Fin whales: progress report on the evaluation of ship strikes in the ACCOBAMS area and protocol to assess ship strikes

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Background and rationale

The issue of ship strikes with large whales has been discussed and addressed in the Mediterranean Sea for several years. Following a paper by Laist and colleagues in 2001, there have been several Institutes and Research groups trying to synthesize the number of fatal ship strikes per year in the Mediterranean Basin. Major effort has been done by the Scientific Committee of the IWC and ACCOBAMS.

Different documents have been prepared and presented to international Conferences, to peer reviewed journals, to the IWC Scientific Committee and to the IMO Marine Environmental Protection Committee. Last year a dedicated project was funded by the Italian Ministry of the Environment to ACCOBAMS, to assess and identify priority conservation and mitigation measures in the Mediterranean Basin. Details of the project are presented in the documents attached (ForInfo XX and ForInfo YY) that were discussed at the IWC SC meeting and at the IMO MEPC meeting in June 2009.

This paper presents details on some actions mentioned in the 2 documents with a strategy for future work to be carried out at the Basin level, with the support of the ACCOBAMS Executive Secretary and Parties. This work has been carried out in cooperation with a number of Institutions and independent researchers, including Tethys Research Institute, Alnitak, Souffleurs d'Ecume, Pelagos Research Institute and IMRAC.

Different actions have been carried out throughout the year to reach the aims foreseen, and these include basin wide gathering information on the problem amplitude, research activities to map large whale presence and naval traffic, public awareness to inform the public at large about this threat for whales and computer simulations to evaluate onboard observers to reduce fatal ship strikes.

Action 1 - Document mortality from ship strikes to obtain reliable estimates of rates of human-caused removals, to generate a database for analysis

Souffleurs d'Ecume and Tethys Research Institute collaborate on an awareness campaign and monitoring of known cases of collisions in the Pelagos Sanctuary (as a priority) and elsewhere in the ACCOBAMS area. The two organisations catalogue all known collisions, with the final goal of providing the updated information to the IWC global database on ship strikes. The data collection protocol includes approaching the following organisations: all companies regularly passing through the north-western Mediterranean sea, all commercial ports, the Navy, yacht clubs and other recreational organisations (for collisions caused by other than commercial vessels), the existing Stranding Networks, any research Institute holding photo-identification data for large cetaceans (for non-fatal cases), and any other entities likely to be involved in this issue (past and present).

A network is being established between the three countries of the Pelagos Sanctuary, to understand known cases of collisions and to monitor them in real time. This network will be made up of designated referral agents, one from each maritime company frequently passing through the zone and all commercial ports of the area. This referral agent must be made aware of the issues related to collisions and of the necessity of informing the partners of all collisions, both confirmed and unconfirmed. Collisions documented in this way will be passed on to the International Whaling Commission.

For France, these actions are run within the framework of the GIS3M program (Groupement d'Intérêt Scientifique pour les Mammifères Marins de Méditerranée, or Scientific Interest Group for Mediterranean Marine Mammals) financed by the French sector of the Pelagos Sanctuary. For Italy, at present the Tethys Research Institute is gathering these information. A dedicated web page (www.collisioni.org) in Italian and English has been created, with general background information on large whales and ship strikes, a download area where public awareness material is available (stickers and posters), reporting forms and basic identification criteria for fin and sperm whales.

Action 4 - Conduct feasibility studies to assess the efficiency of onboard dedicated observers to detect whales (a) to collect data and (b) as a mitigation measure

Observations from vessels may assist in ship strike mitigation in four basic ways:

(i) Contributing to long-term, multi-year, data sets that allow overall patterns of whale distribution to be understood such that shipping lanes and movements may be adjusted to minimise risk.
(ii) Relating whale observational data to environmental variables to allow development of predictive models for whale distribution based on remote monitoring of environmental variables. Such models may allow routeing measures to minimise risk.
(iii) Providing short-term observations from ferries such that the subsequent crossing may be adjusted to minimise risk based on what was seen on the previous crossing.
(iv) Detecting whales with an imminent risk of collision such that avoidance action can be taken.

A number of studies involving dedicated surveys, satellite telemetry, observers on ferries and other platforms of opportunity have attempted to address (i) and (ii) for the western Mediterranean and particularly the Pelagos Sanctuary area (Arcangeli *et al*., 2009; Cotté *et al*., 2009; Laran and Drouot-Dulau, 2007; Littaye *et al*., 2004).

