

Analysis of Protected Species Occurrence During Aerial and Shipboard Surveys in the Jacksonville OPAREA for the Period January 2009 to October 2015

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ABSTRACT

This report describes the analysis of data collected during aerial and shipboard surveys within the Jacksonville OPAREA, undertaken by Duke University and the University of North Carolina at Wilmington, for the period January 2009 to October 2015. The aim of the analysis was to estimate the abundance of cetaceans and turtles in the region of interest using density surface modelling. These estimates should be considered as minimum values because no account was taken of imperfect detection on the trackline or of animals that were below the surface and hence, unavailable for detection. Detection functions were generated for the following species groups: dolphins, medium-sized cetaceans (*Globicephala* sp. and kogiids) large cetaceans (balaenopterids and *Physeter*) and turtles. There were sufficient detections to generate spatio-temporal abundance estimates (uncorrected for availability bias or perception bias) for *Stenella* sp. dolphins, bottlenose dolphins (*Tursiops truncatus*) and loggerhead turtles (*Caretta caretta*). Yet no predictors for bottlenose dolphin distribution were found. Only a mean surface abundance over the time period was estimated for bottlenose dolphins, leatherback turtles and medium-sized cetaceans collectively.

The predicted surface abundance estimate ASSUMING AN AERIAL SURVEY for bottlenose dolphins was 160 (95% confidence interval: 140 – 190). Likewise the predicted surface monthly abundance estimates of *Stenella* sp. dolphins for the time period of interest varied between 90 (10 – 210) and 450 animals (620 – 850). Predicted minimum abundance of medium-sized cetaceans was 13 (5 – 21). Predicted abundance of loggerhead turtles varied between 160 (70 – 290) and 390 (330 – 1040). Predicted surface abundance of leatherback turtles was 19 (15 – 22).

INTRODUCTION

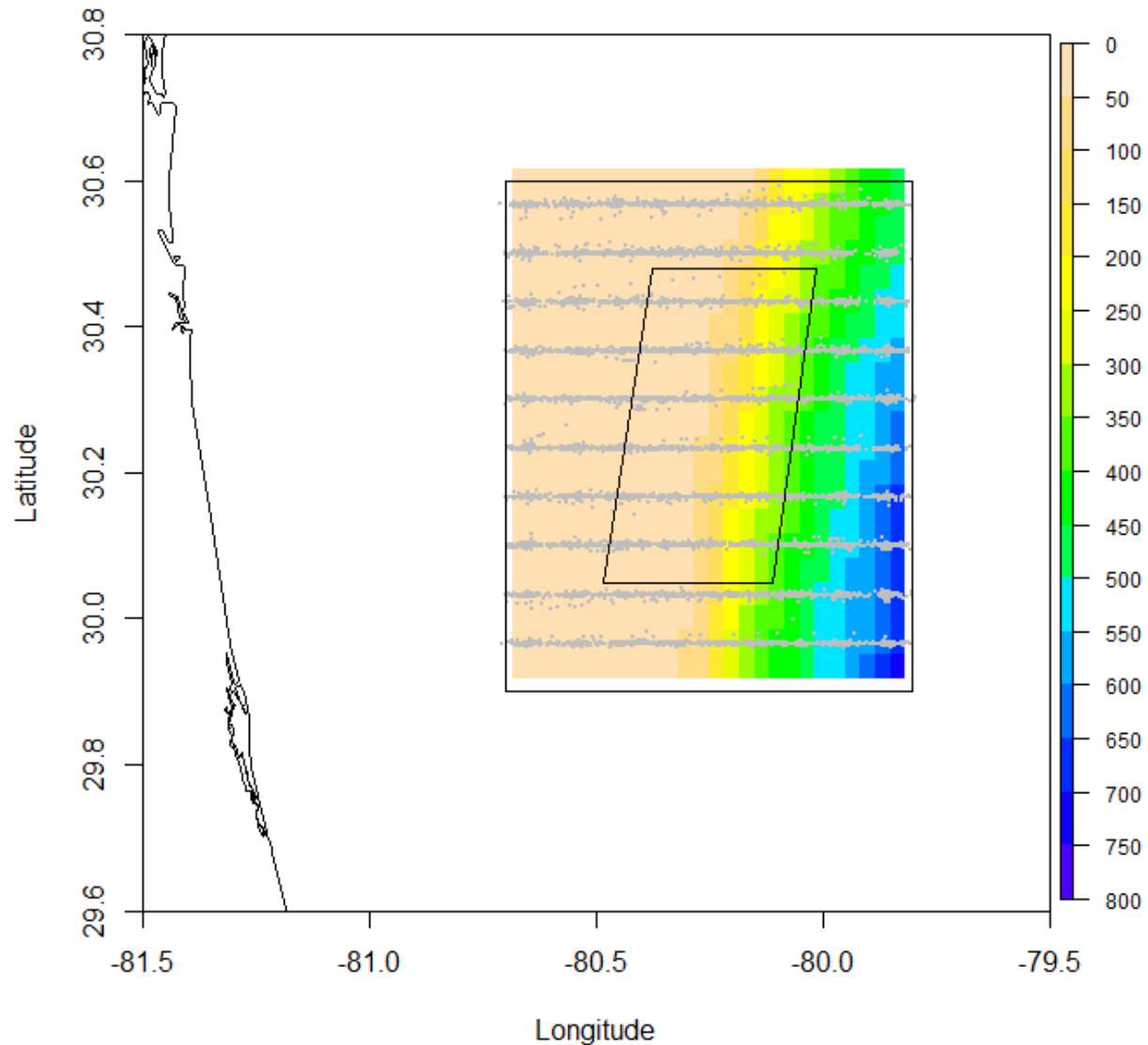
Aerial and shipboard surveys have been conducted in the Jacksonville OPAREA by the University of North Carolina at Wilmington (UNCW) and Duke University, respectively, since 2009. The aim of these surveys was to collect data to estimate density and abundance of marine animals in the Jacksonville USWTR region, which is off the east coast of Florida in the Atlantic (Fig. 1). Maps of estimated density were generated using density surface modelling techniques and abundances were obtained from these results. These techniques allowed density to vary both spatially and temporally through the explanatory variables included in the models and since data had been collected throughout the year, effects of seasonal abundance changes (if any) could be investigated.

SURVEY METHODS

The Jacksonville OPAREA core survey region of interest (hereafter “inner” region) is defined by the boundary of the planned Undersea Warfare Training Range (USWTR) and is shown in Figure 1 along with an outer survey zone (hereafter “outer”). The area of the inner region is approximately 1680 km² and the area of the outer region (excluding inner) is 5028 km². Abundance estimates were obtained for the whole region and also for the inner region and the outer region separately.

Ten parallel transect lines were aligned east-west across the region and both aerial and ship surveys used these transect lines (Fig. 1). Aerial surveys were conducted more or less monthly from January 2009 and generally all transect lines were covered several times during the year. Ship surveys started in July 2009 and were conducted monthly, weather permitting, until March 2011. Between one and four transect lines (random start point) were surveyed during each month. Details of all past survey effort can be found in [Read et al. 2010](#), [Read et al. 2012](#), [Read et al. 2013](#), [Cummings et al. 2013](#), [McAlarney et al. 2014](#), [Swaim et al. 2014](#), [McAlarney et al. 2015](#), [Swaim et al. 2015](#), [Cummings et al. 2016](#), and [Foley et al. 2016](#).

Figure 1. Jacksonville survey region with depth (m) indicated by colours. Each grid cell has dimensions 1/30 degree of latitude and 1/30 of a degree of longitude. Grey lines indicate midpoint of effort segments from all surveys. The boundaries of the outer and inner survey areas are shown by solid lines.



Aerial search protocol

The plane flew at a height of 305m above sea level. Two observers (one on either side of the plane) searched for marine animals and when an animal was detected, they recorded vertical declination angle to the sighting, species and group size. When a whale or dolphin was detected, search effort was suspended while the plane left the transect line to investigate the sighting in order to confirm species and group size. The search effort was resumed along the transect line after leaving the sighting. Environmental conditions were also recorded.

Estimates of perpendicular distance from the transect line to sightings of turtles were obtained either by the observers recording perpendicular distance or by trigonometry from the declination angle of the plane to the observed animals. For cetaceans, perpendicular distances were calculated by trigonometry using the position of the plane at first observation of the animals and subsequent location directly above the animals.

Shipboard search protocol

On detecting animals, observers recorded the species, group size, sighting angle and radial distance to the group as well as environmental conditions. Estimates of perpendicular distance were obtained from the sighting angle and radial distance.

