Agenda Item 6.1	Project Funding through ASCOBANS Progress of Supported Projects
Document 6-04 rev.1	**Project Report: Risk Assessment of Potential Conflicts between Shipping and Cetaceans in the ASCOBANS Region**
Action Requested	• Take note of the report
Submitted by	Secretariat / Sea Watch Foundation

UNEP ASCOBANS

NOTE:
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Risk Assessment of Potential Conflicts between Shipping and Cetaceans in the ASCOBANS Region

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BACKGROUND The ASCOBANS Region contains some of the busiest waterways in the world. The North Sea receives more than 400,000 ship movements a year, with particularly heavy traffic through the traffic separation scheme in the Strait of Dover where approximately 150 ships per day pass in each direction, in addition to an average 300 ferry crossings daily (North Sea Task Force, 1993). The dredged entrance route to Rotterdam/Europort and its connecting route through the Channel permits navigation of vessels of up to 400,000 tonnes with a maximum depth of 24 m. There is also a heavy flow of shipping from the North Sea to the Baltic via the Kiel Canal, with c. 47,000 vessel movements. Most of the European Community's largest ports are on the North Sea coasts and rivers: Hamburg, Amsterdam, Rotterdam, Antwerp, Le Havre and London. Rotterdam/Europort is by far the largest port, followed by Antwerp, Hamburg, and London. Other areas within the ASCOBANS Region also receive shipping traffic, although the relative densities of these are not clearly known. Over the last twenty years, the number of shipping movements, size of vessels and their average speeds have all increased in the region (OSPAR, 2010).

Approximately half the shipping activity in the North Sea consists of ferries and roll-on/roll-off vessels on fixed routes, while, for example, in United Kingdom ports, tanker traffic represents about 10% and chemicals around 4% of ship departures (North Sea Task Force, 1993). These large vessels not only may pose a direct threat of physical damage by collision with cetaceans, they can also significantly raise ambient sound levels by the noise generated from their engines which itself may cause disturbance to cetaceans, and possible habitat displacement (Evans, 2003).

There have been records of vessels colliding with cetaceans dating back at least to the middle of the last century. However, it is only in the last decade that it has been recognised as a potential conservation issue (Vanderlaan & Taggart, 2007, 2009). With the ever greater speeds exhibited by shipping – tankers, ferries, yachts, and a wide variety of small craft, it is a problem likely to increase. In a wide-ranging review of the topic, Laist *et al*. (2001) noted that although all types and sizes of vessels can be involved, most lethal or severe injuries are usually caused by ships travelling 14 knots (26 km/h) or faster and of 80 metres length or more. Damage in the form of cuts to the dorsal fin and back tend to be the result of strikes from small craft, although larger vessels can also cause similar damage. The probability of a ship strike being lethal increases markedly as vessel speeds increase from 10-15 knots (Fig. 4b; Vanderlaan & Taggart, 2007). Evidence of vessel collisions has been reported for at least 21 cetacean species, a third of which were small cetaceans covered by the ASCOBANS Agreement (Evans, 2003).

Since 1990, the UK has been undertaking regular post mortem studies of cetaceans stranding around the British Isles under the Cetacean Strandings Investigation Programme (CSIP). Causes of mortality have been assessed, resulting in estimates of the proportions of post mortem examinations (PMEs) that can be attributed to physical trauma. This excludes animals showing signs of physical damage attributable to either bottlenose dolphin attack or by-catch. However, it includes cases of physical trauma of unknown origin and some of these could belong to one or other of those categories.

Table 1. Cases where physical trauma was diagnosed as most likely cause of death for cetaceans stranded around the British Isles, 1990-2010 (from CSIP database)

Cetacean Species	Number of PMEs	Number with physical trauma	Percent with physical trauma
Fin whale	5	1	20%
Minke whale	20	3	15%
Harbour porpoise	1729	76	4%
Common dolphin	346	15	4%
White-beaked dolphin	52	3	6%
Risso’s dolphin	20	1	5%
Sowerby’s beaked whale	16	1	6%

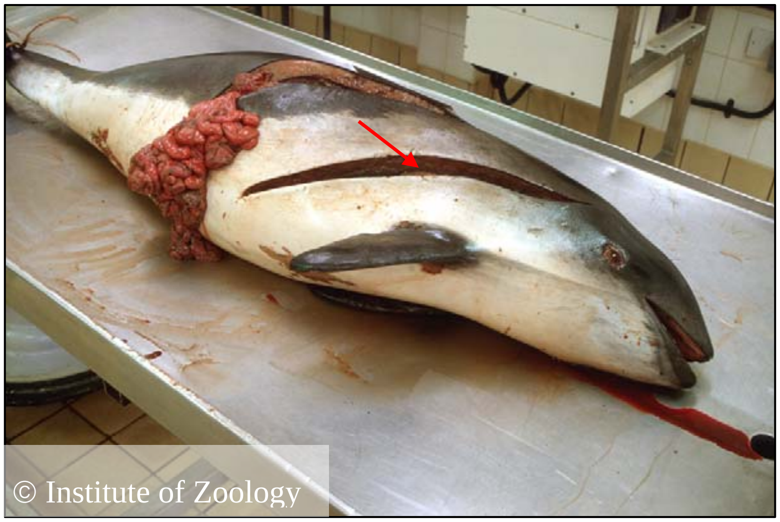
The results indicate that between 15-20% of baleen whales examined at post mortem have suffered mortality from physical trauma whereas in small cetaceans, it is rather less, at between 4-6% (Table 1). Nevertheless, it does highlight that small cetaceans do experience vessel strike, some having clear signs of blunt trauma including propeller cuts (see Plate 1). It is also not confined to just a few species. A review of post mortem resulta from each country’s strandings programmes reveals that a further seven cetacean species in the ASCOBANS Agreement Area have died as a result of physical trauma presumed to be vessel strike: humpback whale, sperm whale, killer whale, long-finned pilot whale, bottlenose dolphin, Atlantic white-sided dolphin, and striped dolphin.

MAIN AIM The principal aim of this project was to reach a better understanding of the risk posed by shipping to small cetaceans within the ASCOBANS Agreement Area, so as to advise on how best to develop ways to mitigate any adverse effects.

SPECIFIC OBJECTIVES

a) Acquire AIS data in synthesized form showing ship movements per unit time over the ASCOBANS Agreement Area.
b) Develop GIS shape files that allow plots of vessel density by grid cell for the major types of shipping.
c) Using effort-related sightings data gathered across the region, plot sightings densities by grid cell for the main cetacean taxa (baleen whales, large toothed whales, dolphins & porpoises).
d) Identify main areas and seasons for potential conflict between shipping and cetaceans.

a) Dead harbour porpoise



b) Living bottlenose dolphin

Plate 1. Evidence of physical trauma in small cetaceans

METHODS

a) Mapping Shipping Distribution

i) AIS and LRIT systems

Automatic Identification System (AIS) is a VHF broadcast system (working on 161.975 MHz and 162.025 MHz) that sends information at regular intervals including the identity of the vessel (MMSI number), its position, course and speed to other vessels and to shore receivers..Since it is a VHF system, transmissions to shore stations (or other vessels) are generally limited to line of sight.

Since January 2005, the International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more tons, and all passenger ships regardless of size. Within the EU, fishing vessels with an overall length of more than 15 metres will also be required to use AIS. Directive 2009/17/EC of the European Parliament sets the timeline for AIS requirements for different sizes of fishing vessels with larger vessels being required to use AIS in 2012 and all over 15m vessels in 2014. It is estimated that more than 40,000 ships currently carry AIS class A equipment.

Normally, vessels with an AIS receiver connected to an external antenna placed on 15 metres above sea level, will receive AIS information within a range of 15-20 nautical miles. Base stations at a higher elevation, may extend the range up to 40-60 nm, depending on elevation, antenna type, obstacles around antenna and weather conditions. The most important factor for better reception is the elevation of the base station antenna. The higher it is, the better. Vessels can be detected 200 nm away, with a small portable antenna placed on an island mountain at 700 metres altitude. However, often the receivers are closer to sea level and coverage is much lower, whilst range can be affected by atmospheric conditions. Data used for this study were derived from www.marinetraffic.com//ais, which has c. 200 AIS receivers within the ASCOBANS Agreement Area. They claim that their base stations cover fully a range of 40 miles and periodically receive information from some more distant vessels. We tested this in the Irish Sea by following the tracks of vessels offshore to determine whether they remained visible through AIS live maps, and they did indeed do so. However, the maximum distance from coast to coast in this region is about 50 nautical miles so that the Irish Sea is likely to be covered by at least one receiving station. This is unlikely to be the case for a more extensive area of sea such as the North Sea, as suggested also from Figure 1.

In addition, passenger ships, high speed craft, and cargo ships of 300 gross tonnage and upwards have been required to be fitted with a Long-Range Identification and Tracking (LRIT) system from 1 January 2009. This is a satellite based system that can relay messages to shore stations from anywhere in the world. This has less frequent transmission, vessels being required to report four times a day to either national or regional LRIT Data Centres. The data sharing system allows IMO member governments to track any ship within a 1,000 nautical mile zone of its coastline. However, unlike AIS which is an open broadcast system that can be received by any suitable equipment, LRIT information is only available through the LRIT Data Centres, and IMO regulations contain a number of provisions on the use of the data. In 2007, it was agreed to set up a European LRIT Data Centre.

ii) VOS Monitoring Systems

Ships from many countries voluntarily participate in collecting meteorological data globally, and therefore also report the location of the ship. Such data can be used to map shipping densities (see Figs. 10 & 11), and have been utilized to identify areas where shipping noise may be a particular threat to marine mammals (NMFS, 2005; AEI, 2010). For this project, we used data collected from 12 months beginning October 2004 (collected as part of the World Meteorological Organization Voluntary Observing Ships Scheme; http://www.vos.noaa.gov/vos_scheme.shtml; see also Halpern *et al*., 2008) as this year had the most ships with vetted protocols and so provides the most representative estimate of global ship locations.

The data include unique identifier codes for ships (mobile or a single datum) and stationary buoys and oil platforms (multiple data at a fixed location); all stationary and single point ship data were removed, leaving 1,189,127 mobile ship data points from a total of 3,374 commercial and research vessels, representing roughly 11% of the 30,851 merchant ships >1000 gross tonnage at sea in 2005 (B. Halpern, *pers. comm.*). All mobile ship data were then connected to create ship tracks, under the assumption that ships travel in straight lines (a reasonable assumption since ships minimize travel distance in an effort to minimize fuel costs). Finally, we removed any tracks that crossed land, buffered the remaining 799,853 line segments to be 1 km wide to account for the width of shipping lanes, summed all buffered line segments to account for overlapping ship tracks, and converted summed ship tracks to raster data. This produced 1 km^2 raster cells with values ranging from 0 to 1,158, the maximum number of ship tracks recorded in a single 1 km^2 cell.

