Density Model for Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*) for the U.S. East Coast: Supplementary Report

Duke University Marine Geospatial Ecology Lab*

Model Version 2.4 - 2016-04-21

Citation

When referencing our methodology or results generally, please cite our open-access article:

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To reference this specific model or Supplementary Report, please cite:

Roberts JJ, Best BD, Mannocci L, Fujioka E, Halpin PN, Palka DL, Garrison LP, Mullin KD, Cole TVN, Khan CB, McLellan WM, Pabst DA, Lockhart GG (2016) Density Model for Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*) for the U.S. East Coast Version 2.4, 2016-04-21, and Supplementary Report. Marine Geospatial Ecology Lab, Duke University, Durham, North Carolina.

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Revision History

Version	Date	Description of changes
1	2014-11-15	Initial version.
2	2014-12-04	Fixed bug that applied the wrong detection function to segments NE_narwss_1999_widgeon_hapo dataset. Refitted model. Updated documentation.
2.1	2015-03-06	Updated the documentation. No changes to the model.
2.2	2015-05-14	Updated calculation of CVs. Switched density rasters to logarithmic breaks. No changes to the model.
2.3	2015-09-03	Updated the documentation. No changes to the model.
2.4	2016-04-21	Switched calculation of monthly 5% and 95% confidence interval rasters to the method used to produce the year-round rasters. (We intended this to happen in version 2.2 but I did not implement it properly.) Updated the monthly CV rasters to have value 0 where we assumed the species was absent, consistent with the year-round CV raster. No changes to the other (non-zero) CV values, the mean abundance rasters, or the model itself.

*For questions, or to offer feedback about this model or report, please contact Jason Roberts (jason.roberts@duke.edu)

Survey Data

Survey	Period	Length (1000 km)	Hours	Sightings
NEFSC Aerial Surveys	1995-2008	70	412	173
NEFSC NARWSS Harbor Porpoise Survey	1999-1999	6	36	31
NEFSC North Atlantic Right Whale Sighting Survey	1999-2013	432	2330	2020
NEFSC Shipboard Surveys	1995-2004	16	1143	42
NJDEP Aerial Surveys	2008-2009	11	60	0
NJDEP Shipboard Surveys	2008-2009	14	836	0
SEFSC Atlantic Shipboard Surveys	1992-2005	28	1731	0
SEFSC Mid Atlantic Tursiops Aerial Surveys	1995-2005	35	196	0
SEFSC Southeast Cetacean Aerial Surveys	1992-1995	8	42	0
UNCW Cape Hatteras Navy Surveys	2011-2013	19	125	0
UNCW Early Marine Mammal Surveys	2002-2002	18	98	0
UNCW Jacksonville Navy Surveys	2009-2013	66	402	0
UNCW Onslow Navy Surveys	2007-2011	49	282	0
UNCW Right Whale Surveys	2005-2008	114	586	0
Virginia Aquarium Aerial Surveys	2012-2014	9	53	0
Total		895	8332	2266

Table 2: Survey effort and sightings used in this model. Effort is tallied as the cumulative length of on-effort transects and hours the survey team was on effort. Sightings are the number of on-effort encounters of the modeled species for which a perpendicular sighting distance (PSD) was available. Off effort sightings and those without PSDs were omitted from the analysis.

Season	Months	Length (1000 km)	Hours	Sightings
All_Year	All	897	8332	2266

Table 3: Survey effort and on-effort sightings having perpendicular sighting distances.

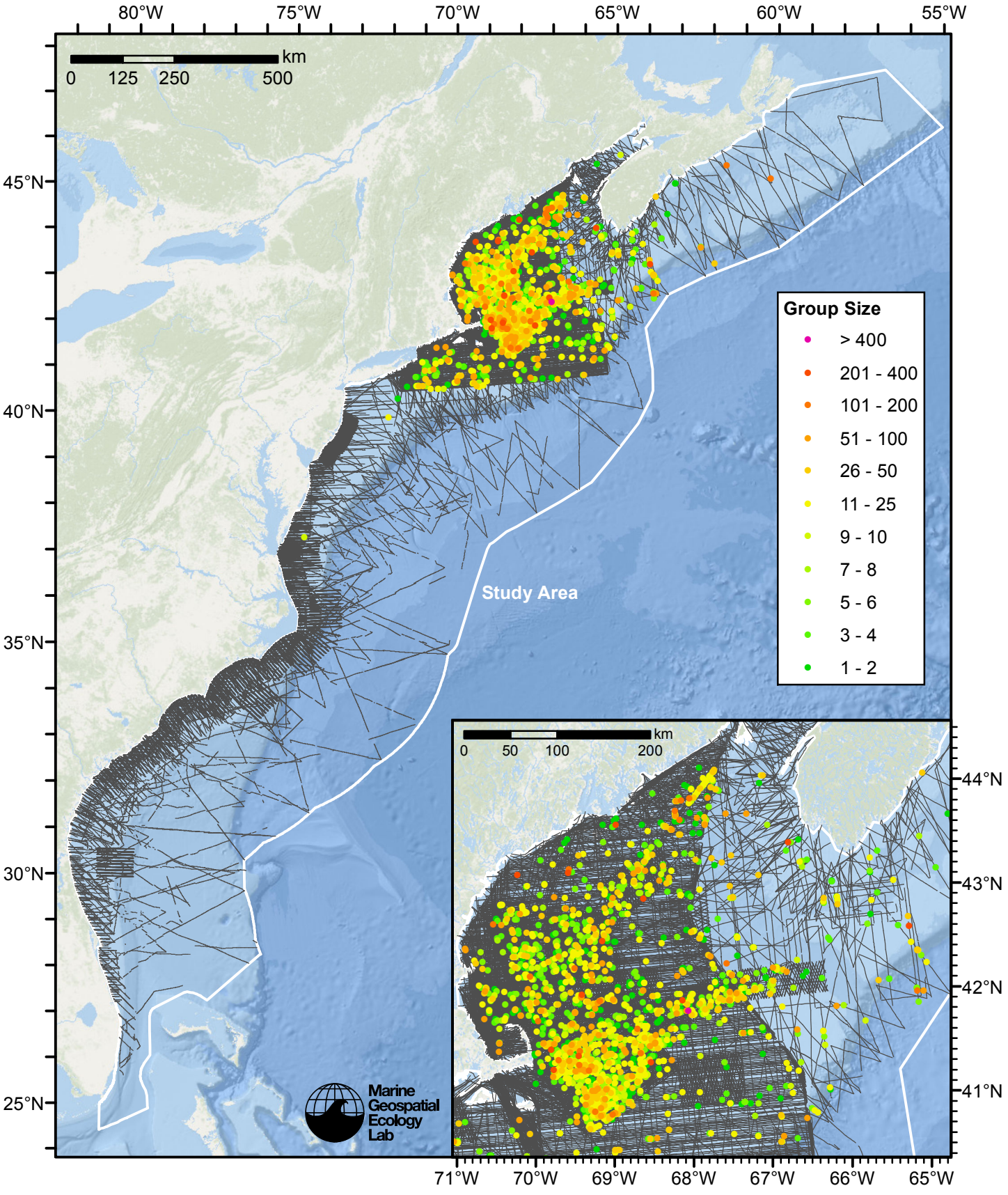


Figure 1: Atlantic white-sided dolphin sightings and survey tracklines.

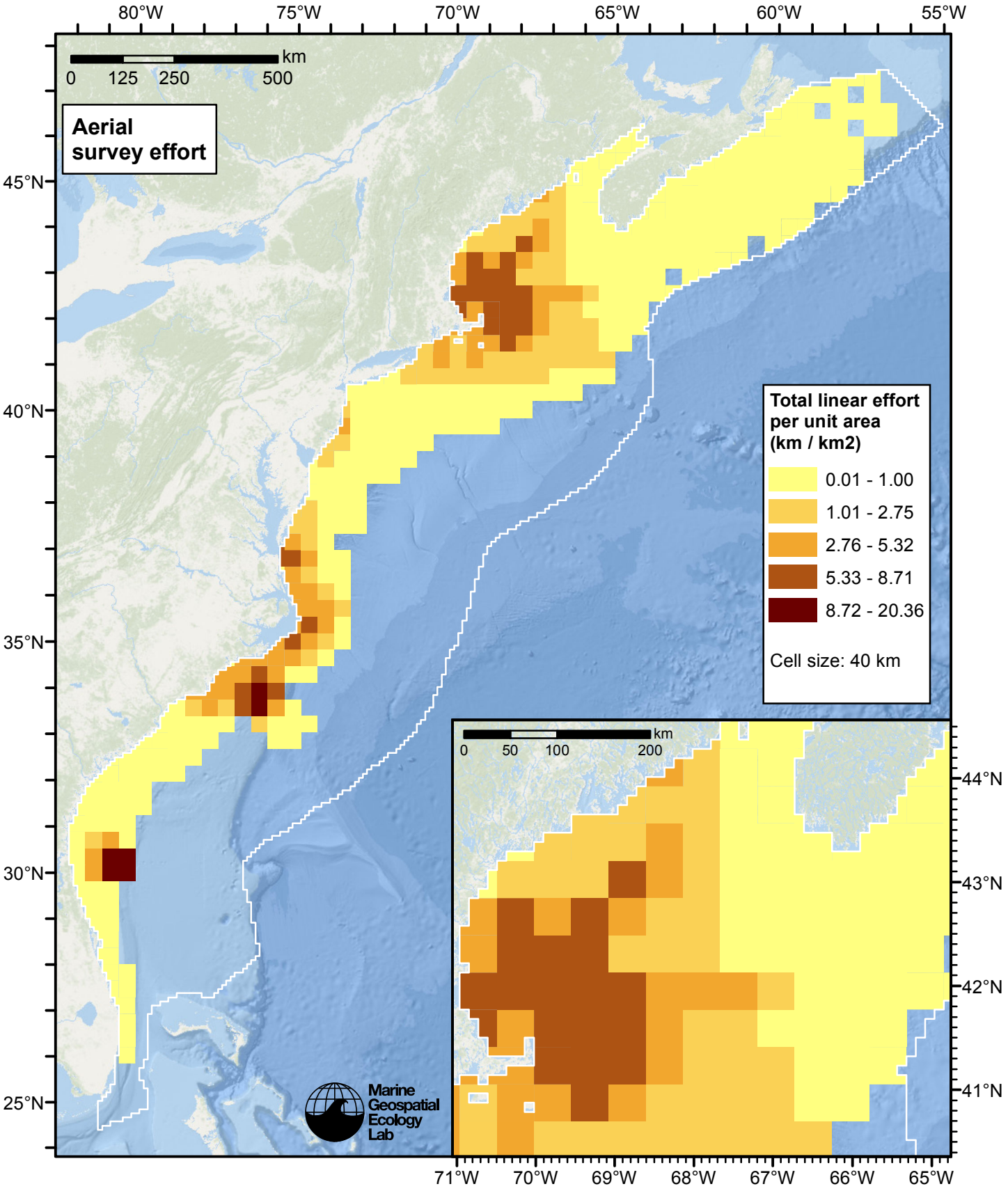


Figure 2: Aerial linear survey effort per unit area.

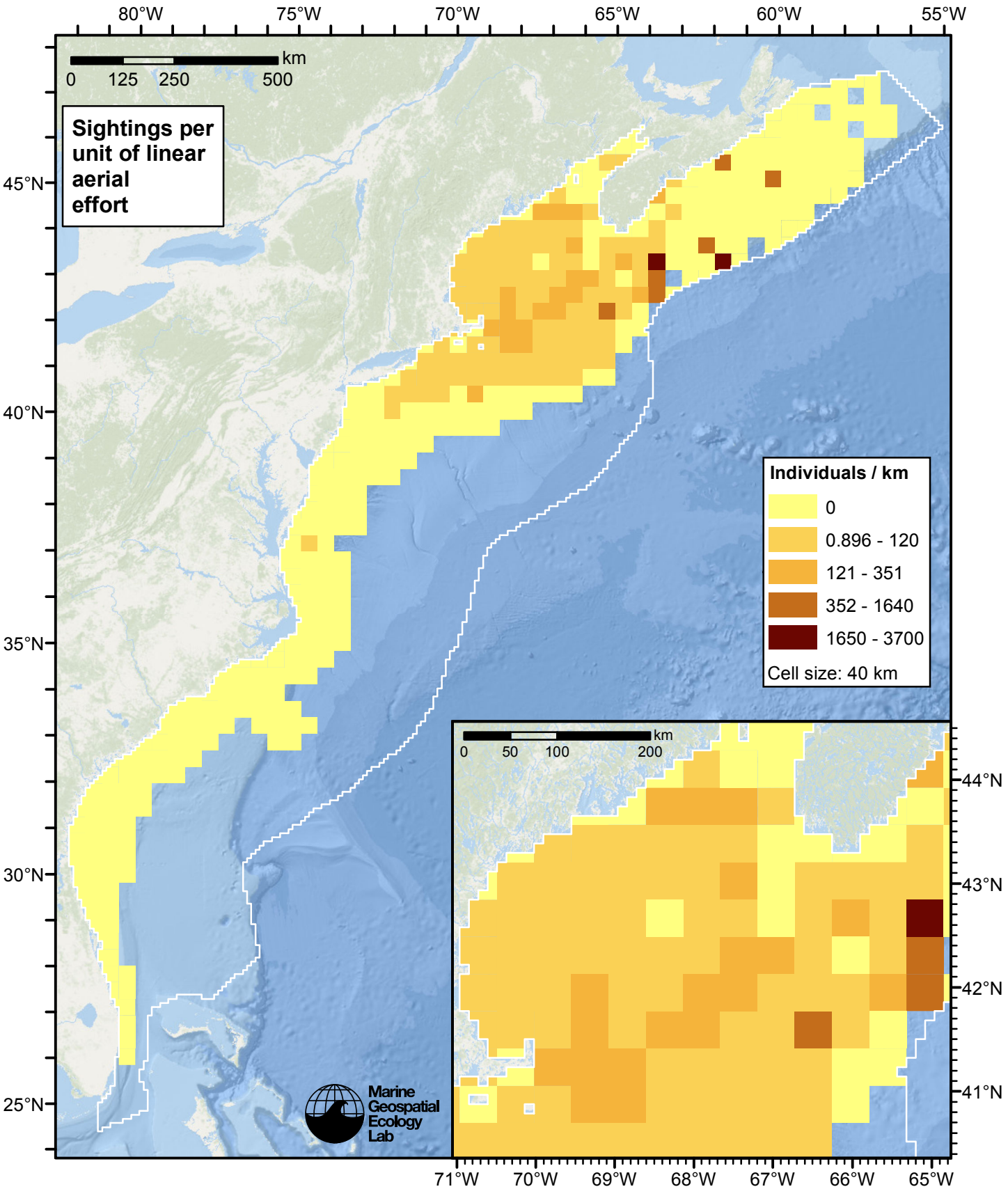


Figure 3: Atlantic white-sided dolphin sightings per unit aerial linear survey effort.

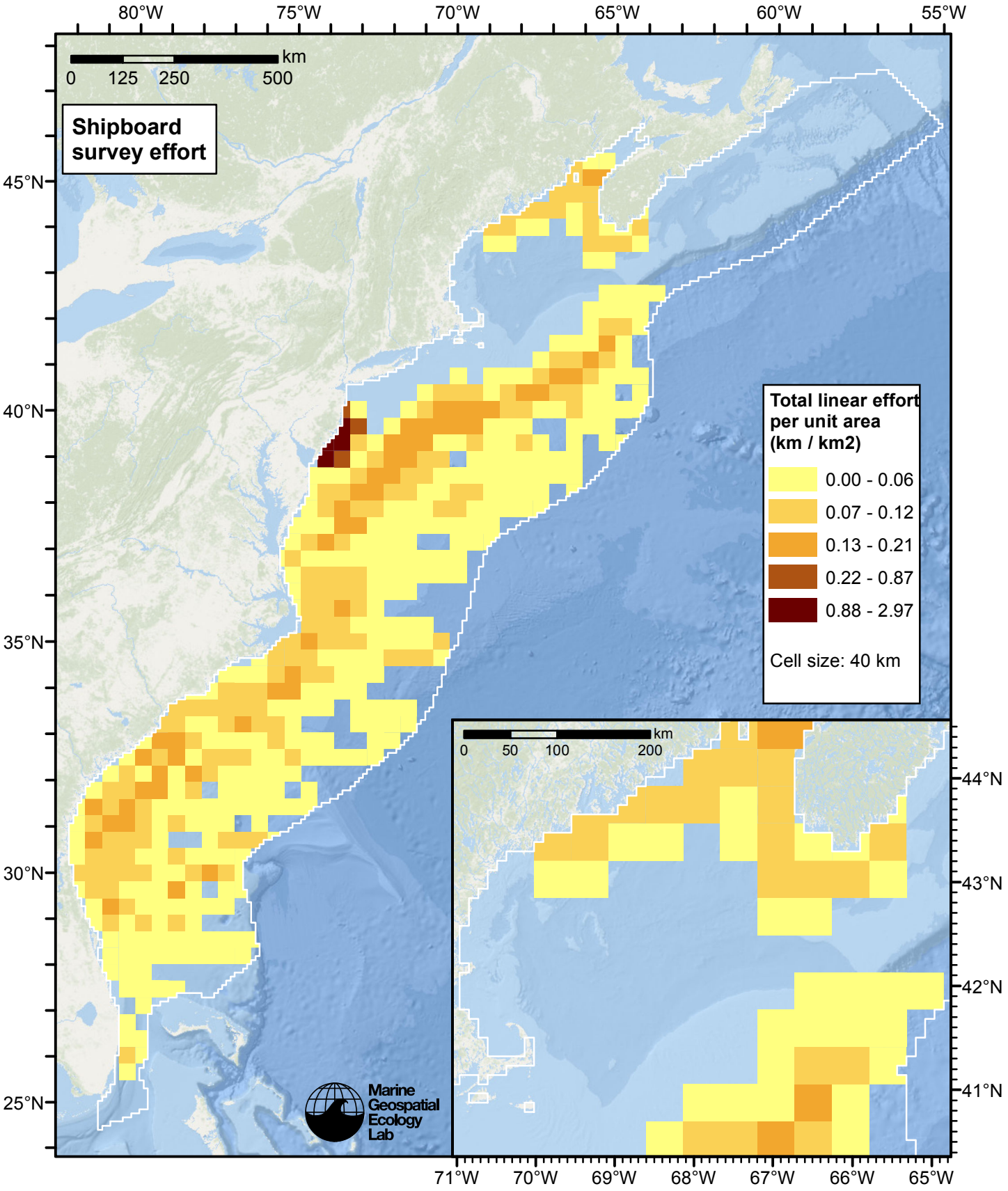


Figure 4: Shipboard linear survey effort per unit area.

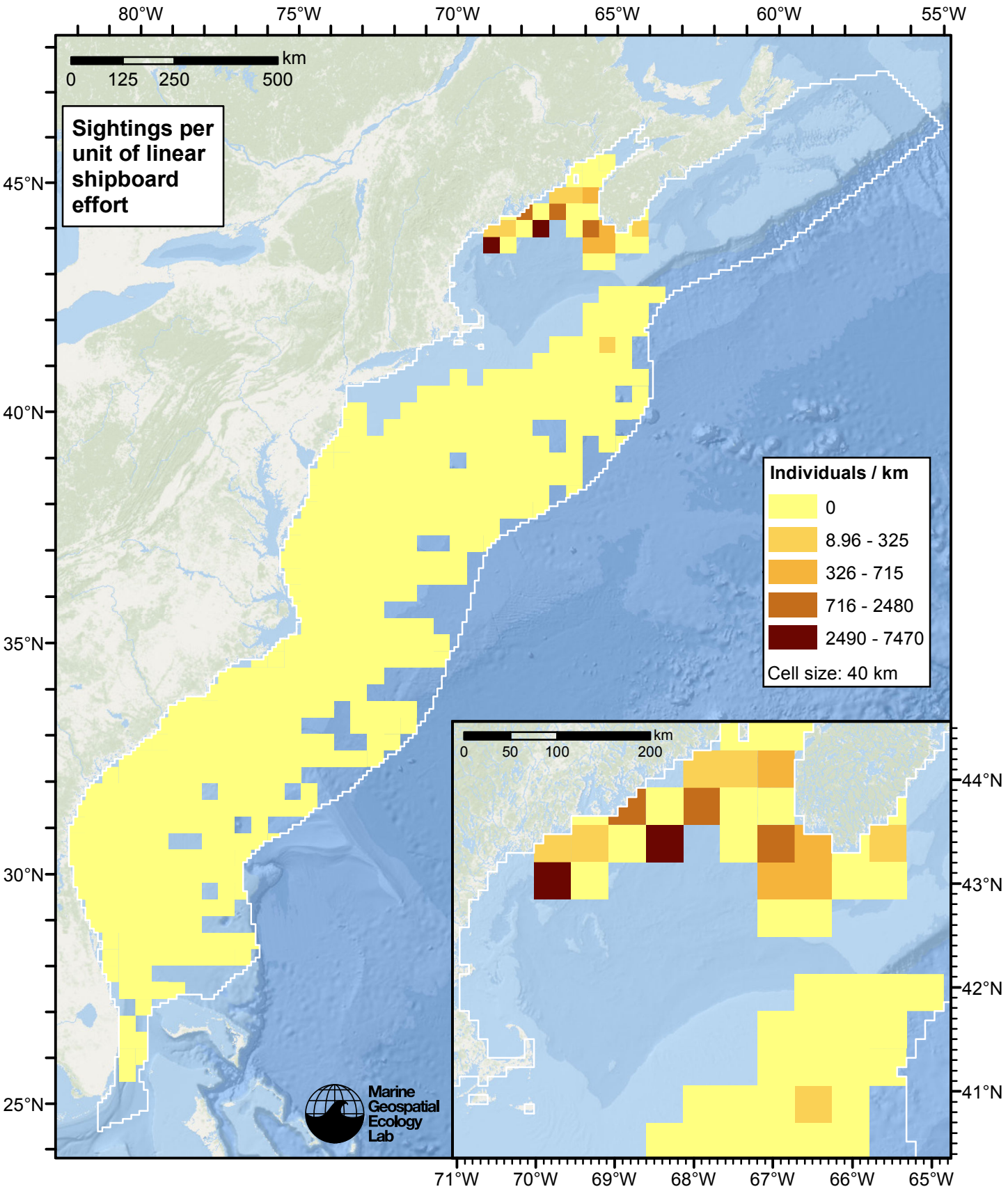


Figure 5: Atlantic white-sided dolphin sightings per unit shipboard linear survey effort.

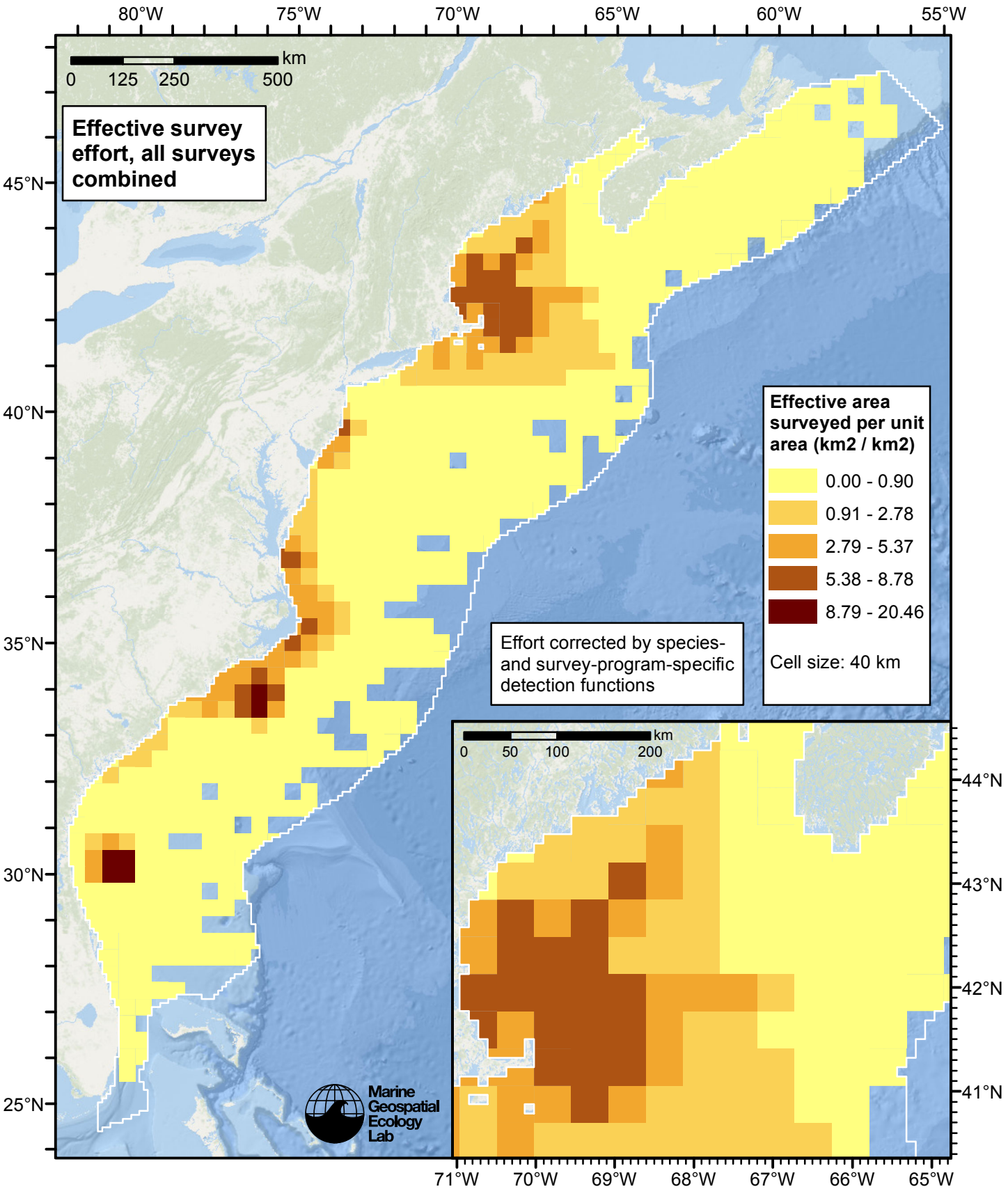


Figure 6: Effective survey effort per unit area, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

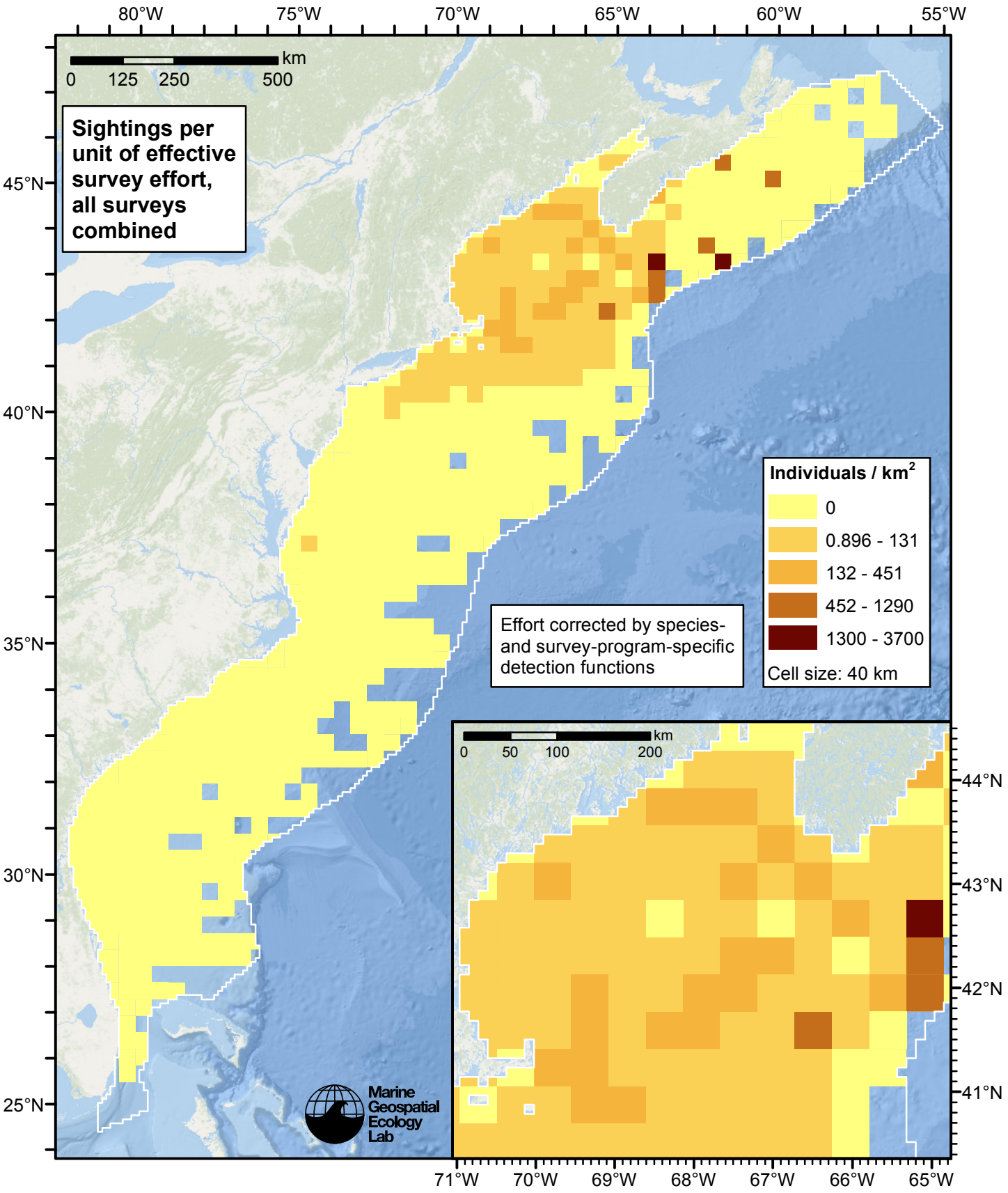


Figure 7: Atlantic white-sided dolphin sightings per unit of effective survey effort, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

Reclassification of Ambiguous Sightings

Observers occasionally experience difficulty identifying species, due to poor sighting conditions or phenotypic similarities between the possible choices. For example, observers may not always be able to distinguish fin whales from sei whales (Tim Cole, pers. comm.). When this happens, observers will report an ambiguous identification, such as "fin or sei whale".

In our density models, we handled ambiguous identifications in three ways:

1. For sightings with very generic identifications such as "large whale", we discarded the sightings. These sightings represented a clear minority when compared to those with definitive species identifications, but they are uncounted animals and our density models may therefore underestimate density to some degree.
2. For sightings of certain taxa in which a large majority of identifications were ambiguous (e.g. "Globicephala spp.") rather than specific (e.g. "Globicephala melas" or "Globicephala macrorhynchus"), it was not tractable to model the individual species so we modeled the generic taxon instead.
3. For sightings that reported an ambiguous identification of two species (e.g. "fin or sei whale") that are known to exhibit different habitat preferences or typically occur in different group sizes, and for which we had sufficient number of definitive sightings of both species, we fitted a predictive model that classified the ambiguous sightings into one species or the other.

This section describes how we utilized the third category of ambiguous sightings in the density models presented in this report.

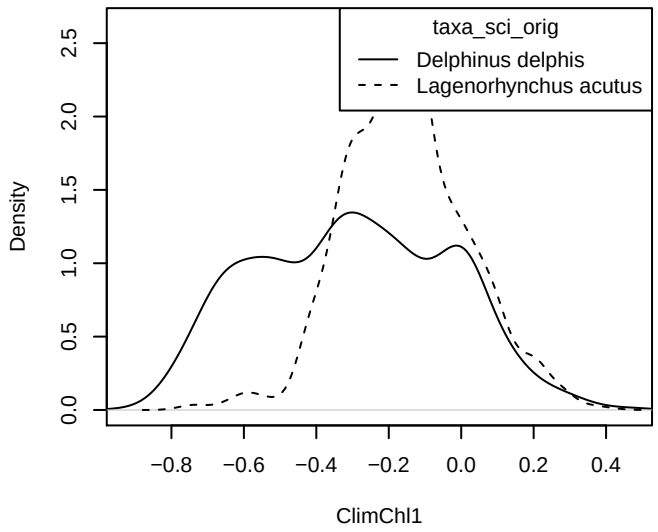
For the predictive model, we used the cforest classifier (Hothorn et al. 2006), an elaboration of the classic random forest classifier (Breiman, 2001). First, we trained a binary classifier using the sightings that reported definitive species identifications (e.g. "fin whale" and "sei whale"). The training data included all on-effort sightings, not just those in the focal study area. We used the species ID as the response variable and oceanographic variables or group size as predictor variables, depending on the species. We used receiver operating characteristic (ROC) curve analysis to select a threshold for classifying the probabilistic predictions of species identifications made by the model into a binary result of one species or another; for the threshold, we selected the value that maximized the Youden index (see Perkins and Schisterman, 2006).

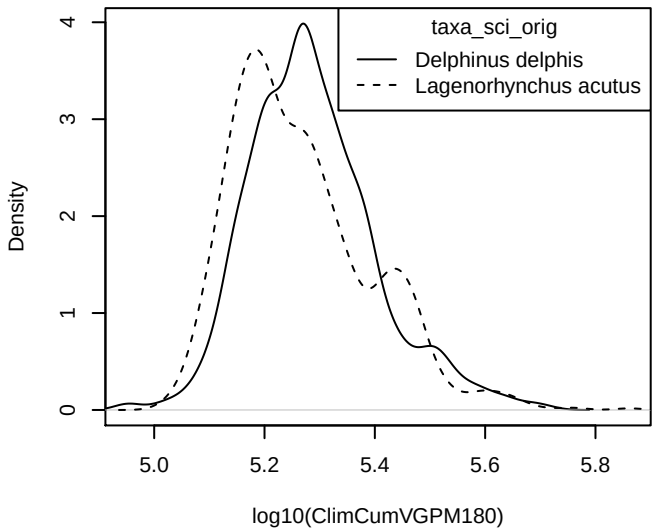
Then, for all sightings reporting the ambiguous identification, we reclassified the sighting as either one species or the other by processing the predictor values observed for that sighting through the fitted model. We then included the reclassified sightings in the detection functions and spatial models of density. The sightings reported elsewhere in this document incorporate both the definitive sightings and the reclassified sightings.

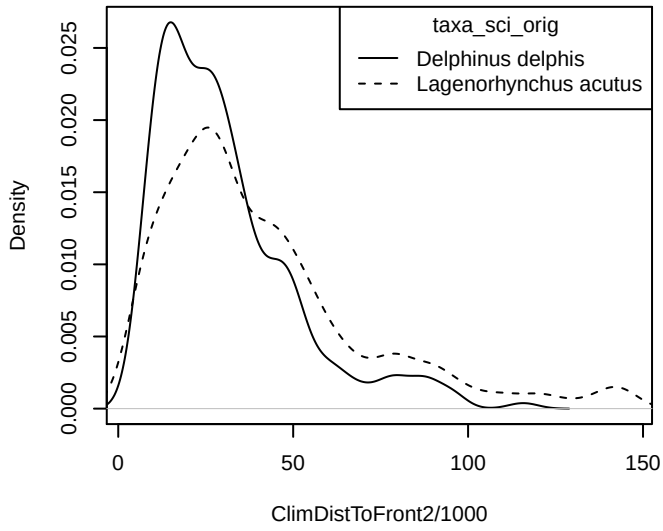
Reclassification of "Delphinus delphis/Lagenorhynchus acutus" in the East Coast Region

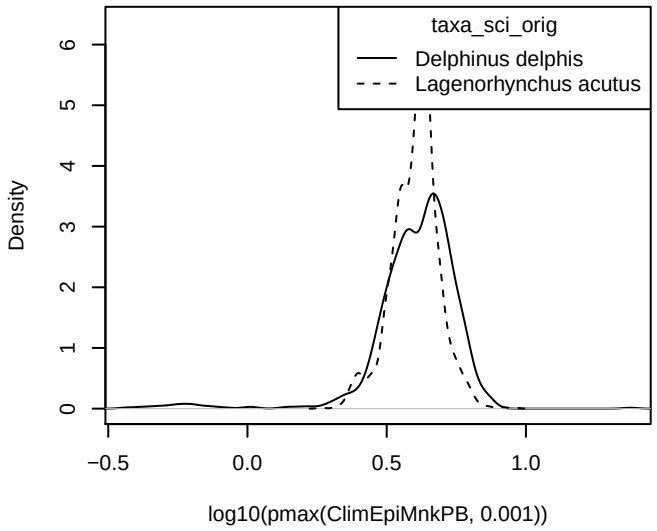
Density Histograms

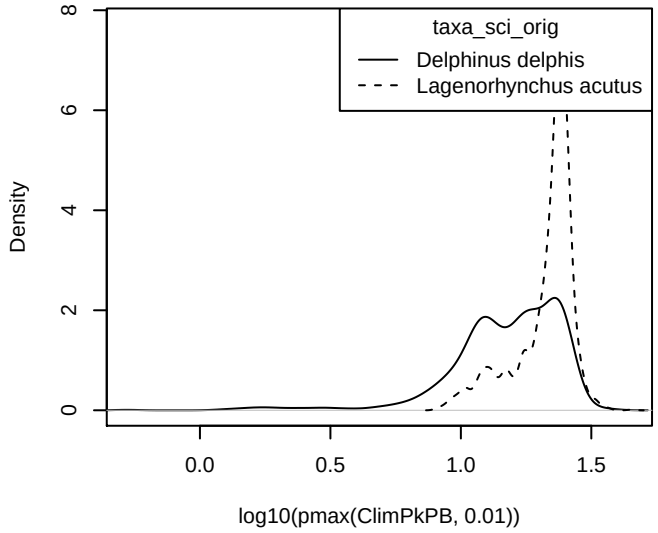
These plots show the per-species distribution of each predictor variable used in the reclassification model. When a variable exhibits a substantially different distribution for each species, it is a good candidate for classifying ambiguous sightings as one species or the other.

