PRELIMINARY RESULTS OF SURVEYS TO INVESTIGATE OVERLAP BETWEEN SHIPPING AND BLUE WHALE DISTRIBUTION OFF SOUTHERN SRI LANKA

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ABSTRACT

Surveys were conducted off the southern coast of Sri Lanka during February to April 2014 in order to investigate the distribution patterns of blue whales (*Balaenoptera musculus*) in relation to current shipping lanes and further offshore. There have been several reported ship strikes of blue whales in this area and the IWC Scientific Committee has recognised the potential for ship strikes to have population level impacts on blue whales in the northern Indian Ocean. A total of 1413km of visual survey effort was conducted on 16 survey days along north south transects between 5° 28’ N and 5° 53’ N. The highest densities of blue whales were observed in the current shipping lanes, peaking at an average of 0.12 individuals km^{-2} in the westbound shipping lane. These high densities of whales combined with one of the busiest shipping routes in the world suggest a severe risk of ship strikes. Previous data on blue whale distribution and coastal upwellings indicate consistent and predictable patterns of whale distribution, suggesting there is considerable potential for effective measures to keep ships and whales apart.

INTRODUCTION

Blue whales (*Balaenoptera musculus*) are found in Sri Lankan waters all year round (Ilangakoon, 2012a; Randage et al., submitted). Sightings rates vary between seasons but seasonal changes are not well understood because effort and sighting conditions also vary considerably between seasons. Martenstyn (2013) reports that blue whales are widely distributed in Sri Lankan waters, occurring in pelagic waters as well as near the continental shelf break and on the continental shelf.

The status of the Northern Indian Ocean population of blue whales is not known, but at least 1294 blue whales were taken from the Arabian Sea in illegal catches by the former Soviet Union between 1963 and 1966 (Mikhalev, 2000). Small numbers of catches were also taken offshore of southern Sri Lanka and between Sri Lanka and the Maldives (Branch et al., 2007). Acoustically, blue whales off Sri Lanka have a distinctive call type (Alling and Payne, 1987), which has also been recorded off Chagos (Stafford et al., 2011) and as far south as Crozet (Samaran et al. 2010). Information on distribution patterns and movements of blue whales in the northern Indian Ocean is reviewed in Branch et al. (2007) and Anderson et al. (2012).

Ship strikes are recognised as an issue for this population (de Vos et al., 2013). Consistent high densities of whales are found off southern Sri Lanka in one of the busiest shipping routes in the world. Ilangikoon (2012b) reports an increase in strandings since 2010, with 22 blue whale strandings reported between 1894 and 2012 off the south and west coast of Sri Lanka, nine of which occurred between January 2010 and April 2012. Of these, several showed signs of blunt force trauma and propeller lesions. During the NE monsoon winds are cross or offshore with strong, westward cross-shore surface currents making it unlikely that carcasses of whales killed in the shipping lanes would strand. In 2012, the Committee drew attention to the urgent need for long-term monitoring of the blue whale population in Sri Lankan waters and elsewhere in the northern Indian Ocean because of the potential for population impacts from ship strikes (IWC, 2013).

There have been concerns over ship strikes with blue whales in other areas. In 2009 the International Maritime Organization (IMO) issued a guidance document for minimizing the risk of ship strikes with cetaceans (MEPC.1/Circ.674). Based on this guidance, the USA presented a proposal to IMO and in December 2012, IMO adopted changes to the shipping lane in the Santa Barbara Channel, California, USA in order to reduce ship strike risk to blue whales (COLREG.2/Circ.64).

The aim of this study was to investigate patterns of blue whale distribution in relation to shipping in a small area off the southern tip of Sri Lanka to provide baseline data that could be used to reduce ship strike risks. In addition to the risks to the whales there is an active whale watching industry in the area which is focussed on blue whales. This results in whale watching vessels operating in areas of high densities of large ships raising potential concerns over maritime safety. Although there are considerable data on whale distribution from whale watching vessels, these data are limited to the areas closest to the port of Mirissa in which most whale watching operations are based. There is still a need for survey data covering a wider area and particularly further offshore. For this study we defined a survey area of approximately 50km from north to south and 150km from east to west (Figure 1). This was based on a combination of operational constraints and the need to survey as far offshore of the current shipping lanes as possible.