Because the VOS program is voluntary, much commercial shipping traffic is not captured by these data. Therefore our estimates of the shipping are biased (in an unknown way) to locations and types of ships engaged in the program. In particular, high traffic locations may be strongly underestimated, although the relative impact on these areas versus low-traffic areas appears to be well-captured by the available data (Fig. 10), and areas identified as without shipping may actually have low levels of ship traffic. Furthermore, because ships report their location with varying distance between signals, ship tracks are estimates of the actual shipping route taken.

b) Mapping Cetacean Distribution

As a preliminary investigation of ways to assess risk to cetaceans of ship strike within the ASCOBANS Agreement Area, the Irish Sea was first chosen since vessel coverage using AIS was likely to be more comprehensive, and there had been a recent collation of cetacean sightings data to investigate distribution patterns (Baines & Evans, 2009). Sixteen research groups contributed 37,266 hours of survey effort data, spanning the years 1990-2007. Spatial coverage amounted to 376 (>90%) of the 414 cells into which the Irish Sea region was divided. The project database comprised 22,422 sightings (77,799 individuals) of 12 cetacean species. Potential biases in sightability relating to survey/platform type and speed were assessed using data gathered from different activities in the same area over the same time period. GIS maps of sighting rates were then prepared using a grid with resolution of 10’ latitude x 10’ longitude, following correction for variation in sightability of different species at different sea states, for land based watches using scan sampling, and for aerial versus vessel surveys.

A variety of interpolation methods were examined to assess the best way to interpolate the data and for plotting smoothed maps of relative abundance. These included Inverse Distance Weighting (IDW), Kriging, Minimum Curvature, Natural Neighbour, Nearest Neighbour, Polynomial Regression, Radial Basis Function, Triangulation with Linear Interpolation, Moving Average, and Local Polynomial. IDW was selected on the basis of giving the best visual representation of the data and the best fit when compared with plots of raw sightings data.

The IDW method assumes that each input point has a local influence that diminishes with distance, weighting the influence of areas closer to the input point greater than those farther away. Input points within a specified radius of 20 km were used to determine the output value for each cell in a raster grid with 299 columns and 239 rows, equivalent to a resolution of approximately 50 seconds of latitude by 50 seconds of longitude. Input points were calculated as the mean position of sightings for any given species within each cell, rather than the cell centroid. Low levels of effort in some cells can give rise to unreasonably high sightings rates, and interpolation may effectively spread such spuriously high values into neighbouring areas, and so data from cells with low levels of effort (2 hours or less per cell) were filtered out before applying the interpolation process.

The next phase of analysis involved taking wider data sets to produce interpolated maps of relative density for cetaceans across the entire ASCOBANS Agreement Area. A number of dedicated surveys have been undertaken between 1990 and the present in Northwest European waters. Data from many of those surveys (including the 1994 and 2005 synoptic SCANS abundance surveys, the CODA shelf sea survey in 2007, the ESAS and SWF databases, and various French surveys in the Bay of Biscay) were collated, corrected for effort, and the effects of sea state upon detection rates incorporated, before plotting relative densities using interpolation by inverse distance weighting using the same procedures as described above for the Irish Sea (Fig. 12). Most surveys were conducted during summer months (April – September), effort being lowest in the first quarter of the year (January – March) (Fig. 13). The database used spanned twenty years of survey effort, totalling just under 100,000 hours and yielding 44,500 sightings.

RESULTS

Two methods of recording shipping were compared: AIS and VOS. AIS had the advantage that it covered a greater variety of vessel types and information on vessel speeds was available. On the other hand, the AIS receiving stations were largely shore-based, and it was clear from a snapshot map of AIS vessel distribution (Figure 1) that even if shipping density offshore is low, shipping is probably under-recorded, with some areas out of AIS range. Twelve hours of observation were undertaken from the north coast of Anglesey (North Wales) where there was a visual range of c. 20 nm. All vessels observed were checked directly against AIS live maps on the internet. One hundred percent of tankers, passenger and cargo vessels were detected by AIS, but no military vessels, fishing vessels, yachts, or other small vessels were recorded. Elsewhere, some fishing vessels were registered by AIS, although generally only the larger ones.

Scripts were written for automatic downloads of AIS data from the marinetraffic website. The shipping data were in ESRI grid format and a sample of ten datasets were then plotted in ArcView. Figure 5 represents the mean density of vessels (i.e. mean number per grid cell). These were then split into five speed categories: <5, 5-10, 10-15, 15-20, and >20 knots (nautical miles/hour). Plots of all but the slowest category are shown in Figures 6a-d. Any vessel with a speed of less than one knot was filtered out as these were probably at anchor or on a mooring.

In the Irish Sea, five cetacean species were recorded regularly and in reasonable numbers: harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), and minke whale (*Balaenoptera acutorostrata*) (Baines & Evans, 2009). The harbour porpoise was the commonest and most widespread species, with concentrations north and west of Anglesey, off Co. Dublin in Ireland, west of Pembrokeshire and in the Bristol Channel. The bottlenose dolphin was the next most frequently recorded species, with a predominantly coastal distribution, particularly concentrated in Cardigan Bay (in summer) and north and east of Anglesey (in winter). Risso's dolphins had a relatively localised distribution, forming a wide band running SW-NE that encompasses west Pembrokeshire, the western end of the Llyn Peninsula and Anglesey in Wales, the south-east coast of Ireland in the west, and waters around the Isle of Man in the north. The short-beaked common dolphin and minke whale both had largely offshore distributions centred upon the Celtic Deep where water depths exceed 50 metres. Besides the minke whale, the only other large cetacean species recorded live were fin whale and humpback whale, both in very small numbers. Figure 7 shows the Irish Sea distribution of all cetacean species combined, with centres of occurrence in the Celtic Deep between South-west Wales and South-east Ireland, and in the central Irish Sea between North Wales and eastern Ireland.

The relative risk of ship strike (Figures 8 & 9) takes vessel speed and sightings rates of cetaceans into account (i.e. it is the density of vessels scaled by speed multiplied by the sightings rates of all cetacean species combined for each cell). Since large cetaceans (baleen whales and the sperm whale) are known to be most vulnerable to ship strikes (because they move relatively slowly and may log at the surface whilst resting), whereas Figure 8 assesses risk for all cetacean species, Figure 9 shows risk using only relative densities of those large cetacean species in the Irish Sea region. However, in both cases, risk was highest in the sea area between North Wales and the central east coast of Ireland (Co. Dublin) and between South-west Wales and South-east Ireland (Co. Wexford), probably reflecting the regular ferry lines that operate across these two regions.

The maps of shipping activity using the VOS system (Figures 10 and 11) apply to a 12-month period and show entire tracks. They therefore show much greater amount of shipping movements than the average of ten AIS snapshots and so are not directly comparable. They also currently omit to show movements from some ferries, which probably explains why the two centres of shipping activity that show up from the AIS data, are not prominent in Figure 11.

On a wider geographical scale, that of the entire ASCOBANS Agreement Area, shipping activity, as determined from both AIS and VOS, indicates the importance of the English Channel and coastal waters of the Netherlands and Germany, along with Inner Danish waters (Belt Seas & Kattegat) (Figures 2 & 10). In the busiest area, most ships are passenger vessels (mainly ferries but also cruise ships in summer), tankers, or cargo vessels (Figure 3). An analysis of average speeds traveled by vessels indicates that most are traveling at speeds exceeding 10 knots (Figure 4a). Modeling studies of risk of lethal strike for large cetaceans off the eastern seaboard of North America highlight the marked increase in risk as vessel speeds increases from 10 to 15 knots (Figure 4b; Vanderlaan & Taggart, 2007).

Cetacean survey effort over the period 1990-2010 has covered most of the ASCOBANS Agreement Area, the main gaps being offshore south of 48^{o} N (Figure 12). Coverage is greatest in near-shore waters. Seasonally, coverage is best between April and September, and worst between January and March (Figure 13).

Relative densities of cetaceans (expressed as numbers per hour of survey effort), combining all species, are lowest in the English Channel and western Baltic, and highest in the southern Kattegat, Danish Belt Seas, northwestern North Sea, NW Scotland, southern Irish Sea, SW Ireland and the Celtic Sea, the Bay of Biscay and off north-west Spain and Portugal (Figure 14). Densities appear to be highest between April and December, and particularly on the continental shelf between July and September.

When large cetaceans (the group at most risk) only are considered, the shelf edge, Bay of Biscay, NW Spain and northwestern North Sea have the highest densities, at least between April and December (Figure 15). Survey coverage during the first three months of the year is probably too low to reveal higher density areas. Overall relative densities for all cetaceans and large whales are depicted in Figure 16, and highlight those areas detailed above.

When shipping densities are incorporated into the models, the main areas of strike risk to show up are in parts of the Celtic Sea, Bay of Biscay, and off NW Spain, both when considering all cetaceans (Figure 17) and specifically for large whales (Figure 18). Despite the very high shipping densities in the English Channel, southern North Sea and inner Danish waters, there are only a few areas (for example porpoises in the Kattegat) where risk of vessel strike appears to be high (Figure 19). This is due mainly to the low cetacean densities (particularly of large whales) in those areas. Of course, it cannot be discounted that the low densities of cetaceans may be in part due to high ship traffic.

CONCLUSIONS & FUTURE RECOMMENDATIONS

Both AIS and VOS data highlight the following areas as having high shipping densities: English Channel, southernmost North Sea, Kattegat and Danish Belt Seas, and western and central Baltic (see Figures 1, 2 & 10). Most of these are well known, in fact, as high shipping density regions. Of those regions, small cetacean species diversity is highest in the western English Channel, whilst porpoise abundance is greatest in the southern North Sea and Danish Belt Seas (Reid *et al*., 2003; Evans *et al*., 2003; Hammond *et al*., 2002; Hammond, 2008). Large cetaceans, the group most vulnerable to ship strike, are comparatively scarce in all those areas, all with the exception of the minke whale occurring mainly in deep waters off the edge of the continental shelf (Figures 19 & 20).

The different systems for monitoring the locations of ships, along with archiving procedures, are still being actively developed, and increasingly, data are becoming available within the public domain. The advantage of the VOS data set is that it has even coverage of the ASCOBANS area, whereas the AIS data that we have accessed only provide coverage within VHF signal range of the coast (which varies with receiver height and meteorological conditions). Although the VOS ship tracks do not differentiate vessel type or speed, those data may still be available. This requires further investigation. A next stage would be to overlay the 30 x 15 minute grid used for plotting cetacean relative densities, and sum the lengths of track segments within each cell to arrive at shipping density values. The same should be conducted for a larger sample of AIS data with ship tracks derived if possible by developing data capture methods to include course, so that vessel tracks leaving and arriving at coastal locations may be plotted on a much wider geographic scale. Alternatively, if archived AIS could be obtained, that would make analyses much more straightforward. The role of vessel speed in assessing risk of a lethal ship strike is crucial, as demonstrated earlier. It would therefore be particularly valuable if a more refined analysis could be conducted (using an extensive data set) to examine spatial and temporal variation in vessel speeds.

