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Abundance estimates for fin whale (*Balaenoptera physalus*) and sperm whale (*Physeter macrocephalus*) in the North Atlantic Marine Demarcation and adjacent waters of the Bay of Biscay (2003-2011)

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ABSTRACT
The project "*Basis for development of conservation plans for cetacean species protected in the North Atlantic Marine Boundary*" is a conservation research project directed by CEMMA in collaboration with AMBAR, EIBE, CEPESMA and other European cetacean organisations and specialists as a contribution to the transposition of the Marine Strategy Framework Directive (Directive 2008/56/EC, of 17 June 2008) into the Spanish regulatory system by means of the law on the Protection of the Marine Environment (41/2010 of 29 December 2010). The main objective of the project is to contribute to the development of Conservation Plans for cetacean species included in the Spanish Catalogue of Endangered Species (Royal Decree 556/2011, of 20 April 2011) for northern Spanish Cantabrian and adjacent waters of the Bay of Biscay, by collecting and assessing scientific information available in the area, and identifying criteria and guidelines to contribute to the development of conservation strategies. Uncorrected abundance estimates for the two main large cetacean species present in the area, fin whale (*Balaenoptera physalus*) and sperm whale (*Physeter macrocephalus*), were obtained using spatial modelling analysis of effort related visual data from designed and non-designed surveys carried out in the area by nine different organisations between 2003 and 2011. During the study period, 64,323 km on effort, 895 fin whale and 74 sperm whale sightings were considered for analysis. The summer uncorrected abundance estimate and density obtained for fin whale was 10,267 (CV=0.048, 95%CI: 9,507-11,101) with a density of 0.0155 animals per square kilometre, and 865 (CV=0.12, 95%CI: 767-1,041) and a density of 0.0013 animals per square kilometre for sperm whale. Different sources of bias having potential positive or negative effects, are discussed.

KEYWORDS: FIN WHALE, SPERM WHALE, BAY OF BISCAY, ABUNDANCE ESTIMATE, CONSERVATION, , MANAGEMENT

INTRODUCTION
The Spanish law on the Protection of the Marine Environment (41/2010 of 29 December 2010) constitutes the transposition of the Marine Strategy Framework Directive (Directive 2008/56/EC, of 17 June 2008) into the Spanish regulatory system. The project "*Basis for development of conservation plans for cetacean species protected in the North Atlantic Marine Demarcation*" is a conservation research project directed by CEMMA in collaboration with AMBAR, EIBE, CEPESMA and other European cetacean organizations and specialists. The main objective is to contribute to the development of Conservation Plans for cetacean species included in the Spanish Catalogue of Endangered Species (Royal Decree 556/2011, of 20 April 2011) for the North Atlantic

Marine Demarcation and adjacent waters of the Bay of Biscay. Uncorrected abundance estimates for the two main large cetacean species present in the area, fin whale (*Balaenoptera physalus*) and sperm whale (*Physeter macrocephalus*), were obtained using spatial modeling analysis of effort related visual data from designed and non-designed surveys carried out in the area by nine different organizations between 2003 and 2011.

MATERIALS AND METHODS

The methodology used in this study for estimating the abundance and critical areas through spatial modeling is described in Cañadas and Hammond (2006, 2008). The data used for the analysis comprise 80,171km of effort and 3,689 sightings of 19 different cetacean species recorded during 14 different projects undertaken by 9 different organizations. The study area was divided into a grid with 82,955 cells of 0.03 x0.03 degrees covering a total area of 793,765 square kilometres. Each cell was characterized using several oceanographic and physiographic variables. After the segmentation process 26,892 segments were obtained with an average size of 2,392 metres covering 64,323 kilometres. Detection functions for fin whale and sperm whale were calculated with Distance 6.0 software, and abundances and density estimates were calculated with 'mgcv'-pack version 1.6-2 for R software (Wood 2001). Nevertheless, data on swimming direction when detecting animals were used to investigate responsive movement in order to detect possible over- or under-estimations (Palka and Hammond, 2001).

