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# Protecting large cetaceans from ship strikes in the Pelagos Sanctuary

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INTERNATIONAL
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Data extracted from the Quiet Ocean and EcoOcean report elaborated for WWF France in 2015 (Folegot *et al.*, 2015).

## Introduction

The Pelagos Sanctuary, created in 2002 to protect cetacean feeding and reproducing grounds, is the first cross-border area of the Mediterranean Sea dedicated to the protection of marine mammals. Six cetacean's species can be regularly encountered in the Sanctuary: striped dolphin (*Stenella coeruleoalba*), bottlenose dolphin (*Tursiops truncatus*), Risso's dolphin (*Grampus griseus*), pilot whale (*Globicephala melas*), sperm whale (*Physeter macrocephalus*) and fin whale (*Balaenoptera physalus*). Its 87,500 $km^2$ territory extends beyond the coastal zone of France, Monaco and Italy; making it one of the largest transboundary protected areas in the Mediterranean.

Thirty percent of the world's commercial maritime traffic transits through the Mediterranean Sea (Piante & Ody, 2015). In the Pelagos Sanctuary, due to the high concentration of cetaceans and heavy maritime traffic, the ship strike rate is 3.25 times higher than elsewhere in the Mediterranean (Panigada *et al.*, 2006).

Research in the Mediterranean has found that at least 16% of fin whale carcasses recovered were killed following a collision (Panigada *et al.,* 2006). The same research estimates that 8 to 40 fin whales are killed each year in the western Mediterranean Sea alone.

Scientific research has identified a navigation speed threshold between 10 and 13 knots (11 to 15 mph) below which the risk and consequences of collisions decrease significantly (Vanderlaan and Taggart, 2006).

For the time being, there is no embedded system on board of commercial vessels to automatically detect cetaceans. One of the technologies identified to report sightings of cetaceans and potentially reduce risks is the REPCET system, which enables the equipped ships to share their observations of cetaceans with other ships to prevent collisions.

### *The REPCET anti-collision system*

The REPCET tool is a software system dedicated to navigation, developed by the NGO *Souffleurs d'Ecume* and the *Chrisar Software Technologies Society* (Souffleurs d'Ecume, 2016). Its aim, first and foremost, is to limit the risks of collision between large cetaceans and vessels. The concept is simple and is based on the following: every sighting of a cetacean by watch-keeping personnel on board a vessel equipped with REPCET is transmitted by satellite in real-time to a server located on land. The

server then centralises the data and sends out an alert to equipped vessels that are likely to be affected. The alerts are displayed cartographically on a dedicated screen on board.

The collaborative nature of the system means it relies on the collaboration of commercial maritime vessels. Other vessels are also welcome to voluntarily contribute to the system by reporting cetacean sightings, especially military vessels, scientists at sea, whale watching operators, and pleasure boats.

Consideration for the work of watch-keeping personnel on the bridge is one of the keys to the effectiveness of the system. That is why particular attention is given to the ergonomics of user interfaces, especially in facilitating reporting of whale sightings. The input interface thus allows rapid entry of sightings into the system, including essential data such as: name and position of the vessel, distance and bearing of the animal, species, number of individuals, etc. A relative positioning tool has been specially designed for this purpose. The mapping interface is designed to display the alerts sent by the server. It allows the user to visualise the alerts on a topographic map and to easily zoom in and pan around the map. An intuitive display allows rapid location of dangers and their nature, in order to adapt the watch on the bridge for example. Detailed information on the alerts can also be called up (origin, time, species and number of individuals).


**Figure 1: REPCET interface**

## Methods

*Study Areas*

Two study areas have been established (Figure 2): (a) the area corresponding to the Pelagos Sanctuary; (b) an enlarged zone expanded to the port of Marseille.

