EVALUATION OF THE TECHNICAL SOLUTIONS AND MANAGEMENT MEASURES IMPLEMENTED AT THE INTERNATIONAL LEVEL TO REDUCE THE RISKS OF COLLISIONS BETWEEN SHIPS AND LARGE CETACEANS

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Introduction

Between 1950 and 2010, world shipping increased by 5% per year. In 2010, it was 17 times as big as in 1950 (Stopford, 2010). Since 2009, the world shipping fleet increased by 37% (UNCTAD, 2012): more than 104.300 ships larger than 100 gross tons[1] cross the world oceans today (UNCTAD, 2012), accounting for 90% of world trade. And this traffic is expected to keep rising in the coming years.

This intense shipping traffic sometimes overlaps with areas of high large cetacean density. These areas can be important feeding grounds (Federal Register, 1994; Mate *et al.*, 1999; Baker and Madon, 2007; Notarbartolo di Sciara *et al.*, 2008), breeding grounds (Baker *et al.*, 1986; Calambokidis *et al.*, 2001; Rowntree *et al.*, 2001; Martinez and Guzman, 2008; Notarbartolo di Sciara *et al.*, 2008) or for their migration between them (Whitt *et al.*, 2013). Because of this overlap, ships sometimes collide with cetaceans. Worldwide, collisions between ships and large cetaceans have been increasing for several decades (Figure 1).
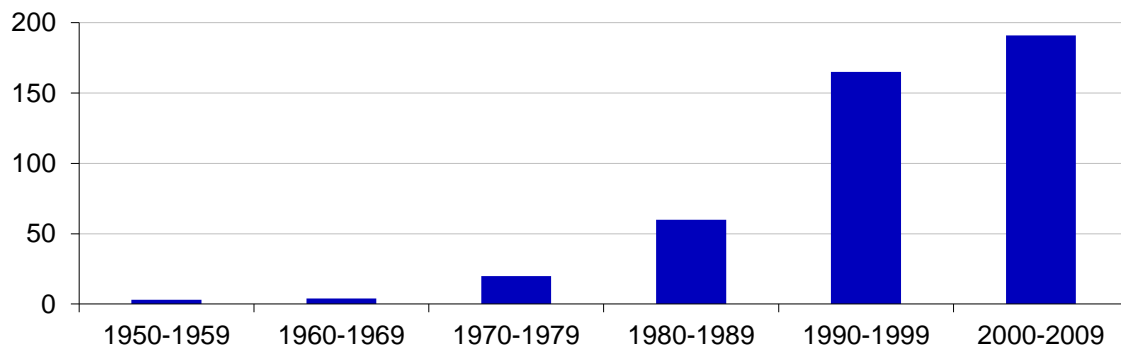
Figure 1. Number of recorded and validated cases in the International Whaling Commission (IWC) "Ship Strike" database, per decade. Figures from March 28, 2013 given by Russell Leaper and Simone Panigada (pers. com.)

Today, eleven species are considered to be susceptible to ship strikes (Laist *et al.*, 2001; Van Waerebeek and Leaper, 2008). These can even represent a real or potential threat to several large cetacean populations around the world (Clapham *et al.*, 1999; Kraus *et al.*, 2005; De Stephanis and Urquiola, 2006; Panigada *et al.*, 2006b; Behrens and Constantine, 2008; Carrillo and Ritter, 2010; Guzman *et al.*, 2012)

These ship strikes can also be detrimental to shipping companies. They can cause significant damage (IWC, 2008) sometimes necessitating dry dock repair (Laist *et al.*, 2001). In addition to repair costs, these damages lead to a shortfall for the company (IWC, 2008). The public image of the company, in terms of environmental impact and on-board safety, can also be deteriorated. Indeed, several ship strikes led to passengers and crew members being more or less severely injured (Honma *et al.*, 1997; Laist *et al.*, 2001) and two cases of death were reported following a collision with a cetacean (De Stephanis and Urquiola, 2006; Anonymous, 2007a).

Many international organisations like the International Whaling Commission (IWC), the International Maritime Organization (IMO) through its MEPC (Marine Environmental Protection Committee), the Pelagos and ACCOBAMS (Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic area) agreements, the scientific committee of the CIESM (*Commission Internationale pour l'Exploration*

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[1] *Également appelé jauge brute, le tonnage brut est la capacité intérieure totale d'un navire.*

Scientifique de la Méditerranée) and the Convention on Migratory Species (CMS) share the same objectives of reducing the risk of collisions between ships and large cetaceans. Many solutions were therefore developed around the world to try to deal with this issue.

This report intends to provide an overview of the different management measures implemented to reduce collisions between large cetaceans and commercial ships[2] and an evaluation of these measures when possible. Ship strikes involving other marine mammals (small cetaceans, sirenians, pinnipeds) and leisure boating are not treated. In fact, ship strikes risks are not as threatening for these species, except maybe for some sirenian populations (Marsh *et al.*, 2011). The concerned economic stakeholders are also different. The case of sailing races will be briefly treated.

First, an inventory and evaluation of the technological tools are presented, followed by a presentation of the different management measures implemented around the world to reduce the risk of ship strikes. Future measures will be presented at the end of this report.

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[2] *In this report, the term commercial ship includes cargos, tankers, container ships, ro-ro, bulk carriers, ferries but also whale-watching vessels.*

1. <u>Technological tools</u>

This first part presents the interests and disadvantages of the different cetacean detection systems developed and being used around the world.

1.1. Inventory of the main cetacean detection devices

The detection range of a large cetacean should be long enough (several thousands of metres) so that the on-board personnel can take the appropriate avoiding actions (Silber *et al.*, 2008). In fact, according to Captain Capoulade, during a crash stop a High Speed Craft (HSC) covers between 345 and 393 metres before complete stop while a regular ferry covers 500 to 1241 metres (David *et al.*, 2005). At 40 knots (kn) a detection range of 2.5km gives the crew 2 minutes to react (Bondaryk (2002) *in* David (2005)) while a detection range of 600m only gives the crew 30 seconds (Carrillo and Ritter, 2010). Before shutting down in 2009, the ferry connecting Hawaiian islands would change direction or reduce speed when a large cetacean is detected in order to keep a 500-m safety distance to the animal (Hawaii Superferry, 2005). According to Kite-Powell *et al.* (2007), the collision risk is considerably higher when the detection range is below 100 metres. Many recorded collisions happened when animals were not detected early enough (Laist *et al.*, 2001).

All these facts underline the interest of developing devices to detect animals early enough in order to take necessary measures to avoid colliding with them. Canada, the United States and more and more other countries are looking for (existing or developing) technical and technological solutions with reduced (economical and environmental) costs to detect cetaceans early enough and in real time to avoid ship strikes (Reeves *et al.*, 2007; Brown *et al.*, 2009)[3]. In 2008, a workshop was held in consultation with concerned stakeholders (shipping experts, shipping company representatives, biologists, institutions, research bodies) to identify and evaluate the different technologies to reduce the risk of ship strikes (Silber *et al.*, 2008).

An inventory of the different technologies to reduce collisions between cetaceans and ships was carried out in several studies (NMFS, 2002; IFAW, 2006; Reeves et al., 2007; Marine Mammal Commission, 2008; Silber et al., 2008). Completed by scientific studies, the results are summed up in Table *1*.

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[3] *Between 2002 and 2005, the United States invested $6.31 million in research and development of efficient technological tools not deeply affecting shipping traffic. These investigations were inconclusive (Reeves et al., 2007).*

Table 1: Inventory of the different technologies to reduce the risk of collisions between ships and large cetaceans

Technologies	Comments	Interests	Disadvantages
Deterrent devices[4]	Consists in triggering an acoustic alarm to move animals away.	- Does not require complex technology; - Relatively cheap.	- Habituation phenomenon from the animals who do not respond to the acoustic stimulus anymore; - Unexpected and variable response from the animals depending on species, geographical area and behaviour; - Possible rapid surfacing or approach of the acoustic source (Nowacek *et al.*, 2004); - Additional acoustic pollution and stress; - Possible disturbance in feeding or breeding grounds potentially affecting populations; - Origin and direction of sound difficult to determine for the animals (Shapiro et al., 2009).
Active acoustics (SONAR such as the FarSounder[5] model)	Can be installed on-board ships or on stationary buoy shipping corridors. Consists in sending a powerful sound wave in the ocean to detect obstacles in the water column (by analysing wave echoes on objects).	- High detection and localisation capacities[6]; - Efficient means to detect cetaceans (Miller and Potter, 2001; Zimmerman and Potter, 2001); - Real-time detections; - Efficient in foggy weather; - If the stationary buoy system turns to be efficient, it would reduce the scope of the buoys and transmit information to nearby ships.	- The stationary buoy system has apparently never been tested to detect marine mammals; - Variable efficiency according to the acoustic properties of water masses and power of sonar; - Adapted to offshore deep waters but low efficiency in coastal shallow waters; - Usually detects animals at close range (Miller and Potter, 2001); - Very expensive (~ $100,000 per unit) ; - Requires a dedicated operator; - Set up and maintenance difficulties on certain types of ships (large size); - Additional acoustic pollution and possible disturbance in feeding or breeding grounds potentially affecting populations[7]; - Possible misinterpretation (detection of schools of fish, submerged object, etc.); - Echo return weakened by the thick blubber layer of the animals (David *et al.*, 2005) and density of their body (similar to water density).

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[4] *Acoustic Deterrent Devices (ADDs) or "Pingers" and Acoustic Harassment Devices (AHDs).*

[5] *The FarSounder model detects cetaceans and can be set up on several types of ships (cruise ship, yacht, ferry) sailing at speeds of 10 to 20kn.*

[6] *An echosounder detection device (Whale Detector Apparatus, developed by Kawasaki Heavy Ind) was installed onboard ferries and jet foils after a passenger died during a collision with a sperm whale in the Canary Islands in 1999. This device detects cetaceans and other floating objects up to 500m away, therefore allowing ships crossing at 40kn*

Satellite telemetry	Consists in attaching a transmitter to an animal and following its movements via satellite (*e.g.* Argos) or a receiver installed on-board a ship or plane.	- Covers a very wide area; - Independent from weather conditions; - Possibility of gathering additional information (*e.g.* dive patterns); - Does not require a particular observation platform.	- Expensive tool (several thousands of dollars per tag + expedition at sea); - Safety concerns for the person in charge of tagging the animal; - Requires the animal to be at the surface to send the data; - Limited attachment and battery life (few hours up to several months); - Intrusive and potential risks of infection; - Only easily approachable animals can be tagged.
Radio (*e.g.* VHF) **and acoustic telemetry**	Consists in attaching a transmitter to an animal and following its movements via a VHF or acoustic receiver.	- Relatively cheap ($500-3,000 per unit for classic models and more than $10,000 for more elaborated ones); - Small size and not very intrusive; - Covers a wide area; - Possibility of following the tagged animal from several types of platforms equipped with an antenna and adapted receivers; - Relatively independent from weather conditions.	- Safety concerns for the person in charge of tagging the animal; - Requires to maintain the platform in the vicinity of the animal; - Requires the animal to be at the surface to send the data; - Limited attachment; - Limited battery life (especially for acoustic telemetry); - Risk of infection according to the attachment system; - Only easily approachable animals can be tagged.
Mobilising a pilot boat	Consists in mobilising a pilot boat that can be equipped with cetacean detection tools to precede and assist larger ships during their manoeuvers in risk areas (*e.g.* port entrances).	- Avoids equipping all ships with expensive devices requiring regular maintenance and dedicated operators.	- Limited to restricted areas (*e.g.* approaching ports); - Very expensive (requires adapted ships and dedicated operators).

Visual prospections (on-board ships or planes)	Consists in mobilising dedicated observers to visually detect surfacing animals with the naked eye or binoculars (*e.g.* Big Eyes[8] model).	- Possibility of covering a large area and provide alerts to mariners in real time; - Photo-identification possible; - Possibility of implementing different research studies (biopsy, satellite tagging, photo-identification, faeces sampling, ethology) on-board ships; - Possibility of spotting dead or entangled large cetaceans; - Possibility of exploiting sighting temporal series thus obtained to develop prediction models.	- Expensive operation (especially true for aerial prospections[9]); - Intensive work; - Only animals close to the route of the ships/planes are detected (several nautical miles (NM) on each side); - Only surfacing animals are detected; - Requires observer training; - Inefficient at night, in poor weather or rough sea conditions; - Safety concerns for offshore aerial prospections[10].
Satellite imaging	Allows obtaining satellite images of the ocean surface and spot large cetaceans.	- Possibility of providing data for prediction models; - Covers vast geographical areas.	- Expensive system (comparable to aerial prospections); - Requires trained personnel to analyse the data; - Resolution often insufficient to identify a large cetacean; - Inefficient in overcast weather and rough sea conditions.
Passive acoustics: anchored buoys (*Autonomous Recording Units* : ARUs)[11]	Fixed underwater sound listening and recording system to determine the position of cetaceans by detecting their vocalisations.	- Efficient to detect large cetaceans; - Some technologies allow obtaining real time information for a more dynamic management (IFAW, 2006); - Possibility to equip this tool with an automatic detection system; - Efficient at night and in bad weather conditions; - More efficient than aerial visual observation in areas where the density of animals is low; - Can be used to implement management measures (*e.g.* identification of areas frequented by the animals and Traffic Separation Scheme proposals[12]).	- Expensive system[13]; - Can be damaged by human activities (*e.g.* shipping, fisheries, leisure boating); - Requires more tests and development; - Reduced efficiency with ambient noise; - Limited detection range (5-10NM); - Only vocalising animals can be detected; - The number and position of individuals is hardly determinable; - Only efficient in good oceanographic conditions for sound propagation (reduced efficiency in shallow waters of the continental shelf; - Energy and time-consuming data processing and transmission; - Requires trained personnel to analyse the data.

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[8] *The wide angle Big Eyes binoculars (25x150) such as those used on-board research ship* Endeavor *or in the study by Moore et al. (2002) are relatively expensive (about 2,200 euros), require available room on the bridge (1m long, 410cm wide and 20kg) and to increase the number of observers to reduce impacts of visual tiredness (an 80-minute watch followed by a 40-minute rest is recommended).*

[9] *In the framework of the North Atlantic right whale (*Eubalaena glacialis) *conservation programme, the budget of aerial prospections (used both for research programmes on the distribution of the animals and as a management measure to avoid ship strikes by communicating sightings of large cetaceans to nearby ships) approached $2,636,000 a year between 2003 and 2005, against $289,000 a year for ship-based prospections (Reeves et al., 2007, Marine Mammal Commission, 2008).*

[10] *For reasons previously cited, Reeves et al. (2007) recommend to gradually replace aerial prospections by passive acoustics, satellite telemetry, ship-based prospections and isotopic analyses (safer techniques with a higher efficiency/cost ratio).*

[11] *According to Moore et al. (2006), acoustic receivers could be combined to existing devices such as tsunami detection buoys, weather or oceanographic buoys (buoy positions available here: http://www.ndbc.noaa.gov/).*

[12] *Cf. chapter 4.1.1.*

Passive acoustics: towed hydrophones	Mobile underwater sound listening and recording system to determine the position of cetaceans by detecting their vocalisations.	- Relatively cheap; - Real-time information; - Efficient at night and in poor visibility conditions; - Possibility of equipping this tool with an automatic detection system.	- Wide price range; - Requires to be towed by a silent ship; - Assumes a sailing speed below 15kn (Patrick Mugnier, pers. com.); - Only vocalising animals can be detected; - Reduced efficiency in rough sea conditions.
Laser technology (*e.g.* LIDAR : Light Detecting And Ranging)	System installed on a small aircraft or satellite allowing obtaining information on distance and nature of an object with a laser beam penetrating the water column and bouncing off objects).	- More reliable and efficient than visual detection; - Detects submerged animals; - Grey whales have been sighted with this technology.	- Still little tested for cetacean detection; - Inefficient in bad weather and rough sea conditions; - Detected targets require a visual confirmation; - Expensive system; - Few aircrafts can be equipped with this system.
RADAR (*RAdio Detection And Ranging*) with ATA/ARPA automatic system	Uses radio waves to detect and estimate the distance to and/or the speed of an object.	- Crew already familiar with this type of tool; - Higher detection range (4-8km[14] for small crafts in moderate sea conditions) than visual observations or infrared devices; - Can be fitted with an automatic detection system; - Efficient day or night and relatively efficient in poor visibility (rain, fog, DeProspo *et al*., 2003); - The *Arété* model allowed detecting fin whales in the Mediterranean Sea.	- Only surfacing animals can be detected; - Poorly efficient in rough sea conditions; - Variable detection efficiency according to the orientation of the animal; - Requires the permanent presence of a person in charge of the RADAR; - Identification of the object sometimes unreliable.
Prediction model	Predicts areas frequented by the animals given environmental parameters (*e.g.* water temperature, chlorophyll *a* concentration, salinity, currentology, depth).	- Cheap once developed; - Possibility of obtaining almost real-time information; - Covers vast geographical areas; - Allows guiding the selection of areas for visual prospection (either aerial or ship-based).	- The relations between the parameters and the animals are not always understood; - Information is not always in real time; - Prediction power can be limited or inaccurate; - Data collection depends on satellite image availability (*e.g.* limited availability in overcast weather or at night).

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[13] *In the framework of the North Atlantic right whale conservation programme, the budget for acoustic detection (used both for research programmes on the distribution of the animals and as a management measure to avoid ship strikes) reached around $468,000 (Reeves et al., 2007 ; Marine Mammal Commission, 2008).*
[14] *6km approximately corresponds to the visual detection range in optimal conditions.*

Night Vision System (NVS): Light Amplifier	Intensifies light by gathering and amplifying the photon energy emitted by objects. The obtained image on the screen is usually green or grey.	- Relatively cheap and affordable; - Possibility to detect animals during full moon nights, close to lit shore or with a beacon.	- Limited efficiency in rough sea (Beaufort>2) or bad weather conditions (Mayol, 2007); - Rapid tiredness (after one hour) for the user of the monocular; - Limited detection range (<100m); - Reduced field of view (40°) at night: requires the presence of several observers (>3); - Increased difficulties in overcast weather, dark night or when the observation platform is too bright (artificial light)[15].
Night Vision System (NVS): Thermal vision system[16]	Uses and amplifies thermal radiations of objects to detect temperature differences with the environment. The image on the screen appears like a negative.	- More efficient than light amplifying technologies to detect cetaceans (Sylvie Quaeyhaegens, pers. com.); - Detects marine mammals by day and night (Olivier Adam, pers. com.); - Some devices, such as FIRST Navy[17], could be fitted with a real time automatic detection system of large cetacean blows, such as the one presented by Santhaseelan et al. (2012).	- Relatively expensive system (50,000–100,000 euros); - Only surfacing animals can be detected; - Reduced efficiency when air temperature is warm (smaller temperature difference between the blow and ambient air) and in rough sea and bad weather conditions; - Reduced detection range[18].

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[15] *Some of this information is taken from: Amanda Cummins and Joe Mobley (pers. com.), Calambokidis and Chandler (2000), Mobley and Uyeyama (2008).*

[16] *Technologies combining light amplifying and thermal imaging are more efficient (e.g. Night Navigator, MEOS: Maritime Electro Optical System).*

[17] *Developed by the German company Rheinmetall Defence Electronics, this device was testes for the first time in July 2009 onboard research ship Polarstern. Additional tests in 2012 showed that FIRST Navy had similar or even higher detection capacities than an experienced observer (Zitterbart et al., 2013).*

[18] *Some of this information is taken from: Cuyler et al. (1992), Perryman et al. (1999), Mccafferty (2007).*

The study from the National Marine Fisheries Service (NMFS) of the National Oceanographic and Atmospheric Administration[19] (NOAA) showed that none of these technologies, existing or in development, could significantly reduce the risks of collisions between cetaceans and ships (NMFS, 2002). Because of the cost, the technical weaknesses (*e.g.* small detection range, inefficiency in low visibility conditions) and the ecological concerns (*e.g.* biological disturbances, fuel consumption) linked to the use of the devices presented in Table 1, none of these technologies constitute a perfect means to avoid ship strikes. This observation is shared by ACCOBAMS (2005) and Abdulla and Linden (2008).

Therefore, as recommended by Silber *et al.* (2008), it is necessary to develop tools considering current ecological priorities (greenhouse gases emission reduction), ergonomic and technical priorities of ships (sensitivity to acoustic emissions and skin infections) and the economic requirements of the concerned stakeholders. Several of these systems exist today, with various methods and techniques.

1.2. REal-time Plotting of CETaceans; the REPCET system

Supported by the Pelagos and ACCOBAMS international agreements (ACCOBAMS, 2010)[20], REPCET[21] is a "client-server" computer system for commercial ship (Mayol, 2007; Mayol *et al.*, 2007; Mayol *et al.*, 2008). Developed by *Chrisar Software Technologies* (industrial coordinator) and *Souffleurs d'Ecume* (scientific coordinator), it aims at reducing the risk of collisions between large cetaceans and ships by setting up a greater observation effort focused on the animals. Each large cetacean observation made by a ship using REPCET is transmitted in real time via a satellite communication to a server on land[22]. The server centralizes the data and then sends it to all the other equipped ships (Figure 2). Observations are mapped on a dedicated screen. In a matter of ergonomics, the interface allows a quickly entry an observation in the system (Figure 3).

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[19] NOAA is the American federal agency in charge of ocean and atmosphere conditions. NMFS is the NOAA service in charge of promoting sustainable fisheries, the recovery of protected species and the health of marine coastal ecosystems.

[20] REPCET was presented during a meeting on Marine Protected Areas (MPA) in 2010 as a useful technological solution in MPA management. It also meets the expectations of IMO which encourages the development of a technological tool allowing the real-time transmission of positions of large cetaceans to mariners in order to implement necessary measures to avoid ship strikes (IMO, 2009).

[21] More information available here: http://repcet.com/docs/SE_2013_03_25_Pres-REPCET_en.pdf and on the website: www.repcet.com.

[22] REPCET meets the expectations of Laist et al. (2001) recommending the immediate transmission of large cetacean observations to mariners in the area.

Figure 2. Schematic of how the REPCET system works.

Figure 3. Screenshot of the REPCET interface. Observations are automatically associated with essential data (name and position of the ship, distance and bearing of the animal, species and number of individuals). A relative positioning target (left) was especially developed for that matter.

In addition to geographically position the observation, the system calculates and displays a risk zone representing the potential presence area of the animal (Figure 4). Rules for the representation of these risk areas are defined in Couvat *et al.* (2012) based on studies on the movements of fin (*Balaenoptera physalus*) and sperm whales (*Physeter macrocephalus*) by Gambaiani (2009) and (Gambaiani *et al.*, 2009) and regularly updated. These dynamic[23] areas represent the risk of sighting the animal initially spotted. Configurable alarms alert the

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[23] *Thanks to an intuitive colour code, their representation allows grasping the level of risk of colliding with the animal.*

crew of a risk of collision, preventing them to constantly watch the screen. When a risk zone disappears due to its obsolescence, the initial position of the observation remains for 24h allowing showing potentially dangerous areas due to the amount of recently sighted cetaceans.
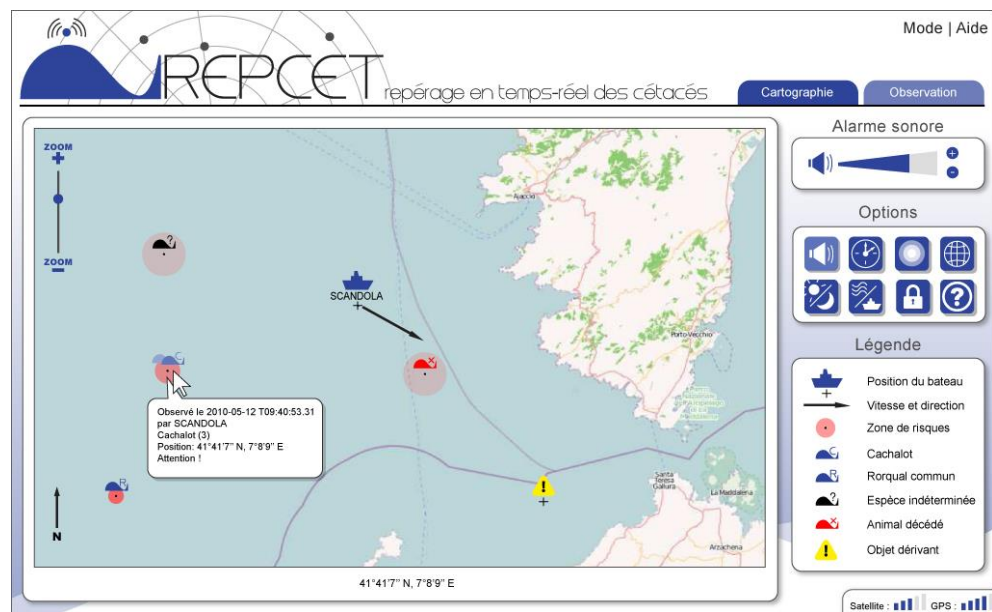

Figure 4. Cartographical representation of the observations. The risk zones appear in red, more or less merging with the background map according to the age of the observation (bright red=recent observation; pale red: old observation).

The system is intended to be collaborative and able to receive and transmit all sources of large cetacean positioning data (*e.g.* visual, automatic passive acoustic, optronic, prediction models). It also allows signalling any floating object that could be a threat to navigation and the presence of small cetaceans for research purposes.

In addition to the very pragmatic aspects previously described, REPCET aims at maintaining and boosting essential collaborations between shipping companies and research and protection studies carried out in the Pelagos Sanctuary and the other MPAs it will be developed in.

Moreover, given that only equipped ships have access to the large cetacean positions, this tool avoids broadcasting information that could, in some case, harm animals (*e.g.* disturbance by disrespectful whale-watching operators, use of the observations by whaling ships). Also working in close collaboration with whale-watching operators along the French coast of the Pelagos Sanctuary, *Souffleurs d'Ecume* developed a smartphone app allowing a restricted number of identified users to send information on the large cetacean observations they make during their professional activities without having access to the positions sent by the other members of the REPCET network. This app was operational in autumn 2013.

Likely to be used anywhere in the world, the REPCET tool was tested and developed in Northwestern Mediterranean Sea and especially in the framework of the Pelagos Sanctuary. Expansion projects in the Bay of Biscay are also on-going.

A similar system also based on visual detection was implemented in New Zealand.

1.3. Visual detection system in Auckland

In New Zealand, a small population of Bryde's whales (*Balaenoptera edeni*) could seriously be impacted by ship strikes. Sighted all year long (sometimes with calves) in Hauraki Gulf near Auckland, this population seems to be genetically distinct from the offshore population (Wiseman, 2008), although the degree of isolation remains uncertain. The population size is estimated to be between 50 and 160 individuals depending on models (Wiseman, 2008).

Hauraki Gulf is highly frequented by both commercial ships going in and out of the Port of Auckland and ferries connecting the numerous islands around. Furthermore, this heavy traffic is expected to increase in the coming years. Behrens and Constantine (2008) identified areas of high collision risks in which commercial ships sail at speeds of 12 to 17kn and up to 22kn for ferries. Stranding studies identified that 34% of stranded animals were probably of definitely killed by a ship strike. Given the many unknown factors concerning this population (*e.g.* reproduction and natural mortality rates, proportion of migrant/resident individuals, etc.), the impact of ship strikes is difficult to estimate but raise concerns. Implementing a database with systematic and accurate report of ship strikes[24], a strict protocol to establish cause of death and improving knowledge on this population are urgent measures to be taken (Behrens and Constantine, 2008).

A system of visual detection and transmission to ships crossing the Gulf was tested in December 2012 and implemented in January 2013 by the Department of Conservation of Auckland Region and the Port of Auckland (Martin Stanley, pers. com.). When a ship sights a whale, it calls the Port of Auckland which records the position and broadcasts it to all the other ships in the area of the whale via the commercial shipping VHF channel. It also recommends to reduce speed and to post additional observers. These recommendations are voluntary and no penalties for ships not complying with them exist at the moment (Stephanie Watts, pers. com.). Five months after implementation, 25 alerts had been broadcast and primary analyses show that area avoidance and speed reduction are respected. No strike had been reported over this period (Martin Stanley, pers. com.). Tests are on-going to couple this system with night vision devices for night time and poor visibility conditions periods. An acoustic detection system would not be efficient because the whales of the Gulf do not vocalize much (Martin Stanley, pers. com.). This simple and cheap system could easily be implemented in other ports facing the same ship strike issue (Martin Stanley, pers. com.).

