Whale-ship collisions:

Work and outlook from a team in the Pelagos Sanctuary
The example of the REPCET project

Background

Collisions between cetaceans and ships occur in all the world's seas (Laist *et al.*, 2001) and represent one of the main manmade threats to isolated populations of whales (e.g. Clapham, 2001). Moreover, in the case of high-speed craft, these accidents can endanger the safety of both vessels and their passengers. One of the most tragic cases was reported in February 1992 when a jetfoil passenger was fatally wounded in an abrupt "emergency stop" in an attempt to avoid a collision with a sperm whale in the Canary Islands (André *et al.*, 1997b). Injuries to people remained negligible until recently (2004 to 2007) when a series of some fifteen collisions involving a number of species in Japanese waters seriously injured several dozen jetfoil passengers, one of whom died (FerriesOutsideEurope, 2006, 2007; Kyodo News, 2006).

Figure 1: Pelagos Sanctuary in the north-western Mediterranean

The western basin of the Mediterranean and especially the Pelagos Sanctuary zone[1] (see Figure 1) constitute an ideal "test area" for measures designed to reduce collision risks and suitable for replication in other seas and oceans of the world.

This area's physiographic and biological characteristics make it a suitable habitat for the genetically isolated populations of fin whales (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*). However, maritime traffic in the sector is particularly intense (see Figure 2) and is growing (European Motorways of the Sea programme). These ecological and human parameters combine to make the Pelagos Sanctuary a high-risk collision zone (see, for example, ACCOBAMS/PELAGOS, 2005)

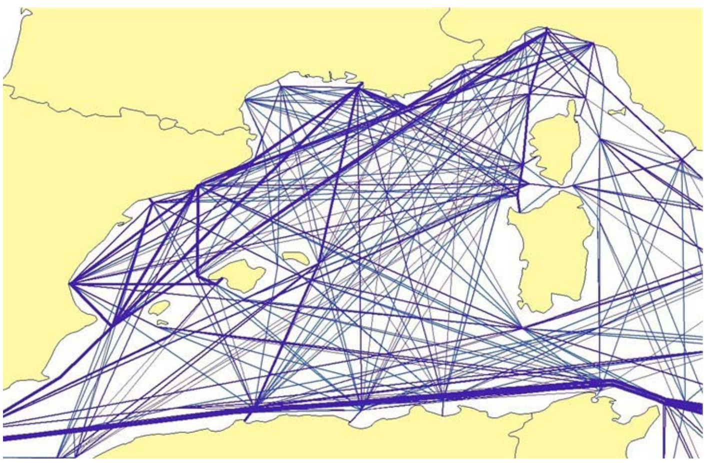

Figure 2: Gridding pattern created by maritime traffic in the western Mediterranean, showing its density and range. In Di-Méglio and David (2006) based on SCOT data (2004).

The threat these accidents represent to the zone's whale populations has been pointed up for several years (see, for example, Beaubrun and David, 2000; Pesante *et al.*, 2000) and attempts at quantification have been proposed of late. For example, Panigada *et al.* (2006) counted 43 fatal collisions from 1972 to 2001 and attributed 20% of the animals found dead to strikes. The authors agree that these figures massively underestimate the reality and state that collisions represent one of the main causes of unnatural death among the whales of the Mediterranean.

In terms of safety, known collisions to date between high-speed craft and

[1] Agreement on the creation of a sanctuary for marine mammals in the Mediterranean, signed by France, Italy and Monaco on 25 November 1999 (see Document IWC/59/CC8 submitted by France in 2007 : http://www.iwcoffice.org/_documents/commission/IWC59docs/59-CC8.pdf).

whales in the Mediterranean have all cracked open the hull and prompted the emergency return of the vessel with, in addition to the safety concerns, serious financial repercussions for the operating company (Capoulade, 1998 and 2001).

Since, a number of onboard merchant ship studies supported by the Ministry in charge of the Environment as part of the Pelagos project have pinpointed several factors that restrict the ability of the watchkeeping crew to detect cetaceans from the bridge. The reasons for this reduced "detectability" are varied: navigational imperatives, bridge ergonomics, the ship's speed, local weather conditions, recognition and interpretation of visual whale signals, and even lack of awareness of the problem.