RESULTS AND DISCUSSION

Fin Whale

Data were truncated at 4,500 m, leaving 895 sightings to adjust the detection function. The best fitted model was a hazard-rate key function with no adjustment terms. One covariate was selected "group of ships" as a two level factor: "large" (ships used in SCANS-II and CODA surveys, where large long range binoculars and experienced observers were used) and "small" (including all other boats from other surveys). The overall ESW was 1,520 m. Figure 1 shows the detection function averaged across the covariates. The best model of abundance of groups containing 3 covariates: depth (depth), and the interaction between spatial covariates latitude (LatMid) and length (LonMid). This model explains 31.9% of the deviance. Figure 2 shows both interactions. The best group size model contains the interaction between latitude and longitude, and explains 20.6% of the deviance (Fig 3). The estimated total abundance of fin whales in the study area is 10,267 animals (density = 0.0155 animals/km2), with a coefficient of variation CV = 4.8% and 95% CI = 9507-11101. The abundances estimated for the different sub-areas are: (1) Euskadi = 4, (2) Cantabria = 8, (3) Asturias = 16, (4) Galicia = 71, (5) Bank = 118, (6) Aviles = 4. Figure 4 shows the prediction of density for fin whale for summers 2003-2011 in the North Atlantic Marine Demarcation and adjacent waters of the Bay of Biscay.

Sperm Whale

Data were truncated at 4,000 m, leaving 74 sightings to adjust the detection function. The best fitted model was a hazard-rate key function with no adjustment terms. One covariate was selected "platform height" (as a continuous covariate) The overall ESW was 1,770 m. Figure 5 shows the detection function averaged across the covariates. The best model of abundance of groups containing 3 covariates: depth (depth), and the interaction between spatial covariates latitude (LatMid) and length (LonMid). This model explains 23.9% of the deviance. Figure 6 shows both interactions. The best group size model contains the distance to the 1,000m isobath, and accounts for 10% of the deviance (Fig 7). The estimated total abundance of sperm whales in the study area is 865 animals (density = 0.0013 animals/km2), with a coefficient of variation CV = 11.8% and 95% CI = 767-1041. The abundances estimated for the different sub-areas are: (1) Euskadi = 3, (2) Cantabria = 6, (3) Asturias = 1, (4) Galicia = 10, (5) Bank = 21, (6) Aviles = 0. Figure 8 shows the prediction of density for sperm whale for summers 2003-2011 in the North Atlantic Marine Demarcation and adjacent waters of the Bay of Biscay.

Table 1 shows the results of the analysis to explore the responsive movement effects upon abundance. There was no statistically positive (attraction) or negative (evasion) effect ($p<0.001$) found for either of the target species following a runs X2 test.

DISCUSSION

The abundance estimate for fin whale obtained in SCANSII-CODA projects was 6,577 (CV=24%) and 1,463 (CV=80%) for blocks 3 and 4 respectively. The sum of these two abundances is 8,001 animals (Hammond et al., 2011), lower that the abundance estimate obtained in this study. In the other hand, the abundance estimate for sperm whale obtained CODA project was 477 (CV=33%) and 661 (CV=33%) for blocks 3 and 4 respectively. The sum of these two abundances is 1,138 animals (CODA, 2009), higher that the abundance estimate obtained in this study. These discrepancies in the values of abundance may be due to several factors that should be taken into account when being compared. First of all, the areas and the study periods are not the same. While in SCANSII and CODA projects data comes from surveys carried out in July 2005 and 2007 respectively, in this study data corresponds to different surveys carried out in summer months (from June to September) during 2003-20011, including SCANSII and CODA data. On the other hand, the study area considered in this study did not correspond exactly with the sum of SCANSII (block w) and CODA (blocks 3 and 4). Secondly the method for collect the data were not the same. While in SCANSII and CODA the surveys were conducted using a 'trial configuration' or BT method (Laake and Borchers, 2004), with two teams of observers located on each survey vessel, in this study the data comes from different surveys carried out using different methods, all of them following the main assumptions of distance sampling method but without the possibility to implement methods to estimate availability bias such as in SCANSII and CODA. Finally, the analyses are also different. As mentioned before the methodology used in this study for estimating the abundance was the spatial modeling method described in Cañadas and Hammond (2006, 2008), and only primary sightings of SCANSII and CODA project were included in this analysis. So the abundance values obtained in this study are not corrected for availability bias and therefore could be underestimated values. Responsive movement is other possible factor that can affect but the results of the analysis to assess the effect of this factor on the abundances is statically no significant for both species.