Another technological tool based on infrared detection allows the successful detection of large cetaceans at night or when weather conditions are too bad for visual observation.

1.4. Infrared vision system

The optronic detection system Night Navigator was developed by the Canadian company Current Corporation and was installed on the ferry connecting the Hawaiian Islands[25] in order to reduce the risk of collisions with humpback whales (*Megaptera novaeangliae*). Several research ships are equipped, such as Whalesong from the Centre for Whale Research in Australia[26]. This device can efficiently and automatically detect large cetacean blows (Mobley and Uyeyama, 2008; Welcome, 2009).
Several models were developed by this company. The technical features and functions of the different models developed by Current Corporation are summed up in Table 2.

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[24] *Cf. chapter 8.*
[25] *Before shutting down in 2009.*
[26] *More information on: http://www.youtube.com/watch?v=VXzufGgID0Y and http://www.cwr.org.au/*

Table 2. Features of the different systems developed by Current Corporation (Sylvie Quaeyhaegens pers. com. and www.currentcorp.com)

Model name	Features

Night Navigator 1	Stabilised technology or not:
	• 1 uncooled high resolution thermal camera;
	    • Initial resolution: 380x288;
	    • Resolution available now: 640x280;
	    • Optical zoom x2 or x4.
	• 1 high definition day camera;
	    • 1080i or 720p;
	    • Optical zoom x10, digital zoom x12.

Night Navigator 3	Technology fitted with a stabilisation system and composed of 3 internal cameras[27]:
	• 1 uncooled high resolution thermal camera;
	    • Resolution: 640x480.
	• 1 high resolution light amplifying camera ;
	    • Field of view: 20°.
	• 1 high definition day camera;
	    • 1080i or 720p;
	    • Optical zoom x10, digital zoom x12.
	Different types[28] of thermal cameras exist:
	• Thermal camera with a single field of view[29];
	• High resolution thermal camera with a single field of view;
	• Thermal camera with a duel field of view:
	    • A 20° field of view;
	    • A 6.8° field of view to zoom in a particular area.

Night Navigator SOS[30]	Technology allowing the automatic merging of thermal technology and light amplifying night vision with a pulse laser[31] passing through water drops in the atmosphere (useful in rainy, foggy or snowy weather and polluted atmospheric conditions):
	• 1 uncooled high resolution thermal camera;
	    • Resolution: 640x480.
	• 1 high resolution light amplifying camera;
	• 1 high definition day camera;
	    • 1080i or 720p.
	• Improved detection range[32] in bad weather conditions;
	• This tool is fitted with an automatic detection system with the "object tracking" option.

Night Navigator 3000	Stabilised technology with the "object tracking" option with two internal cameras:
	• 1 uncooled high resolution thermal camera;
	    • Resolution: 640x512;
	    • Field of view: 20°;
	    • 2° field of view at maximum zoom;
	    • Optical zoom x10, digital zoom x12.
	• 1 high definition day camera;
	    • 1080i or 720p;
	    • Optical zoom x10, digital zoom x12.

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[27] *It is always useful to put both screens side by side (Sylvie Quaeyhaegens, pers. comm.).*

[28] *Many possibilities exist according to detection needs.*

[29] *This tool now has a camera with a 10° fix field of view.*

[30] *This system is used by the Canadian coast guards to save human lives in bad weather conditions.*

[31] *Eyesafe system.*

[32] *Compared to the two devices described above.*

	Compact, robust and light stabilised technology with the "Laser Range Finder" option to estimate distances:
	 • 1 long-range uncooled thermal camera;
	  • Field of view: 25.5°;
	  • 1.7° field of view at maximum zoom;
	  • Optical zoom x15 and digital zoom x13;
	  • 320mm focal.
	 • 1 high definition day camera;
	  • Field of view: 40°;
	  • 1.7° field of view at maximum zoom;
	  • Low light mode.

Night Navigator GS	

Night Navigator 8540	Robust technology specialised for HSC night vision:
	 • 1 light amplifying camera;
	  • Resolution: 756x484;
	  • Field of view: 20°.

The German company Rheinmetall Defense Electronics also developed an automatic infrared detection system for large cetacean blows called AIMMMS[33]. The AIMMMS features are presented in Table **3**.

The device has been tested and improved for two years during several polar expeditions on-board *Polarstern*, ice-breaker of the German Alfred Wegener Institute. However, this technology remains inefficient when sea temperature rises above 10°C or to detect small marine mammals (seals, dolphins).

Table 3. AIMMMS functions and technical features[34]

Functions	• Simultaneous real-time detection and tracking of several targets up to 2NM; • Collision with platform probability calculations; • Regular video clip for human check; • Automatic data archive.
Technical features	• Automatically operational 24/7; • Gyro-stabilised technology; • Horizontal field of view: 360°; • Vertical field of view: 18°.

Other devices based on passive acoustic detection have been developed around the world and appeared to be efficient to detect large cetaceans

1.5. Passive acoustic systems

Several studies such as Clark (1995), Moore *et al.* (2006) or Urazghildiiev and Clark (2006) showed that passive acoustics is an efficient tool to detect large cetaceans when visual observation is limited (bad weather conditions, darkness)[35]. More recent studies also underline the greater efficiency of passive acoustics in animal detections (Clark *et al.*, 2010; Morano *et al.*, 2012; Whitt *et al.*, 2013), although visual prospection remains a necessary means to estimate several population parameters and monitor the impact of ship strikes for example (Clark *et al.*, 2010). Thus, several systems based on passive acoustics were developed around the world.

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[33] *Automatic Infrared-based Marine Mammal Mitigation System.*
[34] *Taken from: http://www.rheinmetall-defence.com/en/rheinmetall_defence/systems_and_products/c4i_systems/reconnaissance_and_sensor_systems/automatic_marine_mammal_mitigation/index.php and from Zitterbart et al. (2013).*
[35] *Such as fin, blue (Balaenoptera musculus), humpback, sperm, grey (Eschrichtius robustus) and North Atlantic right whales.*

1.5.1. Whale Auto-Detection Buoy System: WADBS

In order to reduce the risk of collisions between right whales and ships, three automatic acoustic detection buoys developed by the American organisations Cornell Lab of Ornithology and Woods Hole Oceanographic Institution (WHOI) were initially placed in Cape Cod Bay, Massachusetts. In 2008, 10 additional buoys[36] were fixed every 5NM[37] along the Traffic Separation Scheme accessing the port of Boston (Clark and Peters, 2009).
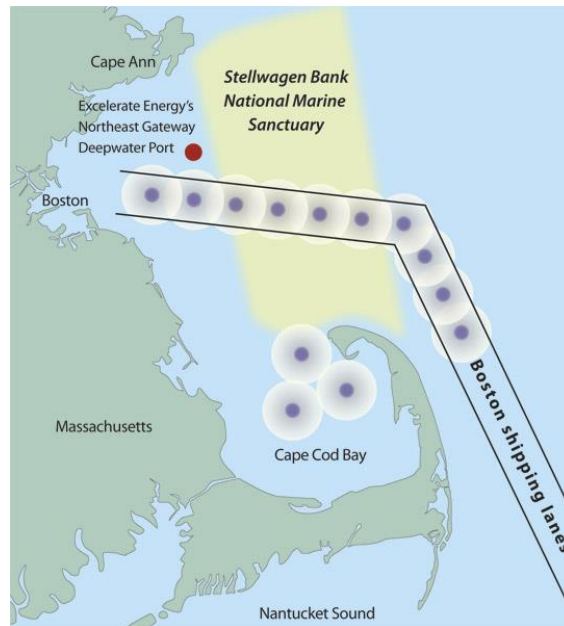
Figure 5. Whale Auto-Detection Buoy System (WADBS) set up in Cape Cod Bay and along the Traffic Separation Scheme off the port of Boston (figure taken from:
http://www.whoi.edu/oceanus/viewImage.do?id=91437&aid=57146).

This system was designed so that the anchoring line can stretch (without breaking) up to 2.5 times its size during a storm to absorb forces, shocks and noise in order for the hydrophone to collect information on whale presence in rough sea conditions (Figure 6).

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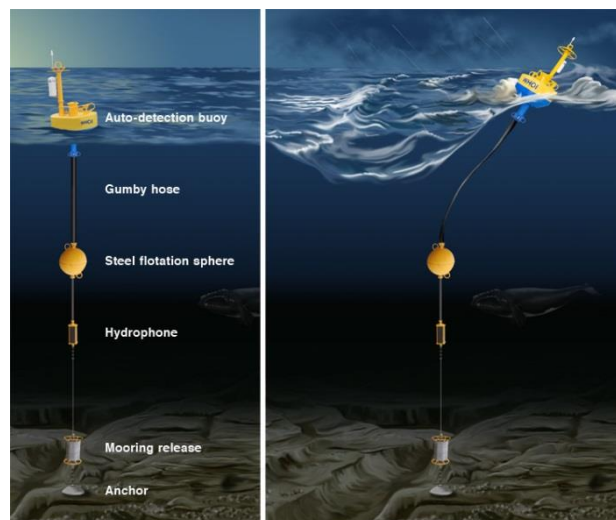
[36] *More information on WADBS available on: http://www.listenforwhales.org and http://www.whoi.edu/oceanus/viewArticle.do?id=57146*
[37] *Efficiency radius of the hydrophones.*

This passive acoustic buoy system automatically detects right whale vocalisations in real time. This information is then transmitted to Cornell bioacoustics laboratory on land via satellite (or phone) every 20 minutes to be analysed and validated[38]. If a whale is detected, the data is sent as a warning message to ships in the area which are expected to reduce speed and increase their watch (Figure 7).

Figure 7. Schematic detailing the different steps of the WADBS (figure taken from: http://www.listenforwhales.org/netcommunity/Page.aspx?pid=430)

This system was developed with the arrival of supertankers from the Excelerate Energy company carrying liquefied natural gas in a terminal off the port of Boston. Indeed, this company had to fund the WADBS to be allowed to operate within the Stellwagen Bank Marine National Sanctuary[39]. Every 20 minutes, people in charge of analysing WADBS data send an update on whale detections from the last 24 hours to Excelerate Energy ships by phone (McGillivary *et al.*, 2009). The Stellwagen Bank Marine Sanctuary and the NMFS require these ships to limit their speed to 10kn and to post a dedicated observer when in a 5NM-distance from a buoy where whales have been detected. (Bettridge and Silber, 2008).

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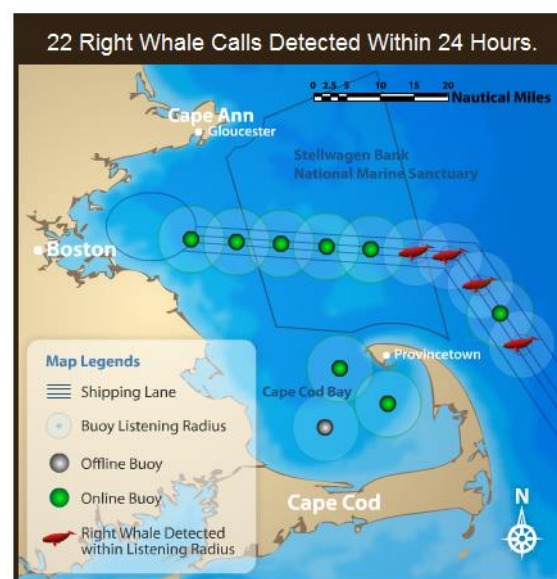
[38] *Two people are in charge of analysing data. Daily record reading from 10 buoys requires 1 to 2 hours of work.*
[39] *This system was funded up to $3.25 million for the first research and development year and up to $3 million for 25 years of maintenance. This system must be used during the whole existence (estimated between 25 and 40 years) of the two natural gas terminals off the port of Boston (Bettridge & Silber, 2008).*

Figure 8. Right whales detected in the last 24 hours (figure taken from: http://www.listenforwhales.org/netcommunity/Page.aspx?pid=430).

When ships carrying liquefied natural gas do not operate in the area, data is still analysed and transmitted every 12 hours to the other ships in the area. Since February 2008, acoustic detections made off the port of Boston have been integrated to NOAA Right Whale Reporting System[40]. In the future, all ships in the area should consult this warning system and reduce their speed when necessary.

Moreover, this pioneer system can both inform mariners of right whale presence and help the study of the animals' vocalisations. It could be exported to other regions of the world facing the same issues. Similar systems have already been set up off Jacksonville (Florida) and in the Bering Sea.

To obtain real-time information on right whale presence, WADBS sends information via the Automatic Detection System (AIS)[41] in collaboration with the U.S. Coast Guards. Tested off of the port of Boston, the objective is to inform ships of the last detections of whales mapped in real time by the AIS (McGillivary *et al.*, 2009).
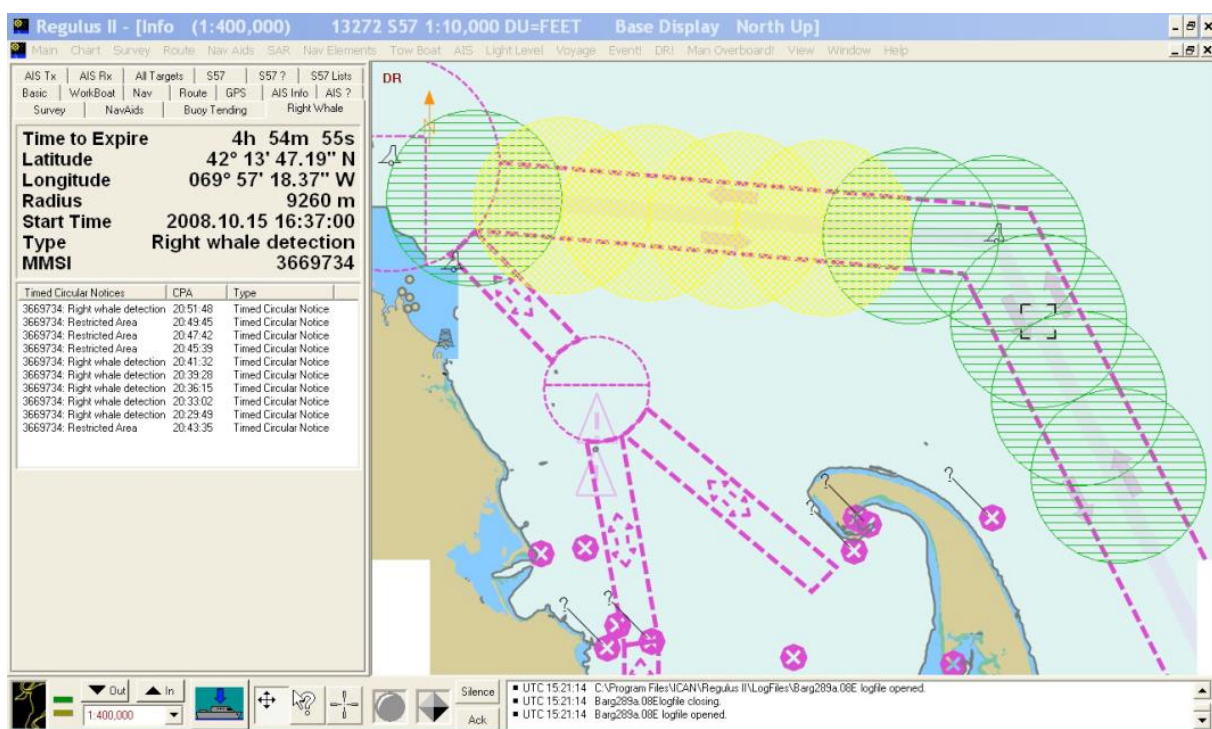
Figure 9. AIS messages as they are received and displayed on the bridge of the concerned ships. Based on acoustic detections from the Cape Cod Bay buoys, these messages are sent from Provincetown (Massachusetts). For each buoy a message is transmitted every 5 minutes. It covers a maximum radius of 20-40 km according to the quality of ship receivers and VHF radio propagation conditions. On this figure, each circle represents a buoy and its detection radius. Yellow circles indicate that a right whale was detected in the last 24 hours (McGillivary et al. (2009).

Wiley *et al.* (2011) modelled the reduction in ship strike mortality in the Stellwagen Bank Sanctuary linked to the implementation of several speed reductions using the speed/mortality model from Pace and Silber (2005). Considering that traffic within the Sanctuary is

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[40] *Cf. chapter 6.2*
[41] *The AIS system is currently used by ships larger than 300 tons (gross weight) and provides information to mariners on the positions of other equipped ships over a 60NM radius.*

representative of traffic in the TSS, Wiley *et al.* (2011) modelled a 57% mortality reduction for a 10kn speed limitation.
.
In 2012, an iPhone or iPad application was created to reach a greater number of ships. Called WhaleAlert, this free application can receive messages sent via AIS by people in charge of analysing the signal. Alerts are then mapped and ships can reduce speed when approaching a buoy that detected a right whale. WhaleAlert also provides information on areas to avoid[42], regulations in force, etc.[43]

However, without a specific software or any feedback from mariners, it is impossible to say if detections transmitted via AIS have been received and/or viewed by mariners (McGillivary *et al.*, 2009). Besides, McGillivary *et al.* (2009) point out that the acoustic system off Boston can only signal living and vocalising animals. It would be interesting to couple it with another detection system such as WACS, developed in the Canary Islands[44] (McGillivary *et al.*, 2009).

1.5.2. Whale Anti-Collision System : WACS

If a global spread of active acoustic detection system is quite unlikely, another promising research option based on passive acoustics exists: WACS, a cetacean detection system based on a chain of acoustic receivers (André *et al.*, 2000; André *et al.*, 2001; Delory *et al.*, 2003; André *et al.*, 2004; Delory *et al.*, 2007). It forms a protection corridor for marine mammals in which they can be detected, classified, localised and their position transmitted to ships using that corridor (Figure 10). WACS is composed of several elements:

- An array of fixed acoustic buoys (or antennas) with 36 receivers each. Each antenna forms a 3-dimension opening allowing the calculation of sound arrival time differences to localise the animal;
- Inter-array and array/land communication systems. Data transmission can be done via radio, cable or existing telephone cable network in some cases (reduction of installation costs);
- An automatic detection, classification and 3D localisation software based on an algorithmic system calculating whale positions horizontally and in the water column (3,000m) with a maximum error of 200m;
- A geographic data receiver on-board each ship.

This entirely automatic system transmits the information processed on land to ships in the area on a screen representing the 3D image. Ideally, transmitted data can be integrated to radars and anti-collision systems already on-board. The device gives a real-time 24h access to accurate information on cetacean movements and the possibility to track individuals one by one. It can work regardless of the number of ships in the area. Passive and therefore non-intrusive system, it reacts to ondotocete as well as mysticete vocalization wavelengths et has the huge advantage of detecting non vocalising animals thanks to Ambient Noise Imaging (ANI) technology. Through this technique, human (*e.g.* ships in the area) or biological (*e.g.* sperm whale clicks) sound emissions reflect on large silent (or dead) cetaceans and allow their detection. Given its passivity, there is no habituation risk for the animals with WACS, unlike deterrent devices.

One antenna used alone can detect vocalising sperm whales in a 5km-radius in Beaufort 3 sea conditions. To create a safety corridor, antennas must be 10km away[45]. To detect vocalizing fin whales, the horizontal opening of the antenna must be much larger given the longer wavelength of fin whale vocalisations compared to sperm whale clicks. To compensate the technical impossibility of creating an antenna several metres high, the designer advocates to use two antennas with a given interval between them (according to Mayol (2007) this interval is not known). This would allow the horizontal opening to be large enough to calculate fin whale long wave sound arrival time differences to be calculated.

To detect non or irregularly vocalising animals, the device must be used in ANI mode. In that case, the action radius of each antenna is reduced to 2.5km in Beaufort 3 sea conditions. In the protection corridor, it is necessary to place an antenna every 5m[46].

Both techniques (passive and ANI) work at the same time and complete each other, one taking over from the other when animals do not vocalise and vice versa.

A demonstration prototype towed by a ship is operating and another in situ prototype is operating in the Canary Islands between Las Palmas de Gran Canaria and Santa Cruz de Tenerife, over a 100km distance with 10 antennas (Michel André, pers. com.).
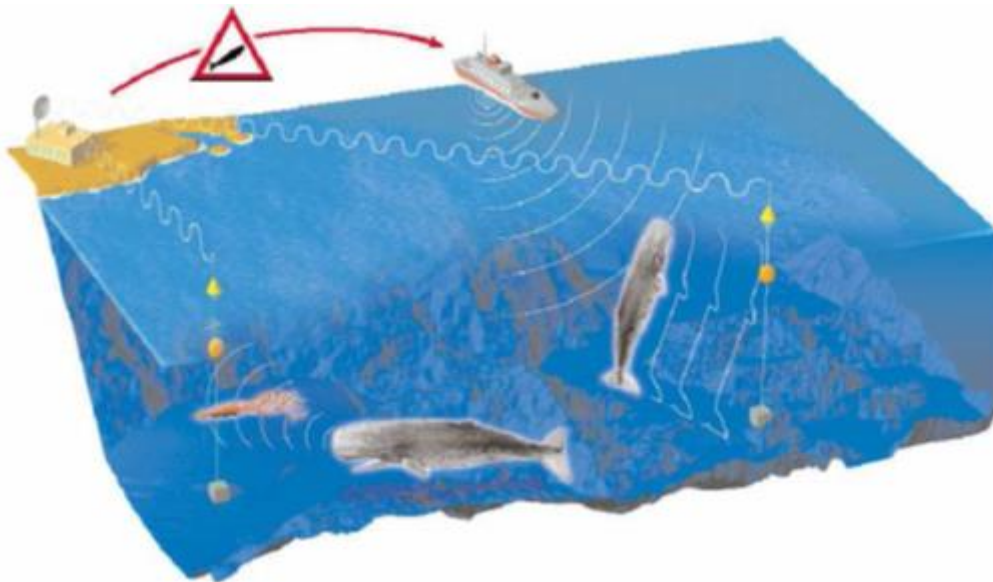
Figure 10. Schematic of the Whale Anti Collision System. The entirely passive system isolates shipping corridors in which all cetaceans (vocalising or not) can be detected with Ambient Noise Imaging (ANI).

With exhaustive detections and their non-intrusive character, passive acoustic technics and ANI are very promising but still require much development and scientific investment to definitely control all parameters (Mayol *et al.*, 2007) and quantitatively their efficiency.

Other examples of passive acoustic detections developed worldwide are presented in the following chapter.

1.5.3. Other passive acoustic systems

Other systems also based on passive acoustic detection have been developed around the world such as:

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[45] *Michel André (pers. com.) indicates that theoretical uncovered areas due to this interval have no effect on cetacean detections (low cetacean presence probability and ability from the system to extrapolate their directionality until their return under covered area).*
[46] *Beyond, the designer indicates that distance steadily decreases.*

- The LIDO[47] programme, developing a real-time acoustic large cetacean detection and tracking system in European waters[48] (IWC, 2009b; André *et al.*, 2010);
- The PAMGUARD[49] passive acoustic software, with funding from the International Association of Oil and Gas Producers for its development (IWC, 2008);
- The autonomous hydrophone system developed by NOAA's Pacific Marine Environmental Laboratory in collaboration with the National Marine Mammal Laboratory[50].

Other technological tools were developed to detect large cetaceans in their natural habitat.

1.6. Other detection systems

Other technologies could be used for cetacean detection, like Autonomous Underwater Vehicles (AUV) such as gliders. A glider is a silent underwater device without engine but with a ballast allowing to oscillate between the surface and 1,000m depth. Very energy-efficient, these devices can travel 25km a day for several months regardless of the sea and weather conditions. It can record water physical and biological parameters (*e.g.* temperature, salinity, fluorescence). This data is sent to research teams via satellite every time the device surfaces (every 2 hours approximately).

Two of these gliders were used in November 2012 by WHOI researchers in the North of the East coast of the United States (Baumgartner *et al.*, 2013). They detected and transmitted presence and positions of right, humpback, fin and sei (*Balaenoptera borealis*) whales in quasi real time. Transmitted to NOAA, these detections triggered the immediate implementation of Seasonal Management Areas (SMA)[51]. Fitted with passive acoustic recorders, their use is cheaper that mobilising a ship and provides accurate day and night information on presence, behaviour and vocalisations of the animals (Infocéan, 2006). They also collected zooplankton samples in order to better understand right whale feeding habits[52].

Other AUV prototypes were tested in Japan to detect sperm whale clicks but results were inconclusive. However, these technologies evolve quickly and more and more performing models are created, opening the door to new developments in terms of detection, real-time tracking and behaviour monitoring (see Kopman *et al.* (2012) for an example).

Another way of detecting cetaceans is the use of Unmanned Aerial Systems or drones[53]. Several drone models likely to be efficient in detecting marine mammals have been listed and classified by Koski *et al.* (2009) according to their technical features (*e.g.* field of prospection, battery life, type of controls, image stabilisation system, video resolution, speed, etc.) their on-board ergonomics (*e.g.* size, weight, take-off and landing from ship system) and their cost. In total, 9 drones[54] could be used for marine mammal prospection and some of these devices have already been tested for that purpose[55] (Stark *et al.*, 2003; NOAA, 2006; Buck *et al.*, 2007; Ireland *et al.*, 2007; Koski *et al.*, 2007b, a; Koski *et al.*, 2009).

Finally, a helium airship propelled with carbon wings has been designed by Stéphane Rousson who wished to test it for marine mammal detection in the Pelagos Sanctuary (Stéphane Rousson, pers. com.)[56].

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[47] *Listening to the Deep-Ocean Environment. More information on : http://listentothedeep.com/*

[48] *From the Arctic to the Gulf of Cadiz and the Mediterranean Sea.*

[49] *More information available here: www.pamguard.org*

[50] *More information available here: http://www.pmel.noaa.gov/vents/acoustics/whales/bioacoustics.html*

[51] *Cf. chapter 5.1.*

[52] *More information available here: http://www.whoi.edu/main/news-releases?tid=3622&cid=159289*

[53] *Also called Unmanned Aerial Vehicle (UAV).*

[54] *The 9 drone models are the following: Insight A-20 (ScanEagle), Manta B (Silver Fox), Arcturus T-16 XL, CryoWing, Elbit Skylark II LE, Fulmar, ZALA 421-16, R-100 Marine.*

[55] *Insight A-20 and Silver Fox have been successfully tested to detect cetaceans.*

[56] *More information on Stéphane Rousson's project in Latour & Rousson (2009).*

Complementary to detection technological aids previously cited, placing a dedicated observer on-board ships is an efficient way of reducing ship strikes.

2. <u>On-board dedicated observers</u>

According to Panigada and Leaper (2010), taking a dedicated observer on-board ferries can contribute to reduce the risk of collisions between large cetaceans and ships by:
- providing multi-annual data on animal distribution which is essential to implement adapted measures (*e.g.* rerouting, Dynamic Management Areas[57]);
- associating animal sightings with environmental parameters to contribute to the development of prediction models, useful to limit the risk of ship strikes;
- sending sightings to following ferries so that the next ones take measures to avoid colliding with previously sighted animals[58];
- detecting large cetaceans early enough so that avoiding manoeuvres can be taken in time.

According to David *et al.* (2005), on-board personnel training on cetacean visual detection or taking a dedicated observer to detect animals early enough is an efficient, cheap and easy to set up solution to reduce the risk of collisions. This opinion is shared by Beaubrun *et al.* (2001), David (2002), Weinrich (2004), ACCOBAMS (2005), Beaubrun (2005), Mayol (2005, 2007), Mayol *et al.* (2007), Weinrich and Pekarcik (2007), Mayol *et al.* (2008) and Weinrich *et al.* (2010).