Based on these observations, our team has been developing applications to reduce the risks of collisions:

The National Merchant Navy School in Marseilles started holding training modules for watchkeeping crew and cadets in 2005. The following subjects have been covered: the Mediterranean's geological, physiographic and biological features, Mediterranean cetaceans and observation cards, national and international legal tools to protect cetaceans, merchant shipping, collisions, acoustics, navigation and fossil fuels (see www.souffleursdecume.com). These classes are designed to help reduce the risks of collisions between whales and merchant ships (information on ecological and safety risks and possible actions to reduce them). The training is supported by Pelagos, ACCOBAMS and the French Ministry for Ecology and also helps develop constructive exchanges between the activities of the Pelagos Sanctuary and the shipping companies to improve knowledge on and the protection of the populations of cetaceans in the area. Rollout opportunities are currently being studied elsewhere in France and in Italy and Tunisia.

In 2007, a special tracking protocol was proposed, including the presence of a specialised whale detection observer. This was underpinned by quantified data on the value of such an approach (see Appendix 2).

Lastly, since 2004, we have been working on developing a real-time whale position reporting network for merchant ships (REPCET project standing for Real-time Plotting of CETaceans). This project, presented in detail in this document, should start operations shortly.

REPCET (Real-time Plotting of CETaceans): A real-time whale position reporting network for merchant ships.

1- General description

Capoulade and Mayol (2004) tested a preliminary whale position reporting device between four merchant ships using the Internet and Inmarsat-C. The results of this experiment were positive and it was decided to develop the concept to create a tool to reduce collision risks.

The project (INPI Soleau Envelope No. 262243) is to develop a whale position transmission system for use by merchant shipping. The principle is straightforward and based on the following elements: when the watchkeeping crew detect whales, they transmit their positions to a server via a satellite communication. These positions are then automatically charted and retransmitted in real time to all liners in the area equipped with an onboard chart-reading device. The merchant shipping hence becomes in turn “informer” and “user” of the REPCET system, giving watchkeeping crew information on the positions of whales recently sighted on their shipping lane. Each player (subscriber to the system) is therefore both information provider (sighting an animal) and information receiver (all the sightings made by other subscribers).

REPCET will be designed as a technological hub comprising a database, a centralised server (shore-based) and clients (the subscriber ships). This technological hub will be open-ended so that it can accept incoming information from all types of sensors (visual observations, sonar, radar, etc.).

REPCET will consequently be a real-time co-operative system designed to reduce the risks of collisions between cetaceans and ships, while providing researchers with a vital database on the distribution of the animals.

2- Operational set-up

Figure 3 presents the general operational set-up. REPCET is a “client-server system”. The “clients” are the merchant ships (providing and using the data in real time) and the research laboratories (processing the data later on). The “server” (which centralises and transmits the data) is located in a shore-based centre. The Inmarsat-C satellite system is set to be the means of communication between the ships and the shore-based server. To date, it is the most inexpensive means of satellite communication (short messages). A study prior to design will look more broadly at all the different means of communication based on the equipment currently used.

Figure 4 shows the detailed technical information-routing set-up. On sighting a cetacean, the watchkeeping crew member enters a series of data and a message is sent to the central server, which consolidates the information and retransmits it to all subscribers. The “onboard” REPCET software processes all the data sent by the server and estimates, on the basis of the ship’s position and known rules, whether the vessel is entering a potential cetacean area. If so, a visual and/or sound alarm warns the bridge and the watchkeeping crew member can decide on the suitable action to take (reduce the ship’s speed, step up vigilance with extra watchkeeping crew, etc.).

Laboratories (or any type of shore-based subscriber) can hook up to the REPCET server completely separately from the reporting system to download past data from the database.