STATISTICAL METHODS

The aim of the analyses was to estimate a density map for each species/taxa using the count method of Hedley *et al.* (2004, 1999). However, the numbers of sightings of some taxa were too few to be able to fit a model reliably to estimate a density surface and so a uniform surface was assumed (i.e. assuming no temporal or spatial fluctuations) – this was equivalent to using a conventional line transect sampling (Buckland *et al.* 2001) estimator.

Methods Overview

For each taxa, the probability of detection associated with each sighting (assuming certain detection on the trackline) was estimated and this probability was then used to estimate abundance in small segments of the trackline. The estimated segment densities formed the response variable in one or more regression-type models with location, habitat and temporal variables used as potential explanatory variables. After model selection, the chosen models were used to estimate density for the region of interest and abundance was obtained by numerically integrating under the predicted density surface. Note that the resulting abundances are relative (rather than absolute) because they do not take into account imperfect detection on the transect line or the availability of animals at the surface. Differences between ship and aerial survey can be accounted for in the spatial model or by using the appropriate mean.

Estimation of detection probabilities

In conventional line transect sampling (Buckland *et al.* 2001), the probability of detection depends only on the perpendicular distance of the sighting to the transect (y) and at zero perpendicular distance the probability of detection is assumed to be one (denoted by $g(0)=1$). Both a hazard-rate ($1-\exp(-y/\sigma)^b$) and a half-normal ($\exp(-y^2/2\sigma^2)$) form were considered as suitable forms for the detection functions (σ is the scale parameter) the most appropriate form for the relevant data (Buckland *et al.* 2001). The effects of covariates, other than perpendicular distance, were incorporated into the detection function model by setting the scale parameter in the model to be an exponential function of the covariates (Marques 2001). Thus, the probability of detection becomes a multivariate function, $g(y, \mathbf{v})$, representing the probability of detection at perpendicular distance y and covariates $\mathbf{v}$ ($\mathbf{v} = v_1, \dots, v_Q$ where Q is the number of covariates). The scale term, σ , has the form:

$$\sigma = \exp \left(\beta_0 + \sum_{q=1}^Q (\beta_q v_q) \right)$$

and β_0 and β_q ($q=1, \dots, Q$) are parameters to be estimated. With this formulation, it is assumed that the covariates affect the rate at which detection probability decreases as a function of distance, but not the shape of the detection function. The covariates considered for inclusion into the aerial detection function were Beaufort sea state (BSS), group size, cloud cover, visibility, glare and species; all but species were treated as continuous variables. Group size was also considered as a simplified code (1 meant 1, 2 meant 2, 3 meant <5, 4 meant <10, 5 meant <= 20, 6 meant <=50, 7 meant <= 100 and 8 was >100). A forward, stepwise selection procedure was used to decide which covariates to include in the model, with a minimum

Akaike's Information Criterion (AIC) inclusion criterion. All model selection was performed using a set of customised functions (mrds v.2.1.10, Laake *et al.* 2013) within the statistical programming package *R* (*R* Developmental Core Team, 2002, v. 3.1.3.).

Some of the data from Jacksonville was supplemented by additional survey data from the UNCW right whale surveys to increase sample sizes to facilitate detection function fitting. Despite this, there was a paucity of sightings for individual species and so data were amalgamated across species into groups with presumed similar detectabilities. For aerial detections, three groups were identified with sufficient numbers to allow abundance estimation; all dolphin species, medium-sized cetaceans (pilot whales and kogiids), large whales and turtles. Species was considered as a factor in the analysis though. For ship detections, two groups were identified; dolphins and turtles.

Estimation of density surfaces

The 'count model' of Hedley *et al.* (2004) was implemented to model the trend in spatial distribution of the different species. The response variable for this model is the estimated number of individuals in a small segment i of trackline, $\hat{N}_i$, calculated using an estimator similar to the Horvitz-Thompson estimator (Horvitz and Thompson 1952), as follows:

$$\hat{N}_i = \sum_{j=1}^{n_i} \frac{s_{ij}}{\int_0^w \hat{g}(y, v_{ij}) \pi(y) dy}, \quad i = 1, \dots, T,$$

where for segment i , $\int_0^w \hat{g}(y, v_{ij}) \pi(y) dy$ is the estimated probability of detection of the j th detected group, n_i is the number of detected groups in the segment and s_{ij} is the size of the j th group. The total number of transect segments is denoted by T . By assumption, $\pi(y)$, the probability density function of actual (not necessarily observed) perpendicular distances is uniform up to the truncation distance; this is satisfied by locating transects randomly or with a random start point.

Having obtained the estimated number of individuals in each segment, the density in segment i , $\hat{D}_i$, was estimated from $\hat{N}_i / a_i$ where a_i is the area of segment i . Segment area (also used as a weight) was calculated as the length of the segment multiplied by twice the truncation distance (which was decided when modelling the detection function). The realised transect lines were divided up into distinct segments based on when the observers had gone on- or off-effort and whether there was a change in environmental characteristics. A target segment length of 10 km for the aerial survey was chosen as an appropriate compromise between maximising the ratio of the number of segments containing sightings to the number of segments not containing sightings, maintaining environmental resolution and giving some measure of spatial independence. However, some segments were much smaller if there had been a break in effort or change in environmental conditions. Thus the analysis aimed to explain density in terms of other variables available for each segment.

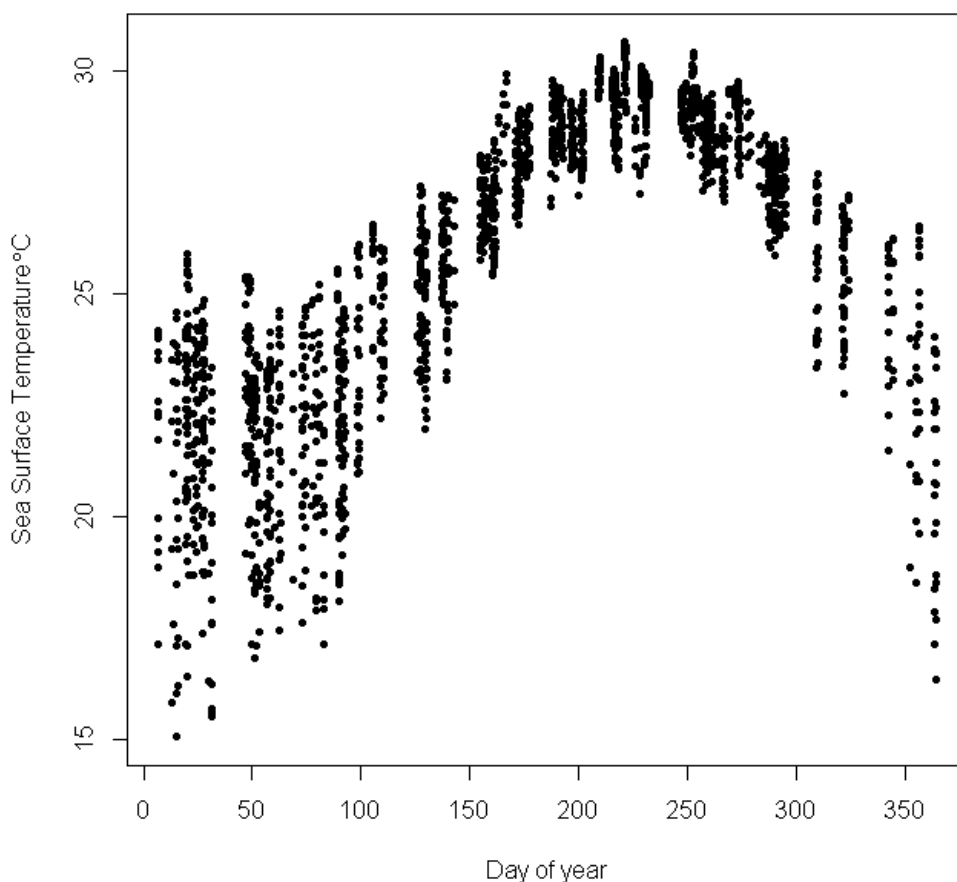
The modelling method is regression and more specifically generalized estimating questions (GEEs, Hardin and Hilbe 2003) were used as the method as a way of dealing with the autocorrelated variation in the residuals from the models. Generalized estimating equations provide some advantages over generalized additive equations in that residual autocorrelation and to an extent zero-inflation are dealt with although they are a little more difficult to implement and models that can be fitted are generally simpler. Their treatment of the autocorrelation

makes them more appropriate for explanatory models and in this analysis allows consideration of all the densities in the explanatory models rather than just presences. Diagnostics indicated a Poisson-like error structure and a log-link was used. The smooths were b-splines fitted with the Splines package in *R* (now part of the base package in *R*).

