DISTRIBUTION PATTERNS OF SPERM WHALES IN RELATION TO SHIPPING DENSITY IN THE HELLENIC TRENCH, GREECE

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ABSTRACT

Ship strikes are a recognized problem for the Mediterranean sperm whale population which is considered as Endangered by IUCN. The Hellenic Trench southwest of Greece is a known area of high sperm whale density which coincides with major shipping routes. Whale distribution is closely related to bathymetry with highest densities close to the 1000m contour. Twelve seasons of visual and acoustic observations of sperm whales were compared with shipping density derived from Automatic Identification System (AIS) data. This analysis identified high risk areas where whales were exposed to very high shipping densities, particularly west of the island of Zakynthos where shipping routes run along the 1000m contour. The level of risk and the potential for small changes in shipping routes to dramatically reduce risk in these high risk areas suggest considerable scope to establish a dialogue with shipping regulators and the shipping industry to discuss routing options.

INTRODUCTION

The Hellenic Trench is core habitat for the eastern Mediterranean sperm whale sub-population which is believed to number just a few hundred individuals (Frantzis et al., in press). The Mediterranean sperm whale population is considered as Endangered by IUCN and is at risk from driftnet entanglement and ship strikes. On the basis of these threats the Scientific Committee of IWC considered that the population might benefit from a Conservation Management Plan and encouraged studies that would fill any data gaps regarding ways that entanglement or ships strikes might be reduced (IWC, 2013).

Frantzis et al. (in press) describe twelve acoustic and visual survey seasons for sperm whales conducted each summer between 1998 and 2009 along the Hellenic Trench. In addition, they note that 61% of the stranded sperm whales along the Greek coasts showed marks from a collision with a large vessel indicating that ship strikes are a serious acute threat. They conclude that the observed patterns of sperm whale distribution in the Hellenic Trench with a pronounced preference for waters close to the 1000m contour and apparent lower densities further offshore suggest that ship strike risk could be greatly reduced by moving shipping lanes.

This paper uses the same data set of sperm whale observations together with over a year of continuous Automatic Identification System (AIS) monitoring from a number of shore stations to examine the potential for measures to reduce ship strike risk to sperm whales in the Hellenic Trench. AIS data have been used in a number of studies to estimate shipping density and other characteristics such as type and speed of vessels, port of departure and destination. Speed is a known factor that influences ship strike risk and information about vessel routes is important for consideration of economic or other environmental impacts of any proposed mitigation measures such as alterations to shipping lanes.

METHODS

Sperm whale data
A detailed description of the combined acoustic searching and visual observation methods is given in Frantzis et al. (in press). A towed hydrophone was monitored every fifteen minutes for sperm whale vocalisations and each listening station was assigned a binary status as either 'sperm whales detected' or 'no sperm whales detected'. Estimates of the detection range at which whales could be heard were made from 62 experiments during which the research vessel travelled directly away from a vocalising individual or group. This gave estimates of the effective detection range of the system (the distance at which there was 50% probability of detection) of 12 to 21km for different sizes of sperm whale groups (Gkikopoulou et al. in prep.). When sperm whales were detected the effort switched from searching to tracking and acoustic bearings were used to direct the vessel towards the individual or group for photo-identification and behavioural observations.

The data set comprised a total of 4399 listening stations resulting in 178 visual encounters with sperm whales. Search effort was conducted from June to October but with the majority in July and August (Table 1).

Table 1. Summary of acoustic search effort

Month	Number of listening stations	Number of listening stations where sperm whales heard
June	71	6
July	1835	107
August	2221	110
September	200	15
October	73	0

These data cannot be used directly for density estimation because the vessel started each day from harbour and did not continue search effort once whales were encountered. For the purposes of evaluating possible mitigation options for ship strikes involving changing ship routes, the key question is the average relative density of whales along the current route compared to possible alternatives. This does not always require unbiased estimates of density across an area. The approach used for this analysis was to use the locations of all sperm whale sightings together with data on shipping density to identify high risk areas where detailed examination of acoustic searching effort might provide appropriate indicators of relative whale density relative to shipping.

AIS data

AIS data were provided by Marine Traffic (www.marinetraffic.com) from shore based receiving stations along the coast. Since the area of interest was generally within 30nm of the coast it was anticipated that there would be a high probability of receiving all AIS signals from vessels within the study area, thus giving valid estimates of the density of AIS equipped ships (AIS is mandatory for all vessels over 300GT). A preliminary inspection of the data was performed by tracking individual vessels and checking whether signals were received consistently along a coastal passage. This suggested some small patches of less than 100% coverage close to the coast but good coverage over the main coastal areas of interest, decreasing further offshore.

The study area was divided up into 1km grid squares and each AIS transmission location received was allocated to a grid square. The distance travelled by each ship in each grid square was then estimated from the speed and time between each AIS message while the vessel was in that square. AIS transmission intervals vary with speed from 2 seconds for very fast moving vessels to 3 minutes for vessels at anchor. Hence there were several messages received from each vessel in each grid square. This minimised the effects of errors at the boundaries of squares being allocated to the wrong square. Monthly shipping density for each grid square was calculated as the total distance travelled by all AIS equipped vessels expressed in km/km^2, which simplifies to km^{-1}.