In the Pelagos Sanctuary, Mayol (2007) notes the efficient complementarity between officers and scientists (2 officers et 1 dedicated observer) in the detection of large cetaceans from HSCs. On-board a commercial ship, a dedicated observer free from navigation requirements and strategically positioned to reduce ergonomic impacts would increase day detectability of cetaceans (Mayol, 2007). According to Mayol (2007), with good visibility, the main elements likely to disturb officers' attention and reduce long-range detectability on-board HSCs are the following:
- shadow areas created by porthole jambs (26cm thick instead of 15cm as recommended by Le Bouar et Chauvin, 2000) covering part of the useful detection angle;
- bright colours and shining ceiling bridges leading to glare and premature visual tiredness;
- far control panels leading to tiredness and periods when officers do not watch the sea;
- salt stains on solar panels marked with folds reducing;
- fragility and bad use of windshield wipers and their freshwater spraying system;
- watertightness problems leading to salt infiltration in the double glazed windows;
- untimely alarm ringing;
- no compliance with permanent watch of the light amplifying NVS screen by a dedicated observer as stipulated in the HSC code (IMO, 2000) and VISTAR NVS (1995);

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[57] *Cf. chapter 5.1.*
[58] *A protocol to evaluate the efficiency of a slight change in ferry routes to reduce the risk of ship strikes previously detected by dedicated observers is proposed and detailed in Panigada and Leaper (2010). However, according to Panigada et al. (2010), such a rerouting measure does not seem to be compatible with spatio-temporal movements of Mediterranean fin and sperm whales thus not allowing the reduction of ship strikes in the area.*

- highly developed electronic means requiring more attention and vigilance (Ministère Français de la Défense, 1998);
- disturbances (*e.g.* safety drill, supporting new officers imposed by HSC bridge conception regulations, stability adjustments to avoid vibration problems) and diverse technical dysfunctions (*e.g.* gas turbines and engines, cooling system, electronic card, helm).

The Laboratory of Public Health of the Medicine Faculty of Marseille has shown that navigation constraints on-board HSCs have a deeper impact on personnel watch from HSCs than from classic ferries (Mayol, 2007).

In the framework of the programme to reduce collisions between ships and right whales on the East coast of the United States, mariners are encouraged to post an observer (capable of identifying right whales) when an animal has been sighted in a 20NM radius around the ship. Moreover, among measures recommended by Carrillo and Ritter (2010) to be urgently taken to reduce collisions between cetaceans and ferries, placing dedicated observers is a priority.

Placing dedicated observers on-board ships to reduce the risk of collisions with large cetaceans has been tested worldwide. Indeed, it has already been implemented:
- on a ferry in Spanish waters (De Stephanis and Urquiola, 2006);
- on a ferry connecting Hawaiian islands: two trained dedicated observers were constantly on the bridge during the humpback whales season (IWC, 2008; Fast Ferry International, 2009). No strike apparently occurred during the two years of operation of the Hawaii SuperFerry (Abramson *et al.*, 2009)[59];
- on a ship of a company from Northern Asia where two dedicated observers were on-board in the framework of its marine mammal protection plan (IWC, 2008);
- on several ferries connecting Corsica and Sardinia to France and Italy. They also collected data on abundance of the different species of cetaceans in the area (Arcangeli *et al.*, 2012b; Arcangeli *et al.*, 2012c; Di-Méglio *et al.*, 2012);
- on cruise ships within the Glacier Bay National Park in Alaska, where Park services have placed dedicated observers to study the interactions between ships and humpback whales and potentially report any case of a collisions since July 2006 (Bettridge and Silber, 2008).

According to Weinrich and Pekarcik (2007), a dedicated observer is capable of detecting an animal at a greater distance (> 400 metres) than the ship captain. Since 2001, the Whale Center of New England has placed dedicated observers on-board HSCs between Boston and Provincetown in the United States. Out of 311 large cetacean sightings, 211 (67.8%) were made by the dedicated observer, 87 (27.9%) by the captain and 13 (4.1%) by other crew members. The study from Weinrich and Pekarcik (2007) highlights the usefulness of an on-board dedicated observer. While no strike occurred in the presence of such an observer, a ferry from a competing company taking the same route without an observer collided with a fin whale.

In order to implement adapted management measures, it is essential to first identify areas where large cetaceans spend the most time and where the risk of ship strike is highest.

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[59] *According to Abramson et al. (2009), some animals were closely avoided in 2008 during the humpback whale season.*

3. <u>Identification of risk areas</u>

Canada and the United States encourage setting up multi-annual studies (such as Knowlton *et al.* (2002) et Leeney *et al.* (2009)) in order to determine large cetacean distribution and spatio-temporal movements. According to Brown *et al.* (2009) and Reeves *et al.* (2007), this type of information can help identifying areas of preferred habitat for the animals in order to set up adapted management measures[60]. In the Mediterranean Sea, many studies on the relations between large cetacean distribution and environmental variables have been carried out (Dubroca *et al.*, 2003; Dubroca, 2004; Littaye *et al.*, 2004; Laran and Gannier, 2005; Panigada *et al.*, 2005; Laran and Gannier, 2008; Panigada *et al.*, 2008b; Cotté, 2009; Praca *et al.*, 2009; Azzellino *et al.*, 2012). Recently, the Joint Research Centre of the European Commission developed a model to predict potential Mediterranean fin whale preferential feeding habitat in western Mediterranean and part of European Atlantic waters. Preferential habitat areas are mainly estimated from the presence of chlorophyll *a* and temperature fronts. Based on a decade of fin whale presence data in north-western Mediterranean Sea (2000-2010), model validation tests showed that 80% of fin whale positions were located less than 10km away from preferential habitat given by the model (Druon *et al.*, 2012). Operational since 2010, a new version implemented in July 2013 relies only on chlorophyll *a*, satellite surface temperature data potentially creating noise and artificial fragmentation of preferential habitat (Jean-Noël Druon, pers. com.)

Meanwhile, shipping traffic studies (number of ships, type, destinations, speed and routes) such as Ward-Geiger *et al.* (2005), Di-Méglio and David (2006), Di-Méglio *et al.* (2010) and David and Di-Méglio (2010) are essential. Among other things, they help visualise high ship concentration areas, identify most frequented ports and consider this data in the implementation of management measures (designing adapted education tools, selecting which ports to distribute them in).
In the framework of a global study to combine information on abundance of the different cetacean populations, their habitat use and human activities in the area, the University of Azores has been collecting AIS data since the beginning of 2013 in order to characterise shipping traffic in the archipelago. This is a preliminary study to identify areas of low and high ship strike risks (Rui Prieto, pers. com.).

Moreover, combining large cetacean and shipping traffic spatio-temporal distribution data[61] allows:
- estimating the impact of shipping traffic on cetaceans;
- determining and modelling spatio-temporal collision risks between ships and large cetaceans;
- mapping areas where risk is high;
- estimating ship strike probability;
- implementing adapted management measures aiming at reducing the collision probability between large cetaceans and ships and therefore reducing the risk of ship strike;
- evaluating mariners' good compliance and efficiency of the implemented measures.

According to IWC, the large amount of available data on cetacean and shipping traffic makes the Mediterranean Sea an ideal pilot area to identify areas at risk (IWC, 2008).

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[60] *For example, NOAA's aerial surveys target areas most frequented by right whales in priority.*
[61] *Examples of studies on animals and shipping traffic distribution: models developed by Garrison (2005), Nichols & Kite-Powell (2005), Fonnesbeck et al. (2008), Williams & O'Hara (2010), Evans et al (2011) and the study by David (2005).*

By combining large cetacean distribution and abundance data and shipping traffic intensity data (ferries, HSCs and commercial ships) David and Di-Méglio (2010) identified ship strike risk areas for fin and sperm whales within the Pelagos Sanctuary given the exposure of the animals to shipping traffic (Figure 11). Therefore, the authors highlighted areas where the risk of ship strike is particularly high and estimated that a ship could meet 7 fin whales and more than 1 sperm whale per summer day in the Sanctuary.

In the aftermath of the development of ferry and HSC lines in the Canary Islands, (Rodríguez *et al.*, 2005), the number of ship strikes soared in the recent years (Ritter, 2007; Carrillo and Ritter, 2010; Ritter, 2010), especially for sperm whales. According to Carrillo and Ritter (2010), the Canary Islands is one of the most concerned areas regarding collisions between large cetaceans and ships and require the short-term implementation of management measures. The prediction model from Tregenza *et al.* (2000), described below, estimates that each pilot whale (*Globicephala melas*) off the coast of Tenerife can collide with a ship up to 1.7 times a year. In order to reduce ship strikes in the area, Ritter (2007) did a similar work to David and Di-Méglio (2010) to identify risk areas by overlaying ferry traffic maps and cetacean presence area maps (Figure 12).
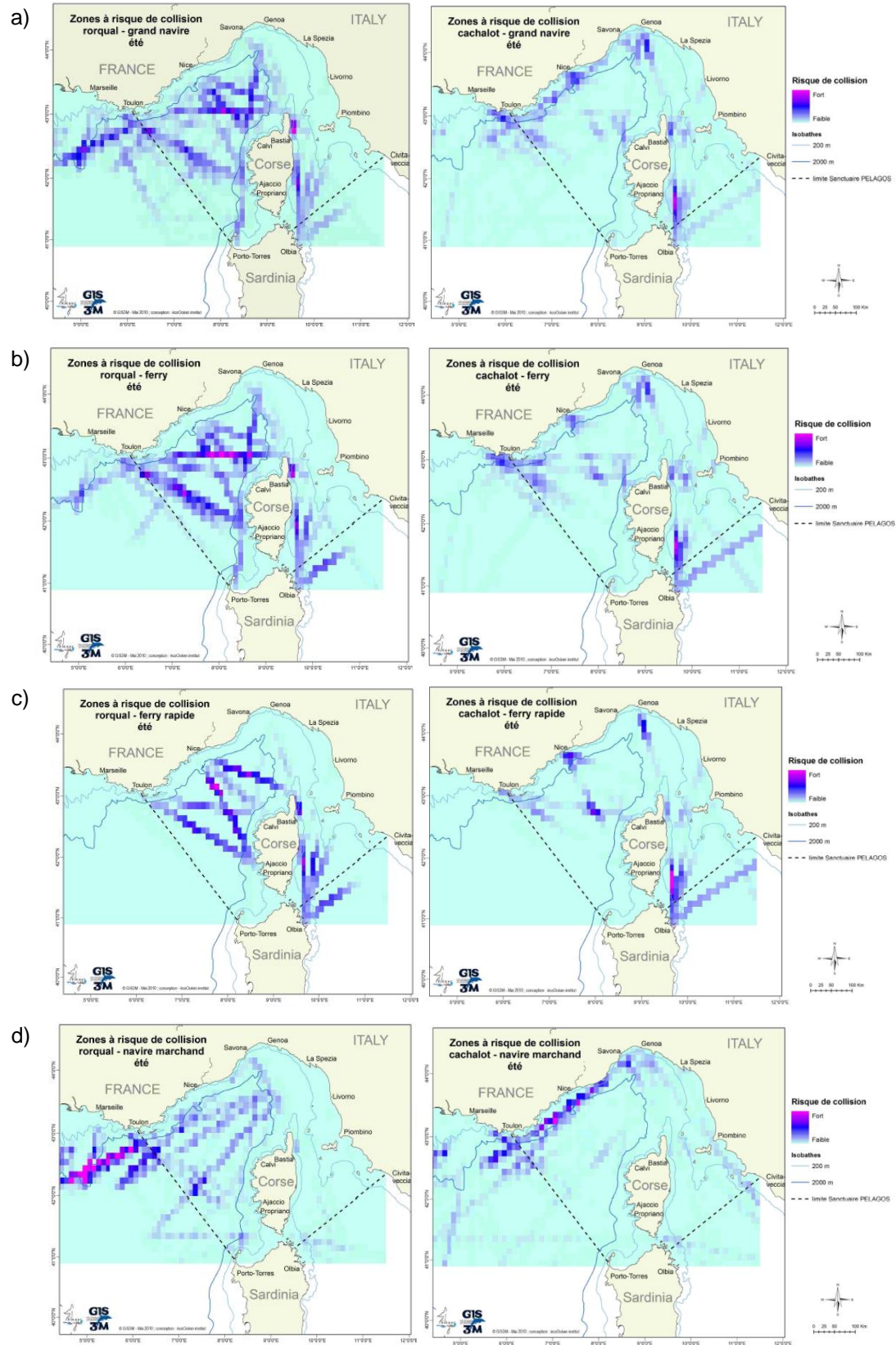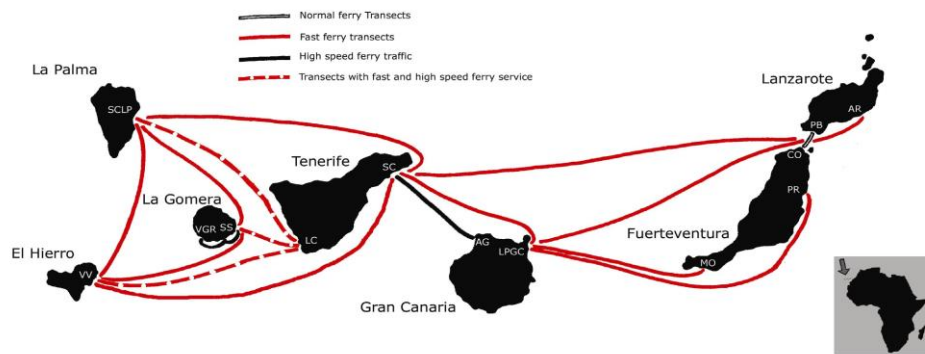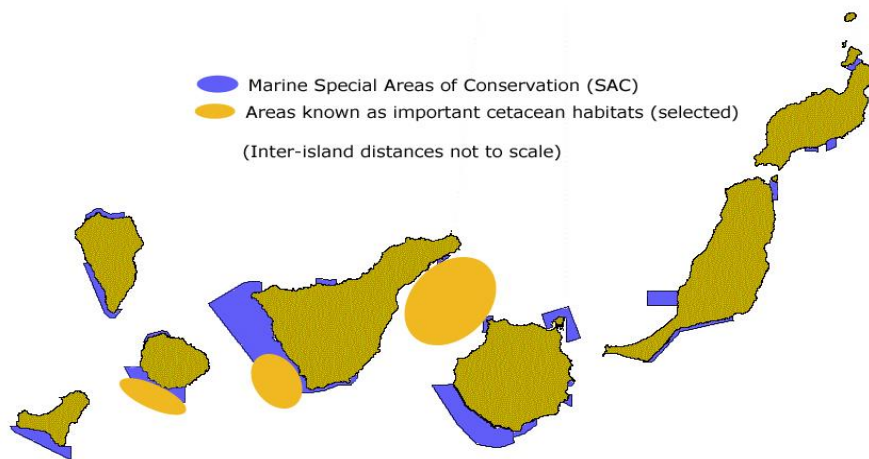
Figure 11. Collision risk in the Pelagos Sanctuary in summer between fin whales (left) or sperm whales (right) and a) large ships; b) ferries; c) fast ferries; d) commercial ships (David and Di Méglio, 2010).
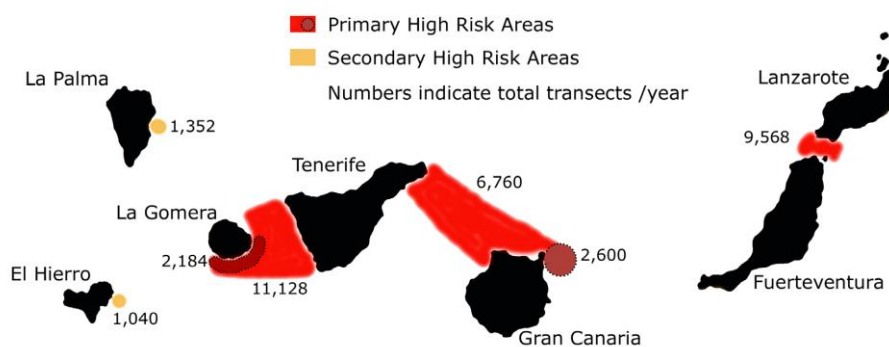
a)

b)

c)

Figure 12. a) Map of inter-island ferry transects operating in the Canary Islands ; b) Map of Special Areas of Conservation (SAC) and important cetacean habitat (modified from Boehkle, 2006); c) Primary and secondary high risk areas for ship strikes between cetaceans and ferries (Ritter, 2007).

Williams and O'Hara (2010) carried out a similar study along the coast of British Columbia by overlaying distribution maps of several large cetacean species (fin, humpback and killer (*Orcinus orca*) whales) and shipping traffic maps in order to highlight areas where the risk of ship strike is high for each of these three species (Figure 13). Evans *et al.* (2011) did something analogous in the North-East Atlantic.
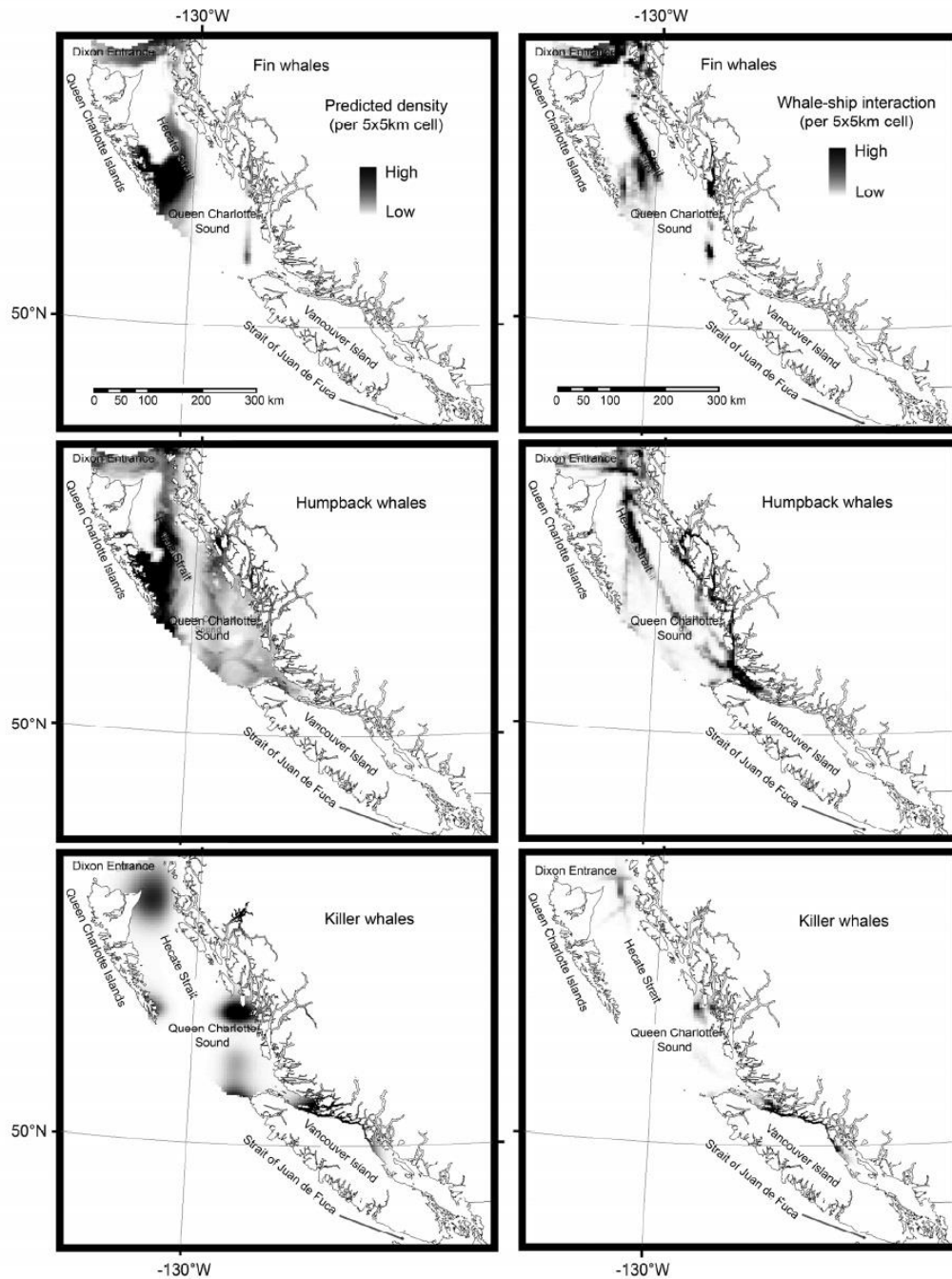
Figure 13. Density surfaces for fin whale, humpback and resident killer whales (left column) and intensity surfaces for whale-ship interactions (right column), from Williams and O'Hara (2010).

Another ship strike risk model (Figure 14) consists in evaluating the theoretical animal number on a ship's route at a given time (Tregenza *et al.*, 2000; Tregenza, 2001). This calculation is based on five hypotheses:

- the vulnerable part of the fin whale can be represented by a line the same length as the animal;
- animal orientation according to the direction of the ship is random;
- the animal does not respond to the ship and does not tend to get in or out of its way;
- the ship's route crosses an area with a fin whale density similar to a larger area in which a density estimation could be obtained;
- ships do not manoeuvre to avoid large cetaceans.

Figure 14. Computer model developed by Tregenza et al. (2000) to estimate the number of animals on the route of a ship at a given period of time.

The formula **n = (W + 0,64L) * (D/1 000) * Y * P * T** takes into account the following six variables:

- W=width of the ship hull at waterline, in metres;
- L=length of the fin whale, in metres;
- D=average length of trips, in kilometres;
- Y=number of HSC rotations during the considered time period;
- P=fin whale population density, in individuals per square kilometre;
- T=0.3: time spent at the surface by the animal (30%).

To this day, the limitations of the model (*e.g.* high number of hypotheses) prevent it from being used as a reliable management tool (Mayol, 2007).

Another computer model was developed by Clyne and Leaper (2004) to estimate the likelihood percentage that different types of ships (30 to 340m ferries, cargos, fishing boats) sailing at different speeds (10 to 20kn) manage to avoid colliding with right whales. This study shows that even in optimal conditions ships over 300 metres can hardly decrease their collision probability by more than 30%. This kind of information is useful in implementing protection devices (types of ships concerned by the measure, determining maximum sailing speed to be imposed or recommended). According to Clyne and Leaper (2004), these results (obtained from right whale data) are valid for many large cetacean species.

Finally, the Direction of Wild Fauna and Flora of the Province of Chubut in Argentina is also in the process of mapping entanglement, ship strike and oil spill risk areas in this region where Southern right whales (*Eubalaena australis*) come to breed (IWC, 2012e).

Another management measure to reduce the risk of collision between large cetaceans and ships consists in modifying navigation procedures.

4. <u>Modification of navigation procedures</u>

According to Reeves *et al.* (2007), the only way to reduce collisions between large cetaceans and ships in the short and medium term is to limit their co-occurrence in space and time. To do so, many studies (USCG, 2006a; Kite-Powell *et al.*, 2007; Elvin and Taggart, 2008; Fonnesbeck *et al.*, 2008) recommend to modify navigation procedures (*e.g.* changing

navigation route, reducing speed, avoiding manoeuvres, etc.) to reduce the risk of collisions between ships and large cetaceans.

4.1. Rerouting

According to Silber *et al.* (2008), the most efficient solution to reduce the risk of collisions between cetaceans and ships consists in limiting the areas were they co-occur. Therefore, different rerouting measures have been implemented around the world.

4.1.1. Traffic Separation Scheme modifications

In order to limit ship collisions, several regions where shipping traffic is dense set up mandatory shipping lanes called Traffic Separation Schemes or TSS (IMO, 1972). In order to protect large cetaceans, several TSS modifications have been implemented worldwide.

- TSS modifications in the United States

The North Atlantic right whale is one of the most endangered cetacean species[62] (Caswell *et al.*, 1999; IWC, 2001; Kraus *et al.*, 2005). Collisions with ships is the main cause of mortality for these animals (Kraus, 1990; Knowlton and Kraus, 2001; Kraus *et al.*, 2005; Kraus and Rolland, 2007; Moore *et al.*, 2007; Van der Hoop *et al.*, 2012).
Multi-annual studies on spatio-temporal distribution of North Atlantic right whales carried out by NOAA's NMFS identified areas of high right whale concentration[63]. When these areas overlap with dense shipping traffic areas, alternative shipping routes are proposed[64]. Constantly revised and updated according to animal distribution (Russell *et al.*, 2001), these measures aim at reducing the risk of ship strikes while considering economic, safety and environmental issues linked to the implementation of such system (Russell *et al.*, 2001).

Several years of study have shown that the TSS off Boston crossed an area of high right whale concentration. In March 2006, a TSS modification proposal was submitted by the United States and implemented by IMO in 2007 (IWC, 2007; Silber *et al.*, 2008). This proposal consisted in diverting the TSS (Figure 15) and reducing both traffic lanes by 0.5NM. According to NOAA, these modifications would reduce the risk of colliding with right whales and with other large cetaceans by 58% and 81% respectively (IMO, 2006; Silber *et al.*, 2008).

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[62] *North Atlantic right whales are classified as "Endangered" (Reilly, S.B. et al., 2012) and their population size is estimated to be between 300 and 350 individuals (Kraus et al., 2005).*
[63] *These areas are wide and located, in the North (January to mid-May) in Cape Cod Bay, Massachusetts Bay and the Stellwagen Bank National Marine Sanctuary and, in the South, on the coast of Florida of Georgia. Right whales migrate between central Florida and South of the Bay of Fundy.*
[64] *In accordance with IMO's General Provisions on Ship's Routing available here:*
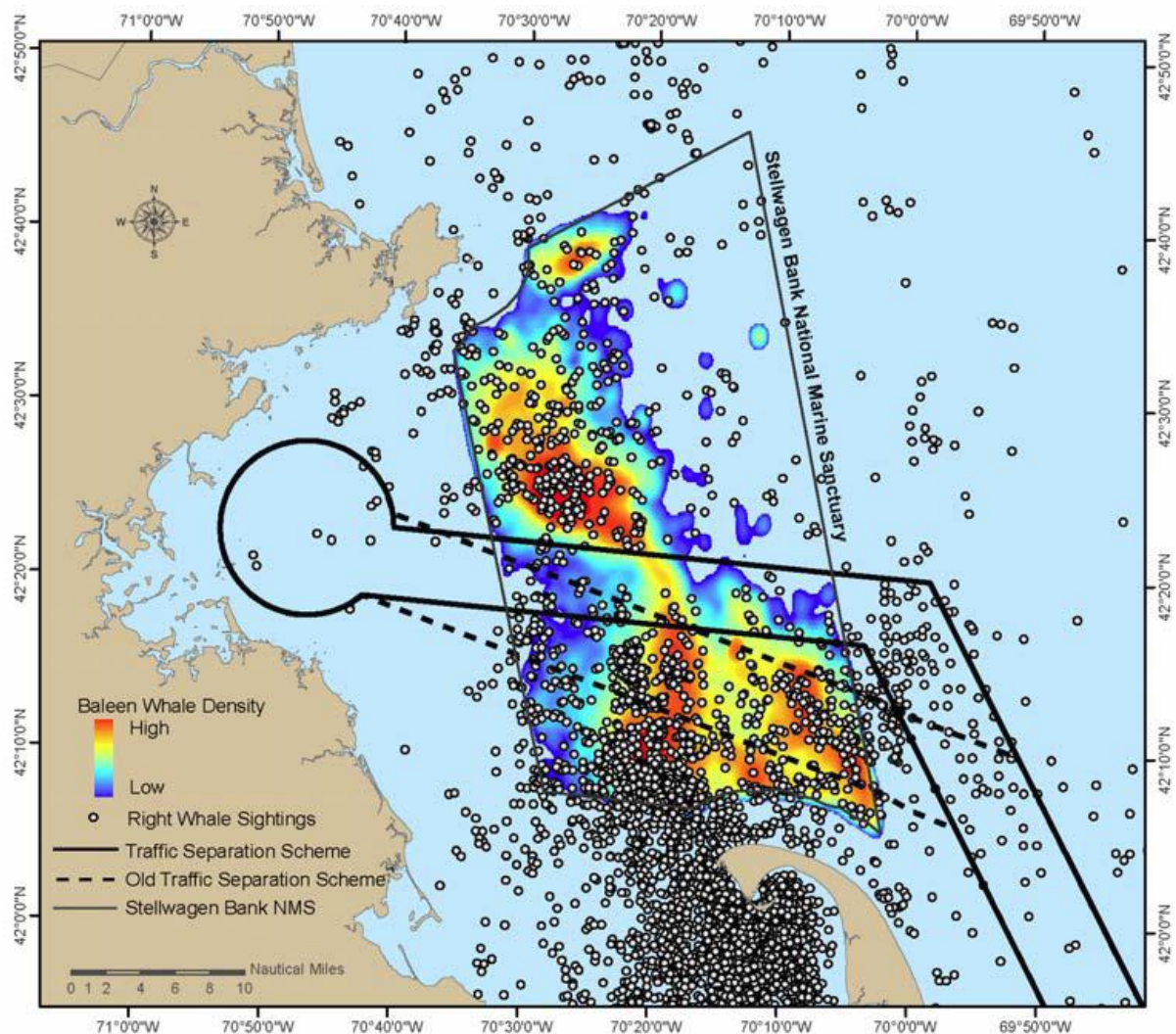*http://www.tc.gc.ca/eng/marinesafety/tp-tp1802-part2-1926.htm*

Figure 15. Right whale distribution and density and past (dashed lines) and current (solid lines) Traffic Separation Scheme approaching the port of Boston, Massachusetts (figure taken from: http://scimaps.org/maps/map/realigning_the_bosto_88/).