All non-factor covariates were considered for inclusion in the model as one dimensional (1D) smooths of covariate value and the smooths of *Easting* and *Northing* were also considered as an interaction. Taking into account the low percentage of segments containing sightings, a maximum of 5 degrees of freedom was initially allowed in the selection of 1D smooths, thus allowing moderate flexibility but reducing the possibility of fitting unrealistically complicated functions. In the case of *Year*, the maximum allowed degrees of freedom was 3 because of the small range of years. The interaction was considered first (and all nested models) before forward selection on the other variables. Model selection was forward using a $P < 0.05$ inclusion criterion after initial backward selection on the interactions of the smooth of Easting and Northing.

Unsurprisingly, *SST* was strongly correlated with *Dayofyear*; *Easting* (*Lon*) and *Northing* (*Lat*) were correlated with *Depth*. Thus, the inclusion of only one variable of these correlated variables in the final models should not be interpreted as necessarily precluding the influence of others. In the case of *SST* and *Dayofyear* only one of these terms was allowed in the final model.

Figure 2. Relationship between day of year and AVHRR-derived sea surface temperature (°C) for each segment of survey effort.



Prediction

The selected models were used to predict density of marine animals in the total region and in the inner and outer regions separately using a 2 minute resolution prediction grid. Animal abundance was estimated by numerically integrating under this predicted density surface. If survey platform was included in the model, abundance was predicted using *Platform* equal to “aerial” as this is the most recent survey technique, If the effect of *Platform* was in the opposite direction from that expected (i.e. the coefficient associated with ship was smaller than the aerial coefficient) the term was omitted. However it should be pointed out that no ship survey has been undertaken since 2011.

Estimation of uncertainty

Variance for the uniform models was estimated by repeating (1,000 times unless otherwise stated) the entire abundance estimation process on samples drawn from the data to obtain a distribution of abundance estimates. Samples were obtained by sampling transects (and associated sightings), at random and with replacement, such that the selected effort reflected the effort in the original sample. For the species with complex spatial models parametric bootstraps were undertaken for both the detection function and the spatial model. Confidence intervals were obtained from this resampling-derived distribution using the 2.5% and 97.5% percentiles to obtain the lower and upper limits, respectively, thus excluding the most extreme values.

Explanatory models

To explore the habitat preferences of specific taxa (bottlenose dolphins, *Stenella sp.* dolphins and loggerhead turtles) a separate set of models were fitted to the data as before but excluding the covariates of latitude and longitude. So a simplified model with the following variables was fitted to the data initially and backwards model selection was performed as before:

$$Platform + s(SST) + s(Depth) + s(Year)$$

Table 1. Realized monthly effort (km) in the Jacksonville survey area. There were no vessel surveys from 2012.

Month	2009		2010		2011		2012	2013	2014	2014
	Aerial	Boat	Aerial	Boat	Aerial	Boat	Aerial	Aerial	Aerial	Aerial
January	888	0	3881	207	1692	138	1658	0	1009	0
February	1706	0	2536	0	1268	0	0	0	2159	0
March	431	0	1680	139	0	205	559	863	1681	887
April	0	0	2047	0	1541	0	1710	0	0	602
May	0	0	811	145	1330	0	1606	1635	1701	0
June	1683	0	3011	309	1029	0	0	890	1325	0
July	1708	166	1024	225	1690	0	1692	0	1458	0
August	1696	256	1696	36	1680	0	0	0	1370	1280
September	3309	210	1643	0	1363	0	1279	1873	1682	0
October	822	137	1534	171	847	0	0	651	1155	1713
November	1688	0	860	0	0	0	1334	0	0	0
December	1816	0	1846	69	0	0	0	0	0	0

RESULTS

The aerial surveys realised 86949 km of search effort and the ship surveys realised 2413 km of search effort. The breakdown of effort by month is given in Table 1.

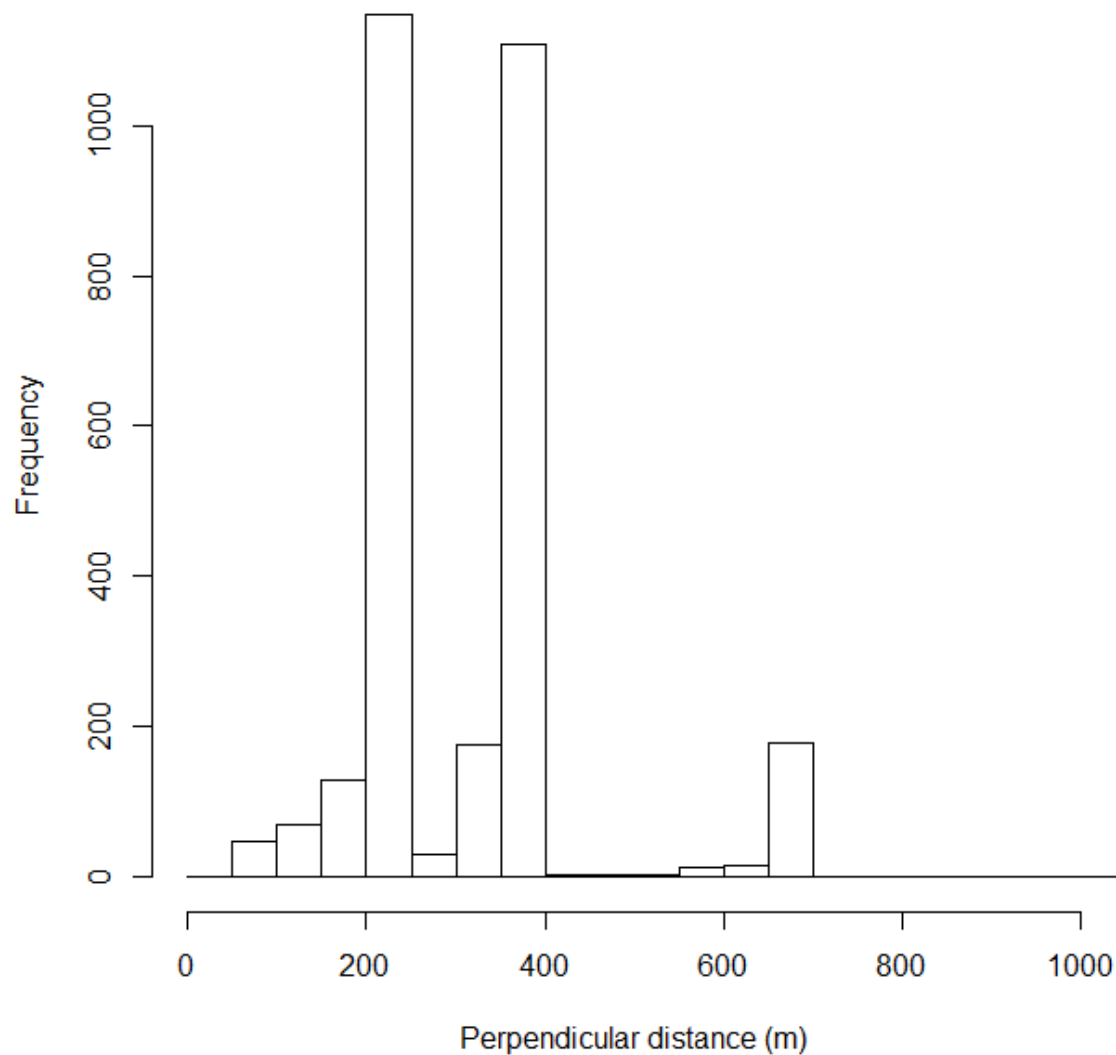
Aerial surveys

There were 802 sightings of groups of smaller dolphins within the truncation distance of 1400 m; these consisted of 377 groups of bottlenose dolphins, 46 groups of Risso's dolphin, 304 of spotted dolphins (*Stenella frontalis*), one unidentified *Stenella* sp. and one sighting of *S. attenuata*, 8 of rough-toothed dolphins (*Steno bredanensis*) and 65 unidentified delphinids. Eighty one percent of dolphin sightings were of animals in groups of fewer than 20, however, a group of 100 spotted dolphins was detected in January, 2009.

Seventeen medium-sized cetacean groups were detected within the truncation distance (14 pilot whales and 2 sightings of kogiids and one unknown whale). There were 16 large whales made up of 8 minke whales, one unidentified balaenopterid, 4 right whales, two humpbacks and a sperm whale and a detection function was fitted mainly for interest.