Concerning to the distribution of the species the results coming from both studies, SCANSII+CODA and this study produce approximately the same high densities areas in both cases for fin and sperm whales. It would be possible that these coincidences were due to a main contribution of data from SCANSII+CODA. This seems not to be the case because 66,91% of the fin whale sightings used in this analysis comes from data collected by CEMMA during opportunistic shipments in tuna fishing boats and only 30,71% of the of the fin whale sightings used in this analysis comes from data collected in SCANSII+CODA projects. In the case of sperm whale this is not so evident (34,66% comes from CEMMA and 53,33% from SCANSII+CODA).

In other to establish a better comparison between both abundance estimates, SCANSII+CODA and CEMMA it would be advisable to perform a separate analysis of data from opportunistic tuna shipments. The results of these analyses would allow assessing the use of opportunistic tuna shipments as a possible method of monitoring the abundance of fin whales and sperm whales in the Bay of Biscay and adjacent waters.

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TABLES AND FIGURES

Table 1. Results of the responsive movement analysis based on swim directions . * (without considering 0º,90º,180ª and 270º).

Species	n1	n2	n3	n4	n3/n1	p
Fin Whale	183	134	195	153	1.07	0.537
Fin Whale*	115	134	131	153	1.14	0.308
Sperm Whale	6	2	9	6	1.50	0.439
Sperm Whale*	3	2	2	6	0.67	0.655

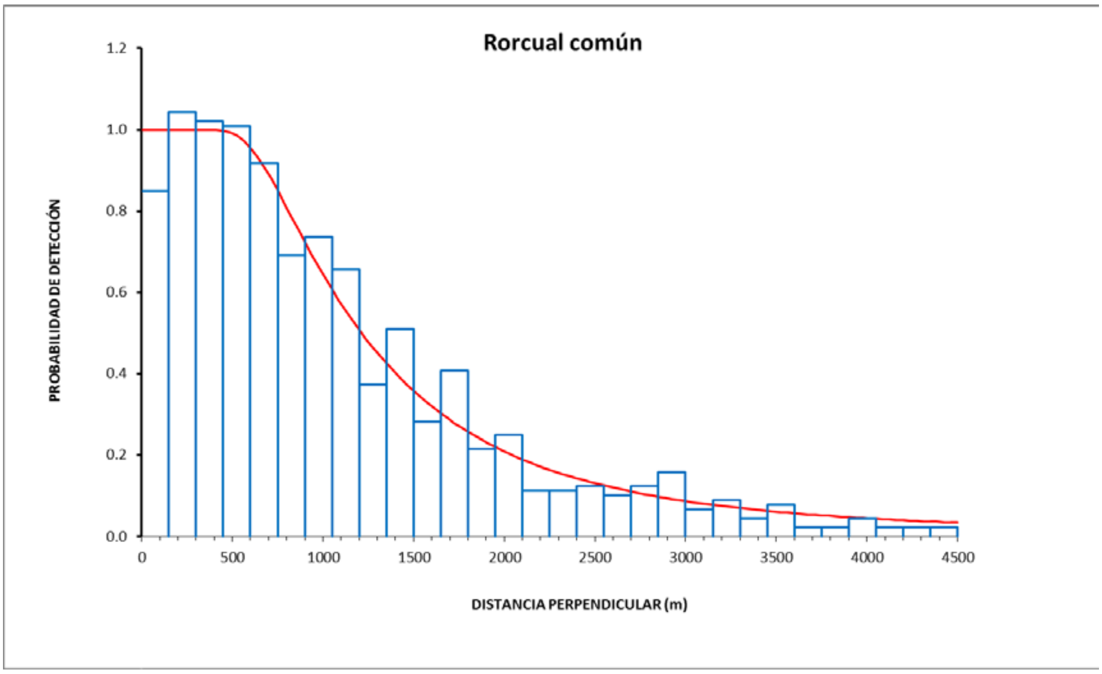

Figure 1. Detection function fitted for fin whale.