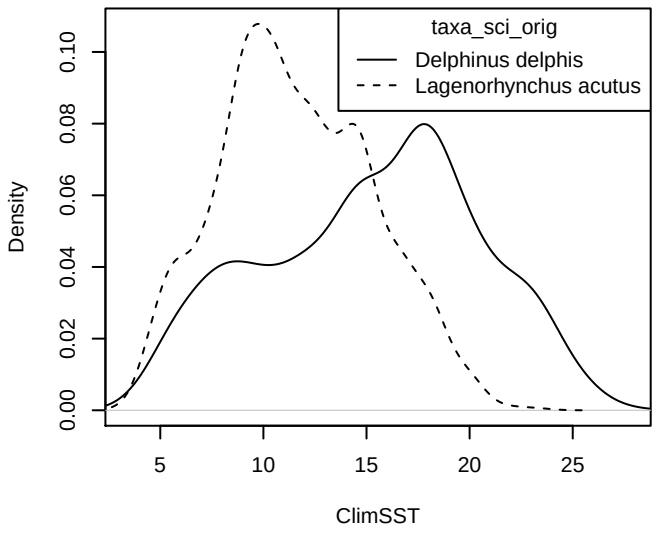

taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
ClimChl1

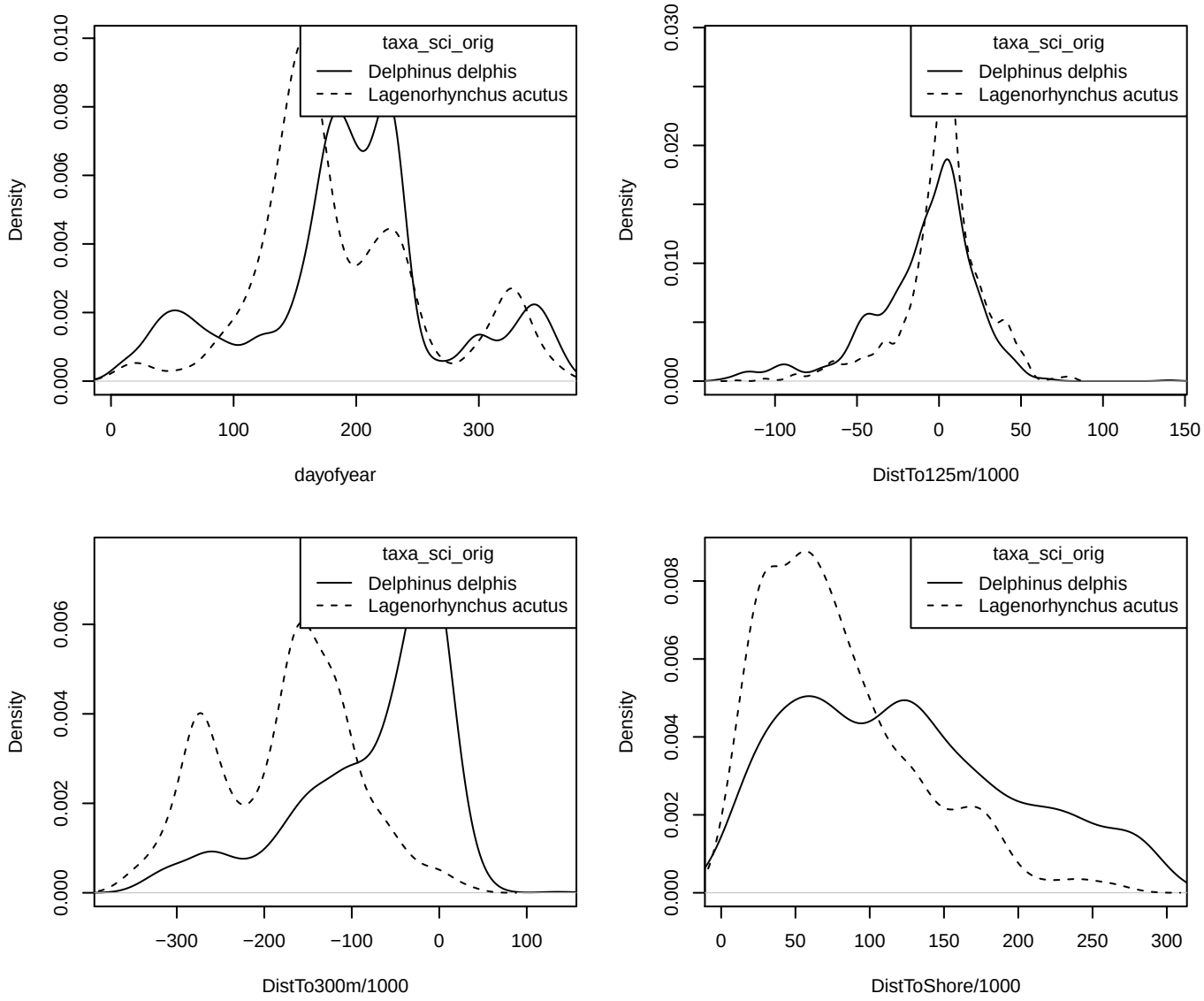

taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
log10(ClimCumVGPM180)


taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
ClimDistToFront2/1000


taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
log10(pmax(ClimEpiMnkPB, 0.001))


taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
log10(pmax(ClimPkPB, 0.01))


taxa_sci_orig
Delphinus delphis
Lagenorhynchus acutus
Density
ClimSST



Statistical output

```
MODEL SUMMARY:
==============

     Random Forest using Conditional Inference Trees

Number of trees:  1000

Response:  factor(taxa_sci_orig)
Inputs:  DistTo300m, ClimPkPB, ClimSST, DistTo125m, ClimCumVGPM180, DistToShore, ClimChl1, ClimEpiMnkPB, dayof
Number of observations:  2934

Number of variables tried at each split: 5

Estimated predictor variable importance (conditional = FALSE):

               Importance
DistTo300m         0.1269
ClimPkPB           0.0683
ClimSST            0.0420
```

```
ClimCumVGPM180       0.0316
DistTo125m           0.0262
dayofyear            0.0229
ClimEpiMnkPB         0.0205
DistToShore          0.0176
ClimChl1             0.0165
ClimDistToFront2     0.0158

MODEL PERFORMANCE SUMMARY:
==========================

Statistics calculated from the training data.

Area under the ROC curve (auc)           = 0.970
Mean cross-entropy (mxe)                 = 0.212
Precision-recall break-even point (prbe) = 0.933
Root-mean square error (rmse)            = 0.256

Cutoff selected by maximizing the Youden index = 0.735

Confusion matrix for that cutoff:

                                Actual Lagenorhynchus acutus  Actual Delphinus delphis  Total
Predicted Lagenorhynchus acutus                         1733                        78   1811
Predicted Delphinus delphis                              210                       913   1123
Total                                                   1943                       991   2934

Model performance statistics for that cutoff:

Accuracy (acc)                                = 0.902
Error rate (err)                              = 0.098
Rate of positive predictions (rpp)            = 0.617
Rate of negative predictions (rnp)            = 0.383

True positive rate (tpr, or sensitivity)      = 0.892
False positive rate (fpr, or fallout)         = 0.079
True negative rate (tnr, or specificity)      = 0.921
False negative rate (fnr, or miss)            = 0.108

Positive prediction value (ppv, or precision) = 0.957
Negative prediction value (npv)               = 0.813
Prediction-conditioned fallout (pcfall)       = 0.043
Prediction-conditioned miss (pcmiss)          = 0.187

Matthews correlation coefficient (mcc)        = 0.791
Odds ratio (odds)                             = 96.595
SAR                                           = 0.709

Cohen's kappa (K)                             = 0.788
```

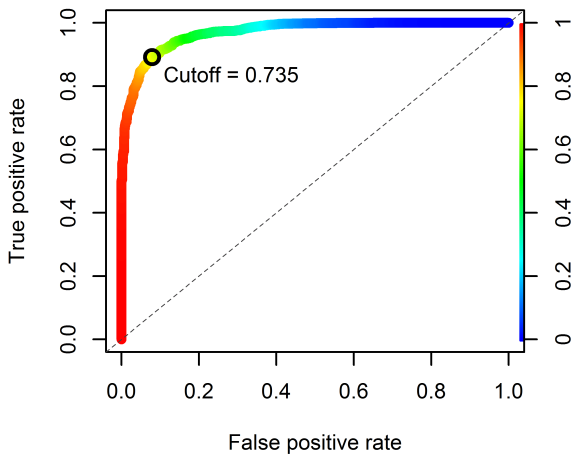


Figure 8: Receiver operating characteristic (ROC) curve illustrating the predictive performance of the model used to reclassify "Delphinus delphis/Lagenorhynchus acutus" sightings into one species or the other.

Reclassifications Performed

Survey	Definitive L. acutus Sightings	Definitive D. delphis Sightings	Ambiguous Sightings	Reclassed to L. acutus	Reclassed to D. delphis
NEFSC Aerial Surveys	214	304	9	2	7
NEFSC NARWSS Harbor Porpoise Survey	32	5	0	0	0
NEFSC North Atlantic Right Whale Sighting Survey	1506	348	909	649	260
NEFSC Shipboard Surveys	191	184	0	0	0
NJDEP Aerial Surveys	0	5	0	0	0
NJDEP Shipboard Surveys	0	19	0	0	0
SEFSC Atlantic Shipboard Surveys	0	37	0	0	0
SEFSC Mid Atlantic Tursiops Aerial Surveys	0	4	0	0	0
UNCW Cape Hatteras Navy Surveys	0	12	0	0	0
UNCW Early Marine Mammal Surveys	0	26	0	0	0
UNCW Onslow Navy Surveys	0	1	0	0	0
UNCW Right Whale Surveys	0	26	0	0	0
Virginia Aquarium Aerial Surveys	0	20	0	0	0
Total	1943	991	918	651	267

Table 4: Counts of definitive sightings, ambiguous sightings, and what the ambiguous sightings were reclassified to. Note that this analysis was performed on all on-effort sightings, not just those in the focal study area. These counts may therefore be larger than those presented in the Survey Data section of this report, which are restricted to the focal study area.

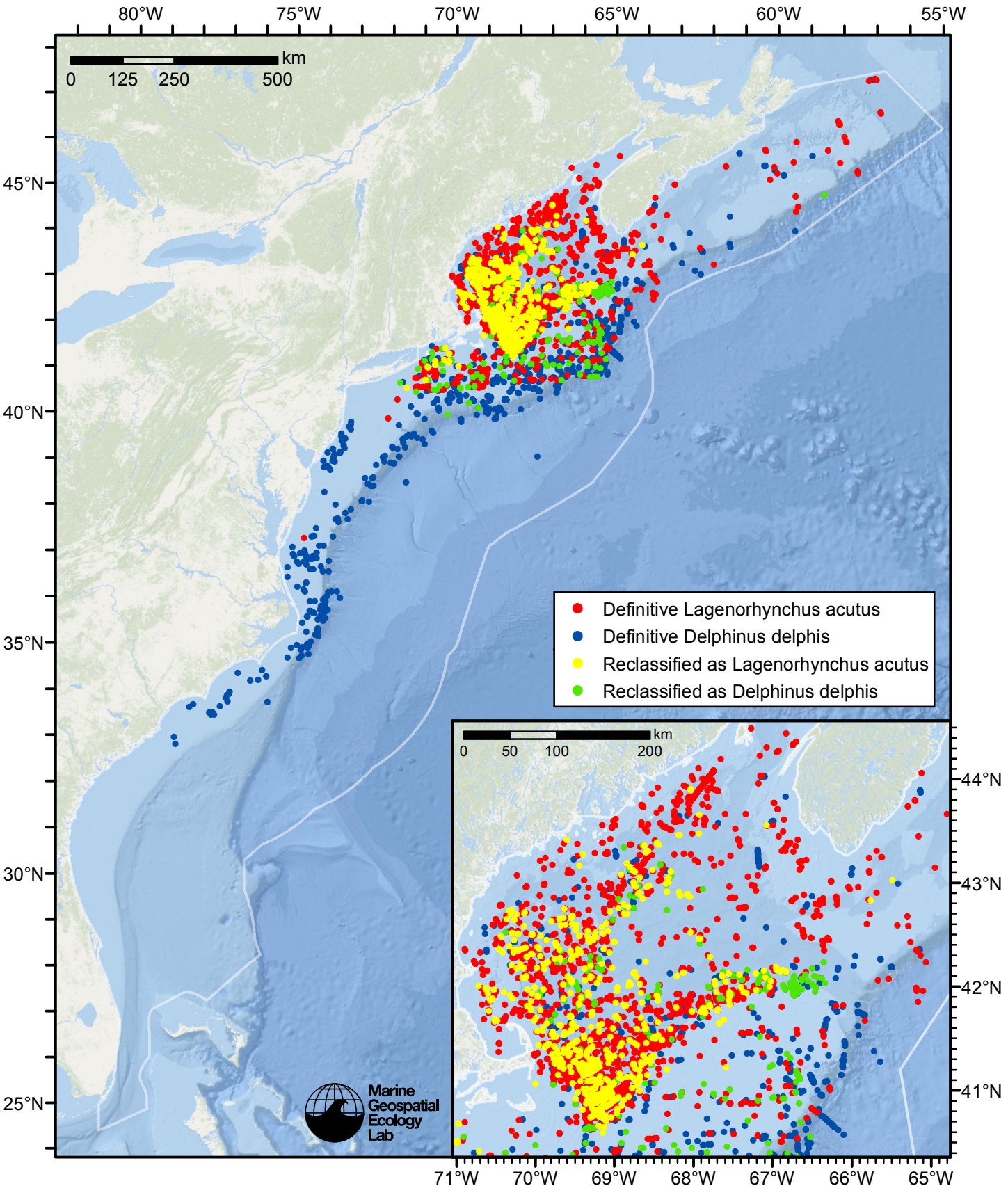


Figure 9: Definitive sightings used to train the model and ambiguous sightings reclassified by the model, by season.

Detection Functions

The detection hierarchy figures below show how sightings from multiple surveys were pooled to try to achieve Buckland et. al's (2001) recommendation that at least 60-80 sightings be used to fit a detection function. Leaf nodes, on the right, usually represent individual surveys, while the hierarchy to the left shows how they have been grouped according to how similar we believed the surveys were to each other in their detection performance.

At each node, the red or green number indicates the total number of sightings below that node in the hierarchy, and is colored green if 70 or more sightings were available, and red otherwise. If a grouping node has zero sightings–i.e. all of the surveys within it had zero sightings–it may be collapsed and shown as a leaf to save space.

Each histogram in the figure indicates a node where a detection function was fitted. The actual detection functions do not appear in this figure; they are presented in subsequent sections. The histogram shows the frequency of sightings by perpendicular sighting distance for all surveys contained by that node. Each survey (leaf node) recieves the detection function that is closest to it up the hierarchy. Thus, for common species, sufficient sightings may be available to fit detection functions deep in the hierarchy, with each function applying to only a few surveys, thereby allowing variability in detection performance between surveys to be addressed relatively finely. For rare species, so few sightings may be available that we have to pool many surveys together to try to meet Buckland's recommendation, and fit only a few coarse detection functions high in the hierarchy.

A blue Proxy Species tag indicates that so few sightings were available that, rather than ascend higher in the hierarchy to a point that we would pool grossly-incompatible surveys together, (e.g. shipboard surveys that used big-eye binoculars with those that used only naked eyes) we pooled sightings of similar species together instead. The list of species pooled is given in following sections.

Shipboard Surveys

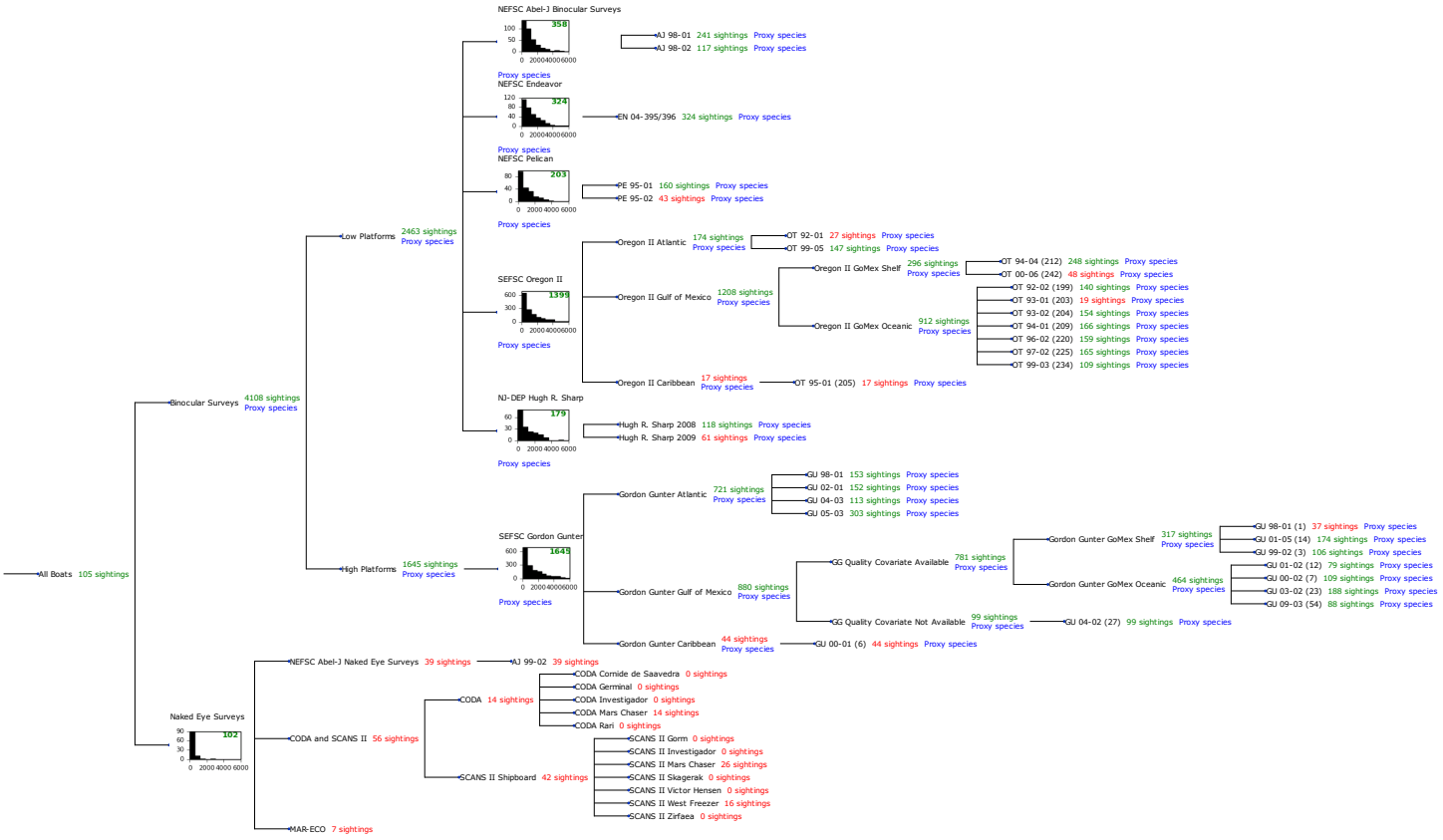


Figure 10: Detection hierarchy for shipboard surveys

NEFSC Abel-J Binocular Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	43
Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	152
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	4
Stenella attenuata	Pantropical spotted dolphin	4
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	63
Stenella frontalis	Atlantic spotted dolphin	9
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	1
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	82
Total		358

Table 5: Proxy species used to fit detection functions for NEFSC Abel-J Binocular Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 6: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	1577
hr			beaufort, quality, size	Yes	0.50	1574
hr			quality, size	Yes	1.35	1558
hr			size	Yes	2.52	1561
hr			quality	Yes	3.94	1586
hr			beaufort, quality	Yes	4.13	1593
hr			beaufort	Yes	4.42	1603
hn	cos	2		Yes	5.28	1504
hr				Yes	5.51	1601
hr	poly	2		Yes	7.06	1551
hr	poly	4		Yes	7.43	1586
hn			beaufort, size	Yes	17.29	1823
hn			beaufort, quality, size	Yes	18.74	1822
hn	cos	3		Yes	20.50	1502
hn			beaufort	Yes	20.71	1817
hn			beaufort, quality	Yes	21.33	1817
hn			quality	Yes	28.71	1823
hn				Yes	29.00	1825
hn			size	Yes	29.10	1825
hn			quality, size	Yes	29.31	1823
hn	herm	4		No		

Table 7: Candidate detection functions for NEFSC Abel-J Binocular Surveys. The first one listed was selected for the density model.

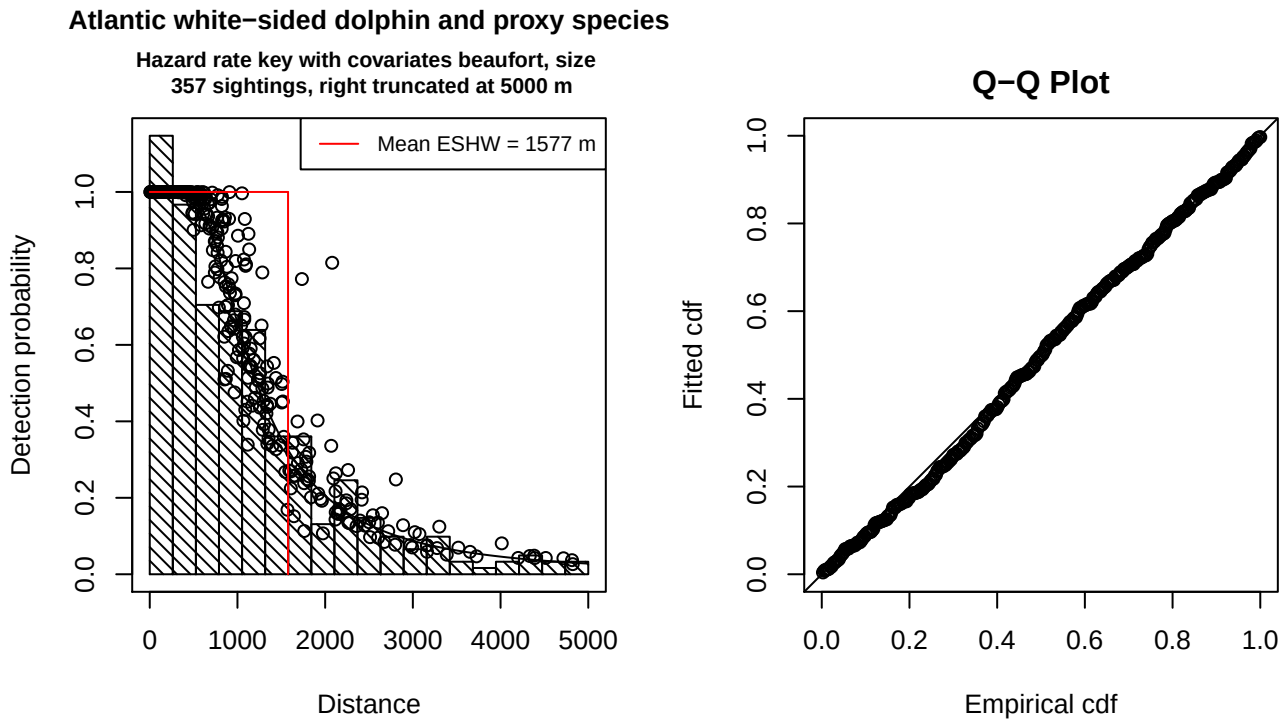


Figure 11: Detection function for NEFSC Abel-J Binocular Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  357
Distance range         :  0  -  5000
AIC                    :  5689.064

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  7.4066476 0.28751588
beaufort    -0.1983371 0.10000894
size         0.1366273 0.07421191

Shape parameters:
             estimate         se
(Intercept) 0.8389089 0.09859879

                        Estimate          SE         CV
Average p              0.3078884  0.01882296 0.06113567
N in covered region 1159.5109828 87.51962437 0.07547977
```

Additional diagnostic plots:

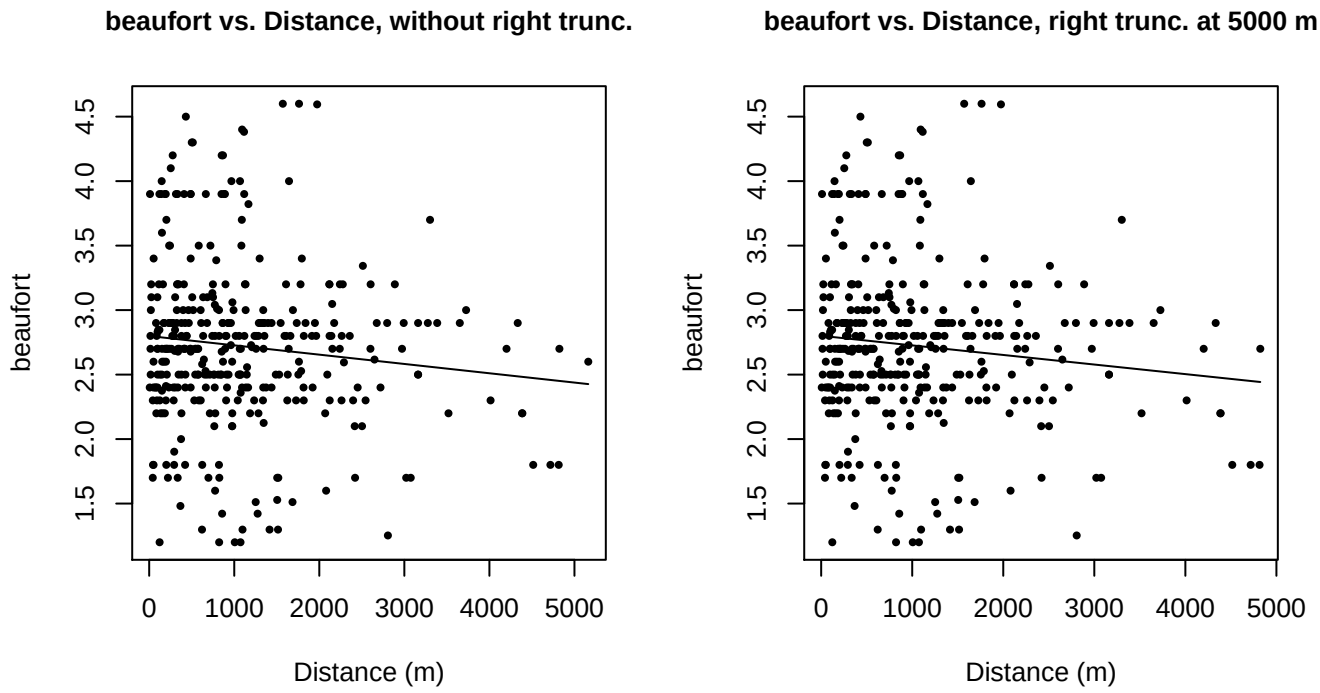


Figure 12: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

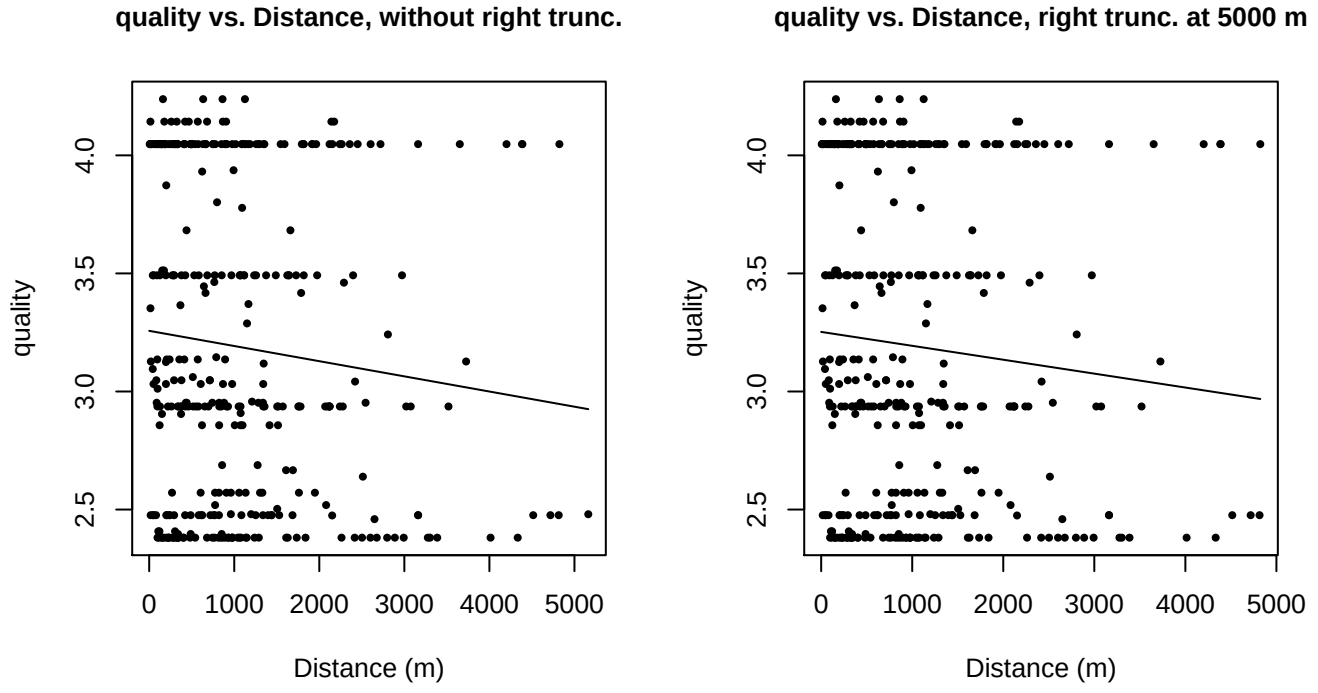


Figure 13: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

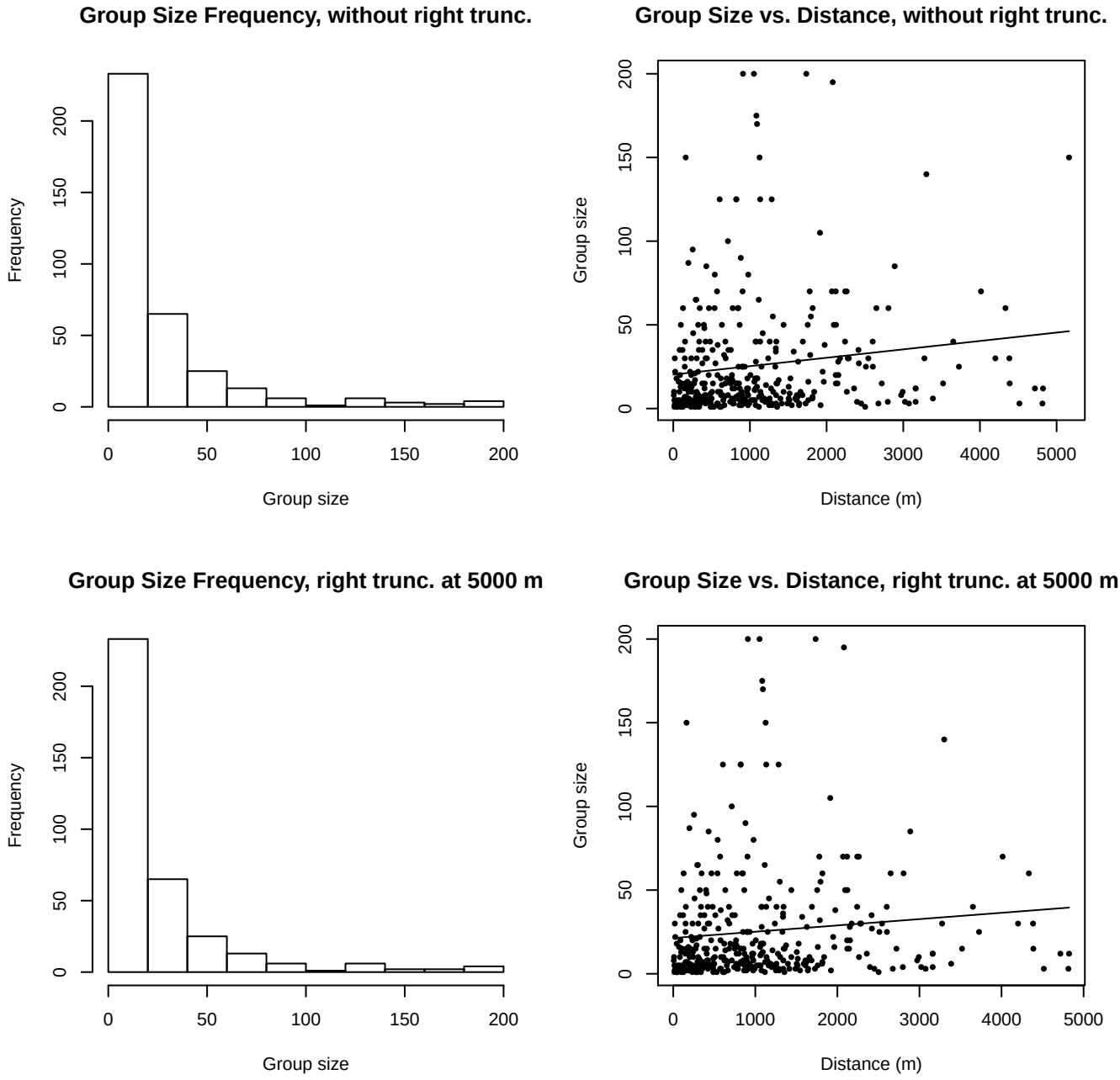


Figure 14: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NEFSC Endeavor

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	100

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	121
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	3
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	3
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	44
Stenella frontalis	Atlantic spotted dolphin	7
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	1
Tursiops truncatus	Bottlenose dolphin	45
Total		324

Table 8: Proxy species used to fit detection functions for NEFSC Endeavor. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 9: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn			beaufort	Yes	0.00	1930
hn			beaufort, size	Yes	1.86	1930
hn	cos	3		Yes	2.67	1684
hn				Yes	4.80	1934

hn	cos	2		Yes	5.68	1833
hn			size	Yes	6.54	1934
hn			quality	Yes	6.66	1934
hr			beaufort	Yes	7.56	2068
hn			quality, size	Yes	8.42	1934
hr			beaufort, size	Yes	8.71	2061
hr	poly	2		Yes	8.83	1805
hr	poly	4		Yes	10.77	1910
hr				Yes	17.87	2030
hr			size	Yes	19.40	2022
hr			quality	Yes	19.70	2039
hr			quality, size	Yes	21.27	2030
hn	herm	4		No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 10: Candidate detection functions for NEFSC Endeavor. The first one listed was selected for the density model.

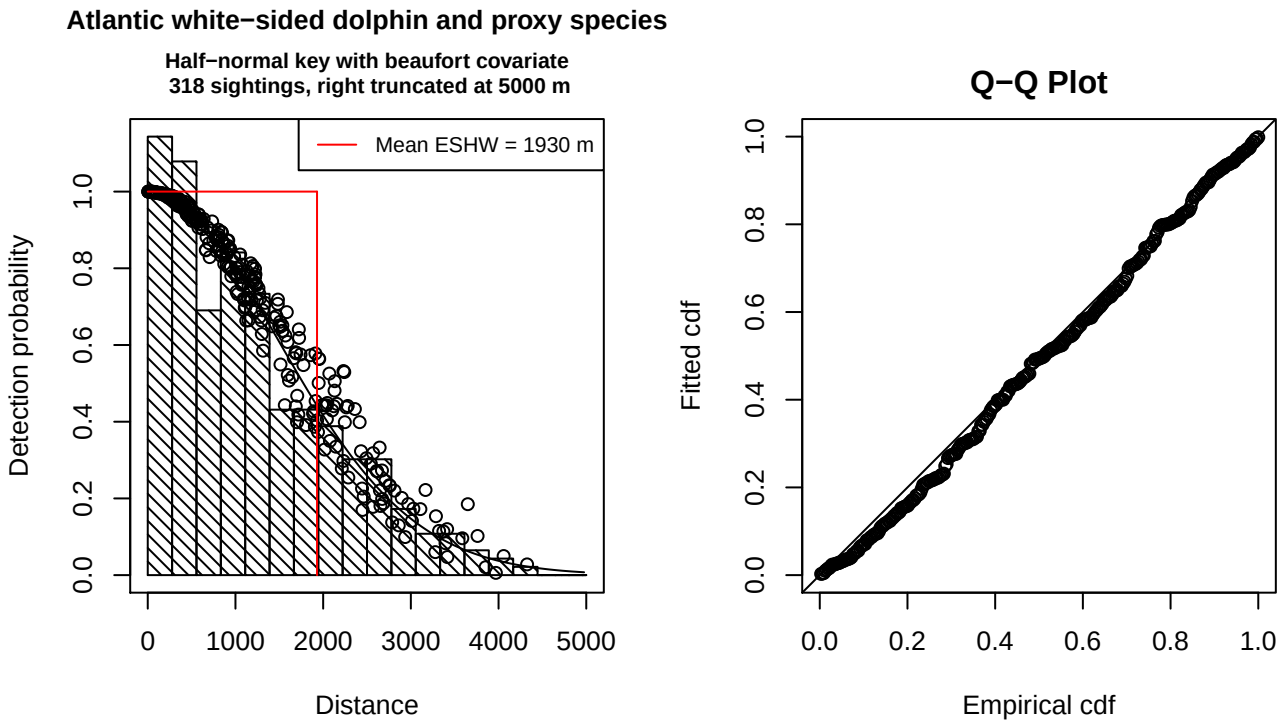


Figure 15: Detection function for NEFSC Endeavor that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  318
Distance range         :  0  -  5000
AIC                    :  5123.58

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  7.6304947 0.11974801
beaufort    -0.1208508 0.04145359

                       Estimate          SE         CV
Average p              0.3811258  0.01527091 0.04006791
N in covered region 834.3701363 49.83226006 0.05972441
```