SURVEY METHODS

Over the period 18 February to 3 April 2014, 16 days of visual and acoustic line transect survey were conducted from ‘Raja & the Whales’, a 13m converted deep-sea fishing vessel (Table 1). Fourteen transect lines were designed to cover the area of the shipping lanes and the surrounding areas, both inshore/offshore and east/west (Figure 1). Transects ran north to south, perpendicular to the shipping lanes (which run east to west). Transects started at 5° 53’ N, 3 nm north of the shipping lane, and ended at 5° 28’ N, 25 nm south of the shipping lanes. Thus the survey box covered the main shipping lane and an area 15 nm further offshore to the south.

Transects were conducted at a survey speed of 6 knots. Observations were carried out from the upper forward deck of the vessel with a platform height of 2.75m. Two observers using naked eye and Opticron 7x15 binoculars searched a 90^o sector either side of the vessel, and recorded sightings data for all marine fauna detected. Distances and angles to sightings were measured using binocular compass and reticles. Where conditions did not allow the use of reticles, an estimate of distance was made. These, and other sightings and environmental data, were recorded using Logger 2010 (Gillespie et al., 2011). No data were collected in conditions above sea state Beaufort 5.

In addition to data on whale distribution, data on other vessel traffic (including small fishing vessels) were recorded. Passive acoustic monitoring using a towed hydrophone was carried out to provide quantitative data on sperm whales and dolphin relative abundance data in and around the shipping lane, and continuous acoustic recordings made. Data on prey distribution were collected continuously using a Lowrance HDS-5 Gen 2 echosounder.

Although the main aim of the survey was to examine relative distribution patterns, absolute estimates of abundance are valuable for estimating ship strike risk and for comparison with other areas. Thus programme Distance (Thomas et al., 2010) was used to estimate strip widths and will be used for further analysis of density and associated variance estimates. However, no attempt was made to estimate g(0) which was assumed to be 1. In addition to Distance analysis, transects were divided into 1km segments for the purposes of spatial modelling. The results presented here are for a simple spatial Generalized Additive Model (GAM) including possible covariates of Latitude, Longitude, Depth Category, Sea State (Beaufort scale), and Sightability. Sightability was a subjective category of how good the observers judged the conditions for seeing blue whales to be based on all factors. Depth category was based on contours from Gebco, but it is envisaged that more detailed bathymetry data will be used for future analyses. The response variable was the number of whales sighted in each 1km segment of survey track. Modelling was performed using the mgcv package in R (Wood, 2006).

Automatic Identification System (AIS) data were collected from a receiving aerial at the University of Ruhuna, in Matara in order to measure density of shipping traffic with respect to type and speed of vessels off Dondra Head. In order to cover a wider area than the reception range (20-30nm) of this aerial, sources of satellite received AIS data will be investigated.

SURVEY RESULTS

A total of 1413 km of full observational effort on pre-determined transects was achieved. A total of 117 groups of blue whales were seen during this effort with a mean group size of 1.29, resulting in a total of 150 individuals. Locations of all sightings are shown in Figure 2. There were no sightings of sperm whales but acoustic data have not yet been analysed.

Distance and angle data were available for 113 sightings. These were truncated at a perpendicular distance of 2500m (removing two sightings) resulting in the detection function shown in Figure 3. The estimated strip half width was 1264.0m (95% CI 1094-1460m). This strip width and the total effort of 1413km on transect gave a density estimate of 0.041 individuals km^{-2}. For the survey area of 50km by 150km, this gives an abundance estimate of 306 blue whales. Further analysis is planned to estimate the variance associated with this estimate.

For the spatial model, 80 of the 1km segments of trackline had whales present ranging from 1 to 13 animals within a segment. Of the exploratory co-variates included in the model, Latitude, Longitude, Depth Category, and Sea State were all significant whereas Sightability was not. The model selected using poisson distributed whale counts with a log link function based on the restricted maximum likelihood (REML) score was a function of Latitude, Longitude, Sea State and Depth Category. Further analysis is planned with better bathymetry data and zero-inflated distributions for whale numbers in each segment.