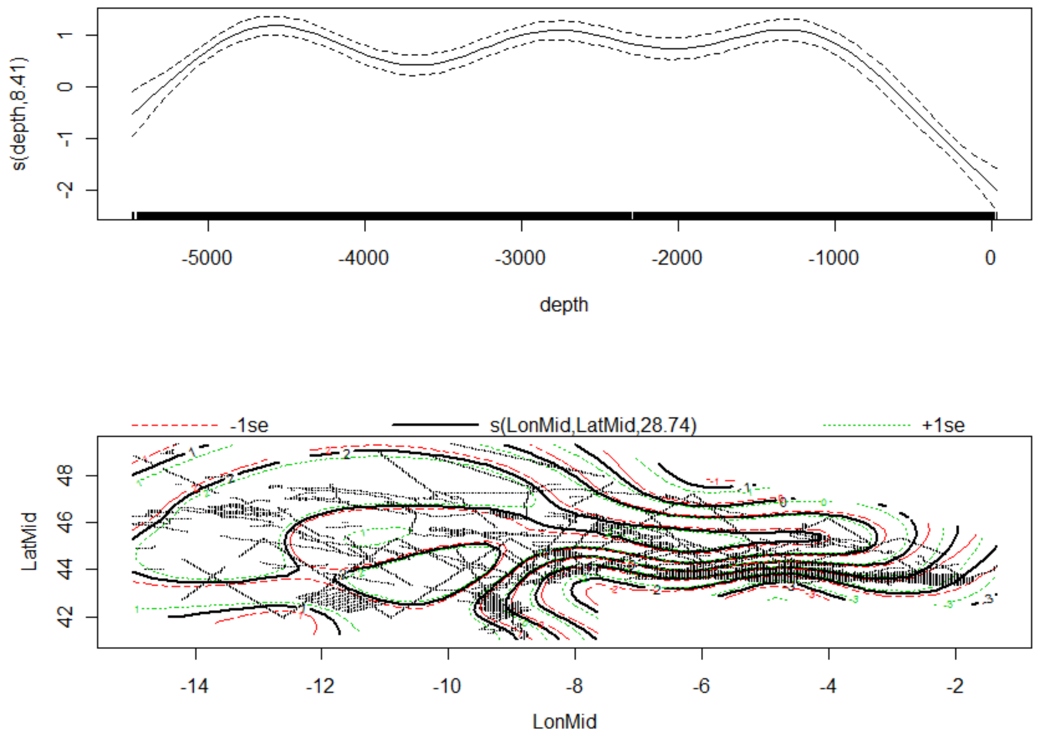

Figure 2. Variables selected for the abundance of fin whale groups. Latitude x longitude and depth.