Additional diagnostic plots:

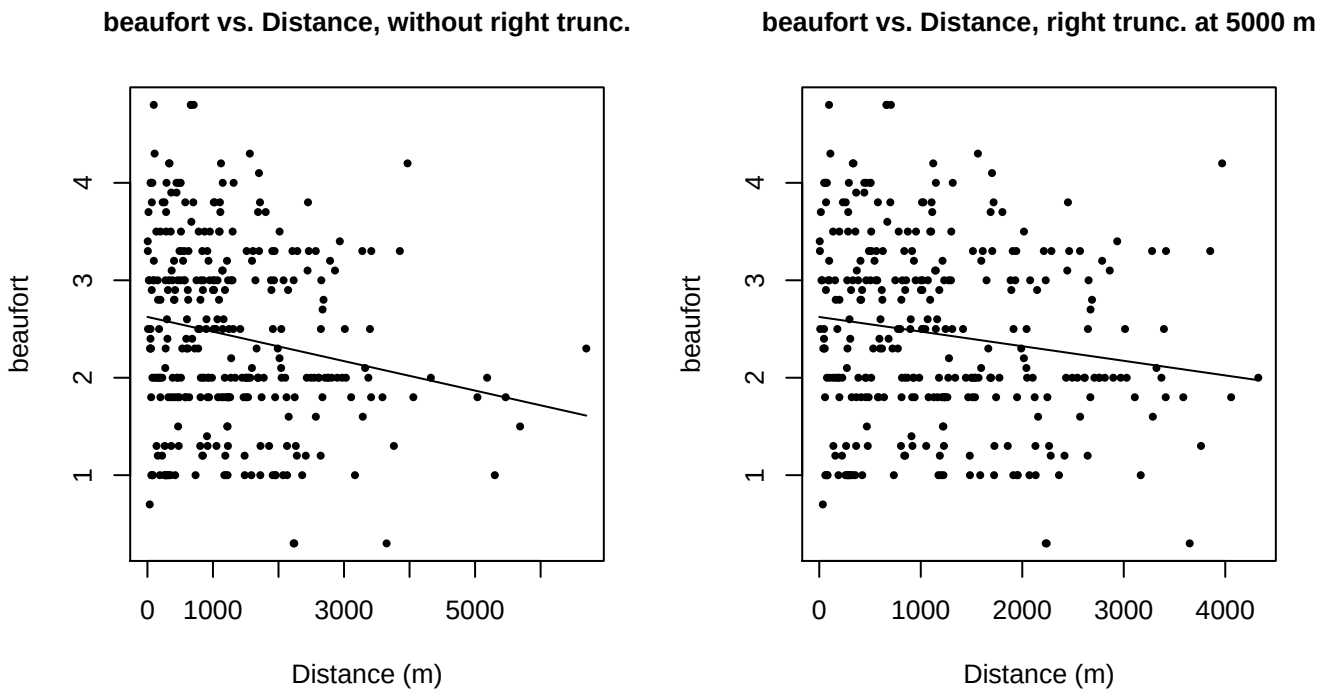


Figure 16: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

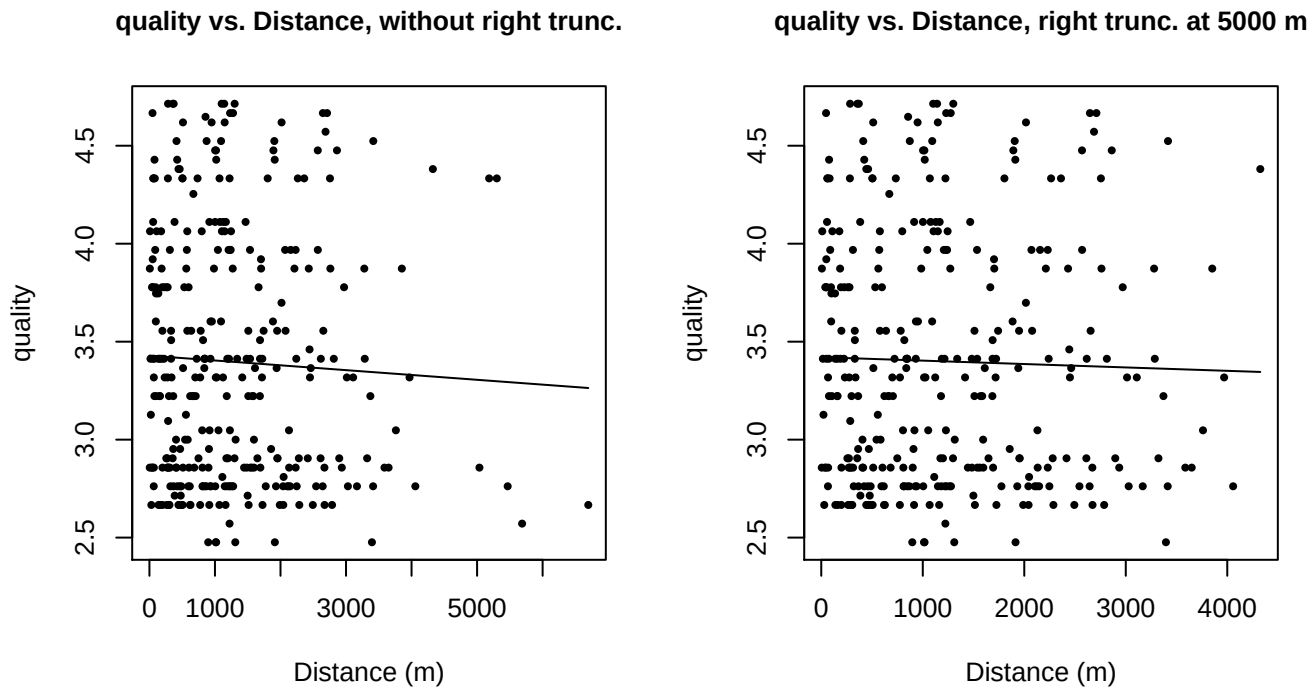


Figure 17: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

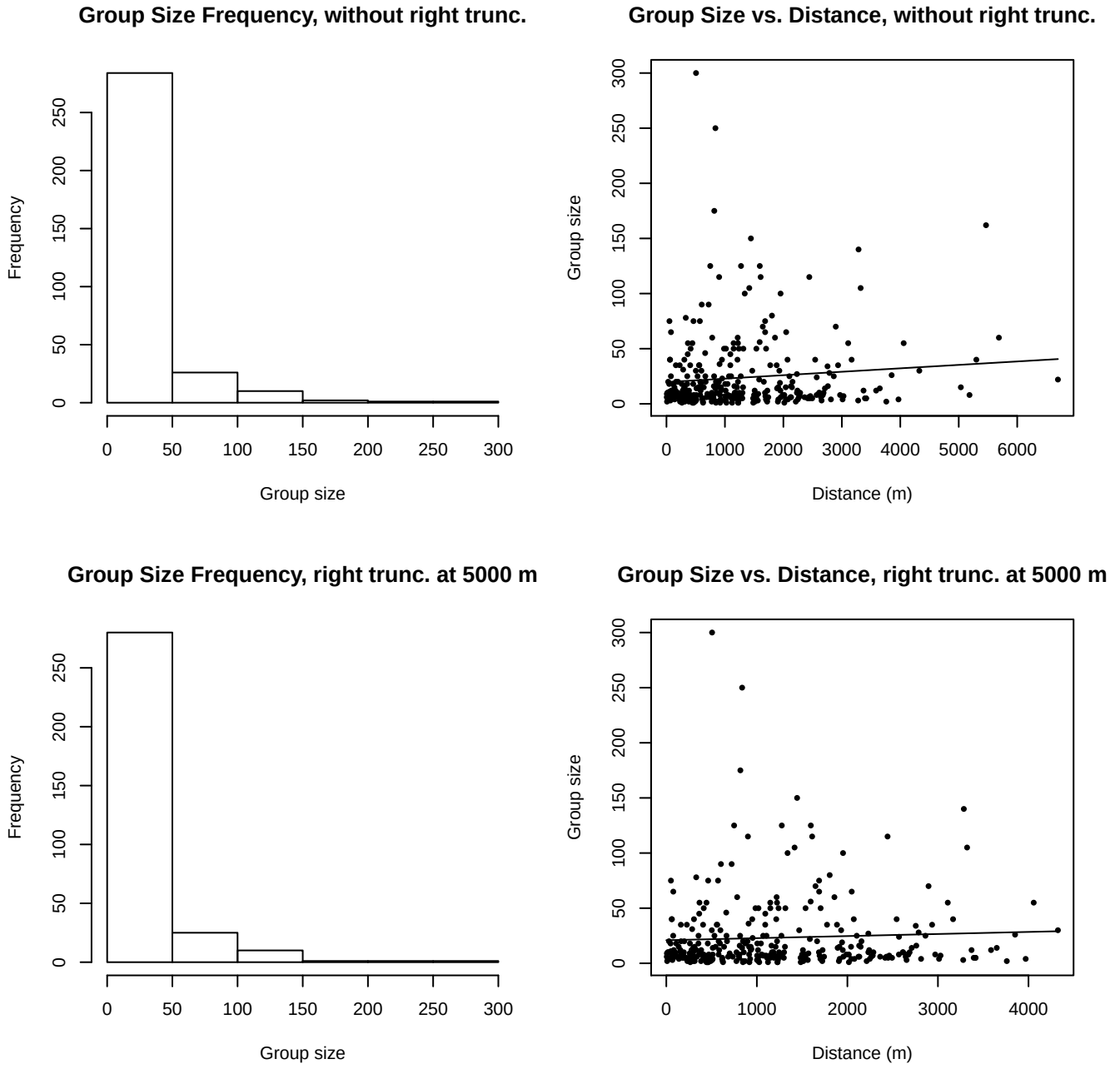


Figure 18: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NEFSC Pelican

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	30

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	1
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	79
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	1
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	3
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	30
Stenella frontalis	Atlantic spotted dolphin	9
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	50
Total		203

Table 11: Proxy species used to fit detection functions for NEFSC Pelican. The number of sightings, n, is before truncation.

The sightings were right truncated at 4000m.

Covariate	Description
beaufort	Beaufort sea state.
size	Estimated size (number of individuals) of the sighted group.

Table 12: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	1405
hr			size	Yes	7.20	1311
hr			beaufort	Yes	7.25	1403
hn			beaufort, size	Yes	8.79	1619
hr	poly	4		Yes	11.78	1180
hr	poly	2		Yes	11.96	1142

hn	cos	3		Yes	14.21	1252
hn			size	Yes	15.02	1620
hn	cos	2		Yes	15.51	1358
hr				Yes	16.02	1231
hn			beaufort	Yes	18.43	1610
hn				Yes	22.69	1616
hn	herm	4		No		

Table 13: Candidate detection functions for NEFSC Pelican. The first one listed was selected for the density model.

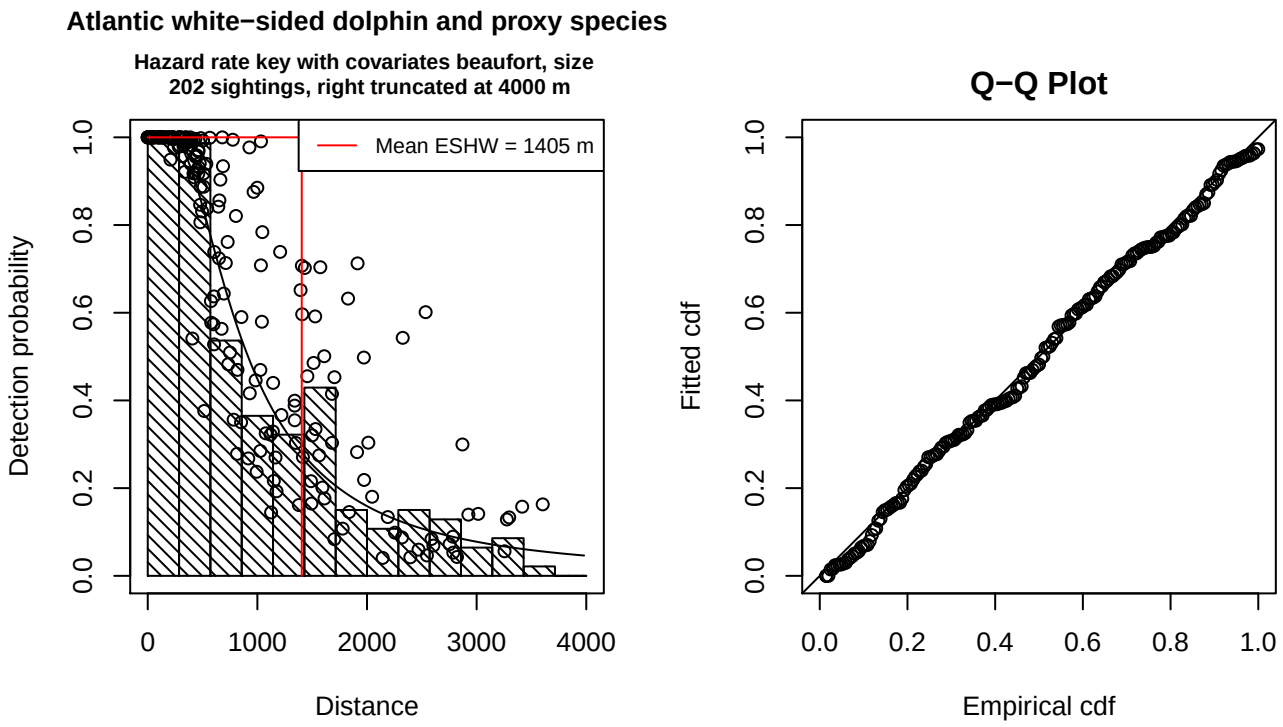


Figure 19: Detection function for NEFSC Pelican that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  202
Distance range         :  0  -  4000
AIC                    :  3161.875

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate        se
(Intercept)  7.5661326 0.3373562
beaufort    -0.4175079 0.1318920
```

```
size         0.4252084 0.1774154

Shape parameters:
             estimate        se
(Intercept) 0.7200614 0.1414368

                      Estimate          SE         CV
Average p             0.309672  0.03001865 0.09693692
N in covered region 652.303008 74.43038285 0.11410400
```

Additional diagnostic plots:

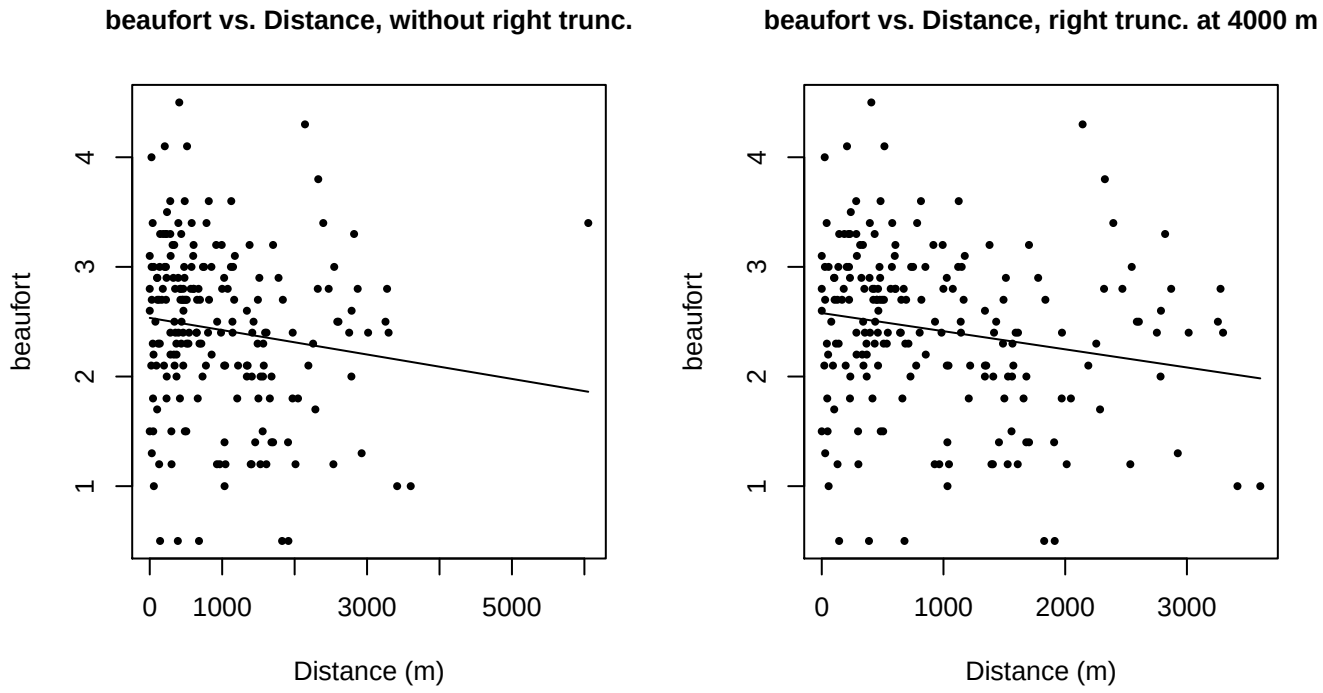


Figure 20: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

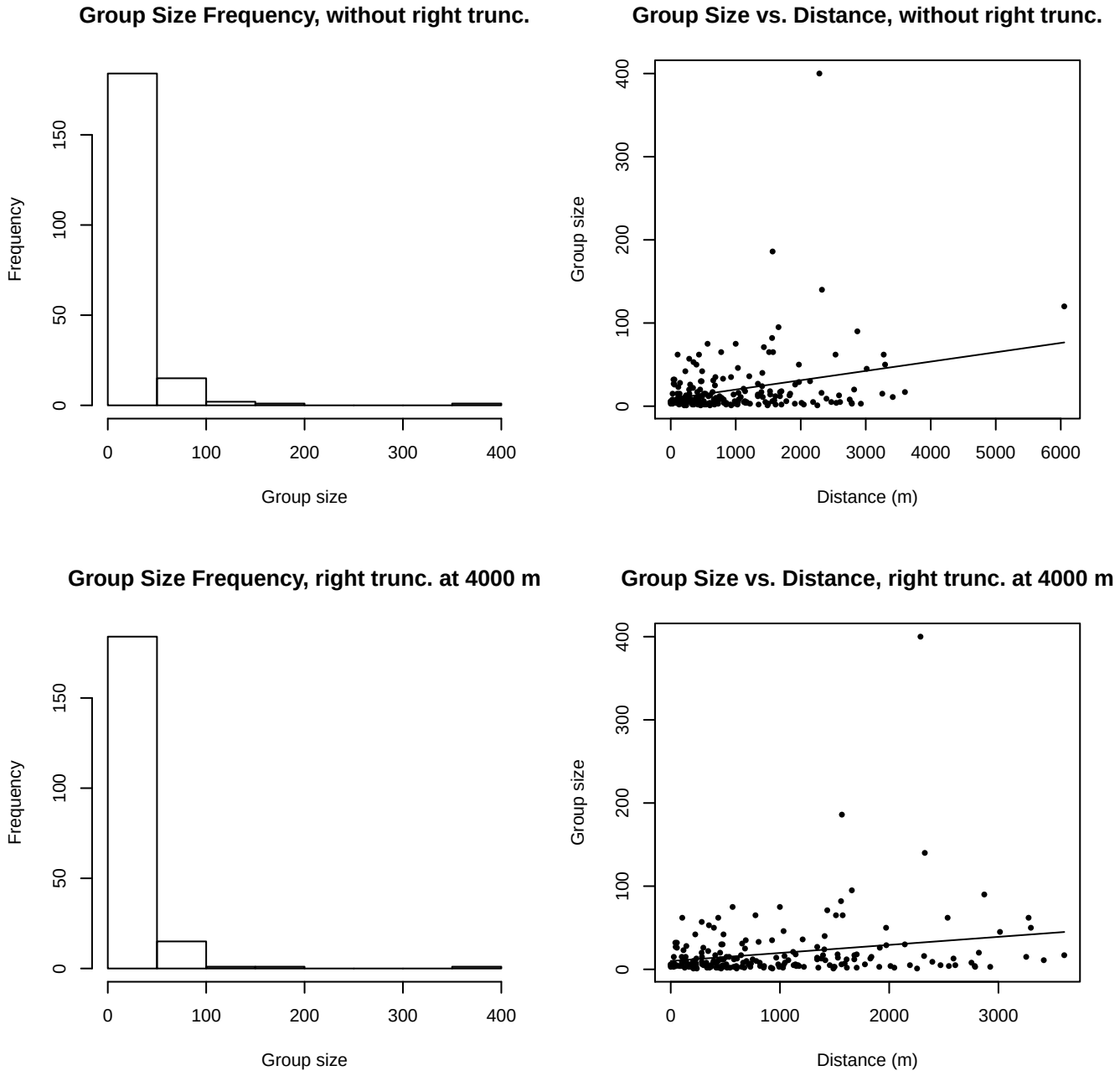


Figure 21: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SEFSC Oregon II

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	2

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	156
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	3
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	17
Stenella attenuata	Pantropical spotted dolphin	347
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	44
Stenella coeruleoalba	Striped dolphin	48
Stenella frontalis	Atlantic spotted dolphin	242
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	38
Steno bredanensis	Rough-toothed dolphin	22
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	490
Total		1409

Table 14: Proxy species used to fit detection functions for SEFSC Oregon II. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 15: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	807
hr			size	Yes	40.78	712
hr			beaufort, quality	Yes	52.03	579
hr			quality	Yes	77.42	536

hr			beaufort	Yes	89.47	513
hr	poly	4		Yes	96.59	501
hr	poly	2		Yes	103.38	525
hr				Yes	121.28	461
hn	cos	3		Yes	341.53	1351
hn	cos	2		Yes	345.64	1510
hn			beaufort, quality, size	Yes	393.07	1951
hn			quality, size	Yes	417.71	1946
hn			beaufort, size	Yes	440.00	1977
hn			beaufort, quality	Yes	454.31	1929
hn			size	Yes	465.37	1968
hn			quality	Yes	465.95	1932
hn			beaufort	Yes	518.70	1941
hn				Yes	529.51	1944
hn	herm	4		No		
hr			quality, size	No		
hr			beaufort, quality, size	No		

Table 16: Candidate detection functions for SEFSC Oregon II. The first one listed was selected for the density model.

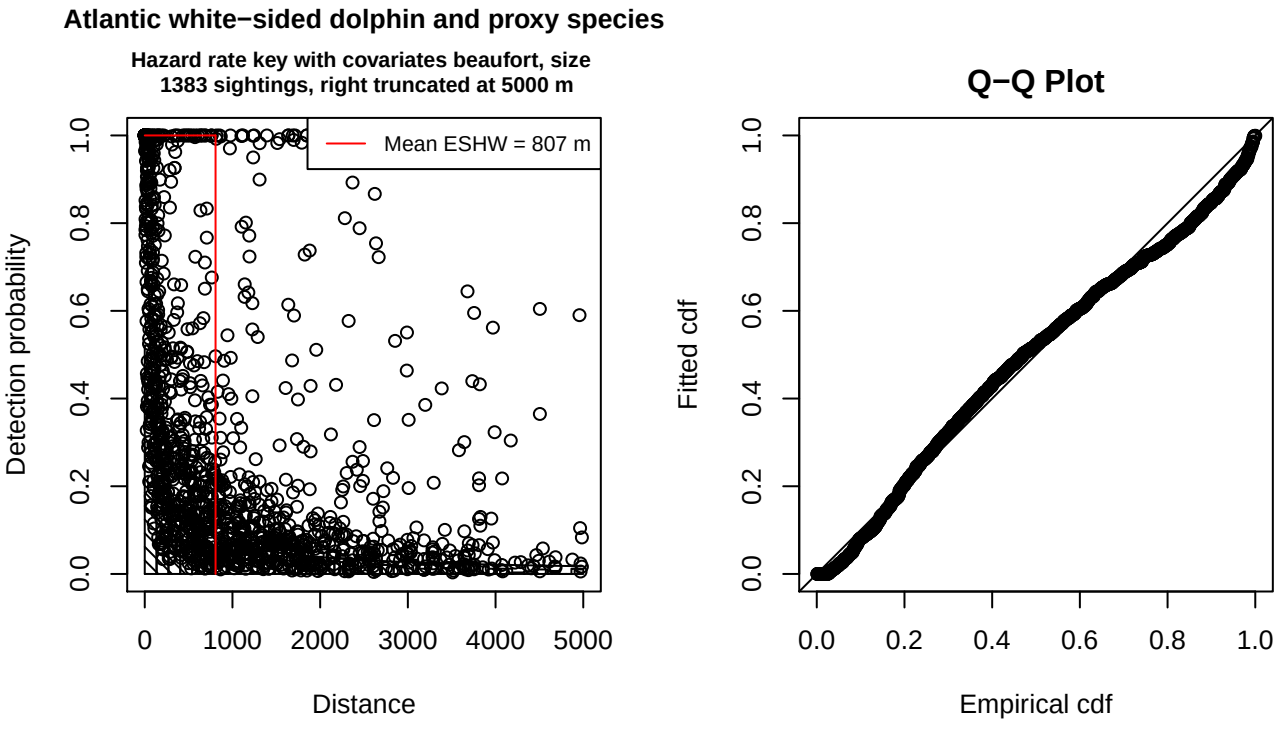


Figure 22: Detection function for SEFSC Oregon II that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1383
Distance range         :  0  -  5000
AIC                    :  21780.64

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate         se
(Intercept)  5.2365302 0.21037652
beaufort    -0.5641442 0.06785362
size         2.0803998 0.20713158

Shape parameters:
            estimate         se
(Intercept)        0 0.03476077

                         Estimate           SE        CV
Average p            6.366213e-02 6.540950e-03 0.1027447
N in covered region 2.172406e+04 2.309731e+03 0.1063213
```

Additional diagnostic plots:

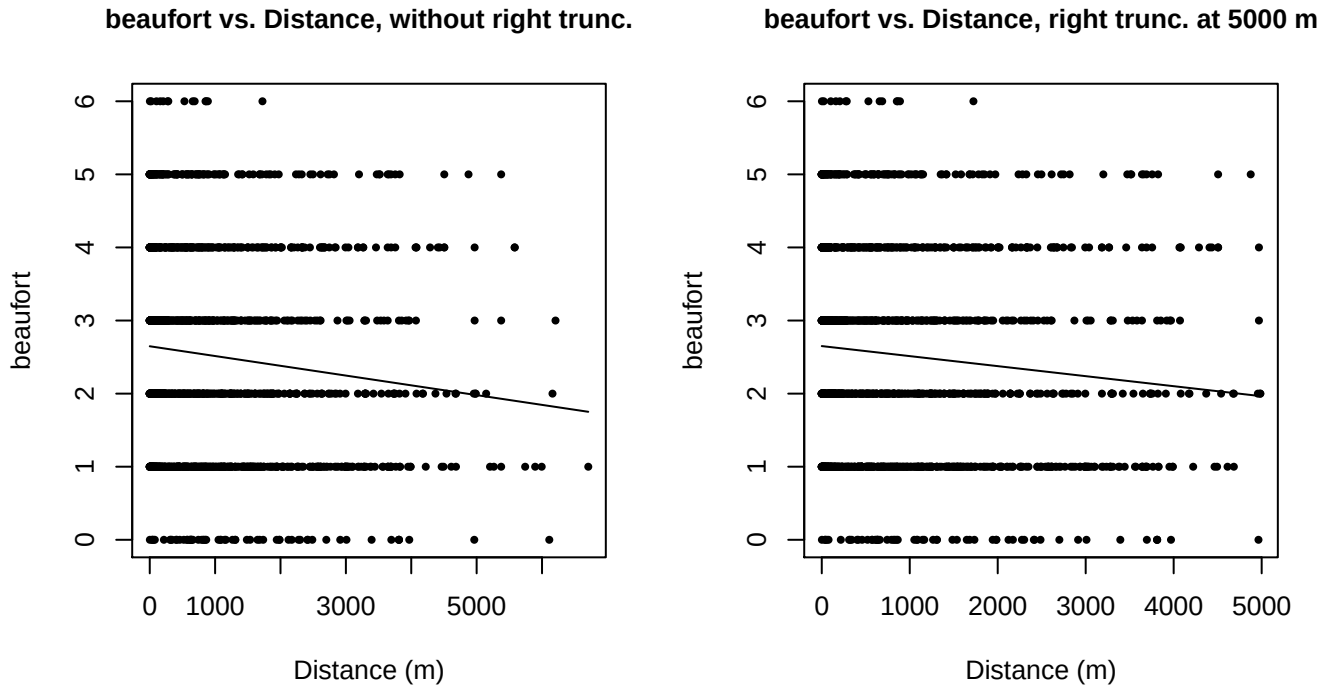


Figure 23: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

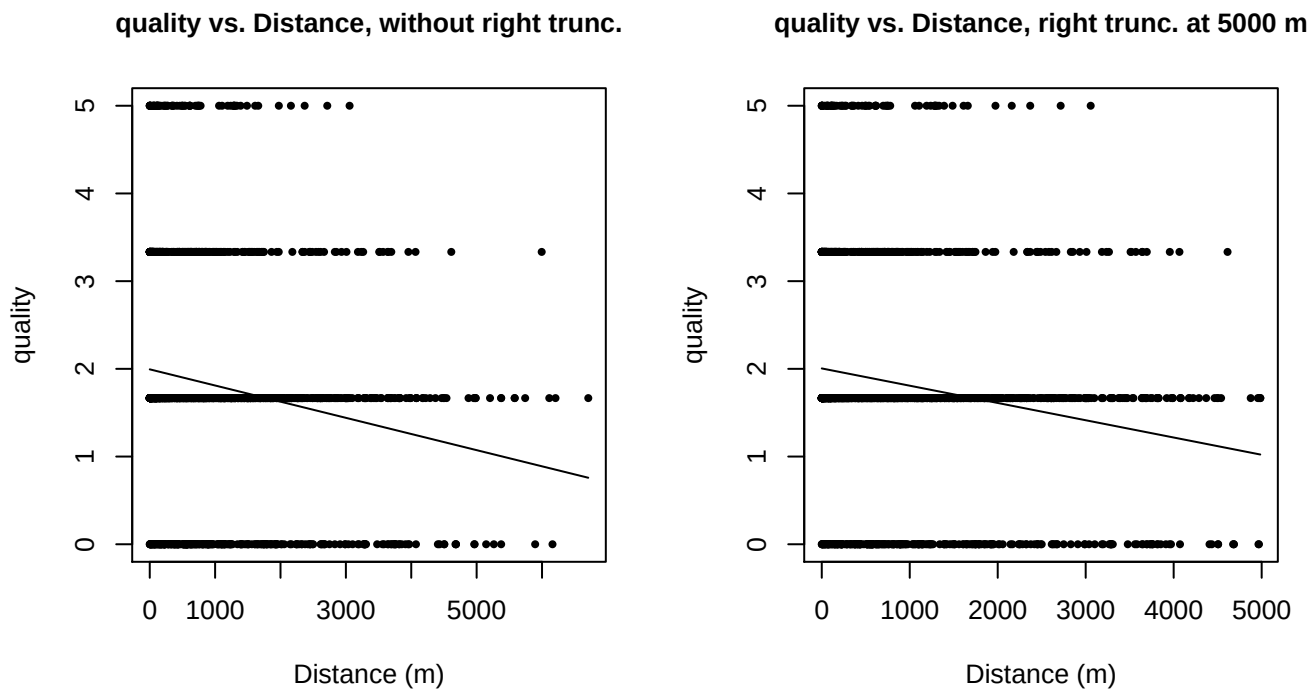


Figure 24: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

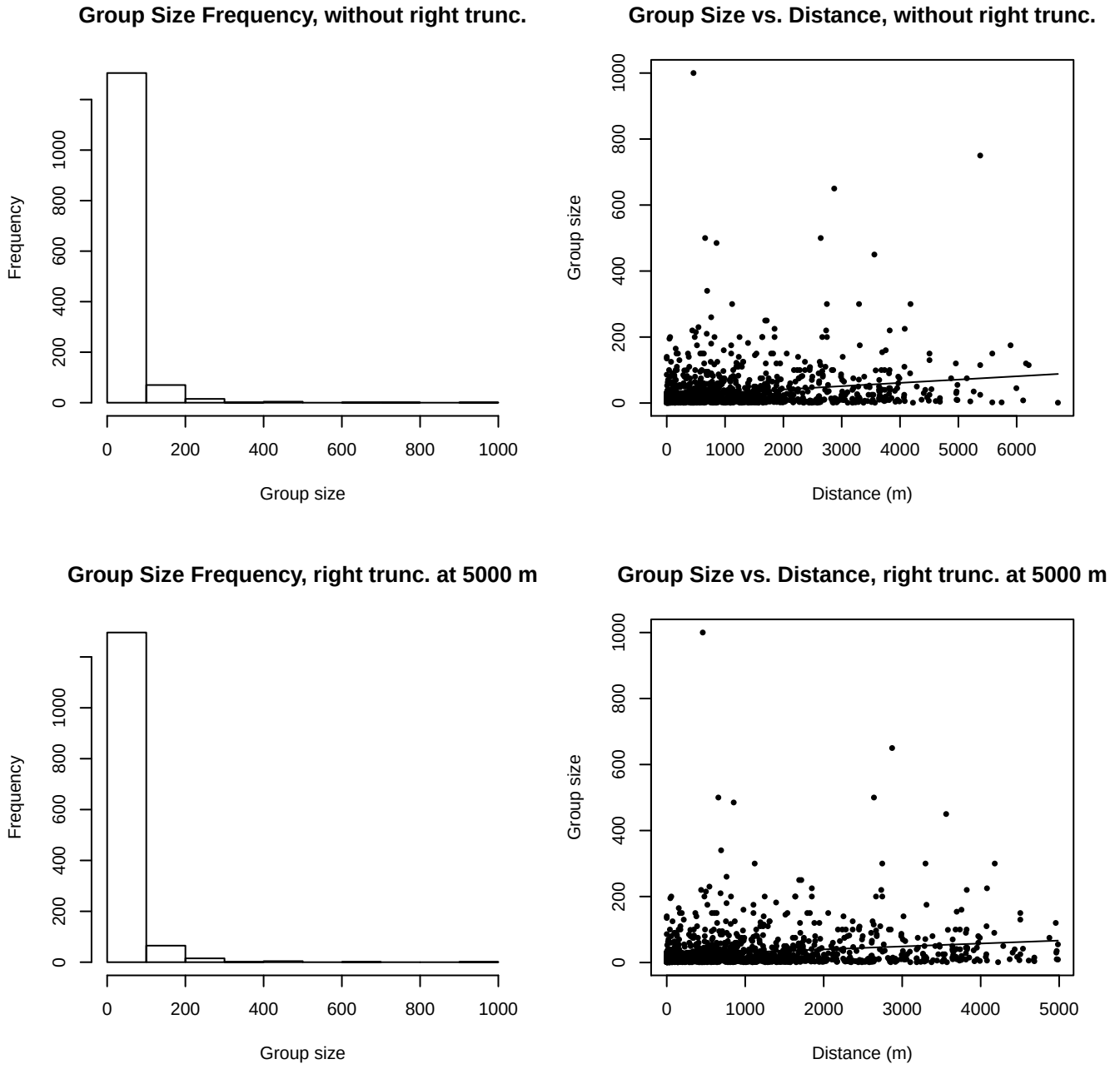


Figure 25: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NJ-DEP Hugh R. Sharp

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	19

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	0
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	0
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	160
Total		179

Table 17: Proxy species used to fit detection functions for NJ-DEP Hugh R. Sharp. The number of sightings, n, is before truncation.

