Density model for False killer whale in the AFTT area - version 1

Laura Mannocci, Jason J Roberts, David L Miller, Patrick N Halpin

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This report documents the density model developed for False killer whale in the AFTT area. It provides information on available data, methodological decisions, the selected model, predictions, uncertainty, model checking and qualitative evaluation of predictions based on the literature. Information on classification of ambiguous sightings, detection function fitting and g(0) estimates can be found in the EEZ model report for this taxon (Roberts et al. 2015).

Citation for this model: Mannocci L, Roberts JJ, Miller DL, Halpin PN (2015) Density model for False killer whale in the AFTT area. Version 1, 2015-01-23. Marine Geospatial Ecology Lab, Duke University, Durham, NC.

Citation for the related peer-review publication: Mannocci L, Roberts JJ, Miller DL, Halpin PN. Here be dragons: extrapolating cetacean densities into the unsurveyed high seas of the western North Atlantic. Submitted to Ecological Applications.

1- Available data

Table 1: Effort (km) and sightings per region (CAR: Caribbean, EC: East coast, EU: European Atlantic, GM: Gulf of Mexico, MAR: Mid-Atlantic ridge).

Region	Effort	Sightings
CAR	24264.47	3
EC	1044357.70	2
GOM	194715.35	19
All regions	1263337.53	24

Table 2: Effort (km) and sightings per month.

Month	Effort	Sightings
January	77892.79	1
February	123591.37	2
March	117923.54	1
April	117929.72	3
May	149765.03	4
June	129393.69	4
July	135693.85	6
August	129660.43	2
September	71696.07	1
October	82560.18	0
November	69210.92	0
December	58019.93	0
All Months	1263337.53	24

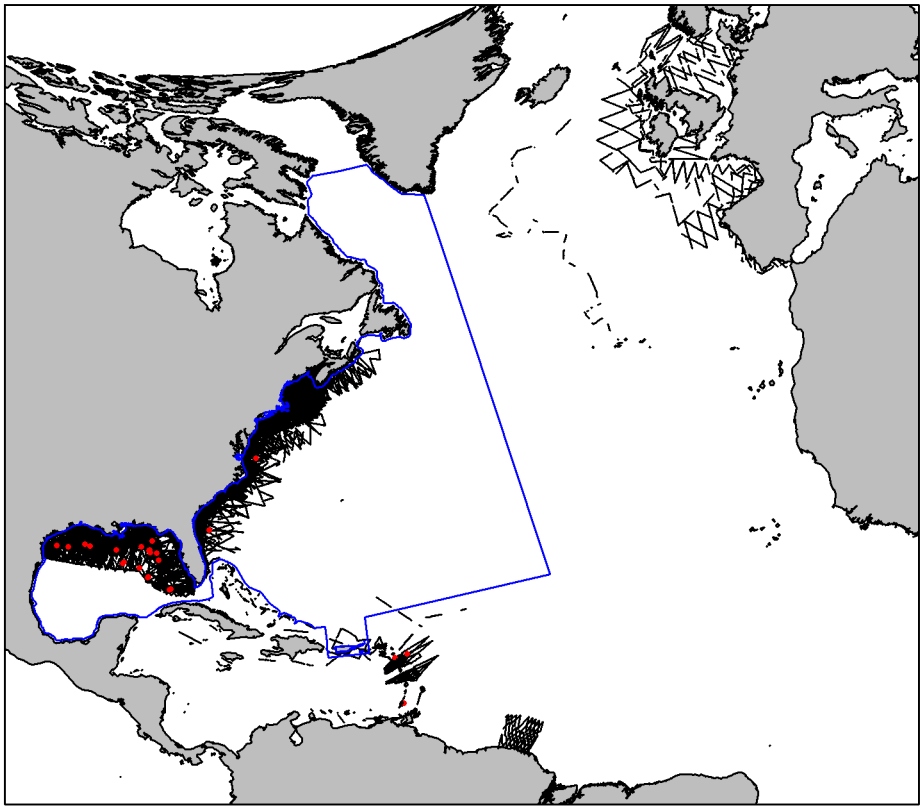


Figure 1: Map of segments (black lines) and sighting locations (red dots). An Albers equal area projection optimized for the AFT area is used.