Turtles were the most numerous taxa detected (2666 groups within the truncation distance, see below) with loggerhead turtles the most detected species of turtle (2130 groups). The other turtle species detected were leatherback (144 groups) and Kemp's ridley (3 groups) along with 389 groups of turtles that were detected but the species could not be identified (these were randomly assigned to identified species on a pro-rata basis). The majority (79%) of turtle detections were of single animals but groups of up to 20 turtles were detected. The distribution of calculated perpendicular distances shows distinct grouping for the "angle down" bins (Figure 3) and does not conform to the shape expected from a distance sampling survey (i.e. monotonically declining detection probability with increasing distance). The reasons for the unusual distribution are not known and worthy of further investigation but it may have been caused, in part, by rounding of distances; a substantial number of sightings had a perpendicular distance around 210m and 370m. Due to this odd distribution and because the immediate 100 m underneath the plane is obscured, the data were left truncated at 100m (i.e. all sightings with a perpendicular distance of 100m were excluded from analyses and 100m was subtracted from all remaining perpendicular distances) and then right truncated at 400m (an original distance of 500m) and the distances binned into intervals of 200m. Species was considered as a covariate but with only three sightings of Kemp's ridley turtle within the truncation distance estimating coefficient values reliably proved difficult so Kemp's ridley sightings were omitted from the data prior to detection function fitting.

Figure 3. Histograms of actual perpendicular distances of aerial turtle sightings up to 1000m prior to truncation.



Shipboard surveys

Sixty-one groups of dolphins were detected within the truncation distance made up of spotted (36), bottlenose (24) and one group of unidentified delphinids. The majority of dolphins were in groups of between one and ten animals. The maximum group size was 55 spotted dolphins recorded in October, 2010.

Sixty-six groups of turtles were detected within the truncation distance, made up of loggerhead (56) and leatherback (10) turtles. One group of two loggerhead turtles was detected otherwise all other sightings of turtles were of single animals.

No medium-sized cetaceans and no large cetaceans were detected during the ship surveys.

Detection functions

The (scaled) histograms of perpendicular distances (after truncation) and the fitted detection functions are shown in Figures 4 & 5 with details provided in Table 2. Perpendicular distances were binned into intervals for model fitting and to avoid a long tail in the detection function (Buckland *et al.* 2001), typically between 5 -10% of the longest distances were truncated.

Table 2. Summary of detection function models; number of detected groups (*n*) within the given truncation distances, detection function (DF) form (half normal HN or hazard rate HR), covariates added in addition to perpendicular distance and detection probability within the truncation distance.

Species	Platform	<i>n</i>	Truncation distance (m)	DF form	Additional Covariates	Detection probability (se)
Dolphin	Aerial	802	1400	HN	Visibility	0.509 (0.015)
	Ship	61	250	HR	BSS + Weather	0.287 (0.039)
Turtles	Aerial	2663	400*	HN	Group Size	0.914 (0.020)
	Ship	66	80	HN	Weather	0.486 (0.115)
Medium cetaceans	Aerial	18	1200	HN	-	0.564 (0.211)
	Ship	0	-	-	-	-
Big cetaceans	Aerial	16	1200	HN	-	0.716 (0.147)
	Ship	0	-	-	-	-

*after left truncation at 100 m.

Figure 4. Aerial detections: fitted detection functions overlaid onto scaled perpendicular distance distributions (data binned into 200 m distance intervals); a., dolphins, b. turtles, and c. medium-sized cetaceans, d. big cetaceans. The points are individual detections.

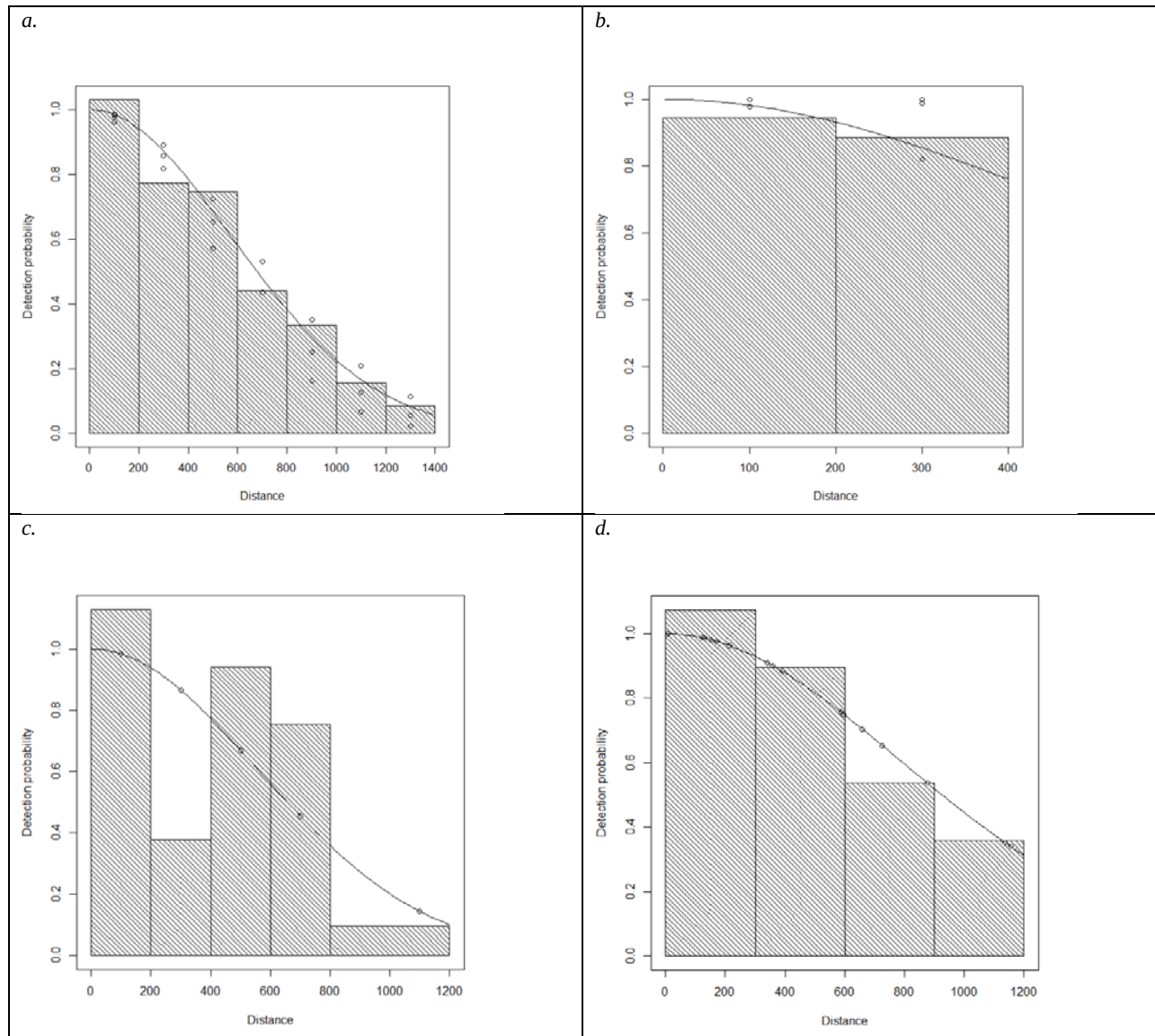
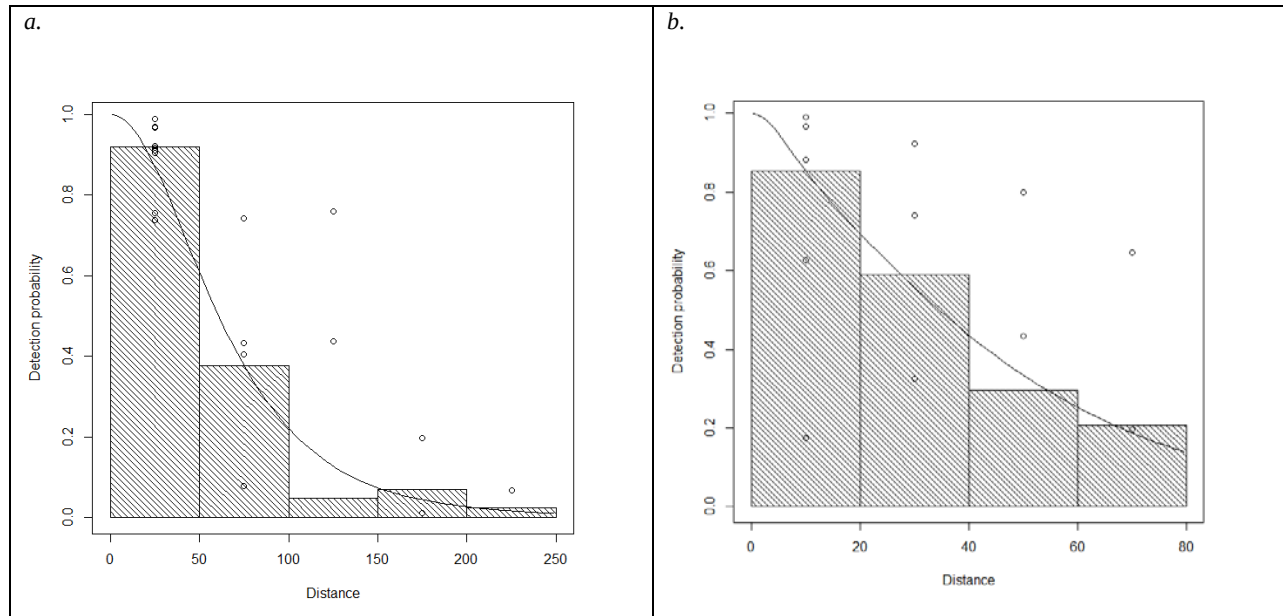


Figure 5. Ship detections: fitted detection functions overlaid onto scaled perpendicular distance distributions; a. dolphins (data binned into 50m sections), b. turtles (data binned into 20m sections).