RESULTS

The total study area and search tracks are shown in Figure 1. This covers the portion of the Hellenic Trench from mainland Greece south to Crete. Sighting locations for all sperm whales encountered are shown in Figure 2. Densities of shipping are shown in Figures 3 and 4. The decrease in apparent shipping density to the west of the maps is due to loss of AIS signals. For the coastal areas the shipping shows concentrations of inter-island traffic, traffic in the narrow passages between the Aegean and Ionian Seas, and traffic passing west up the Greek coast. Based on these shipping density estimates, the exposure to shipping for each sperm whale sighting location could be estimated. These are shown in three colour categories in Figure 2.

Based on visual inspection of these plots, four areas were selected for further investigation, labelled as A-D in Figure 2. Sperm whales in areas A-C are exposed to the highest levels of shipping as indicated by the red circles but area D also has a high density of sightings. Within an area, the relative density can be inferred from the encounter rate or proportion of search trips on which whales were encountered. These are summarised for the four areas in Table 2 along with the mean shipping density for all whales in that area. It can be seen that area A has both the highest encounter rate, highest group size and the highest exposure to shipping. Area D has a similar encounter rate but a smaller group size and much lower exposure to shipping (by a factor of ten). This suggests area D would be lowest priority for shipping measures and it is not considered in further detail here.

Table 2. Summary of encounter rates and shipping densities for the four areas shown in Figure 2.

Block	Number of search trips	Number of trips with	Proportion of search days	Number with visual	Mean group	Mean shipping density (km^{-1}) for whale

	(days)	acoustic encounter	with whales present	encounter	size	sighting locations (SD)
A	84	50	0.60	37	7.3	25.6 (14.4)
B	51	25	0.49	15	5.7	21.1 (25.1)
C	28	11	0.39	10	5.4	22.7 (23.2)
D	200	114	0.57	87	4.0	2.4 (2.4)

Area A

A more detailed plot of shipping density and sperm whale sighting locations for area A is shown in Figure 5. The thick black line indicates approximately the centre line of the main shipping route. It can be seen from Figure 6 that the search tracks lie both sides of this 'centre line' and cover a larger area perpendicular to the line compared to the locations where sperm whales were observed. The locations of sightings are also concentrated along this 'centre line' indicating the highest possible overlap of shipping and whale distribution (Figure 7). In this area the depth drops very quickly to >1000m close to the coast of Zakynthos and contours run parallel to the coast concentrating shipping and whales in the same area. The distribution of whale locations in Figure 7 suggests whale densities drop off very rapidly with perpendicular distance offshore of the 1000m contour and current shipping route. In this area the search effort extends well offshore and all whales that were heard offshore of the 'centre line' were subsequently encountered closer to the line. This provides strong support from the acoustic search data of very low or zero densities further offshore. This is illustrated in Figure 8 which plots the perpendicular distance from the centre line of the acoustic station at which whales were first heard against the perpendicular distance to the subsequent visual encounter.

Area B

The shipping situation for area B is more complex than area A because shipping is turning around a headland (Figure 9). There is also limited data from the search tracks further offshore of the current main shipping routes (Figure 10). The highest area of risk seems to be where the 1000m contour falls in the highest density of shipping which could be avoided by shipping staying a little further offshore and turning less sharply around the headland.

Area C

Area C contains a major shipping route between the Ionian and Aegean Seas for ships following the south coast of the Peloponnese north of the island of Kithira (Figure 11). The 1000m contour follows a complex pattern here with shipping generally crossing it rather than running parallel as in areas A and B. This provides fewer options for shipping to take routes that reduce risk.

DISCUSSION

This preliminary analysis has investigated areas which have already been identified as high risk due to the overlap between a small population of sperm whales and shipping. It has not been possible to estimate absolute sperm whale density and the data were only collected in summer. However there is evidence of sperm whales in the Hellenic Trench year round with strong individual site fidelity to the area, and the same individuals have been observed moving along the Hellenic Trench (in the areas A, B, C, D), daily crossing very high risk areas (Frantzis et al., in press). In addition, the data set covers a 12 year period suggesting consistent patterns of distribution between years. Within area A, sperm whales were found on 60% of survey days with a mean group size of 7.3. This suggests that there are more than 7 whales along this section of shipping route at least 60% of the time and this is certainly a negatively biased estimate since the whole area was not surveyed on each occasion. The densities of shipping along this route with an average around $300\text{km}^{-1}\text{year}^{-1}$ are higher than the major route across the eastern Mediterannean from Suez to Sicily (Leaper and Danbolt, 2008). This level of risk and the potential for small changes in shipping routes to dramatically reduce risk in both areas A and B suggest considerable scope to establish a dialogue with shipping regulators and the shipping industry to discuss routing options. Although there is scope for further analysis and data collection to improve the risk analysis, at least for areas A and B, there seems no need to wait for further data to begin such discussions.