2- Methodological decisions

Modeled taxon

False killer whale (*Pseudorca crassidens*)

Model type

Due to the small sample size, we fitted a simple habitat-based density model with sea surface temperature (SST) as the single covariate for this taxon. SST was successfully used in predictive distribution models of cetaceans in data poor situations (Kaschner et al. 2006).

Modeled season

We fitted a year-round model as we found no evidence in the literature that this taxon undertakes extensive migrations or exhibits contrasting behaviors (e.g. feeding versus breeding) in different seasons.

Segments

We used segments from the east coast, Gulf of Mexico and Caribbean since these were the three regions that included sightings.

Temporal resolution of predictions

Since there was insufficient evidence in the literature to support the monthly variations in predicted densities, we produced a year-round density prediction by averaging the twelve monthly density predictions.

3- Best model

- **Selected covariates**: sea surface temperature
- **Model summary**:

```
##
## Family: Tweedie(p=1.555)
## Link function: log
##
## Formula:
## abundance ~ s(SST, k = 4, bs = "ts") + offset(log(area_km2))
## <environment: 0x067de6e4>
##
## Parametric coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -37.13      16.13  -2.302   0.0214 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Approximate significance of smooth terms:
##          edf Ref.df     F p-value
## s(SST) 1.868      3 3.671 0.00276 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## R-sq.(adj) =  0.000197   Deviance explained = 58.5%
## -REML = 361.69  Scale est. = 1551.6    n = 124752
```

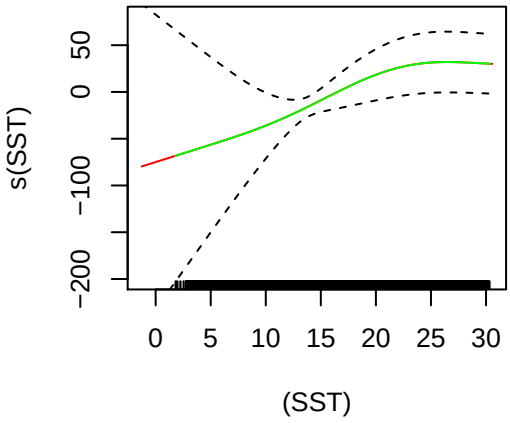
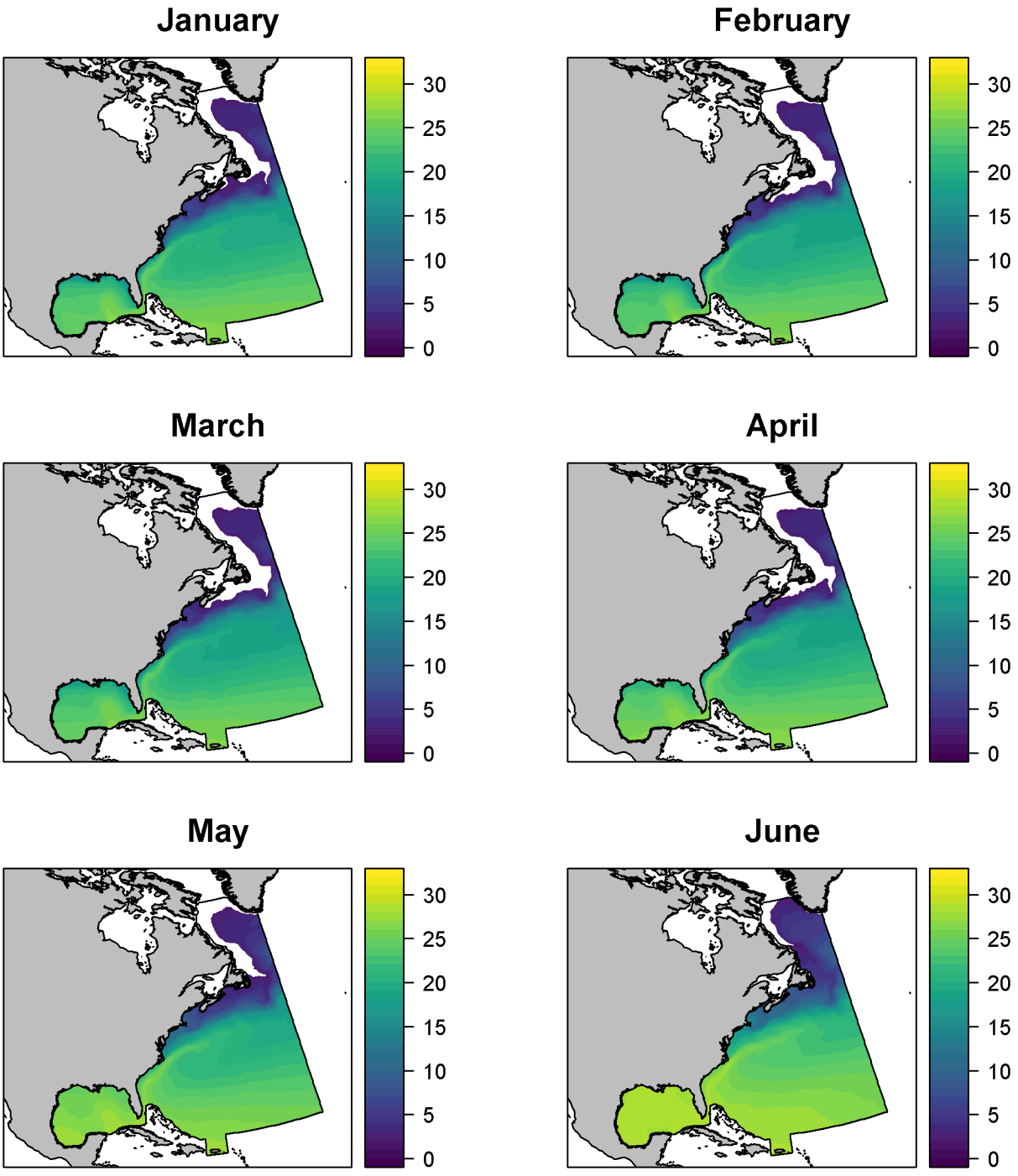