Density surface models for abundance

The aerial search effort was divided into 9581 segments with a mean length 9.08 km (max. length 15 km). The ship effort was divided into 600 segments with a mean length of 4.02 km (max. length 14.1 km). Summaries of the fitted predictive models are given in Table 3.

Table 3. Summary of density surface models used for abundance estimation: selected model (where *s(var)* indicates a smooth function of *var*) and percentage of deviance explained by the model. The total number of segments was 9581 and % non-zero segments is the number of segments containing detections.

Species	Model	Natarajan et al's (2007) "coefficient of determination"	% non-zero segments
<i>Stenella</i> sp.	$\text{Survey} + \text{KmEW} + \text{bs}(\text{Depth}, df = 3) + \text{bs}(\text{Dayofyear}, df = 4) + \text{bs}(\text{Year}, df = 3)$	2%	4
Loggerhead turtles	$\text{Survey} + \text{bs}(\text{Easting}) * \text{bs}(\text{Northing}) + \text{bs}(\text{Year}, df = 3)$	11%	17

Bottlenose dolphins

The most surprising result for this year was the GEE model of density picked up no predictors for bottlenose dolphin in this region. In fact a GAM model of density had the same effect. The models fitted for this region have always varied a lot year to year so it is plausible that there the animals are just uniformly distributed over this area. A naïve inspection of the data suggests no pattern in the sightings (Figure 6). Assuming an aerial survey and a uniform distribution suggested a surface population of 160 (140 – 190). Note that this is far less than in previous years because in previous years a ship survey was assumed when the predictions were made. Bottlenose dolphin were present in 4% of segments.

Figure 6. Centers of effort segments (grey) and estimated detection corrected densities (red) with area proportional to density

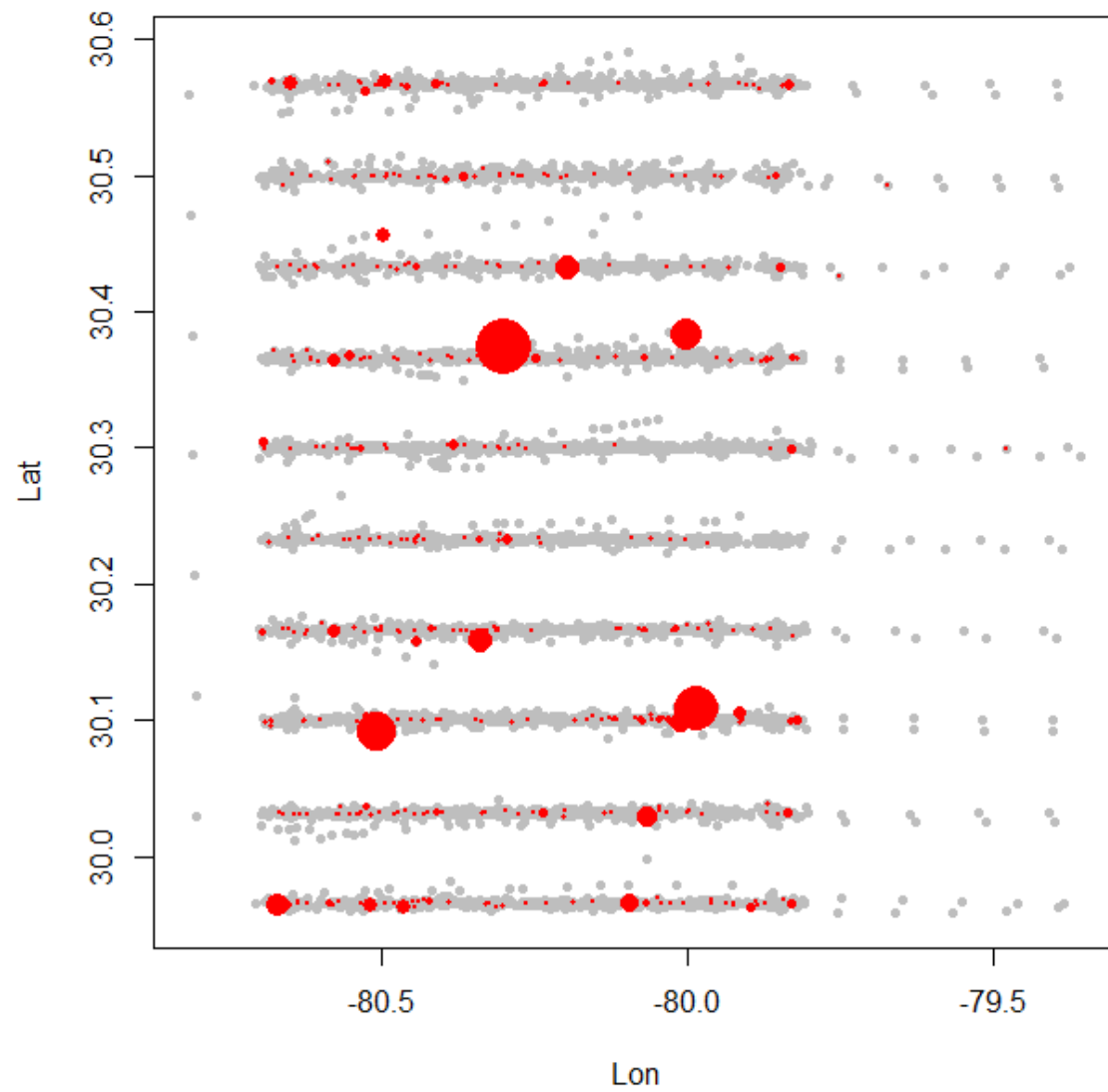
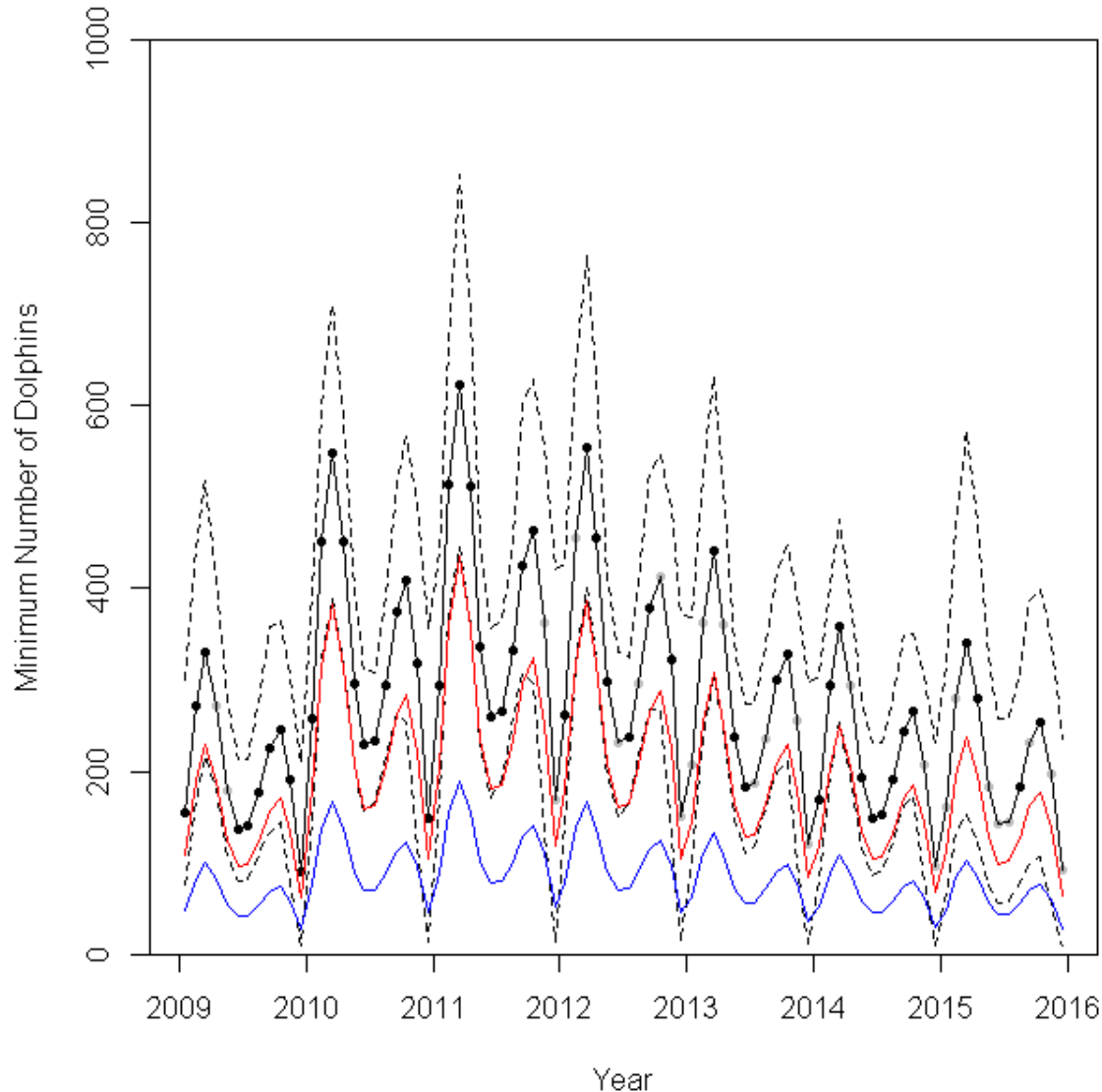