Sighting rates were highest in Sea State 3 (Figure 4) reflecting the difficulty of seeing whale blows in higher sea states with whitecaps but also the lack of contrast in very calm conditions which can make blows difficult to detect. The relative density with respect to Latitude and Longitude is shown in Figure 5. Whale densities increased with water depth up to depths of around 1000m (Figure 6).

Further data are being gathered on shipping density, but the few days of AIS data available show the majority of ships following the shipping lanes off Dondra Head which run directly east-west with some transits further south (Figure 1). West of Dondra Head the shipping distribution tends a little to the north. The spatial model allows average whale densities to be estimated for different shipping routes. For this preliminary analysis we have just considered the main east-west route between Longitude 8^{o} 25’E and 8^{o} 45’E. Within this area, shipping density can be expressed as a function of

Latitude since almost all large ship traffic is heading directly east or west. The modelled densities with Latitude are shown in Figure 7 with average values in the shipping lanes and equivalent width lanes 15nm further south in Table 2.

PREVIOUS DATA

A key issue in evaluating ship strike risk is to understand the inter- and intra-annual variability in whale distribution and in particular the distribution patterns of high density areas of whales. The survey results presented here need to be considered in the context of longer-term data sets on distribution patterns.

Blue whale distribution patterns are often associated with bathymetry. Off the east coast, Alling et al (1991) reported seeing most blue whales around the 200m contour with none seen in the deepest water surveyed furthest offshore. These authors also concluded that Sri Lankan waters were an important feeding area based on depth sounder traces of repeated dives into dense patches of presumed prey and frequent observations of defecation at the surface. Blue whales off the south coast are also frequently seen to defecate and show the same high proportion of dives initiated with a fluke up. This suggests the south coast is also an important feeding area. Martenstyn (2013) notes concentrations of sightings recorded around submarine canyons where whales are thought to aggregate for feeding.

Data have been collected on all whale sightings made by the whale watch company Raja and the Whales since January 2013. Sightings of blue whales are summarised in Table 3 with locations shown in Figure 8. These sightings showed no significant differences in median Latitude or Longitude by month or year. Ilangakoon (2012) also presents some sightings data in a similar area from 2008/09 and from 2011. The survey tracks are not shown, but in 2008 and 2009 whales were seen inshore of the 1000m contour whereas in 2011 they were seen within the shipping lanes. The more inshore distribution in 2008/09 does indicate that the whale distribution may change in response to environmental conditions. Martenstyn (2013) also lists over 100 sighting locations from the Sri Lanka navy vessel Princess of Lanka operating whale watch trips out of Galle between 12/11/2011 and 19/02/2013. The furthest south of any of these sightings was 5^{o} 39.745’ N which corresponds to the southern edge of the eastbound shipping lane. However, it is not clear if the vessel ever searched any further south than this. These show very similar locations to the data from Raja and the Whales suggesting little change in distribution within the whale watch areas for 2011-2014.

DISCUSSION

The results of surveys in 2014 and previous data all indicate consistent high densities of blue whales occurring in the major shipping route south of Sri Lanka. The 2014 surveys were the first to systematically survey further offshore and suggest much lower whale densities south of the current shipping lanes. Patterns of coastal upwelling suggest that this density gradient is likely to be associated with bathymetry and therefore likely to persist over time. Nevertheless, further survey data in offshore areas in future years and at different times of year would be valuable. In particular, there is a lack of data during the SW monsoon period (May-August) when observation conditions are difficult. Further surveys are planned to address these data gaps.

There are also very few whale watch data from the SW monsoon period, as whale watching activity is mainly concentrated during the inter-monsoon and NE monsoon periods. However, blue whales have been seen off the west coast of Sri Lanka, 30-190nm offshore during the SW monsoon (Martenstyn, 2013). In addition, during the SW monsoon (May-October) there is a chlorophyll *a* (*chl a*) bloom attached to the southern coast of Sri Lanka (Vinayachandran et al, 2004). Coastal upwelling driven by monsoon winds is identified as the physical mechanism causing nutrient enrichment in the surface layer. Vinayachandran et al (2004) report high *chl a* occurrence around Sri Lanka for all the summer monsoons during 1998–2002, suggesting that this is a regular seasonal feature. Between July and October, a narrow band of *chl a* exists along the southern coast of Sri Lanka but *chl a* decreases offshore (Vinayachandran et al, 2004). These observations indicate high coastal productivity which may also support blue whale feeding during the SW monsoon period.