The sightings were right truncated at 4000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 18: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	1377
hr			beaufort, quality, size	Yes	1.75	1369
hr			beaufort	Yes	3.38	1206
hr			beaufort, quality	Yes	4.50	1230

hr	poly	4		Yes	5.11	915
hn	cos	3		Yes	8.26	1264
hr			size	Yes	8.29	1080
hn			beaufort, size	Yes	8.82	1847
hr			quality, size	Yes	9.44	1024
hr	poly	2		Yes	10.14	978
hr				Yes	11.84	803
hr			quality	Yes	12.63	823
hn			beaufort	Yes	13.51	1797
hn	cos	2		Yes	19.72	1521
hn			quality, size	Yes	20.75	1842
hn			size	Yes	21.08	1838
hn			quality	Yes	24.69	1812
hn				Yes	24.83	1815
hn	herm	4		No		
hn			beaufort, quality	No		
hn			beaufort, quality, size	No		

Table 19: Candidate detection functions for NJ-DEP Hugh R. Sharp. The first one listed was selected for the density model.

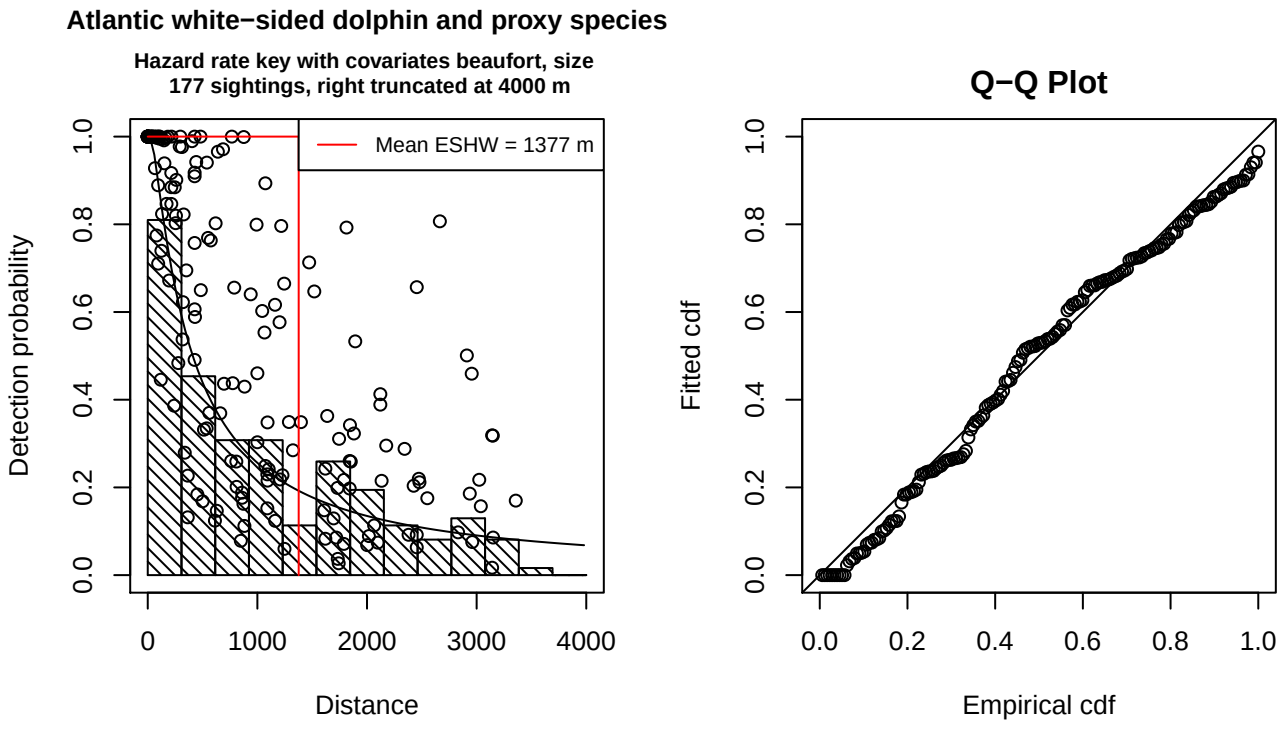


Figure 26: Detection function for NJ-DEP Hugh R. Sharp that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  177
Distance range         :  0  -  4000
AIC                    :  2801.518

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate        se
(Intercept)  6.9376906 0.4645111
beaufort    -0.5811025 0.1584283
size         0.9312215 0.3687349

Shape parameters:
             estimate       se
(Intercept) 0.2435139 0.154517

                        Estimate           SE        CV
Average p              0.2205363   0.04259245 0.1931313
N in covered region 802.5890737 165.26700704 0.2059173
```

Additional diagnostic plots:

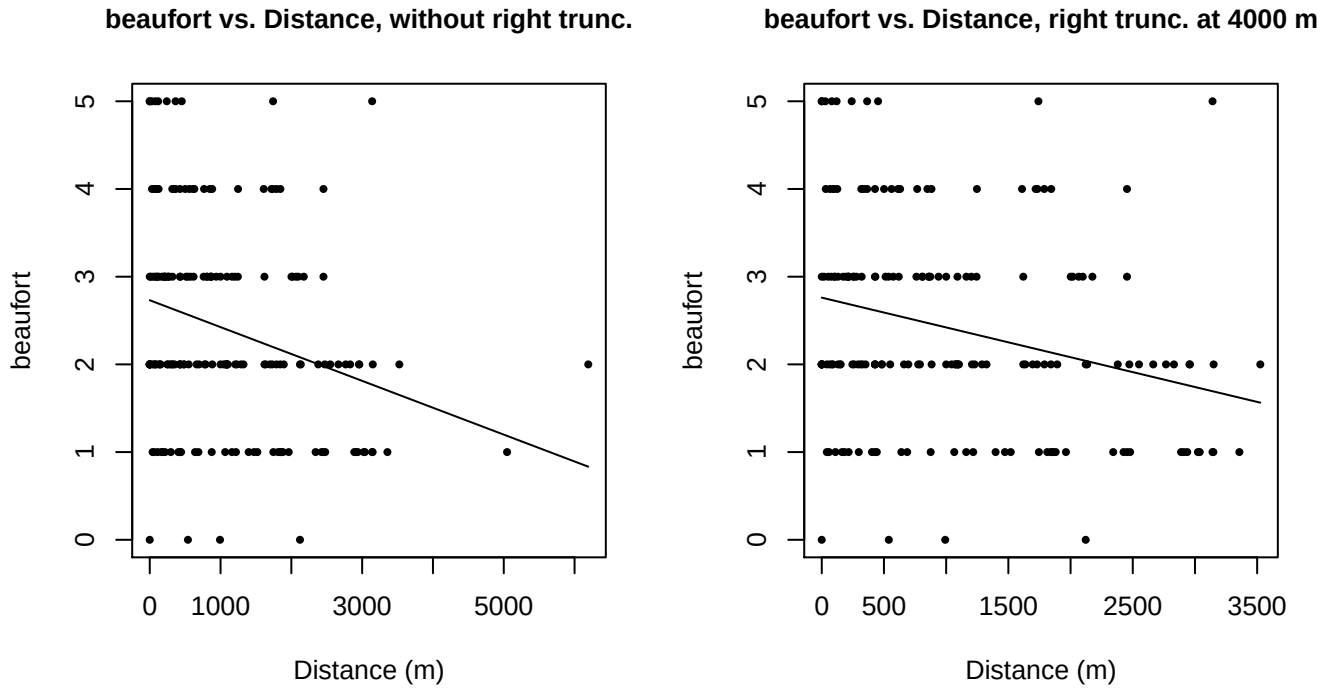


Figure 27: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

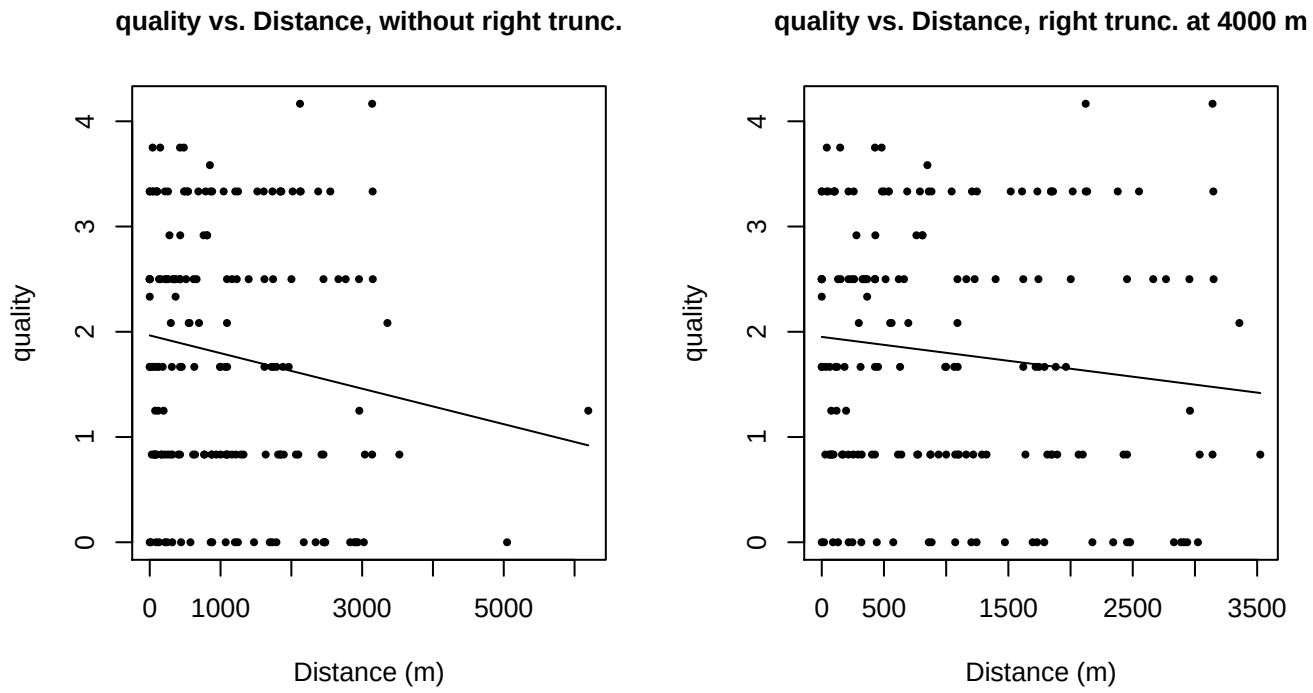


Figure 28: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

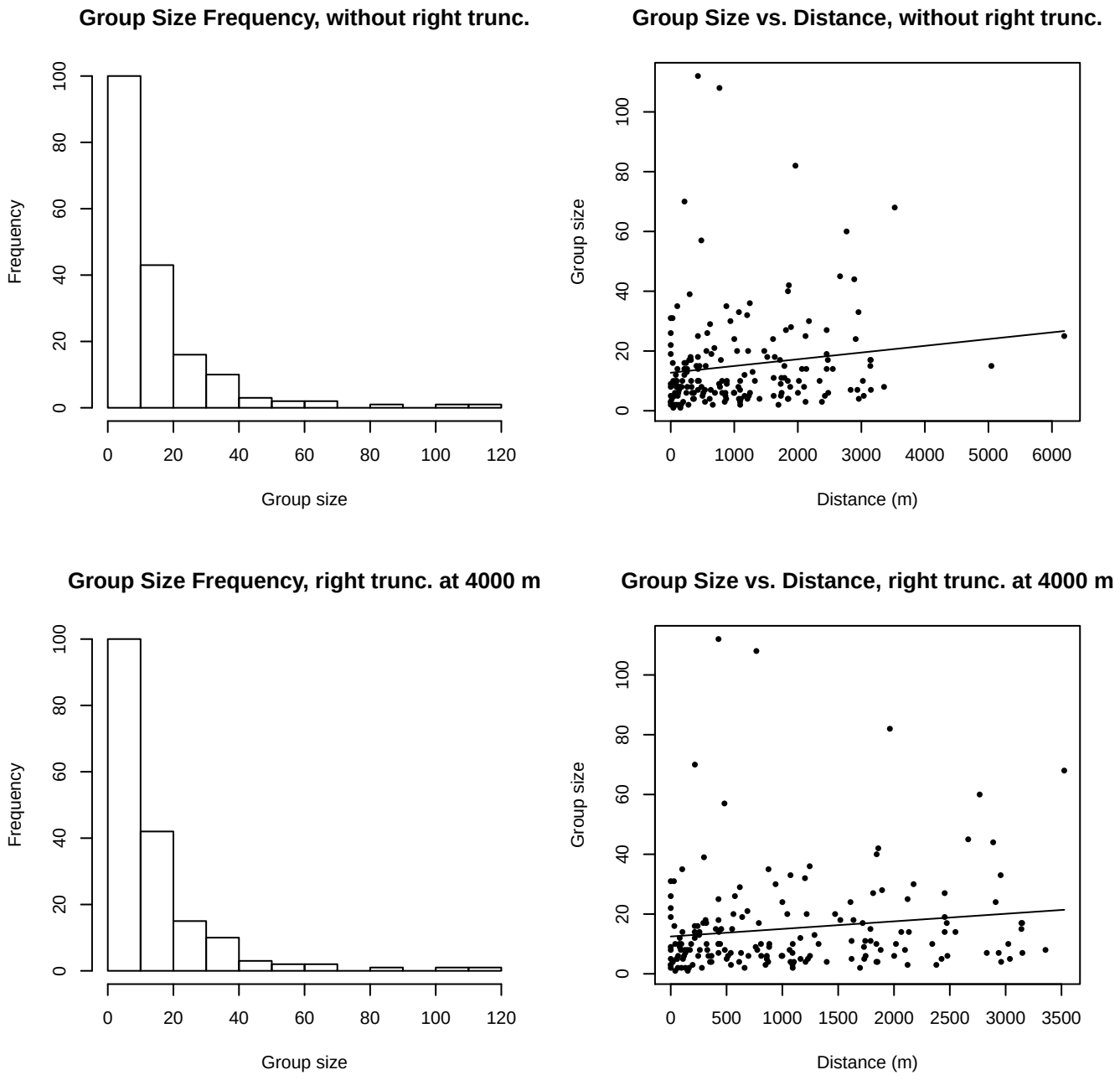


Figure 29: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SEFSC Gordon Gunter

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	9
Delphinus delphis	Short-beaked common dolphin	35

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	129
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	1
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	30
Stenella attenuata	Pantropical spotted dolphin	303
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	29
Stenella coeruleoalba	Striped dolphin	78
Stenella frontalis	Atlantic spotted dolphin	376
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	1
Stenella longirostris	Spinner dolphin	24
Steno bredanensis	Rough-toothed dolphin	24
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	606
Total		1645

Table 20: Proxy species used to fit detection functions for SEFSC Gordon Gunter. The number of sightings, n, is before truncation.

The sightings were right truncated at 6000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 21: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort	Yes	0.00	861
hr			beaufort, quality	Yes	1.16	862
hr			quality, size	Yes	17.00	914
hr			size	Yes	40.68	841

hr	poly	4		Yes	83.07	702
hr	poly	2		Yes	94.66	744
hr			quality	Yes	103.29	665
hr				Yes	123.56	629
hn			beaufort, quality, size	Yes	303.42	2354
hn			beaufort, size	Yes	304.27	2355
hn	cos	3		Yes	308.60	1667
hn	cos	2		Yes	316.44	1858
hn			beaufort, quality	Yes	379.30	2326
hn			beaufort	Yes	380.03	2326
hn			quality, size	Yes	403.38	2381
hn			size	Yes	421.43	2386
hn			quality	Yes	469.63	2346
hn				Yes	483.10	2348
hn	herm	4		No		
hr			beaufort, size	No		
hr			beaufort, quality, size	No		

Table 22: Candidate detection functions for SEFSC Gordon Gunter. The first one listed was selected for the density model.

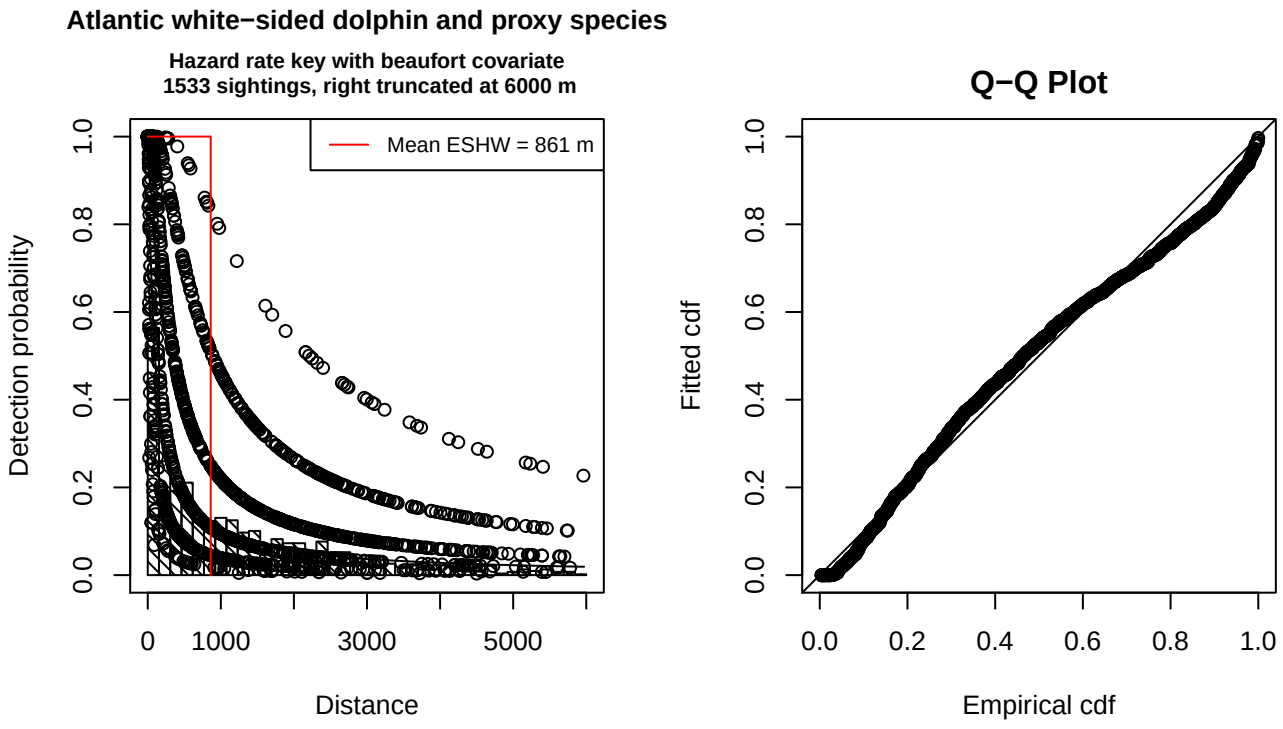


Figure 30: Detection function for SEFSC Gordon Gunter that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1533
Distance range         :  0  -  6000
AIC                    :  24824.97

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  7.3357681 0.20055457
beaufort    -0.9138459 0.07688769

Shape parameters:
            estimate         se
(Intercept)        0 0.03560043

                         Estimate           SE        CV
Average p            7.334755e-02 7.716610e-03 0.1052061
N in covered region 2.090049e+04 2.262528e+03 0.1082524
```

Additional diagnostic plots:

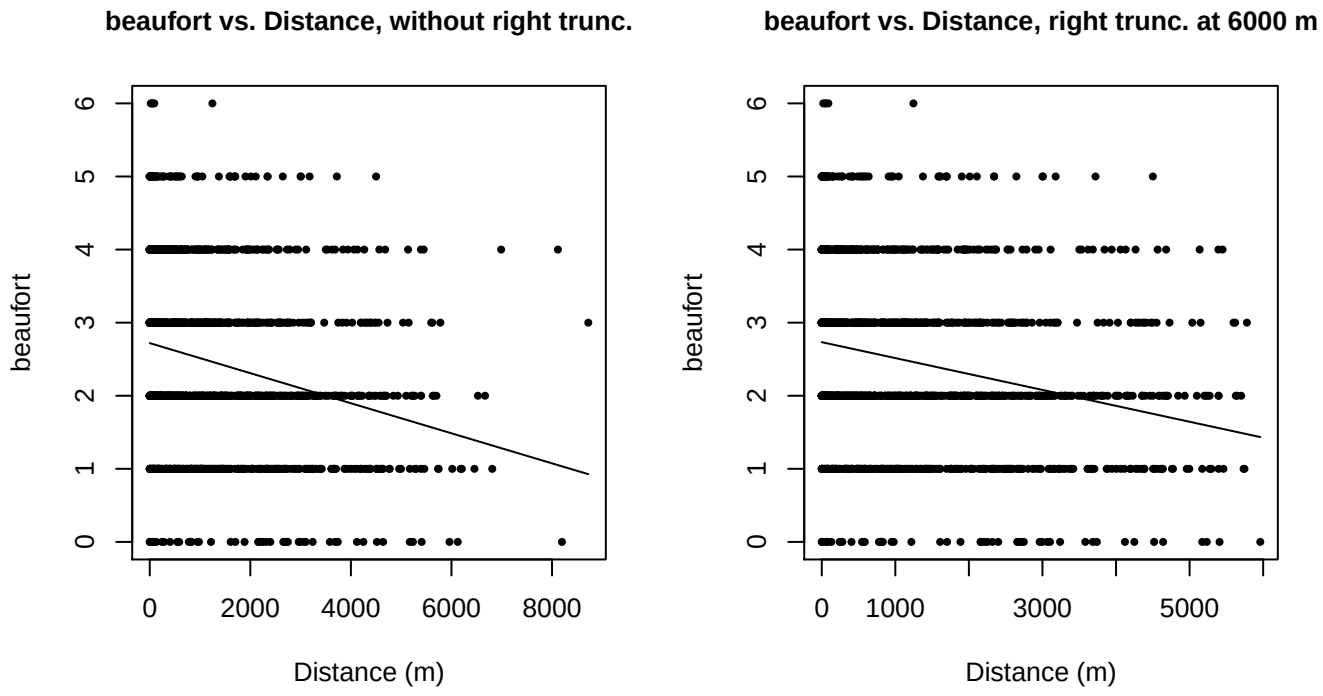


Figure 31: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

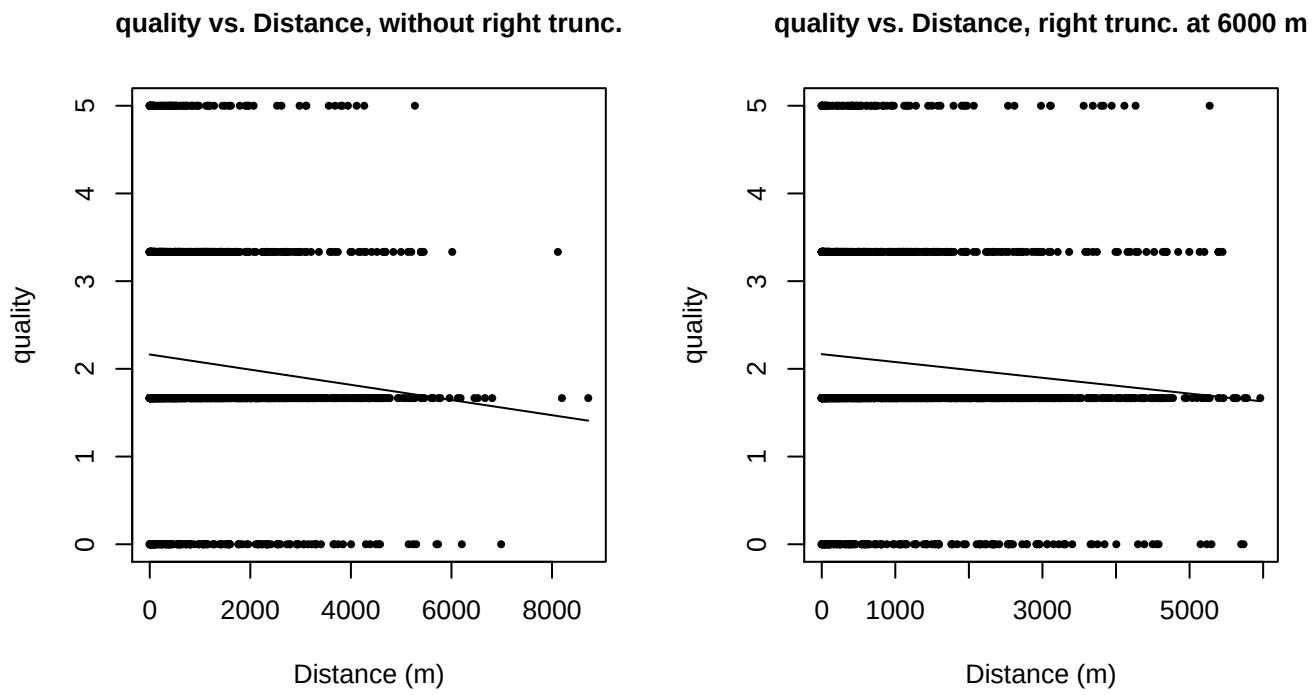


Figure 32: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

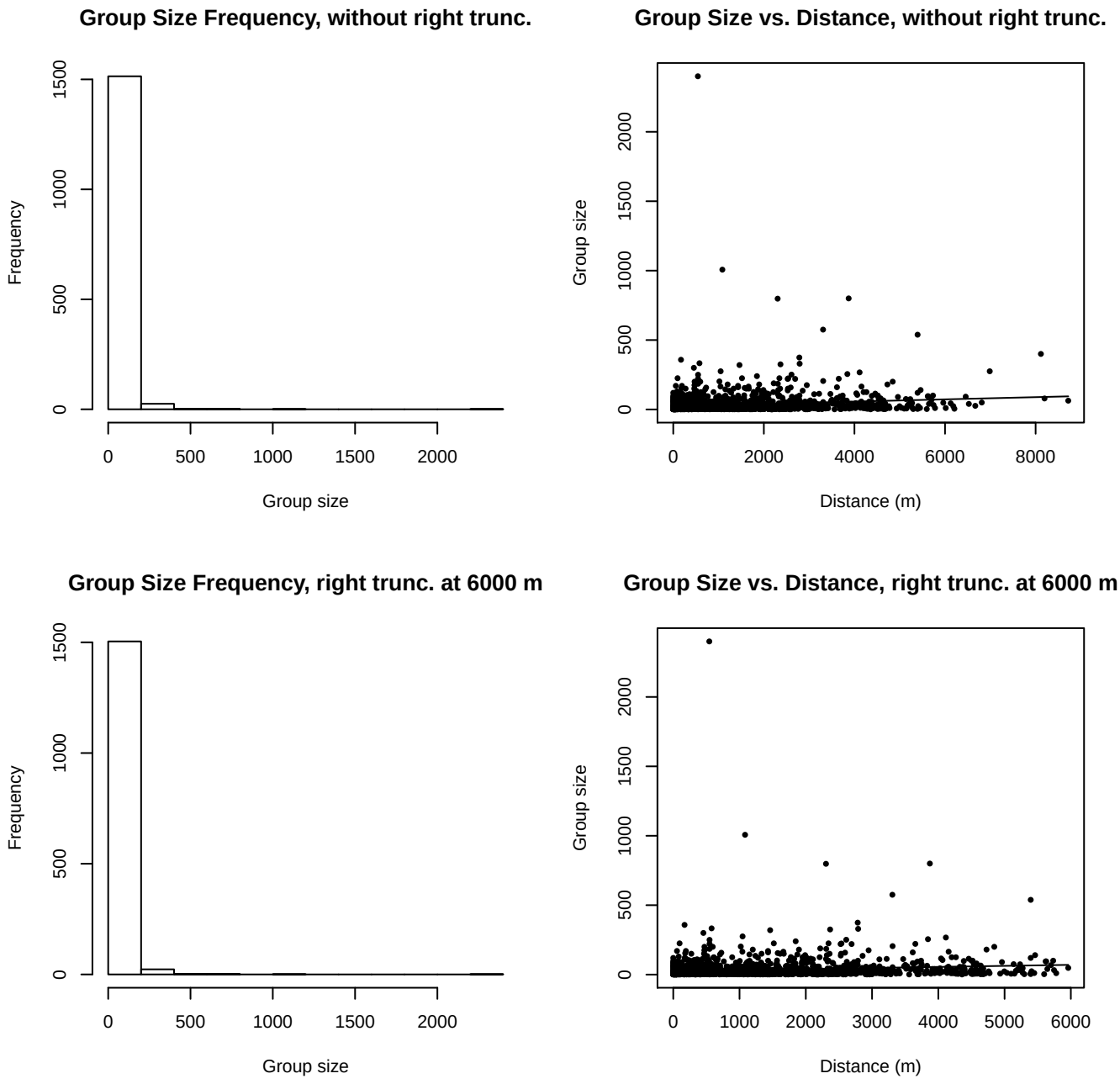


Figure 33: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Naked Eye Surveys

The sightings were right truncated at 1300m.

Covariate	Description
beaufort	Beaufort sea state.
size	Estimated size (number of individuals) of the sighted group.

Table 23: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn			size	Yes	0.00	537
hn			beaufort, size	Yes	2.00	537
hr				Yes	11.75	413
hn	cos	2		Yes	11.78	429
hr	poly	2		Yes	12.68	383
hr	poly	4		Yes	12.93	393
hn	cos	3		Yes	13.36	409
hn				Yes	15.43	517
hn	herm	4		No		
hn			beaufort	No		
hr			beaufort	No		
hr			size	No		
hr			beaufort, size	No		

Table 24: Candidate detection functions for Naked Eye Surveys. The first one listed was selected for the density model.

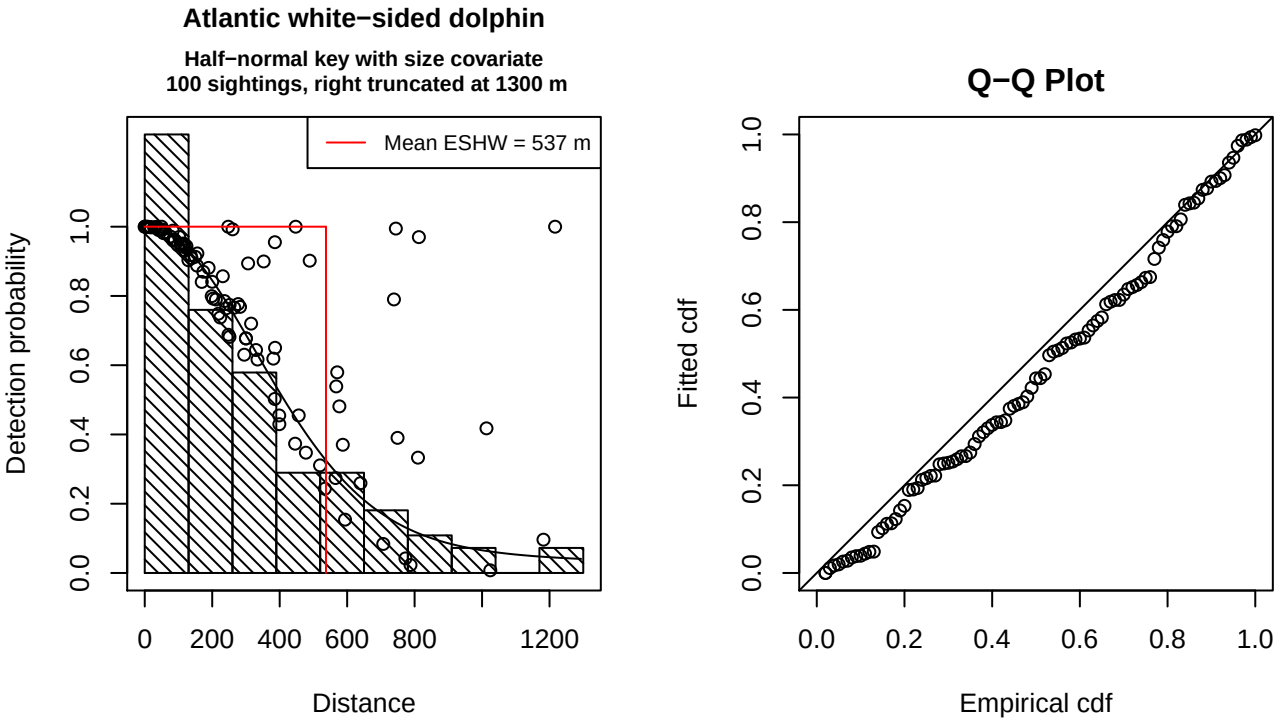


Figure 34: Detection function for Naked Eye Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
```

```
Number of observations :  100
Distance range         :  0  -  1300
AIC                    :  1334.447

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.625225 0.09172021
size        1.375292 0.48407844