As noted above, AIS data obtained from VHF receivers will always have limited range and therefore will not readily capture shipping data from far offshore. For this, ship locations from satellite, such as held by the European LRIT Data Centre, would be necessary. On the other hand, actual ship tracks and vessel speeds may be difficult to calculate from these alone. If shipping data were available seasonally, a seasonal comparison of the two data sets could also be made.

The data set used in the current analysis to obtain relative sightings densities for the entire region covered by the ASCOBANS Agreement, still has some gaps in survey coverage, particularly for offshore waters beyond the continental shelf edge, as well as west of the Iberian Peninsula, and the western sector of the Bay of Biscay (and between October and March, most of the rest of the Bay of Biscay). Surveys that have been conducted in the offshore areas include the NASS surveys (in 1985, 1987, 1995, 1996-2001) by Iceland, Norway, the Faroe Islands, and, in earlier years, Spain. Incorporating those data with the other surveys would give more complete coverage and ultimately yield more representative maps of ship strike risk.

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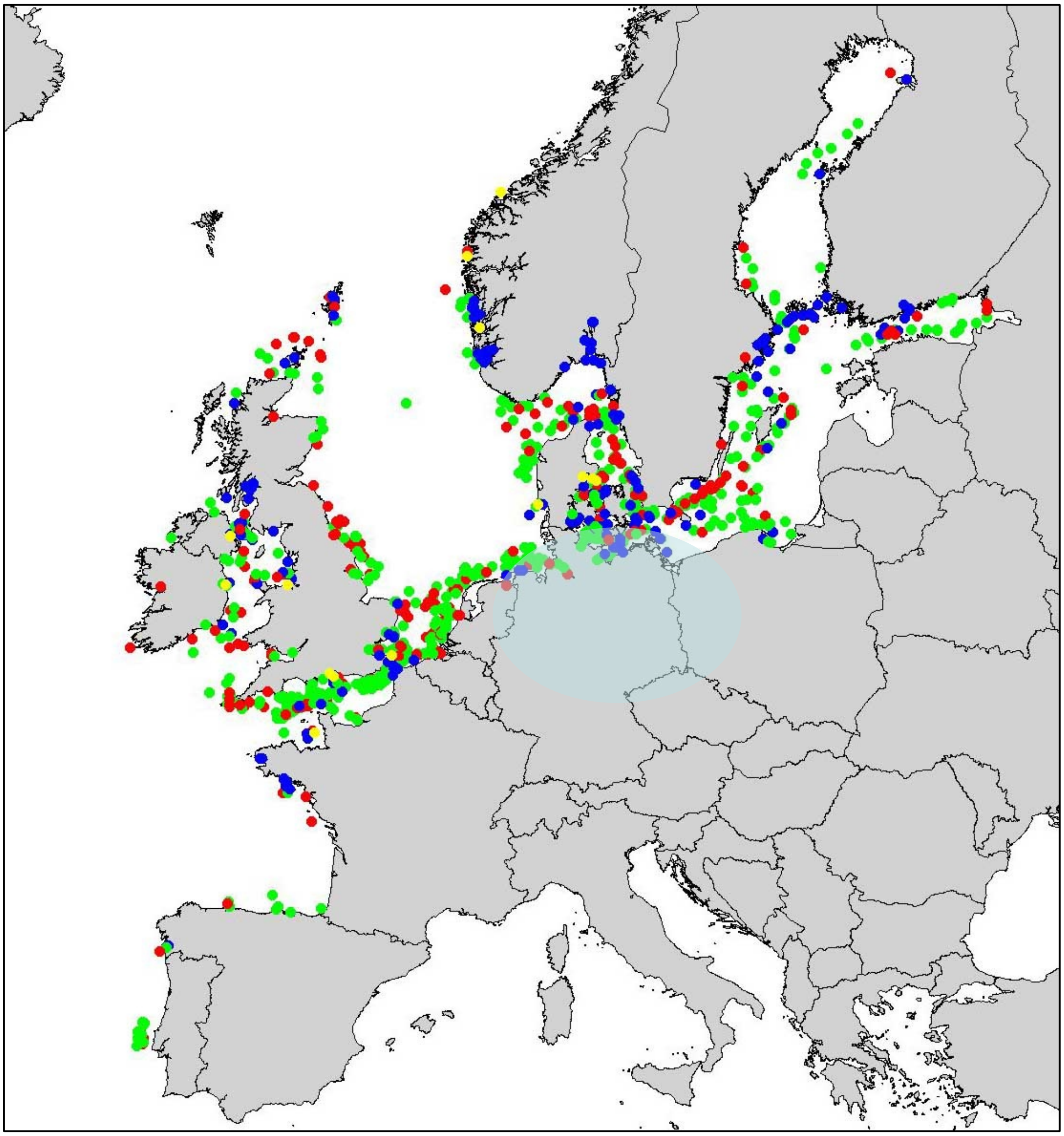


Fig. 1. AIS Plot for shipping in ASCOBANS Region during 20 Feb 2010 (red = tankers; blue = passenger vessels; green = cargo vessels; yellow = high speed craft)

Fig. 2. Number of ships recorded by AIS in the ASCOBANS Agreement Area, 15 Aug 2010 (oval area highlighted is shown at higher resolution in Fig. 3)

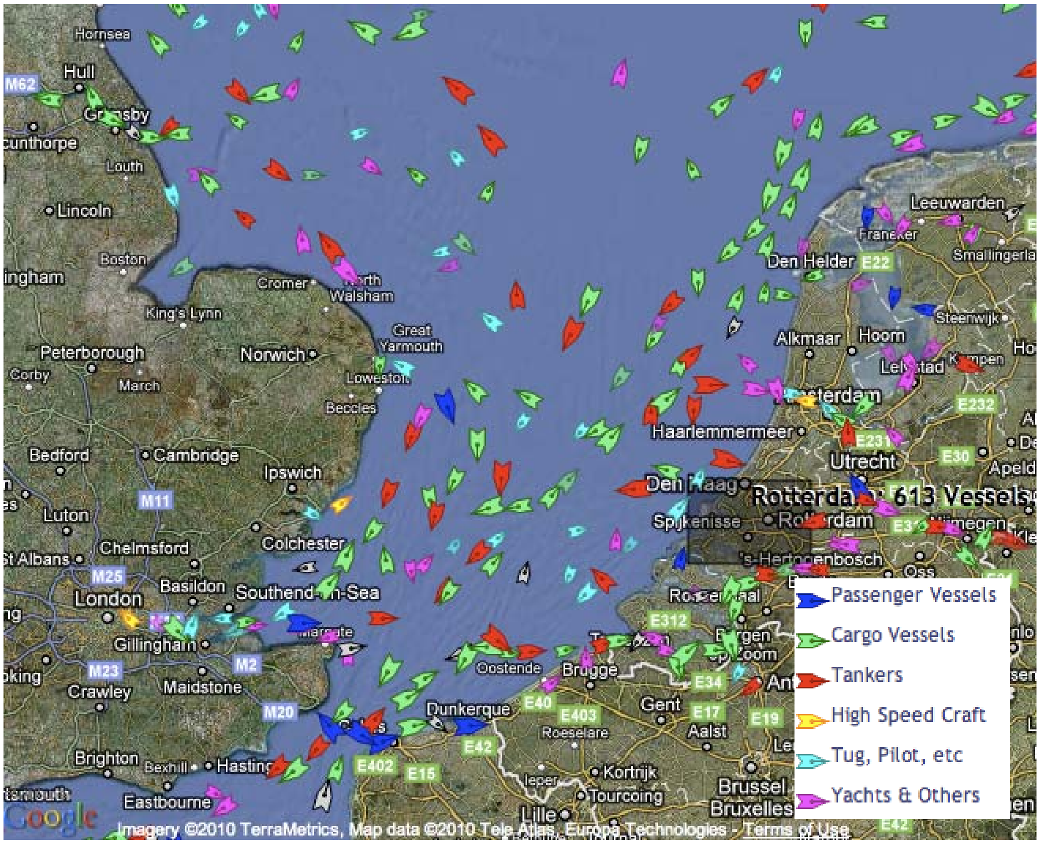
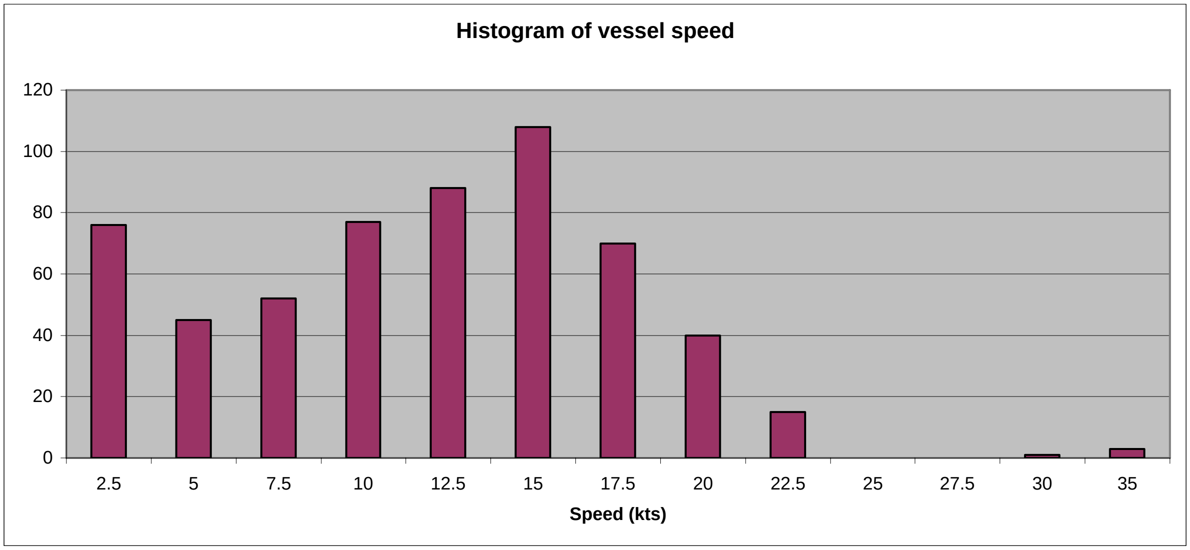


Fig. 3. Distribution of Shipping in the Southern North Sea & English Channel, 15 Aug 2010

a)



b)

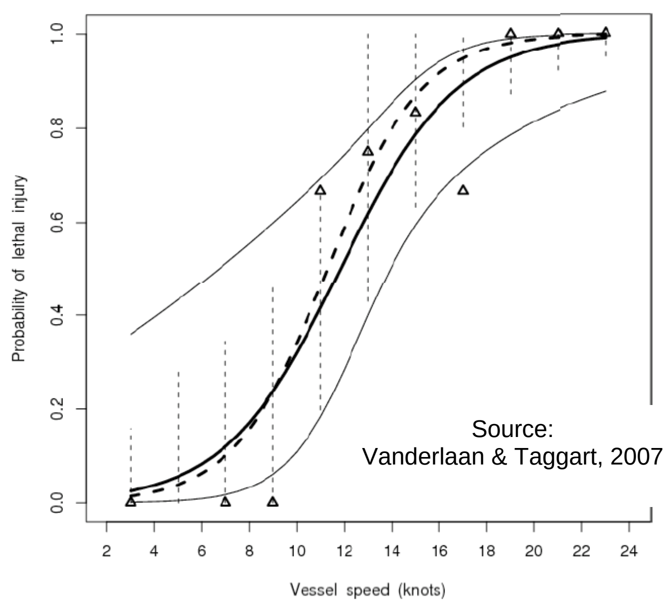


Fig. 4. a) Frequency of Vessel Speeds amongst Shipping in the ASCOBANS Agreement Area; and b) Probability of a Lethal Strike at different Vessel Speeds