The distribution of ship speeds (Figure 9) and mean speed of 12.6 knots (SD = 3.6knots) is typical of global shipping. The coincident very high densities of whales and shipping suggest a severe risk of ship strikes. Any collision deaths are likely to be substantially under reported as most ships are unaware that they have struck a whale and the often strong surface currents in this area (Shankar et al., 2002) would take floating carcasses away from shore.

The predictable patterns of whale distribution indicate the potential for measures to keep ships and whales apart. Such measures will need to take account of economic considerations for vessels visiting ports in Sri Lanka in addition to traffic on passage across the Indian Ocean. Coastal fishing activity also needs to be considered. Measures to reduce ship strike risks to blue whales may improve maritime safety for the whale watch operators. Although blue whales occur in much higher densities than other species, the distribution of other potentially vulnerable species should be taken into account. Acoustic data were collected on all transects to investigate the distribution of sperm whales but these have yet to be analysed. There were six sightings of Bryde's whales and all these were north of 5^{o} 36'N. Whale watch data also suggest a more coastal distribution for Bryde's whales compared to blue whales.

Further AIS data including from satellites could inform mitigation measures by giving better indications of patterns of shipping movements over a wider area than the current receiving aerial at Matara. It is hoped to use satellite derived AIS for this.

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FIGURES

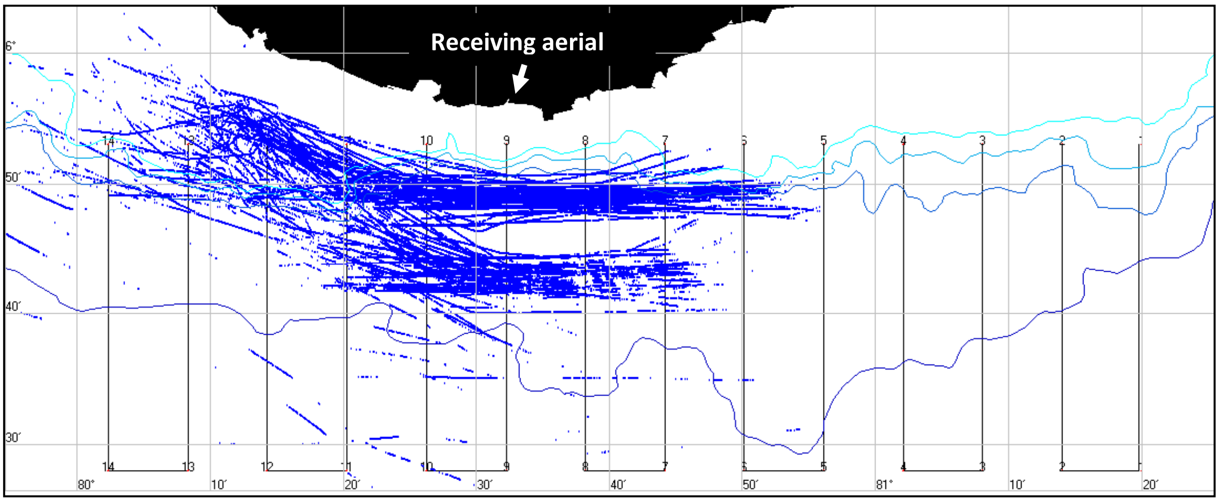

Figure 1. Survey area off the southern tip of Sri Lanka showing numbered transect lines. Depth contours are 200m, 500m, 1000m and 3000m. Blue lines indicate the tracks of ships from AIS data received from an aerial at the University of Ruhuna.