                       Estimate        SE        CV
Average p             0.3618269  0.023174 0.0640472
N in covered region 276.3752216 28.984156 0.1048725
```

Additional diagnostic plots:

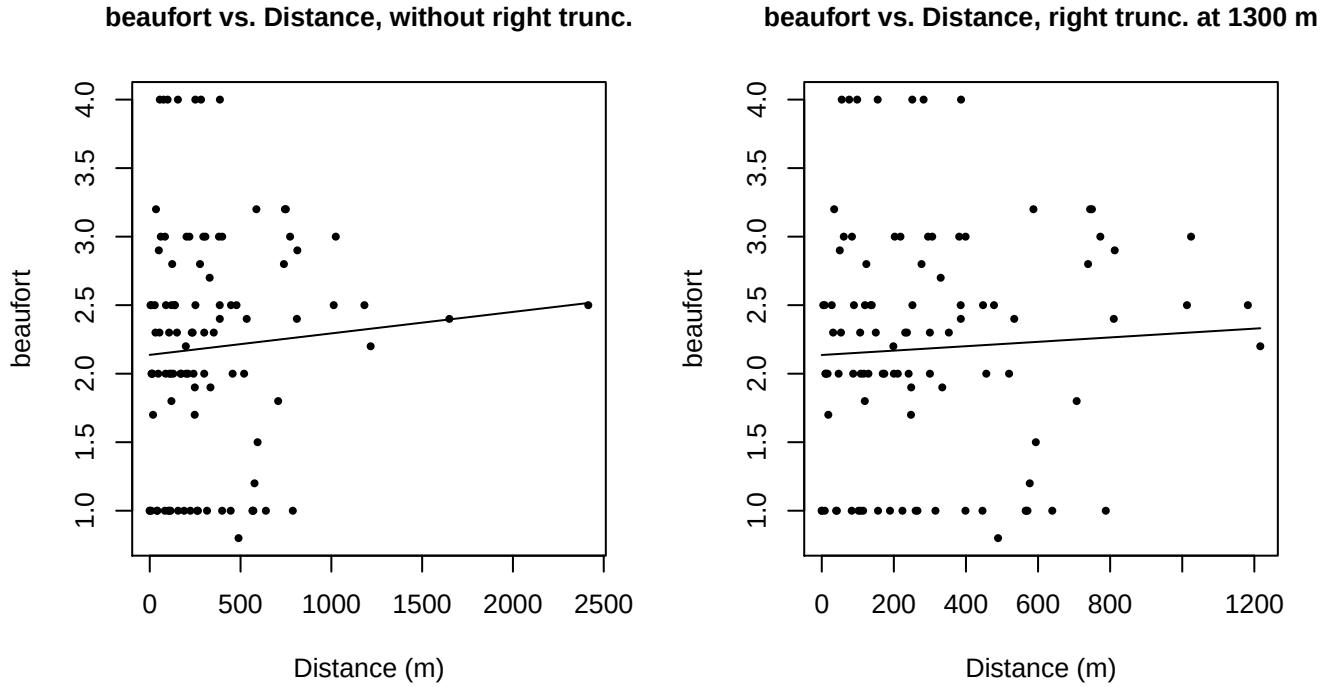


Figure 35: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

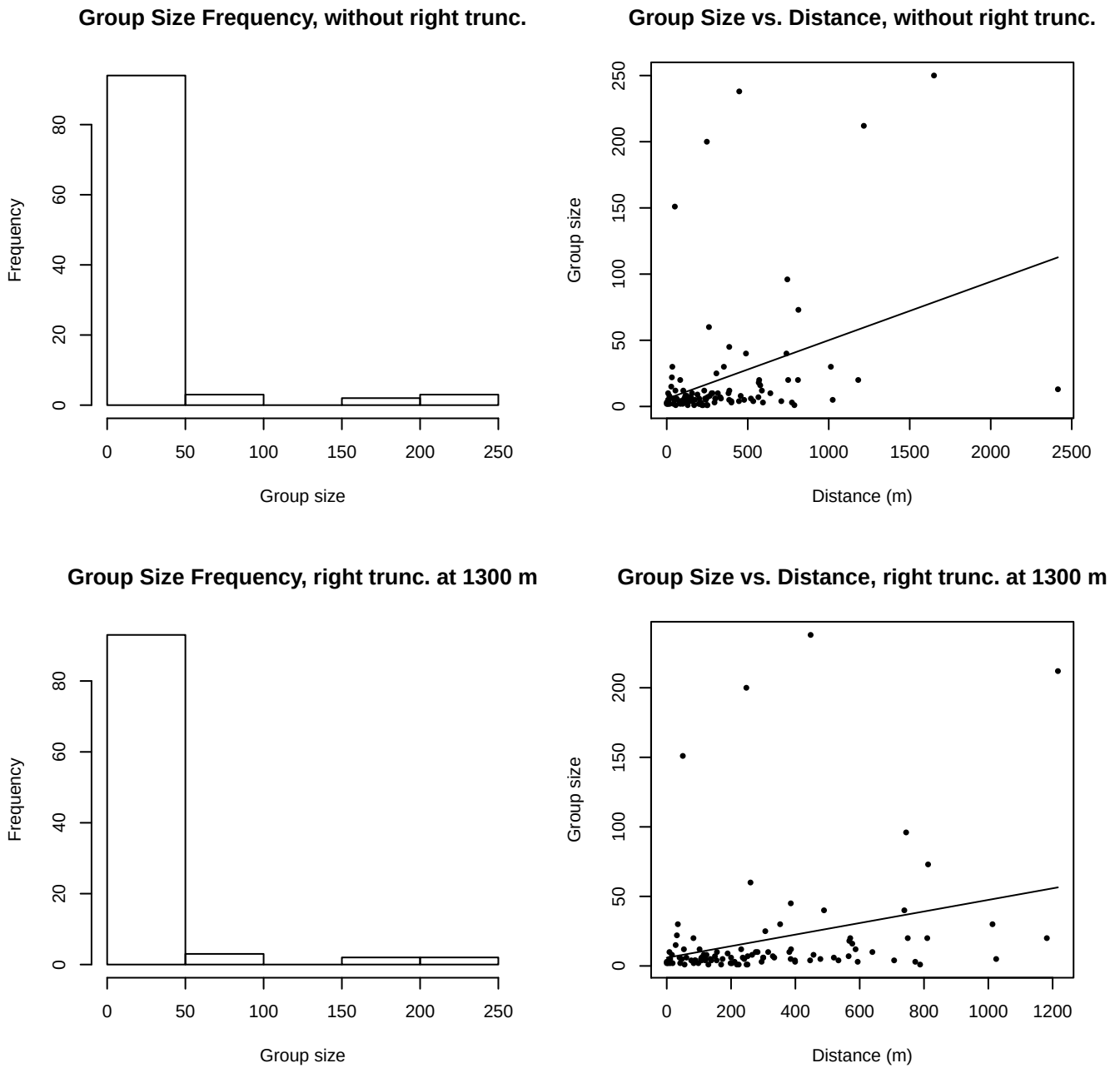


Figure 36: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Aerial Surveys

Figure 37: Detection hierarchy for aerial surveys

With Belly Observers

The sightings were right truncated at 1000m.

Covariate	Description
beaufort	Beaufort sea state.
size	Estimated size (number of individuals) of the sighted group.

Table 25: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			size	Yes	0.00	331
hr			beaufort, size	Yes	1.99	331
hr				Yes	3.38	328
hn	cos	2		Yes	4.04	283
hr	poly	4		Yes	4.95	325
hr	poly	2		Yes	5.24	324
hr			beaufort	Yes	5.36	329
hn			size	Yes	10.02	337
hn			beaufort, size	Yes	10.45	336
hn	cos	3		Yes	11.57	296
hn				Yes	12.11	335
hn			beaufort	Yes	12.34	335
hn	herm	4		No		

Table 26: Candidate detection functions for With Belly Observers. The first one listed was selected for the density model.

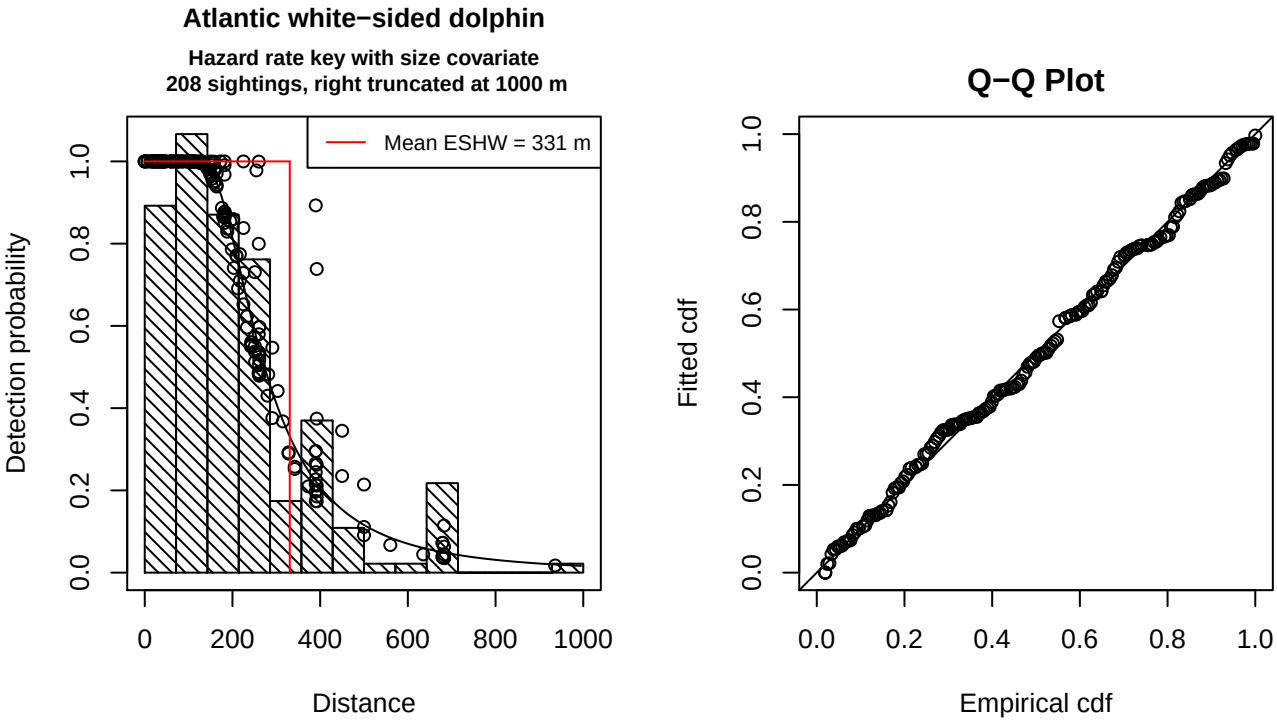


Figure 38: Detection function for With Belly Observers that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  208
Distance range         :  0  -  1000
AIC                    :  2616.35

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept) 5.4099314 0.10517864
size        0.1660475 0.08327068

Shape parameters:
            estimate        se
(Intercept) 1.097366 0.1241438

                       Estimate          SE         CV
Average p             0.3233173  0.02142675 0.06627159
N in covered region 643.3308714 56.38117201 0.08763946
```

Additional diagnostic plots:

Figure 39: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

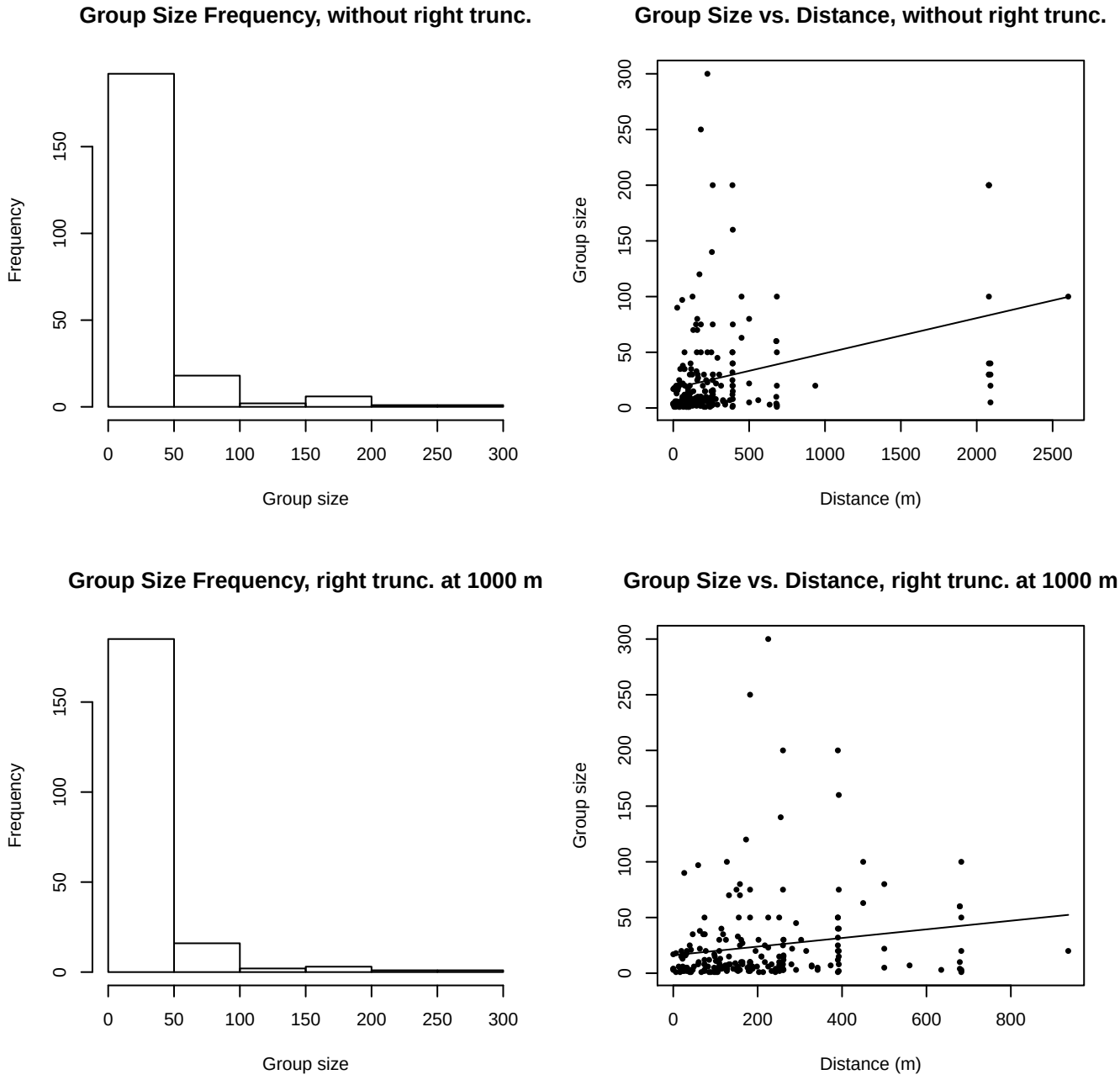


Figure 40: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NEFSC Quality Covariate Available

The sightings were right truncated at 1000m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 27: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			quality, size	Yes	0.00	287
hr			quality	Yes	0.25	291
hr				Yes	1.31	291
hr			size	Yes	1.98	285
hr	poly	2		Yes	3.31	291
hr	poly	4		Yes	3.31	291
hn			quality	Yes	3.40	279
hn			quality, size	Yes	3.96	279
hn	cos	2		Yes	5.22	250
hn				Yes	8.77	282
hn	cos	3		Yes	10.05	260
hn			size	Yes	10.29	282
hn	herm	4		No		
hn			beaufort	No		
hr			beaufort	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 28: Candidate detection functions for NEFSC Quality Covariate Available. The first one listed was selected for the density model.

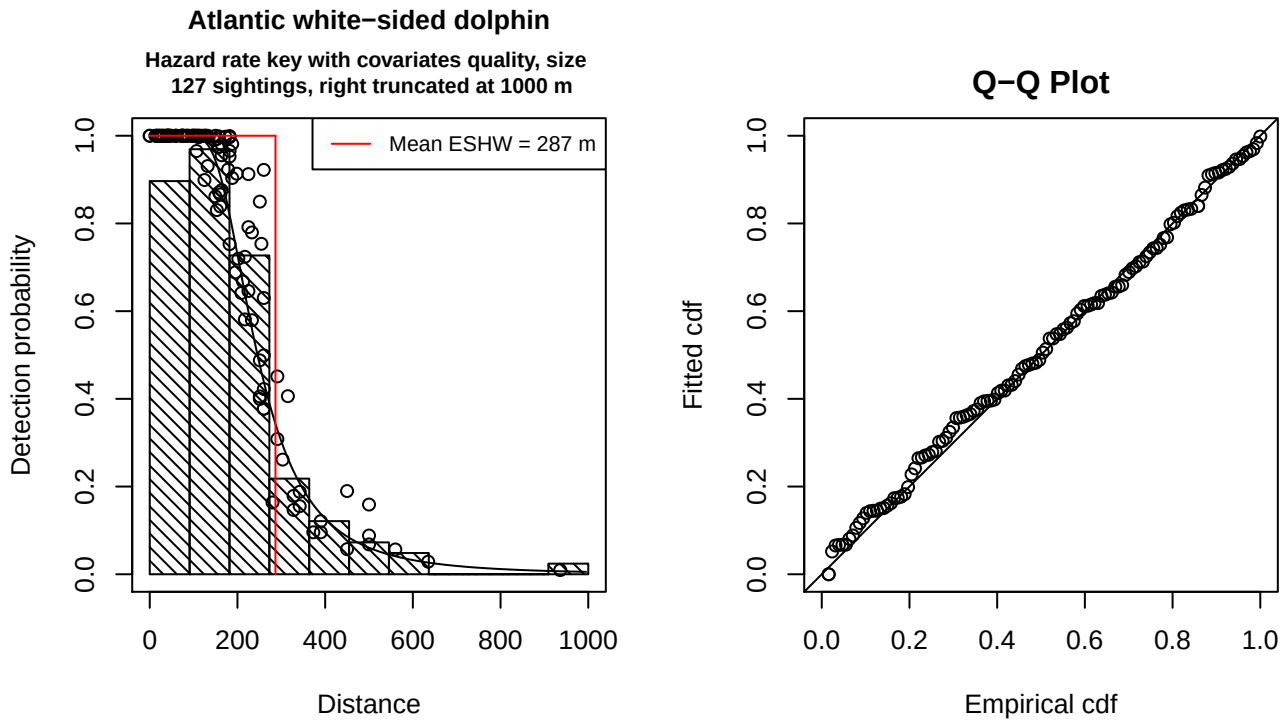


Figure 41: Detection function for NEFSC Quality Covariate Available that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  127
Distance range         :  0  -  1000
AIC                    :  1553.157

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
               estimate         se
(Intercept)  5.76360339 0.24642165
quality     -0.15111622 0.08262924
size         0.07843576 0.10223268

Shape parameters:
            estimate        se
(Intercept) 1.263129 0.1623347

                       Estimate          SE         CV
Average p             0.2797668  0.02195403 0.07847261
N in covered region 453.9495606 49.48579175 0.10901165
```

Additional diagnostic plots:

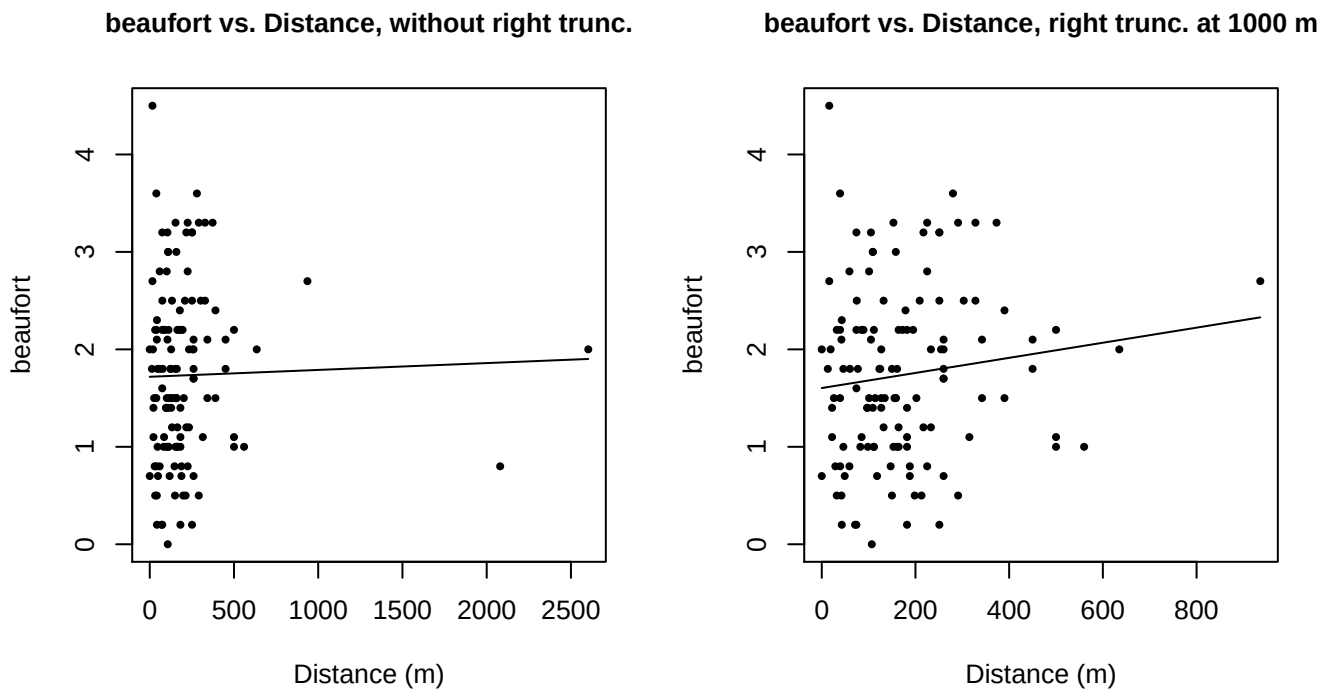


Figure 42: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

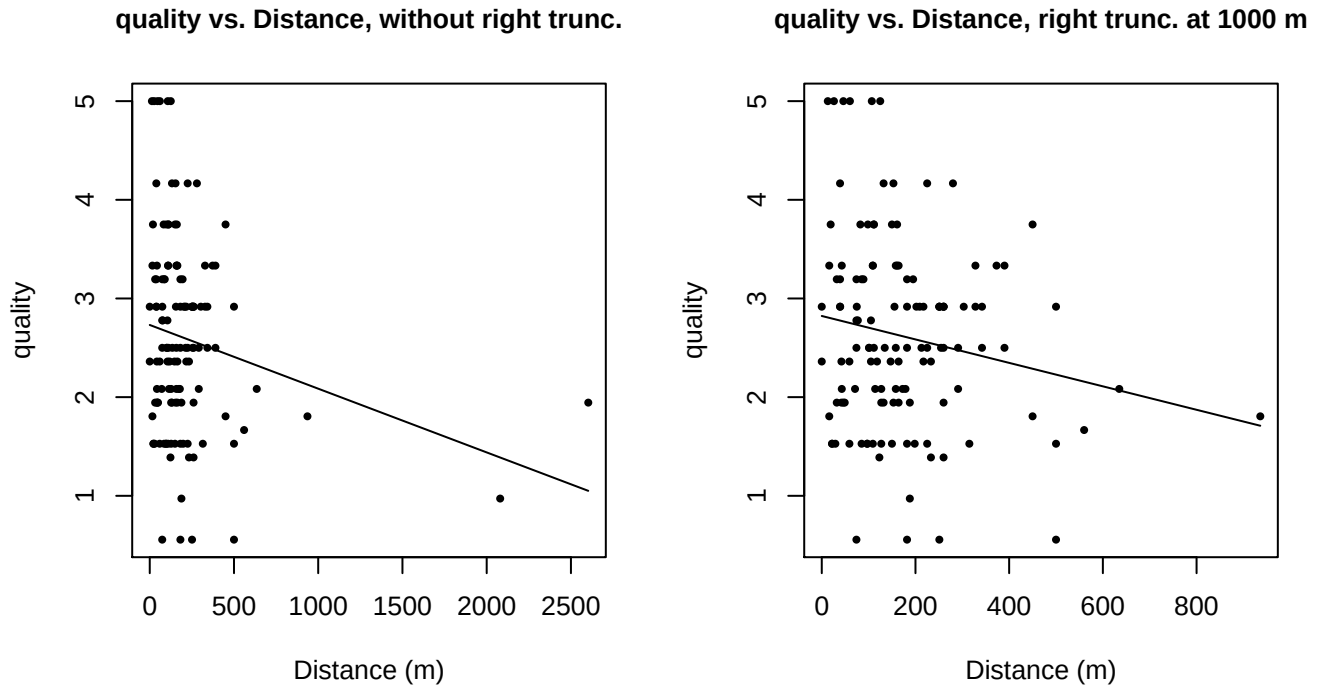


Figure 43: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

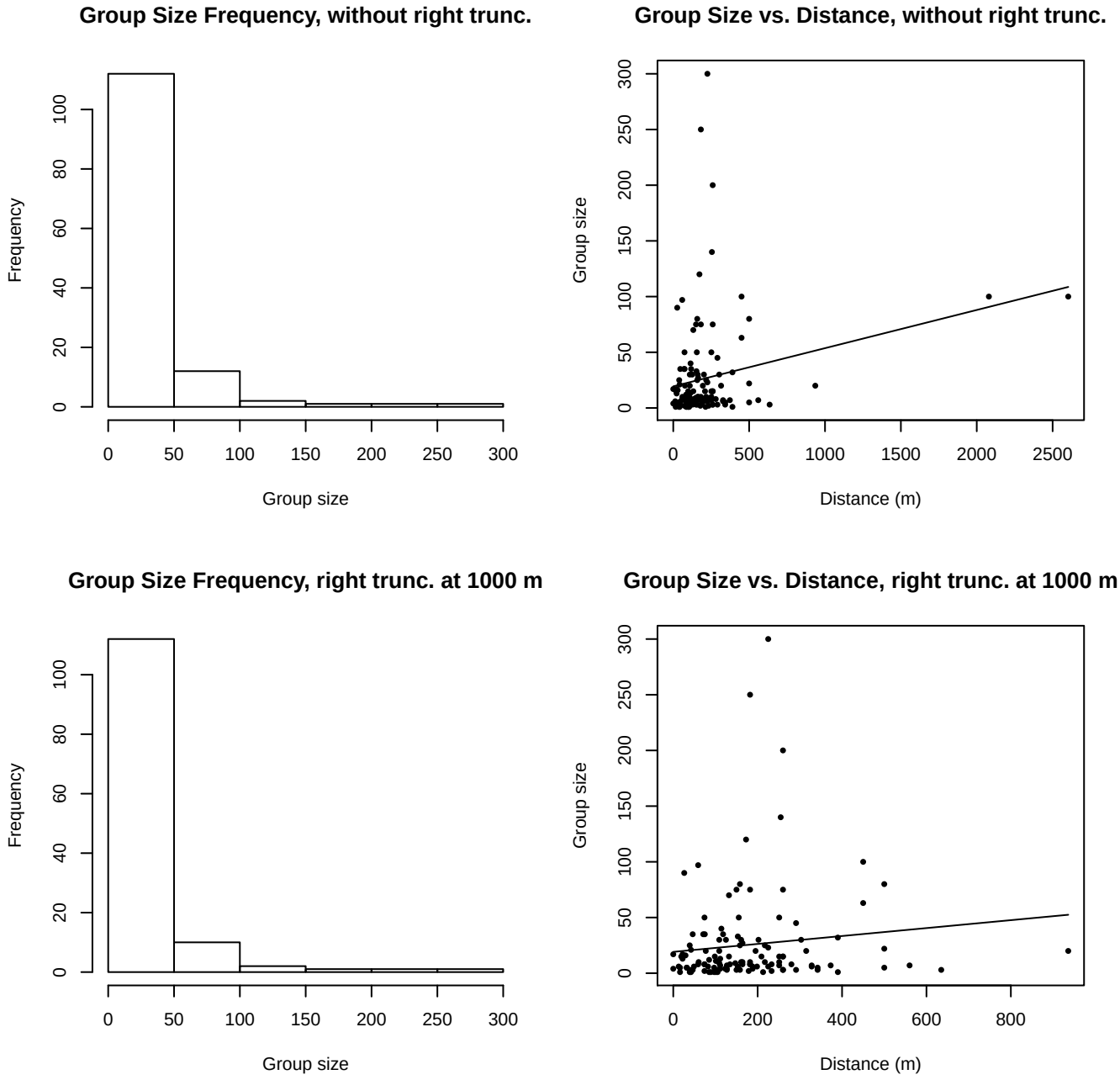


Figure 44: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Without Belly Observers - 600 ft

The sightings were right truncated at 400m.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn				Yes	0.00	179
hn	cos	3		Yes	1.31	150
hn	herm	4		Yes	1.77	190

hn	cos	2	Yes	1.95	187
hr	poly	4	Yes	4.31	149
hr			No		
hr	poly	2	No		

Table 29: Candidate detection functions for Without Belly Observers - 600 ft. The first one listed was selected for the density model.

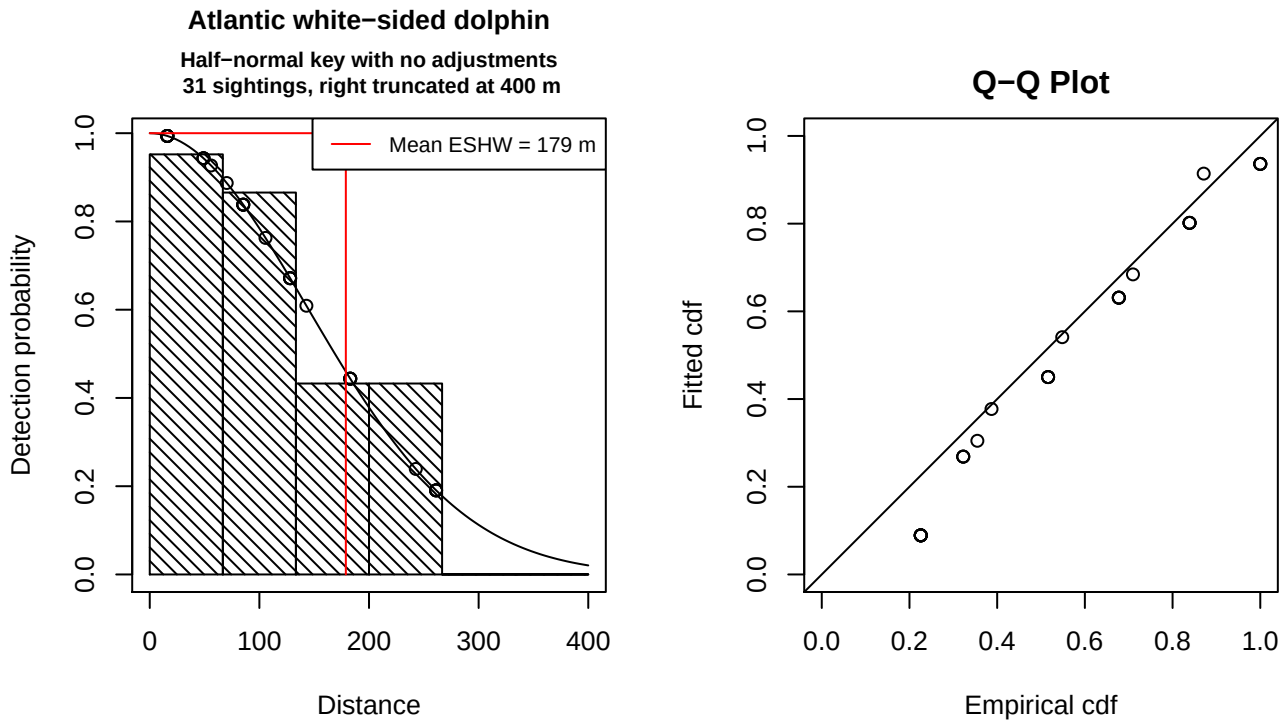


Figure 45: Detection function for Without Belly Observers - 600 ft that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  31
Distance range         :  0  -  400
AIC                    :  353.1477

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept) 4.966141 0.1603502

                      Estimate         SE        CV
Average p            0.4471552  0.0684115 0.1529927
N in covered region 69.3271555 14.0787871 0.2030775
```

Without Belly Observers - 750 ft

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	5
Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	75
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	2
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	14
Stenella attenuata	Pantropical spotted dolphin	94
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	12
Stenella coeruleoalba	Striped dolphin	17
Stenella frontalis	Atlantic spotted dolphin	82
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	11
Steno bredanensis	Rough-toothed dolphin	9
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	1597
Total		1918

Table 30: Proxy species used to fit detection functions for Without Belly Observers - 750 ft. The number of sightings, n, is before truncation.

The sightings were right truncated at 1296m. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 31: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			size	Yes	0.00	392
hr				Yes	8.40	388
hr	poly	4		Yes	10.40	388
hr	poly	2		Yes	10.40	388
hn	cos	2		Yes	39.37	354
hn	cos	3		Yes	59.74	342
hn			size	Yes	81.83	402
hn				Yes	95.31	401
hn	herm	4		Yes	96.83	401
hn			beaufort	No		
hr			beaufort	No		
hn			quality	No		
hr			quality	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 32: Candidate detection functions for Without Belly Observers - 750 ft. The first one listed was selected for the density model.

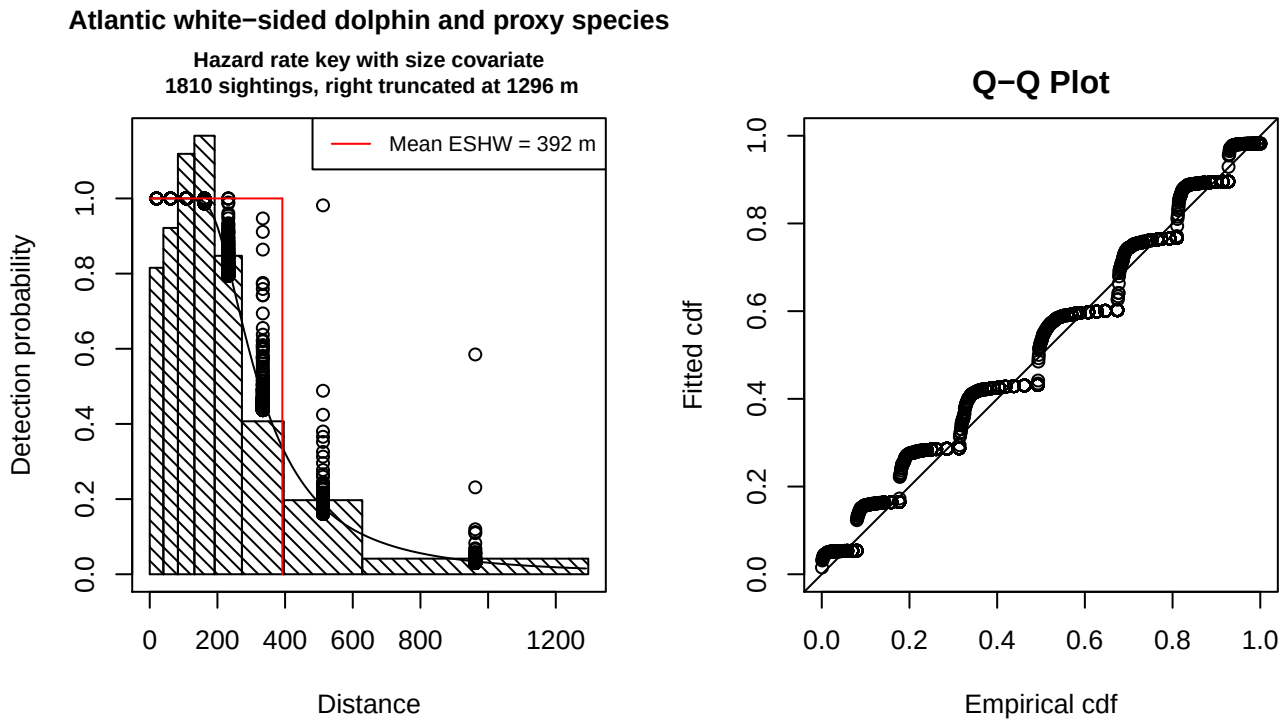


Figure 46: Detection function for Without Belly Observers - 750 ft that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1810
Distance range         :  0  -  1296
AIC                    :  7378.655

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept) 5.6089758 0.03891011
size        0.1034154 0.02841552

Shape parameters:
            estimate         se
(Intercept) 1.023682 0.04367625

                        Estimate           SE         CV
Average p              0.3000244 7.474818e-03 0.02491404
N in covered region 6032.8435368 1.916069e+02 0.03176063
```

Additional diagnostic plots:

Figure 47: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

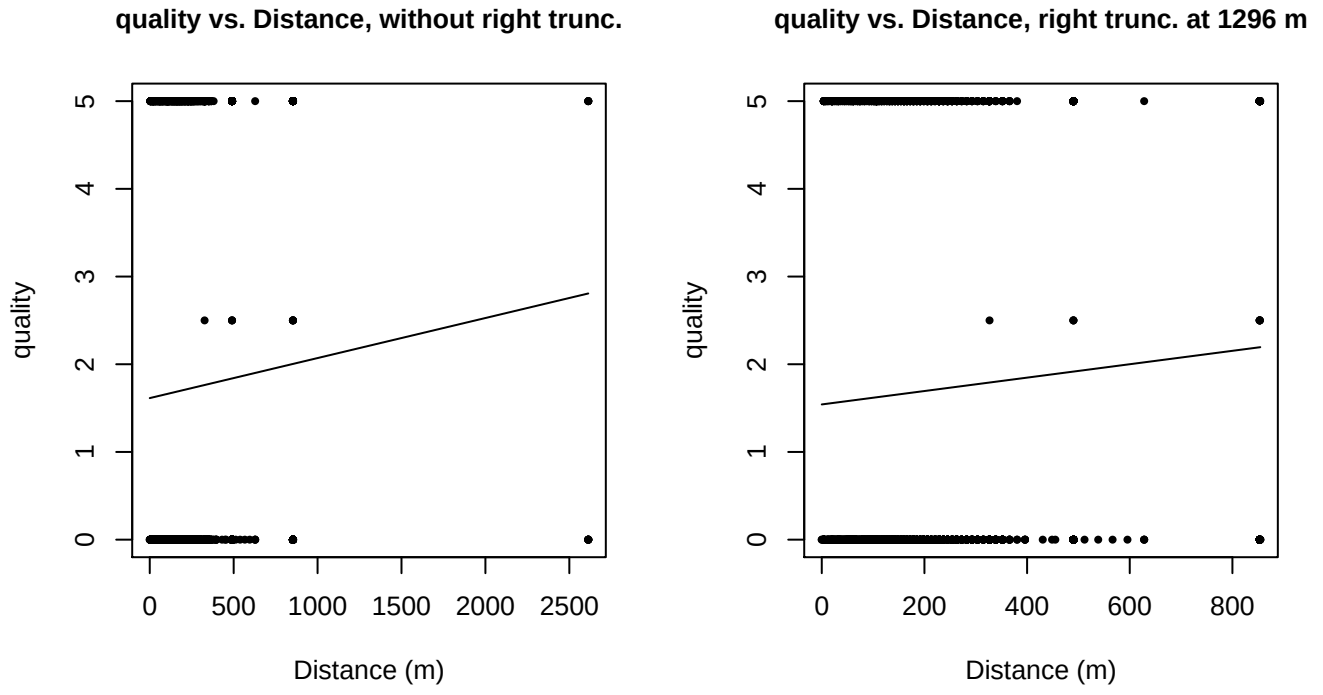


Figure 48: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

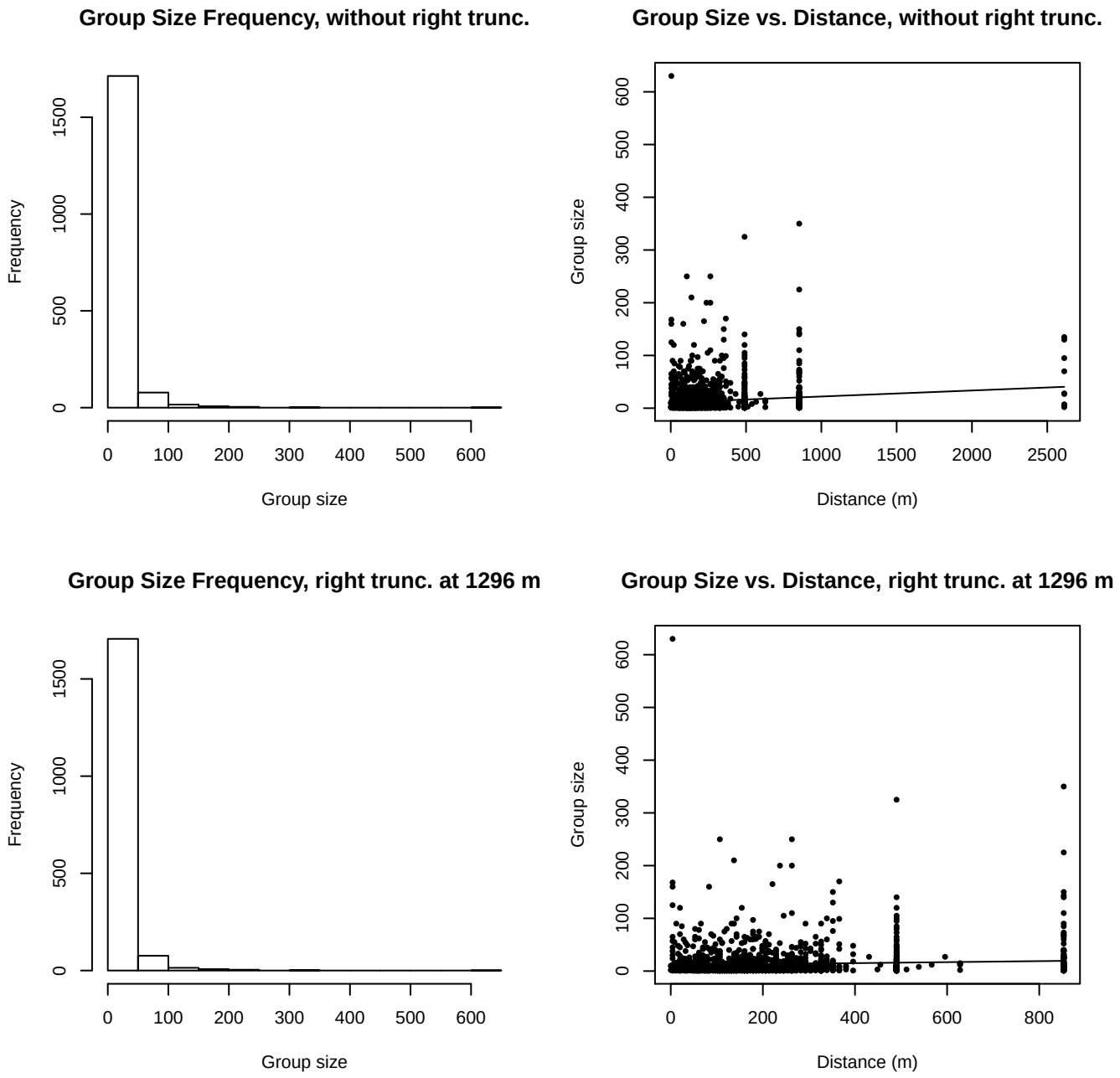


Figure 49: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SE_secas92

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	0

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	1
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	9
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	103
Total		113

Table 33: Proxy species used to fit detection functions for SE_secas92. The number of sightings, n, is before truncation.

The sightings were right truncated at 900m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 40 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
size	Estimated size (number of individuals) of the sighted group.

Table 34: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort	Yes	0.00	249
hr			beaufort, size	Yes	1.98	254

hr			size	Yes	15.77	257
hr				Yes	18.01	216
hn	cos	2		Yes	19.23	189
hr	poly	2		Yes	20.01	216
hr	poly	4		Yes	20.01	216
hn			size	Yes	26.97	316
hn			beaufort	Yes	35.20	260
hn				Yes	41.73	264
hn	cos	3		Yes	41.97	219
hn	herm	4		Yes	43.30	264
hn			beaufort, size	No		

Table 35: Candidate detection functions for SE_secas92. The first one listed was selected for the density model.

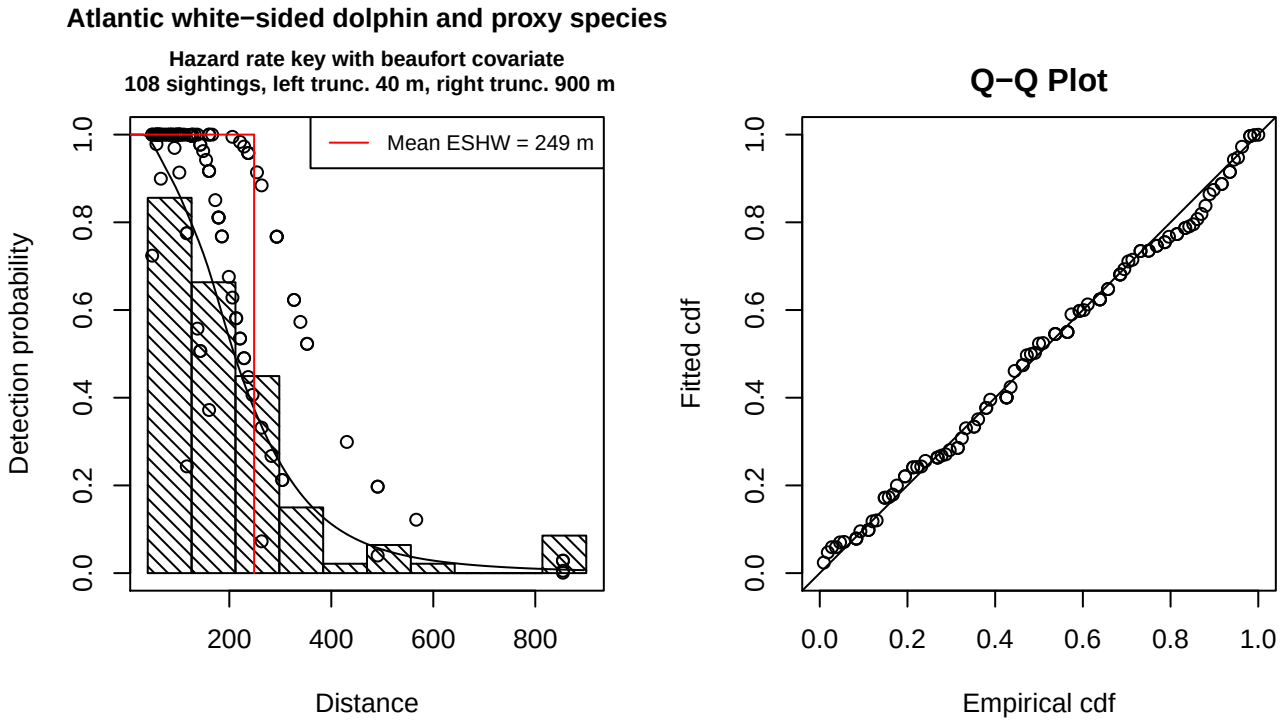


Figure 50: Detection function for SE_secas92 that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  108
Distance range         :  40  -  900
AIC                    :  1288.381

Detection function:
 Hazard-rate key function
```

```
Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  5.7829497 0.12346060
beaufort    -0.4573296 0.09973202

Shape parameters:
            estimate        se
(Intercept) 1.299333 0.1172672

                       Estimate          SE        CV
Average p              0.2208124  0.03796305 0.1719244
N in covered region 489.1028683 94.44375144 0.1930959
```