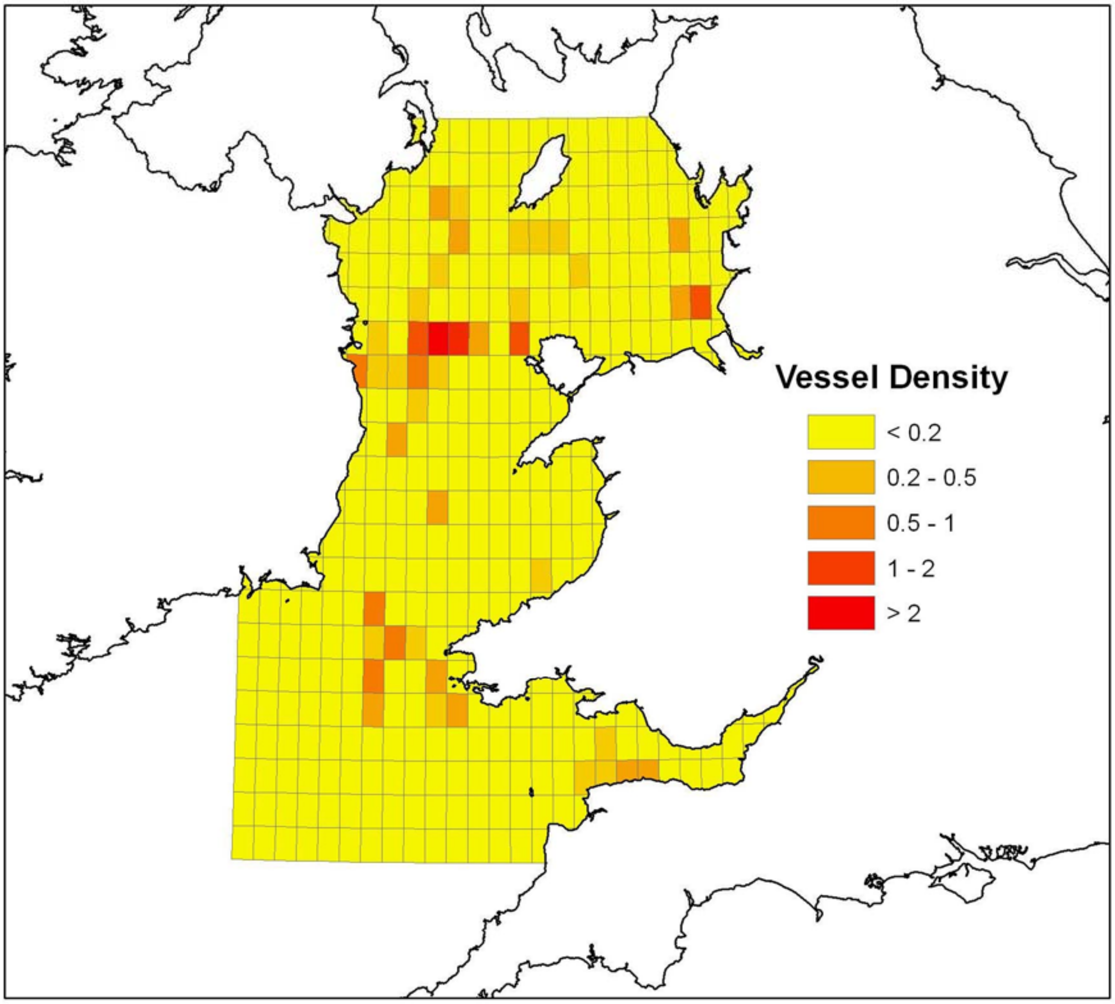


Fig. 5. Vessel Densities within the Irish Sea from AIS data

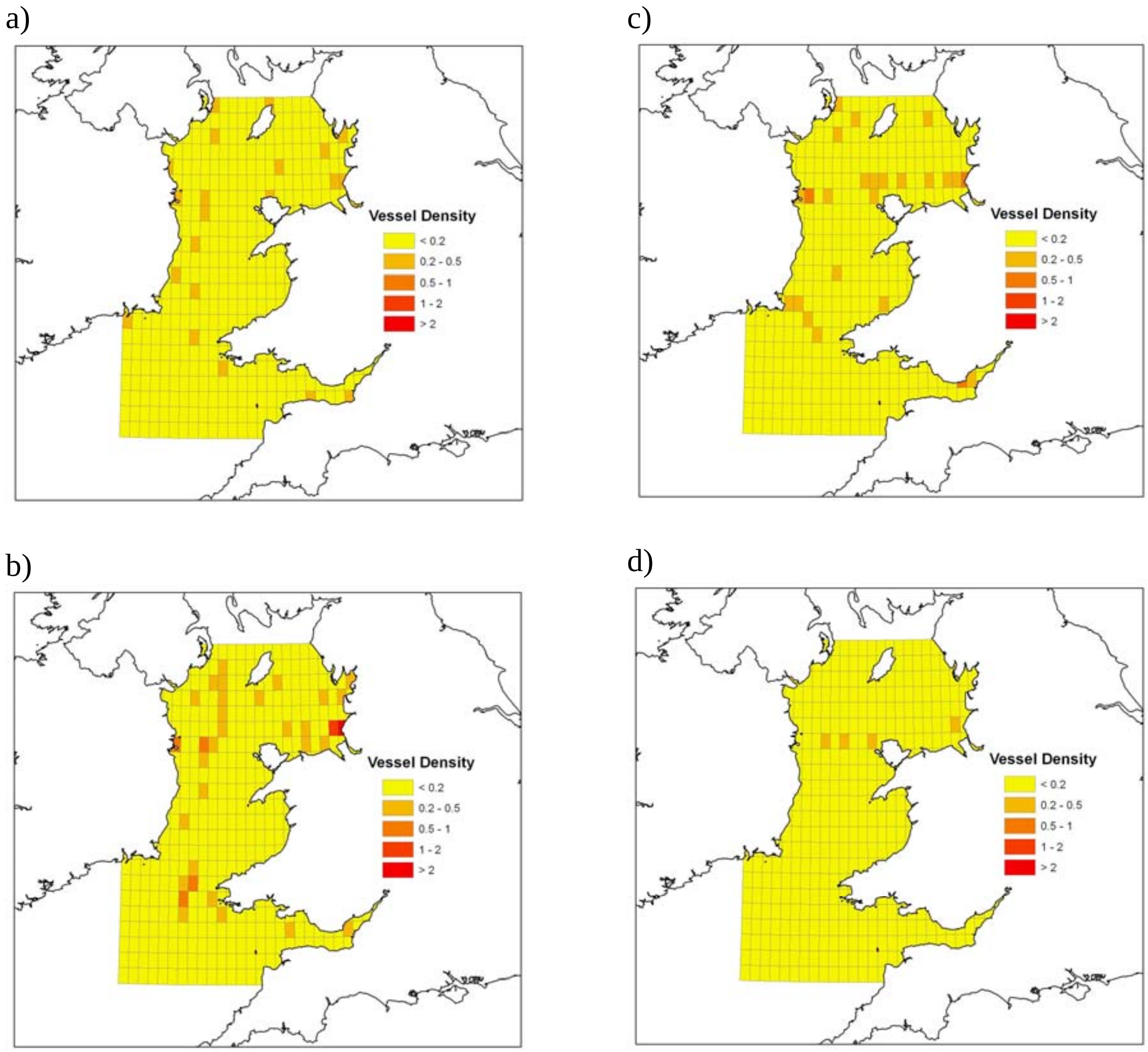


Fig. 6. Vessel Densities within the Irish Sea from AIS data for vessels travelling at speeds of a) between 5 and 10 knots; b) between 10 and 15 knots; c) between 15 and 20 knots; and d) over 20 knots

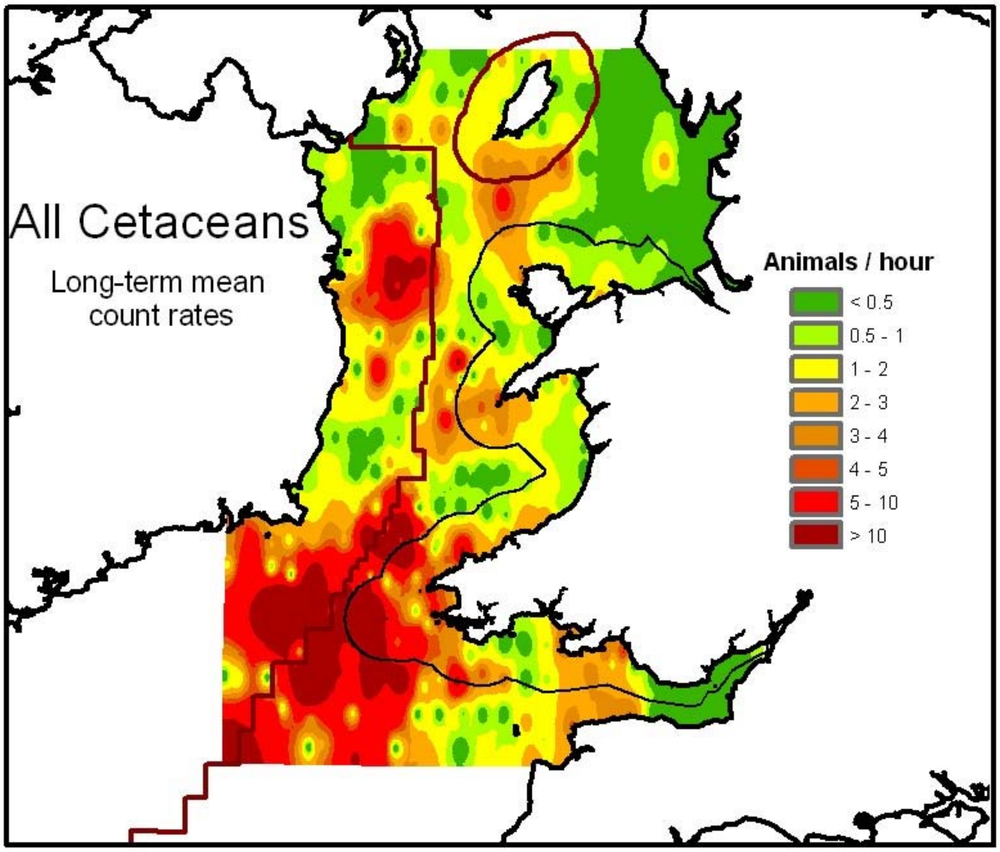


Fig. 7. Interpolated Map of Relative Densities of all cetacean species recorded from the Irish Sea, 1990-2007 (from Baines & Evans, 2009)