Figure 3: REPCET general operational set-up

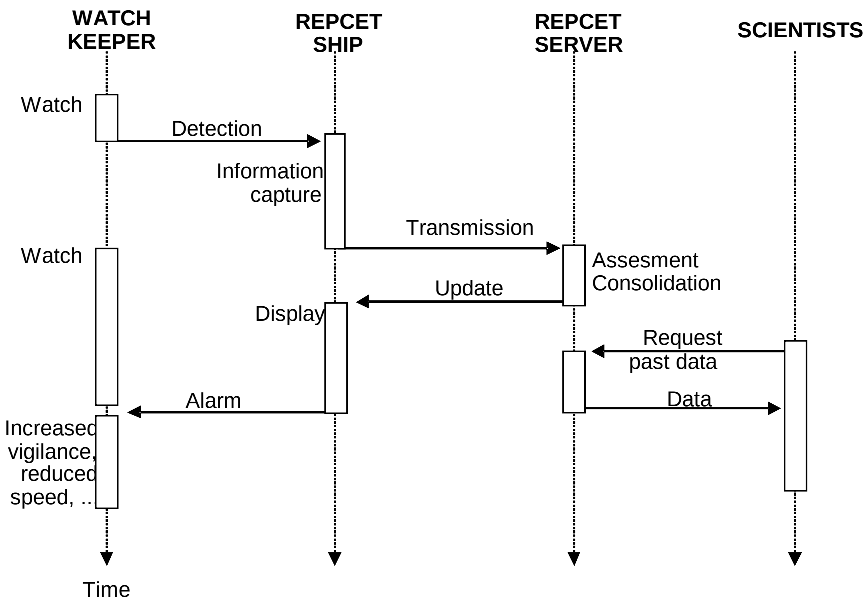

Figure 4: REPCET detailed technical information-routing set-up

2.1- User interface

The onboard data entry interface needs to be simple, concise and user-friendly (Figure 5). The content of the entries needs to be as relevant as possible to the studies on the distribution of cetaceans and the constant development of information validity rules.

The same criteria hold for the representation of the positions of whales recently sighted on the shipping lanes. A colour code will show how recent the sighting is and information will be available on each position (Figure 6). Known collision probability zones will be marked on request in red. The system will calculate these areas based on the position of the sighting, any information on the animal's course and its maximum speed (according to the species). An alarm will sound in addition to this display.