Additional diagnostic plots:

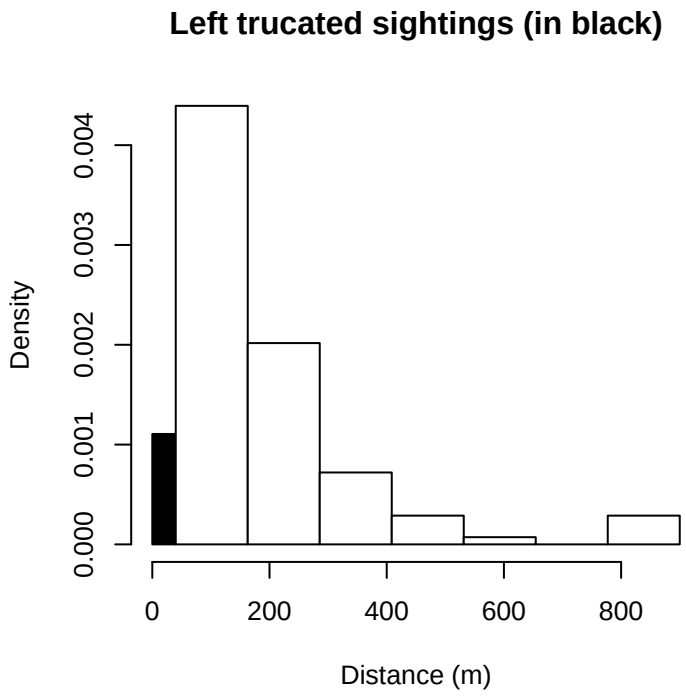


Figure 51: Density of sightings by perpendicular distance for SE_secas92. Black bars on the left show sightings that were left truncated.

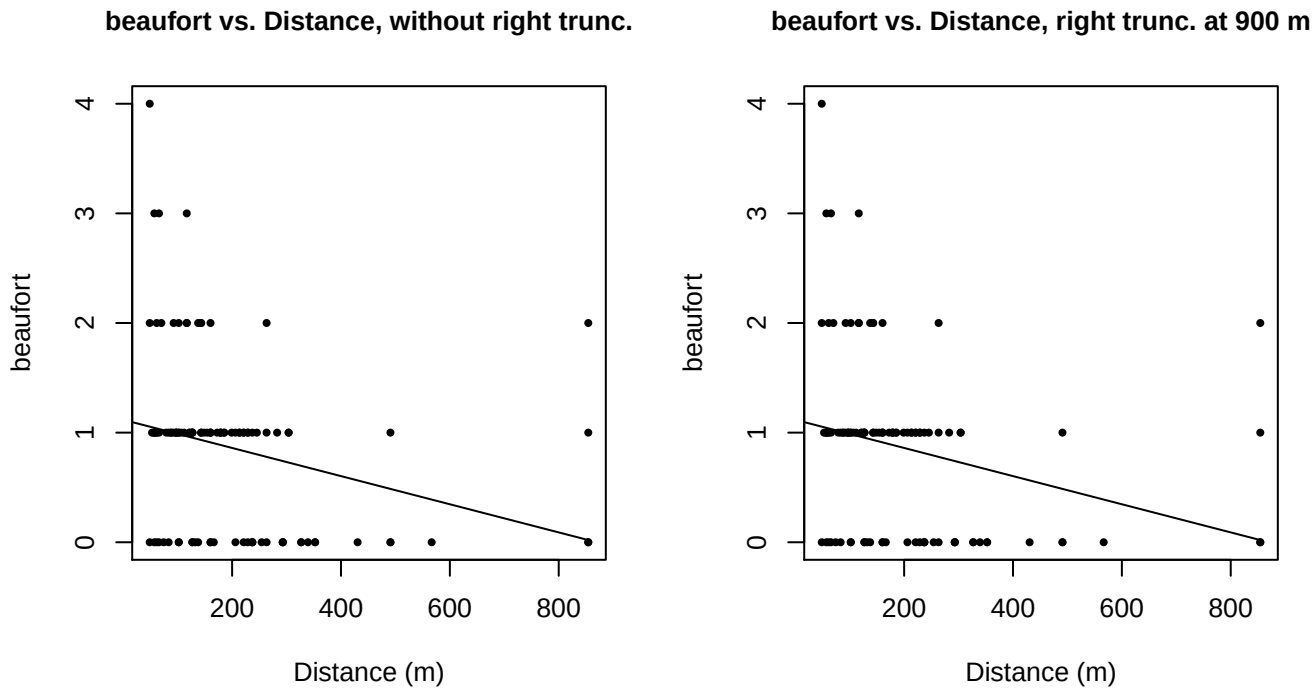


Figure 52: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

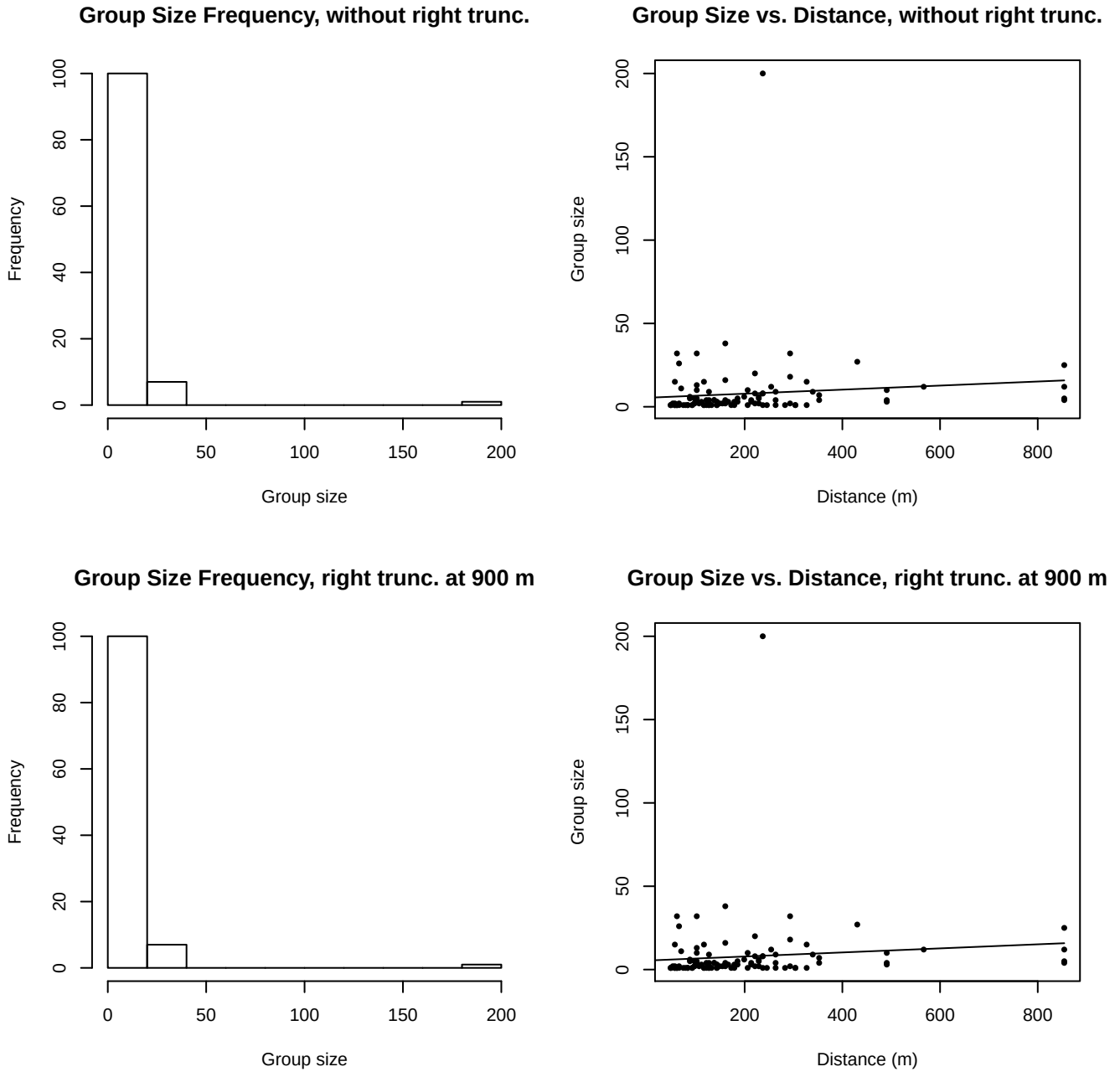


Figure 53: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SE_secas95

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	0

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	2
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	1
Stenella frontalis	Atlantic spotted dolphin	10
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	113
Total		126

Table 36: Proxy species used to fit detection functions for SE_secas95. The number of sightings, n, is before truncation.

The sightings were right truncated at 900m. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 37: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			quality	Yes	0.00	361
hr				Yes	1.17	370
hr	poly	2		Yes	3.17	370

hr	poly	4		Yes	3.17	370
hn			quality	Yes	3.44	351
hn				Yes	4.36	352
hn	cos	3		Yes	5.36	390
hn			beaufort, quality	Yes	5.41	351
hn	cos	2		Yes	5.97	333
hn	herm	4		Yes	6.17	351
hn			beaufort	Yes	6.35	352
hr			beaufort	No		
hn			size	No		
hr			size	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 38: Candidate detection functions for SE_secas95. The first one listed was selected for the density model.

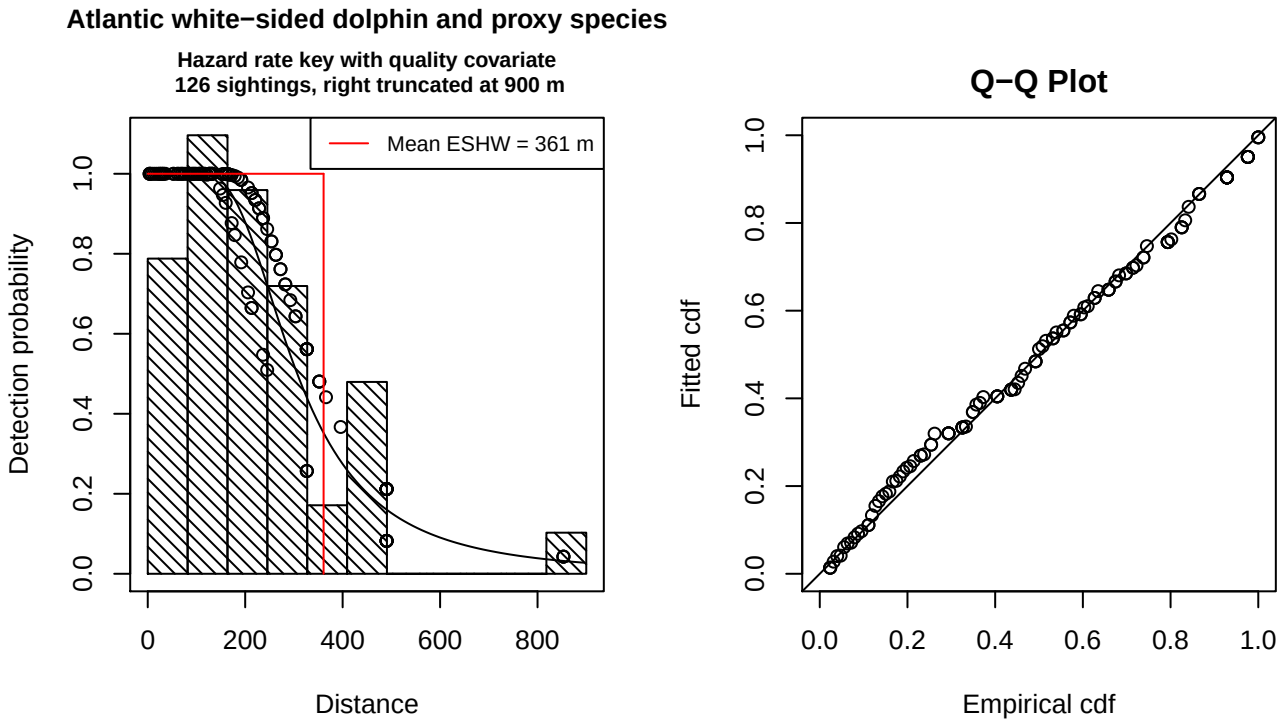


Figure 54: Detection function for SE_secas95 that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  126
Distance range         :  0  -  900
AIC                    :  1599.263

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
               estimate         se
(Intercept)  5.72521560 0.13241064
quality     -0.06684612 0.03458459

Shape parameters:
            estimate        se
(Intercept) 1.116802 0.1798011

                        Estimate          SE         CV
Average p              0.3924197  0.03385989 0.08628489
N in covered region 321.0848094 35.66094937 0.11106396
```

Additional diagnostic plots:

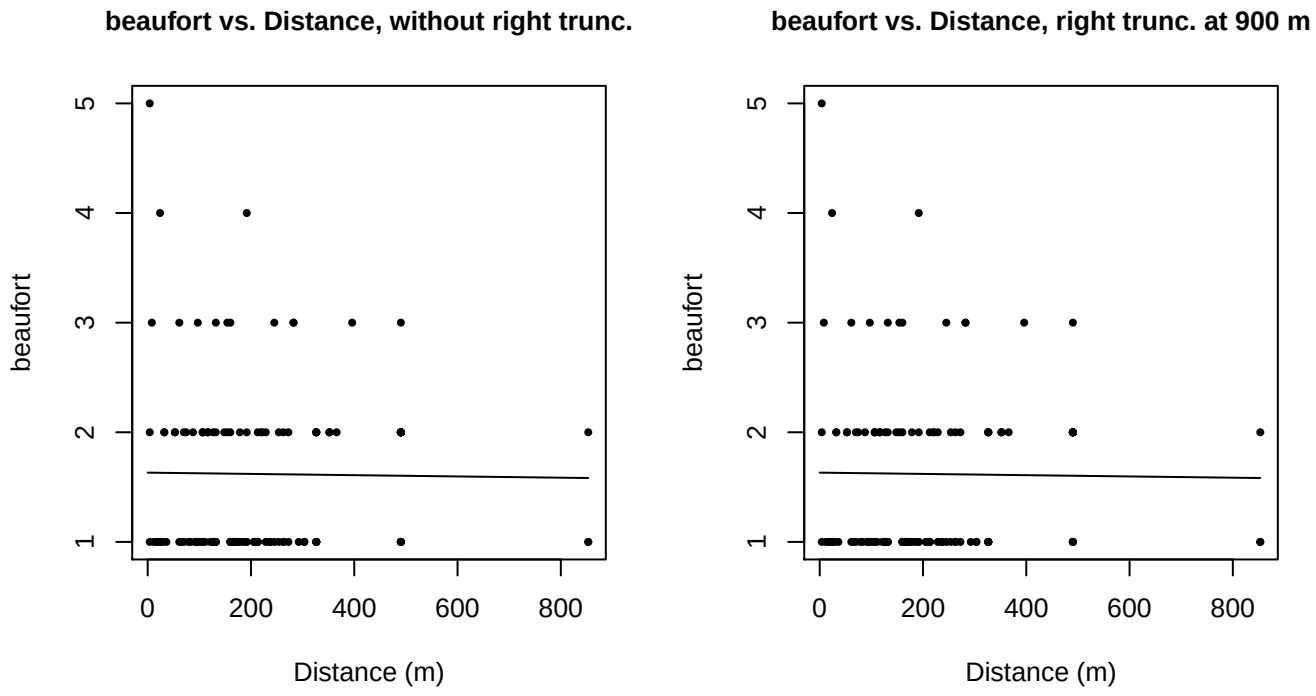


Figure 55: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

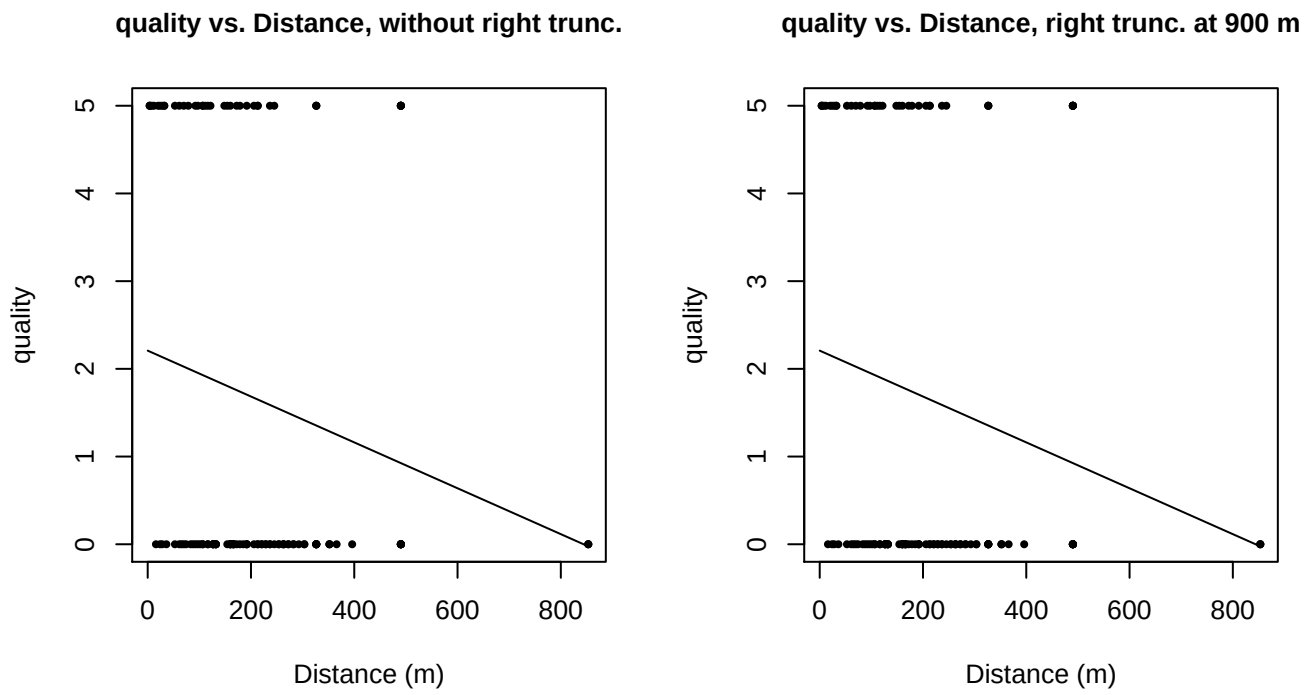


Figure 56: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

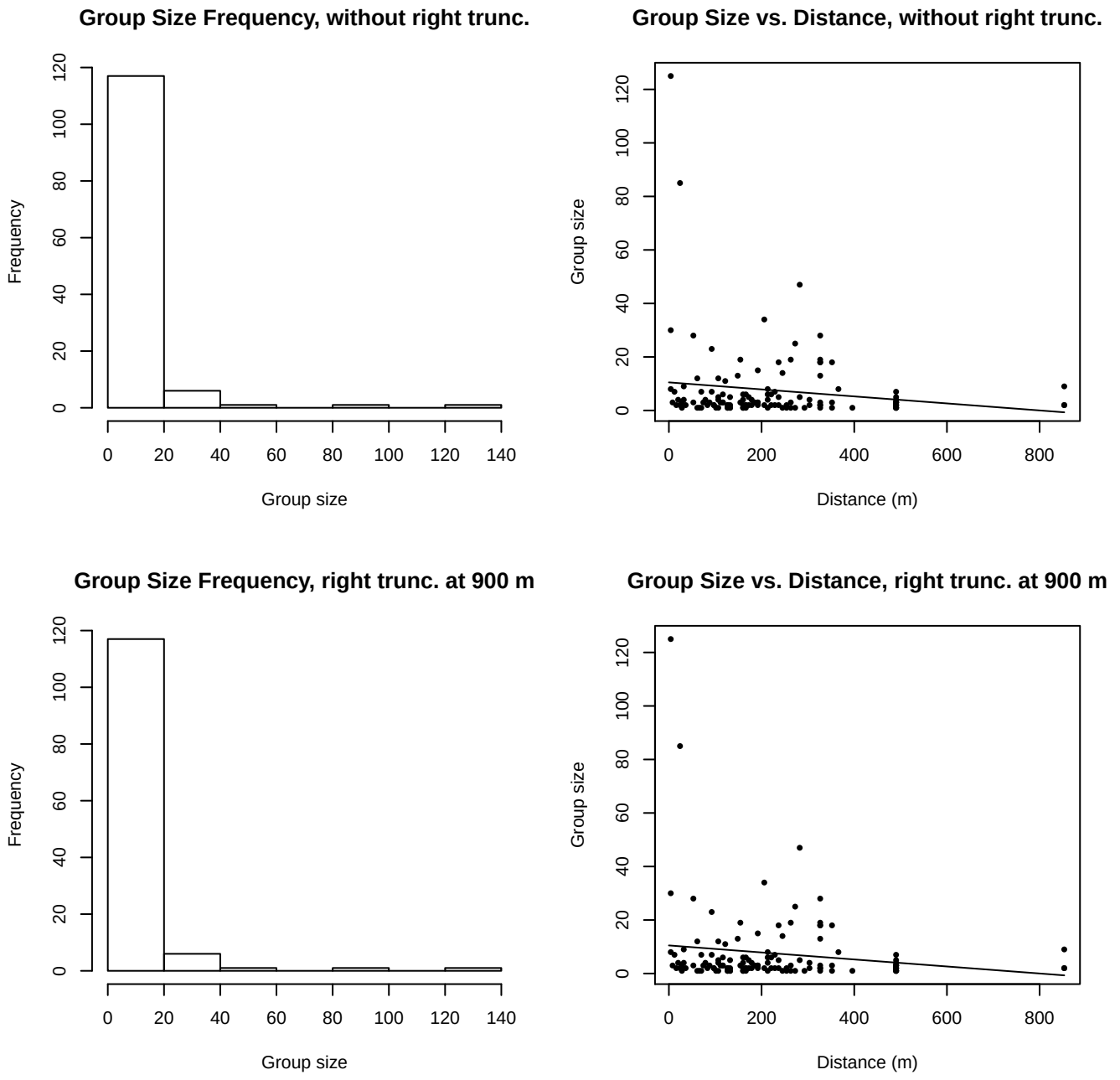


Figure 57: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Mid Atlantic Tursiops Survey 1995

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	0

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	0
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	3
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	116
Total		119

Table 39: Proxy species used to fit detection functions for Mid Atlantic Tursiops Survey 1995. The number of sightings, n, is before truncation.

The sightings were right truncated at 1296m. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 40: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr				Yes	0.00	416
hr			quality	Yes	1.20	425
hr	poly	2		Yes	2.00	416

hr	poly	4		Yes	2.00	416
hr			quality, size	Yes	3.04	426
hn	cos	2		Yes	3.19	334
hn				Yes	6.62	397
hn			quality	Yes	7.34	397
hn			size	Yes	7.67	397
hn	cos	3		Yes	8.38	376
hn	herm	4		Yes	8.59	397
hn			quality, size	Yes	8.74	397
hn			beaufort	No		
hr			beaufort	No		
hr			size	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 41: Candidate detection functions for Mid Atlantic Tursiops Survey 1995. The first one listed was selected for the density model.

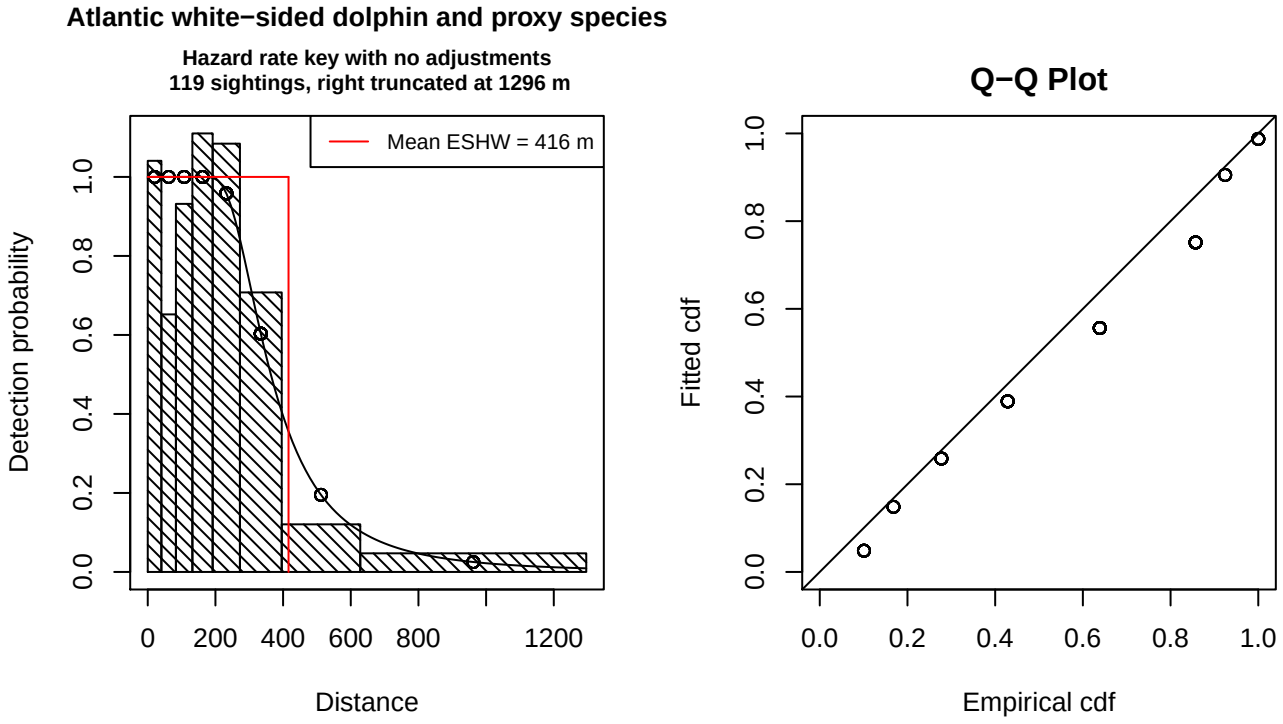


Figure 58: Detection function for Mid Atlantic Tursiops Survey 1995 that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  119
Distance range         :  0  -  1296
AIC                    :  481.8071

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept) 5.788608 0.1178554

Shape parameters:
            estimate        se
(Intercept) 1.222676 0.1596548

                        Estimate          SE         CV
Average p              0.3210204  0.02782412 0.08667398
N in covered region 370.6929540 42.61855213 0.11496995
```

Additional diagnostic plots:

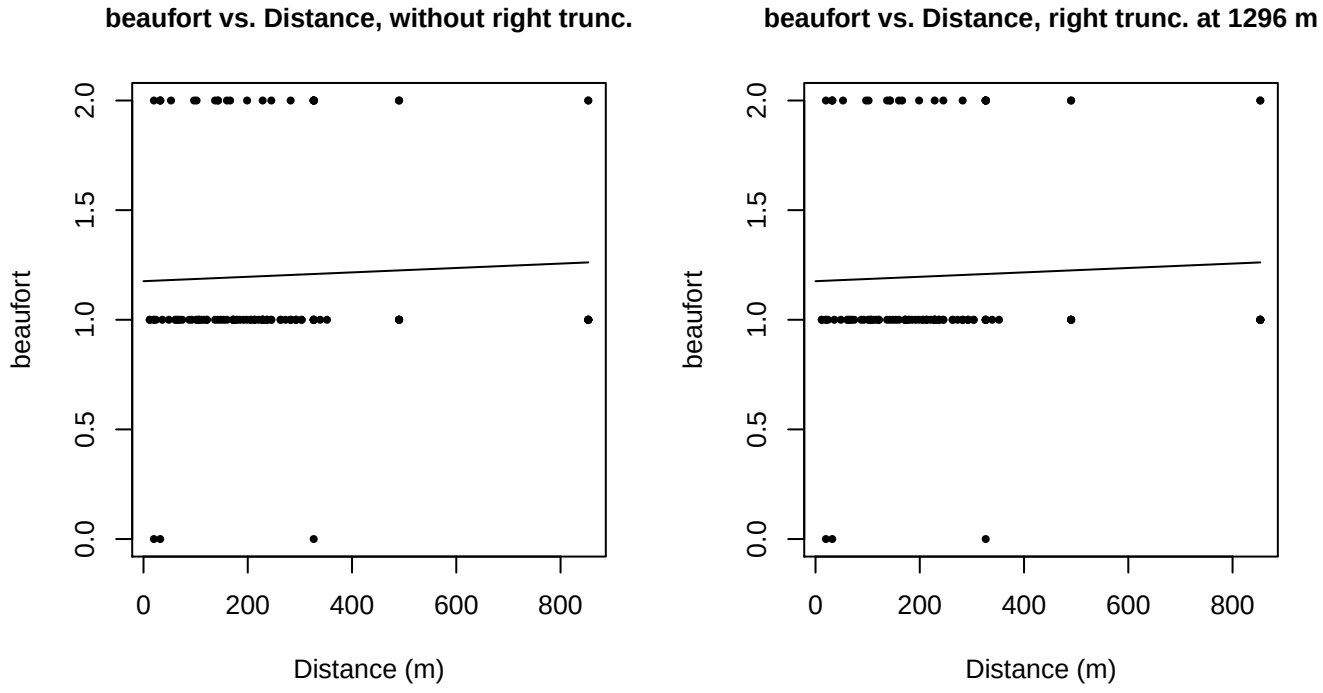


Figure 59: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

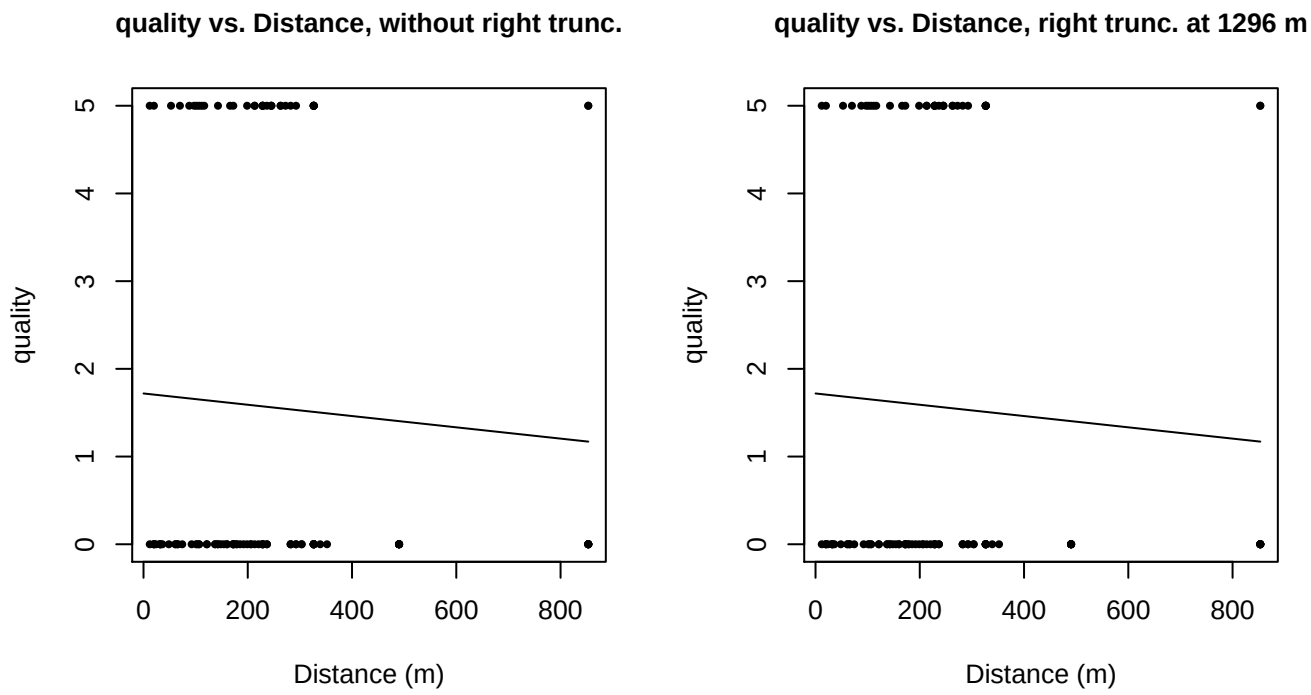


Figure 60: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

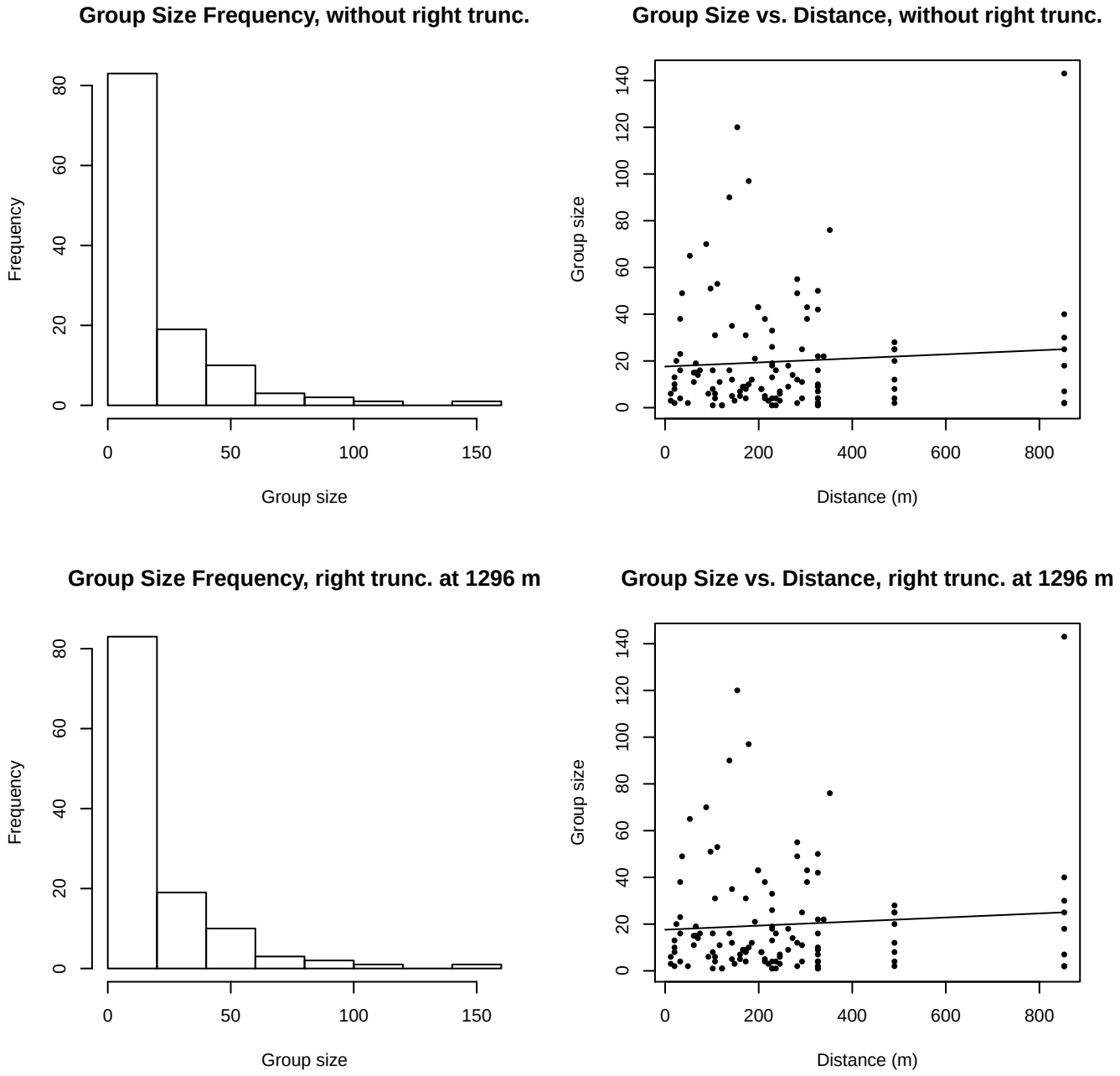


Figure 61: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

GulfCet Aerial Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	0

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	71
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	2
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	10
Stenella attenuata	Pantropical spotted dolphin	94
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	12
Stenella coeruleoalba	Striped dolphin	16
Stenella frontalis	Atlantic spotted dolphin	36
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	11
Steno bredanensis	Rough-toothed dolphin	9
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	237
Total		498

Table 42: Proxy species used to fit detection functions for GulfCet Aerial Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 1296m. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 43: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			size	Yes	0.00	402
hr				Yes	1.41	394
hr	poly	2		Yes	3.41	394

hr	poly	4		Yes	3.41	394
hn	cos	2		Yes	4.97	368
hn	cos	3		Yes	10.69	340
hn			size	Yes	31.42	441
hn				Yes	34.80	439
hn	herm	4		Yes	36.57	439
hn			beaufort	No		
hr			beaufort	No		
hn			quality	No		
hr			quality	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 44: Candidate detection functions for GulfCet Aerial Surveys. The first one listed was selected for the density model.