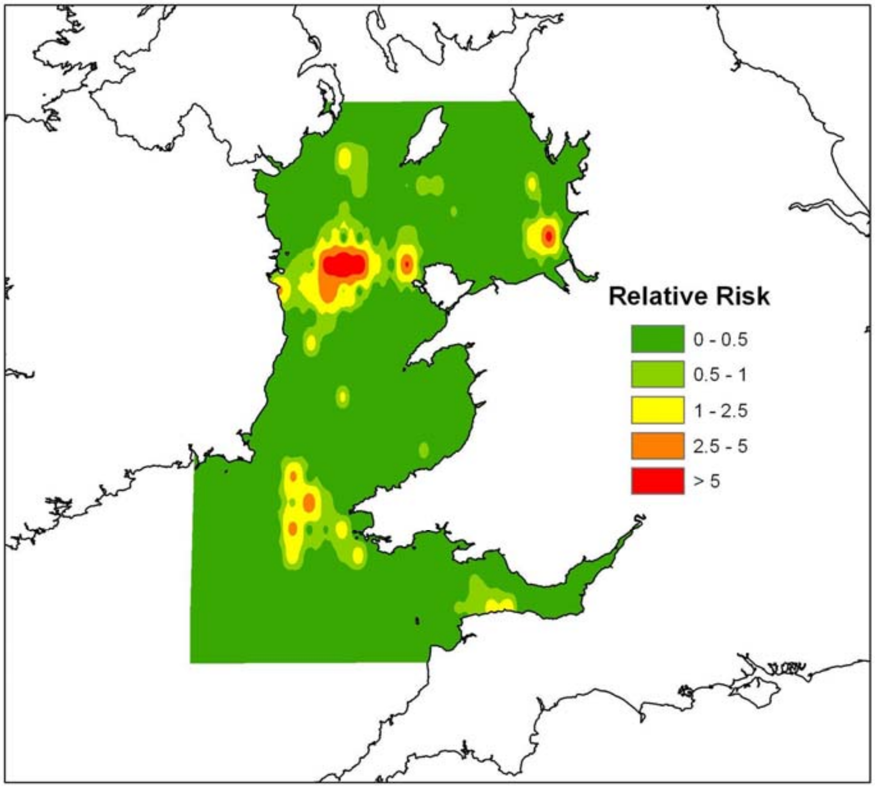


Fig. 8. Relative Risk of Encounters between cetaceans & shipping

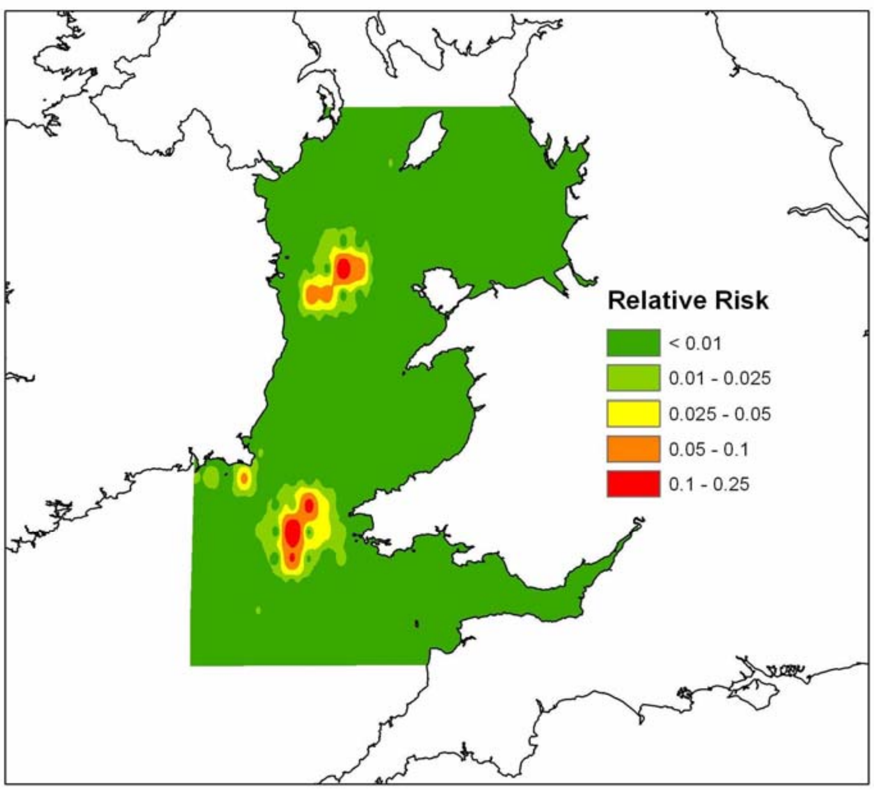


Fig. 9. Relative Risk of Encounters between large cetaceans & shipping

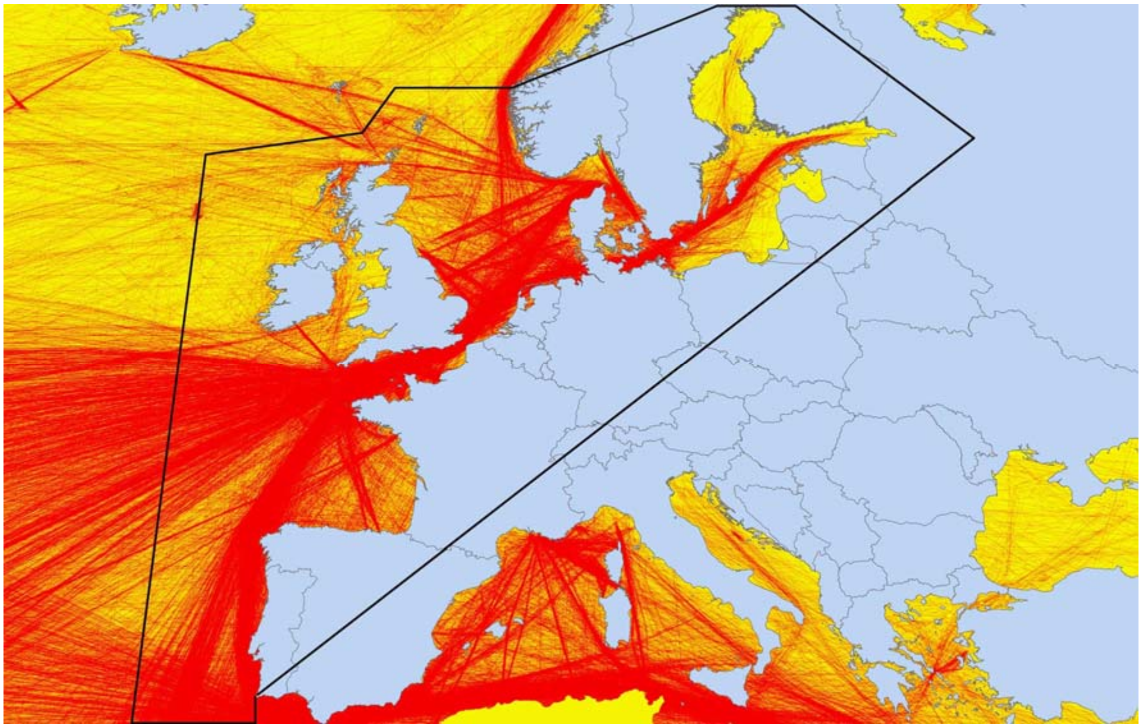


Fig. 10. VOS annual tracks of commercial vessels in the ASCOBANS Region

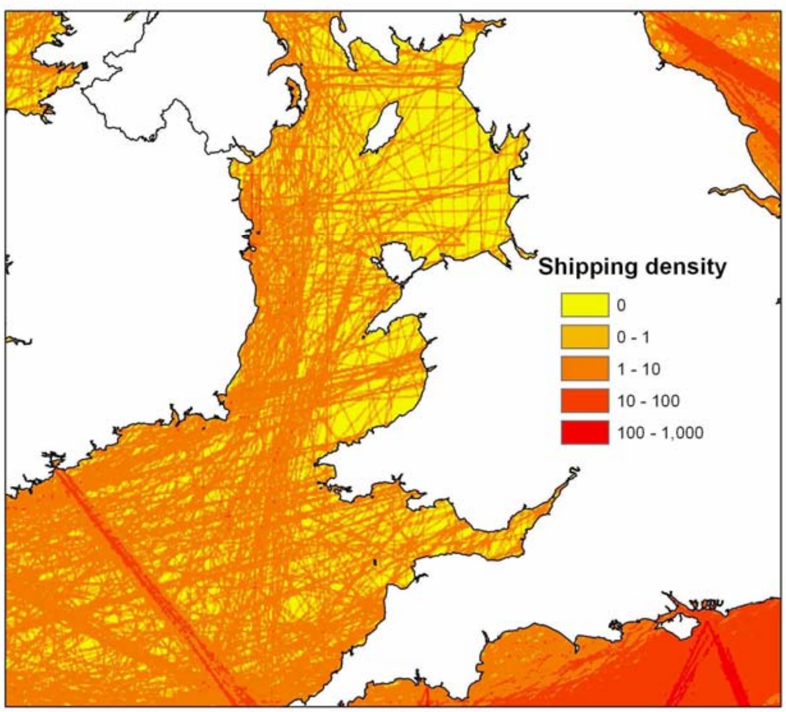