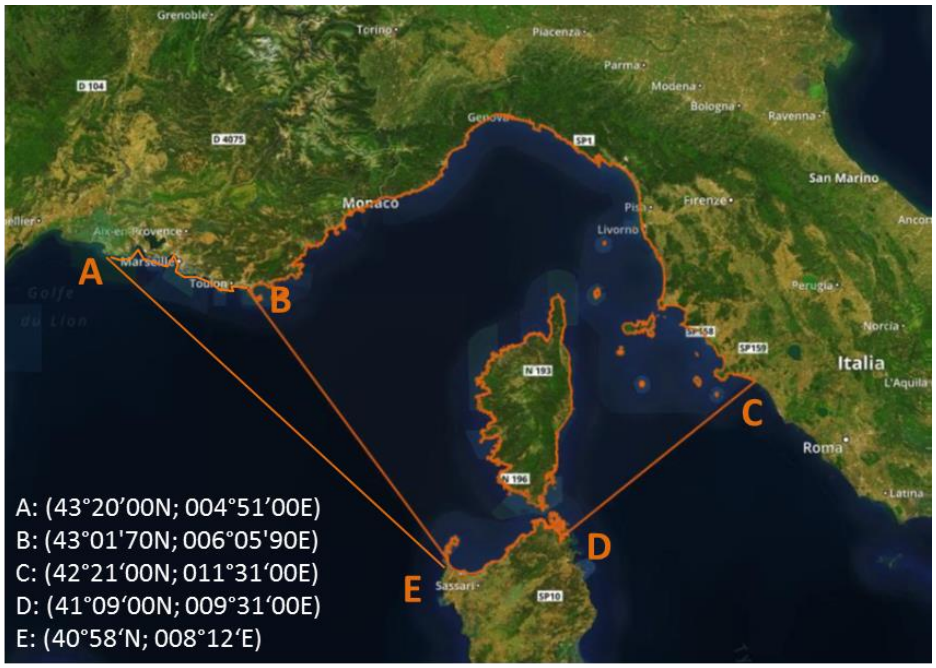


**Figure 2: Study area – enlarged zone is bounded by points A, C, D and E - the Pelagos Sanctuary is bounded by points B, C, D and E**

*Traffic Characterization*

The characterization of the traffic was established from a data set from the Automatic Identification System (AIS) to describe ship movements in a given period, and to identify the ships within the study area. The use of AIS is mandatory for ships over 300 tons engaged in international navigation and passenger ships (International Maritime Organization, 2004) and is also recommended for smaller ships (merchant ships, fishing and boating). AIS data are particularly useful to know the vessels speed. The original dataset is characterized as follows:

- Supplier : Vessel Finder (Astra Paging)
- Territory Coverage : Enlarged area described in the methods section
- Temporal Resolution: 1 hour
- Period : 06/01/2013 – 06/01/2015
- Type of Ship : All categories
- Initial Volume : # 1.8 Go (> 14 million lines)

*Accumulated travelled distance by ship*

Accumulated distance was calculated according to the following: $\Delta_i$ represents the distance between two consecutive points among N points from a ship ($v$) trajectory portion in the cell. With $S(v,m)$ representing the number of segments of trajectory from a ship ($v$) in a cell ($m$).
The distance travelled in a cell by portion of trajectory ($s$) from ship $D_c(s)$ is:

$$D_c(s) = \sum_{i=1}^{N} \Delta_{il}$$

The distance calculated for the ship (*v*) in the cell (*m*) is:

$$D_c(v,m) = \sum_{s=1}^{S(v,m)} D_c(s)$$

The total distance travelled per ship (*v*) through *M* cells is:

$$D_c(v) = \sum_{m=1}^{M} D_c(v,m)$$

The cumulated distance travelled by $N_v$ ships in a cell is:

$$D_c(m) = \sum_{v=1}^{Nv} D_c(v)$$

*Traffic at Risk Evaluation and Integrated Weighted Distance Travelled*

The risk of collision with cetaceans depends on several factors: the distance travelled by the ship, speed, and the presence and number of cetaceans in the water surface (on the basis that cetaceans below the water surface have a lower risk of ship encounters (Laist *et al.* 2001)).