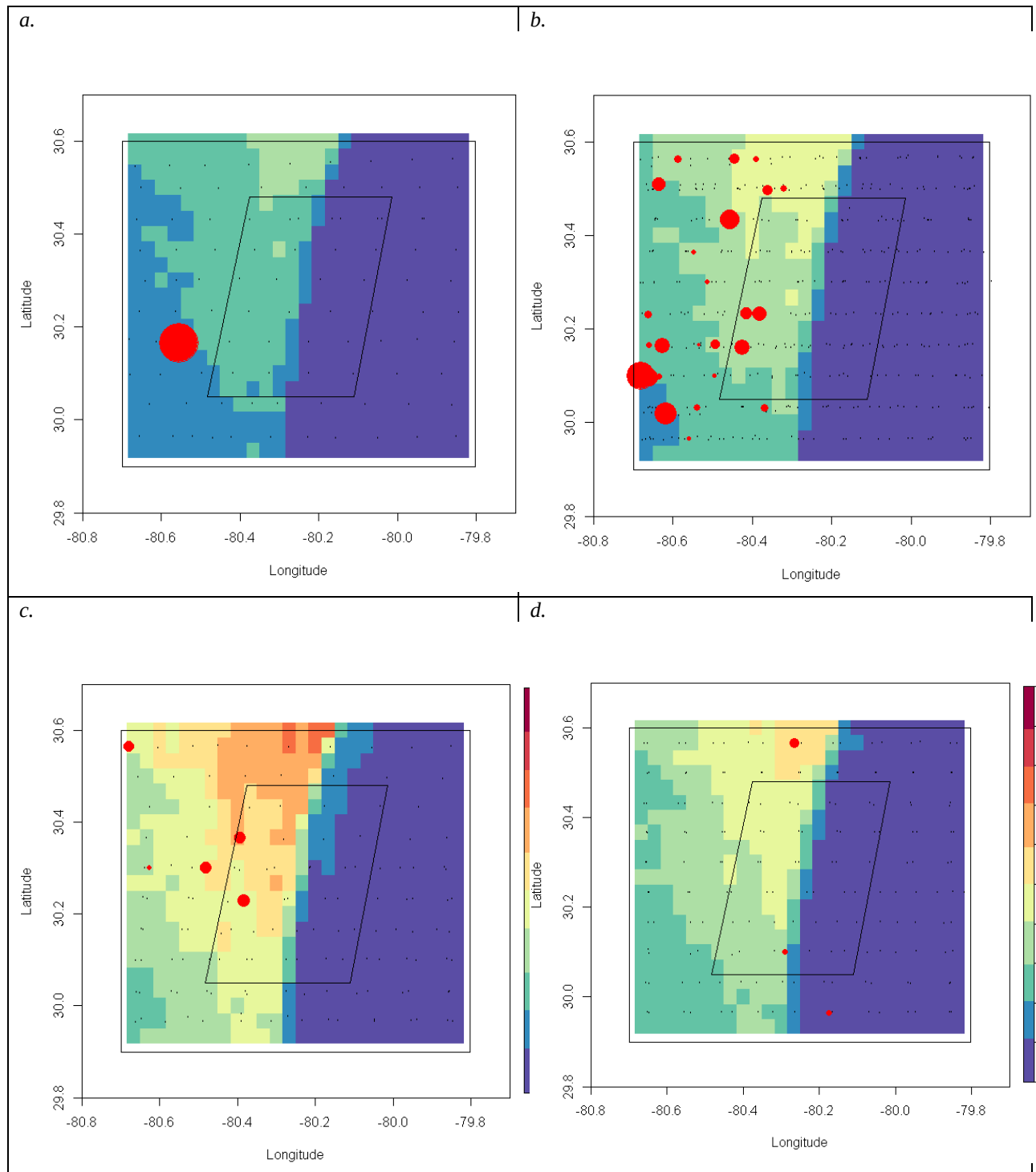
Figure 7. Predicted surface abundance of *Stenella sp.* dolphins. Black indicates abundance estimates for the whole region and red and blue represents the abundance estimates for the inner and outer areas, respectively. Dashed lines represent the upper and lower 95% confidence bounds for the abundance estimates for the whole region. Black points indicate when there was effort as opposed to grey points indicating where there was no effort. For clarity confidence bounds for the inner and outer area estimates are not given.



Stenella sp.

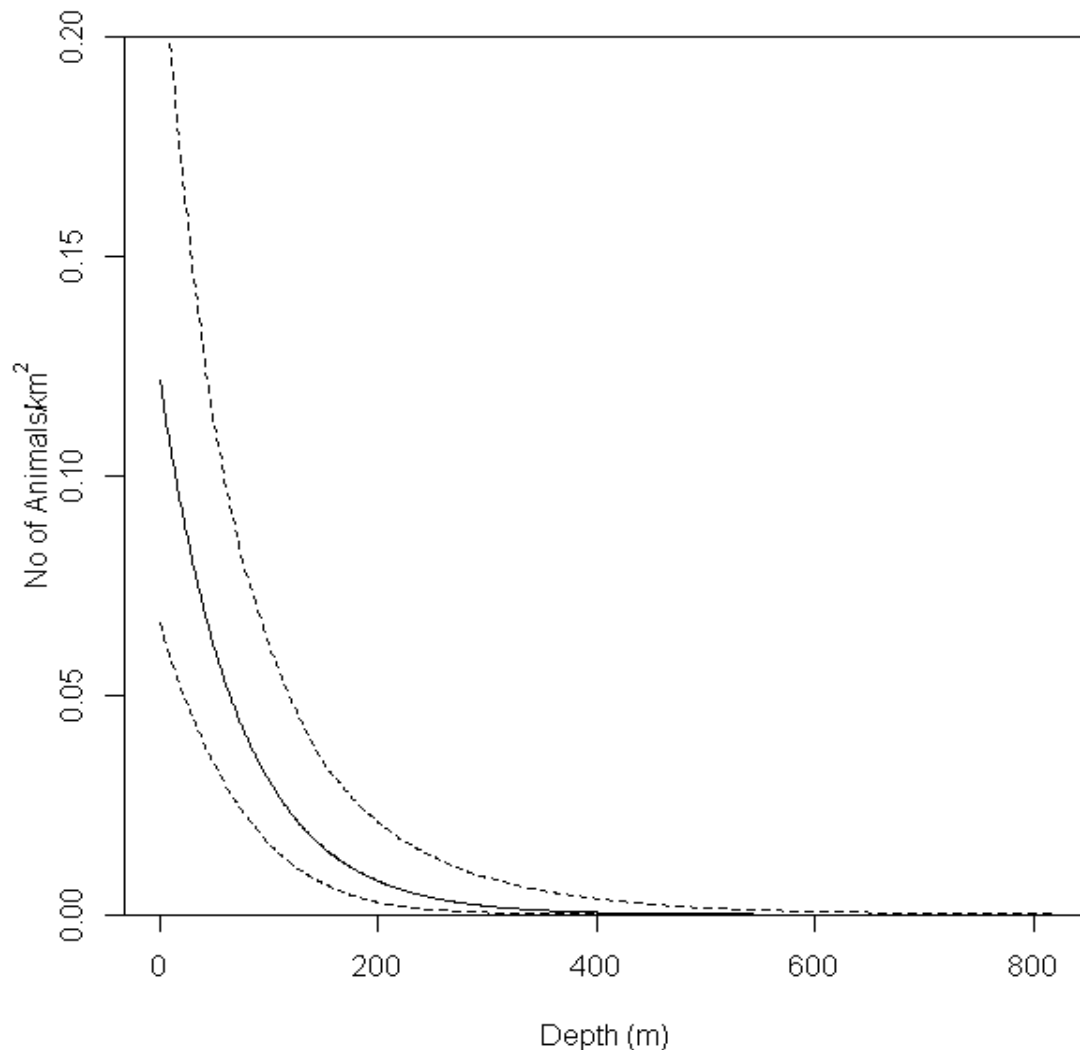
Seasonality is more obvious than last year with a fall in *Stenella* numbers in the summer (Figure 7). The predictions are different to those made last year. *Stenella sp.* dolphins appear to avoid the deeper waters offshore (Figure 8). Predictions were made both assuming an aerial platform. The minimum estimate over the entire area was 90 (10 – 210) in December 2009 and the maximum was 450 (620 – 850) in March 2011.