REFERENCES

Frantzis A., Alexiadou P., Gkikopoulou KC., 2014 in press. Sperm whale occurrence, site fidelity and population structure along the Hellenic Trench (Greece, Mediterranean Sea). Aquatic Consrevation.

Gkikopoulou KC, Frantzis A, Matthiopoulos J. in prep. Sperm whale abundance estimation in the Hellenic Trench, Eastern Mediterranean Sea. A combined acoustic and visual survey.

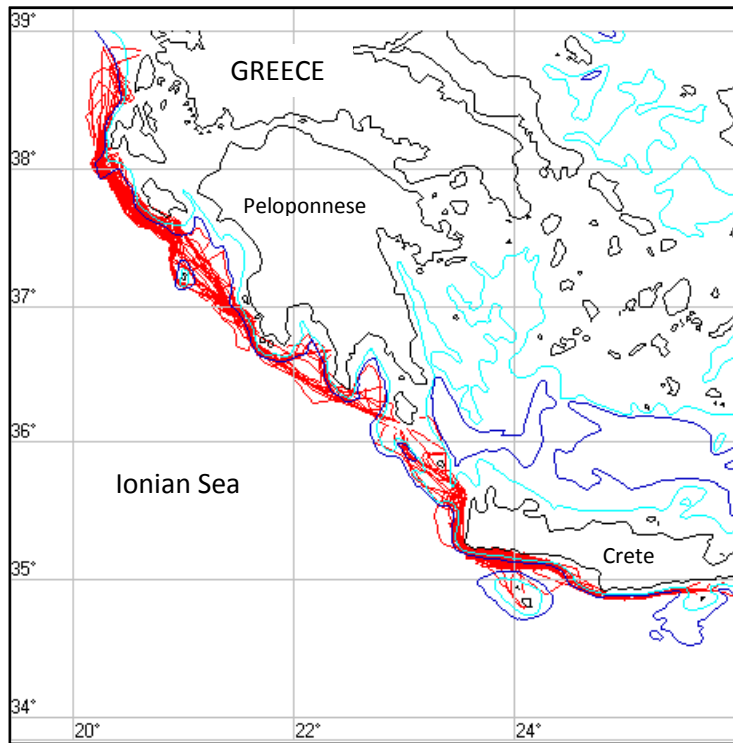IWC. 2013. Report of the Scientific Committee. Jeju, Korea.

FIGURES

Figure 1. Map of study area with land outline in black, 500m depth contour pale blue and 1000m depth contour dark blue. Acoustic search tracks shown in red lines.
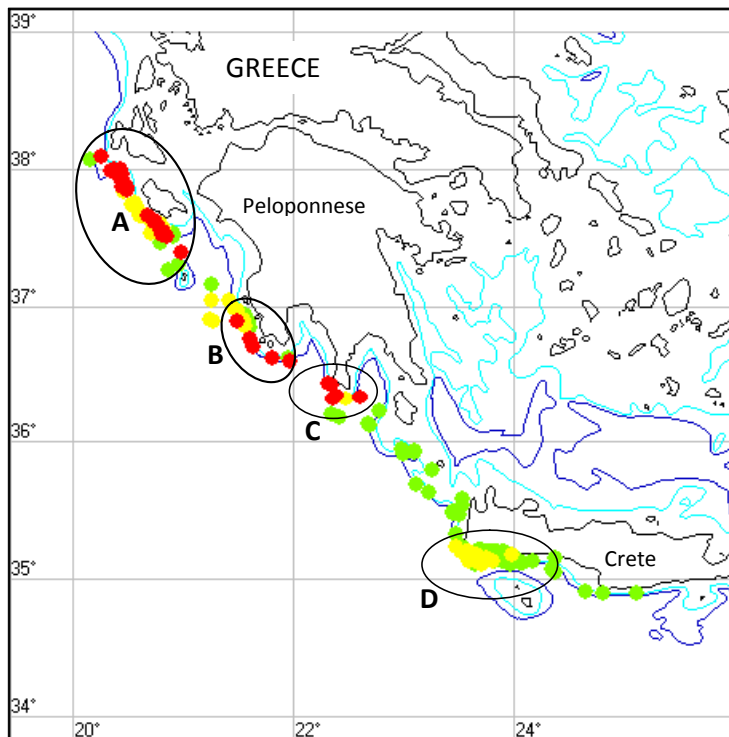
Figure 2. Locations of all sperm whale sightings (circles). Colour of circle indicates the average shipping density for the location of the sighting (red = >20km^{-1}, green = 5-20km^{-1}, yellow =<5 km^{-1}). Black ovals show selected regions for more detailed analysis.
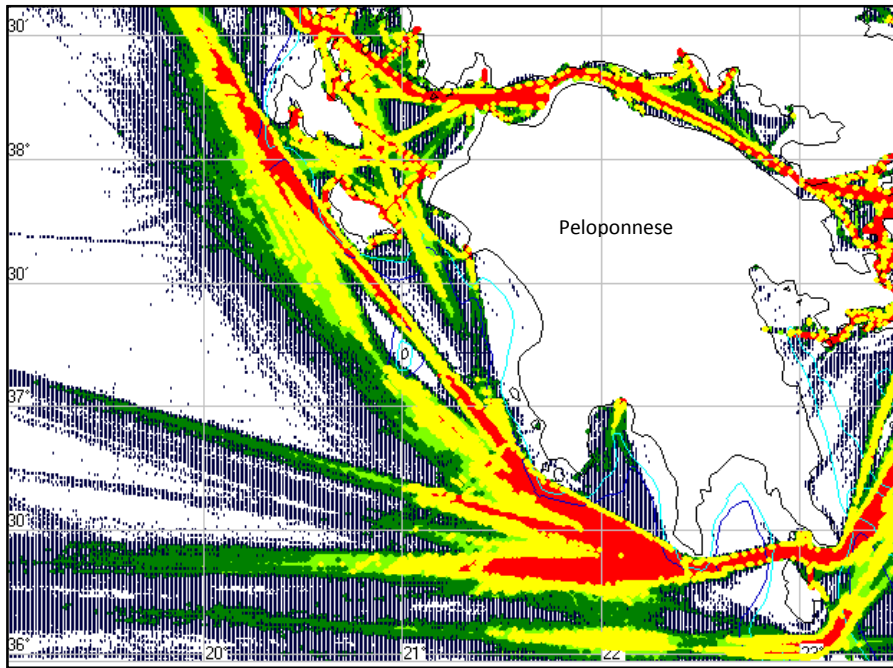
Figure 3. Shipping density for northern portion of study area. Densities are average total monthly distance travelled by all vessels according to the colour key below.