To prioritize issues, an indicator of the probability of lethal injury due to collision has been established. The collision lethal injury probability law established by Vanderlann and Taggart, 2007, is applied to every path portion (s) for each vessel (n), in each cell (m) they cross. It takes into account the travelled distance (Dc) and the coefficient of collision risk related to the vessel speed for a given cell and day (Cs), which depends on the vessel speed (Vs). The indicator is the result of the cumulative number of kilometers travelled in the cell and the likelihood of lethal collision injury due to high vessel speed (Figure 3). This indicator is calculated from an average distance weighted by the risk of collision - IWTD (Integrated Weighted Distance Travelled):

$$E(m) = \sum_{n} \sum_{s=1}^{S(n,m)} D_c(s).Cs(n) = \sum_{n} \sum_{s=1}^{S(n,m)} \frac{D_c(s)}{1 + e^{(4.89 - 0.41 V_s(n))}}$$

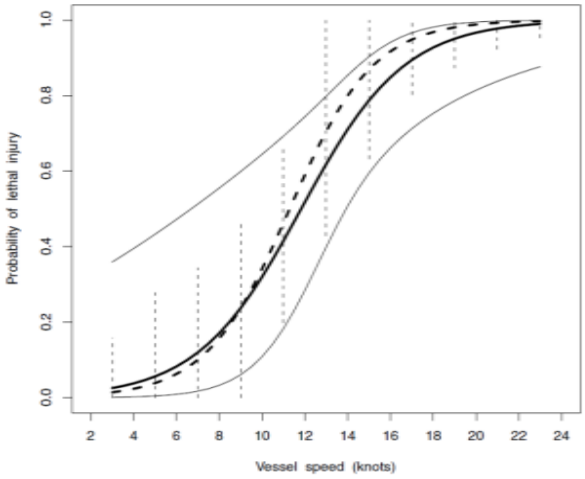


**Figure 3: Lethal collision probability based on the ship speed. According to Vanderlaan and Taggart, 2007**

*Large Cetaceans Data in the Pelagos Sanctuary*

To identify the geographical areas most inhabited by fin whales (*Balaenoptera physalus*) and common sperm whales (*Physeter macrocephalus*), existing summer data from 1994 to 2008 was used (Delacourtie *et al.*, 2009). As a result, reference encounter rate maps have been established for each of these two species. Comparison with recent publications in this area shows that these reference maps are still valid.

Therefore, kriged encounter rates (i.e. number of observations/km of observation effort) are the reference to evaluate collision risks. These data have the advantage of being representative and quantitative with a relatively fine spatial resolution based on a regular cell grid of 0.1 ° x 0.1 ° side, which is about 90 km² each, and covers all of the Pelagos Sanctuary (Figure 4 & Figure 5).

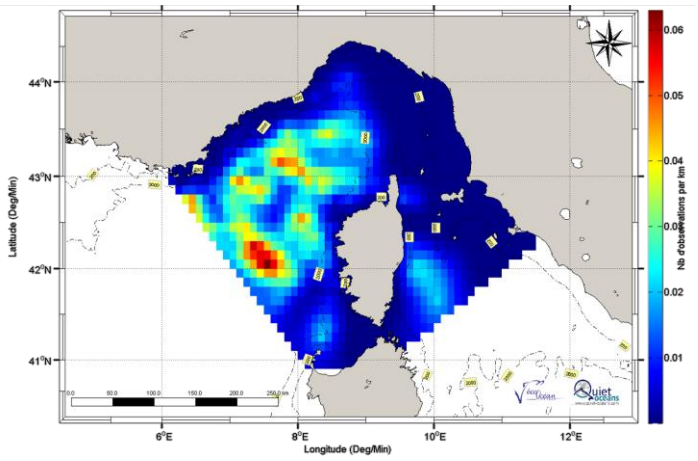


**Figure 4: kriged summer map of the contact rate (number of observations/km) for fin whale (Delacourtie *et al.*, 2009)**