Fig. 11. VOS annual tracks of commercial vessels in the Irish Sea

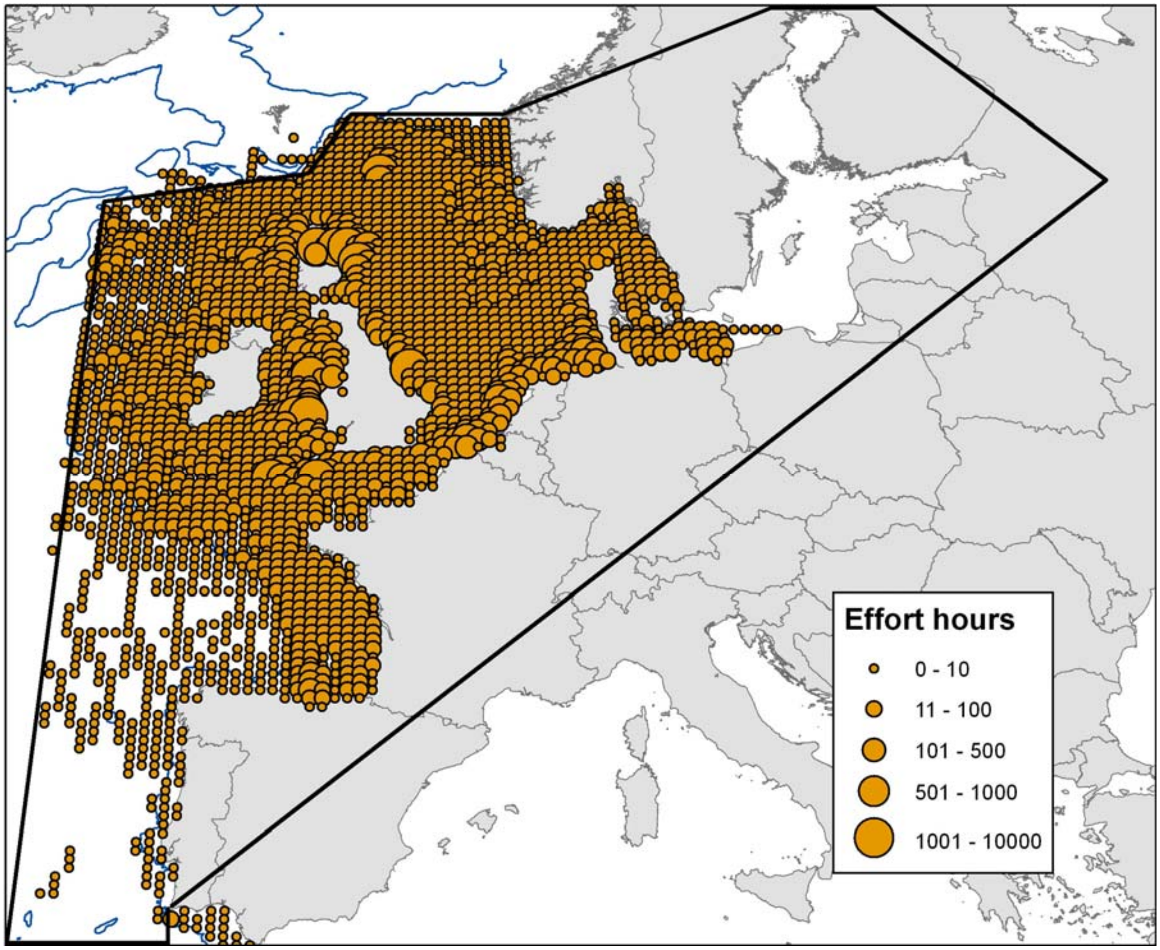


Fig. 12. Distribution of Survey Effort, 1990-2010

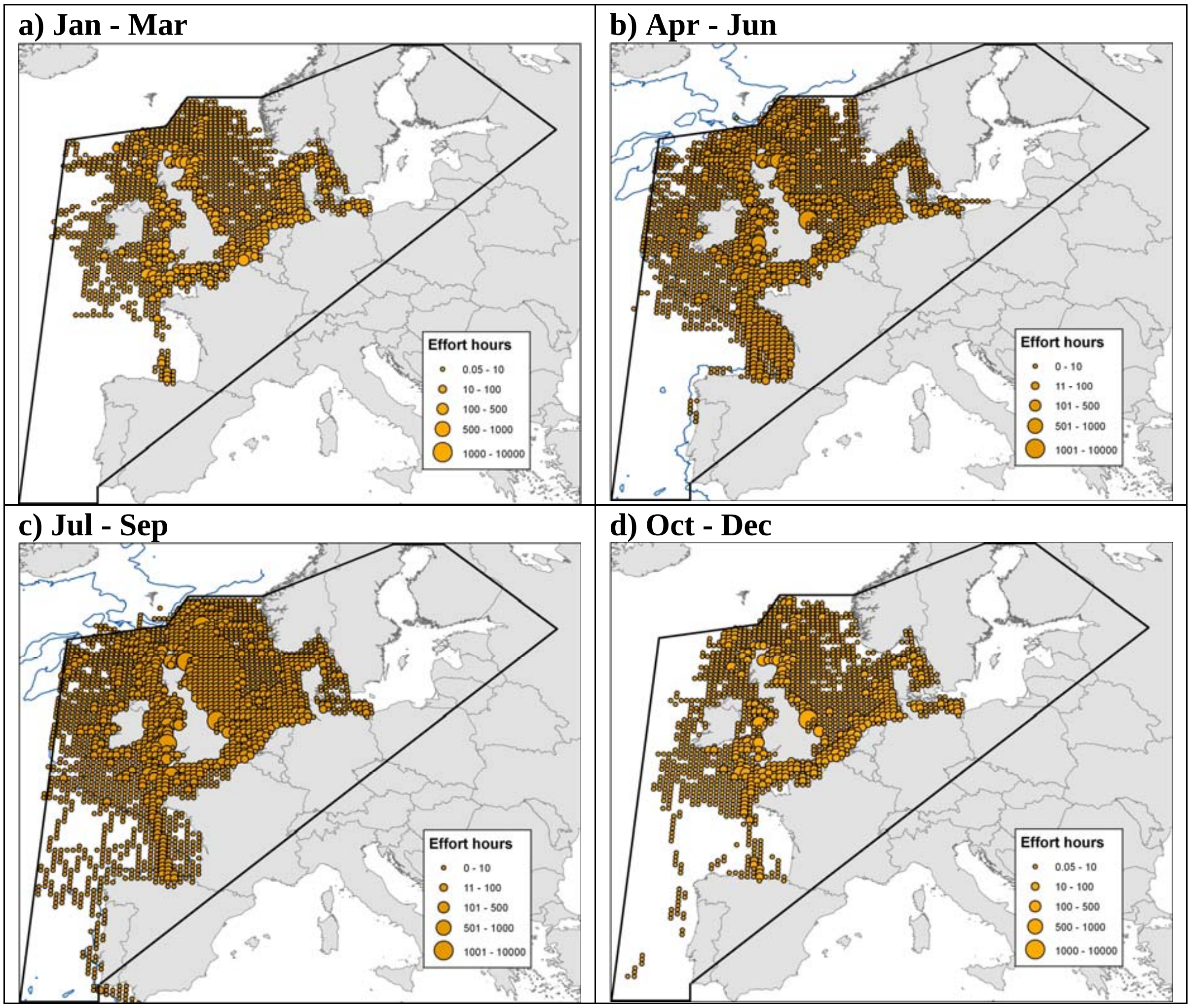


Fig. 13. Seasonal Variation in Survey Effort, 1990-2010

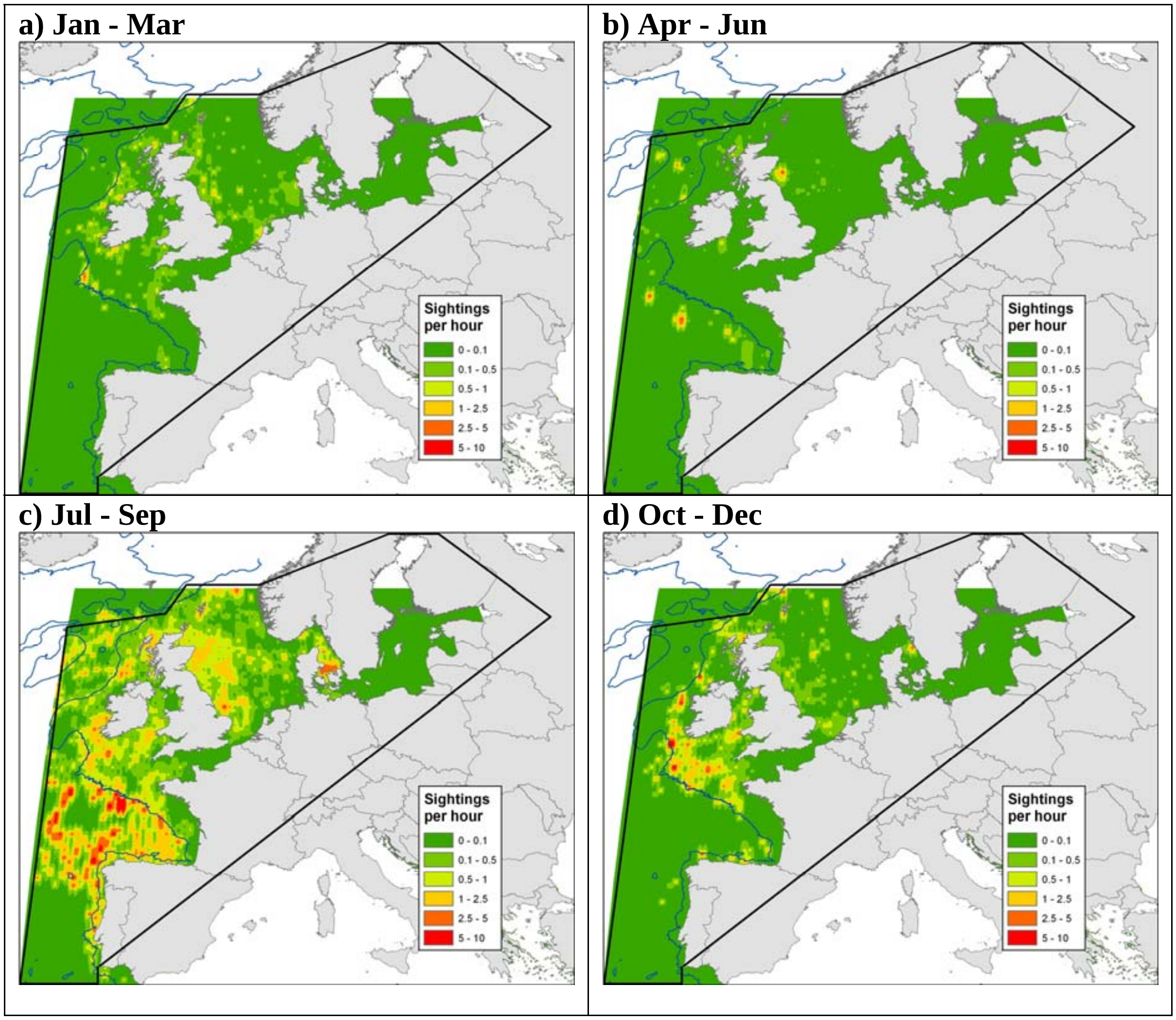


Fig. 14. Seasonal Variation in Relative Densities of all Cetaceans, 1990-2010