Figure 8. Predicted surface density of *Stenella sp.* dolphins in a. Jan 2009, b. September 2009, c. May 2011 & d. July 2015. Colours indicate the density of surface animals per km². Black points indicate the midpoints of effort segments for that month.



Explanatory model selection retained *Year* and *Depth* (Figure 9).

Figure 9. *Stenella* sp. dolphin density in response to Depth assuming it is 2015.



Medium-sized cetaceans (pilot whales and kogiids)

Medium-sized cetacean groups were only detected in 17 segments out of 9581 and so no model was fitted except for a Survey effect. The minimum surface prediction was 13 (5 – 21) assuming an aerial survey over the whole surveyed area.

Large cetaceans (Baleen and sperm whales)

With only 12 sightings over 6 years it can be stated that large cetacean abundance is close to zero.

Loggerhead turtles

Loggerhead turtles were found in a relatively large proportion of effort segments (17%) compared to the other species of turtle and indeed cetaceans. The observed decline in numbers commented on, in the last few years, is still present. One hundred and fifty bootstraps were undertaken. No seasonality was detected. The lowest predicted minimum abundance over the whole region was 160 (70 – 290) in 2015 and the highest 390 (330 – 1040) in 2009 (Figure 10). Loggerhead turtles exhibit a moderately consistent seasonality with very few seen in January and April. High abundances are never predicted for the deeper part of the survey region (Figure 11).

Strangely explanatory model selection retained *Dayofyear* (as a spline with 3 df) in addition to *Year*, and *Depth* despite no seasonal effect in the prediction model. This model is illustrated in Figure 12.

Figure 10. Predicted surface abundance of loggerhead turtles. Black indicates abundance estimates for the whole region and red and blue represent the abundance estimates for the inner and outer areas, respectively. Dashed line is the 95% confidence interval for the total region. Black points indicate when there was effort as opposed to grey points indicating where there was no effort.

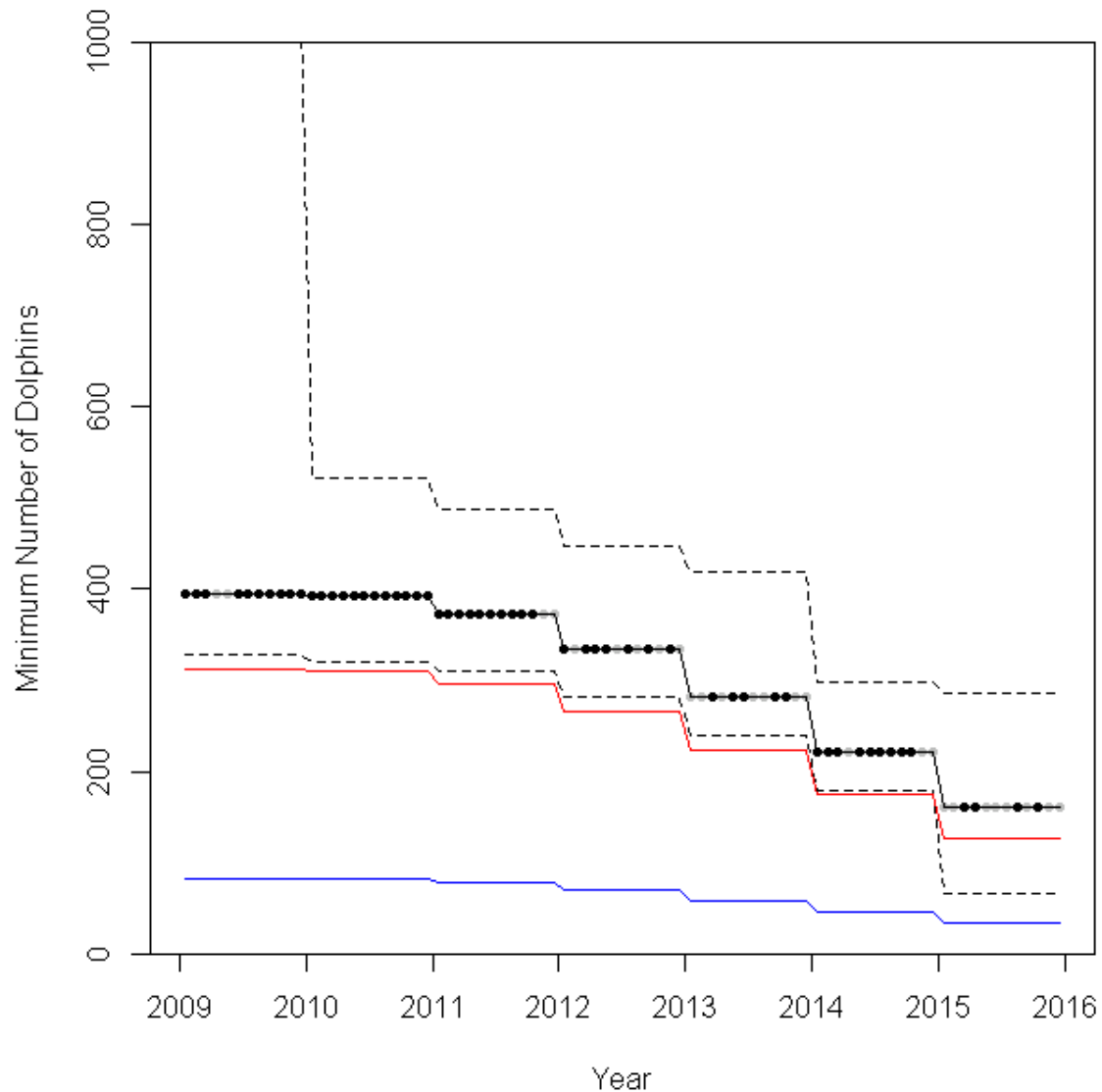


Figure 11. Predicted surface abundance of loggerhead turtles in a. 2009, b. 2010, c. 2012 and d. 2015. Colours indicate the density of surface animals per km². Grey points indicate the midpoints of effort segments and the area of the red circles is proportional to the adjusted density of observed animals per km². N.B. predictions for 2009 and 2010 are almost identical.