In 2008, another proposal consisting in reducing the width of both shipping lanes (from 2NM to 1.5NM) of the TSS off Boston (USCG, 2006a; IWC, 2008; Silber *et al.*, 2008) was submitted by the United States and came into force in June 2009 (IWC, 2008; Bettridge and Silber, 2009).

On the West coast, a similar measure was recently implemented around the Channel Islands National Marine Sanctuary. This area is an important feeding ground for blue whales and several other species susceptible to ship strikes (especially humpback and fin whales). The previous TSS partly overlapped this feeding ground and several strikes have been recorded each year since 1988 (Berman-Kowalewski *et al.*, 2010; NMFS, 2011). By applying a carcass detection rate of 17% (calculated for right whales by Laist *et al.* (2001)), Redfern *et al.* (2013) estimated that 5.9 humpback whales, 7.1 fin whales and 10.8 blue whales would have undergone a strike every year between 2005 and 2010.

Furthermore, in 2009, the California Air Resources Board imposed commercial ships sailing less than 24NM from the coast to use low-sulphur (but more expensive) fuel to limit sulphur and nitrogen oxides emissions (Soriano *et al.*, 2008). After this ruling, many ships left the TSS and chose a navigation route getting around Santa Barbara Channel Islands from the South (McKenna *et al.*, 2012), thus increasing the risk of colliding with other ships and with

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cetaceans. Year 2009 was the second deadliest year in terms of ship strikes for fin whales in the area (NMFS, 2011).

In 2012, a double modification proposal was therefore submitted by the United States to IMO, following the study by Redfern *et al.* (2013) and a study by the Coast Guards aiming at reducing accident risks, improving traffic flow and limiting ship strikes (USCG, 2011). The proposal intended to move the southern shipping lane accessing the port of Los Angeles-Long Beach 1NM north (Figure 16) and to create a new TSS south of the Santa Barbara Channel Islands for ships choosing to get around it. Indeed, Redfern et al. (2013) studied the different navigation route possibilities (Figure 17) and showed that this solution was the best compromise since no option would allow the reduction of ship strike risks for these three species simultaneously. Already adopted by IMO's Sub-Committee on Safety of Navigation and Maritime Security Committee in late 2012, this modification was implemented on 1 June, 2013 (USCG, 2013). However, this case study shows how difficult it is to manage the issue of ship strikes for several sympatric species and underlines the fact that a ship strike risk reduction measure for one species is not necessarily beneficial to other species.
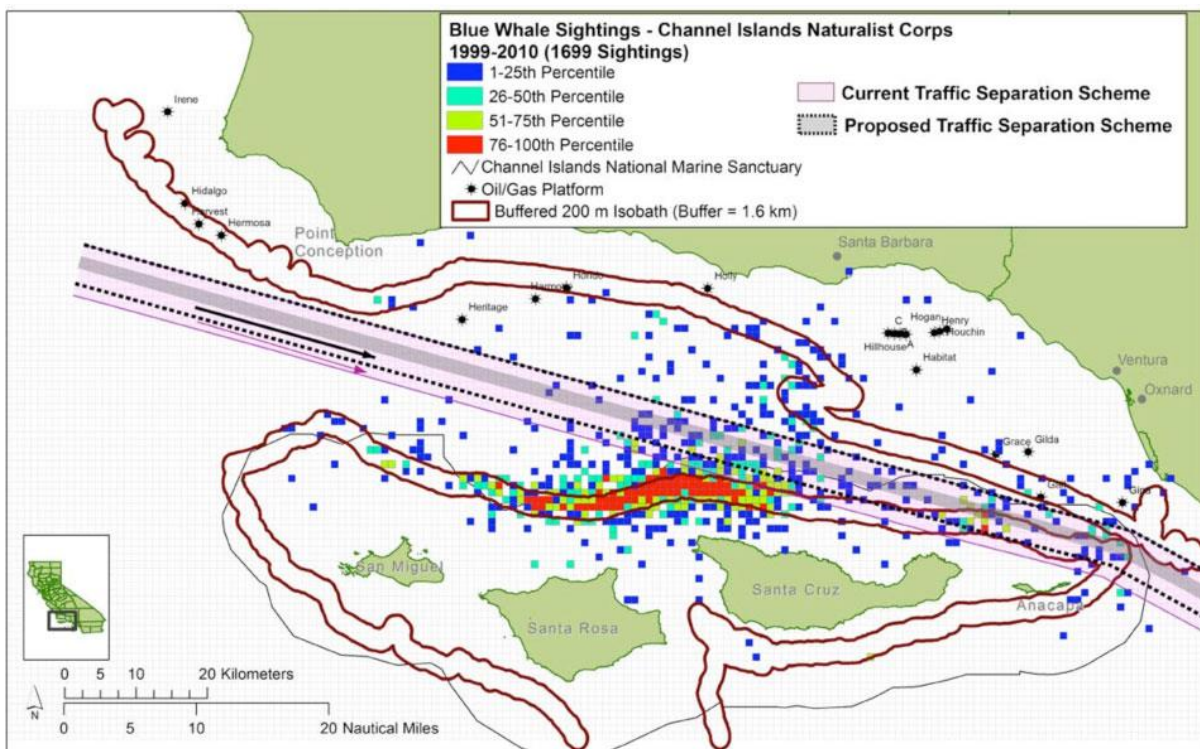

Figure 16. Distribution of blue whale observations and old (pink) and new (dashed lines) TSS off the port of Los Angeles-Long Beach, California. Taken from: http://channelislands.noaa.gov/focus/management.html
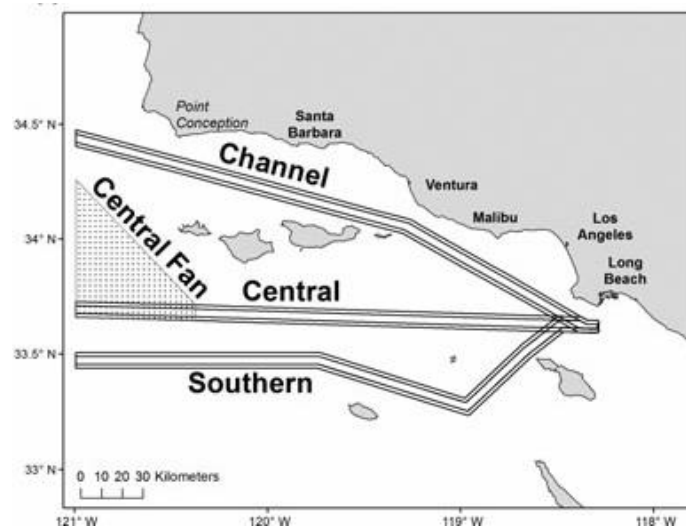
Figure 17. Options of traffic lines examined by Redfern et al. *(2013) according to risks of collisions with blue, fin and humpback whales.*

Another TSS modification came into force on 1 June 2013 off the port of San Francisco. All three navigation lanes were extended and their funnel replaced by a straight line in order to reduce overlaps with fishing areas and blue and humpback whale feeding grounds (USCG, 2013).
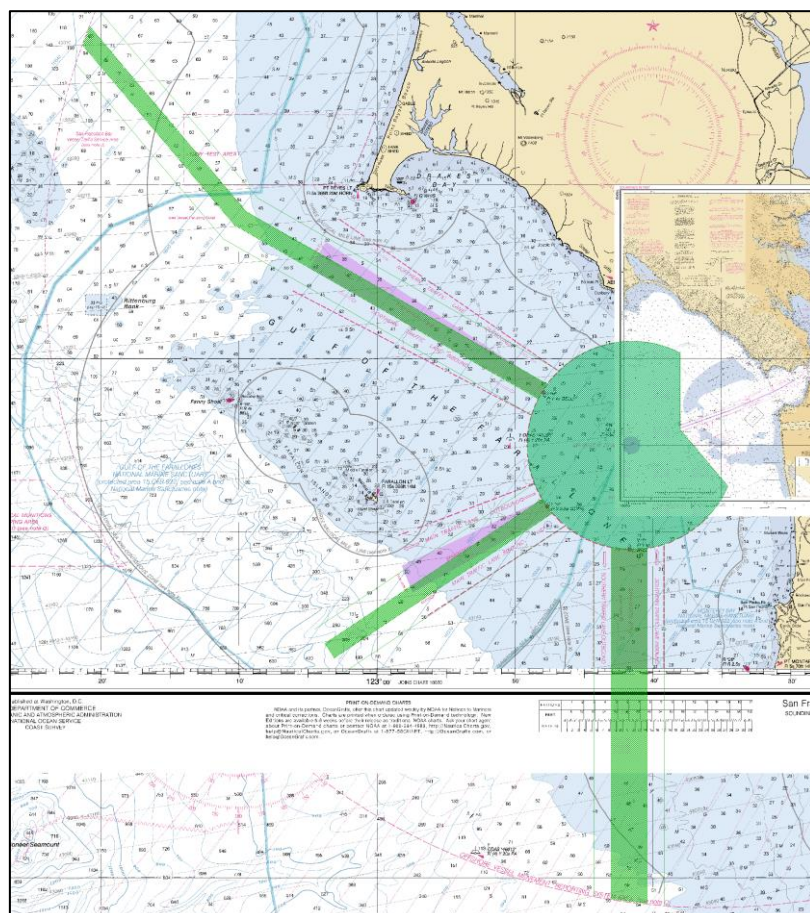

Figure 18. TSS modification off the port of San Francisco. Past (pink) and current (green) schemes for the three shipping corridors (USCG, 2013).

Similarly, a TSS modification was set up in Canada to reduce the risk of collisions between right whales and ships.

- TSS modification in Canada

Canada implemented a management plan for the protection of North Atlantic right whales (Brown *et al.*, 2009) aiming at increasing population size over three generations (IWC, 2010a). The first of the seven objectives of this programme is to reduce collisions between ships and right whales (Brown *et al.*, 2009).

In this framework, the Bay of Fundy TSS, implemented in 1983, was modified in 2003 by IMO based on 13 years of right whale distribution study and consideration of navigation requirements (Figure 19). This amendment should reduce the risk of ship strikes by 90% and the risk of deadly strikes by 62% in the area (Vanderlaan *et al.*, 2008). It was successfully set up and maritime documents like nautical charts, Notices to Mariners and Navigation Rules (Brown *et al.*, 2009) were updated.
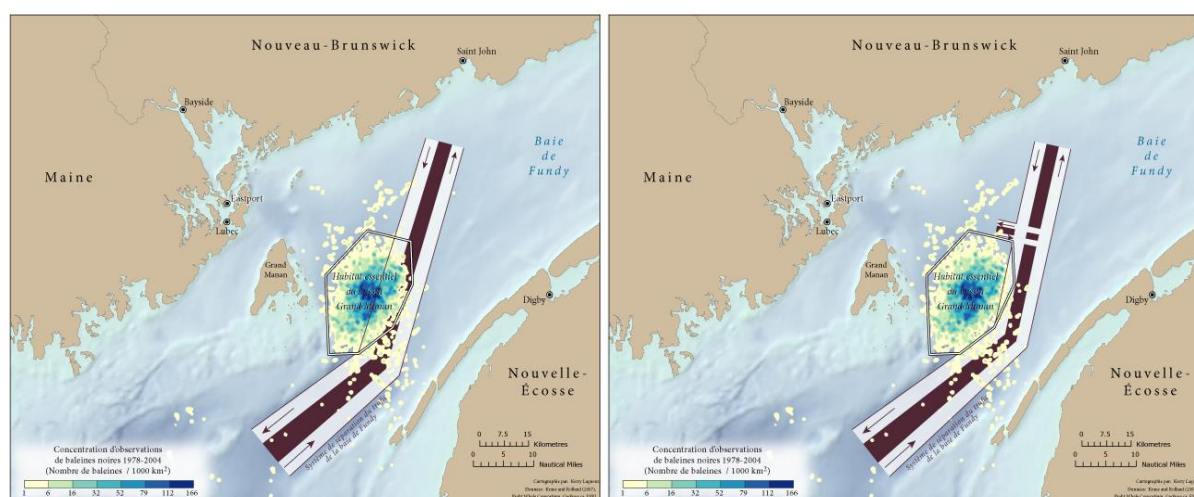

Figure 19. Right whale concentration between 1978 and 2004 and TSS before (left) and after (right) modification in 2003. Taken from http://www.baleinenoire.ca/shippinglanes-routesnavigation_f.php

According to Porter (2001), such a rerouting system could be permanently or dynamically applied to existing shipping lanes (without TSS), given the spatio-temporal distribution of large cetaceans. However, such programmes require deep and updated knowledge on seasonal distribution of concerned populations and the implementation of large scale awareness campaigns for on-board personnel.

Another example of TSS modification was established in Spain.

- TSS modification in Spain

In the framework of the European LIFE Nature[65] project for both the development of a conservation plan for the loggerhead turtle (*Caretta caretta*) and bottlenose dolphin (*Tursiops truncatus*) and the creation of a management plan of the Special Area of Conservation (SAC) south of Almeria, repositioning the TSS off *Cabo de Gata*[66] in the North-East (Figure 20) Alboran Sea was implemented in 2006 (SEC, 2005; Tejedor Arceredillo *et al.*, 2008).

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[65] *Conservation of cetaceans and sea turtles in Murcia and Andalusia (LIFE02NAT/E/8610).*
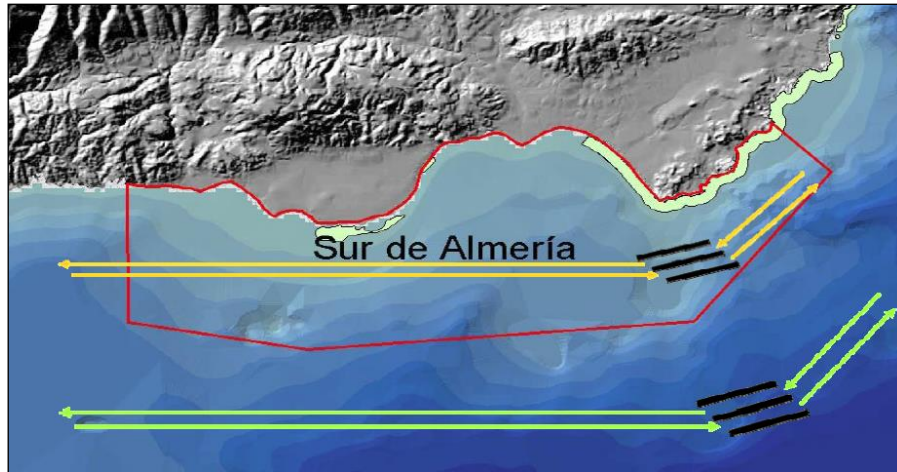[66] *Area classified as a UNESCO Biosphere Reserve.*

Figure 20. Repositioning of the Cabo de Gata *TSS off Andalusia. Red: SAC limits set up for bottlenose dolphins (*Tursiops truncatus*) and loggerhead turtles (*Caretta caretta*) populations; Yellow: TSS initially set up 5NM from the coast; Green: new TSS moved 20NM from the coast (figure taken from Tejedor Arceredillo* et al.*, 2008).*

This measure primarily intends to reduce strikes between the numerous ships in the *Cabo de Gata* protected area also benefits the other cetacean species in the area. The new TSS position is mentioned on Notices to Mariners and international nautical charts. According to Silber *et al.* (2012), the AIS data analysis shows that there was complete compliance with this measure by ships transiting through Gibraltar and the Alboran Sea (Figure 21). Tejedor *et al.* (2010) also noticed an increase in pilot whale relative densities in 2007 and 2008 (more recent results pending). It is to be noted that the previous TSS used to cross the main distribution area of these animals (Tejedor *et al.*, 2010).
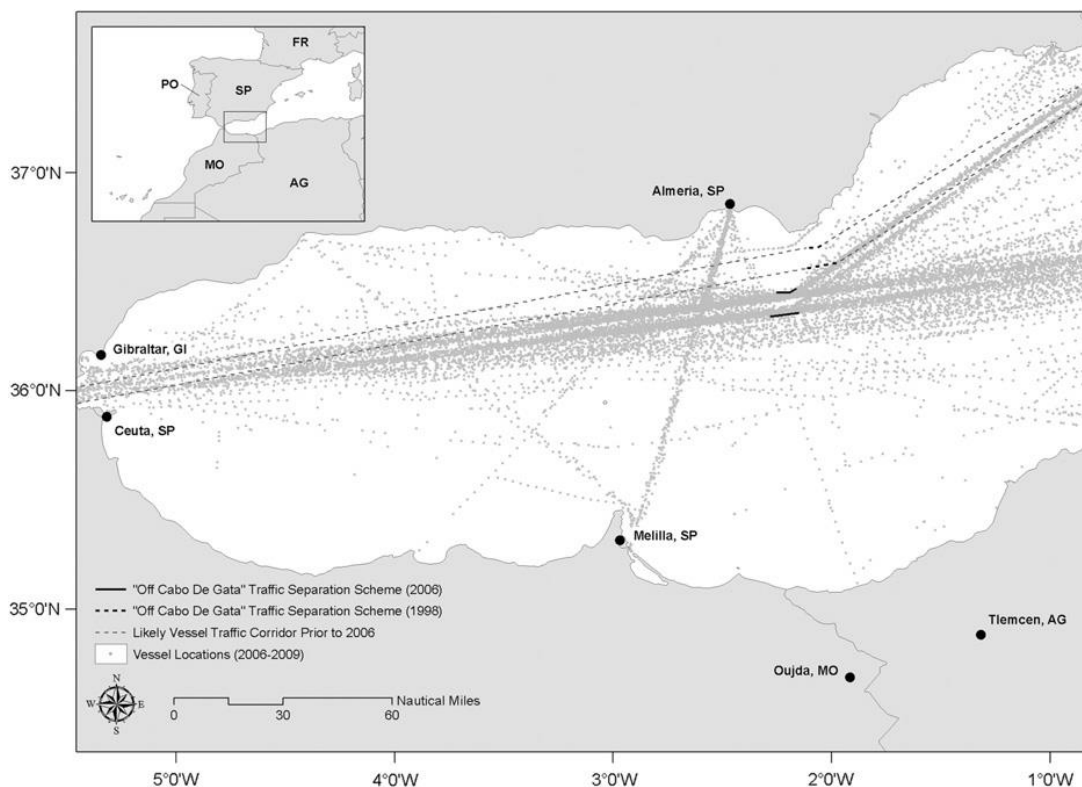

Figure 21. Past Cabo de Gata *TSS trajectory in dashed lines and ship routes from AIS data since the TSS modification (Silber* et al.*, 2012).*

Setting up Recommended and Mandatory Shipping Routes is another rerouting mean of reducing the risk of collisions between ships and large cetaceans.

4.1.2. Recommended and Mandatory Shipping Routes

In November 2006, NOAA established a Recommended Shipping Route system in areas most frequented by right whales in Cape Cod Bay and off three ports of Georgia (port of Brunswick) and Florida (ports of Jacksonville and Fernandina, Figure 22), based on recommendations from a U.S. Coast Guards Port Access Route Study (PARS, USCG (2006a)). The objective is to reduce shipping traffic in right whale habitats and optimise safety at sea while reducing impacts on the shipping industry. NOAA's NMFS estimates that if ships use these shipping routes, interaction risks between ships and whales could be reduced by 37 to 45% off Cape Cod Bay (Nichols and Kite-Powell, 2005) and by 16%, 26% and 32% for the ports of Brunswick, Jacksonville and Fernandina respectively (Garrison, 2005). Mariners are informed of these Recommended Shipping Routes via Notices to Mariners, the U.S. Coast Pilot[67], NOAA's website[68] or on Massachusetts' updated nautical chart[69] (Turner and Robinson, 2008).

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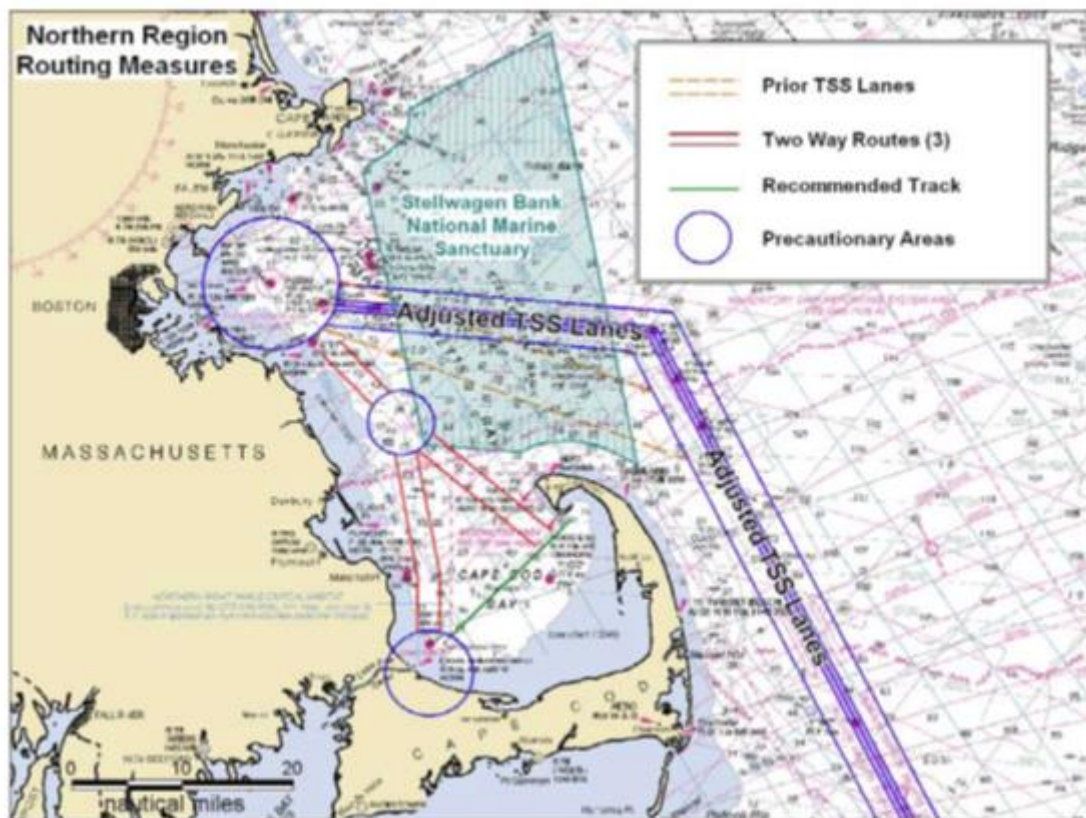
[67] *The U.S. Coast Pilot is a document gathering all information on specific regional environmental conditions, threats to navigation and regulations. To this day, captains of commercial ships larger than 1,600 tons (gross weight) must have this document on-board when sailing in U.S. territorial waters. Abstracts on right whale conservation are available here:*
http://www.nero.noaa.gov/shipstrike/doc/US%20Coast%20Pilot%20Extract.htm
[68] *http://www.nmfs.noaa.gov/pr/shipstrike/routes.htm*
[69] *Digital version of this chart is available here: http://www.noaa.gov/charts.html*
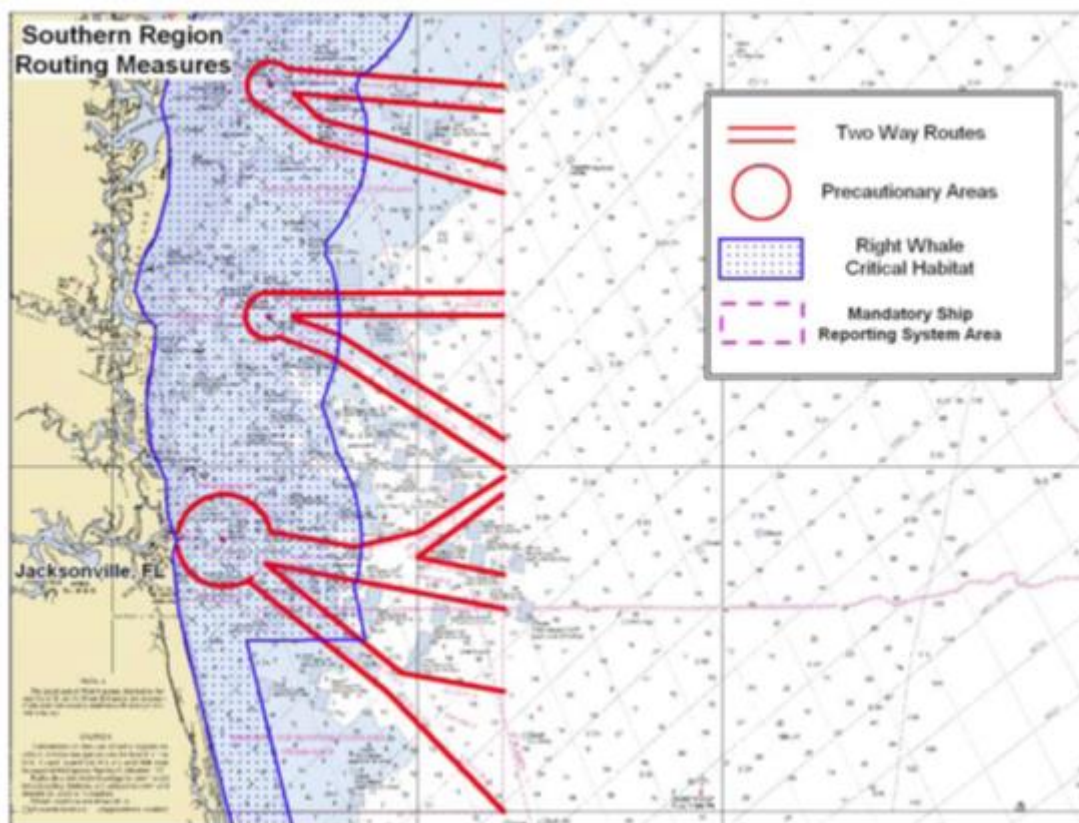
Figure 22. Recommended Shipping Routes in Cape Cod Bay and off the coast of the States of Georgia and Florida.