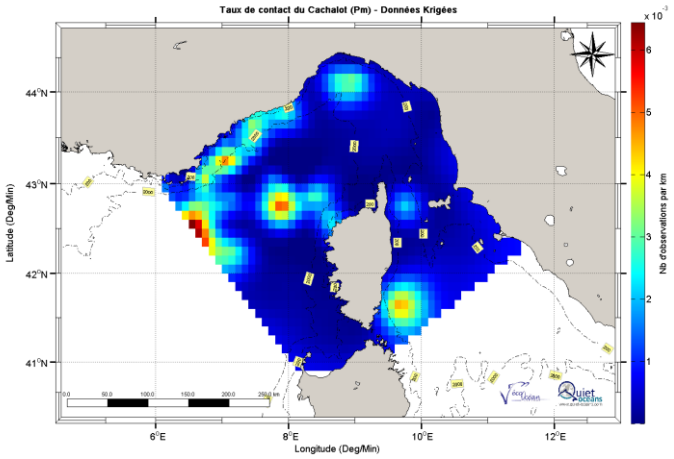


**Figure 5: kriged summer map contact rate (number of observations/km) for sperm whale (Delacourtie *et al.,* 2009)**

Given the lack of data concerning cetacean density in the winter season, we have chosen to only use summer data. Additionally cetacean spatial distribution is similar in both seasons. Moreover, the fact that summer is the period of highest abundance for both species, we can work on the "high" risk assumption, as if the animals remained all year long in the sanctuary with the same abundance.

*Collision Risk Event and Observation Occurrence Assessments*

The collision risk is based on the number of situations where the route of a ship and a whale meet, these situations are called "Collision Risk Events". This model takes into account the width of the vessel (W), the length of the cetacean's species (L), the distance travelled by vessel (Dc), the % of time the animal spends at the sea surface (T), the density of cetaceans (P) by cell; to every path portion (s) for each vessel (n), for each cell (m) they cross. It has been quantified using the Tregenza model (Tregenza, *et al*., 2000) and adapted by David, 2005:

$$N_{Collision\ Risk\ Event}(n) = \sum_{m=1}^{M} \sum_{s=1}^{S(n)} \frac{(W(n) + 0.64L)}{1000} . D_c(s).T.P(m)$$

**Results**

*Maritime Traffic in the enlarged area*

The maritime traffic (AIS equipped vessels) in the enlarged area consisted of 13,856 different ships during the period between 01/06/2013 and 31/05/2015. 4638 ships were present during the last half of 2013 and the first half of 2015, but did not visit the area in 2014, when 9218 ships were identified; demonstrating that significant volatility characterizes the maritime traffic.

By far in 2014, passengers and cargo ships travel the longest distance in the area, followed by cruise ships and fishing vessels (Figure 6). Passenger ships combine 33% of the accumulated distances in all categories, while cargo ships combine 28%.

62% of the ships in the area between 01/06/2013 and 31/05/2015 were European. They represent 75% of the total distance travelled by vessels in the area. Italian and French vessels accounted for more than 50% of the travelled distance in 2014 (Figure 7).