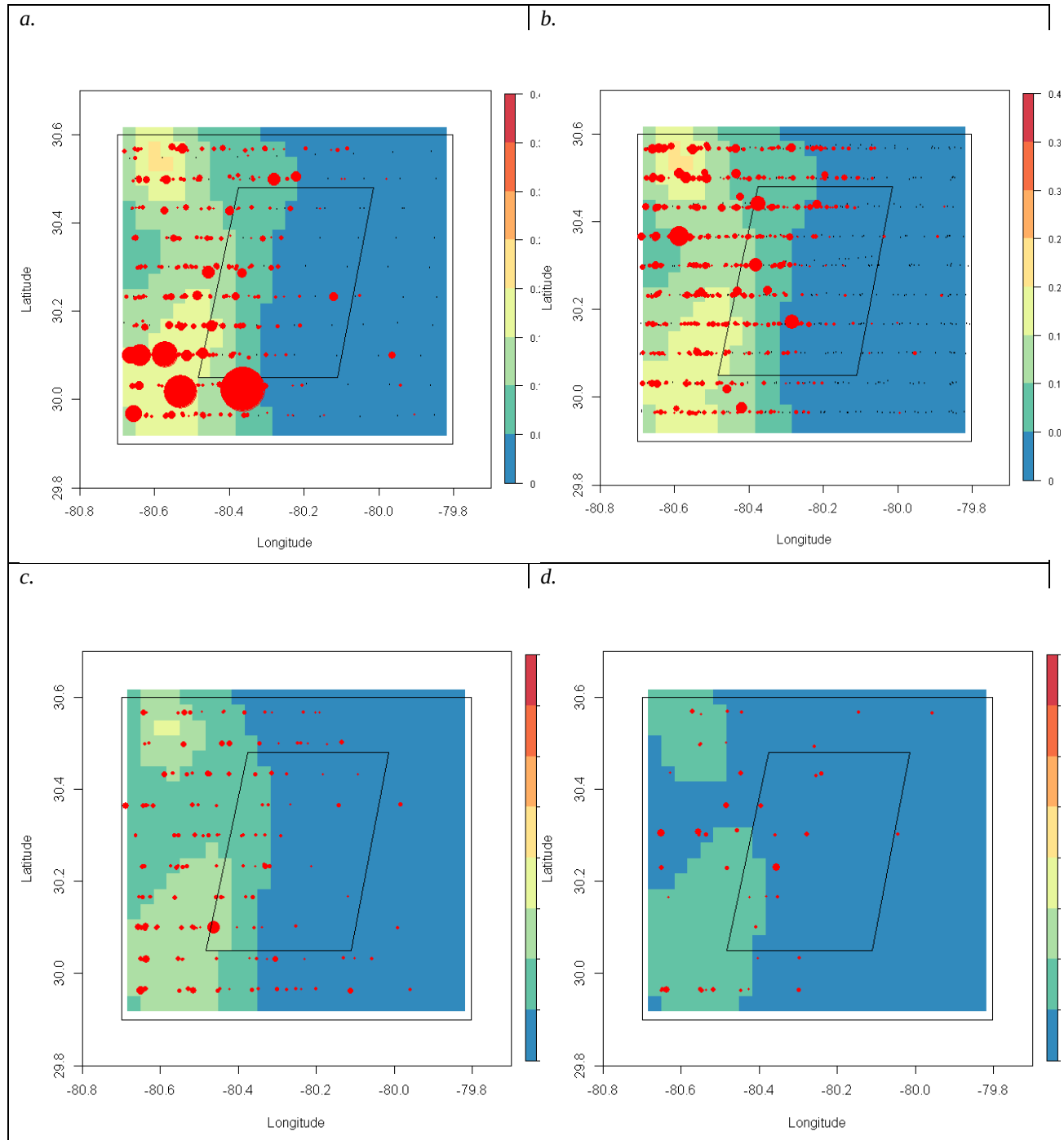
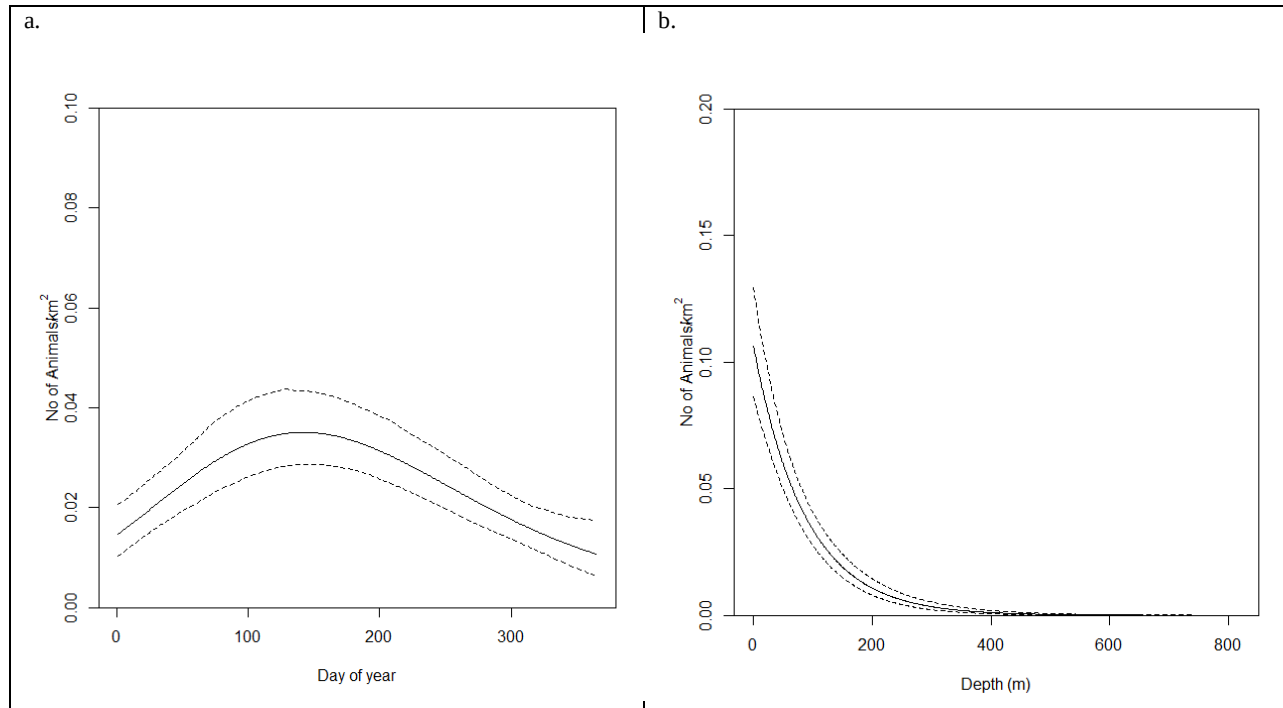


Figure 12. Loggerhead turtle probability of presence in response to a. *Dayofyear* assuming a survey in 2015 and 100m depth and b. *Depth* assuming a survey in 2015 and day 170.



Leatherback turtles

Again an attempt was made this year to produce a spatio-temporal model of observed surface leatherback density over the whole area but owing to the sparse nature of the data satisfactory estimates could not be made. The overall surface estimate of abundance over the entire survey region assuming no temporal fluctuation (assuming an aerial survey) was 19 (15 – 22) with the uncertainty based on 700 bootstraps.

DISCUSSION

Detection functions could be readily fitted to the estimated perpendicular distances although further consideration should be given to the distribution of turtle distances.

The lack of ability to fit a model to bottlenose dolphins is not due to a lack of data, but a lack of signal in the data so perhaps bottlenose dolphins really have no habitat preferences over the Jacksonville region.

The lack of very clear seasonality in the observed densities of loggerhead turtles in the predictive model is surprising given that turtles tend to surface more at lower temperatures (Hochscheid *et al.* 2010). A *Dayofyear* effect was found in the explanatory model but it was slightly different to that seen in previous years perhaps implying that it is not really a strong signal.

The abundance estimates should be regarded as a minimum because they do not take into account perception bias on the trackline (i.e. not all animals may be detected by the observers) and availability bias (i.e. not all animals may be at the surface to be detected). In the case of turtles, the random allocation of unidentified turtles to species probably lessened the bias associated with the estimates, at the cost of making the models less precise.

The more conservative model selection criteria employed this year produced simpler models than last year. Given the noticeable changes at year boundaries, future modelling work might consider modelling time as continuous days from an origin and the influence of model selection on uncertainty.

This year unlike previous years all cetacean abundances were predicted assuming aerial surveys. It may be given a confounding of actual abundance and survey type predicting assuming a plane underestimates and predicting assuming a ship over estimates. Where survey type was shown to have an effect, prediction was made assuming a ship survey. However no such surveys have been undertaken since 2011 rendering more recent predictions problematic.

Recommendations for the future

Assuming the Jacksonville survey work is on-going, issues of potential interest in the future work might include:

1. Investigation of the strange pattern of reported distances for turtles during the aerial surveys.
2. Investigation of whether dolphins are being attracted to the ship before detection.
3. Investigation of reliable methods for estimating $g(0)$ without double-observer survey. Options include cue-based methods and use of appropriate availability correction methods based on data on availability patterns for each species.
4. Further elucidation of the environmental drivers of cetacean density in the area of interest, perhaps by the use of additional variables.
5. Records of water opaqueness may be a useful explanatory variable to include in the detection functions for turtles.
6. More ship surveys to better calibrate the aerial/ship correction.

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