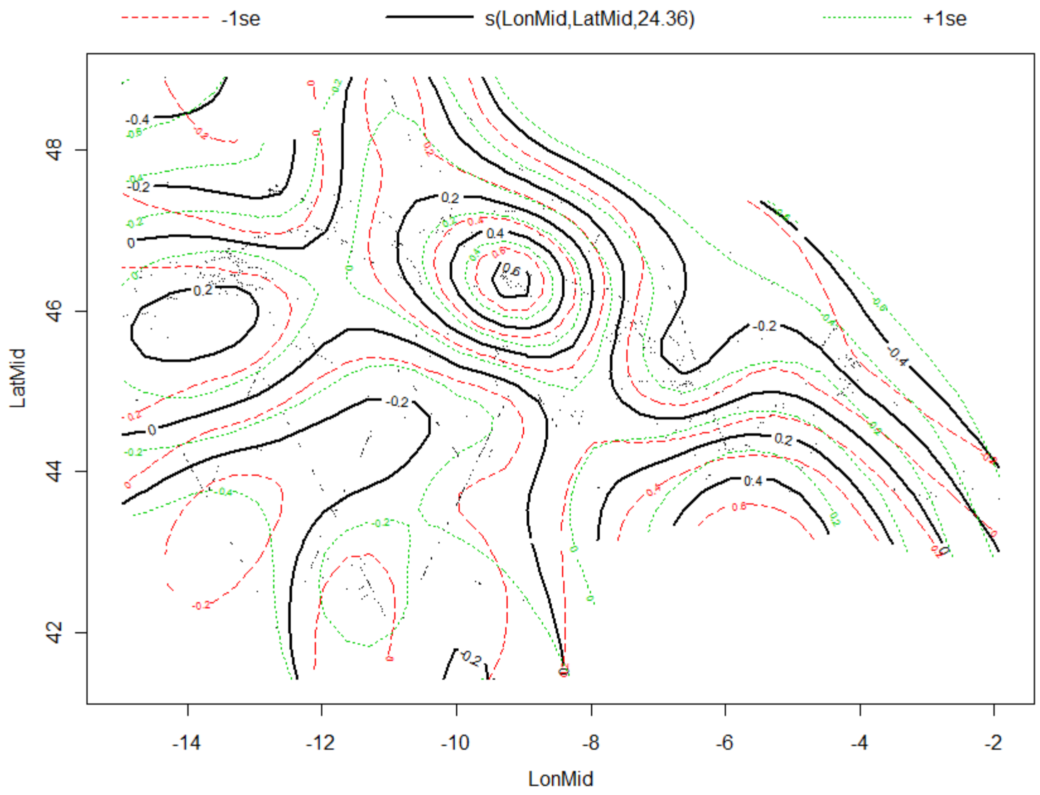

Figure 3. Variables selected for fin whale group size. Latitude x Longitude

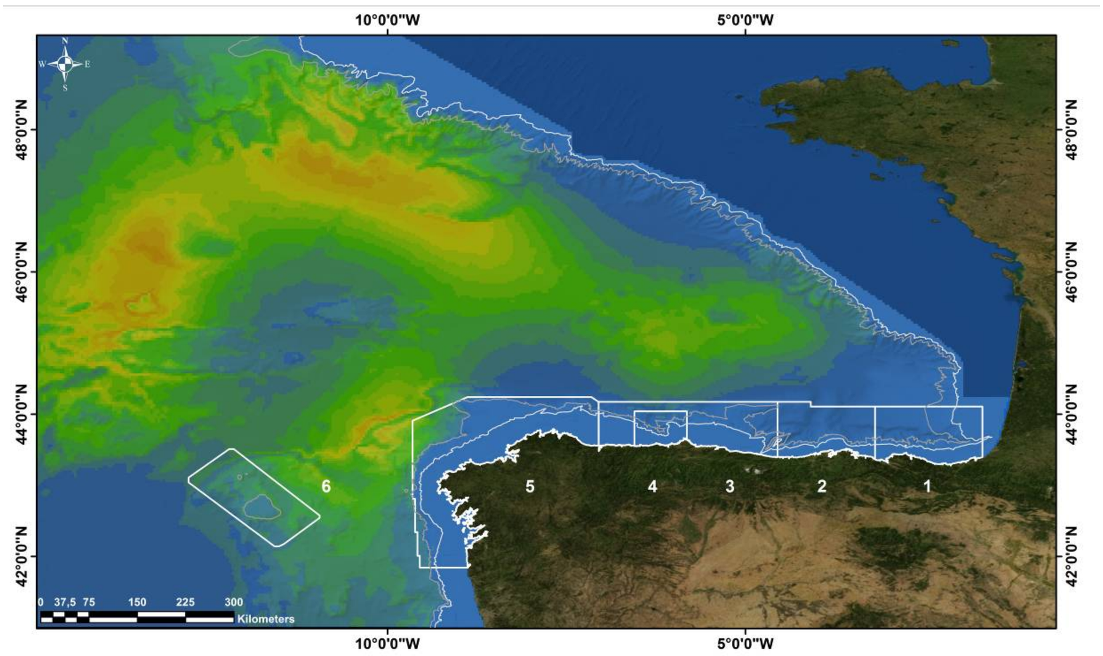

Figure 4. Predicted densities for fin whale for summers 2003-2011 in the North Atlantic Marine Demarcation. Área 1: Euskadi, área 2: Cantabria, área 3: Asturias, área 4: cañón de Avilés, área 5: Galicia y área 6: banco de Galicia.