NMFS wishes to study mariners compliance with the Recommended Shipping Route system with the possibility of implementing regulations if necessary (USCG, 2006b; Reeves *et al.*, 2007). As a response, Lagueux *et al.* (2011) examined mariners compliance with these measures off the ports of Georgia and Florida. Using AIS data from 2005 to 2009, the authors showed that compliance steadily increased over the years up to 96% in 2009 (Figure 23). With such a compliance rate, this measure could reduce ship strike risks by 54% (Lagueux *et al.*, 2011).
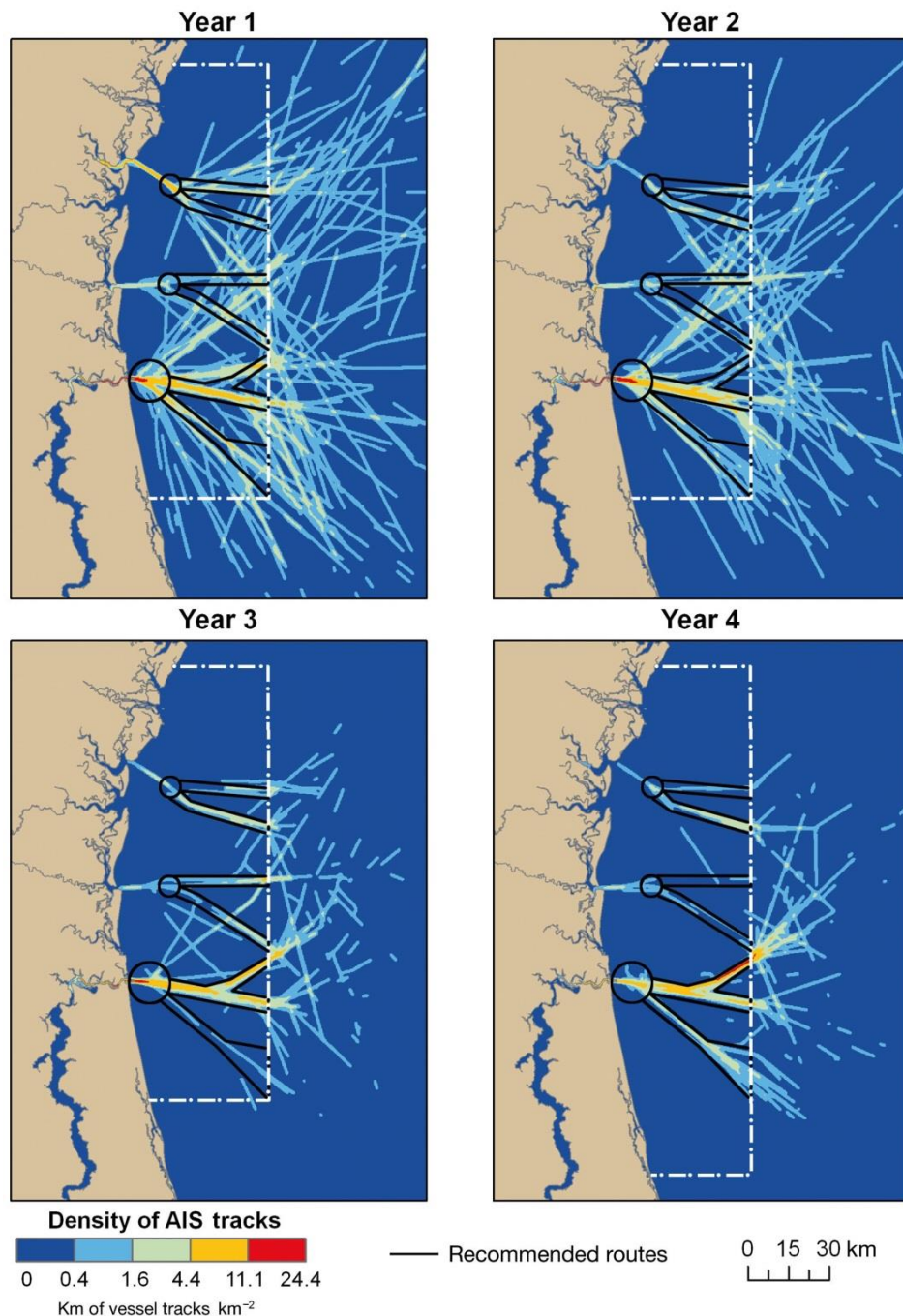
Figure 23. Density of vessel traffic around the Recommended Shipping Routes (black lines) at the entrance of the ports of Georgia and Florida (Year 1, 2, 3, 4: winter 2005-06, 2006-07, 2007-08 and 2008-09 respectively). Taken from Lagueux et al. (2011).

Moreover, mandatory shipping route systems can also be established in several regions. This is the case in Glacier Bay National Park in Alaska where first ship impacts[70] on humpback whales were noticed in 1978. Since then, shipping management measures were implemented by the Park Service[71]. These measures include a research and monitoring

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[70] *Especially cruise ships more than 2,000 gross tons certified to carry more than 12 passengers.*
[71] *The management measure history successively established is given by Abramson et al. (2009).*

programme[72] and different types of regulations (*e.g.* speed limits[73], ship rerouting[74], permits[75]).

Since 1979, Glacier Bay areas where humpback whale presence probability is high ("*Whale Waters*") are covered by speed and rerouting regulations in order to reduce the impact of ship traffic on the animals.
At the entrance of Glacier Bay, a humpback whale high density area, ships must keep a minimum distance of 1 mile (1,6 km) from the coast between 15 May and 30 September.

Moreover, in whale presence areas (Figure 24), ships larger than 5.5 metres must keep a 1MN distance from the coast. When they cross narrow areas, these ships must sail in the middle of the navigation channel. All the specific regulations to humpback whale presence areas are detailed in Abramson *et al.* (2009).
Mariners are informed of these regulations through the Park Service press releases, NOAA's charts, radio shows daily broadcast by the Park Service, weather forecast bulletins and VHF contacts with the Park Service.

Figure 24. Humpback whale areas (Whale Waters, Abramson et al., 2009).

Finally, in Argentina, the Ministry in charge of environment and the Province of Chubut set up a series of measures to reduce the risk of collisions between ships and South Atlantic right whales in Peninsula Valdes (IWC, 2012e). Especially, a recommended navigation corridor was created in order to reduce the encounter probability between ships and whales (Figure 25). This measure is applicable from May to September and sailing speed is also

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[72] *Implemented since 1981, this programme aims at studying prey abundance and humpback whale spatio-temporal distribution and interactions between ships and whales (e.g. Baker & Herman, 1989). Regulations in force are based on the information gathered from these studies.*
[73] *Cf. chapter 5.*
[74] *Cf. chapter 4.1.*
[75] *Cf. chapter 10.1.*

regulated[76] (Disposición Madr, RIA N°069/09 completed the following year by the Disposición Madr, RIA N°80/10).
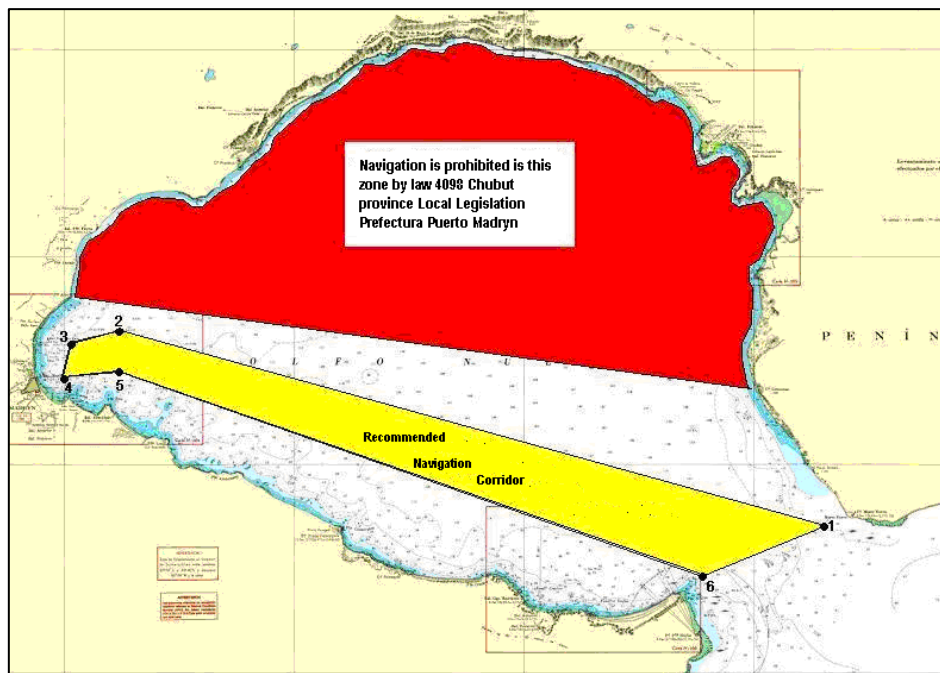

Figure 25.Proposed Recommended Navigation Corridor in Golfo Nuevo*, south of the* Peninsula Valdes *(IWC, 2009a).*

Other rerouting systems relying on setting up seasonal Areas To Be Avoided were implemented around the world.

4.1.3. Seasonal Areas To Be Avoided (ATBA)

This system consists in getting around areas of high large cetacean concentrations were established in several regions of the world.

- ATBA in the United States

In 2008, a proposal aiming at setting up an ATBA to reduce the risk of collisions between right whales and ships in the Great South Channel off Boston was submitted by the United States to IMO (IMO, 2008) and was implemented in June 2009 (Bettridge and Silber, 2009). Mariners can choose to get around this area (Figure 26) and thus should consider this route modification in their voyage planning. If they collaborate, this rerouting measure should reduce ship and whale encounters by 39% (Vanderlaan *et al.*, 2009). The ATBA concerns ships larger than 300 tons (gross weight) and is applicable from 1 April to 31 July, when right whales frequent the area. The life time of this measure is determined according to the ecology of the species (*e.g.* distribution, biological cycle, migration, etc.) but also to reduce the impact of shipping traffic and optimise safety at sea.
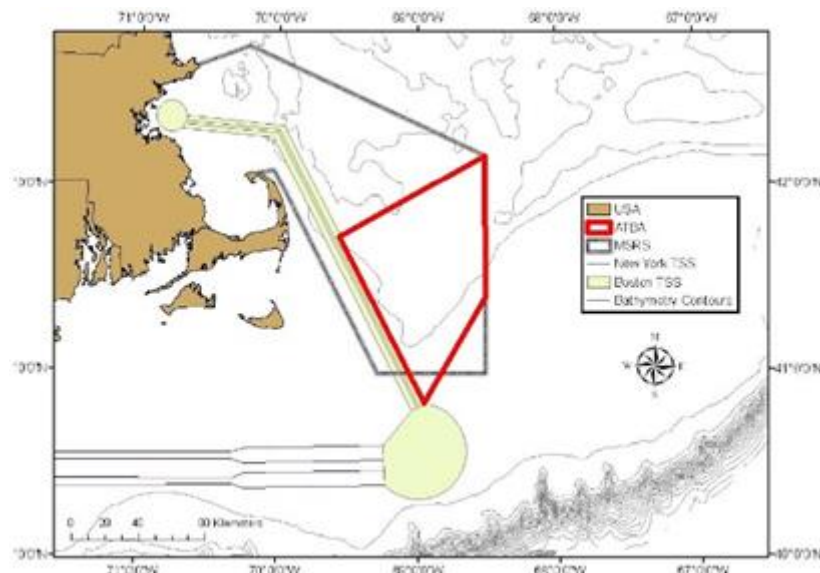
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[76] *Cf. chapter 5.3.*

Figure 26. Red: Seasonal Area to be Avoided (ATBA) in the Great South Channel *area off Massachusetts (figure taken from: http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/atba_chart.pdf).*

A preliminary study of AIS data was carried out to evaluate mariners' compliance with speed[77] and rerouting recommendations in areas of the Great South Channel where right whales were detected[78]. Results were unsatisfactory since only 2 out of 40 ships changed their trajectory to avoid right whale areas and only one ships significantly reduced its speed (Moller *et al.*, 2005). This is all the more unfortunate that Merrick and Cole (2007) estimated that setting up this ATBA could reduce ship strike risks by 63%. Another evaluation of compliance with voluntary speed limitation and rerouting measures for the Great South Channel ATBA is on-going (Greg Silber, pers. com.).

According to Firestone (2009), although rerouting ships in the Great South Channel can significantly reduce the risk of collisions with right whales, the recommended route is considerably longer (480km) than the existing one (348km). Therefore, getting around the area increases trip duration by 3.5 to 5.5 hours for ships sailing at 20 and 13kn respectively.

Other similar rerouting measures were implemented in Canada.

- ## ATBA in Canada

The two areas most frequented by right whales in Canada (Grand Manan Basin in the Bay of Fundy and Roseway Basin on the Scotian shelf) where designated as "Conservation Areas" in 1993 by the Department of Fisheries and Oceans (DFO, 2000). Creating these non-regulatory areas aims at raising mariners' awareness on North Atlantic right whale population (Brown *et al.*, 2009). In fact, Conservation Areas appear on official marine charts. Moreover, information on the presence of right whales in these two areas and recommendations to reduce the risk of interactions between ships and these animals are contained in the navigation regulations of the Atlantic area.

Implemented in 1993, the Grand Manan Basin Conservation Area is not included in the Canadian MPA network created in 1996 by the Oceans Act (Ministry of Justice of Canada, 1996). In the event of a designation as an MPA, Hinch and De Santo (2011) evaluated how well the Grand Manan Basin fits the MPA designation criteria of the International Union for Conservation of Nature (IUCN). Globally, this area fits the criteria and the conservation objectives well (Hinch and De Santo, 2011). Although several points need to be improved

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[77] *Cf. chapter 5.1.*
[78] *Right Whale Advisory Zones.*

(socio-economic and cultural impacts, creation of a management plan with evaluation measures and implication of local stakeholders in decision-making processes), authors estimate that adding this area to the Canadian MPA network would be very beneficial. This recommendation is in accordance with Mullen *et al.* (2013) who argue that failure of the different management measures for the conservation North Atlantic right whales lie in the lack of connectivity between the different protected areas for this species.

In 2007, IMO validated the creation of an ATBA in the Roseway Basin (IMO, 2007). Set up by Canada in 2008, this voluntary measure only applies to ships larger than 300 tons (gross weight) and is applicable every year between 1 June and 31 December (Figure 27). According to Vanderlaan and Taggart (2009), mariners generally comply with this measure (71%, Figure 28) which would reduce the risk of lethal strikes by 82%. Still according to Vanderlaan and Taggart (2009), it is very likely that mariners cooperation is due to the fact that this measure was implemented by IMO, a highly internationally recognised United Nation organisation (Roberts, 2005). Furthermore, according to Firestone (2009), the Roseway Basin area being relatively confined, getting around this area is not a major constraint for mariners (increasing trip length by 8 to 13km depending on the initial route of the ship). Mariners are informed of the presence and corollaries of this ATBA via Notices to Mariners (updated in the 2008 edition) and the Roseway Basin nautical chart (Figure 29).
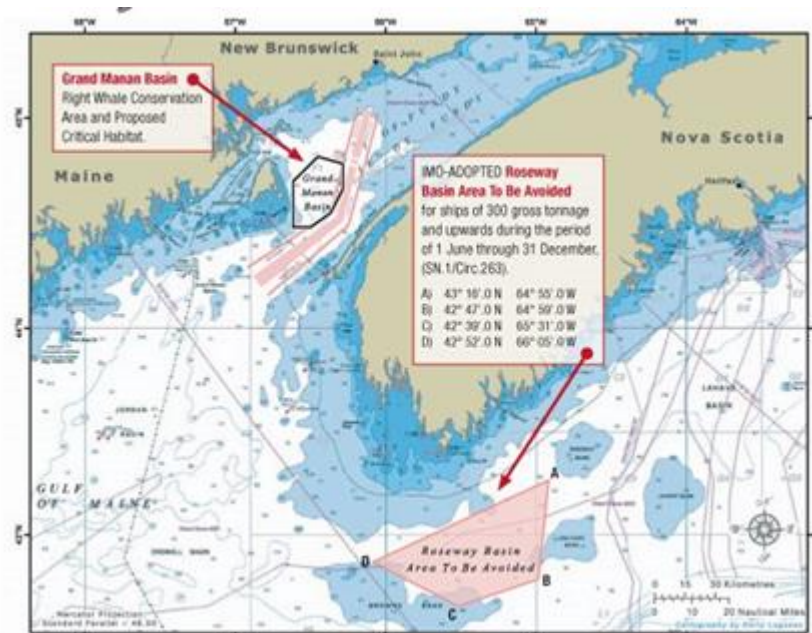

Figure 27. Roseway Basin ATBA and Grand Manan Basin Conservation Area du (figure taken from: http://www.neaq.org/).
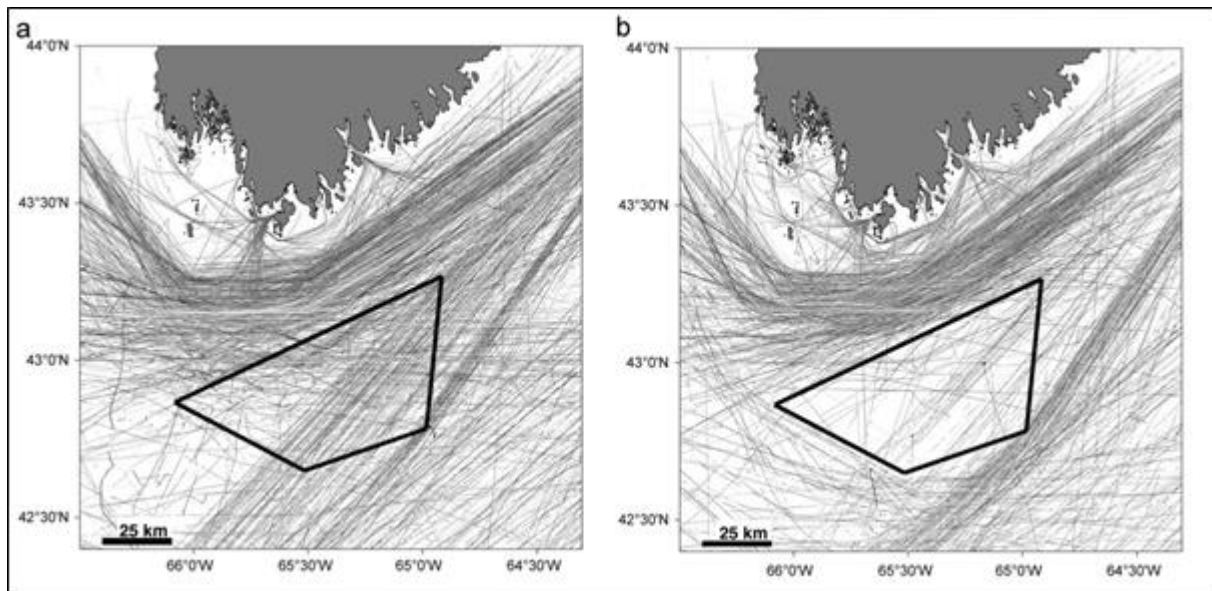
Figure 28. Roseway Basin ATBA (black polygon) and vessel tracks in the area a) before (June 1 to October 31, 2007), and b) after implementation of the ATBA (June 1 to October 31, 2008, Silber et al. (2012) modified from Vanderlaan and Taggart (2009).
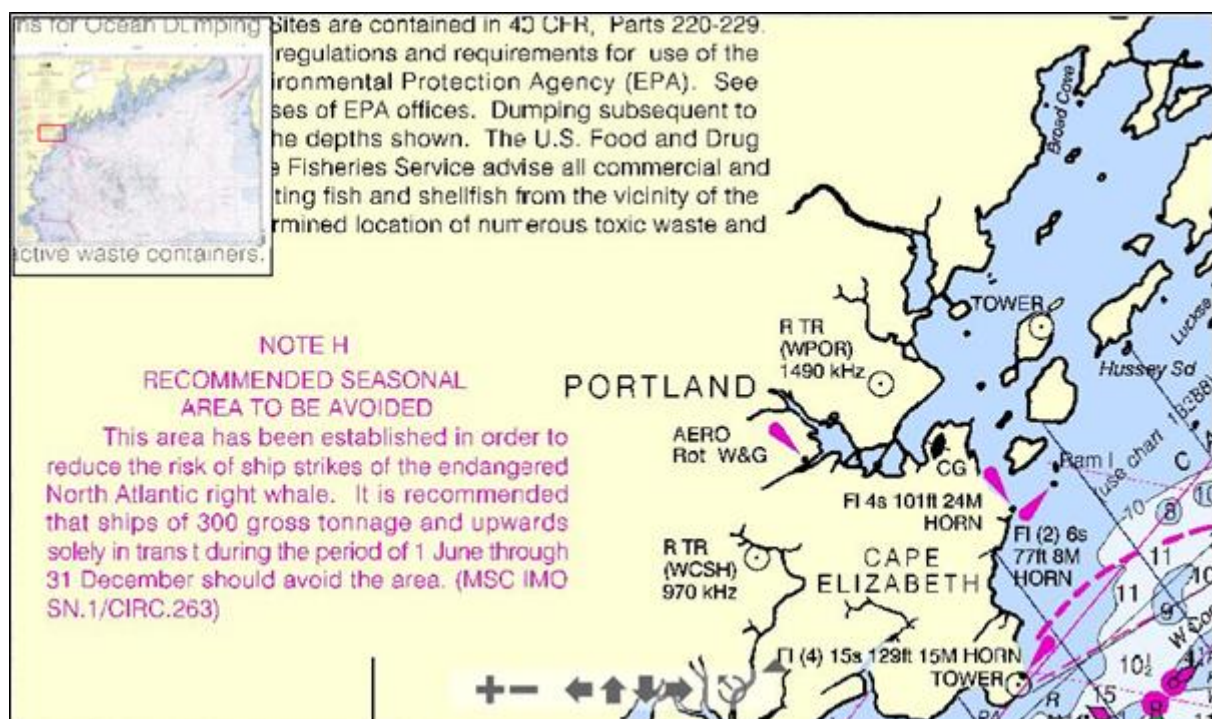
Figure 29. NOAA nautical chart with precautions to take in an ATBA (taken from: http://www.charts.noaa.gov/OnLineViewer/13260.shtml)

It is important to note here that rerouting measures previously cited have the potential of diverting some ships (*e.g.* HSCs) to other areas frequented by the animals (Reeves *et al.*, 2007). Beyond the fact that rerouting requires additional manoeuvers, this measure increases distance and time to destination. Therefore, as pointed out by Firestone (2009), these route modifications result in economic (*e.g.* increased fuel consumption), environmental (*e.g.* increased greenhouse gas emissions) and health (*e.g.* increased emissions of particles like SO_2) impacts.

Between 2002 and 2005, the development cost of ship rerouting measures[79] implemented by the United States in the framework of the programme to reduce the risk of collisions with North Atlantic right whales was about $375,000 per year (Reeves *et al.*, 2007).

When rerouting is not possible (*e.g.* bathymetry constraints, port entrances, etc.), speed limitations can be established to reduce the risk of collisions between ships and large cetaceans (Russell *et al.*, 2001; Reeves *et al.*, 2007).

5. <u>Speed limitation</u>

Ship speed is a determining factor in the rate and severity of collisions between ships and large cetaceans (Laist *et al.*, 2001; Pace and Silber, 2005; Kite-Powell *et al.*, 2007; Vanderlaan and Taggart, 2007; Van Waerebeek and Leaper, 2008; Wiley *et al.*, 2011; Conn and Silber, 2013). Not only does it increase the probability of mortality after impact but it also reduces the detection range of cetaceans (Gende *et al.*, 2011).

According to Jensen and Silber (2004), the mean speed of ships involved in a collision with a large cetacean leading to severe injury or death of the animal is 18.6kn. According to Laist *et al.* (2001), 89% of deadly or severely injuring collisions happened with ships sailing at speeds higher than 14kn. Moreover, damages on ships after a strike were noted when speed was higher than 10kn (Jensen and Silber, 2004). These figures are coherent with those from Vanderlaan and Taggart (2007) who calculated that probability of mortality rises from 20 to 100% when vessel speed goes from 9 to 20kn, that rise being the sharpest between 10 and 14kn (Figure 30). The model from Kite-Powell *et al.* (2007) estimates that the risk of a collision between a right whale and a conventional ship sailing between 20 and 25kn can be reduced by 30% and 40% by limiting speed to 12-13kn and 10kn respectively.
Furthermore, hydrodynamic effects created by large ships (>150m) on right whales (including forces attracting the whale to the ship) increase with speed and reducing depth (Knowlton *et al.*, 1995; Silber *et al.*, 2010).
Finally, in the Mediterranean Sea, since 1996 (date of introduction of HSCs in the area), 43% of ship strikes involved this type of ship (Panigada *et al.*, 2006a).

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[79] *This cost mainly involves carrying out many necessary studies (e.g. socio-economic studies, environmental impact assessments, PARS) before implementing such regulations.*
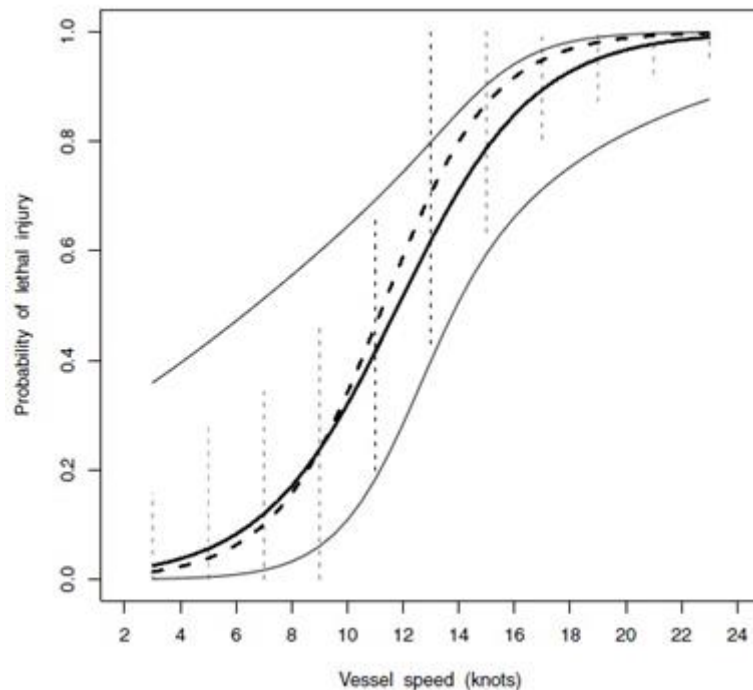
Figure 30. Probability of lethal injury after a ship strike as a function of vessel speed based on the simple logistic regression (solid heavy line) and the logistic fitted to the bootstrapped predicted probability distributions (heavy dashed line, Vanderlaan and Taggart, 2007).

Therefore, according to Reeves *et al.* (2007), ship speed is an adapted measure allowing crews to manoeuver efficiently to avoid the animal and cetaceans to get away from the ship (Abdulla and Linden, 2008; Gende *et al.*, 2011). Following this observation, speed limitation measures were implemented around the world in order to reduce the risk of collisions between ships and large cetaceans.

5.1. Speed limitations in the United States

Mandatory and voluntary vessel speed reduction measures are widely implemented in the United States. For example, a mandatory speed regulation system was set up by NOAA in the framework of the programme to reduce the risk of collisions between ships and North Atlantic right whales[80] (Federal Register, 2008). This scheme requires all ships (leisure and commercial) larger than 65 feet (19.8m) under U.S. jurisdiction (or entering/leaving a port or region under U.S. jurisdiction) to reduce their speed to 10kn when crossing Seasonal Management Areas (SMA)[81]. Located along the East coast of the United States (Figure 31), these SMAs come into effect during certain periods in right whale calving grounds and migrating areas[82] (Federal Register, 2008).