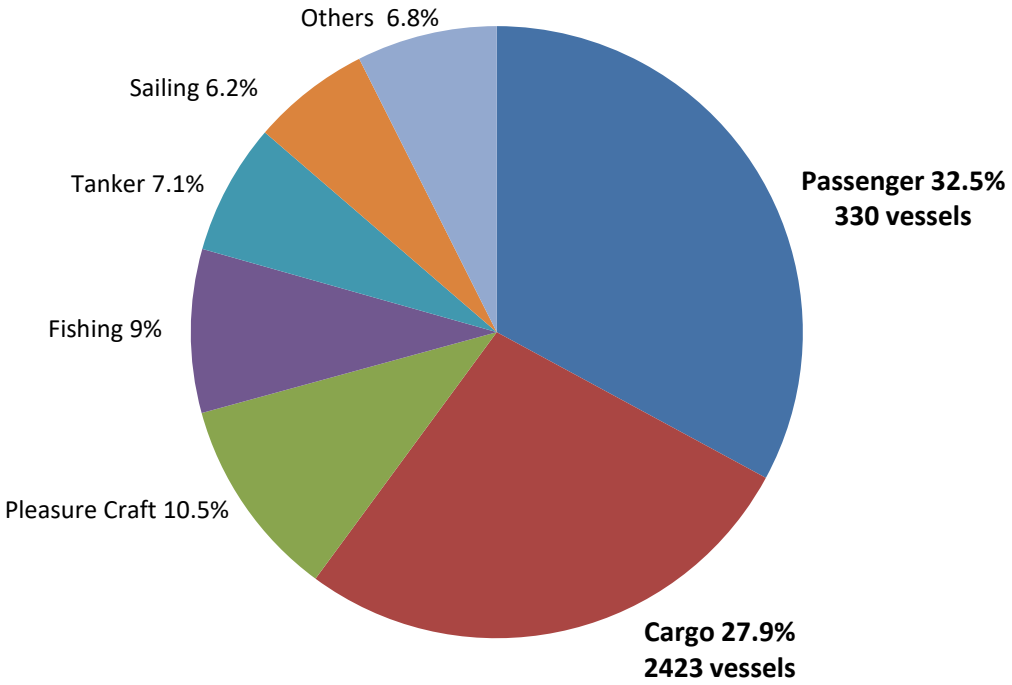


**Figure 6: Travelled distance per ship category**

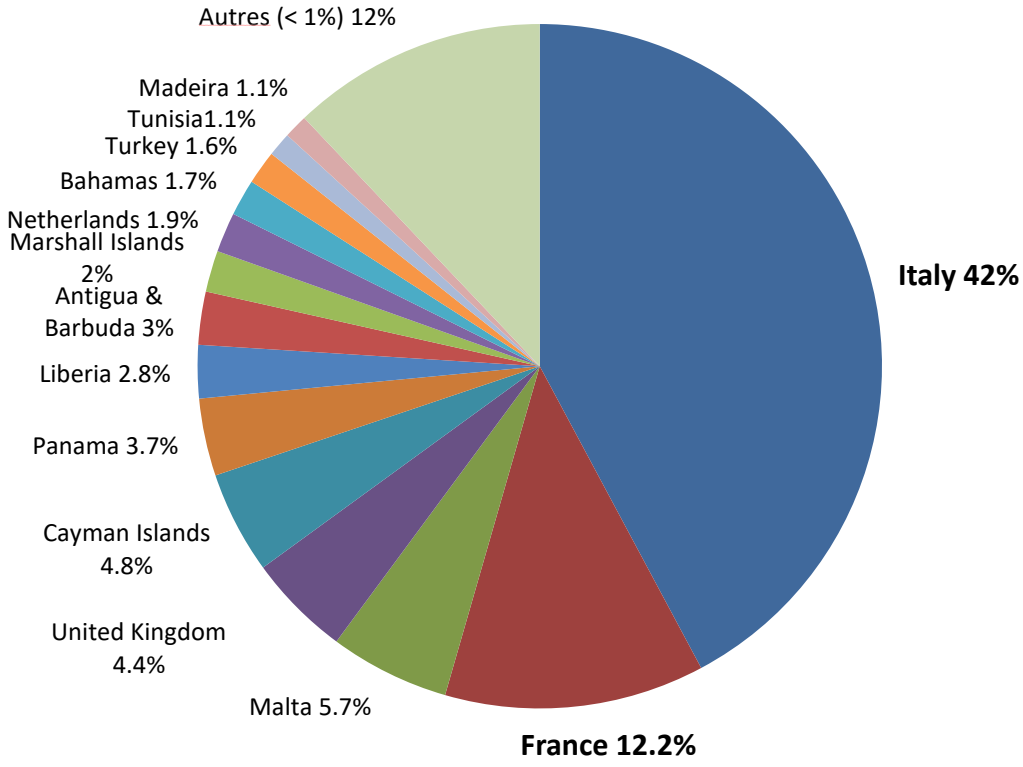


**Figure 7: Presence (in kilometres) by country flags in the Pelagos Sanctuary in 2014**

*Collision issues in the Pelagos Sanctuary*

Several indicators are used to identify collision issues in the Pelagos sanctuary:

- Integrated Weighted Travelled Distance (IWTD) which gives an overview of the risk related to the main traffic characteristics (distance and speed);
- the theoretical number of Collision Risk Events (CRE) which takes into the animal presence probability;
- finally, the number of CRE during the day helps identifying vessels where installing the REPCET system would be most beneficial in potentially reducing collision risk with cetaceans.