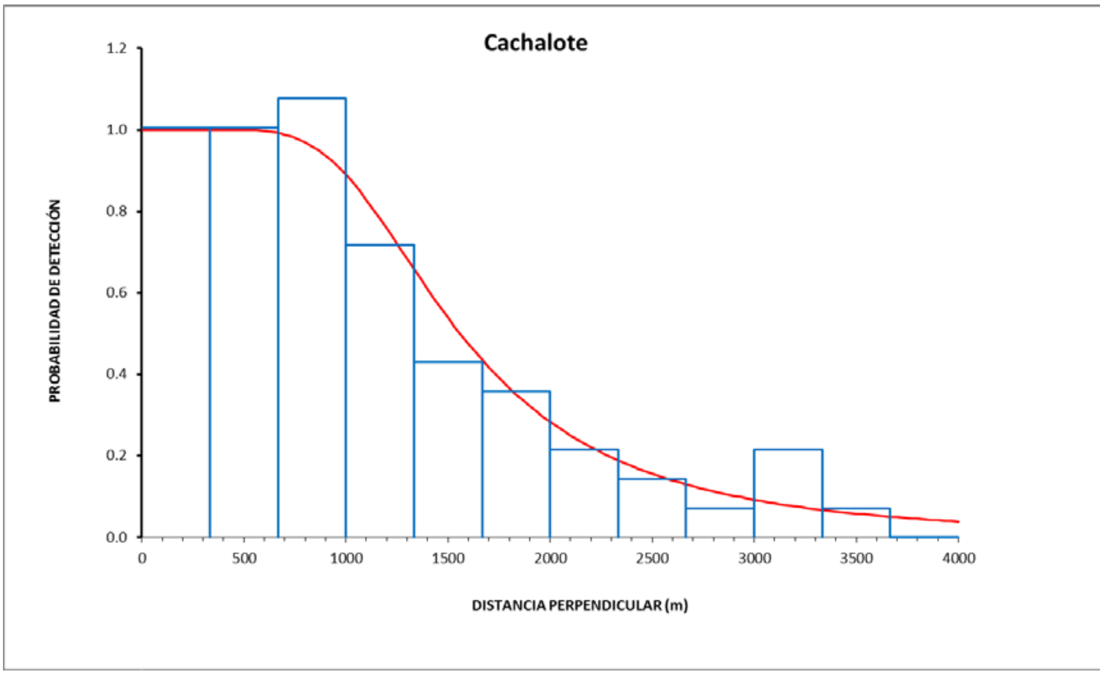

Figure 5. Detection function fitted for sperm whale.

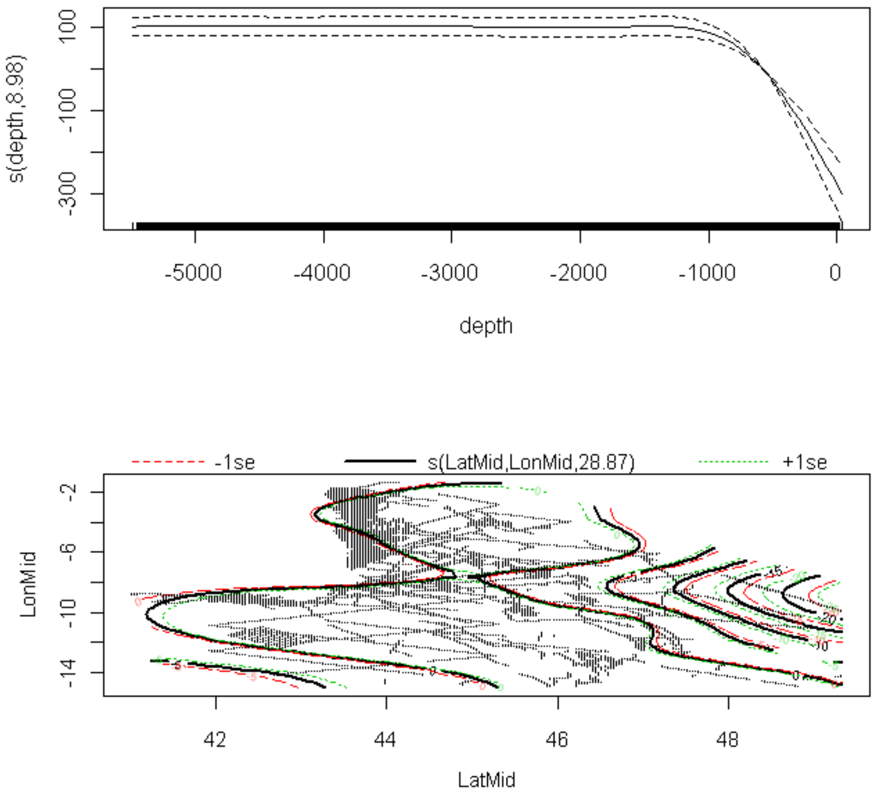

Figure 6. Variables selected for the abundance of sperm whale groups. Latitude x longitude and depth.