Red	> 20km travelled per km^2 per month
Yellow	10-20 km travelled per km^2 per month
Pale Green	5-10 km travelled per km^2 per month
Dark green	3-5 km travelled per km^2 per month
Blue	0.5 – 3 km travelled per km^2 per month
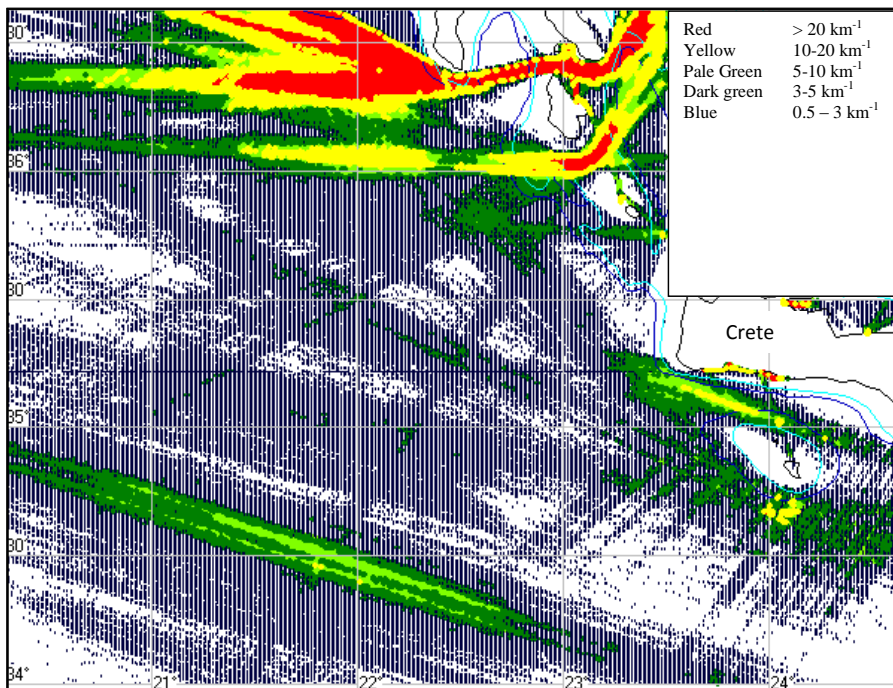
Figure 4. Shipping density (average monthly total distance travelled, km^{-1}) for southern portion of study area.