Overall, the entire 2014 traffic in Pelagos generated a theoretical collision probability of 3465 CRE among which 3168 events were related to fin whales and 297 to sperm whales. The difference between the two species is related to their respective abundance. This figure is much higher than that of known collisions, when we take into account the research findings of Panigada, that estimated 8 to 40 fin whale lethal collisions per year. We can partly explain this by the fact that the calculation of theoretical CRE is based on the summer abundance of animals, which is probably higher than in winter.

Among the 3465 collision probabilities, 1523 (43%) would occur during the day, facilitating observation and the implementation of REPCET.

Vessels flying the French and the Italian flag, two signatories of the Pelagos Agreement bear more than half of traffic at risk (57%, Figure 8).

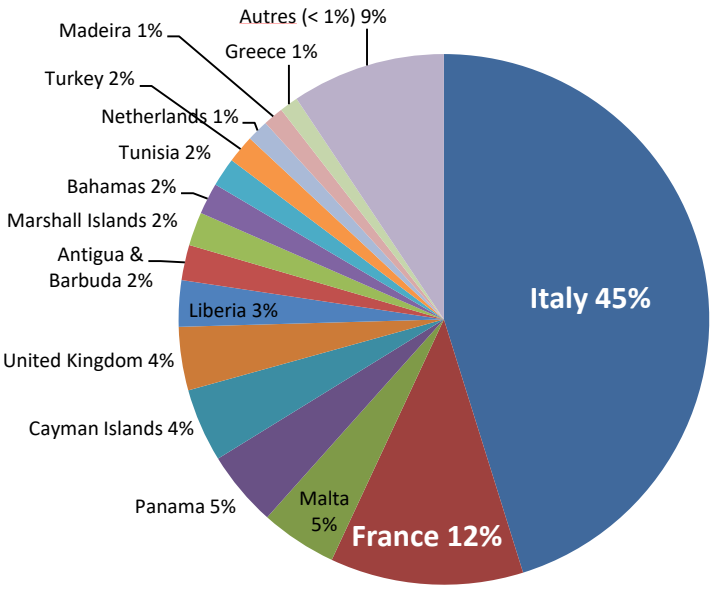


**Figure 8: Global collision issues (traffic weighted by the IWTD collision risk)**

Passenger and cargo ship traffic is more at risk with 79% of the traffic collision risk weighted (IWDT) and 82% of the theoretical collision risk (CRE) (Figure 9). Passenger traffic is seasonal, with doubled

frequency in the summertime; and fast, with speeds exceeding 20 knots (23mph). This suggests that vessels for which a warning system would be most useful are passenger ships, followed by cargo ships.