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[80] *Ship Strike Reduction Rule.*
[81] *Except when a manoeuver is necessary in terms of ship, navigation, environment or human safety (e.g. search and rescue, medical emergency, storm avoidance procedure, bad weather conditions, marine pollution risk) (Russell, 2001).*
[82] *Routes between feeding and breeding grounds taken by the animals.*
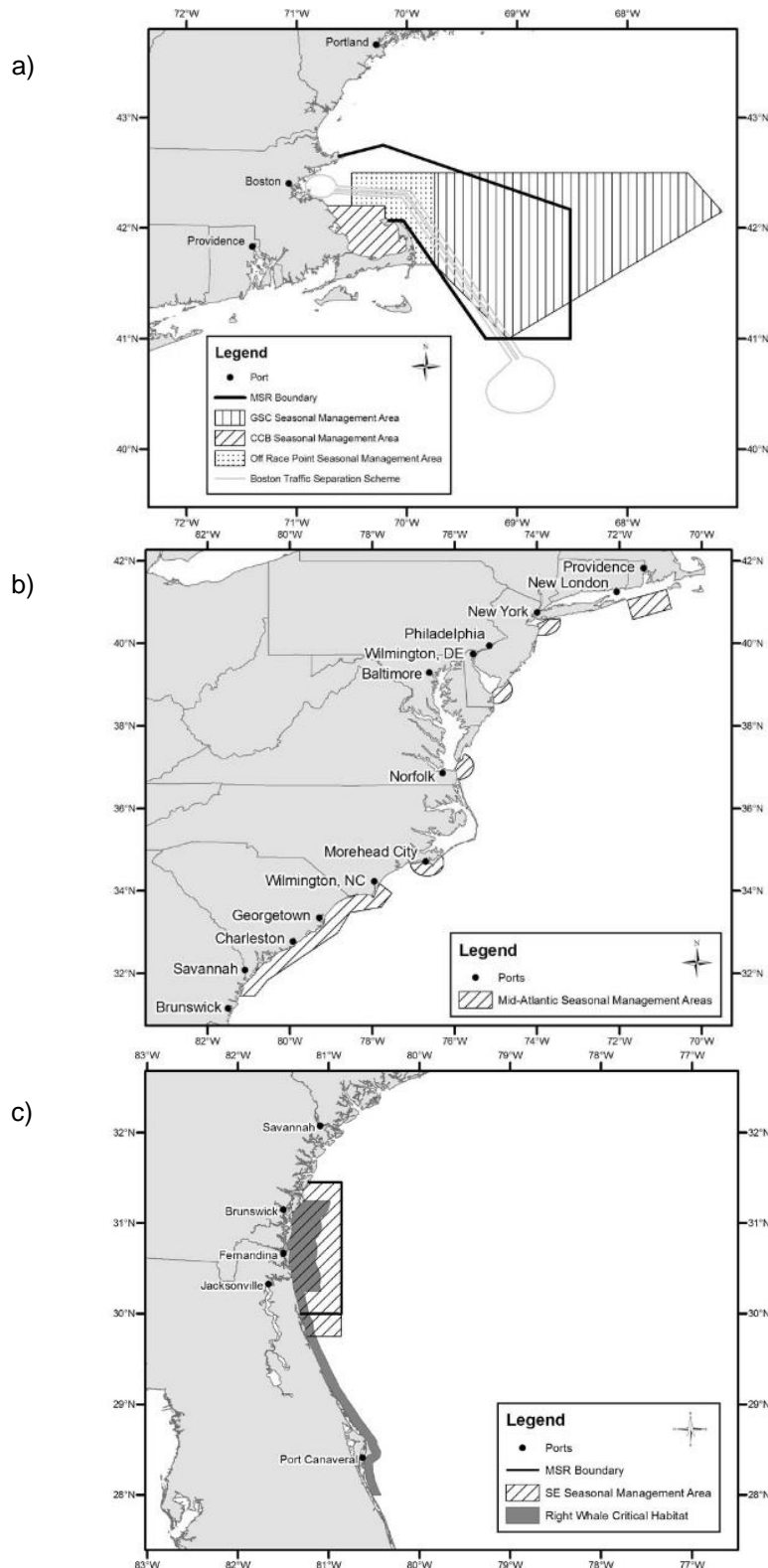
Figure 31. Seasonal Management Areas implemented on the American East coast: a) North-East region: Cape Cod Bay from January 1 to May 15; Off Race Point from March 1 to April 30; Great South Channel from April 1 to July 31 b) Mid-Atlantic Region: from November 1 to April 30[83] c) South-East region: from November 15 to April 15 (figure taken from: http://www.nmfs.noaa.gov/pr/pdfs/shipstrike/map_sma.pdf).

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[83] *Speed limitation is applicable over a 20NM area off Wilmington to Brunswick. However, according to Schick et al. (2009), SMAs currently only cover part of right whale habitat and should extend to 30NM.*

The Stellwagen Bank Sanctuary partly covers two SMAs (Off race Point and Cape Cod Bay) and is crossed by the TSS leading to the port of Boston (Figure 31a). Wiley *et al.* (2011) showed that a 14kn speed limitation over the whole Sanctuary would reduce the probability of mortality after a strike by 11%. This probability would decrease by 29.4% with a 12kn speed limit and by 56.7% by a 10kn speed limit, given that all ships comply with it.

Between 2002 and 2005, the development cost of speed limitation measures set up in the United States in the framework of the programme to reduce the risk of collisions with North Atlantic right whales was more than $330,000 per year (Reeves *et al.*, 2007). Kite-Powell and Hoagland (2002) estimate that a 10kn speed limitation for all ships in SMAs leads to a 0.5% increase in operating costs.

Voluntary speed limitation measures are also in force on the U.S. East coast. Based on right whale multi-annual distribution studies, Dynamic Management Areas (DMA) are established by NOAA. Mariners are recommended to avoid these highly frequented areas or reduce their speed to 10kn while crossing them. The list of DMAs currently in force is available on NOAA's website[84]. Information on these areas is also transmitted to mariners via NOAA's marine communication tools.

The areas these speed limitation measures cover and their period of application are constantly revised and updated given the right whale distribution. Criteria to establish DMAs are detailed in Russell *et al.* (2001). Reeves *et al.* (2007) recommend that presence of a female right whale with its calf is a sufficient criterion to establish these areas because:
- these individuals spend more time at the surface and thus are more vulnerable to ship strikes;
- mothers have an important role in terms of reproduction for the population;
- out of the 7 right whales being killed by a strike between 2001 and 2006, 6 were females.

Furthermore, since May 2005, NOAA recommends ships via its weather radio, the Mandatory Ship Reporting System[85] or other communication means to limit their speed to 12kn around areas where right whales have recently been sighted (Reeves *et al.*, 2007). Between December 2008 and June 2011, 61 DMAs were created (Asaro, 2012).

Compliance with these speed limitations is controlled by different means listed in Russell *et al.* (2001). Reeves *et al.* (2007) note that the AIS system, used to obtain information on vessel speed, can be used to control mariners' compliance with these regulations. In fact, a pilot study combining acoustic data from the buoys fixed off the port of Boston and AIS data on shipping traffic was carried out in the Stellwagen Bank Marine Sanctuary. This study can evaluate interactions between ships and whales in real time (Reeves *et al.*, 2007). According to Moller *et al.* (2005) and Reeves *et al.* (2007), this system can be used to choose protection measures (*e.g.* designation of DMAs) and control mariners' compliance with them. However, the spread of this control system is very unlikely because it would require setting up (very expensive) acoustic buoys over a wide area and managing a large amount of data from AIS and the acoustic buoys (Reeves *et al.*, 2007).

In 2012, an evaluation of these speed limitation measures showed that compliance was low. Regarding SMAs, 21% of transits were made below 10kn in 2009, 22% in 2010 and 33% in 2011 (Silber and Bettridge, 2012). Yet, authors note a general decrease in vessel speed as the proportion of transits where speed was above 10kn on more than half of the transit was 41% in 2009 against 22% in 2011. This compliance rate was also increasing in 2012 (Greg Silber, pers. com.). Still, these measures seem to have reduced the risk of lethal strikes by

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[84] *http://www.nmfs.noaa.gov/pr/shipstrike/*
[85] *Cf. chapter 6.1.*

80-90% with levels closer to 90% in the last two years (Conn and Silber, 2013). Indeed, they led to a general decrease of vessel speed in SMAs.

The SMA off Georgia and Florida (South-East Region, Figure 31c) is particular. Lagueux *et al.* (2011) noted that compliance with speed limitations was low when these were voluntary (between 9.8% in winter 2005-06 and 23.2% in winter 2007-08) but rose to 75% when limitations became mandatory (winter 2008-09). According to the authors, this corresponds to a decrease of ship strike risk by 38.5%. It is to be noted that these speed limitations were implemented in 2005, three years before the area was designated as a SMA.

This observation is identical for DMAs where mean vessel speed for all types of ships was above the 10kn recommended speed and avoiding manoeuvers have only been observed for 18 out of 66 transits. However, the authors underline the increase in compliance with these limitations over time, especially in 2011, showing the positive effect of awareness campaigns for mariners[86]. The authors also evaluated the direct and indirect negative impacts resulting from these speed limitations to be $52.4 million and $79 million according to 2009 and 2011 bunker fuel prices respectively (Silber and Bettridge, 2012).

This speed limitation system by creation of SMAs and DMAs will expire on 9 December 2013. However, in June 2013, NOAA officially requested that these measures are not abandoned but become permanent instead (Federal Register, 2013). This request went under public consultation until 5 August 2013. Right whale habitat protection area extension proposals were made by several authors including Schick *et al.* (2009), Whitt *et al.* (2013) or Asaro (2012) who highlights a wide right whale presence area identified by DMA localisations (Figure 32) but not yet protected by the current device. Morano *et al.* (2012) also underline the necessity of better protecting Massachusetts Bay where right whales have been acoustically detected all year round and not only during high concentration periods (February to May).
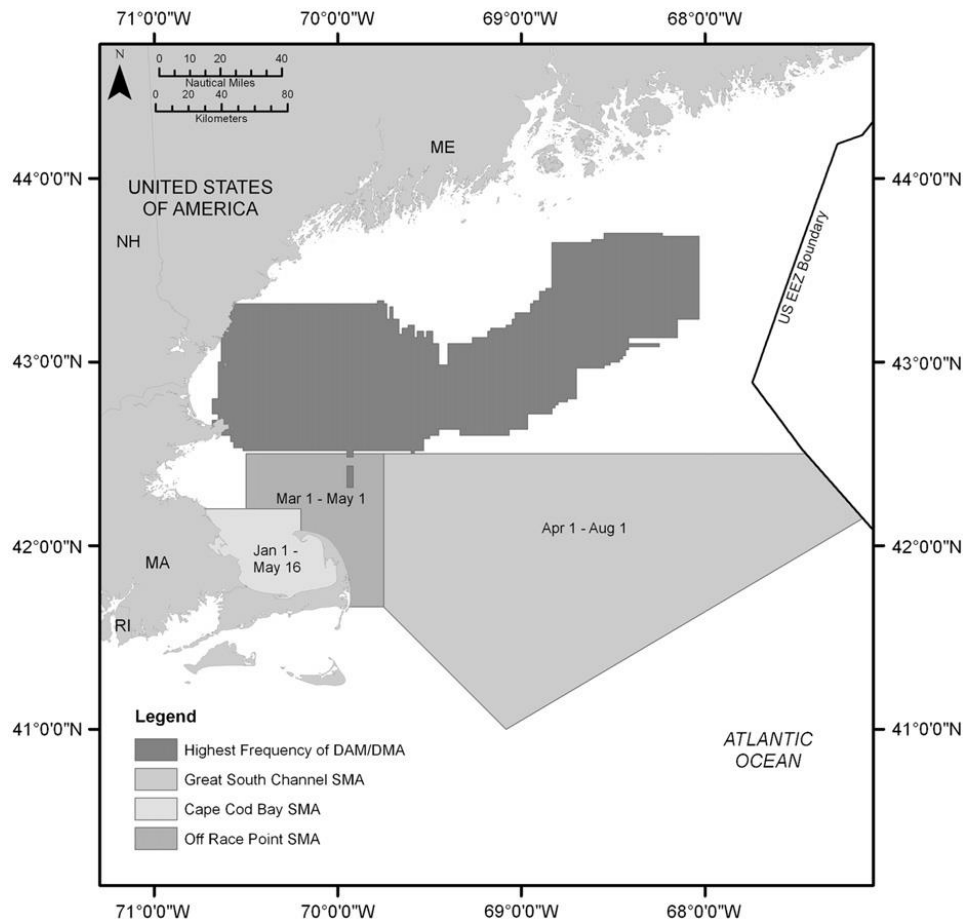
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[86] *Cf. chapter 9.1.*

Figure 32. High DAM and DMA density (dark) not overlapping the three existing SMA (Great South Channel, Cape Cod Bay and Off Race Point).Taken from Asaro (2012).

This extension would be all the more welcome that mortality analysis of eight large cetacean species between 1970 and 2009 along the Canadian and U.S. Atlantic coasts seem to show that mandatory measures implemented in the North-West Atlantic by the United States and Canada are not efficient in reducing human-induced mortalities (*e.g.* entanglements, ship strikes; Van der Hoop *et al.* (2012)). However, the authors admit that the scale of analysis cannot highlight local positive trends (*e.g.* Lagueux *et al.* (2011)) and that a similar analysis should be conducted in 2013 to evaluate the impact of these measures 4 years after implementation. Extension of these rules would also allow monitoring on a longer-term and therefore a better evaluation of the efficiency of these regulations.

Other regions off the U.S. coast are concerned by vessel speed regulations. In the North Pacific, Glacier Bay National Park is one of them. Within the humpback whale presence areas (Figure 24), ships must limit their speed to 10kn. Moreover, at the entrance of Glacier Bay, where humpback whale density is usually the highest, speed is limited to 20kn between 15 May and 30 September. When regular studies from the Park biologists show that whales are homogeneously distributed in the area, the Park Superintendent reduces speed limit to 13kn (NPS, 2003).

Another voluntary speed limitation programme was set up off the coast of California. In fact, after several collisions with blue whales in 2007 in the area (Berman-Kowalewski *et al.*, 2010), the Channel Islands Sanctuary and its Advisory Council established protection

measures[87] to reduce the risk of collisions with large cetaceans in the Santa Barbara Channel[88] (Abramson *et al.*, 2009).

The Channel Islands Marine Sanctuary, NMFS and the U.S. Coast Guards recommend that ships limit their speed to 10kn in shipping lanes leading to the ports of Los Angeles and Long Beach when blue whales are in the area. To do so, a prevention message is transmitted to mariners entering the Santa Barbara Channel to warn them of the presence of blue whales and recommend them to reduce their speed to 10kn (Bettridge and Silber, 2008). This message is emitted via Notices to Mariners and NOAA's weather radio. Preliminary results seem to indicate that compliance with these recommendations is generally high (Bettridge and Silber, 2008).

Another speed regulation example was implemented in the Pacific to avoid ship strikes within the Humpback Whale Hawaiian Islands Marine Sanctuary (Figure 33). Since its creation in 1992, this Sanctuary is aware of the threats of shipping traffic on large cetaceans. Several collisions mainly involving whale-watching vessels happened in the area (Abramson *et al.*, 2009). Protection measures and a workshop (NOAA, 2003) on the ship strike issue were set up by the Sanctuary. After these strikes, the Pacific Whale Foundation created a research programme to better understand factors increasing the risk of ship strikes related to surprise encounters and near-misses. Surprise encounters are whales that surface less than 300m from the boat without been detected before. Among others, results show that the part of young and sub-adults in the surprise encounters is significantly larger than other age classes (Richardson *et al.*, 2011). Regarding ferry routes connecting Hawaiian Islands, they are mainly located in deep sea areas not much frequented by humpback whales. However, when a ferry enters shallow waters (<183m), its speed must be limited to 25kn.
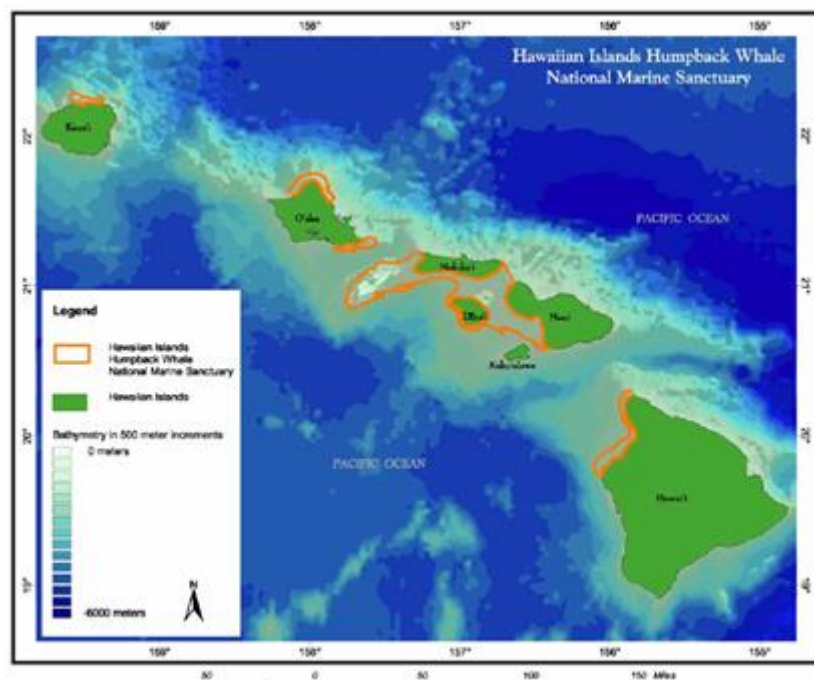

Figure 33. Hawaiian Islands Humpback Whale National Marine Sanctuary, in orange (NOAA, 2003).

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[87] *Inspired by experiences from Glacier Bay National Park, Stellwagen Bank Marine Sanctuary Hawaiian Islands Humpback Whale Marine Sanctuary.*
[88] *More information on management measures implemented to reduce ship strikes in the Channel Islands Marine Sanctuary here: http://channelislands.noaa.gov/focus/alert.html*

Similar speed limitation regulations have been established in the Strait of Gibraltar in the Mediterranean Sea.

5.2. Speed limitations in Spain

The Strait of Gibraltar is the second most transited natural navigation channel in the world after the English Channel (De Stephanis and Urquiola, 2006). More than 110,000 commercial ships (ferries, HSCs, cargos, tankers and supertankers) transit through the strait with an steadily increasing number of shipping companies and navigation routes (De Stephanis *et al.*, 2005; De Stephanis and Urquiola, 2006; Tejedor *et al.*, 2010). Species most susceptible to collisions in the area are sperm and fin whales (De Stephanis and Urquiola, 2006). This phenomenon worsened in late 2007 with the opening of the new commercial port of Tangier "Oued Rmel" (De Stephanis *et al.*, 2005; De Stephanis and Urquiola, 2006) leading to ferries and HSCs crossing sperm whale feeding grounds (Figure 34).
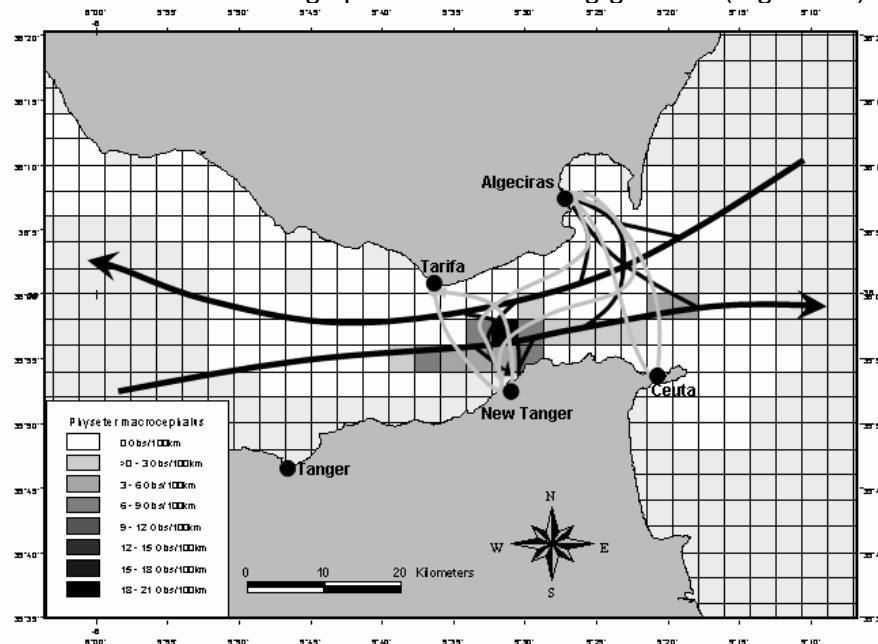

Figure 34. Shipping routes (black: cargos and tankers; grey: ferries and HSCs) implemented after the construction of the new commercial port of Tangier and sperm whale distribution in the Strait of Gibraltar between 2001 and 2004 (number of sightings per 100km of effort in each quadrate, De Stephanis and Urquiola, 2006).

In order to reduce the risk of collisions between ships and cetaceans in the area, a Notice to Mariners was published in 2007 by the Hydrographic Institute of the Spanish Navy and measures were implemented within the area most frequented by cetaceans called "Critical Area" (Figure 35). These measures recommend ships to sail carefully and limit their speed to 13kn between April and August (IHM, 2007). This Notice to Mariners is mentioned on international nautical charts and mariners are informed via radio during the same period every year, when sperm whale density in the area is highest (Tejedor Arceredillo *et al.*, 2008).
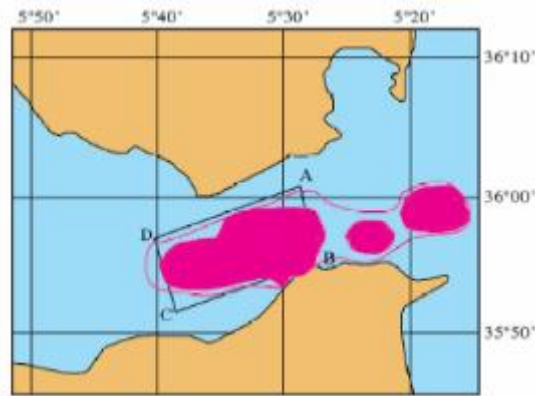
Figure 35. Identified critical areas (pink) for cetaceans in the Strait of Gibraltar (Tejedor Arceredillo et al., 2008).

A study based on theodolites[89] and AIS tool from land has been carried out by CIRCE since 2009 to evaluate mariners' compliance with the speed limitations set up in the Strait of Gibraltar. Between June and July, mean speed for three ship categories (cargos, ferries and HSCs) was higher than 13kn (Figure 36). Only 45.5% of cargos, 15.6% of ferries and 7.1% of HSCs seem to have complied with the 13kn recommended speed limitation in the area. This could be due to the fact that mariners are not informed of the regulations in force in the Strait of Gibraltar. VHF information on this recommendation was apparently never broadcast (Tejedor *et al.*, 2010). In case mariners would not voluntarily comply with these limitations, the possibility of strengthening them will be examined (ACCOBAMS, 2010). In fact, this solution is advocated by Tejedor *et al.* (2010).

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[89] *Tool usually used in topography to measure angles between two dimensions (horizontal and vertical) to determine a direction.*
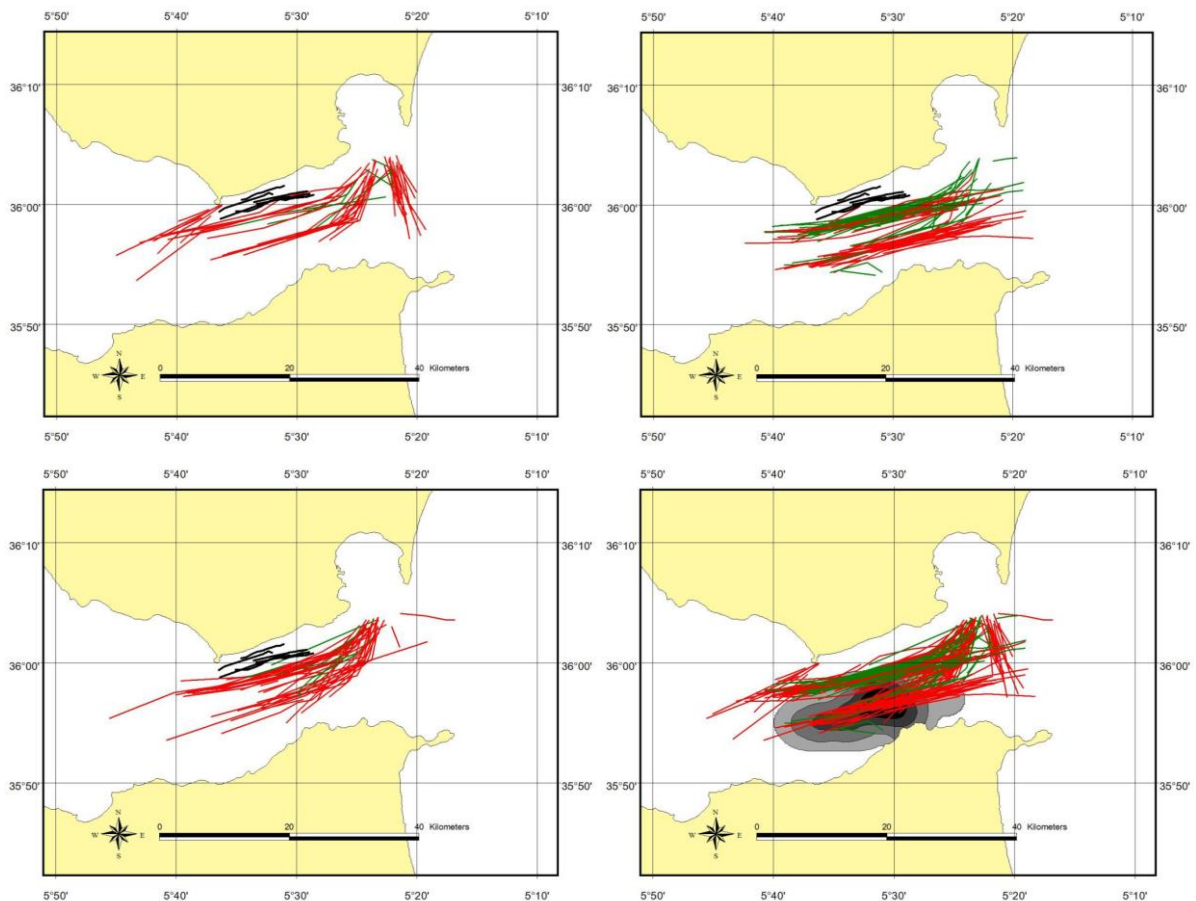
Figure 36. Tracks of fin whales (black) and a) high-speed ferries, b) cargos, c) ferries d) all ships in the Strait of Gibraltar (green: speed <13kn, red: speed >13kn,Tejedor et al., 2010).

Furthermore, the study from CIRCE showed that sperm and fin whales are also present in the strait in winter. Therefore, as recommended by ACCOBAMS (2010), it would be wiser to enforce these regulations all year round in the Strait of Gibraltar.

In the Canary Islands, where ferries make up to 17,000 trips a year between the islands (Ritter, 2010), , Scheer and Ritter (2013) measured bow-radiated noise from three types of ferries (classic, fast, HSC). Results showed that a fast ferry was detectable at 1.67km, a classic ferry at 1.61km and a HSC at 1.37km. Considering the speed of these ships, the authors estimated that cetaceans on the trajectory of these ferries have 2.53min, 3.5min and 1.38min to avoid a fast ferry, a classic ferry and a HSC respectively. If these durations seem long enough, many unknown such as the sperm whale ship acoustic detection capacity combined to the increased ambient noise level at the surface (where animals are more at risk of a collision) make this information worrying for the authors. Therefore, this led the authors to support the recommendations from Carrillo and Ritter (2010) to urgently implement speed limitations in the Canary Islands. In addition to advantages mentioned before, this would increase the duration given to whales to get out of the ship's way therefore reducing the probability of a collision. However, this recommendation has never been considered yet.

Similar speed limitation measures were developed in other countries.

5.3. Other examples of speed limitations around the world

In order to reduce the risk of collisions between ships and Southern right whales in the South Atlantic, a regulation (MADR N°119/08) was enforced in Argentina by the Coast Guards.

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Implemented in Peninsula Valdes, this measure imposes ships in the area to limit their speed to 10kn between 1 June and 30 November in an identified navigation corridor[90] (De Lichtervelde, unpub). These measures are part of a plan set up by the province of Chubut and the Argentinian Ministry in charge of the environment (IWC, 2012e).

In Japan, after 4 collisions between the HSC "Beetle" and large cetaceans in February and March 2006 along a route connecting the Japanese island of Kyushu and South Korea, the JR Kyushu Jet Ferry company decided to reduce crossing speed from 42 to 36kn, leading to an increase in trip duration by 20 minutes out of 2h55 (Anonymous, 2007b). This reduction, insignificant regarding studies on the importance of speed on the collision risk and lethality probability for the animal (Pace and Silber, 2005; Kite-Powell et al., 2007; Vanderlaan and Taggart, 2007; Vanderlaan et al., 2008; Wiley et al., 2011; Conn and Silber, 2013) did not prevent the strike causing the death of a passenger in 2006 (Anonymous, 2007a). Meanwhile, the speed reduction was limited to coastal South Korean waters in 2007, reducing the delay to 10 minutes (Anonymous, 2007b).