Figure 2: GAM term plots with the log-transformed abundance on the y axis. The solid green line is the smooth function fitted to the data. The solid red line is the smooth function extrapolated to all covariate values in the prediction area. The dashed lines represent the approximate 95% confidence intervals. The rug plot on the x-axis shows the range of covariate values sampled in the data. Note that transformations were used for some covariates.

4- Environmental envelopes



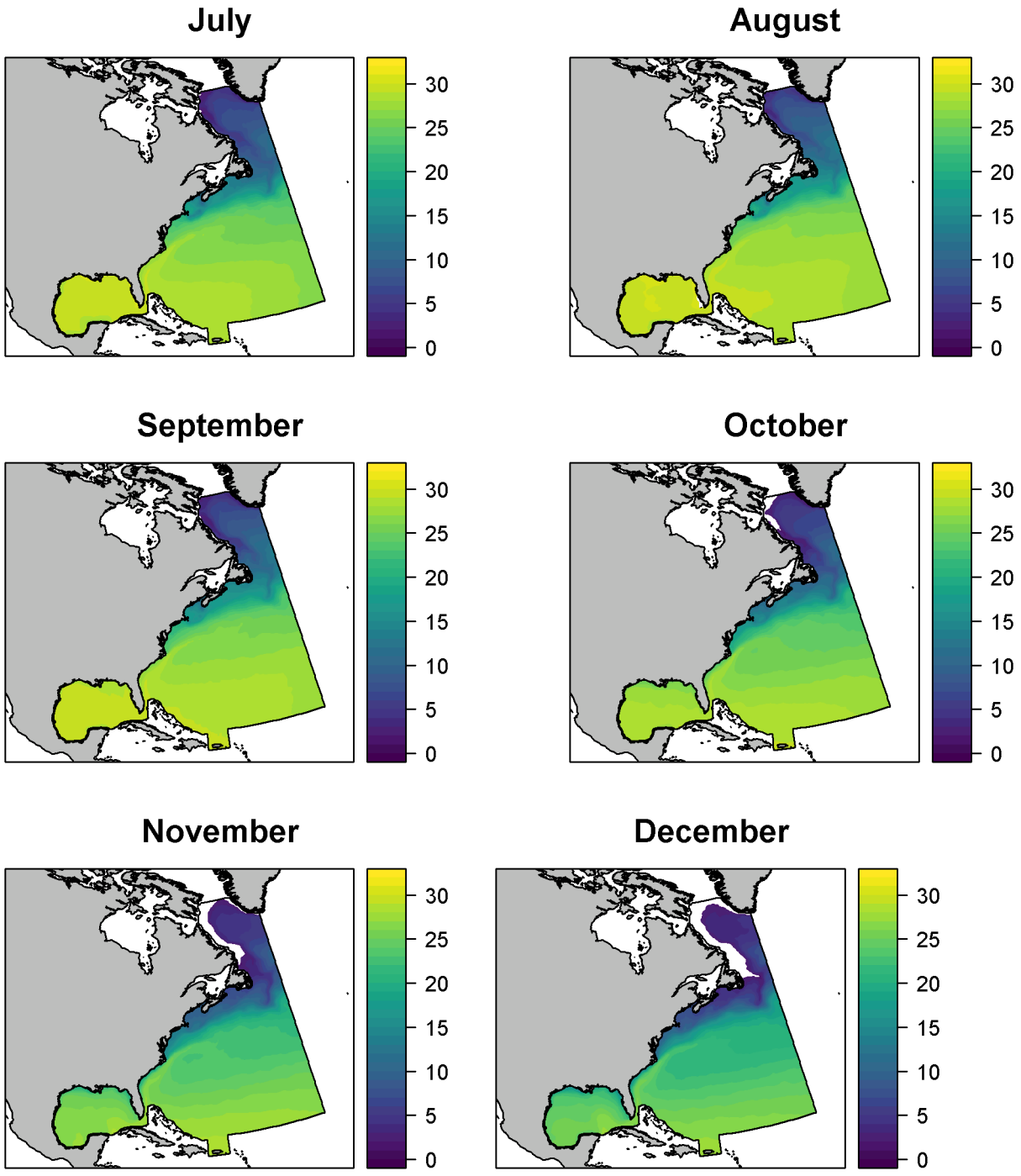


Figure 3: Monthly environmental envelopes for CMC_SST. White cells within the AFTT polygon indicate areas where covariate values fell beyond the range of covariate values sampled by the surveys.