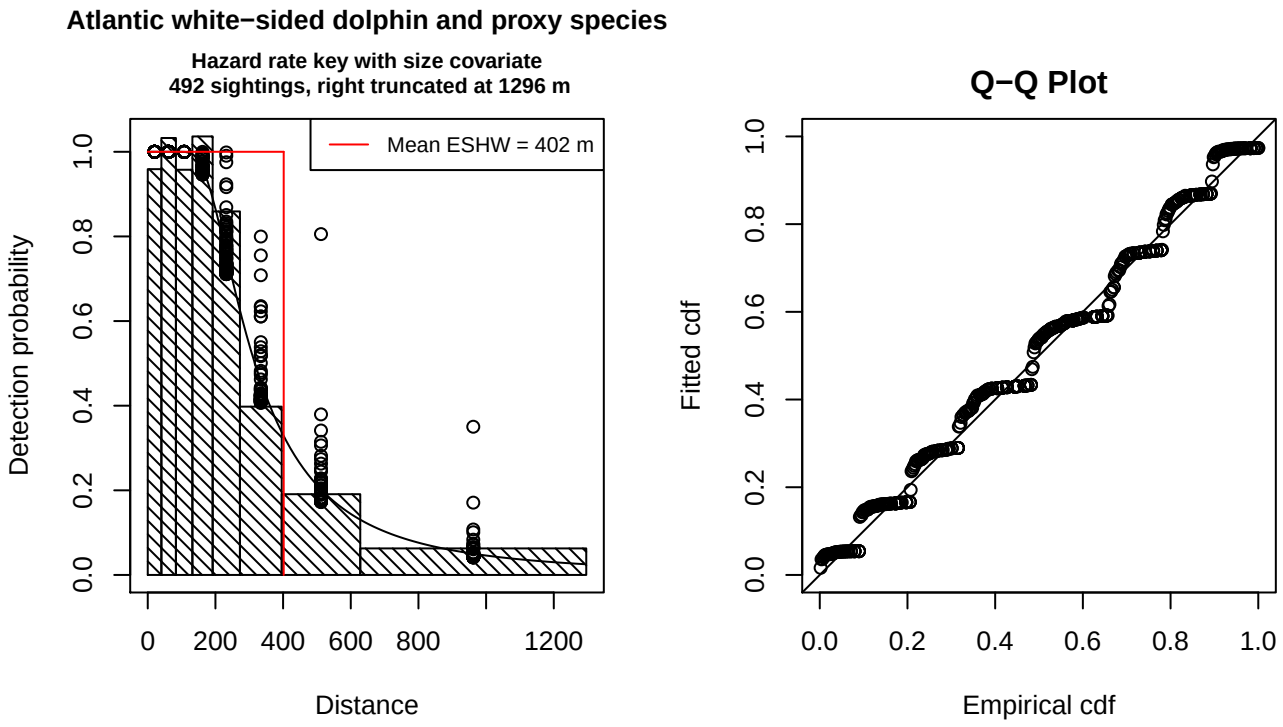


Figure 62: Detection function for GulfCet Aerial Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  492
Distance range         :  0  -  1296
AIC                    :  2031.84

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.535347 0.09109734
size        0.139986 0.06272901

Shape parameters:
            estimate         se
(Intercept) 0.866934 0.08296851

                         Estimate          SE         CV
Average p              0.3057269   0.0166754 0.05454346
N in covered region 1609.2795060 106.6843878 0.06629326
```

Additional diagnostic plots:

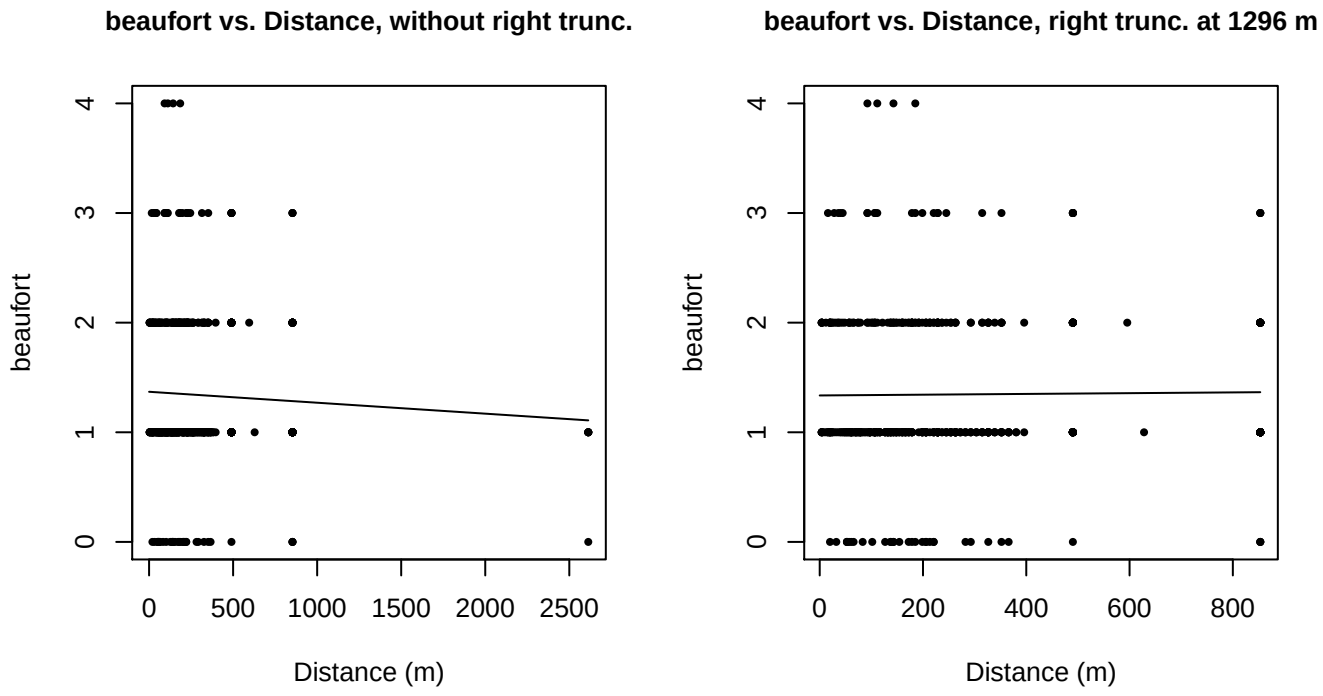


Figure 63: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

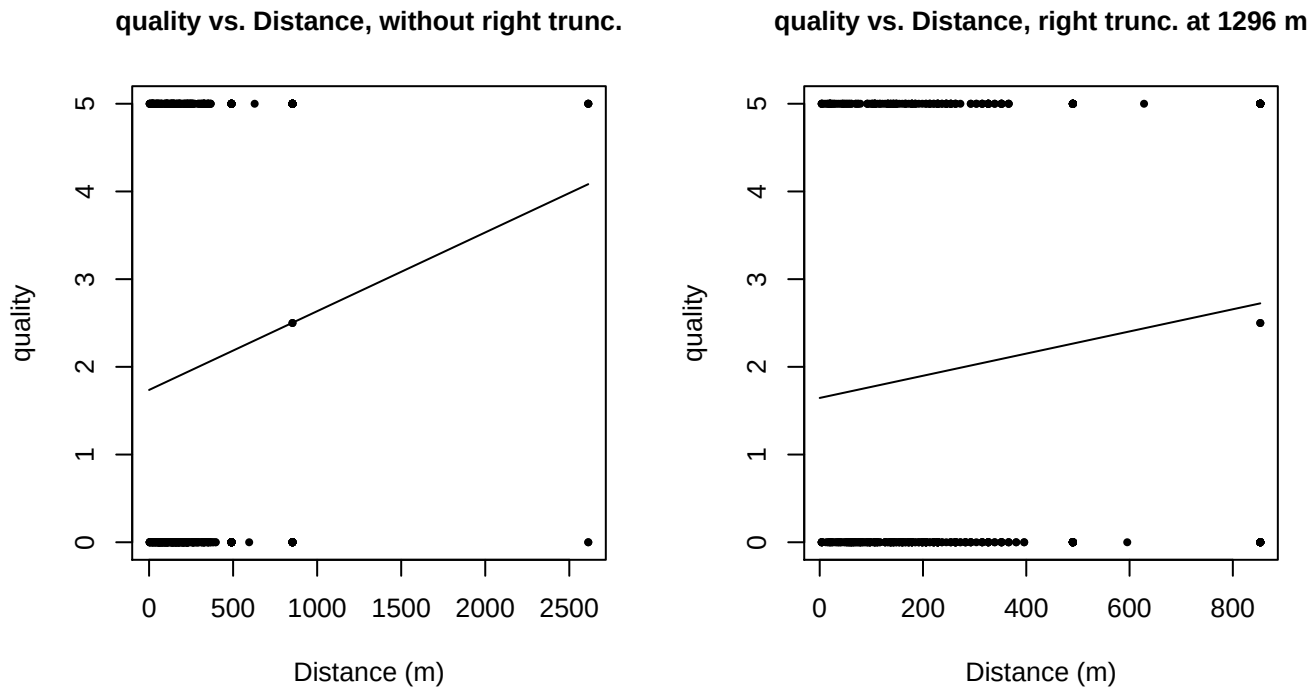


Figure 64: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

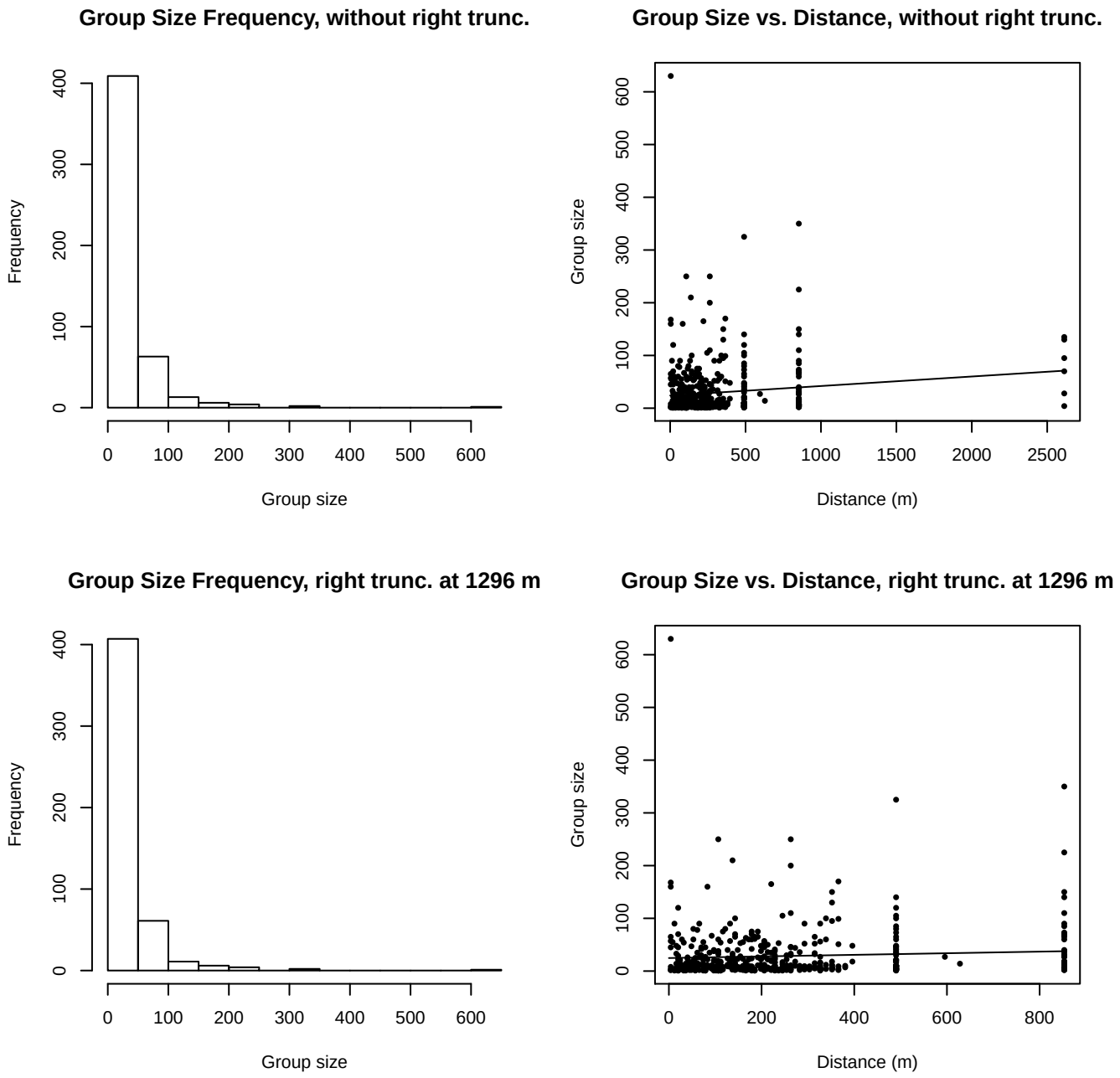


Figure 65: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

GOMEX92-96 Aerial Survey

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	0

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	4
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	1
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	24
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	936
Total		965

Table 45: Proxy species used to fit detection functions for GOMEX92-96 Aerial Survey. The number of sightings, n, is before truncation.

The sightings were right truncated at 1296m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 83 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 46: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)

hr			size	Yes	0.00	281
hr	poly	4		Yes	4.73	273
hn	cos	3		Yes	4.85	220
hr				Yes	4.90	278
hr	poly	2		Yes	5.13	269
hn	cos	2		Yes	12.07	259
hn			size	Yes	39.53	304
hn				Yes	41.94	304
hn	herm	4		Yes	43.71	304
hn			beaufort	No		
hr			beaufort	No		
hn			quality	No		
hr			quality	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 47: Candidate detection functions for GOMEX92-96 Aerial Survey. The first one listed was selected for the density model.

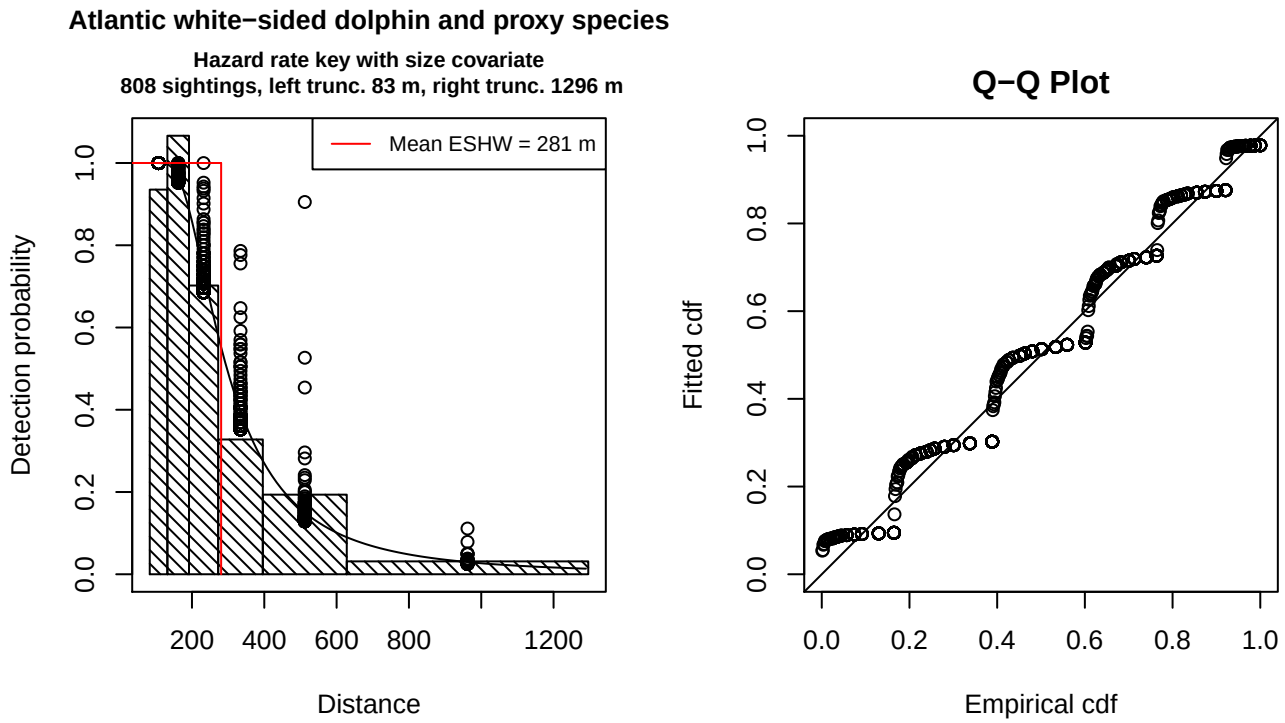


Figure 66: Detection function for GOMEX92-96 Aerial Survey that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  808
Distance range         :  83.2036  -  1296
AIC                    :  2832.217

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept) 5.49007390 0.06761203
size        0.09577309 0.04016336

Shape parameters:
            estimate         se
(Intercept) 0.9893445 0.05859387

                         Estimate           SE         CV
Average p                0.2138621   0.01146898 0.05362795
N in covered region 3778.1360570 234.49525749 0.06206639
```

Additional diagnostic plots:

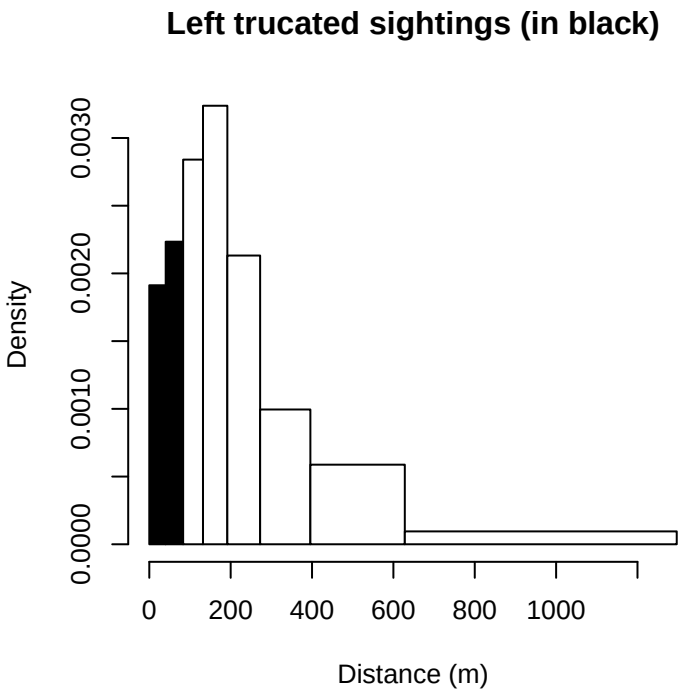


Figure 67: Density of sightings by perpendicular distance for GOMEX92-96 Aerial Survey. Black bars on the left show sightings that were left truncated.

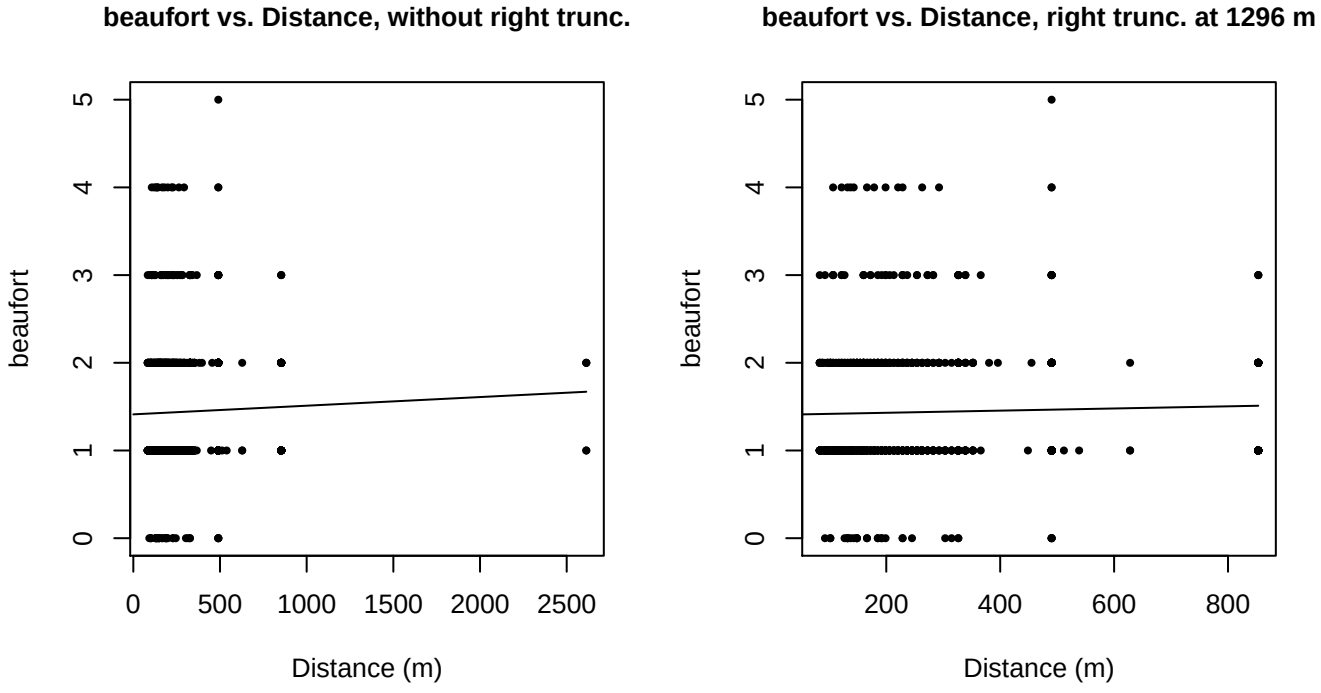


Figure 68: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

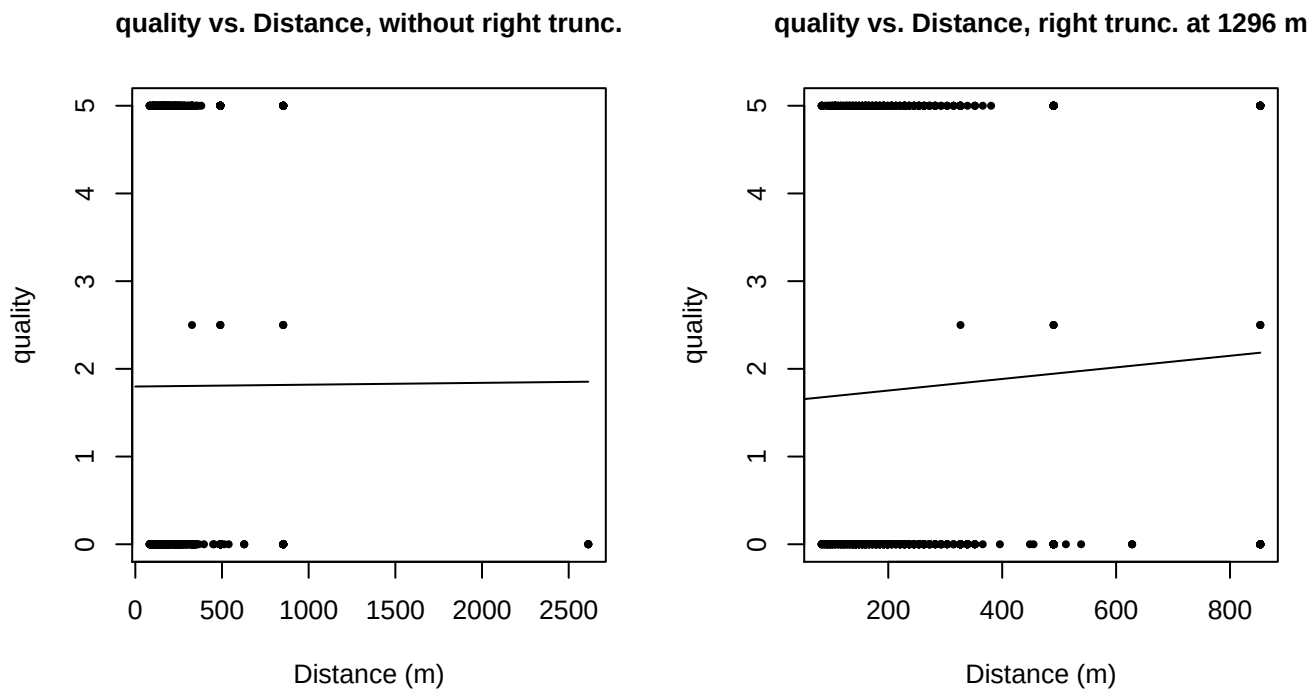


Figure 69: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

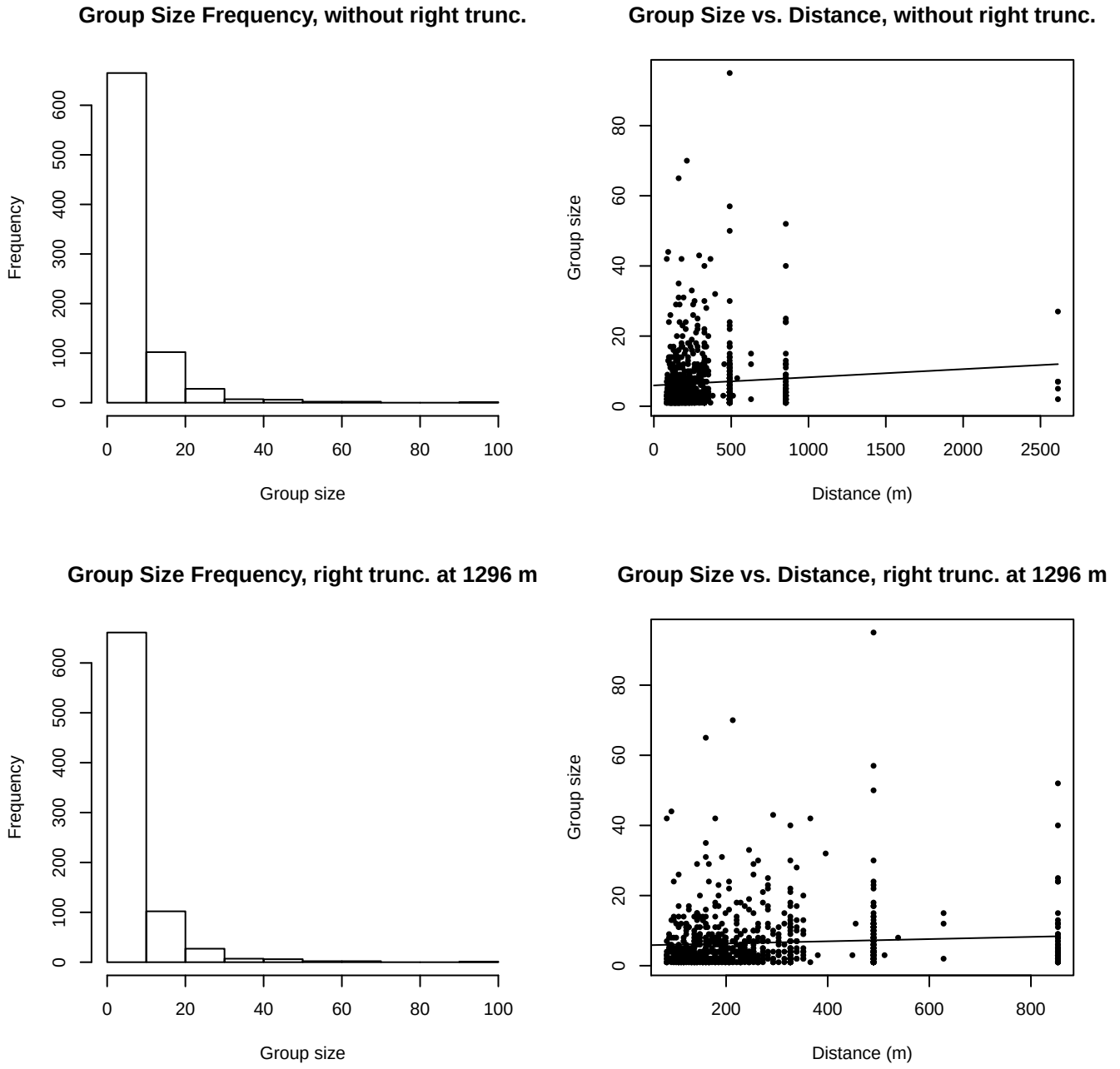


Figure 70: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

UNCW Navy Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	13

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	56
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	1
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	1
Stenella attenuata	Pantropical spotted dolphin	1
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	3
Stenella coeruleoalba	Striped dolphin	3
Stenella frontalis	Atlantic spotted dolphin	341
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	1
Steno bredanensis	Rough-toothed dolphin	9
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	567
Total		996

Table 48: Proxy species used to fit detection functions for UNCW Navy Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 1500m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 49: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn			size	Yes	0.00	754
hn			quality, size	Yes	0.22	754
hn			beaufort, size	Yes	1.76	754
hn			beaufort, quality, size	Yes	1.86	755

hn	herm	4		Yes	4.03	787
hn	cos	2		Yes	6.16	795
hn				Yes	6.29	753
hn			quality	Yes	7.23	753
hr	poly	2		Yes	7.54	825
hn	cos	3		Yes	8.04	736
hn			beaufort	Yes	8.24	753
hn			beaufort, quality	Yes	9.14	753
hr	poly	4		Yes	9.77	841
hr			size	Yes	10.22	901
hr			quality, size	Yes	10.94	900
hr			beaufort, size	Yes	12.22	901
hr			beaufort, quality, size	Yes	12.93	900
hr				Yes	16.65	887
hr			quality	Yes	17.70	886
hr			beaufort	No		
hr			beaufort, quality	No		

Table 50: Candidate detection functions for UNCW Navy Surveys. The first one listed was selected for the density model.