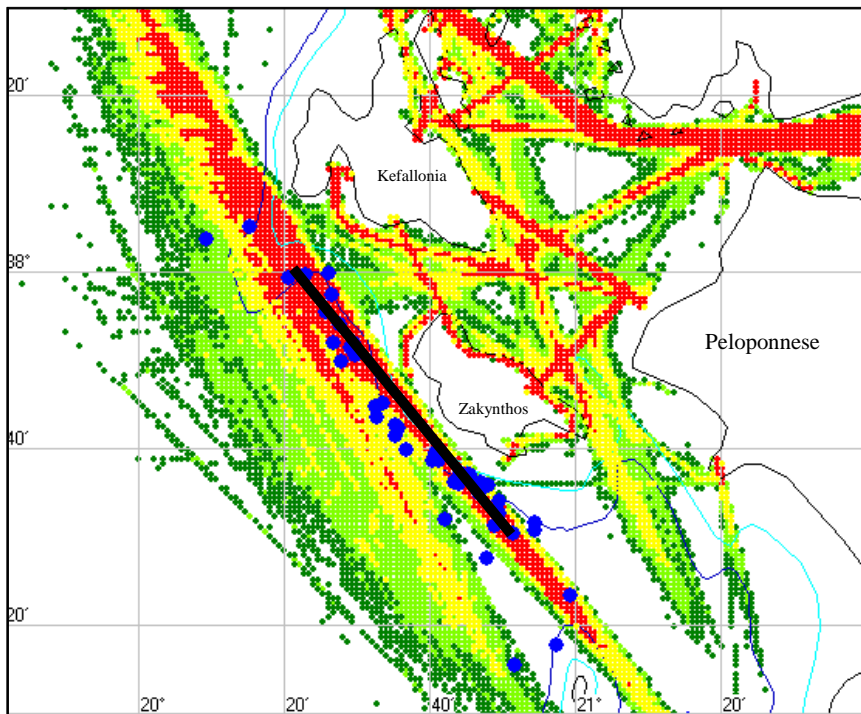
Figure 5. Area A shipping density (colour codes as for Figure 3). Blue circles indicate sperm whale encounters. Thick black line indicates 'centre line' of shipping route between 37° 30'N and 38° N.
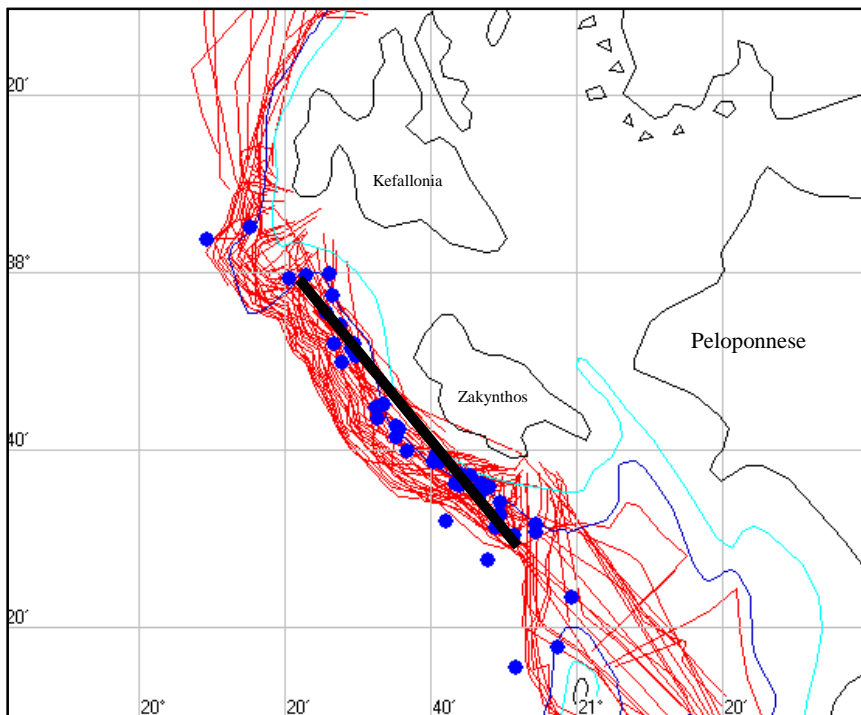
Figure 6. Area A showing survey tracks and all sperm whale sightings. Thick black line indicates 'centre line' of shipping route between 37° 30'N and 38° N.