5- Predictions

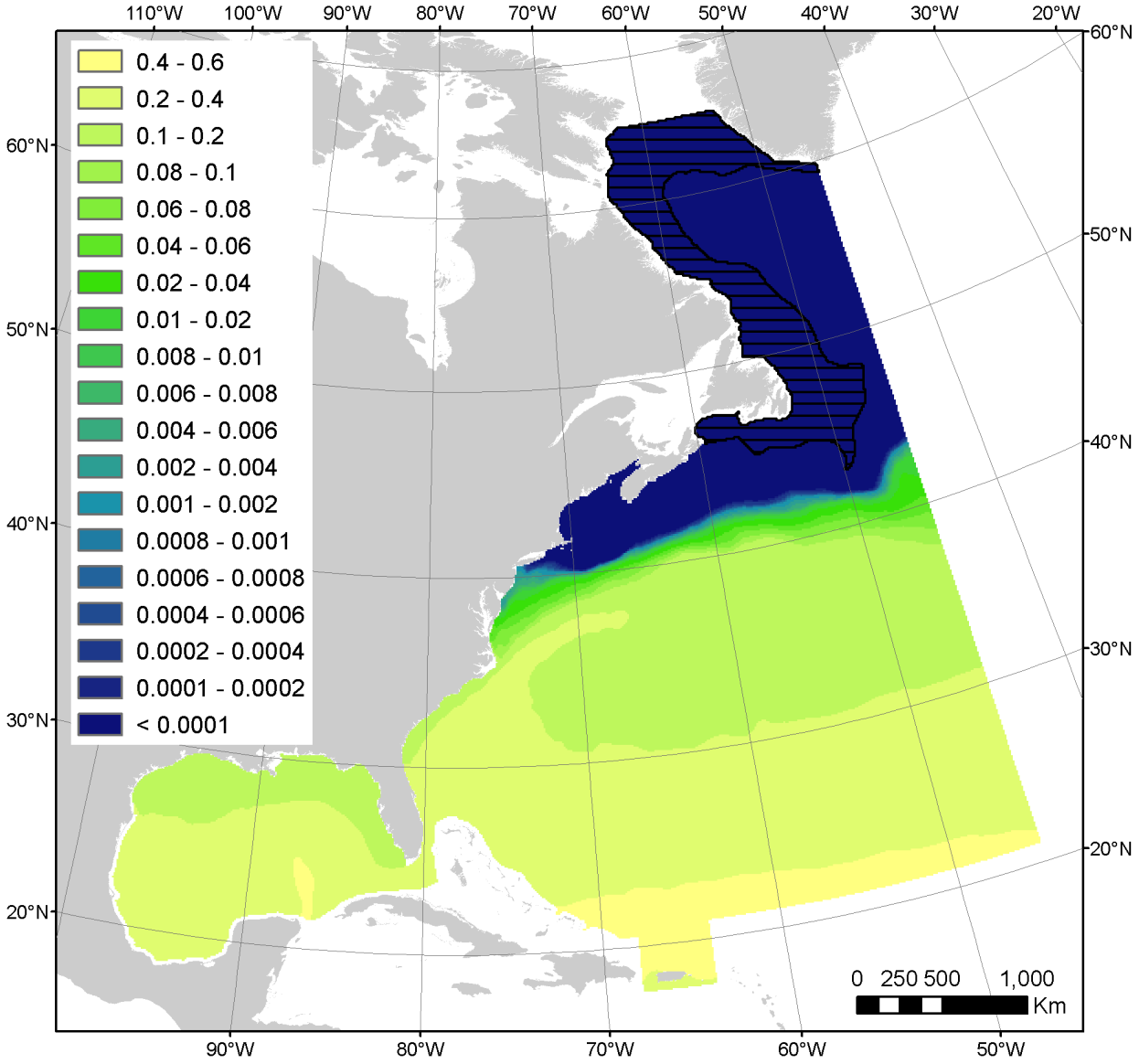


Figure 4: Mean predicted densities (individuals 100 km-2) in the AFTT area. Areas where we extrapolated beyond the sampled covariate ranges are indicated with black crosshatches. An Albers equal area projection is used.

Table 3: Mean predicted abundance (individuals) in the AFTT area and associated coefficient of variation (CV). The CV only reflects uncertainty in the estimated GAM parameters. It does not consider extrapolation beyond the sampled covariate ranges and is therefore strongly underestimated.