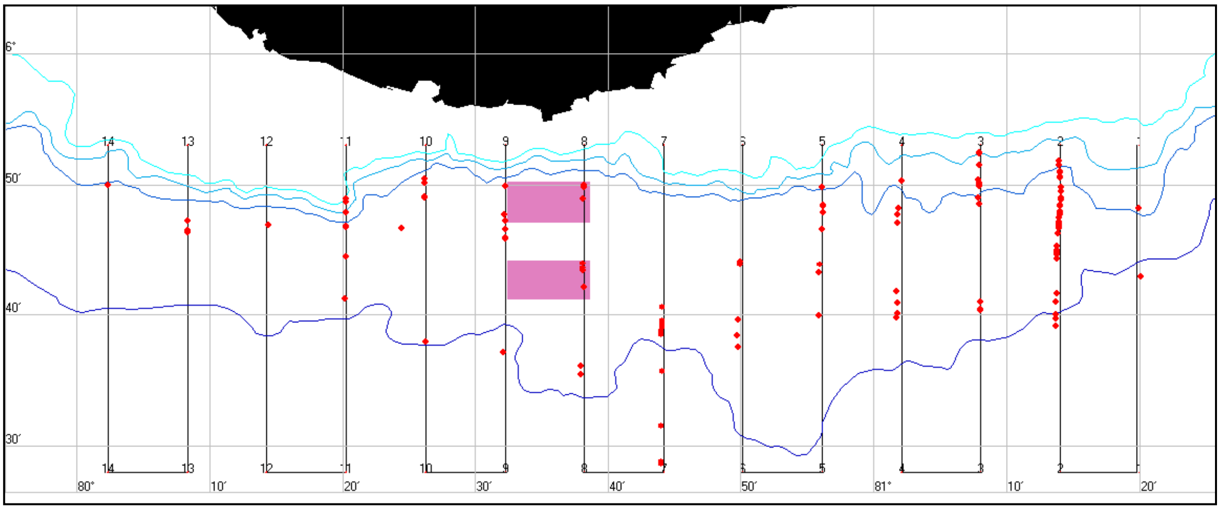

Figure 2. Locations of blue whale sightings from survey transects. Pink boxes are current shipping lanes associated with a Traffic Separation Scheme off Dondra Head.

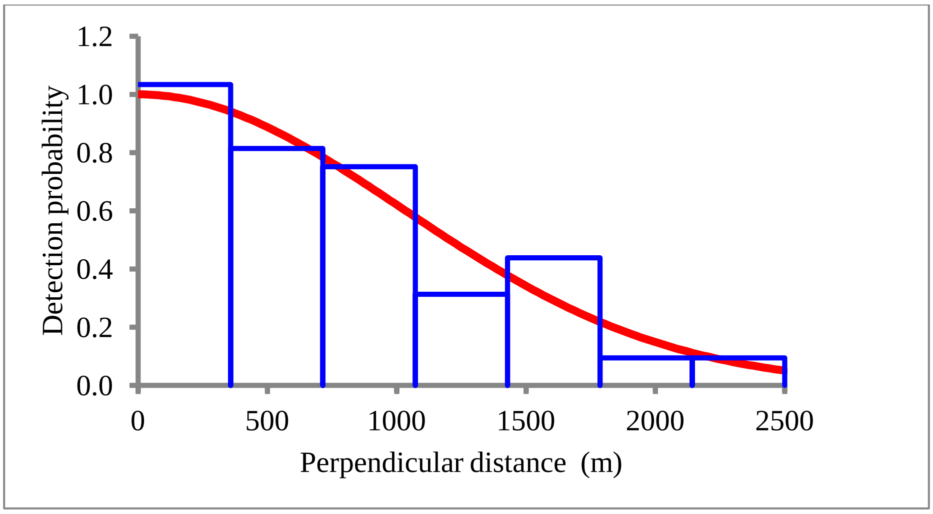

Figure 3. Histogram of frequency distribution of 'observed perpendicular distances' and detection function fitted using Distance.