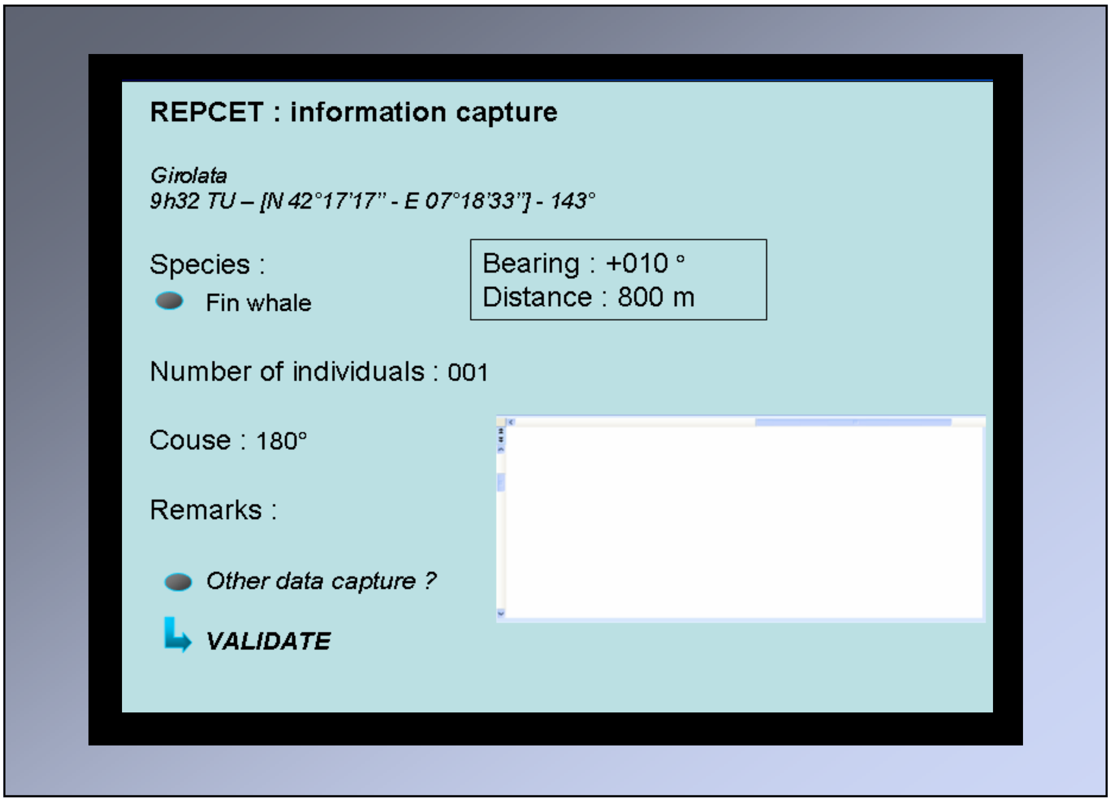

Figure 5: Planned REPCET data entry interface

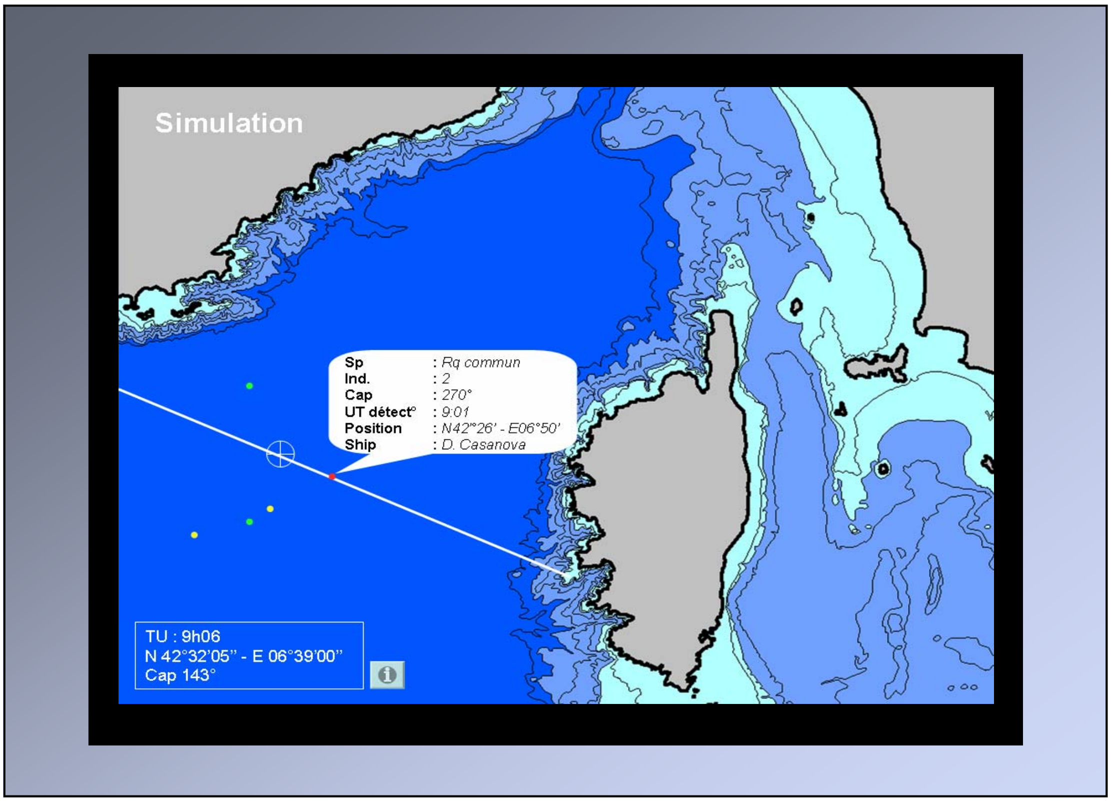

Figure 6: Planned REPCET charting interface

2.2- Open-ended technology

The use of optronic sensors will probably be developed in the long run to help detect cetaceans. One of the technologies in mind is thermal infrared. However, to date, the tests on using this technology to detect a cetacean in the Mediterranean are far from complete (see, for example, Petit & Stretta, 1991; McCafferty D. J., 2007). A number of hypotheses need to be studied, including:

- The external body temperature of the animals in the Mediterranean is close to the temperature of the sea, which could make any thermal detection impossible,
- The animals' breath, however, is generally warmer and therefore detectable.

Right from the start of the project, a detailed study will be made of the state of the art in optronic technologies and tests will be scheduled. The introduction of such technologies will only be envisaged in a second phase of the project.

The use of underwater acoustic data to detect whales is problematic:

- The use of active acoustics is not an option since it can physically harm the animals (see, for example, André, 1997; André *et al.*, 1997a; André *et al.*, 2001a; Roussel, 2002),
- The onboard use of conventional passive acoustics implies a speed of less than 15 knots (P. Mugnier, personal memo),

These considerations mean that, as things stand at present, there are no plans to include acoustic sensors in the first version of REPCET.