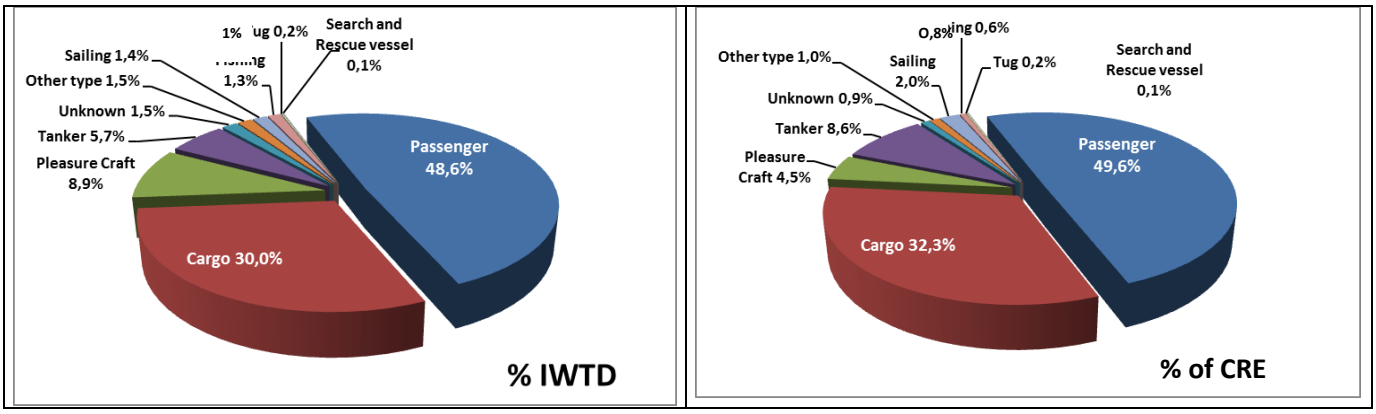


**Figure 9: Global Collision Issues (IWTD, traffic collision risk weighted) and theoretical collision risk (CRE) by vessel types**

*Collision Issues per ship and the REPCET system*

Collision issues concern a relatively small number of vessels. Looking at the global traffic risk indicator (IWTD) in the established area: 26 vessels accumulate 30% of the total traffic risk in the Pelagos Sanctuary (2014), and 84 vessels bear 50% of the traffic risk (IWTD) (Figure 10).

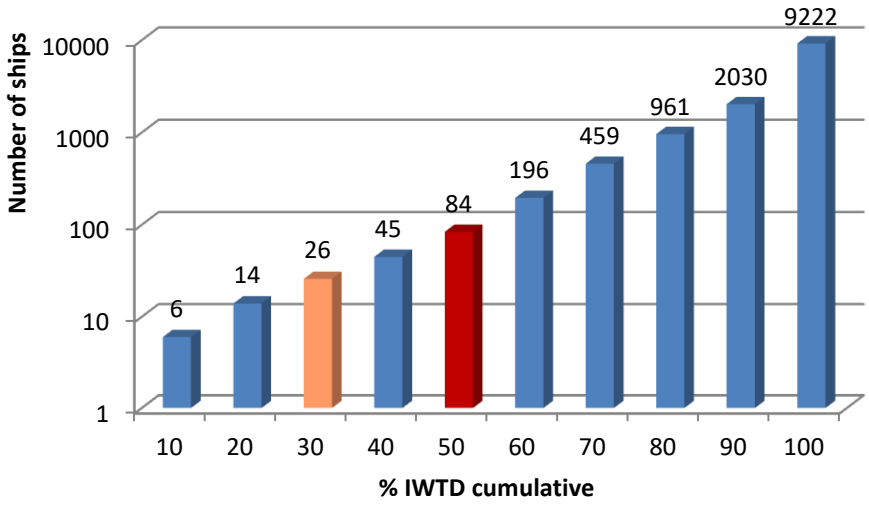


**Figure 10: Number of vessels based on the cumulative percentage of traffic risk (IWTD)**

Looking at the theoretical collision risk per day (CRE), 29 ships generate 30% of the collision probability, and with 172 ships we reach 50% (Figure 11).