Abundance	CV
19855	0.326

6- Uncertainty

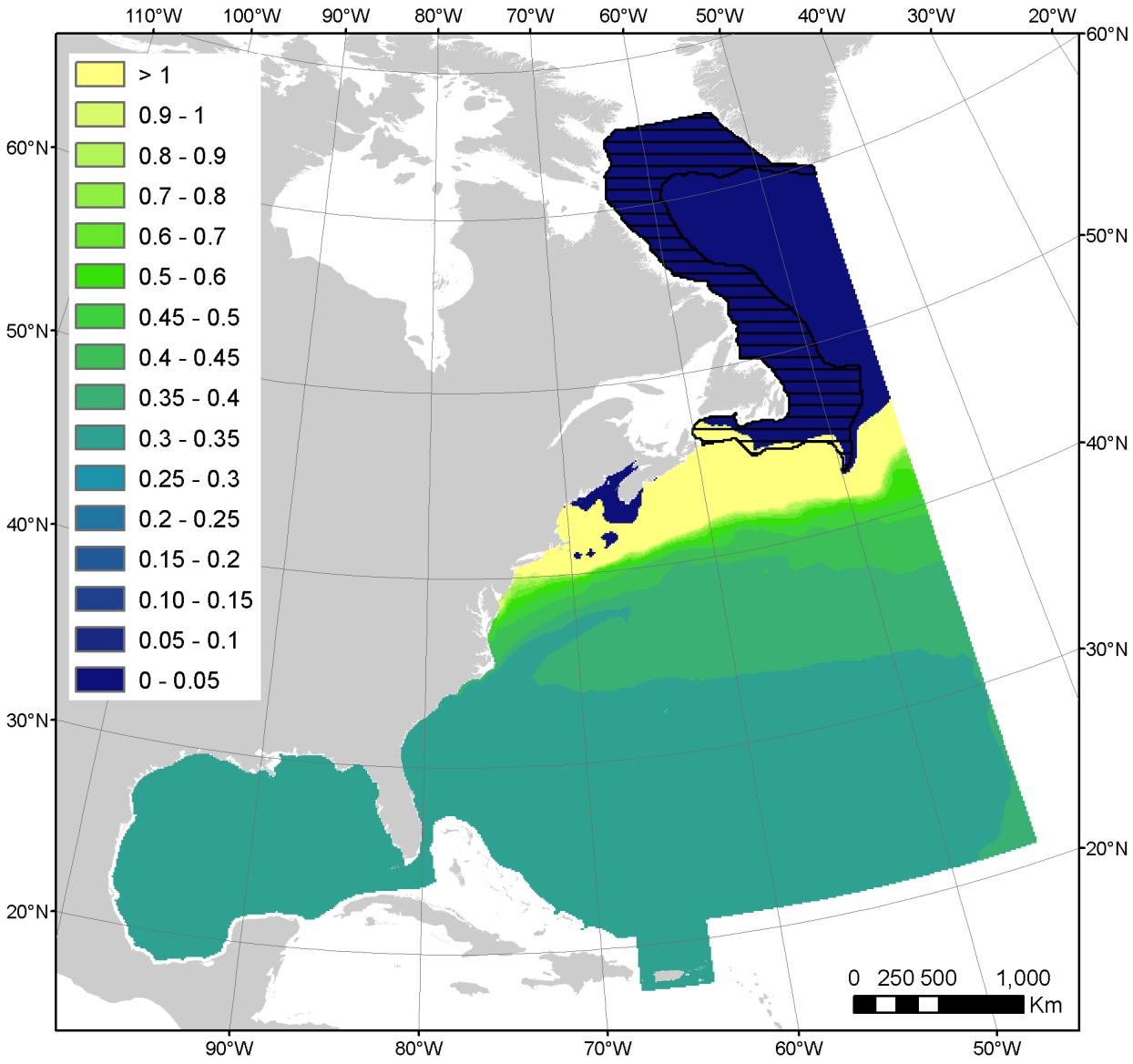


Figure 5: Mean predicted coefficients of variation (unit-less) in the AFTT area. Areas where we extrapolated beyond the sampled covariate ranges are indicated with black crosshatches. An Albers equal area projection is used.