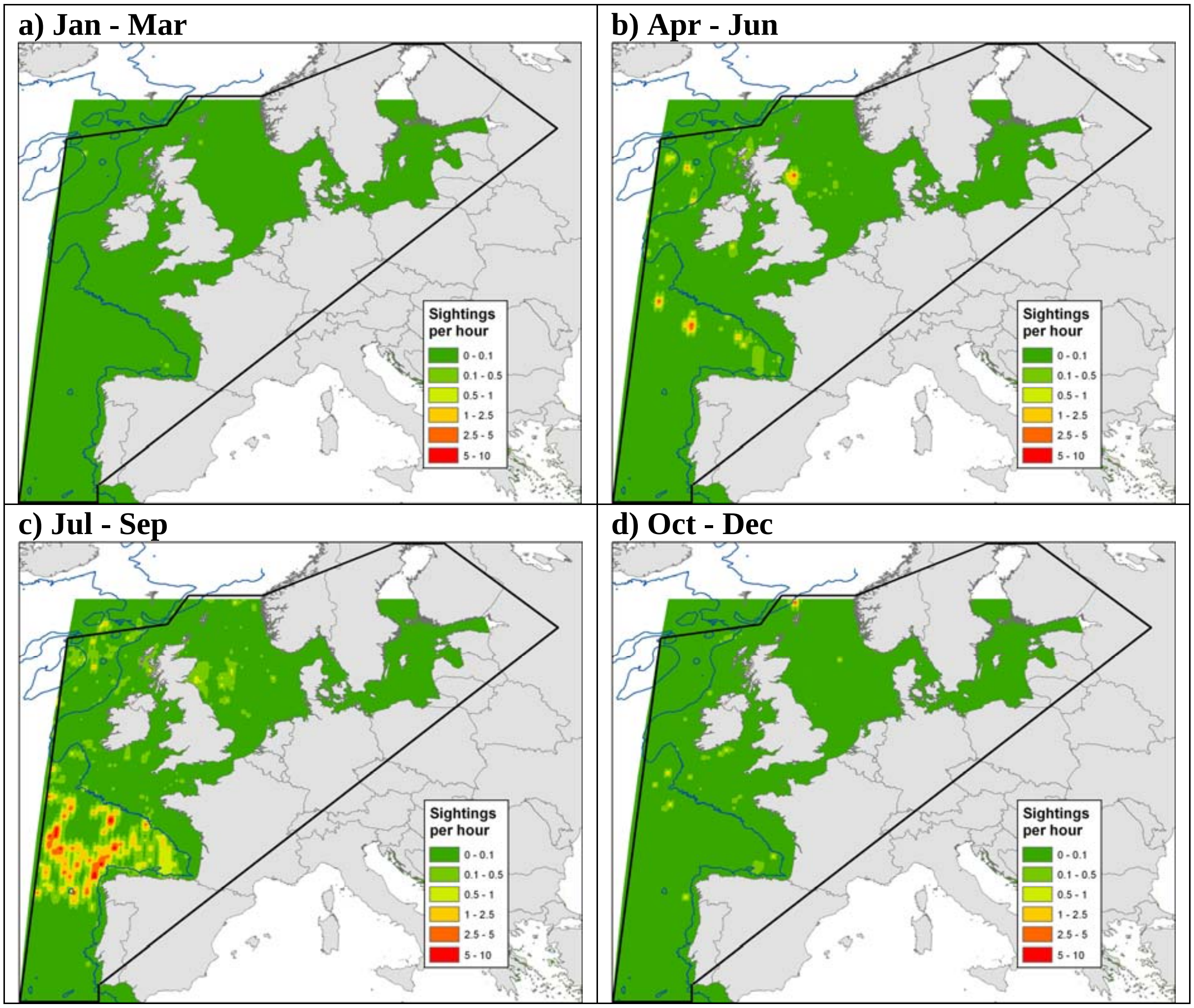


Fig. 15. Seasonal Variation in Large Whale Relative Densities, 1990-2010

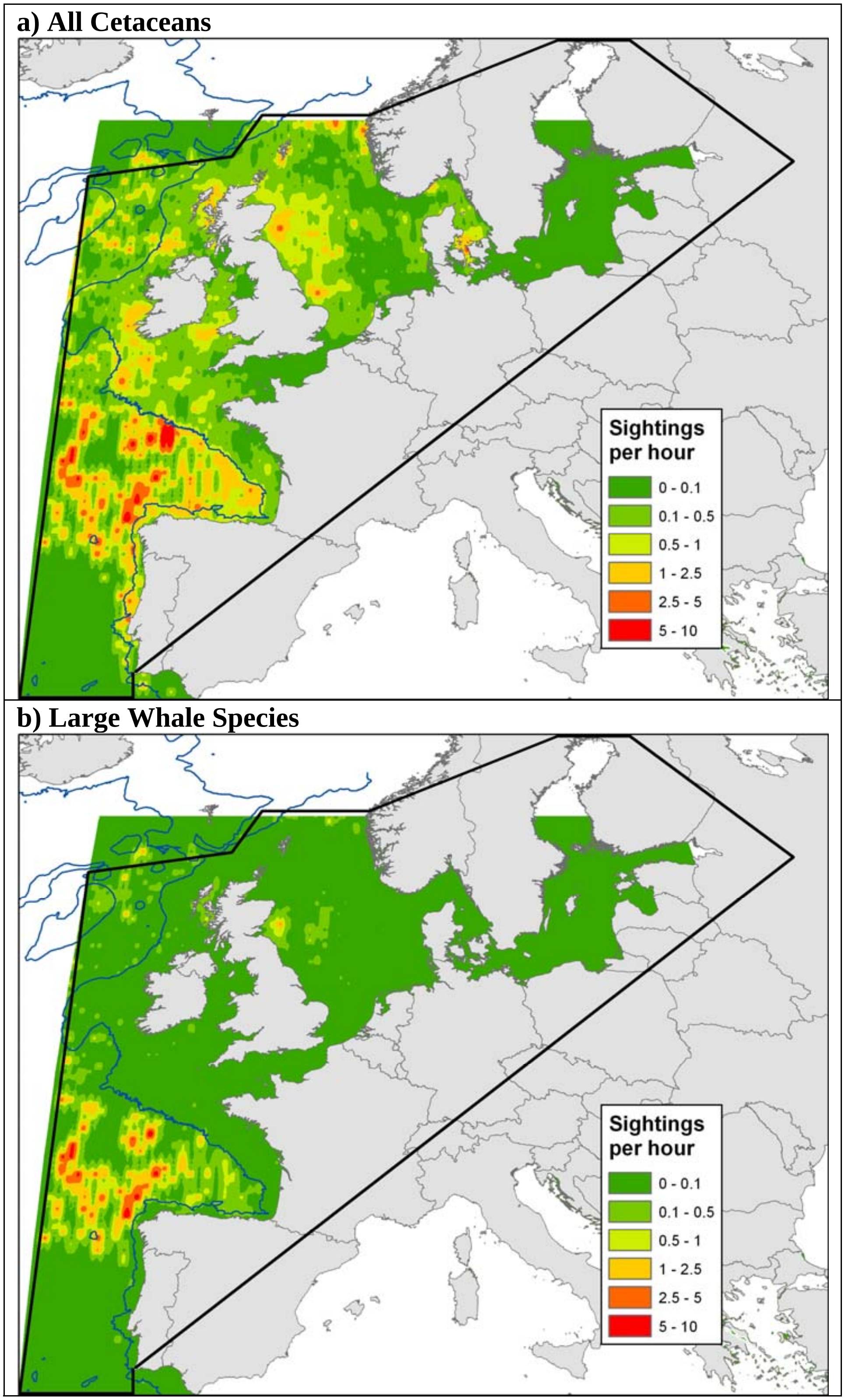


Fig. 16. Cetacean Relative Densities in the ASCOBANS Region, 1990-2010

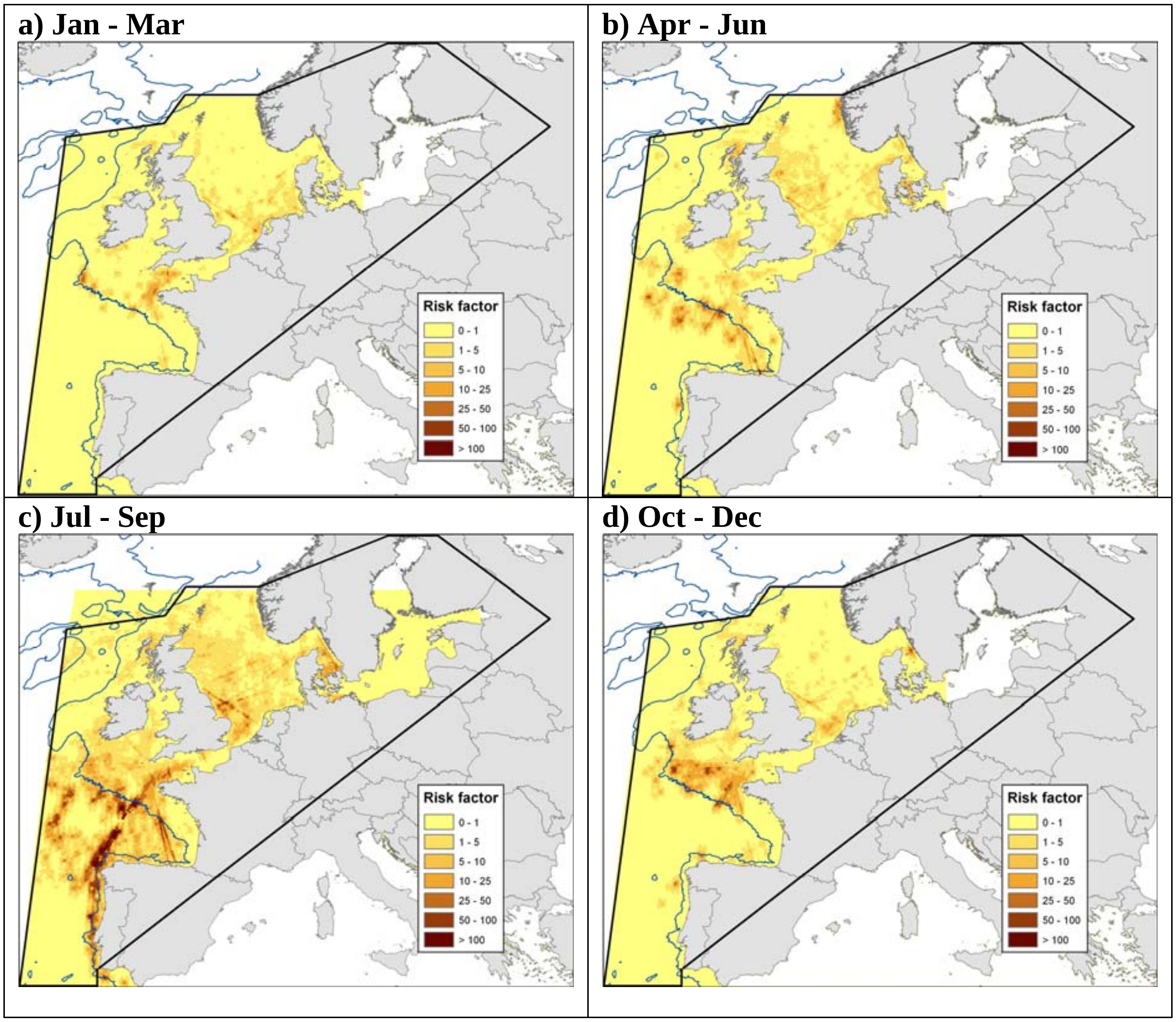


Fig. 17. Seasonal Variation in Ship Strike Risk to All Cetaceans in the ASCOBANS Area