On (iii), Panigada and colleagues (2009) suggested a possible experimental design to investigate the potential for risk reduction through route switching on consecutive ferry transits, depending on what is seen by observers. For this approach to achieve any risk reduction, the spatial distribution of whales needs to persist for at least the length of time between ferry transits. It has not yet been possible to conduct these experiments, due to low number of fin whale sightings during summer 2009, but Arcangeli *et al*. (2009) found no correlation between sightings rates on consecutive transits on three ferry routes to and from Corsica and Sardinia. This result suggests that aggregation patterns on a fine scale that may allow practicable route switching may not be persistent over sufficiently long periods for this to be an effective risk reduction measure. Results from a telemetry study of an individual fin whale also indicated a tendency for long periods of straight line movement between periods of more convoluted track (Mouillot and Viale, 2001), which may also suggest movement patterns that are not suitable for route switching.

Simulation of effectiveness of observers for whale avoidance
The effectiveness of avoidance manoeuvres following sightings of whales will depend on a number of factors including the distance at which whales are detected, their diving behaviour, the speed and manoeuvring characteristics of the vessel. Clyne and Leaper (2004) describe a simulation framework for modelling the sightings process and avoidance manoeuvres to estimate the proportion of sightings that might potentially be avoided. Using that framework and observations of fin whale behaviour some simulations were conducted for typical ferries operating in the Ligurian and Tyrrhenian Sea to Corsica and Sardinia (assumed values for ferry characteristics are shown in Table 1). Fin whale behavioural parameters in Table 1 were taken from Lafortuna *et al.* (2003). The probability of detection a fin whale blow was based on the model used in Clyne and Leaper (2004) with parameters adjusted to be consistent with observational data from ferries reported in Arcangeli *et al.* (2009). These authors report maximum perpendicular distances of 3–4.3 km and estimated strip widths of 1.5-1.7 km. In the simulations the probability of detection was assumed to be zero for radial distances > 4 km and the strip width calculated from the simulated observations was 2050 m. Cotté and colleagues (2009) reported a rather lower strip width (864 m) than Arcangeli *et al.* (2009) but these data were year round observations from a ferry between France and Algeria and may have included less favourable sightings conditions.

For this study we have presented results with one observer and five observers, but these results could also be representative of poor sighting conditions or good sighting conditions with the same number of observers. The model assumes that avoiding action is taken for any whale directly in the path of the vessel regardless of how far away it is. It is also assumed that avoidance occurs after seeing just one blow and therefore does not take into account whale movement.

Simulation results
The results of the simulations are shown in Table 2. These show the probability that a whale directly in the path of the vessel would be detected (g(0)) calculated from the simulation output, and the proportion of whales which would have been hit but were successfully avoided by turning the vessel away from the sighting (*S*). Although g(0) is often assumed to be 1 for fin whales in sightings surveys, such surveys are usually conducted at slower speeds (typically 10 knots) and the lower g(0) values from the simulations are a result of faster vessel speeds. The value of g(0) essentially sets an upper bound on the proportion of whales that can be successfully avoided.

For a ferry travelling at 14 ms^{-1} (28 knots), the values of *S* vary from between 0.34 and 0.67 for detection parameters giving strip widths comparable with observed data. If detection range could be improved by 50% then *S* increases to 0.82 with three observers. It should be noted however that these are upper bounds and there will be many practical considerations that would result in lower success at avoidance. In particular, the simulation allows for quite severe manoeuvres that may not be possible under many conditions. The results also do not take into account poor visibility and night time.

These results illustrate a potential trade-off between shorter response times with the officer on watch or a lookout on the bridge making the detections and initiating a manoeuvre very rapidly and having additional observers who may improve detection probability but there is likely to be a greater response time due to relaying the message to the bridge.

A possible further development of the current simulation model would be to allow for two types of observer with different detection probabilities and response times. This could be used to investigate the likely value of having observers scanning with binoculars well ahead of the vessel in addition to the watch keeper on the bridge. The long range observers would have a longer response time but this will only have a small effect on sightings seen further away. It would be expected that this combination of observers would be the most efficient but the simulation could be used in an attempt to give some quantified indication.

Table 1. Simulation parameters

Whale behaviour	
Whale swim speed	1.4 ms^{-1}
Dive duration	225 s
Surfacing period	62 s
Number of blows during surfacing	5
Ferry characteristics in model	
Length	175 m
Beam	28 m
Cruising speed	24 - 34 knots (12 - 17 ms^{-1})
Pivot point as a proportion of total length aft of bow	0.3 (defines a highly manoeuvrable vessel according to the model)
Response time. Time from sighting being detected until the officer on watch initiates manoeuvre	5 – 30 s

Table 2. Simulation results. *S* indicates the proportion of collisions that would have occurred but were successfully avoided by altering course. g(0) indicates the proportion of the animals directly on the trackline of the vessel that are detected and is therefore an upper bound on *S*.