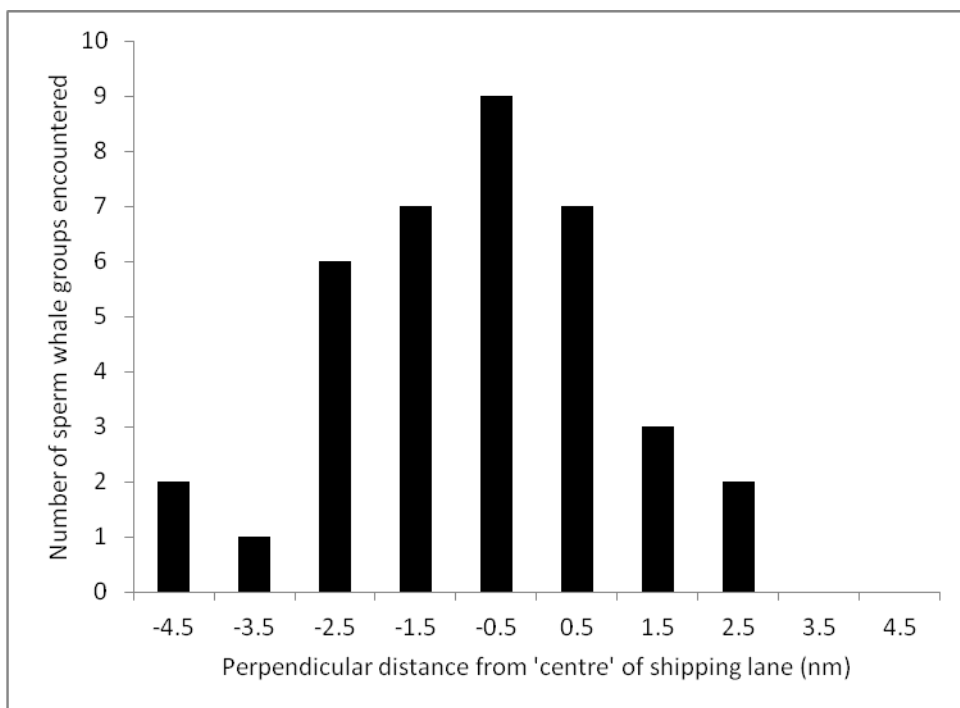
Figure 7. Frequency distribution of perpendicular distances of sperm whale groups from 'centre line' of main shipping route in area A. Negative distances indicate whales offshore of the line, positive distance are for whales inshore.
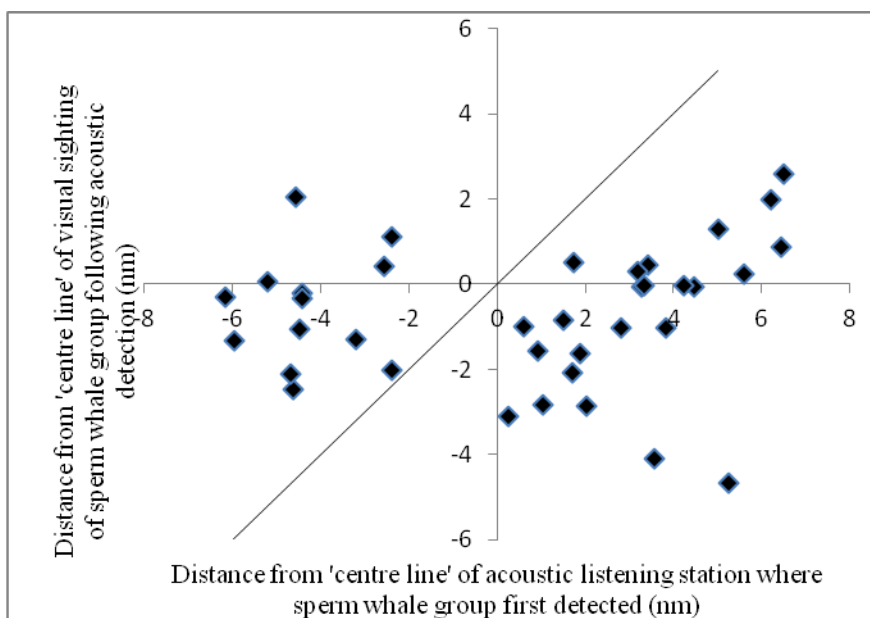