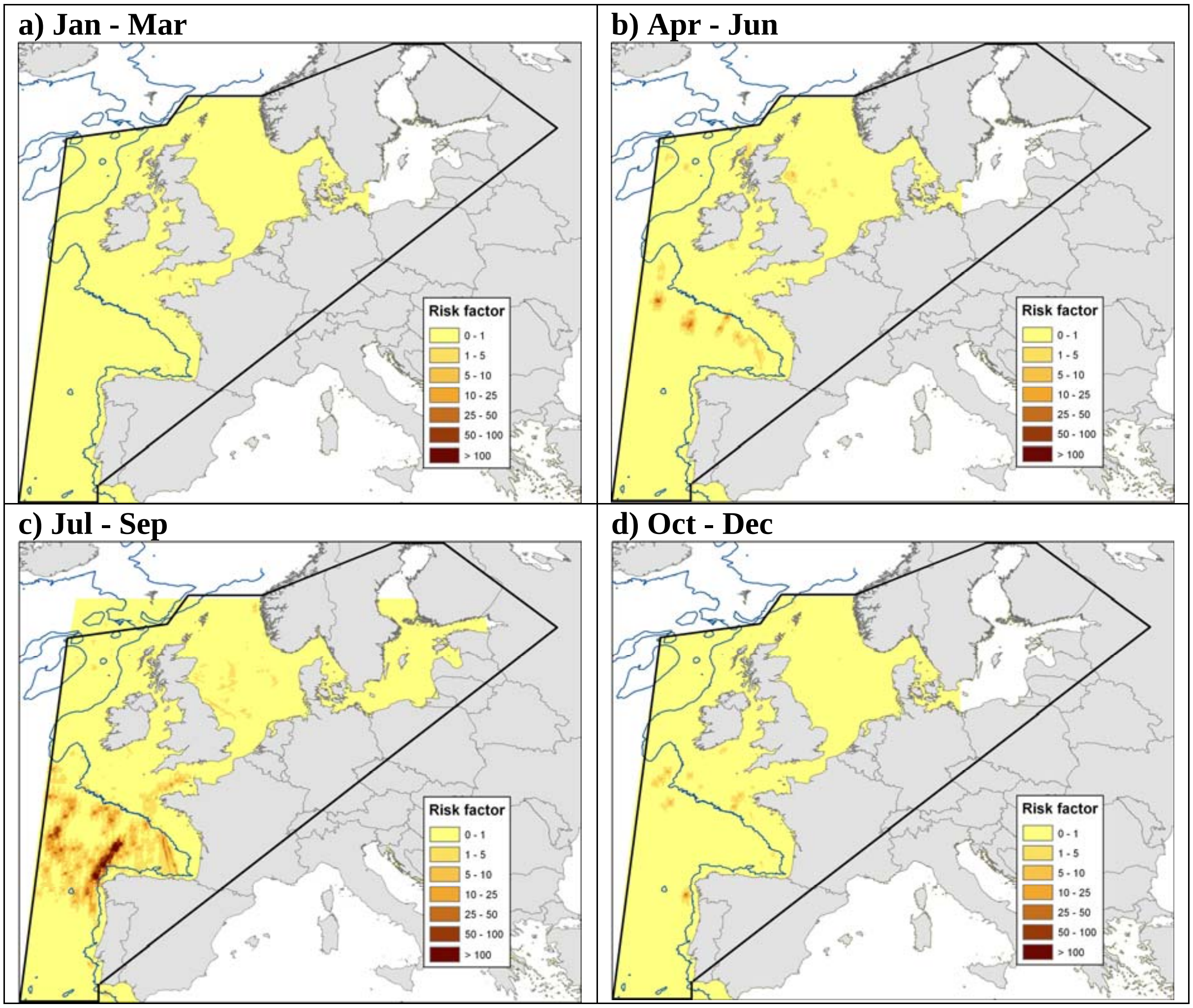


Fig. 18. Seasonal Variation in Ship Strike Risk to Large Whale Species in the ASCOBANS Area

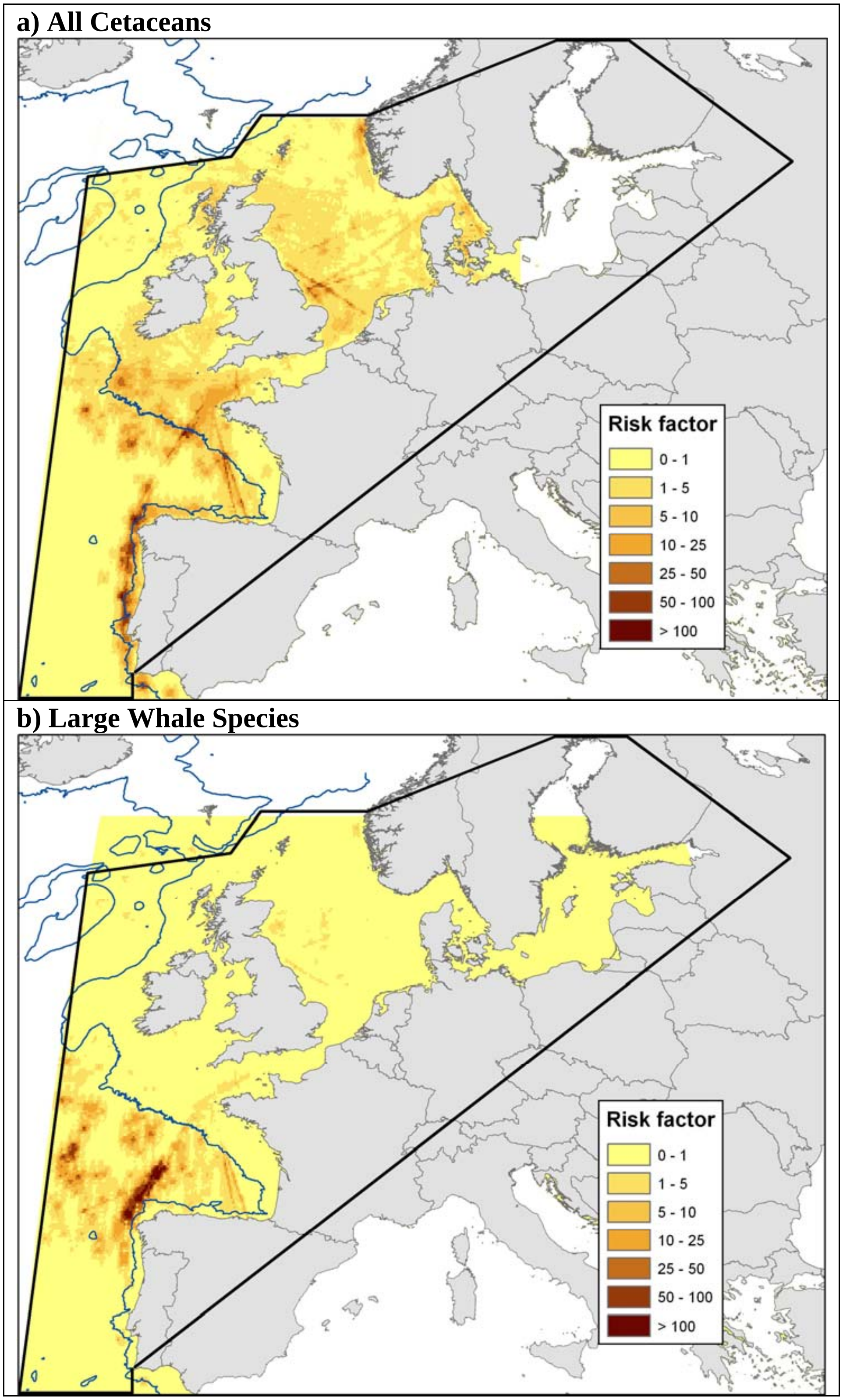


Fig. 19. Cetacean Ship Strike Risk in the ASCOBANS Region

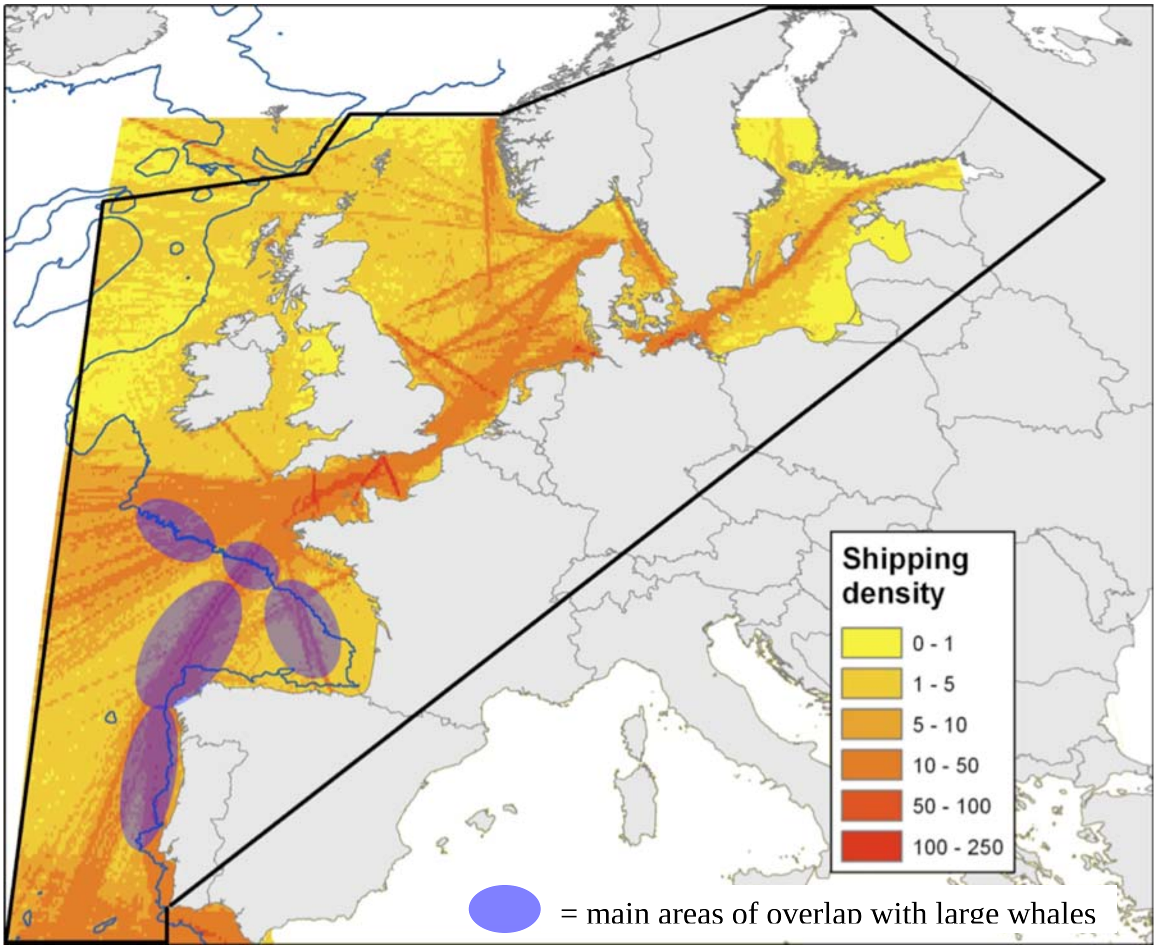


Fig. 20. Potential Risk Areas for most vulnerable cetaceans in the ASCOBANS Region