	Vessel speed ms^{-1}					
	12	13	14	15	16	17
Scenario 1 (30 s response time, 1 observer)						
g(0)	0.66	0.60	0.55	0.52	0.48	0.46
S	0.42	0.36	0.34	0.33	0.29	0.28
Scenario 2 (30 s response time, 3 observers)						
g(0)	0.83	0.82	0.74	0.71	0.68	0.63
S	0.59	0.59	0.55	0.52	0.49	0.47
Scenario 3 (30 s response time, 5 observers)						
g(0)	0.90	0.85	0.80	0.77	0.73	0.69
S	0.69	0.66	0.58	0.59	0.55	0.50
Scenario 4 (15 s response time, 1 observer)						
g(0)	0.64	0.60	0.58	0.55	0.52	0.49
S	0.48	0.46	0.42	0.39	0.40	0.36
Scenario 5 (5 s response time, 1 observer)						
g(0)	0.66	0.60	0.55	0.52	0.48	0.46
S	0.57	0.50	0.48	0.45	0.40	0.40
Scenario 6 (15 s response time, 5 observers)						
g(0)	0.90	0.86	0.80	0.78	0.72	0.71
S	0.78	0.70	0.67	0.66	0.59	0.58
Scenario 7 (30 s response time, 3 observers, detection range increased by 50% to 3075 m strip width)						
g(0)	0.99	0.98	0.96	0.93	0.90	0.87
S	0.89	0.89	0.82	0.75	0.72	0.66

***Ad-hoc* study on the "detectability" of whales from merchant ships (especially high-speed craft)**

This study presents results from a working season (from April 2001 to January 2002) with a dedicated whale observer travelling on board three high-speed craft (HSC – single-hull vessels capable of speeds of up to 40 knots). The line-transect technique was applied over 24,000 nautical miles between Corsica and mainland France.

The data was used mainly to compare sightings of fin whales by two "teams": a) the dedicated whale observer and b) the two navigating officers on board this type of craft.

The high speed of the study platforms implies that a momentary lapse of concentration or inadequate tracking can be enough to "miss" a sighting of a whale or any other object likely to hamper the vessel's progress or present a risk to onboard safety. In the light of these elements, an effective detection bearing was calculated to be 30° in the present case, based on the maximum speeds of the vessel and the animals. To maximise whale sightings, the tracking area needs to be focused solely within this angle. Obviously, although the dedicated observer was able to concentrate on this bearing, the officers with their navigational imperatives had to sweep a much wider angle.

A comparison of the two teams' **initial whale detection bearings** showed that the observer made 65% to 70% of sightings within a 30° bearing either side of the route. The lateral areas were monitored in the main by the officers and virtually all the fin whales found alongside the vessel would appear to have been detected by this team only.

A similar analysis was made with the **detection distances**, showing that the dedicated observer's sightings were evenly spread along the range of distances, with the farthest being six nautical miles away. Conversely, the officers' distribution of whale contacts shows that their sighting concentration was high in an area of up to 0.5 nautical miles from the vessel (61% of their sightings). It was still significant up to two nautical miles from the boat (additional 36%). However, their range did not extend beyond 3 miles since the remaining 3% were made within this threshold.

Among the different **ergonomic factors** studied, our work showed the effect of the porthole frames on whale detectability. Figure 3 shows the gaps in detection for bearings of 20° either side of the axis, closely related to the blind spots created by the porthole jambs.