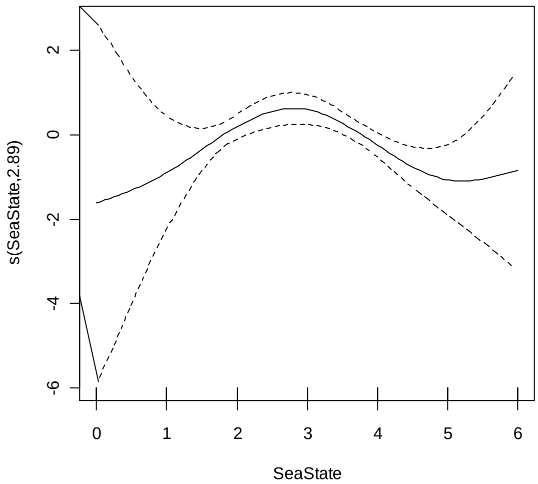

Figure 4. Modelled relative sighting rates with Sea State (log scale), shown by solid line with standard errors shown by dotted line.

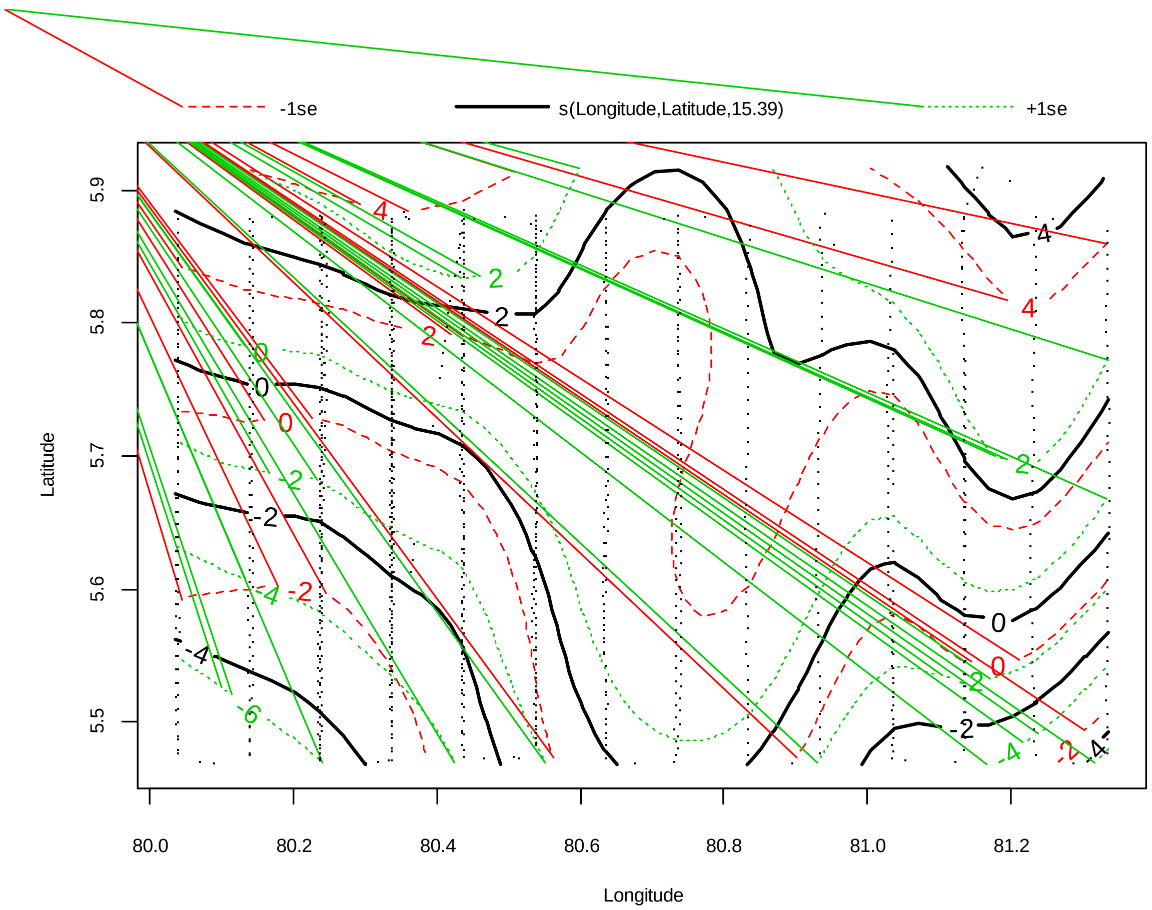

Figure 5. Contour plot of modelled relative density with respect to Latitude and Longitude. Contour labels are a log scale showing highest densities in the NE corner and lowest in the SW. Dotted lines indicate standard errors (green above mean, red below mean).