Firestone (2009) notes that recommended speed limitation measures in areas where rerouting is not possible increases travel time and manoeuvring work but reduces fuel consumption and polluting particle emissions in the atmosphere.

In the Mediterranean Sea, ferry companies are generally unfavourable to the implementation of speed limitations because it would cause longer trips and discrepancies between rotations and loading/unloading periods. A longer trip duration would also displease passengers. However, according to a survey made by the Italian institute ISPRA[91] on ferries connecting Italy to Corsica and Sardinia, 79% of passengers on the *Civitavecchia-Golfo Aranci* line are favourable to a 30-minute increase of their trip duration to protect Mediterranean cetaceans (Arcangeli et al., 2012a).

Other protection measures require some ships to report their position when entering large cetacean areas.

6. Reporting systems

6.1. Mandatory Ship Reporting System, MSRS

In the framework of their actions for the conservation of right whales, NOAA, in collaboration with the U.S. Coast Guards, established a Mandatory Ship Reporting System[92] in July 1999 in right whale areas (Ward-Geiger et al., 2005; Silber and Bettridge, 2006). This regulation requires ships larger than 300 gross tons entering these areas to report their position, speed and trip details (*e.g.* destination, route, etc.) to a station based on land. These areas are located off New England and the States of Georgia and Florida[93] (Figure 31). As a feedback, ships are informed of the right whale population, their threats, precautionary measures to take in order to avoid ship strikes and positions of the last observations made by aerial prospections[94] (Figure 37).