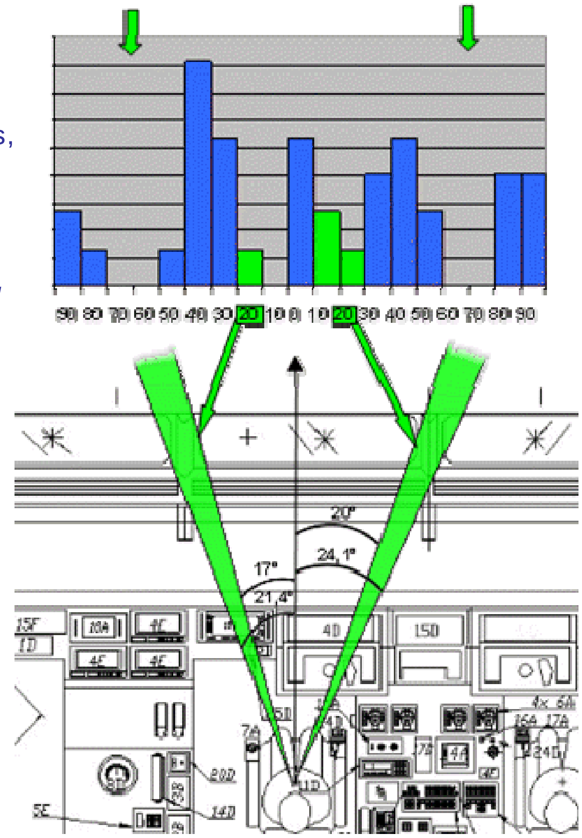

Figure 3: Effects of bridge blind spots (background diagram ©Alstom) on the officers' whale detection bearings.

This study also discussed behavioural changes among certain fin whales (diving when the animal had been on a steady course, change of course or sudden leaps in the air). Beyond 1.5 nautical miles, 18% of the observed individuals changed behaviour and this value rose little between 1.5 nautical miles and 0.5 nautical miles. The value rose to 33% between 0.5 and 0.3 nautical miles and shot up (62%) at less than 0.3 nautical miles. A detailed study should be conducted on this subject to confirm these elements, but they are already significant enough to be able to posit a minimum distance of 0.3 to 0.5 nautical miles to be respected to prevent a behavioural change that could aggravate the risks of collision (zigzagging, hesitant flight, leaping, etc.).

Recommendations to reduce the risks of collisions

The roles of each team onboard (1 dedicated observer/2 officers) involve different and complementary ways of detecting whales in terms of distance and bearing. For example, the two teams perfectly complement one another in an **effective whale detection tracking area** based on observations spread over the range of distances (up to 6 nautical miles) and remote detections within an angle of up to 30° either side of the vessel.

A dedicated onboard observer, who has nothing to do with the navigational imperatives and is strategically placed to have a minimum effect on ergonomics, would improve the detectability of whales in day light. By night, this observer would be the operator required to optimise the nocturnal detection systems (light intensifiers or infrared systems). Such a system would **improve safety onboard high-speed craft**.

We also recommend taking the "whale detectability" factor into account in **ergonomic studies** of ship bridges (e.g. limitation of blind spots within the effective detection angle and strategic positioning of night monitoring apparatus).

The study also shows that crew awareness radically improves the crew's whale detection faculties compared with less aware teams. An informed crew is also more willing to contribute to **research programmes**.

Lastly, until such time as effective systems are developed to reduce night collisions, it is highly recommended to **limit shipping at night**, especially high-speed craft for safety reasons.

Onboard dedicated observers witnessing ship strikes with fin whales

Opportunistic visual surveys were made onboard the ferry Borja II from Balearia lines connecting Valencia and Mallorca (Balear Islands) during 2007 and 2008. The project, coordinated by L'Oceanogràfic of the City of the Arts and Sciences of Valencia, in collaboration with Fundación Balearia, Avinença and the Environmental Department of the Local Governement of Valencia, Spain, aimed to the identification of critical periods of the year and zones of the vessel course of maximum fin whale collision risk.

Line transect methods were applied with 3 observers located in the wheel bridge on duty for 45 minute periods (a total of 6 experienced observers) and two groups of volunteers (maximum of 14 people) located in both sides of the upper deck for the full transect from port to port. A total of 7 surveys were made from November 2007 to August 2008, until the ferry company stopped the project due to the lack of funding. A total of 6 single fin whale sightings distributed in 4 surveys were logged.

Two of these sightings included a fin whale collision and a near to contact vessel overpass. Both events are further described:

Fin whale collision:

During the survey made on April 26th 2008, one fin whale was first sighted at 14:32 on port side at 26º and 900 meters apparently moving in north direction. Vessel speed was 19 knots. Next blow sequence 7 minutes later and including three blows was still in very similar angle, indicating collision track between the vessel and the whale. The first blow of the third sequence occurred less than 100 m in the bow and the whale did not seem to notice the presence of the vessel. The second blow of this last sequence occurred right in the bow and the whale was struck by the starboard bow side of the hull (not the underwater bulb) just after the blow while initiating a turn to the right (towards the vessel) probably as a startle response to the imminent contact with the hull. The hull contacted the right ventral flank of the whale probably behind the right pectoral fin followed by contact at the peduncle and caudal fin while energetic fluking reaction. The whale was at the surface during the whole collision sequence. The vessel track was perfectly perpendicular to the line crossing both footprints from the last sighting sequence. Neither more blows nor sightings from this whale were detected after the collision.