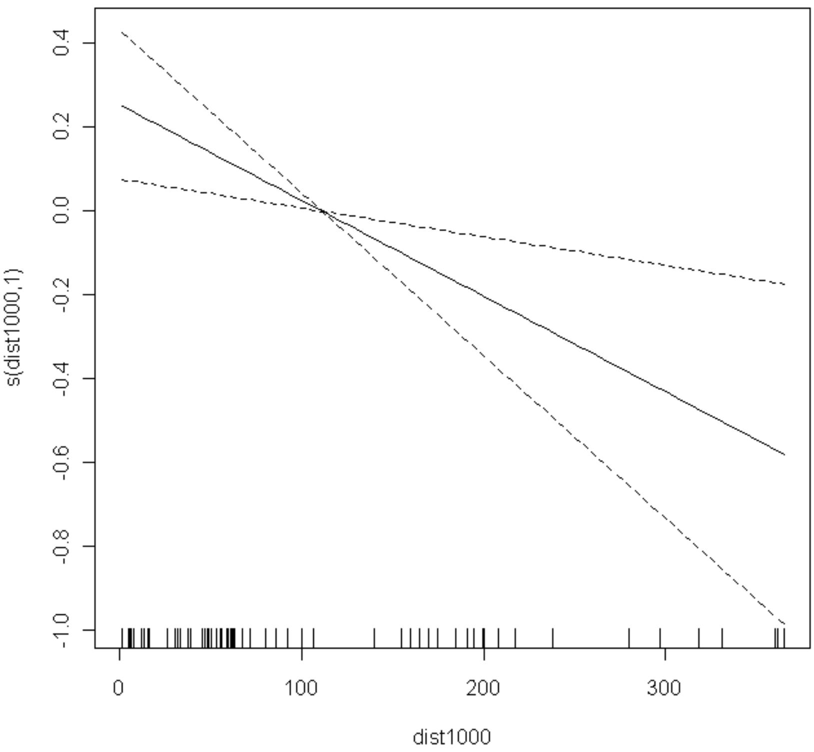

Figure 7. Variables selected for sperm whale group size. Dist1000m.

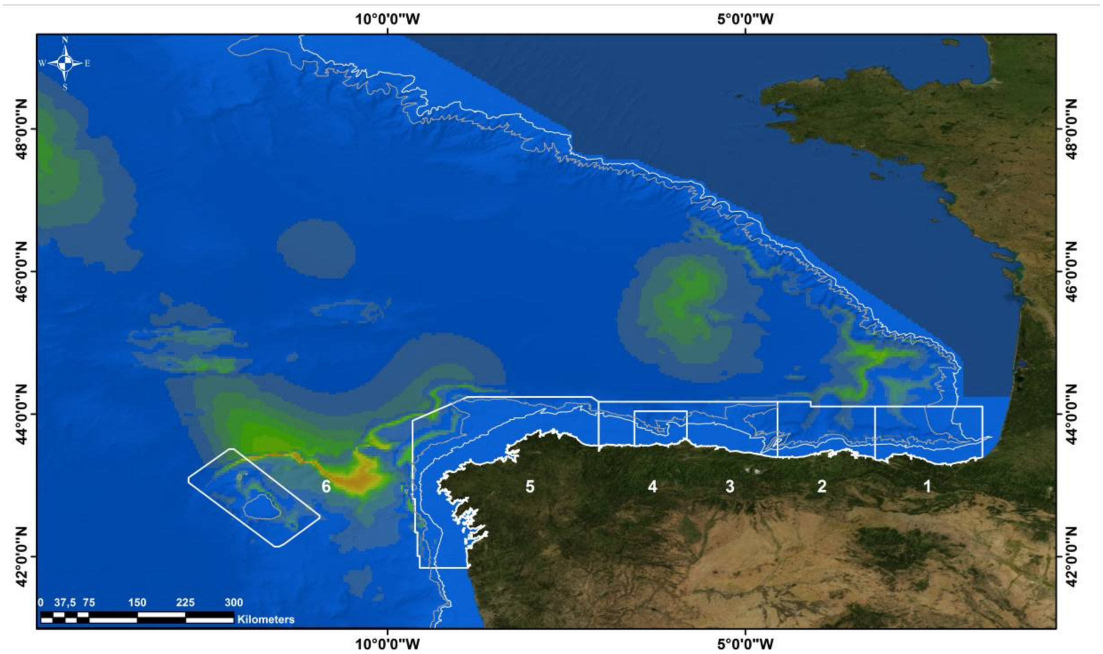

Figure 8. Predicted densities for fin whale for summers 2003-2011 in the North Atlantic Marine Demarcation. Área 1: Euskadi, área 2: Cantabria, área 3: Asturias, área 4: cañón de Avilés, área 5: Galicia y área 6: banco de Galicia.