Yet this eventuality has not been ruled out and REPCET will be designed to include all types of sensors. Moreover, a number of projects under development are looking at underwater acoustic detection (gliders, setting up of acoustic channels, etc.) and may well come up with solutions that could be included in REPCET at a later date (e.g. the SEA-EXPLORER project by the PACA Sea Competitive Cluster, the PIMC project by the Paris 12 and Toulon Universities on the observation of these animals through the analysis of their sound emissions, the Whale Anti-Collision System by the Bioacoustics Application Laboratory of Catalonia, etc.).

3- Steering mechanism and project partners

REPCET is a collaborative project involving a number of scientific partners[2], the NGO Souffleurs d'Ecume and the shipping companies. It was selected for co-financing by the French government in a call for innovative research and development projects. It also receives the following support:

- ACCOBAMS Agreement (2006)
  http://www.accobams.org/database/index.php?s=public_researches&action=show&id=37
- Pelagos Sanctuary for Marine Mammals in the Mediterranean (2006)
  www.sanctuaire-pelagos.org
- Coup de Chapeau Victor award from the Veolia Environment Foundation (2007)
- Unanimous quality certification from the PACA Sea Competitive Cluster (2007)
  http://polemerpaca.tvt.fr/article.php3?id_article=630

The total development budget is €300,000. The French Single Interministerial Fund (FUI) and the Nicolas Hulot Foundation contribute to funding. Other funders have been contacted, including the Prince Albert II of Monaco Foundation. Tests will begin as soon as all the necessary financial resources have been obtained.

[2] REPCET partners: Chrisar Software Technologies, Ecole Pratique des Hautes Etudes, Armateurs de France, University of Nice-Sophia-Antipolis, Compagnie Méridionale de Navigation, Société Maritime de Navigation Corse Méditerranée and Météo France.

4- Conclusions

REPCET is a project based on a simple technology. It has the advantage of being able to be put into operation very quickly, especially in the north-western Mediterranean due to the partnerships set up with French shipping companies since 1999. As such, it supplements both existing actions and projects under consideration. Once the system connecting ships with the Internet server is up and running, REPCET will be able to move towards greater effectiveness, especially at night. For example, studies could look into the use of optronic detection systems and passive acoustics and the identification of areas of potential whale concentrations (evaluated by oceanographic parameters). Also of note is the fact that, in view of the Mediterranean whale-watching management programme being set up, operators could provide information to the system to further improve its performance.

Access to the system will be made secure and licences issued to prevent misuse (whaling, unauthorised whale-watching, etc.). On this matter, the partners plan to set up an official ethics committee for which the Pelagos and ACCOBAMS bodies have been contacted for the Mediterranean.

REPCET is therefore an open-ended system that will help reduce the risks of collisions in the short run and could significantly curb them in the medium run as we add to our knowledge and expertise. Yet in addition to these highly practical aspects, REPCET also aims to nurture and power up the all-important co-operative actions between shipping companies and the research and conservation work conducted in the Marine Protected Areas in which the system will be developed.

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ANNEXE 1: Findings of a study on the "detectability" of whales from merchant ships (especially high-speed craft).

Methodologies

Throughout an entire working season (from April 2001 to January 2002), a dedicated whale observer travelled 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 needs to be taken into account to properly understand this approach. The speed consideration means 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. For example, an HSC covers 5.7 nautical miles whilst a fin whale is sounding. This shows how important it is to monitor a suitable sector to be able to detect the animals from afar. In the light of these elements, an effective detection bearing was calculated based on the maximum speeds of the vessel and the animals (30° in the present case, see Figure 7). 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. This partly explains the differences found between the two teams, as detailed below.

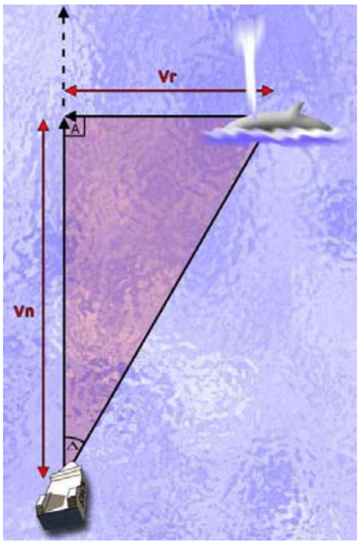

Figure 7: Effective detection angle

Some findings

A comparison of the two teams' **initial whale detection bearings** (Figure 8) 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.