Vessel overpass:
During the survey made on August 6th 2008, one fin whale was sighted at 16:53 on starboard side at 19º and 500 meters apparently moving in south direction. Vessel speed was 20 knots. First blow of the second sequence was observed at approximate 50 meters from the starboard side of the bow and a few seconds later the whale appeared right at the bow, surfacing approximately 10 meters from the underwater bulb. It suddenly changed the course turning to the right and adopting a similar course as the vessel and dramatically increased fluking speed while arching to point downwards. The underwater bulb passed over the whale presumably without contacting it while the whale was fluking extremely fast and diving. Neither more blows nor sightings from this whale were detected after the overpass.

Weather conditions during both events were good, Beaufort 1 to 1.5 and less than 20% cloud coverage. During both events, whale sightings occurred several minutes before the close encounter and collision risk could have been probably reduced or avoided by changing vessel course a few degrees or decreasing speed. During both events, bridge officers did not seem worried by the collision course observed, the vessel was run on autopilot and officers on duty did not even approached the side of the bridge to check the whale.

Even if the sample size is very small, it is striking that 2 of 6 (33.3%) fin whale sightings included a close encounter and collision. The fact that both whales were first sighted at distances of 900 and 500 meters, minutes before the close encounter indicates that collision mitigation is feasible by implementing observation effort from the wheel bridge, at least during good visibility conditions, in periods and course zones of higher fin whale presence. Also, the little, if any, reaction by the captain and officers on duty during these two events suggests that fin whale collisions do not represent any risk to the vessel and are probably more common than declared.

The conditions for the observation from the wheel deck were strict and included not to interact with the crew or the captain. Even if they knew the whale was on collision course, they did not take any avoidance reaction. This experience proves that, at least for this Spanish ferry company, whale collisions are not a subject of concern. There are two messages to take home from this experience: 1) observation effort during daylight and good sea conditions allow the detection of whales time ahead to avoid the collision, at least in some cases and 2) even if there are observers onboard, if there is no commitment from the ferry company the effort is absolutely useless.

Action 5 - Further develop and implement real-time networks between commercial ships to report the position of large cetaceans to limit collision risks (REPCET)

Researchers, engineers and representatives of maritime transport companies have joined forces to develop an innovative system. REPCET (REal-time Plotting of CETaceans) is a collaborative computer system based on the density of the navigation network. REPCET allows commercial vessels real-time access to the positions of large whales last seen on their navigation routes in order to reduce the risks of collision.

The concept is simple and is based on the following: every sighting of large cetaceans by watch-keeping personnel on board a vessel in possession of REPCET is transmitted by satellite in semi-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.

The onboard mapping interface is designed to present the alerts sent by the server. It allows the user to visualise the alerts on a topographic map and to easily zoom in and move around the map. An intuitive display allows rapid location of dangers and their nature, in order to alert the bridge watch.

In addition to accurately positioning the whale sightings, the system calculates and displays the associated risk zones. These shaded circular areas correspond to the initial risk of encountering the detected animal. The display allows intuitive comprehension of the level of risk within the mapped zone. After a certain time period, the zone is deemed no longer at risk and the risk areas disappear. The position of the initial sighting however remains for 24 hours, identified by a different marker.

Statistical models have been developed to predict areas of cetacean presence according to environmental data provided by satellite such as temperature, currents, salinity, and chlorophyll concentration. REPCET will be soon integrated with such habitat prediction models, thus rendering it more reliable in identifying high collision risk areas.

REPCET is designed to evolve with technology. Relying initially on visual detection in its earliest version, it is designed to integrate all types of sensors (on-board infrared sensors, underwater passive acoustic detection systems, sonar, etc.). Thus in future versions, the system will be capable of automatically processing the positions of large cetaceans detected by these sensors, and, as a result, optimise the performance of the system, particularly at night.

REPCET benefits from the support of the Pelagos Sanctuary, by means of a Recommendation which was voted at the Parties' last conference (see Pelagos, 2009). It is thus being developed prioritarily in the Pelagos area, but the system will eventually be applied to all areas where collisions are a known issue, in the ACCOBAMS area (Strait of Gibraltar, Greece) and further away (Canary Islands, North Atlantic, Japan, New Zealand, etc.).

A support request has been recently submitted to the European Neighbourhood and Partnership Instrument (ENPI), under the acronym SECURIWHALE, with the aim of expanding REPCET in several western Mediterranean countries (France, Spain, Italy and Tunisia).