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[90] *Cf. chapter 4.1.2.*
[91] Instituto Superiore per la Protezione e la Ricerca Ambientale*, Institute for Environmental Protection and Research.*
[92] *This system is in conformity with the 1974 Safety Of Life At Sea International Convention (SOLAS 74) and meets IMO's criteria.*
[93] *Whalesouth and Whalenorth reporting systems respectively target the South-East and North-East coasts of the United States. These two systems are independent. Whalenorth is applicable all year round while Whalesouth only takes effect between 15 November and 16 April.*
[94] *More information on aerial prospections here:*
http://www.nefsc.noaa.gov/read/protspp/RightWhale/page2.html#h

```
MANDATORY SHIP REPORTING SYSTEM

YOU ARE ENTERING NORTH ATLANTIC RIGHT WHALE HABITAT. THE SPECIES IS
CRITICALLY ENDANGERED AND VULNERABLE TO BEING HIT BY SHIPS; WHALES MAY
NOT AVOID SHIPS. COLLISIONS CAN DAMAGE VESSELS.

EXERCISE PRUDENT SEAMANSHIP AND ADVANCE PLANNING TO AVOID RIGHT WHALES.
ASSUME ANY WHALE SIGHTED IS A RIGHT WHALE. MONITOR USCG BROADCAST
NOTICE TO MARINERS, NAVTEX, AND NOAA WEATHER RADIO FOR LATEST
ADVISORIES AND SIGHTINGS. CONSULT NAVTEX, INMARSAT C SAFETYNET, US
COAST PILOTS, BRITISH ADMIRALTY PUBS AND NOTICES TO MARINERS FOR WAYS
TO AVOID HITTING RIGHT WHALES AND APPLICABLE REGULATIONS. RIGHT WHALE
CRITICAL HABITATS ARE MARKED ON RECENTLY UPDATED NOAA CHARTS.
INFORMATIONAL PLACARDS, VIDEOS AND OTHER MATERIALS ARE AVAILABLE FROM
AGENTS, PORT AUTHORITIES, PILOTS AND USCG.

REPORT ALL STRUCK, DEAD OR ENTANGLED WHALES IMMEDIATELY TO USCG ON VHF
CHANNEL 16.

BE ADVISED THAT WHALES MAY NOT REMAIN AT REPORTED LOCATIONS. WHALES MAY
ALSO OCCUR AT UNREPORTED LOCATIONS. WHALES SHOULD BE ANTICIPATED
THROUGHOUT THE NORTHEAST U.S. CRITICAL HABITATS AND ADJACENT AREAS FROM
JANUARY THROUGH JULY.

WHALES SIGHTED AT:

4203N 07008W
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Figure 37. Example of a message automatically transmitted to ships having reported their position in the framework of the Mandatory Ship Reporting System.

NMFS and the Coast Guards noted a constant increase in mariners' compliance with MSRS (IMO, 2001; Silber *et al.*, 2002; Reeves *et al.*, 2007). Reeves *et al.* (2007) advocate that messages transmitted to ships by the Coast Guards also recommend them to reduce their speed in right whale areas.

Between 2002 and 2005, the development cost of the mandatory reporting measures implemented by the United States in the framework of the programme to reduce the risk of collisions with North Atlantic right whales was over $280,000 per year (Reeves *et al.*, 2007).

A whale reporting system was also created in the North Atlantic in the framework of the programme to protect right whales.

6.2. Right Whale Sighting Advisory System (RWSAS)

In the United States, a Right Whale Sighting Advisory System was developed on the Atlantic coast to reduce the risk of ship strikes.
Right whale sighting positions made in the framework of NOAA's aerial prospections or transmitted by different sources (*e.g.* research groups, Coast Guards, NOAA ships, whale-watching vessels, leisure boats, general public, acoustic buoy off Boston[95], Khan *et al.* (2009)) are daily transmitted to ships by the Coast Guards via different communication systems (*e.g.* NAVTEX, VHF, Notice to Mariners, emails, NOAA's website, fax machine, MSRS[96], NOAA's weather buoys and radio, port authorities). Concerned ships are therefore encouraged to increase their watch and limit their speed to 10kn in sighting areas. Figure 38 shows an example of a message sent to mariners.

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[95] *Cf. chapter 1.5.1.*
[96] *Cf. chapter 6.1.*

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Figure 38. Example of a message sent on April 11, 2006 reporting the last right whale positions and advising ships to be alert in the concerned areas.

According to Reeves *et al.* (2007), it is important to ensure that all ships in the areas are informed of the presence of right whales. However, for administrative reasons, only ships approaching ports are informed. Inspired by studies carried out in the Great South Channel[97], an evaluation of the system and compliance with the RWSAS would be necessary (Reeves *et al.*, 2007).

More reliable reporting systems in terms of safety, environment and power and more economical[98] than aerial prospections are under study (Russell *et al.*, 2001; Reeves *et al.*, 2007).

Among the measures implemented around the world, modifying government vessel operations could be an efficient way of reducing ship strike risks.

7. <u>Modification of government vessel operations</u>

The American federal law[99] requires the army, the Coast Guards and the Navy to ensure that their activities do not threaten protected species and their habitats (Silber and Bettridge, 2006; Reeves *et al.*, 2007).

Therefore, American federal agencies modify their operations in North Atlantic right whale areas (Table 4).

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[97] *Cf. chapter 4.1.3.*
[98] *Between 2002 and 2005, the development cost of the whale reporting measures implemented by the United States in the framework of the programme to reduce collisions with North Atlantic right whales was over $1,280,000 (Reeves et al., 2007).*
[99] *Section 7 of the Endangered Species Act. The 1973 Endangered Species Act aims at protecting species threatened with extinction due to unsustainable economic development and growth.*

Table 4. Actions implemented by the American federal agencies to avoid collisions with North Atlantic right whales (from Silber and Bettridge, 2006).

U.S. Coast Guards (*USCG*)	• Organising a training session for ship crews on the issues of North Atlantic right whale protection; • Placing dedicated observers when sailing in right whale areas; • Recommending mariners to increase their watch and reduce their speed in the vicinity of right whales; • Participating to the RWSAS; • Transmitting right whale sighting messages to ships via NAVTEX.
Navy (*USN*)	• Recommending mariners to increase their watch and reduce their speed in the vicinity of right whales; • Avoiding right whale areas to the extent that it does not impede a crucial mission; • Placing dedicated observers when sailing in right whale areas; • Accomplishing missions in right whale areas by day and with good visibility as much as possible; • Participating to the RWSAS; • Funding aerial prospections in the framework of the RWSAS.
USACE (*United States Army Corps of Engineers*)	• Placing dedicated observers during missions off the States of Georgia and Florida; • Accomplishing missions by day as much as possible; • Limiting USACE dredger ship speed to 5kn when operating in right whale areas in low light or visibility; • On NOAA's request, Cape Cod channel traffic controllers warn mariners of right whale sightings.

In 2005, NOAA contacted all American federal agencies to ask them to limit their speed to 12kn in right whale areas. Most of them voluntarily apply this measure providing that it does not impede crucial missions (Silber and Bettridge, 2006).

Similarly, the Australian Navy set up procedures and training sessions updated every year to reduce disturbances on cetaceans (IWC, 2007).

To our knowledge, no evaluation study was carried out to quantitatively evaluate the efficiency of these measures.

Another management tool to implement adapted measures to reduce the risk of collisions between ships and large cetaceans consists in creating a database where each strike case is reported.

8. "Ship strike" database

According to Reeves *et al.* (2007), a quality "Ship strike" database is an excellent tool to develop efficient protection measures without disturbing shipping activity. Using a database to report ship strikes is also advocated by ACCOBAMS (2010).
The main objectives of such an inventory of collisions between ships and large cetaceans are to:
- evaluate the threat ship strikes represent for cetacean populations;
- determine how parameters like ship speed or type can influence ship strike risk;
- identify and model areas where ship strike risk is high and likely to seriously affect large cetacean populations;

- raise stakeholders' awareness on the issue of ship strike, encouraged to feed the database;
- implement appropriate protection measures.

Several draft databases were created around the world (Laist *et al.*, 2001; Pesante *et al.*, 2001; Jensen and Silber, 2004; Van Waerebeek *et al.*, 2006). The need to create a common database to inventory collisions between ships and large cetaceans was highlighted in several technical reports (ACCOBAMS, 2005; Van Waerebeek *et al.*, 2006; Panigada *et al.*, 2008a) and by the IWC, IMO and ACCOBAMS (Leaper and Donovan, 2009).

Therefore, an ergonomic international database managed by the IWC was created (Van Waerebeek *et al.*, 2006; Van Waerebeek and Leaper, 2007; Leaper and Donovan, 2009) and is easily accessible online on the IWC website[100]. In fact, IMO encourages all its Member States to feed this database (IMO, 2009). In April 2013, it contained about 500 verified and validated records (Simone Panigada, pers. com., Figure 1) and the figures are increasing (Panigada and Ritter, 2013). Few records were directly transmitted by mariners (IWC, 2010a). This fact should change with the awareness campaigns developed by the IWC. Indeed, an awareness leaflet[101] on ship strike issues and the interest of reporting them to the database was created by the Government of Belgium to be distributed to shipping stakeholders (Leaper and Donovan, 2009). A kakemono presented for the first time at the 27[th] Conference of the European Cetacean Society in April 2013 was also created by the IWC to present its role in evaluating, reducing and raising awareness on ship strikes.

In the Canary Islands, Ritter (2007) and Carrillo and Ritter (2010) recommend the creation of mandatory ship strike reporting system to feed the IWC database.

A ship strike inventory within the Pelagos Sanctuary in Northwestern Mediterranean Sea is currently on-going. To do so, a network of shipping company and port referents was set up[102] and a ship strike reporting sheet was created[103]. Collected by the Pelagos Sanctuary, the information from these sheets is transmitted to the IWC to be integrated to the existing database. The Italian NGO Tethys Research Institute also created a similar online ship strike reporting system[104].

Furthermore, some regions of the world require that ship strikes, emergency avoidance manoeuvers and approaches under 100m be imperatively noted in the logbook and transmitted to a referent. In the case of the Hawaii Islands, before the Super Ferry shut down, the Director of Marine Operations had to be informed of every emergency avoidance manoeuver (Hawaii Superferry, 2005). In the event of a collision with a cetacean, the captain had to inform NMFS, the Coast Guards and the Hawaiian Islands Humpback Whale Sanctuary as soon as possible. The ship involved in the collision had to stay in the area and take pictures or film the collided animal as much as possible. Finally, a written report had to be transmitted within 24h to the Director of Marine Operations (Hawaii Superferry, 2005). Moreover, every collision case is inventoried and studied by the Marine Sanctuary and government agencies (*e.g.* NOAA Fisheries Pacific Islands Regional Office, NOAA Office of Law Enforcement).

On the East coast of the United States, a ship witnessing a strike, colliding with an animal or meeting a dead, injured or entangled animal must transmit its observation to the Coast

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[100] http://iwc.int/ship-strikes

[101] *Leaflet downloadable here:* http://www.iwcoffice.org/sci_com/shipstrikes.htm

[102] *One referent per shipping company and one per port (both commercial ports and pilot stations were contacted).*

[103] *Available here:* http://www.souffleursdecume.com/etudes_collisions.html

[104] *More information available here:* http://www.tethys.org/collisioni/segnala_en.htm *and here:* http://www.tethys.org/collisioni/_download/poster_collisions_en.jpg

Guards via VHF (channel 16) or to NMFS by phone or via NOAA's website. Information given by the witness mariner will be sent to the other ships by the Coast Guards.

In Australia, when a cetacean is injured or killed in the Whale Sanctuary, a report must be sent to the Ministry in charge of the environment within 7 days after the incident (IWC, 2006). Furthermore, in the framework of a national plan to reduce ship strikes, a "Ship strike" database was created in 2012 by the Australian Marine Mammal Centre. Modelled on the IWC database, it will help monitoring ship strike reports and increase the number of records in the IWC database (IWC, 2012a).

Similarly, an emergency plan was developed in Chile for fishing boats colliding with a cetacean (IWC, 2010a). Implemented by the 2008 law on the protection of cetaceans (Law 20293), this system establishes a protocol to follow in the event of a strike (*e.g.* actions to set up, human means to mobilise, data to collect).

According to Vanderlaan *et al.* (2008), ship strike risk reduction is a function of ship speed but also of mariners complacency. Therefore, developing educational tools and training programmes is essential.

9. <u>Training courses and awareness campaigns</u>

Compliance with and efficiency of (voluntary or mandatory) implemented management measures depend on mariners' awareness and understanding (Mayol, 2007; Reeves *et al.*, 2007; Vanderlaan *et al.*, 2008). Thus, educational tools were set up in several countries.

9.1. Educational programme in the United States

In the United States, many communication tools were created in order to raise mariners' awareness on the issue of collisions with large cetaceans and to encourage them to comply with established conservation measures (Bettridge and Silber, 2009). These tools were widely broadcast and protection measures were annotated on official navigation documents.
The communication campaign set up in the United States goes beyond the shipping industry alone and also targets maritime authorities (*e.g.* Marine Police, Coast Guards, etc.), the military sector (Navy), the cruising industry and leisure boaters. In the framework of this campaign, several educational tools presented hereafter were created.

9.1.1. CD-ROM

A code of conduct for mariners[105] in the form of an interactive CD-ROM was created by NMFS and the U.S. Coast Guards. This tool is an educational support to be voluntarily consulted by mariners sailing along the East coast of the United States and likely to encounter right whales[106]. Contents (Figure 39) were provided by different American organisations such as the shipping industry, Non-Governmental Organisations (NGO), and institutions in charge of resource management in the State of Georgia.
This tool contains information on:
- North Atlantic right whale identification and ecology (*e.g.* status, distribution, threats, etc.);
- (voluntary or mandatory) measures set up to reduce the risk of ship strikes;
- mariners' role and responsibility in reducing ship strikes (*e.g.* consult communication tools such as the U.S. Coast Pilot, the Notices to Mariners, NOAA's weather radio to

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[105] *Title: A Prudent Mariner's Guide to Right Whale Protection.*
[106] *Copies of this CD-ROM are freely available to harbour pilots on the East coast of the United States, to NMFS or the Coast Guards. It is also downloadable here: http://www.nero.noaa.gov/shipstrike/doc/mtr.html*

obtain information on right whales; bring the CD-ROM and show it to the crew; increase vigilance and post dedicated observers in right whale areas);

- warnings in the event of an encounter with a large cetacean (*e.g.* not expect the animal to get out of the way, stay behind their path, etc.);
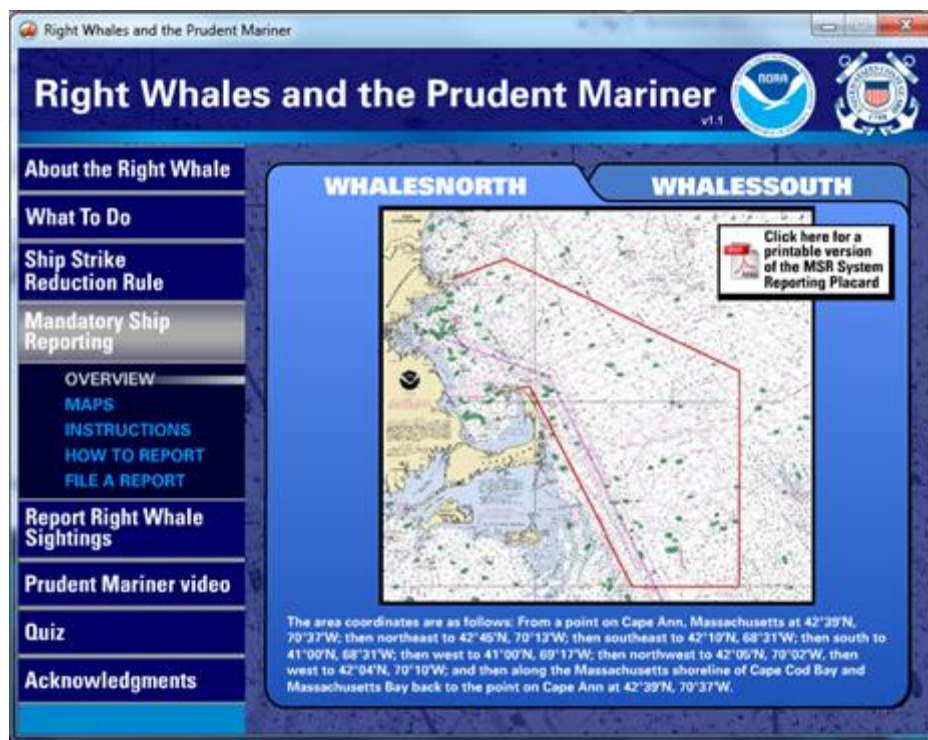- MSRS[107];
- RWSAS[108].

Figure 39. Home page and contents of the CD-ROM.

A 14-question quiz and a video aiming at raising mariners' awareness on the issue of ship strikes and its threats to the right whale population is also available on the CD-ROM.

On 28 May 2007, this educational CD-ROM was presented during the IWC Annual Meeting in Anchorage, Alaska. It was very successful since more than 380 copies were booked less than 24 hours after its presentation (NOAA and USCG, 2007).

With the same conservation objective, the cruising company Holland America Line[109] developed an interactive CD in collaboration with NOAA on measures to reduce collisions between ships and whales (Silber and Bettridge, 2006; Bettridge and Silber, 2008). This tool is now a prerequisite for all captains and crew members to work in this company. According to Silber and Bettridge (2006) and Bettridge and Silber (2008), efforts were made to have this CD distributed to the whole cruising industry and beyond (*e.g.* HSC industry, European Union governments).

An educational video was also created to raise mariners' awareness.

9.1.2. Video

Available on NOAA's CD-ROM, the Prudent Mariner Video was made in 1999. The objective is to raise awareness among captains and crew members on right whales (*e.g.* status,

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[107] *Cf. chapter 6.1.*
[108] *Cf. chapter 6.2.*
[109] *More information on the company's environmental implication:* http://www.hollandamerica.com/sustainability

distribution, detection, identification, behaviour, management measures, educational tools and publications). It also contains interviews of different stakeholders and shipping managers sharing their experience with right whales and their implication in the protection of these animals.

In the frame of their North Atlantic right whale protection programme, the United States also developed a training course for shipping school students.

9.1.3. Training course

In June 2003, NMFS asked the New England Aquarium to develop an educational module[110] for shipping school students[111]. In August 2005, the Aquarium signed a contract with 7 shipping schools from the East coast of the United States (including The Coast Guards and the Navy) to collaborate on the incorporation of the module to their programme. In 2006, two modules (50 and 15 minutes long) were thus developed, tested, adapted, updated and incorporated to the educational programme of these 7 pilot schools. A kit containing a CD-ROM, PowerPoint presentations and a binder was made available for teachers in charge of training students on the issue of ship strikes[112].

According to Knowlton *et al.* (2007), the module must be regularly updated (according to the involved school feedbacks and needs, evolution of regulations, etc.). The last update was made in April 2012[113] (Amy Knowlton, pers. com.). Actualisations are clearly and systematically communicated to the concerned stakeholders (email alerts and downloadable documents online).

Since its creation, this educational module has been:
- presented to shipping crews and shipping schools;
- made available for international shipping school (Canada, Sweden and countries sailing in the American North Atlantic area)[114];
- translated, when necessary, in the language of the new countries interested in the module.

Between 2002 and 2005, the cost of awareness and educational campaigns set up by the United States in the framework of the programme to reduce collisions with North Atlantic right whales was about $187,000 (Reeves *et al.*, 2007). According to (Reeves *et al.*, 2007), evaluation of the impacts of those campaigns is necessary. However, quantitatively identify these impacts among all the other measures established in the meantime seems hardly possible.

A collaboration with the Coast Guards was envisaged by Knowlton *et al.* (2007) in order to include questions on right whale protection in their final exams.

In Hawaii, the Pacific Whale Foundation managed to federate whale-watching operators around an awareness programme called "Be Whale Alert" containing a code of conduct with

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[110] Called "Voyage Planning and Marine Environmental Protection Measures to Avoid Collisions with the North Atlantic Right Whale".
[111] The training module was funded by NMFS and developed by Amy Knowlton from the New England Aquarium, Bruce Russell from JS&A Environmental Service Incorporated, William Mc Weeny from Green Cove Consulting and Pat Gerrior from NMFS.
[112] According to Knowlton et al. (2007), a technical assistance (telephone or email) can be set up for training organisations for 12 months.
[113] Available from the NOAA-NMFS website: http://www.nmfs.noaa.gov/
[114] In order to spread this training course internationally, Reeves et al. (2007) encourage NMFS to collaborate with other organisations such as IMO to raise awareness among foreign mariners on the issue of ship strikes and the measures implemented for North Atlantic right whales.

distance and speed recommendations to follow[115]. A free 1-day training session is also given in order to address the rules of the code of conduct and federal laws. First aid procedures in the event of an encounter with an entangled whale are also given. Operators are also encouraged to hoist a distinctive red and yellow flag to indicate to other vessels that they are in activity and that they are whales in the area.

Moreover, in the framework of the "Anti-collision" management plan set up by the Channel Islands Marine Sanctuary on the West coast of the United States, a training session for mariners (commercial, fishing, cruise and whale-watching ships) is being developed (Abramson *et al.*, 2009).

The U.S. Coast Guards developed a training programme on the issues of and means to reduce collisions with right whales for their crews[116].

In order to protect large cetaceans, other educational programmes have been set up in the United States.

9.1.4. Other awareness raising plans

Different communication tools for mariners and the general public were developed in the United States.

In fact, given that several collision cases with small leisure boats have already been reported, signs were displayed in several ports of the U.S. East coast to inform leisure boaters of the impacts of ship strikes on right whale populations (Silber and Bettridge, 2006). A code of conduct[117] for professional sailors operating off the East coast of the United States was also developed. This guide presents the conditions of application of the different measures implemented for the protection of North Atlantic right whales. Several codes of conduct were established in Canada, especially on the East coast for whale-watching operators and fishermen[118].

Furthermore, in order to protect humpback whales in the Hawaiian Islands Marine Sanctuary, an awareness campaign (*e.g.* distribution of leaflets and stickers) and a code of good conduct[119] were developed for mariners in the Sanctuary.

Risk areas, protected areas, MSRS areas[120] and marine sanctuaries are also displayed on official nautical charts.

Finally, it is to be noted that the Alaska Marine Safety Education Association published two pages on risks of collisions between leisure boats and whales and recommendations to avoid them in its winter 2012 newsletter.

A training course similar to the one developed on the East coast of the United States was created in France.

9.2. Educational programme in France

The different awareness actions developed in France are presented hereafter.

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[115] *More information here: http://www.pacificwhale.org/BWA*

[116] *Cf. chapter 7.*

[117] *Called "Compliance Guides for Right Whale Ship Strike Reduction Rule." This guide is available here: http://www.nero.noaa.gov/shipstrike/doc/compliance_guide.pdf*

[118] *More information here: http://www.baleinenoire.ca/index.html*

[119] *Available on: http://hawaiihumpbackwhale.noaa.gov/explore/whale_guidelines.html*

[120] *Cf. chapter 6.1.*

9.2.1. Training course

It has been shown that a crew aware of the ship strike issues is more likely to reduce their impacts (Mayol, 2007). Moreover, raising awareness among sedentary personnel in charge of the environmental policy of the company is absolutely necessary so that ship owners get involved in the long term in risk limitations processes. Beyond raising awareness, the point is also to train crews on the existence and use of technologies aiming at reducing ship strike risks. Therefore, the training course for crews and student officers called "Shipping and cetaceans: issues involved and how to improve relations?" was set up at the French Superior School of Shipping of Marseille by the association *Souffleurs d'Ecume* in response to studies from David *et al.* (2005) et (Mayol, 2007).

Every year, this free training course, open mainly to shipping company crews, aims at contributing to reduce the risk of collisions between large cetaceans and commercial ships. It is also open to other important stakeholders in that field such as Maritime Authorities, CROSSMED (French Maritime Rescue Coordination Centre for the Mediterranean coast, MRCC), French Navy, etc. The training course is composed of two distinct modules: one for student officers and the other for professionals in activity. Since 2005, 8 shipping companies, 72 crew officers, 11 executive sedentary officers, 26 officers (Maritime Authorities, CROSSMED and French Navy combined) and around 450 students participated to the training course. An official certificate is given on request to each participant by the French Ministry in charge of the environment. Moreover, *Souffleurs d'Ecume* supervised three master theses from the French Superior School of Shipping of Marseille on ship strikes presented in 2006, 2009 and 2012.

This training course is based on the following observations:
- crews need to be informed of the Mediterranean cetacean species, their ecology and the threats these populations face;
- crews aware of the impacts of ship strikes have better large cetacean detection performance;
- protocols to reduce ship strike risks exist or are being developed but need to find a way to be broadcast and often depend on visual observation;
- crews should be familiar with the use of future technological systems like REPCET[121] ;
- shipping companies involved in sustainable development request general information on the marine ecosystem and the impact of their activity;
- new collaborative approaches must be engaged to enhance relations between commercial shipping and managers of the Mediterranean environment;
- according to ACCOBAMS (2005), officers and crew members are not always informed of the impacts of ship strikes and showed interest in setting up measures to reduce these impacts.

This training course was developed with scientific and technical support from many organisations and financial support from institutions such as the Pelagos Sanctuary, ACCOBAMS and the PACA region. It fosters constructive discussions between the Pelagos Sanctuary and shipping companies for a better knowledge of conservation of Mediterranean cetacean populations. Since 2009, the shipping company *La Méridionale* received the ISO 14001 certification for the development of its environmental management programme. In that framework, the company committed to having 6 officers attending the training course every year.

Such a training course has many advantages for shipping companies, ports, environment managers and large cetacean populations:

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[121] *Cf. chapter 1.2.*

- safety on-board improvements (for fast ferries);
- promotion of the shipping company sustainable development policy and reduction of negative impacts in terms of public image when a whale is brought back to the harbour on the bow;
- reduction of health risks and costs related to the elimination of the dead animal;
- reduction of ship strike mortality risks;
- stimulation of collaborations with shipping companies to contribute to research programmes (*e.g.* report on cetacean ecology data collected by the crew).

Other awareness actions were developed to reduce the risk of collisions with large cetaceans in the Mediterranean Sea.

9.2.2. Other awareness actions

An awareness raising process was started in relation to the study by Mayol (2007). It involves the *SNCM* shipping company which initiated an awareness programme for its crew members through two actions:
- an internal monthly newsletter called "SNCM and Cetaceans" published by Captain Frédéric Capoulade between 2000 and 2005 in order to inform crews of cetacean presence in the Pelagos Sanctuary;
- a significant awareness action of his own crew by this Captain which led to a major increase in the number of transmitted sighting sheets.

Indeed, according to Mayol (2007), the number of sighting sheets transmitted to the CIESM by the SNCM since the year 2000 was 10 times higher than before (Pierre Beaubrun, pers. com.), which shows the interest of such awareness actions. Although these actions were interrupted when Captain Capoulade retired, the Safety/Environment Service of the company has been informing crew members of cetacean presence since 2006.

Finally, short messages on the Pelagos Sanctuary, collisions with large cetaceans and the whale-watching activity have been broadcast in French to mariners since 2009 on the VHF channel of Naya Radio (Monaco radio service)[122].
These awareness messages aim at informing mariners of the most common cetacean species encountered in the Mediterranean Sea, the impacts of collisions between large cetaceans and ships and measures implemented to reduce them. The next step would be to generalise this type of message to the whole Sanctuary.

Other awareness actions, not mentioned above, were implemented around the world to reduce the risk of collisions between ships and large cetaceans.

9.3. Educational programmes elsewhere in the world

In Australia, in the framework of a national plan to reduce ship strike probability and severity in Australian waters, several awareness and education actions are being developed are will be operational soon (IWC, 2012a).

10. <u>Other measures</u>

Beyond the systems detailed above, other actions were implemented in different countries in order to reduce the risk of collisions between ships and large cetaceans.

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[122] *This radio's main objective is to broadcast weather bulletins for the Saint Raphaël/Menton/Corsica/Port Camargue area.*

10.1. Permit system

Since 1981, a Vessel Permitting System was implemented in Glacier Bay National Park to cope with shipping traffic growth combined with the need to protect humpback whales in the area. This strict system established a 153 cruise ship quota[123] in summer time (June to August) and a 92 quota during off-season. A maximum of 2 ships per day are allowed in the area (Abramson *et al.*, 2009). These quotas are reassessed[124] every year by the Park Superintendent[125]. As an example, about 255 ships were allowed to sail in the waters of the Park between May and September 2013 (Scott Gende, pers. com.). In 2009, 95% of the Park visitors came by ferry, representing about 400,000 people (Gende *et al.*, 2011).

Obtaining a permit requires (private ship) mariners entering the Park for the first time of the year to attend a training session with the Park rangers on the needs to protect humpback whales and the navigation rules implemented in the Park (Bettridge and Silber, 2008). Furthermore, all ships wishing to obtain a permit must comply to requirements in terms of acoustic pollution and air emission reductions (Abramson *et al.*, 2009). Conditions to obtain a permit and relative regulations are detailed in NPS (2003). According to Abramson *et al.* (2009),regulations for the conservation of humpback whales implemented in the Park were efficient.

Other conservation measures consist in prohibiting ships from approaching large cetaceans within a given distance.

10.2. Animal approach restrictions

In the United States, several laws prohibit ships from approaching too close to whales. The Endangered Species Act and the Marine Mammal Protection Act prevent ships from approaching right whales less than 100 yards (91m) in and out of the Hawaiian Islands Humpback Whale Marine Sanctuary.

Similarly, American federal law prohibits all ships and aircrafts (including whale-watching vessels) from voluntarily approaching right whales within 500 yards (457m) away since 1997 (see Reeves *et al.* (2007) for an example).

Another example in Glacier Bay National Park where a ship cannot approach a humpback whale within 0.25NM (463m) since 1985, except for fishing boats engaged in a given activity (e.g. trawling, placing or removing fishing lines or cages). In the event of a ship being inadvertently within the 463m area, it must immediately limit its speed to 10kn. The mariner must maintain its direction (as constant as possible) to sail more than 463m from the animal. Moreover, when a ship (or aircraft) is located less than 0.5NM from a humpback whale, it cannot change direction or speed in order to get closer to the animal.

According to Mayol (2007), improving knowledge on large cetacean behaviour related to ships in the Mediterranean Sea would allow requiring mariners not to approach animals within a given distance to prevent a reaction from the cetacean likely to increase collision risks[126].

Many codes of conduct exists worldwide to reduce the impact of ships (including whale-watching vessels) on cetaceans (see Garrod and Fennell (2004) for a comparative

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[123] *A cruise ship is a motor vessel larger than 100 tons or 2,000 gross tons certified to carry more than 12 passengers.*
[124] *Upward or downward on a maximum basis of 2 ships a day.*
[125] *Based on recent scientific data, information provided by the general public, etc.*
[126] *A whale approached too closely could take a random and hesitating path therefore increasing collision risks (Mayol, 2007).*

analysis)[127]. They are very similar and all establish minimum approach and observation distances. Some are voluntary while others are mandatory.

Another efficient means of reducing collisions between ships and large cetaceans consists in encouraging collaboration programmes and organising international conference on this issue.

10.3. Collaboration conservation agreements and international conferences

Collaboration between countries[128] and/or between regional or international organisations[129] is encouraged by IMO (IMO, 2009; De Lichtervelde, unpub) in order to:
- favour data free movement and pooling (e.g. scientific data on cetacean distribution, shipping traffic data, etc.);
- implement common protection measures and protocols (e.g. communication tools, management plans, actions to set up in the event of a strike, etc.);
- define protection measures for the attention of international organisations;
- etc.

In the same idea of pooling information, organising international workshops on the issue of collisions between ships and large cetaceans is essential. During the first International Conference on Marine Mammal Protected Areas[130], the issue of ship strikes was addressed in a discussion on measures to be implemented within the MPA network[131]. These conferences play a major role in establishing connexions and links between managers and favouring exchanges between them (*e.g.* experience feedback, management tool sharing, spread of an efficient action plan, pooling scientific data).

Similarly, many workshops on risks of collisions between ships and large cetaceans were organised in the recent years, especially by the IWC and the ACCOBAMS Agreement. The first one was held in Beaulieu-sur-Mer[132] in 2010 (IWC-ACCOBAMS, 2011) and focused on the ship strike issue in the Mediterranean Sea. The report underlines the lack of information on several cetacean populations and on shipping traffic itself. Six areas were identified as priority areas for data collection to improve evaluation of ship strike impacts:
- the Strait of Gibraltar;
- the Pelagos Sanctuary;
- South-East Crete;
- The Balearic Islands;
- East of the Alboran Sea ;
- The Canary Islands.

A two-year work plan was decided during the workshop and was focused on four main actions:
- Development of a protocol for investigating and documenting ship strikes injuries and mortalities in cetaceans;
- Mediterranean basin wide survey to evaluate the impacts of ship strikes;
- Improved reporting to the IWC global ship strike database;

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[127] A list is available on the IWC's website: http://iwc.int/index.php?cID=3107&cType=document
[128] As recommended by Elvin & Taggart (2008), Canada and the United States established a bilateral agreement (initiated by NOAA) and work in close collaboration for the conservation of North Atlantic right whales.
[129] Such as collaborations between the IWC and ACCOBAMS or between IMO and the IWC. The latter was approved by OMI's General Assembly (in IWC, 2010).
[130] Organised on Maui Island in Hawaii from 30 March to 3 April 2009.
[131] "How can MPAs and networks of MPAs ensure threat mitigation to cetaceans?"
[132] Report available here: http://iwc.int/shipstrikes10

- Development of appropriate modelling techniques to identify high priority areas (IWC-ACCOBAMS, 2011).

A second workshop was held in October 2012 in Tenerife (Tejedor *et al.*, 2013). IT provided for the development of a worldwide awareness and educational programme for professionals of the sea and the development of a real-time information system to be used on-board ships. A pilot project at a regional scale was advocated in order to test these measures before spreading them (Tejedor *et al.*, 2013).

In November 2011, IMO organized a workshop on the environmental aspects of the Polar Code. Collisions with cetaceans were clearly listed as an environmental impact to be taken into consideration in the next IMO version. Speed reduction was proposed to reduce risks. Twenty-four recommendations were made in order to be included in the environmental chapter of the mandatory Polar Code. Recommendation 24 stipulates that voyage planning[133] should be mandatory and that high cetacean density areas should be avoided or crossed at reduced speed (DET Norske Veritas Ltd., 2011).

In April 2012, a workshop gathering scientists, shipping company representatives and managers took place in London on the issue of ship strikes in the Bay of Biscay[134] (Bull and Smith, 2012).

Still in 2012, in the framework of the Specially Protected Areas and Wildlife (SPAW) protocol in the Caribbean area, two workshops on large cetacean entanglements and ship strikes were planned with joint support from the Caribbean Environment Programme of the United Nation Environment Programme (CEP-UNEP) and the IWC (IWC, 2012c). The first one was held in English and Spanish in Mexico with support from the Stellwagen Bank Marine Sanctuary in November 2012. Divided in a theoretical part and a practical part, this workshop described the best methods to manage such events. The second workshop should be held in late 2013 in English and French in the French Caribbean. However, despite their title, these workshops are a lot more focused on entanglements than ship strikes.

Beyond the management measures previously cited, preventive measures can be taken to reduce the risk and severity of ship strikes. Starting from ship design.

10.4. Ship design

Ship design (e.g. shape of the hull, propulsion type, etc.) can be studied to avoid injuring animals (CH2MHILL, 2007; Silber *et al.*, 2008). For example, it can consist in:
- making the ship as manoeuvrable as possible (e.g. quick stopping, turning and slowing down capacities);
- replacing propellers by other types of propulsion (e.g. hydrojet);
- setting up propeller protections.

It is to be noted that within IMO, the Ship Design and Equipment Sub-Committee, related to the MEPC works on the implementation of measures during ship design to reduce the impact of shipping traffic on the environment. Coordinated by the United States, this sub-committee proposed a list of provisions to reduce noise from ships and its adverse impacts on marine life (IMO, 2012). However, no proposal was made and no discussion seem to be engaged on measures to reduce the risk of collisions with large.

Another preventive management measure consists in implementing a navigation plan taking the ship strike issue and the associated precautionary measures into consideration.

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[133] *Cf. chapter 10.5.*
[134] *Report available here: http://www.repcet.com/docs/April_2012_Ship_Strike_Workshop_Report.pdf*

10.5. Anticipated voyage planning

Silber *et al.* (2008) highlight the interest of establishing a voyage plan considering large cetacean migratory movements and areas most frequented by them. By informing mariners of the potential presence of cetaceans, several technological tools (*e.g.* REPCET, presence prediction models, passive acoustics, etc.) can be helpful in designing the voyage plan. Silber *et al.* (2008) made a summary table on measures to take to anticipate areas of animal aggregations and reduce ship strikes risks (Table 5).

Table 5. Synthetic table on the actions to implement to anticipate the areas frequented by the animals and reduce the risk of ship strike (modified from Silber et al., 2012)

	Time scale over which actions must be taken before reaching the cetacean area	Distance between ship and cetacean area	Actions needed	Potential tools
Voyage planning	1 week +	1,000 MN	- General course planning; - Increase awareness and crew training.	- Historical records; - Forecasts ; - Predictive models.
Voyage adjustments	1 day–1 week	200–1,000 MN	- Adjust route or speeds; - Post dedicated observers; - Obtain whale alerts.	- Notices of whales in area of travel.
Precautionary and evasive actions	During transit to and from high-density whale areas	0 to 20-30 MN	- Slow down; - Post dedicated observers; - Obtain whale alerts; - Establish anticipatory communications on ship; - Contact nearby mariners; - Change route.	- NAVTEX ; - Buoy or other whale alerts; - Visual observation aids; - Electronic observation aids (sonar, radar, passive acoustics).

11. Sailing races special case

According to Ritter (2009), 81 collisions (and 42 near-misses) between cetaceans and sailing boats were recorded between 1966 and 2008. These events generally occurred during regattas involving monohulls sailing at speeds between 5 and 10kn (Ritter, 2009). Cetaceans concerned by these (sometimes lethal) strikes were mainly large cetaceans (*e.g.* humpback and sperm whales). Property[135] and human (*e.g.* crew members injured) damages were often noted after a collision between a sailing boat and a large cetacean. IMO recommends that measures be taken to reduce ship strike risks during these types of sporting events (IMO, 2009).

It is to be noted that according to Ritter (2009), collisions between sailing boats and large cetaceans do not occur at great speeds (usually between 5 and 10kn) and that there are safety concerns for crews even at very low speed (*e.g.* 3kn). This observation underlines the interest of setting up educational programmes for all mariners.

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[135] *Three ship losses were recorded following a collision with a large cetacean.*

During the 2008-2009 Volvo Ocean Race, participants had to avoid the Stellwagen Bank Marine Sanctuary (638 MN^2) off Boston. Organisers chose to make sailors get around the Sanctuary 5NM from the North, leading to a 400NM lengthening of the race (Figure 40).

Figure 40. Exclusion zone including the Stellwagen Bank National Marine Sanctuary off Boston that participants to the 2008-2009 Volvo Ocean Race sailing competition had to avoid (figure taken from: http://www.nytimes.com/imagepages/2009/04/25/sports/25sailing.map.ready.html)

For the 2011-2012 Global Ocean Race (GOR) the race organisation signed a partnership with the Environmental Investigation Agency (EIA), a British campaigning organisation, to improve awareness among crews, organisers and amateur boaters on the issue of collisions with large cetaceans (Jennifer Lonsdale, pers. com.). Several concrete actions were carried out towards crews (written briefing on ship strikes, question-answer sessions, call for vigilance in risk areas such as around Cape Town, reporting sheets given to feed the IWC database) and amateur boaters who follow the race through EIA and GOR's websites. Press releases and a presentation on the issue during the Southern Ocean Racing Conference Solo Offshore Racing Festival were also made (Jennifer Lonsdale, pers. com.). No strikes were recorded during this race and the partnership should be renewed for the next race in 2014-2015. Other regattas could also sign such a partnership, including the Volvo Ocean Race (Jennifer Lonsdale, pers. com.).

12. North Atlantic right whale case

Mullen *et al.* (2013) retraced all the North Atlantic right whale conservation actions implemented since the species was listed on the U.S. Endangered Species Conservation Act in 1970. Despite all measures established to reduce the impact of ship strikes and entanglements in fishing gear since the first recovery plan in 1991, this population remains extremely threatened. The main reason brought by par Mullen *et al.* (2013) lies in habitat fragmentation. In fact, most conservation efforts targeted both feeding grounds in the Gulf of Maine and the breeding ground along the coast of Georgia and Florida (Mullen *et al.*, 2013). Although ship strike risks have decreased in these areas, it remains very high along the migratory corridor between these areas. The lack of protection of this corridor would impede the recovery of this population. Among their recommendations, Mullen *et al.* (2013) insist on designating migration habitat and defining different and complementary protection levels between these habitats and feeding and breeding grounds. The likely renewal of the measures implemented by NOAA to reduce the risk of collisions between ships and North Atlantic right whales (Federal Register, 2013) in December 2013 is the perfect occasion

according to Mullen *et al.* (2013) to revise and adjust these measures so that all efforts made over the last 20 years to save this populations finally pay off.

13. <u>Ship strike risk limitation projects to come</u>

In addition to the many systems presented along this report, other projects should be implemented in the coming months or years.

13.1. *Particularly Sensitive Sea Area*

Several measures were proposed to reduce ship strike risks in the Pelagos Sanctuary. However, this protected area mainly covers international waters. A national regulation, being either French, Italian or Monegasque, cannot apply to the whole Sanctuary. Designation of the Pelagos Sanctuary as a Particularly Sensitive Sea Area (PSSA) by IMO would ease the establishment of ship strike reduction measures. For this purpose, a primary application was written by the French Party of the Sanctuary in late 2012 and is now in the hands of its Monegasque and Italian counterparts. A reporting system for ships entering the Sanctuary, the use of a real-time cetacean spotting system and the report of any ship strike or near-miss are some of the proposals made by the French Party regarding ships larger than 300 gross tons. The application will be submitted to IMO when approved by all three Parties. However, a submission in 2013 would not be effective before 2016 (Bigan and Barcelo, 2013).

13.2. *National legislation*

In 2011, an amendment to the Mexican General Law on Wildlife (*Ley General de la Vida Silvestre*) allowed to extend the notion of critical habitat to aquatic and marine ecosystems, therefore leading the way to the identification of protected areas with associated management measures to reduce threats on these areas. Following this dynamic, a collaborative research programme was set up between the National Institute of Ecology in Mexico (*Instituto Nacional de Ecología*) and the American NMFS to study grey whale movements during their migration. The objective is to identify ship strike risk areas when defining shipping routes. In March 2012, 19 satellite tags were deployed and the programme should keep on going for several years (IWC, 2012d).

13.3. *Action plans*

13.3.1. Canada

In the framework of the Recovery Plan under the Species At Risk Act (SARA), the Direction of Fisheries and Oceans published a Partial Plan for Blue, Fin, Sei and North Pacific Right Whales in early 2013 (Fisheries and Oceans Canada, 2013). Collisions with ships and physical disturbances due to the presence of ships are the first two threats listed in the plan. Several measures were proposed to improve knowledge on the phenomenon, evaluate its impacts and reduce them. According to current schedule, concrete measures to reduce ship strike risks could be established by 2020. The first public consultation phase took place in April and May 2013 and another one is expected in late 2013. However, this plan is considered partial because current knowledge do not allow the complete identification of critical habitats for these four species (Fisheries and Oceans Canada, 2013).

13.3.2. International

During the 64th Annual Conference of the IWC in 2012, the Conservation Committee approved the creation of a ship strike strategic plan (IWC, 2012c). Planned over five years, its objective is to try to describe the IWC ship strike strategy by establishing the most

advanced state of knowledge and tackling the issue at a global scale (Fabian Ritter, pers. com.).

13.4. Conservation Management Plans

A Conservation Management Plan (CMP) is a document giving clear objectives and conservation actions over a defined period of time to sustainably recover a population or species to a favourable level of conservation. It is a flexible document easily alterable over time to account for new information or preliminary results. The IWC adopted CMPs in 2008 and published a series of directives to assist Member States in the creation of these CMPs (IWC, 2011). To this day, three CMPs were approved by the IWC and are being applied. The first plan concerns North Pacific grey whales and the two others, developed hereafter, target Southern right whales.

13.4.1. South America

Although Southern right whales are not as threatened as their Northern Hemisphere counterparts (Reilly *et al.*, 2013a), several countries in South America worry about the low numbers and reproduction rates of the South-West Atlantic and South-East Pacific populations. In fact, the latter was recognised as a priority area for research by the IWC (IWC, 2010b). Ship strikes are one of the main threats to these populations, along with habitat degradation, entanglement in fishing gear and kelp gull (*Larus dominicanus*) harassments (Iñiguez Bessaga *et al.*, 2012). Therefore, Argentina, Brazil, Chile and Uruguay submitted a recommendation to the IWC in 2011 (adopted later) to create a CMP for South American right whales. Such a plan was thus created for the South-West Atlantic population (Iñiguez Bessaga *et al.*, 2012) and a similar one for the South-East Pacific population (Galletti Vernazzani *et al.*, 2012).

Regarding ship strikes, the South-West Atlantic population CMP recommends a close collaboration with the IWC Ship Strike Working Group and actions to better quantify the issue (*e.g.* photo-identification monitoring, improvement of the stranding network and public awareness), identify the specific aspects of the issue and develop mitigation measures (*e.g.* movement monitoring using telemetry, creation of an expert council). Most of these measures are long-term actions (Iñiguez Bessaga *et al.*, 2012).

Because of the small number of individuals (Reilly *et al.*, 2013b) and the growth of shipping traffic, the South-East Pacific population CMP considers that ship strike and entanglement potential impacts are major and that priority of action is extreme (Galletti Vernazzani *et al.*, 2012). Given the overlapping risks between shipping traffic and right whale areas, one of the priorities is to identify areas where risk is highest. Creating, among others, a right whale sighting database could help setting up appropriate mitigation measures. Rerouting, speed limitation and creation of MPAs are also proposed as well as a warning and awareness system for crews to evaluate their compliance with these regulations. Constant monitoring is also advocated as well as data reporting to the different concerned international databases (Galletti Vernazzani *et al.*, 2012).

13.4.2. Arabian Sea

Between India and the Arabian Peninsula, the Arabian Sea supports blue and humpback whale populations. The latter seem to be small and differentiated from that of the Indian Ocean (Mikhalev, 1997). The fragility of this population and the increase of shipping traffic led the IWC Scientific Committee to declare this population as candidate for the creation of a CMP. The redaction process of the CMP for Arabian Sea humpback whales is on-going (IWC, 2012c) and should be examined by the IWC soon.

13.5. TSS in Panama

The Republic of Panama is the leading country in the world in number of registered ships. It has 8,127 registered ships accounting for 7.8% of world shipping traffic and 21.39% of world deadweight tonnage (dwt)[136] (UNCTAD, 2012). About 17,000 commercial ships transit through the Panama Canal every year and traffic is expected to increase in the coming years (IWC, 2012b). Meanwhile, 13 collisions between ships and large cetaceans (mainly humpback whales) were reported between 2009 and May 2011 in Panamanian Pacific waters (Guzman *et al.*, 2012). As a response, Panama seized the opportunity hosting the 64th Annual Meeting of the International Whaling Commission in 2012 to present the creation of a TSS at the South end (Pacific Ocean) of the canal (IWC, 2012b; Panama, 2012), according to recommendations made by Guzman *et al.* (2012) (Figure 41).
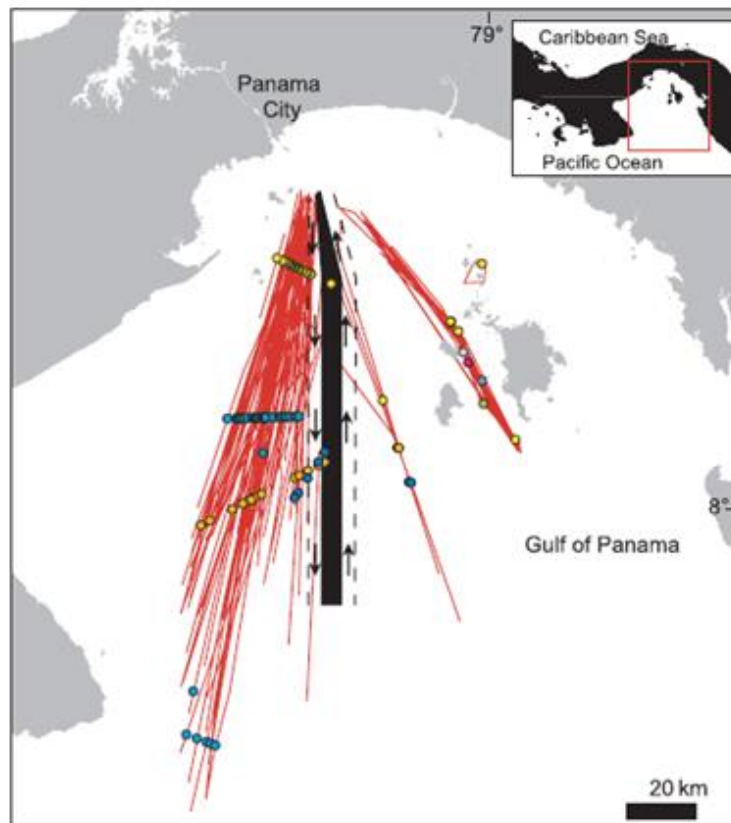
Figure 41. TSS proposal (black) at the Pacific end of the Panama Canal over-lapping tracks of 81 ships (red lines) and 97 interactions between these ships and 8 humpback whales. Each colour represents an individual (Guzman et al., 2012).

13.6. Acoustic monitoring in Greece

The Mediterranean sperm whale population is estimated to be around a few hundred individuals and collisions with ships are one of the main threats (Notarbartolo di Sciara and Birkun, 2010). The area of the Hellenic Trench in Southern Greece is considered to be one of the six priority areas for the reduction of ship strike risks in the Mediterranean Sea (IWC-ACCOBAMS, 2011). Up to 61% of stranded sperm whales along the Greek coast were killed by a collisions (Frantzis *et al.*, in press). A project of installing acoustic buoys along a shipping corridor awaits funding. This system could greatly reduce collisions with sperm whales (Alexandros Frantzis, pers. com.). A project to move this shipping corridor could also be submitted in the coming months (Alexandros Frantzis, pers. com.).

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[136] *Deadweight tonnage is the total weight a ship can carry. It includes shipment, consumables (e.g. fuel, foodstuffs, etc.) and the weight of the people on-board (crew, passengers and their luggage).*

13.1. Collaboration between Pelagos and Agoa Sanctuaries

Collaboration between the Pelagos Sanctuary in the Mediterranean Sea and the Agoa Sanctuary in the Caribbean is under study. Mainly focused on ship strikes, it would allow a skill transfer so that Agoa could benefit from studies already carried out in Pelagos (*e.g.* provision of protocols and documents, technical exchanges, participation to an examination of knowledge on and reduction of ship strike risks in the Caribbean through training and deployment of technological tools). This collaboration was already initiated during the 2nd International Conference on Marine Mammal Protected Areas in Martinique Island in November 2011 (Mayol *et al.*, 2011) and should be achieved in early 2014.

Conclusion

The issue of collision between large ships and large cetaceans is global, complex, and many species are susceptible to it. Thus, a great variety of management measures and technological tools was developed around the world in order to limit that risk. However, none is the ideal solution to reduce ship strikes. The different systems do not always meet the technical, economic (*e.g.* speed limitations, rerouting) and ergonomic (*e.g.* night vision systems) requirements of ships and are not always respectful from an ecological point of view (*e.g.* ADDs, sonar). Some are well-adapted to the area they were developed but can hardly be applied everywhere (*e.g.* WADBS, WACS, permit system). The only measure applicable everywhere in the world is the training and awareness raising efforts for concerned stakeholders. I would allow, among others, to reduce the lack of cooperation with, knowledge on or compliance with certain measures. Therefore, a combination of several measures (voluntary or mandatory, in the short term and the long term) must be adopted in collaboration with stakeholders and given the environmental (*e.g.* ecology, ethology and distribution of the targeted species) and economic (*e.g.* features and requirements of local shipping traffic) characteristics of the concerned region. Beforehand, some measures (*e.g.* speed limitations) would require a technical and socio-economic feasibility study.

In the meantime, updated studies on large cetacean population spatio-temporal distribution and wide awareness campaigns for mariners (*e.g.* training courses, Notice to Mariners, websites) must be carried out. Finally, permanent monitoring during implementation of the measures and a final evaluation at the end are essential to determine its efficiency and propose potential improving ideas.

Anyway, given the risk magnitude for some populations and the ecology of these slow-breeding species, only long-term measures will significantly reduce ship strike impacts. It may be the most difficult point to deal with but it is crucial if we want to see these populations tend to sustainable stability and keep participating to the balance of the oceans and the marine ecosystems on which Mankind is more than ever dependent.

Term and acronym list

ACCOBAMS	Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Atlantic Area
ADD	Acoustic Deterrent Device
AIMMMS	Automatic Infrared-based Marine Mammal Mitigation System
AIS	Automatic Identification System
ANI	Ambiant Noise Imaging
ATBA	Area To Be Avoided
AUV	Autonomous Underwater Vehicle
CMP	Conservation Management Plan
DMA	Dynamic Management Area
EIA	Environmental Investigation Agency
GOR	Global Ocean Race
IMO	International Maritime Organization
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
MPA	Marine Protected Area
MSRS	Mandatory Ship Reporting System
NGO	Non Governmental Organisation
NM	Nautical Mile
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
PARS	Port Access Route Study
PSSA	Particularly Sensitive Sea Area
REPCET	REal-time Plotting of CETaceans
RWSAS	Right Whale Sighting Advisory System
SAC	Special Area of Conservation
SMA	Seasonal Management Area
SPAW	Specially Protected Areas and Wildlife
TSS	Traffic Separation Scheme
UNEP-CEP	United Nations Environmental Programme - Caribbean Environmental Programme
WACS	Whale Anti-Collision System
WADBS	Whale Auto-Detection Buoy System
WHOI	Woods Hole Oceanographic Institution

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