7- Residual diagnostics

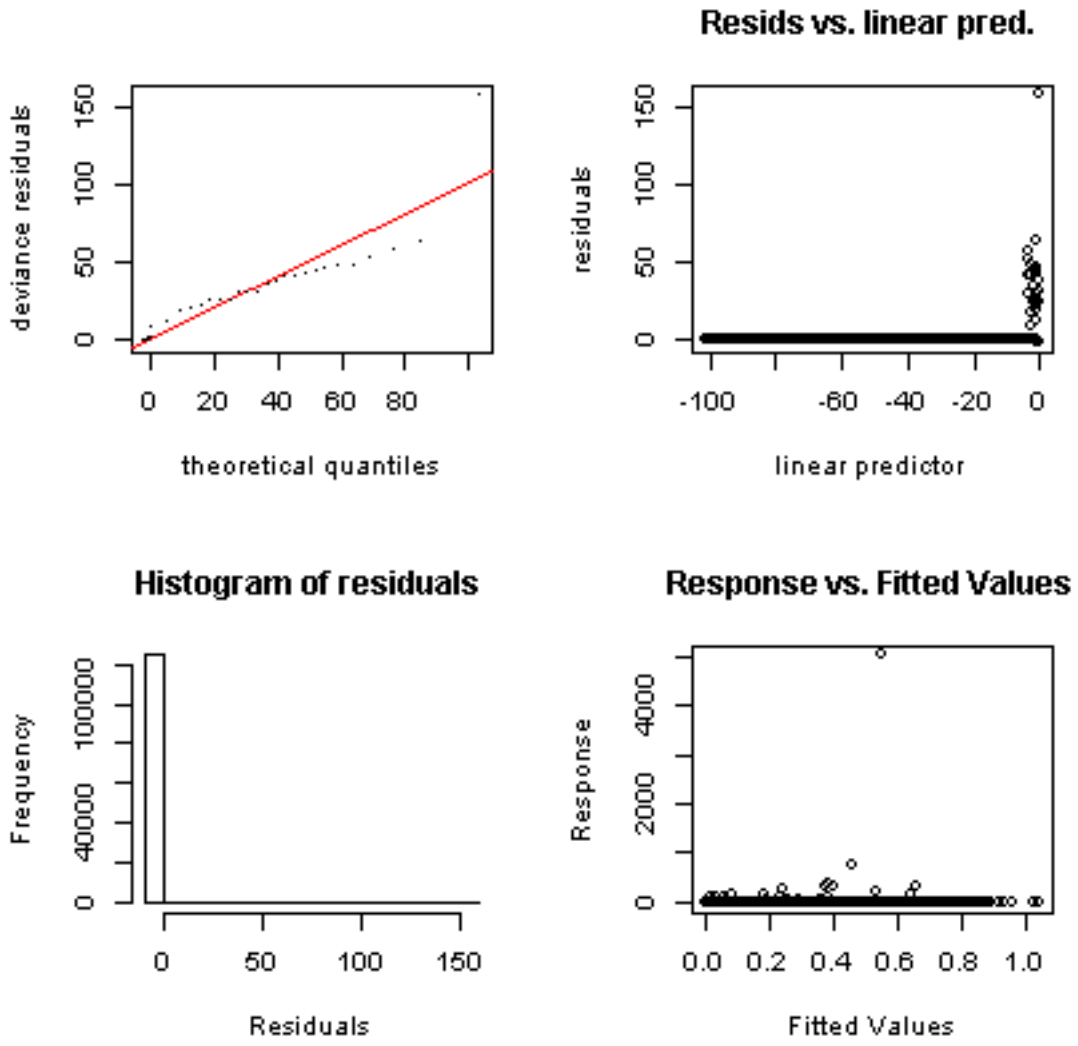


Figure 6: Diagnostic plots of deviance residuals. The normal Q Q plot is useful to assess goodness of fit.