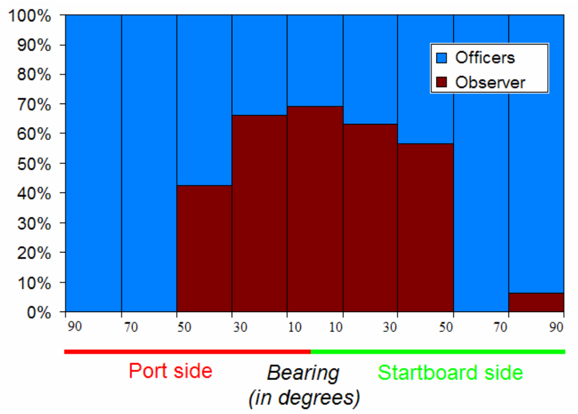

Figure 8: Comparison of rates of initial whale detection bearings by type of observer and degree bearing.

A similar analysis was made of **detection distances** (Table 4). It showed 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.

Table 4: Cumulative percentages of initial sightings, by cetacean type and observer category (Obs. = dedicated observer; Off. = officers).

	Large cetaceans		**Small cetaceans**	
6 n. miles	Obs.	Off.	Obs.	Off.
5 / **4 n. miles**	100			
3 / **2 n. miles**	95	100	100	100
1 / **0.5 n. miles**	75	97	93	99
0 n. miles	23	61	66	87
n (contacts)	*91*	*35*	*165*	*85*

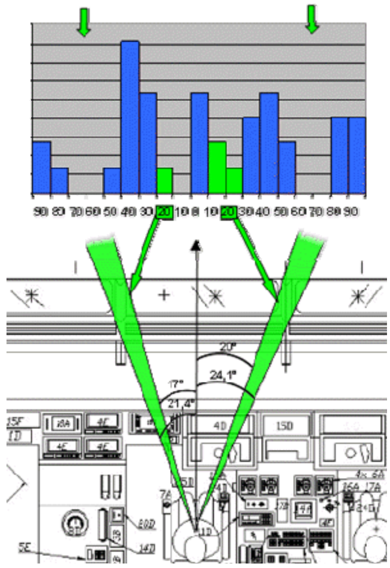

Figure 9: Effects of bridge blind spots (background diagram © Alstom) on the officers' whale detection bearings.

Among the different **ergonomic factors** studied, our work showed the effect of the porthole frames on whale detectability. Figure 9 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.

Lastly, without going into the complicated details of an ethological study, our observations turned up 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). Figure 10 presents the new behaviour pattern curve based on the minimum distance at which the HSC passed by the fin whale, a ratio confirmed by a chi-squared test (χ^2 = 15.737; D.L. = 3; P < 0.001)

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. An additional quantitative analysis of the "standard residuals" (accuracy of χ^2) returns the precise threshold of this association between distance and rate of behavioural change. It clearly shows the bracket of [0; 0.3[NM as one of substantial behavioural change when passing by an HSC (SR < -1.96 or > 1.96). 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.).

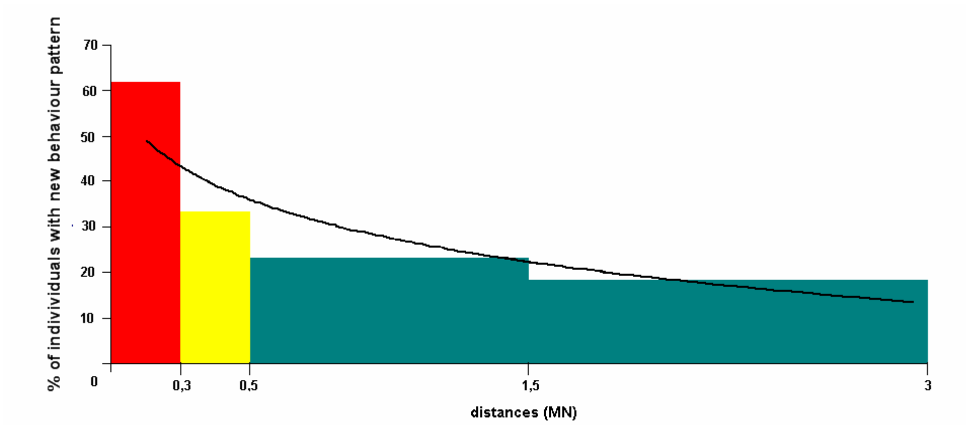

Figure 10: Behavioural changes observed based on the distance between the HSC and the fin whale.