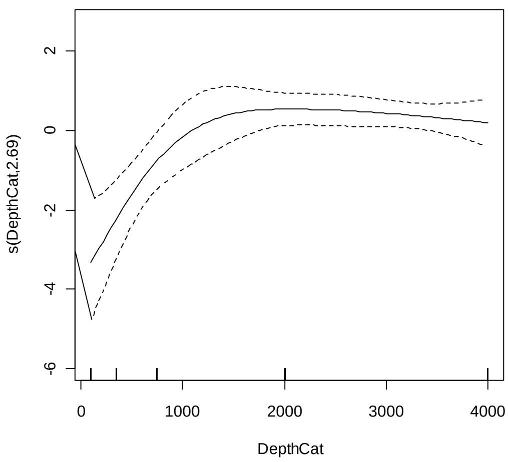

Figure 6. Relative sighting rates with depth (log scale) shown by solid line, with standard errors shown by dotted lines.

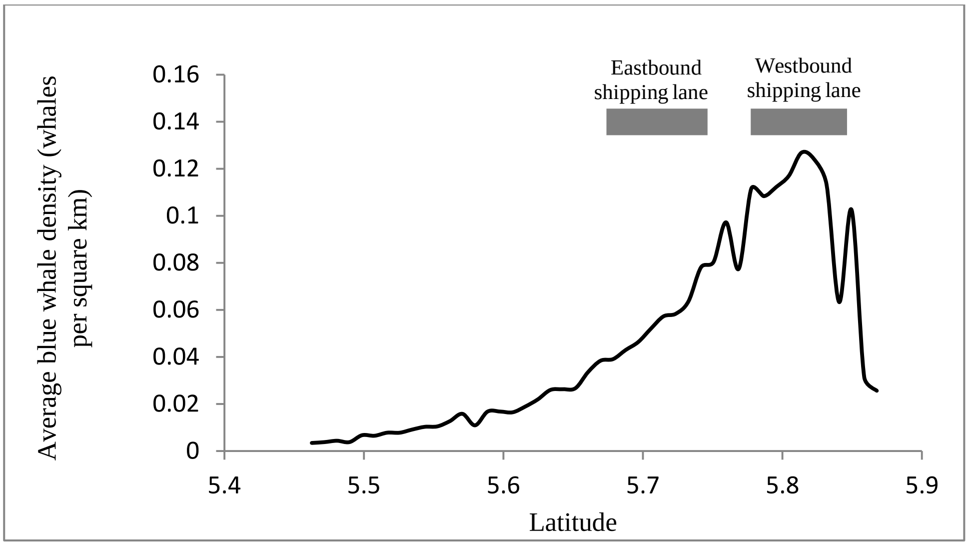

Figure 7. Average modelled blue whale density by latitude between longitudes 80° 25’ and 80° 45’. Latitudes of eastbound and westbound shipping lanes off Dondra Head shown as grey bars.

