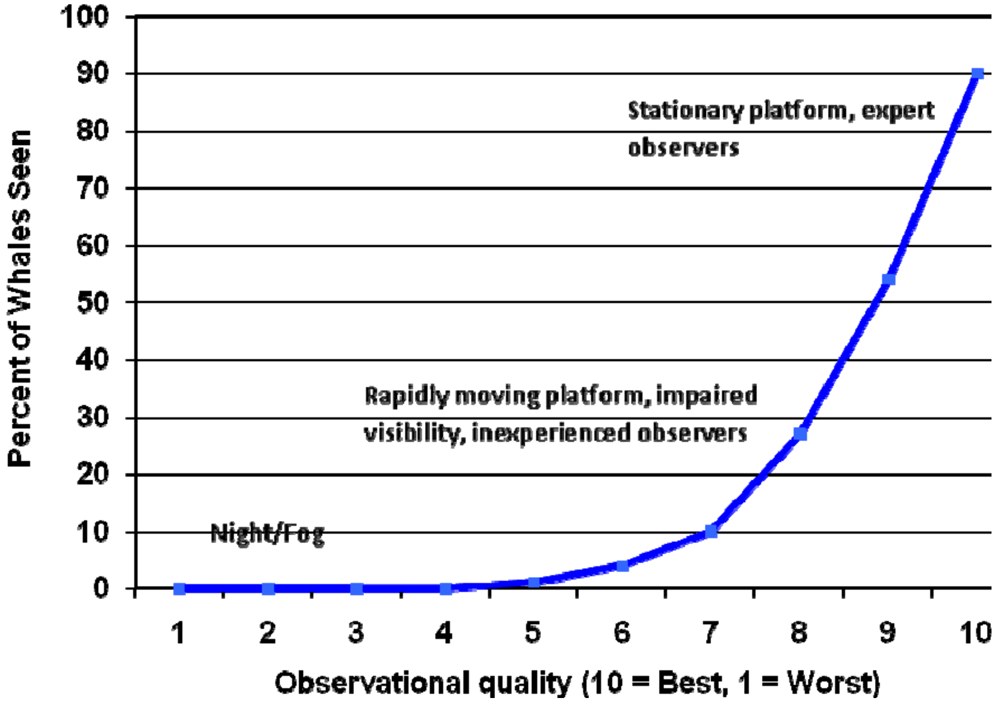

Figure 2. Hypothetical depiction of whales seen as a function of observational quality, going from zero sightability at night or in fog through sightability approaching 100% from a stationary platform using expert observers. Graphic provided by Richard Merrick, Northeast Fisheries Science Center, NMFS). (Silber *et al*., 2008)

10 Reducing ship strikes: an industry perspective

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The International Chamber of Shipping will review the work of the International Maritime Organization with regard to ship strikes on whales and other related work. Potential conflicts between these work streams will be highlighted and comments will be made on the need to find compromises that provide the best possible protection whale populations.

11.1 Watch out and sail carefully! A close look at collisions between sailing vessels and cetaceans worldwide

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Collisions between sailing vessels and cetaceans are increasing worldwide and it appears that ocean races and regattas can significantly contribute to this problem. This presentation will summarize the updated findings of an online-survey created to receive reports about collisions and near-miss events involving sailing vessels worldwide. The number of collisions and near-misses, their location and distribution, as well as the types of vessels involved, will be described. The frequency of incidents will be related to the different species affected. Aspects including time of day, vessel speed, the context (e.g. regattas) and the occurrence of injuries to humans and cetaceans as well as damage to vessels will be discussed. Several measures are proposed which could contribute to mitigating the problem, including placing watchposts, speed reduction, avoiding important cetacean habitats, careful planning of regattas and ocean races, thorough reporting as well as educational initiatives to raise awareness.

11.2 A review of strikes of whales by sailing yachts: a serious problem for whales, sailors and yachts

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This review provides examples of incidents experienced by sailors of strikes and situations that presented increased risks of strikes. It proposes the need to work with stakeholders involved in the sailing industry to increase awareness of this threat, increase reporting of incidents and develop a range of mitigation measures to significantly reduce the risk and cost of collisions between whales and sailing yachts.

12 Whalewatch vessel strikes: high risk or more accurate reporting?

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Commercial Whalewatch vessels are often considered to have an unusually high risk of collision with whales due to the amount of time they spend in their proximity and the number of reported strikes when compared to other vessel types. However, this likely reflects a reporting bias as strikes from commercial whale watch vessels are more likely to be reported than those involving other vessel types. It is important to note, however, that in many cases the experience and vigilance of commercial whalewatch crews in spotting whales, especially from a distance, may actually reduce their risk of a strike when compared with other vessel classes. As result, we suggest redefining how strikes are categorised from those involving commercial whale watch boats to considering risk for 'vessels in the vicinity of whales'. We propose there are two categories to consider: collisions that take place when a vessel is engaged in whale watching; and collisions that occur when a vessel is in transit. In the latter case, whale watch vessels represent no greater risk, and may represent less risk, than any other similarly sized boat operating in the vicinity of whales. Knowing the rate of strikes in this latter category may be very helpful in modeling the true risk of strike for this class of vessels, due their higher reporting rate and more easily quantifiable effort. We will also present a series of whalewatch 'guidelines' from the northeastern region of the United States that were designed with the primary goal of reducing the risk of strike, and discuss their applicability to other areas and non-whale watch vessels.

13 Role of the International Maritime Organization in large-whale ship-strike reduction: processes, measures and effectiveness

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Vessels strikes present a worldwide threat to large whale species. Various modifications to vessel operations have been proposed and implemented in an attempt to reduce this threat. The International Maritime Organization (IMO) is the recognised international authority governing international shipping interests and safety of navigation at sea. As such, the IMO represents a valuable and effective forum for establishing measures by which whale strikes may be reduced, particularly with regard to whale species that migrate among various national and international jurisdictions. A specialized agency of the United Nations with 168 Member States, the IMO was established in 1948 by the International Convention for the Safety of Life at Sea (SOLAS) to address maritime safety. The IMO develops a suite of comprehensive shipping criteria, guidelines, and regulations that address maritime safety, environmental concerns, legal matters, technical co-operation, and the efficiency of shipping. Specialized committees focus on technical work used to update existing legislation or develop and adopt new regulations. To secure IMO-endorsed vessel operation actions or measures, a proposal must be developed and submitted by a member state to the IMO for consideration. The document must identify the problem and the reason for needed action, and address any potential adverse effects to maritime interests and activities. Proposals relevant to environmental matters tend to be reviewed, approved, and adopted by at least two committees that may include the Sub-Committee on Safety of Navigation, the Marine Safety Committee, and the Marine Environment Protection Committee. In some cases, solicitation of an IMO endorsement must be founded on corresponding domestic regulation, legislation, or other action implemented by the submitting member state. In this paper we identify various vessel-routing measures sanctioned by the IMO; and focus on specific examples of IMO measures implemented or modified to reduce whale strikes while also maintaining navigational safety: Areas To Be Avoided, Traffic Separation Schemes, and Mandatory Ship Reporting Systems. We review the timing and processes used to seek and obtain IMO adoption of such measures, and summarize case studies of IMO-endorsed measures established in waters off Canada, the U.S.A., and in the Mediterranean that have been implemented in an effort to reduce vessel strikes of whales. We then assess the effectiveness of the measures in reducing the risk of vessel strikes.