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.[3] 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 therefore improve the detectability of whales by day. 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**. However, it would need to be extended to all merchant shipping if the goal is also to **improve whale conservation**.

At a time when there is a huge need for ecological knowledge on cetaceans in the Pelagos Sanctuary, and more generally in the Mediterranean as a whole, to propose efficient and consistent management measures, this work also shows the dedicated observer's ability to conduct research (**monitoring populations** of whales, findings not detailed here, see Beaubrun *et al.*, 2006).

We also recommend taking the "whale detectability" factor into account in **ergonomic studies** of ship bridges (limitation of blind spots within the effective detection angle, positioning of main commands to reduce non-monitoring time and electrical seat adjustment to deal with different console depths, especially for high-speed craft, efficiency of the porthole cleaning systems to improve the possibilities of distant sightings of whale blows and humps, 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** (the number of cetacean sightings reported on the observation cards available on the bridge can vary by a factor of 4!). This observation was behind the decision to set up a training course at the National Merchant Navy School in 2005.

Inspired by the ship reporting systems in use in the North Atlantic, this study also proposes a whale position reporting programme (REPCET) for use by ships to improve whale detectability. This programme is currently being developed.

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.

[3] The data presented here were collected up to Beaufort force 4. Above this, the drop in visibility due to the state of the sea halves the number of sightings although this does not put in issue the complementarity of the two types of observation.

APPENDIX 2: Technical aspects of REPCET

The system uses the JAVA technologies to easily interact between the server and tools based on the new information and communication technologies (Internet, mobile telephones, PDAs, portable computers, etc.).

REPCET needs to respect the following criteria if it is to meet the objectives:

- Quick to put into operation as there is a strong need, in both the Mediterranean and elsewhere
- Reliable and simple to use since a ship's bridge already has a heavy workload. From this point of view, the man-machine interface specifications will be ergonomically optimised following consultations with the shipping companies to make the system easy to access, integrated and user friendly for the watchkeeping crew. The key factors for success are that it should be quick and easy to use.
- Real time
- Technologically open-ended to be able to incorporate all types of sensors (optronic and acoustic) in the future,
- Open to and able to be integrated into existing navigational systems while remaining autonomous.
- Contribute to the enrichment of scientific knowledge

Server

The server will be made up of a PC working in an open source environment under Linux. The design phase will define database needs based on the types of requests that could be put:

- *Relational* database for complex requests: PosgresSql
- *Web-services* database to serve Internet applications: MySql

The server hosts a database and the following services:

- Centralisation of information from the subscribers (sightings)
- Consolidation: correlation of sightings
- Charting of potential presence areas for sighted animals based on their initial position, observed bearing and time lapsed. Application of rules based on how recent the information is, rules based on current knowledge enriched by the database analysis as REPCET is used
- Transmission of the information to the system's subscribers

Subscribers

The "ship" subscribers have the following functions and services onboard:

- Chart representing the real-time positions of the animals sighted by all the subscribers and the high-risk zones
- Data-entry interface to report sightings
- Alarm

The ships' existing equipment aside, the following technical specifications are required for this onboard configuration:

- A portable computer
- A satellite receiver (GPS + transmission of messages)
- A satellite subscription

In the majority of cases, the ships already have sophisticated equipment. A study phase prior to the design of the system will define the interface possibilities with the equipment generally found on the vessels:

- Inmarsat-C satellite receiver + subscription
- GPS receiver
- Calculator available or not
- Navigational software charting function with a standard interface to display additional information (e.g. NMEA)

An extensive study will be made of the ability to integrate the software directly into the ships' navigation systems as this would greatly reduce the cost of owning the licence to use REPCET while improving the system's ergonomics.

The "research laboratory/centre" subscribers are provided with services related to their work:

- Consultation of past sighting data
- Consultation by category
- Direct access to the database for multicriteria searches, etc.