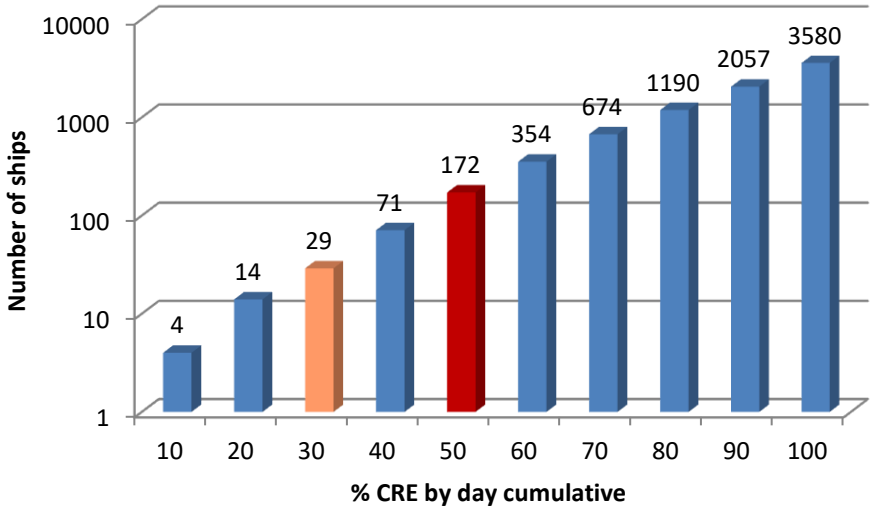


**Figure 11: Number of vessels based on the cumulative percentage of theoretical collision risk by day (by day CRE)**

To identify the companies operating the vessels most affected by collisions and therefore would potentially benefit with the implementation of REPCET type collision avoidance systems, they have been placed on a chart crossing on the one hand the risk of collision and on the other hand the number of vessels operated by the company, which cannot be displayed here due to confidentiality. The number of vessels operated by a company is an indicator of the investment to be made by the company to get the equipment.

Seven primarily affected companies were thus identified. The 96 ships belonging to those companies represent almost half of the traffic risk in the Pelagos sanctuary and one third of the theoretical collision risk. Two of these companies are French, the other five are Italian.

**Discussion**

The Pelagos Sanctuary is severely impacted by maritime traffic with more than 18 million kilometres travelled in 2014 by vessels equipped with the AIS system. With an average growth rate stabilized at 4% per year (Piante & Ody, 2015), the traffic is expected to double every 17 to 18 years.

This traffic generates nuisances for cetaceans, disturbance and noise, but also the more serious risk of collisions that can lead to lethal injury. The collision rate is 3.25 times higher in the Pelagos Sanctuary than elsewhere in the Mediterranean (Panigada *et al.*, 2006) because in this area there is a combination of high abundance of cetaceans and heavy marine traffic, especially ferries for French and Italian islands.

The theoretical collision risk calculation results in an annual number of potential collisions of 3465 (3168 for fin whales and 297 for sperm whales). The ecological cost (feeding, reproduction, socialization, etc.) of this disturbance is unknown but potentially significant.

If thousands of ships have travelled the Pelagos sanctuary in 2014, a relatively small number concentrate the collision risk. Thus a few hundred ships represent half of the traffic risk and generate a little less than half of the collision risk per day.

Concerning these 100 vessels, an annual budget of € 360,000 (3600 € per vessel) would make it possible to equip them with a REPCET type collision avoidance system, and potentially significantly reduce the collision risk.

In France, REPCET became mandatory on July 1st 2017 (LOI n° 2016-1087 du 8 août 2016 pour la reconquête de la biodiversité, de la nature et des paysages) for French passenger boats, cargos and state boats, longer than 24m and crossing Pelagos Sanctuary more than 10 times a year. This increase of REPCET equipped vessels increased reported cetacean observations to 927 sightings in 2017 compare to 492 in 2016. Today 35 vessels are equipped with REPCET: 31 French vessels and 4 Italian vessels.

*Recommendations*

With the uptake of REPCET on more ships, an evaluation of its efficiency, the reduction of collisions, increased reporting, and user perceptions is necessary. Additionally, the collision rate data with stranding and collision reports from 2006 needs to be updated and monitoring indicators defined. WWF-France, Thetys and Souffleurs d'ecume plan to carry out these activities by 2020.

Furthermore, innovative solutions are currently being investigated for the situations outside of REPCET's current capabilities, such as conditions with low visibility or night use.

Finally, the declaration of Pelagos as a Particularly Sensitive Sea Area (PSSA) would allow additional management measures to be implemented, such as speed reduction requirements, which would reduce risk of collision to cetaceans even further.

**List of figures**

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