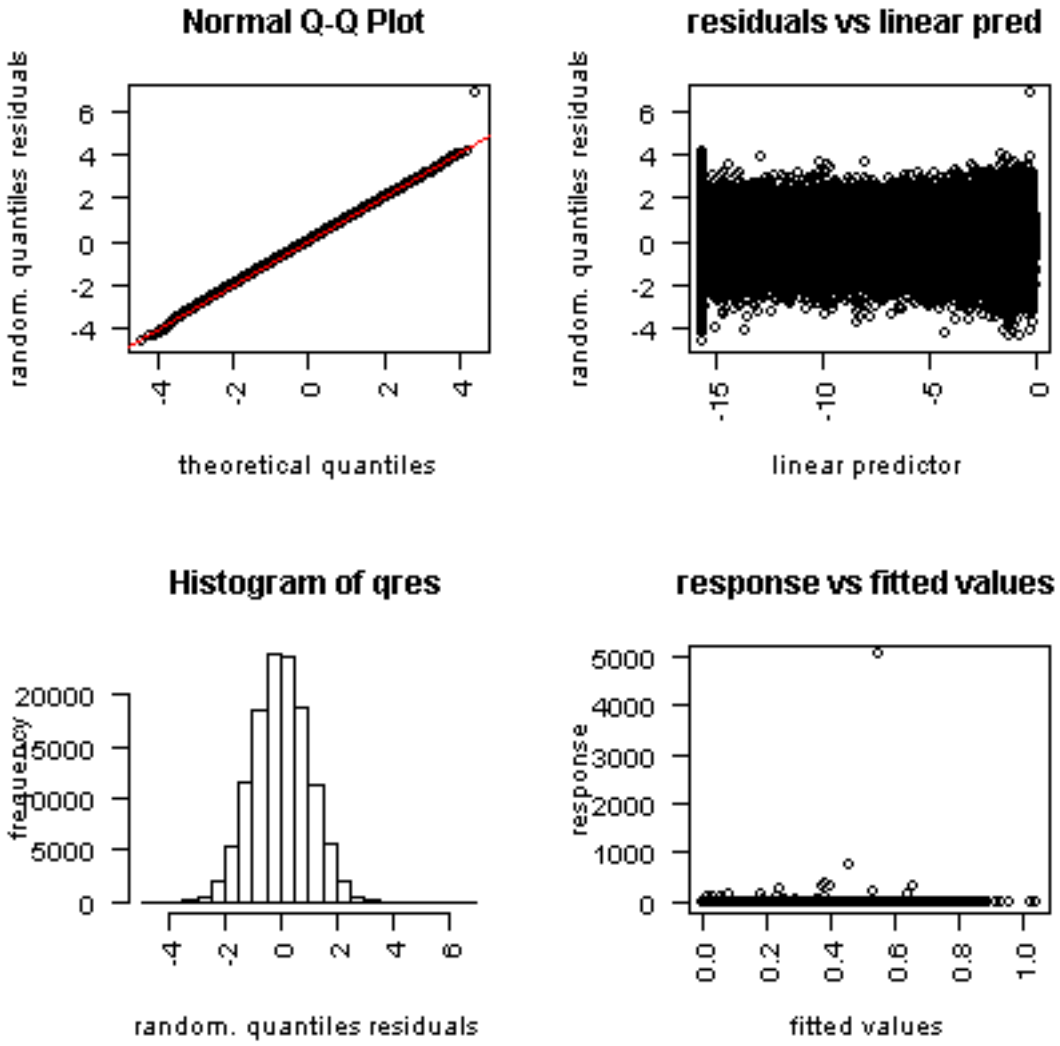


Figure 7: Diagnostic plots of randomized quantile residuals. Randomized quantile residuals (exactly normal residuals) are the most adapted residuals to visualize diagnostic plots of regression models applied to count data. The plots of residuals versus linear predictor and response versus fitted values are useful to investigate patterns in the residuals (e.g. non constant variance).

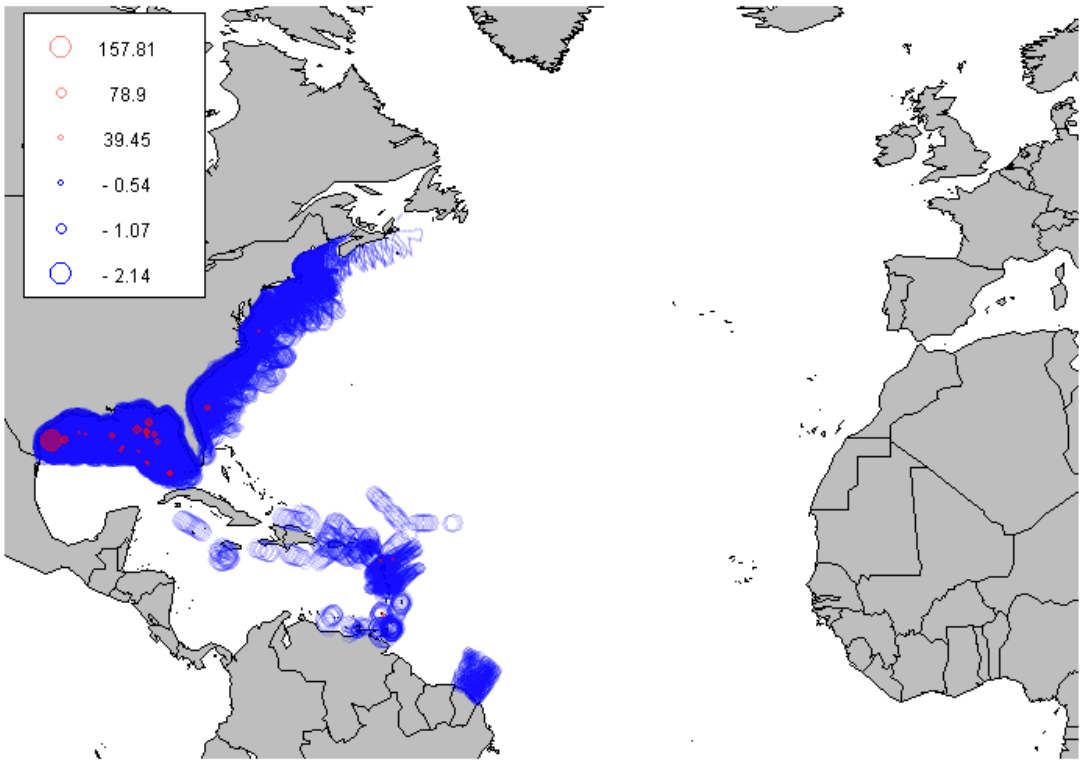


Figure 8: Map showing the spatial distribution of deviance residuals with positive residuals in red and negative residuals in blue.

8- Qualitative evaluation of predictions

Model predictions are consistent with the reported distribution of false killer whales throughout tropical and warm temperate waters, primarily in deep waters (Baird 2009).

Predictions in the southern Gulf of Mexico are compatible by strandings and sightings from opportunistic shipboard surveys (mainly in oceanic waters) (Jefferson and Schiro 1997, Ortega-Ortiz 2002).

Predictions around Puerto Rico are compatible one sighting record (Mignucci-Giannoni 1998).

Future model improvements

The acquisition of additional sightings data would increase the sample size and potentially allow fitting a habitat-based density model with a full variable selection procedure.

REFERENCES

Baird, R. W. 2009. False killer whale. Pages 405-406 Encyclopedia of marine mammals 2nd Edition. Academic Press.

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