Figure 8. Perpendicular distances from 'centre line' of main shipping route for first acoustic detection and subsequent visual encounter. Negative distances indicate offshore of the line, positive inshore.
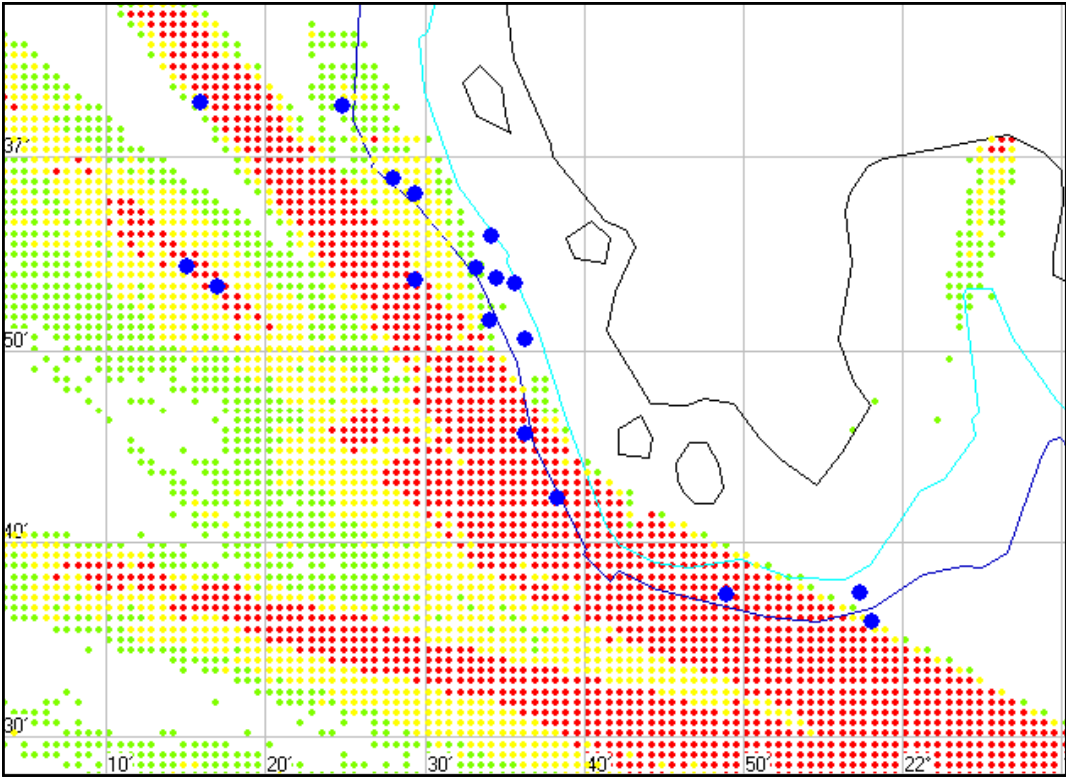
Figure 9. Area B shipping density (colour codes as for Figure 3). Blue circles indicate sperm whale encounters.
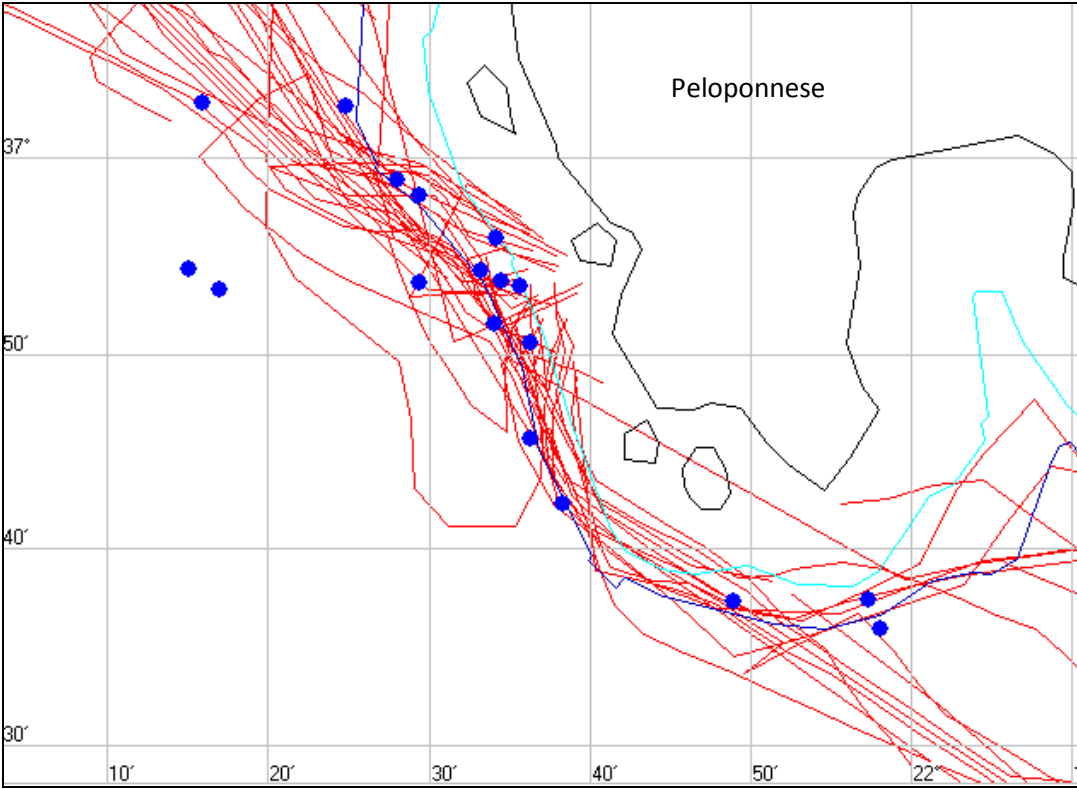