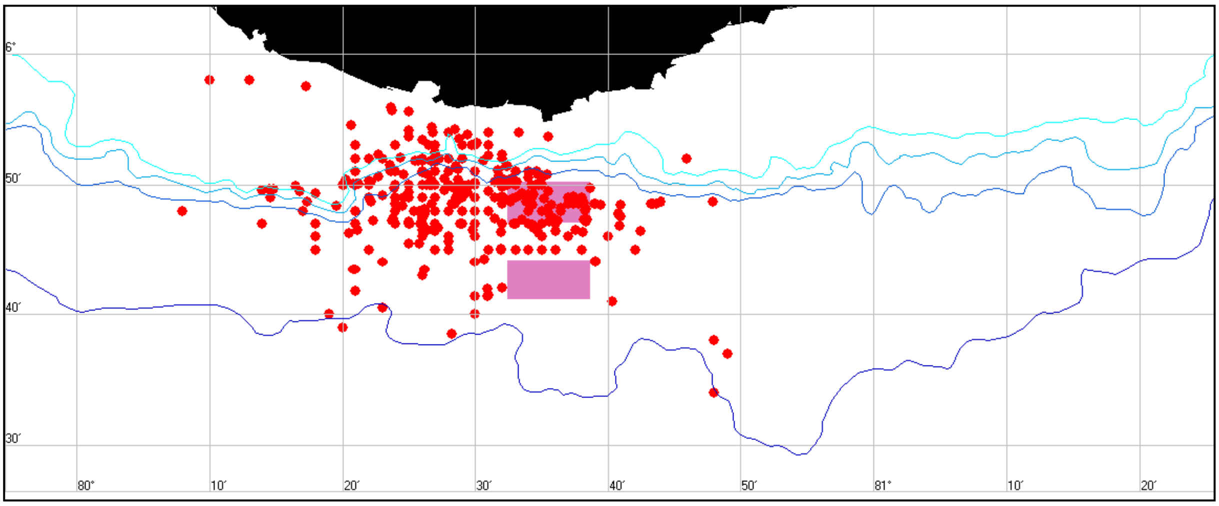

Figure 8. Sightings from whale watching operations during 2013 and 2014 (Raja and the Whales).

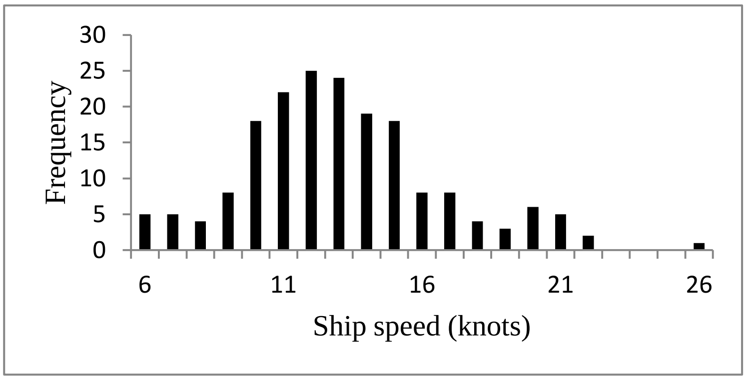

Figure 9. Distribution of observed ship speeds from AIS data.

TABLES

Table 1. Dates of survey transects and effort achieved.

Date	Total effort (km)	Min of SeaState	Max of SeaState	Transect pair
18/02/2014	44.5	1	6	10-11 (incomplete)
19/02/2014	91.4	2	4	9-10
21/02/2014	93.1	1	4	11-12
22/02/2014	65.2	4	6	3-4 (incomplete)
28/02/2014	92.4	2	6	11-12
02/03/2014	93.1	3	4	13-14
04/03/2014	92.5	4	4	7-8
05/03/2014	92.4	3	4	9-10
06/03/2014	92.9	3	4	11-12
20/03/2014	93.4	2	4	1-2
21/03/2014	97.8	2	4	3-4
22/03/2014	93.0	2	4	5-6
23/03/2014	93.6	2	4	7-8
24/03/2014	94.5	2	4	9-10
31/03/2014	93.1	0	4	11-12
03/04/2014	93.0	1	3	13-14

Table 2. Whale density with respect to Latitude between Longitude 8^o 25’E and 8^o 45’E

Area	Average whale density (individuals km^{-2})
Current Westbound lane 5^o 47.2’N – 5^o 50.2’N	0.098
Current Eastbound lane 5^o 41.2’N – 5^o 44.2’N	0.043
Westbound lane shifted 15nm south 5^o 32.2’N – 5^o 35.2’N	0.019
Eastbound lane shifted 15nm south 5^o 26.2’N – 5^o 29.2’N	0.009

Table 3. Blue whale sightings from whale watch trips by Raja and the Whales

Period	Number of days at sea	Number of blue whale groups	Number of individuals	Mean group size
01/01/2013 – 02/05/2013	112	202	495	2.5
08/08/2013 – 31/12/2013	95	103	187	1.8
01/01/2014 – 28/03/2014	75	107	199	1.9