Figure 10. Area B showing search tracks (red lines) and all sperm whale sightings (blue circles)
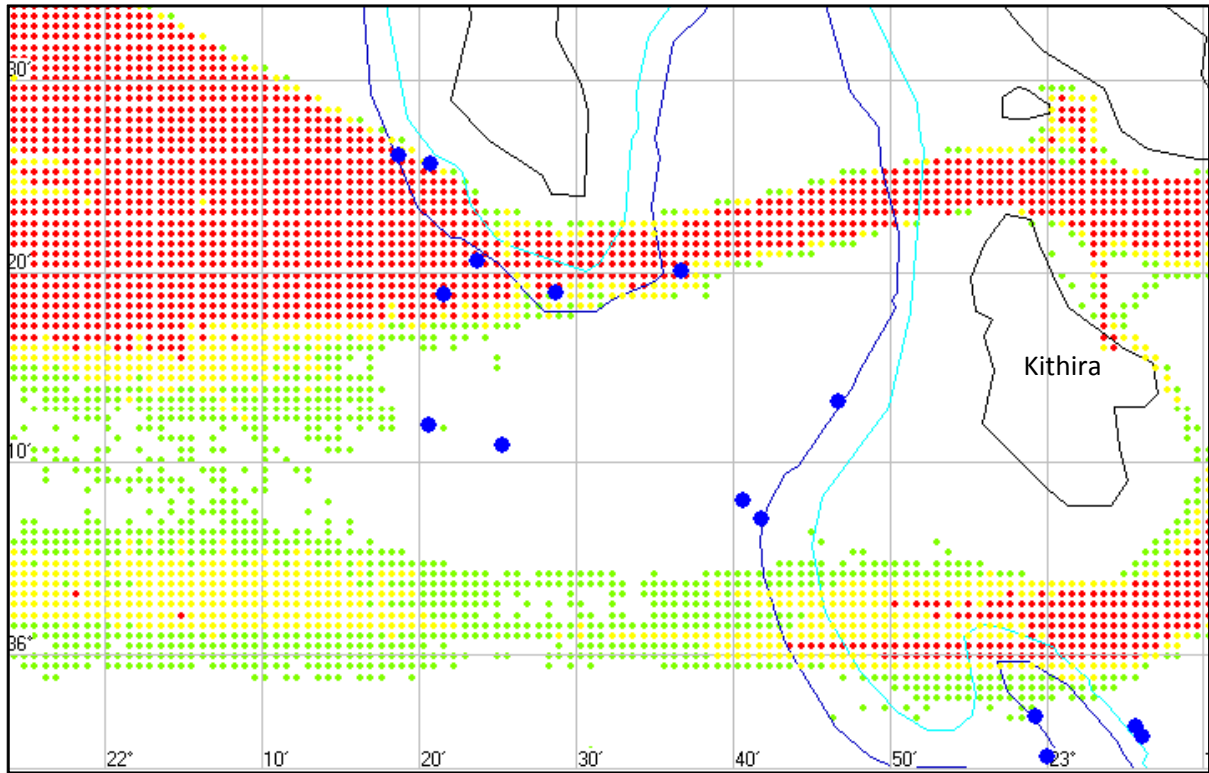
Figure 11. Area C shipping density (colour codes as for Figure 3). Blue circles indicate sperm whale encounters.
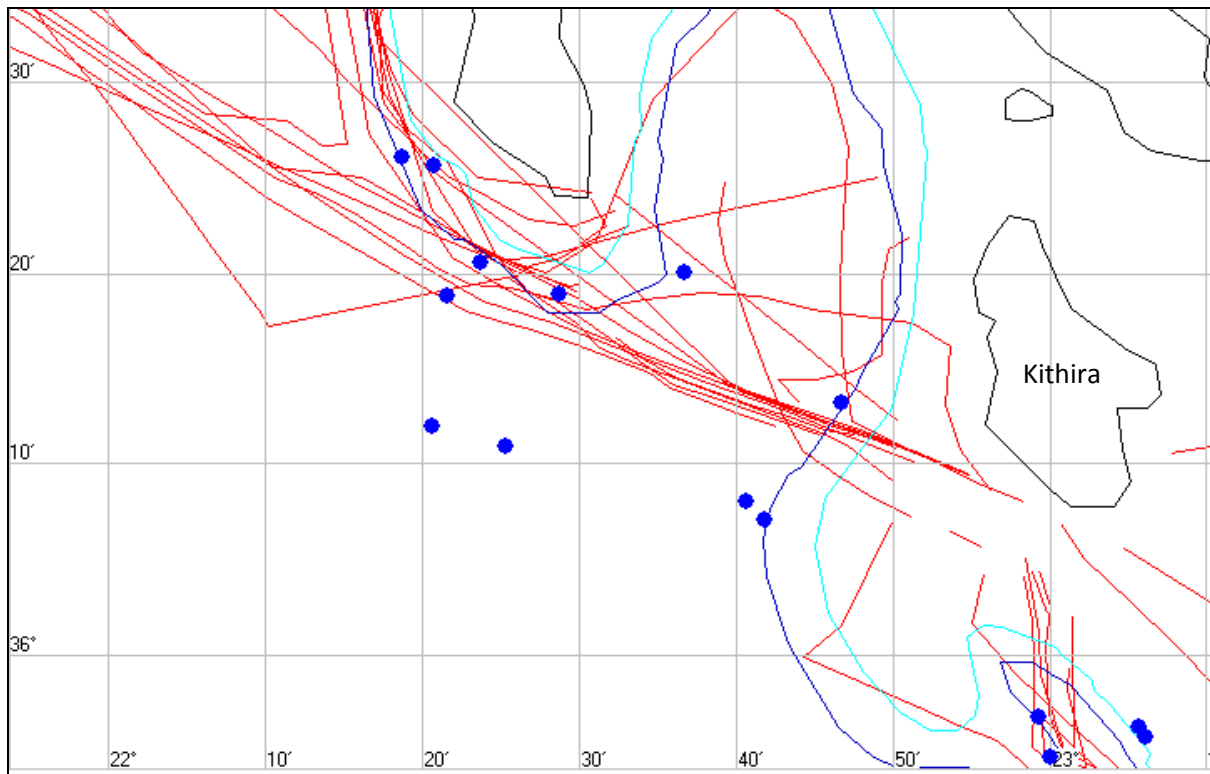

Figure 12. Area C showing search tracks (red lines) and sperm whale sightings (blue circles).