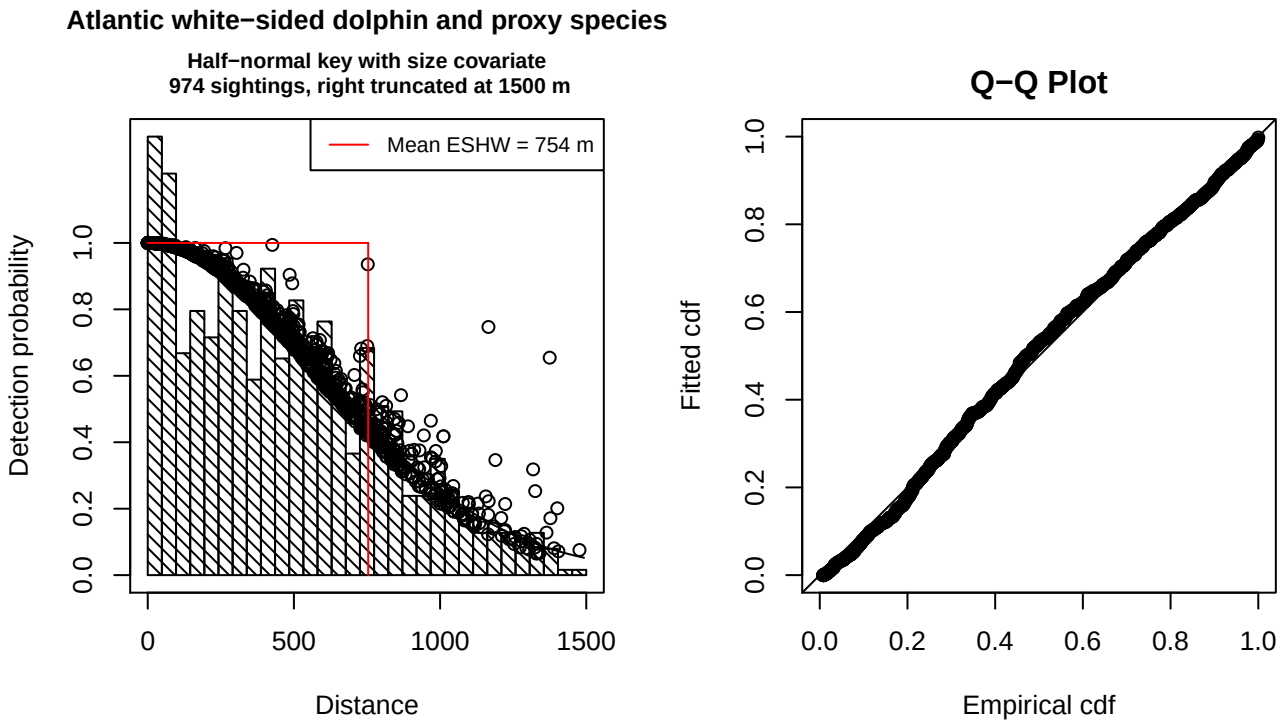


Figure 71: Detection function for UNCW Navy Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  974
Distance range         :  0  -  1500
AIC                    :  13779.06

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept) 6.3388868 0.04000233
size        0.1172576 0.05082555

                         Estimate          SE         CV
Average p                0.4997021  0.01337788 0.02677171
N in covered region 1949.1611578 68.45627661 0.03512089
```

Additional diagnostic plots:

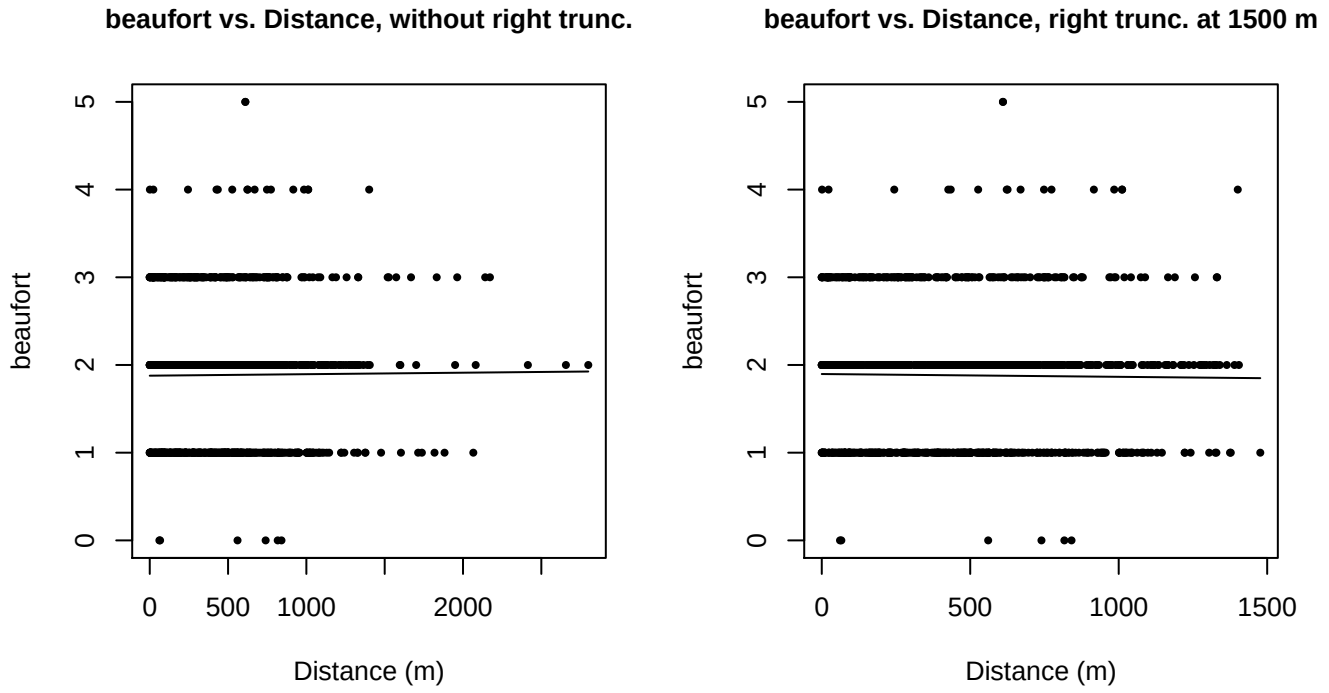


Figure 72: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

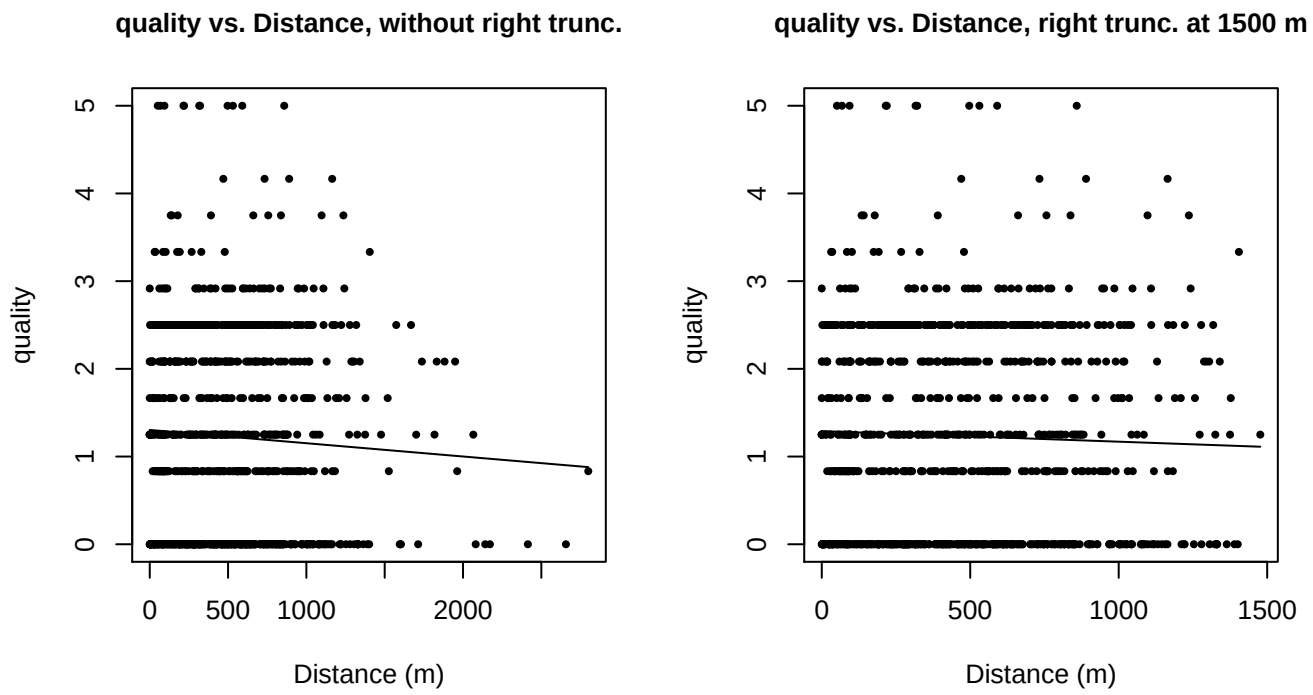


Figure 73: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

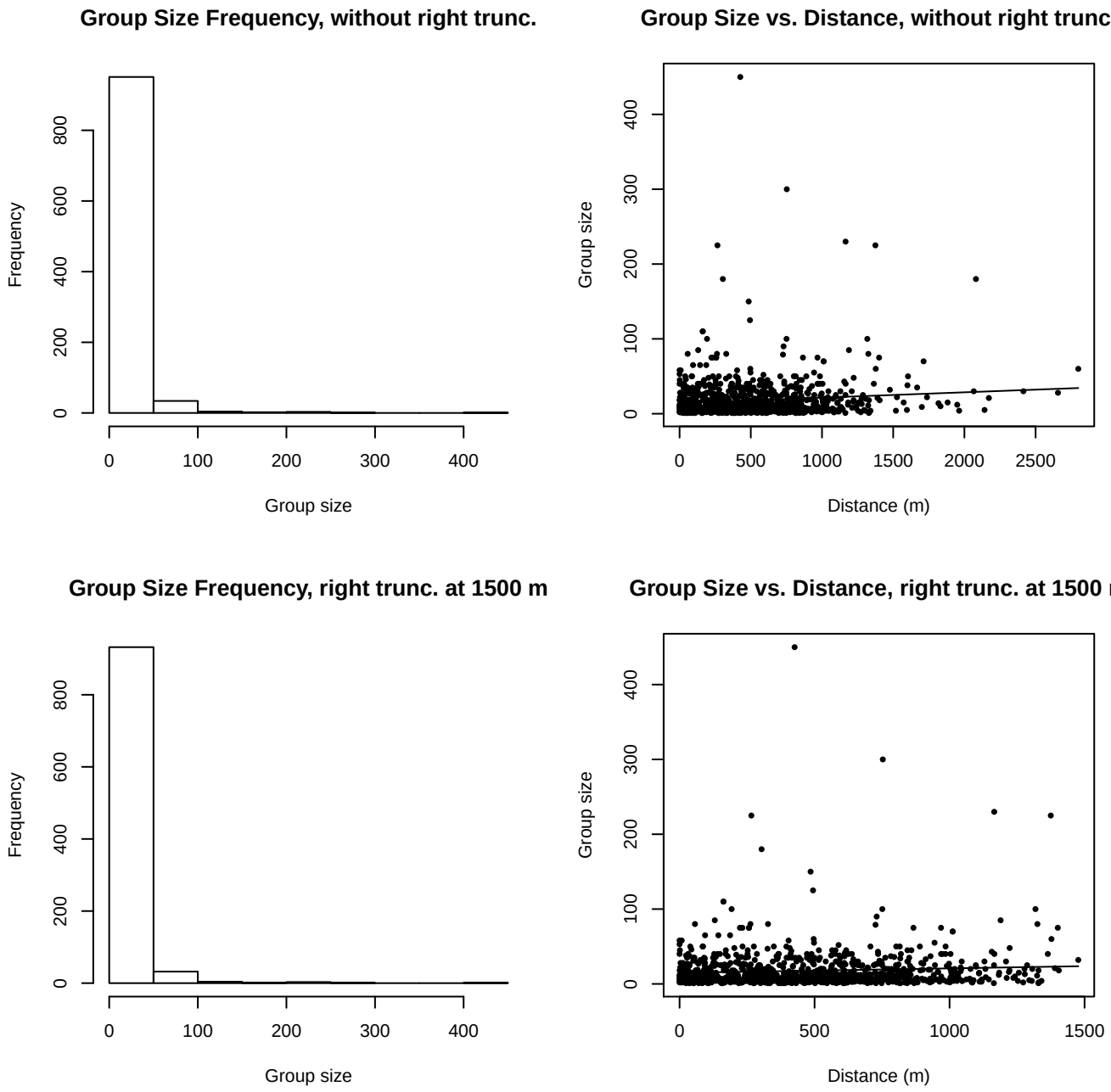


Figure 74: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

UNCW Right Whale Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	26

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	0
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	5
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	1855
Total		1886

Table 51: Proxy species used to fit detection functions for UNCW Right Whale Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 837m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 111 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances. The vertical sighting angles were heaped at 10 degree increments, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 52: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)

hr			beaufort	Yes	0.00	162
hr			beaufort, size	Yes	1.38	162
hr				Yes	2.22	161
hr	poly	4		Yes	4.22	161
hr	poly	2		Yes	4.22	161
hn	cos	2		Yes	62.20	87
hn				Yes	77.91	103
hn	cos	3		Yes	78.05	117
hn	herm	4		Yes	79.70	103
hn			beaufort	No		
hn			quality	No		
hr			quality	No		
hn			size	No		
hr			size	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 53: Candidate detection functions for UNCW Right Whale Surveys. The first one listed was selected for the density model.

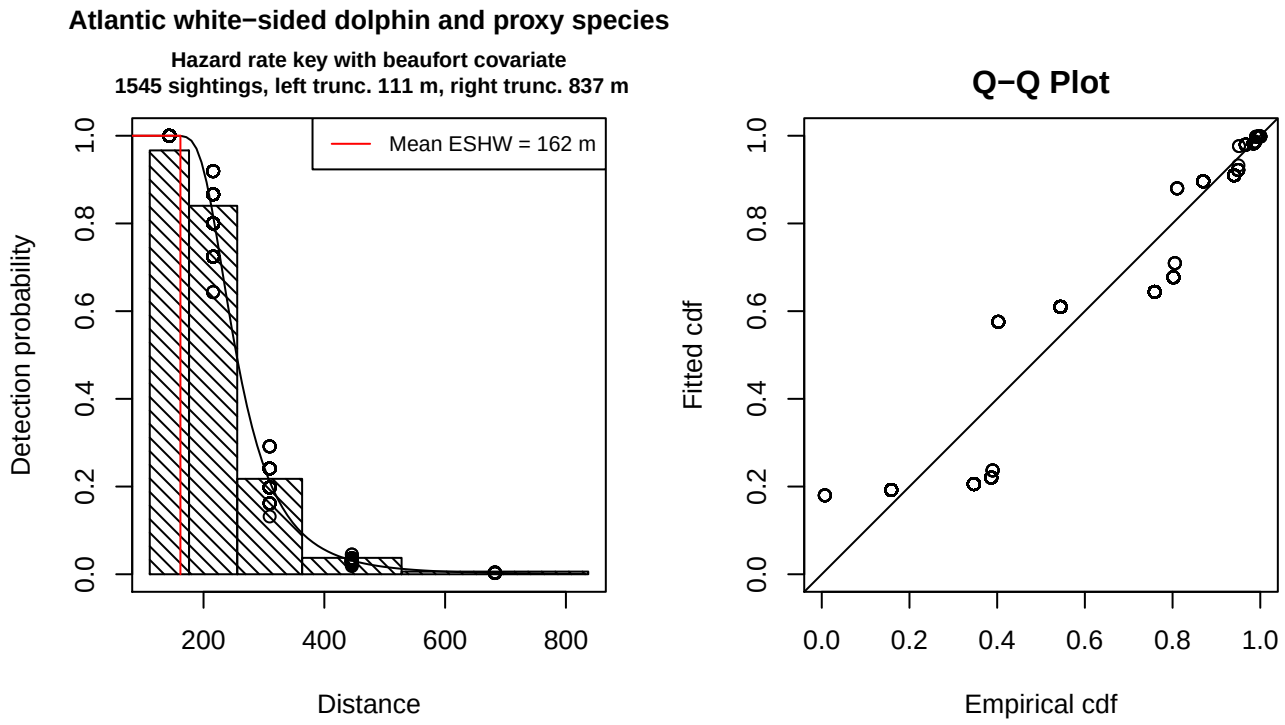


Figure 75: Detection function for UNCW Right Whale Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1545
Distance range         :  110.9381  -  837
AIC                    :  3681.827

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
               estimate         se
(Intercept)  5.54196336 0.04042409
beaufort    -0.04042406 0.02041452

Shape parameters:
            estimate         se
(Intercept) 1.707667 0.04319172

                         Estimate           SE         CV
Average p               0.1927444   0.00547895 0.02842598
N in covered region 8015.7956844 292.42037285 0.03648052
```

Additional diagnostic plots:

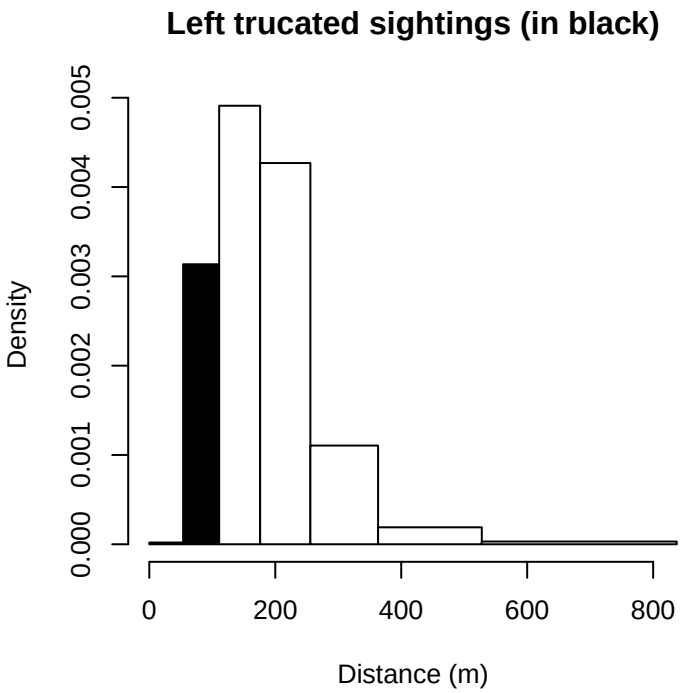


Figure 76: Density of sightings by perpendicular distance for UNCW Right Whale Surveys. Black bars on the left show sightings that were left truncated.

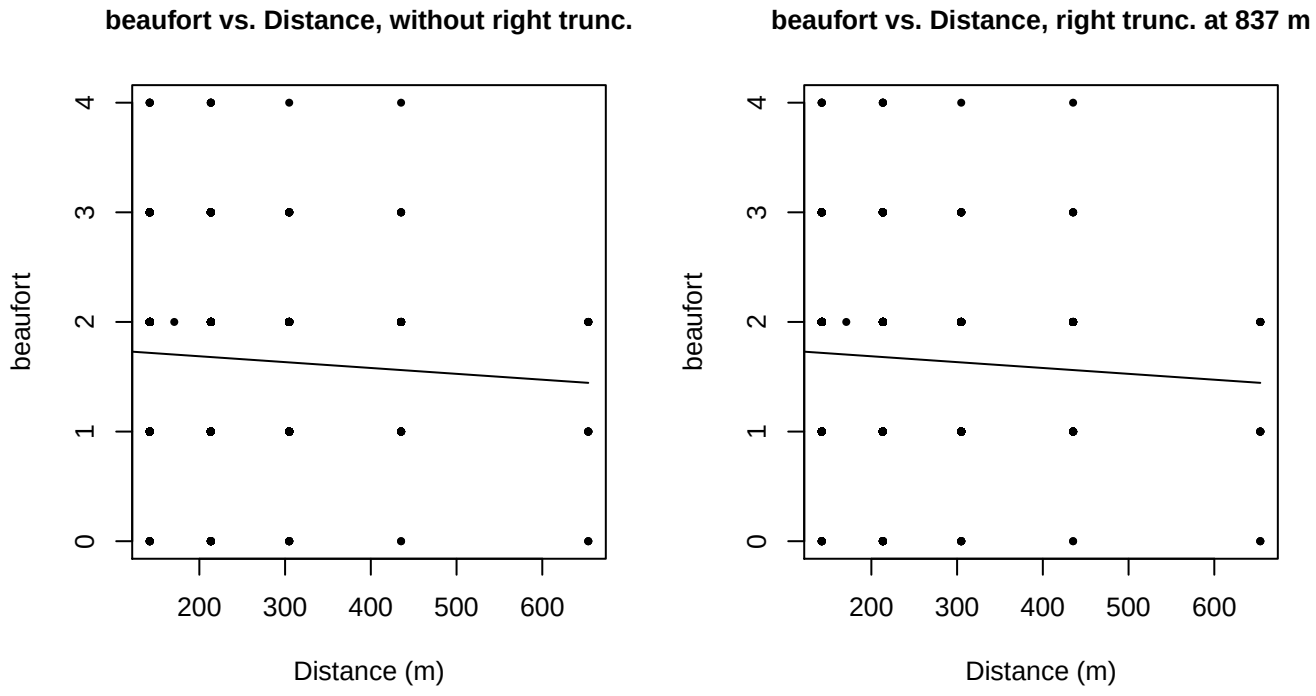


Figure 77: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

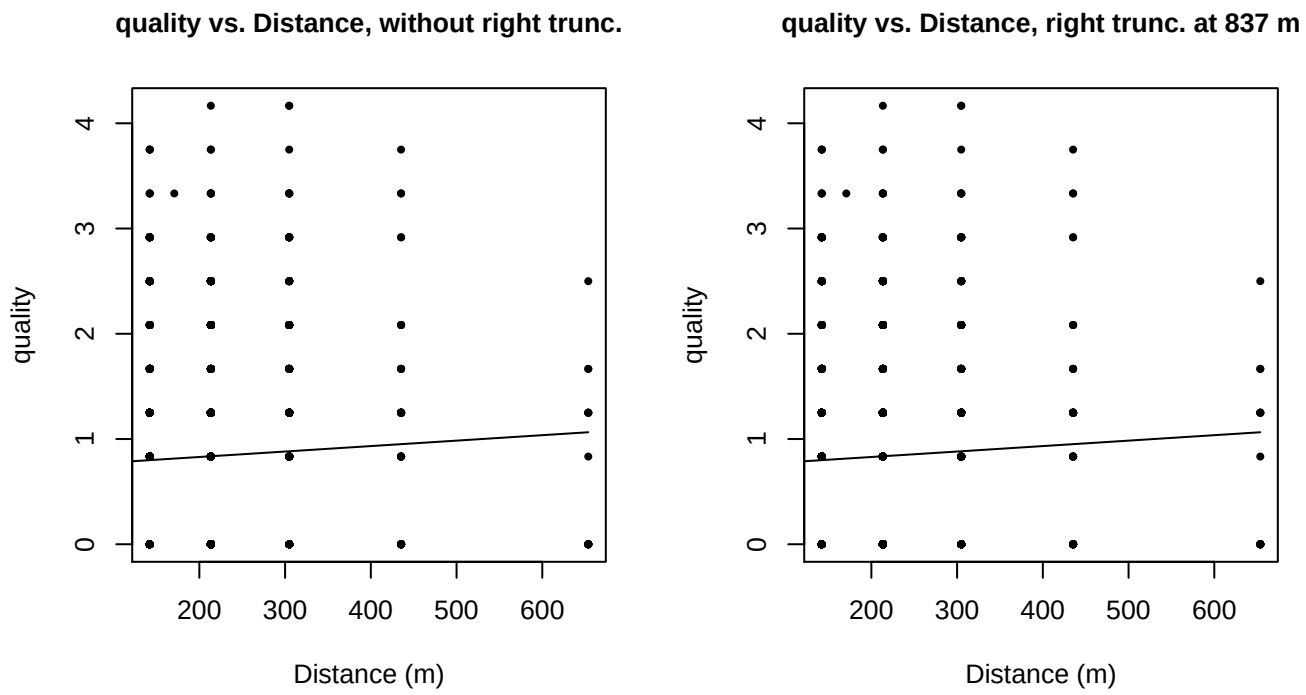


Figure 78: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

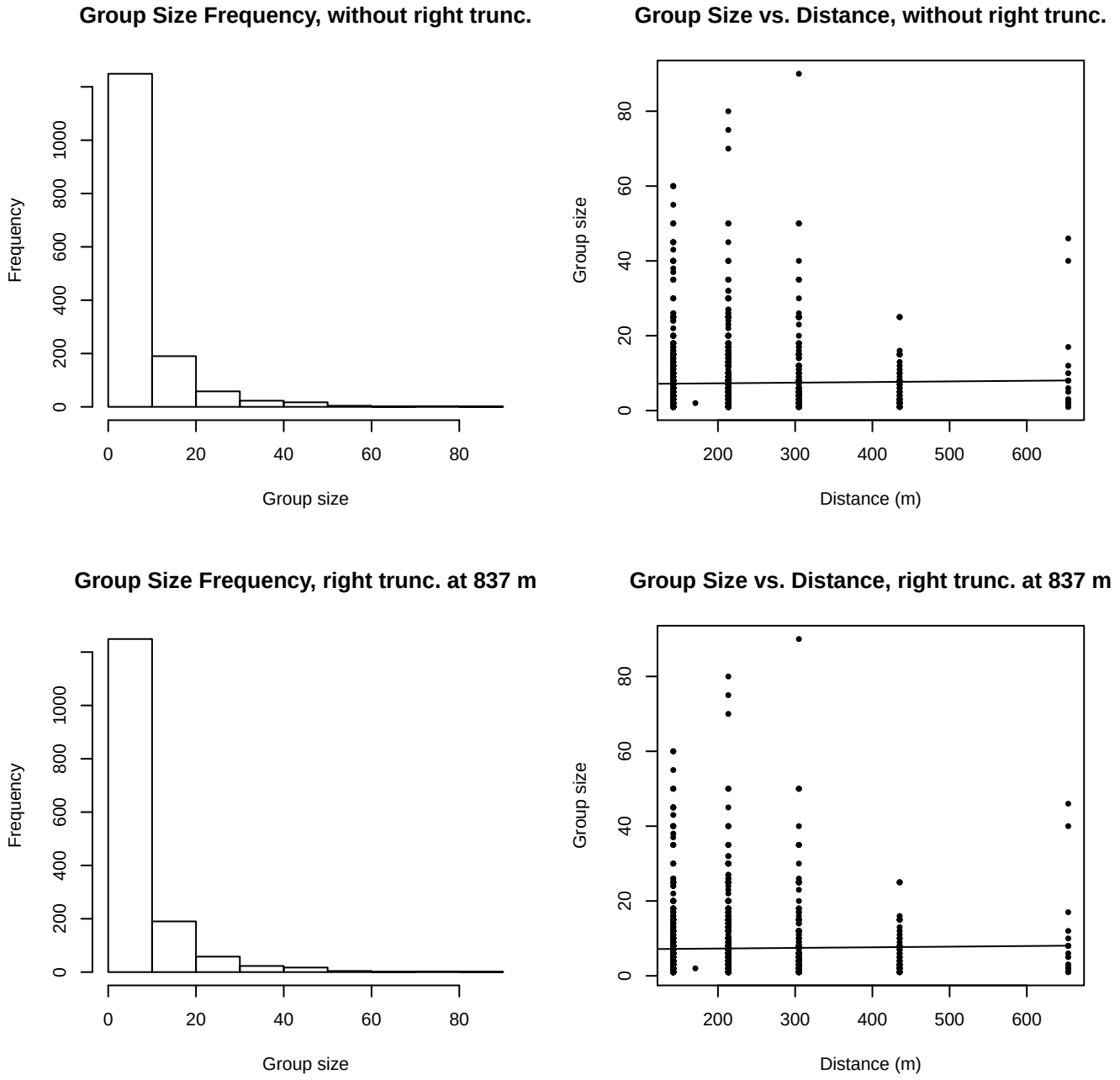


Figure 79: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

UNCW Early Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	5

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	0
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	1
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	350
Total		356

Table 54: Proxy species used to fit detection functions for UNCW Early Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 332m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 13 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 55: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn			beaufort	Yes	0.00	158

hn				Yes	2.97	157
hn	herm	4		Yes	4.33	164
hn	cos	2		Yes	4.73	164
hn			quality	Yes	4.80	157
hr	poly	4		Yes	4.86	167
hn	cos	3		Yes	4.95	159
hr	poly	2		Yes	5.37	165
hr			beaufort	Yes	5.57	187
hr				Yes	8.04	173
hr			quality	Yes	9.35	173
hn			size	No		
hr			size	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			quality, size	No		
hr			quality, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 56: Candidate detection functions for UNCW Early Surveys. The first one listed was selected for the density model.

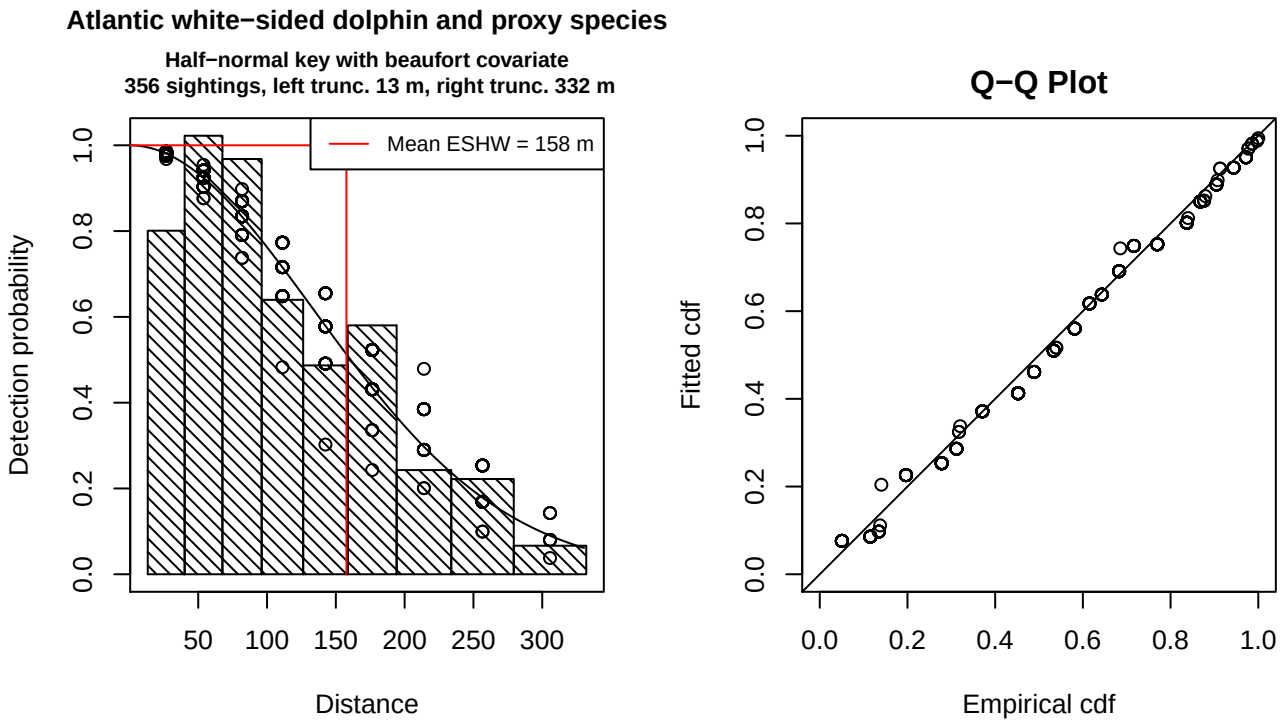


Figure 80: Detection function for UNCW Early Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  356
Distance range         :  13.30786  -  332
AIC                    :  1491.715

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  5.1726896 0.13721406
beaufort    -0.1299227 0.06484242

                      Estimate          SE         CV
Average p             0.4700677  0.02238003 0.04761023
N in covered region 757.3377587 46.49751992 0.06139601
```

Additional diagnostic plots:

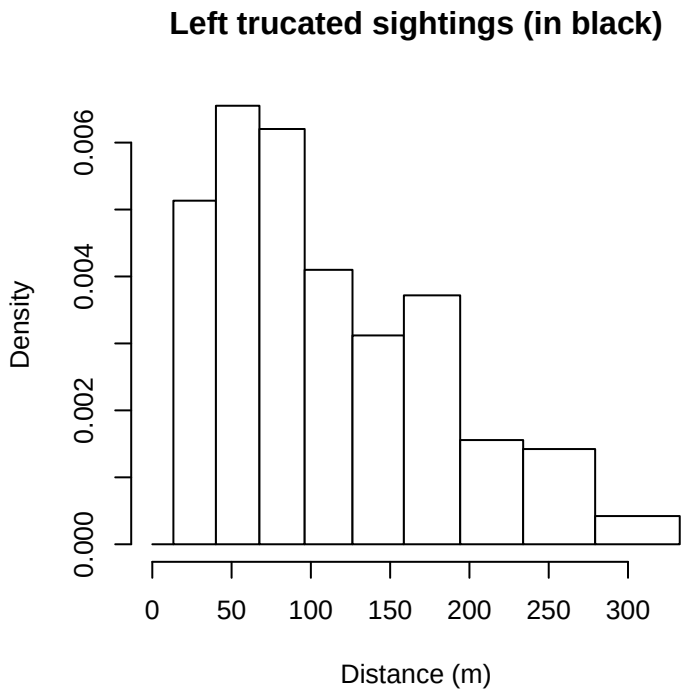


Figure 81: Density of sightings by perpendicular distance for UNCW Early Surveys. Black bars on the left show sightings that were left truncated.

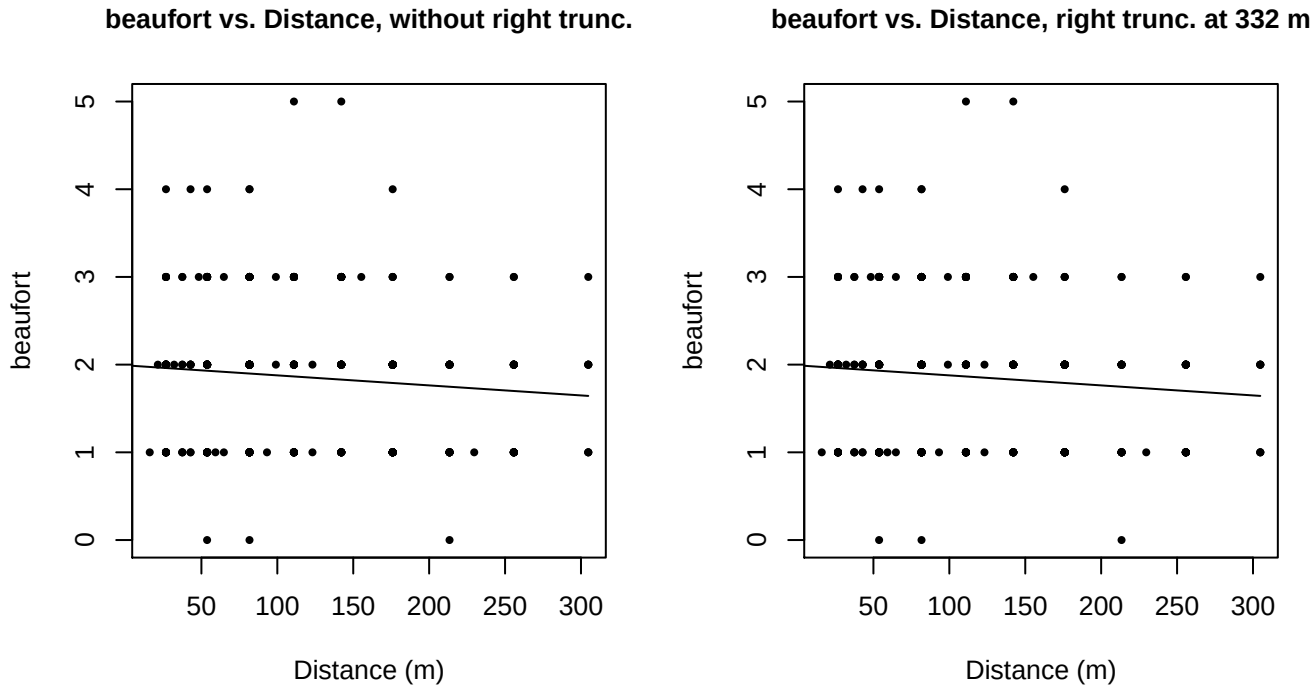


Figure 82: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

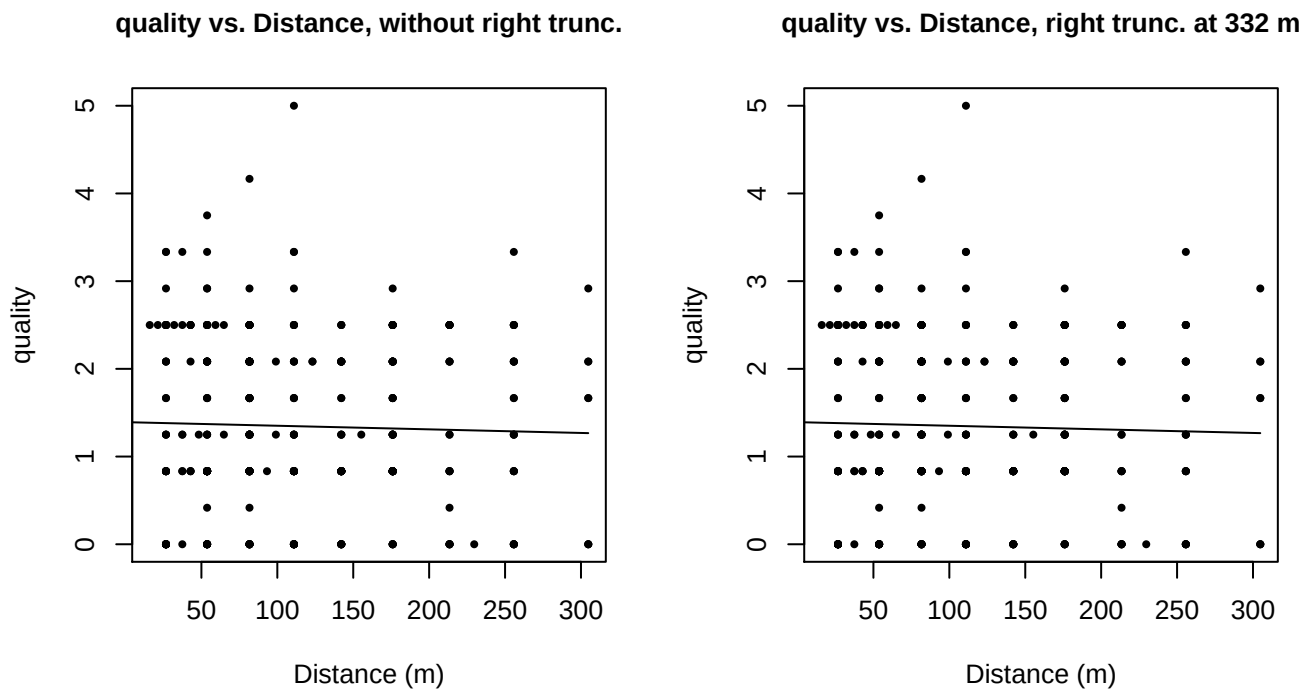


Figure 83: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

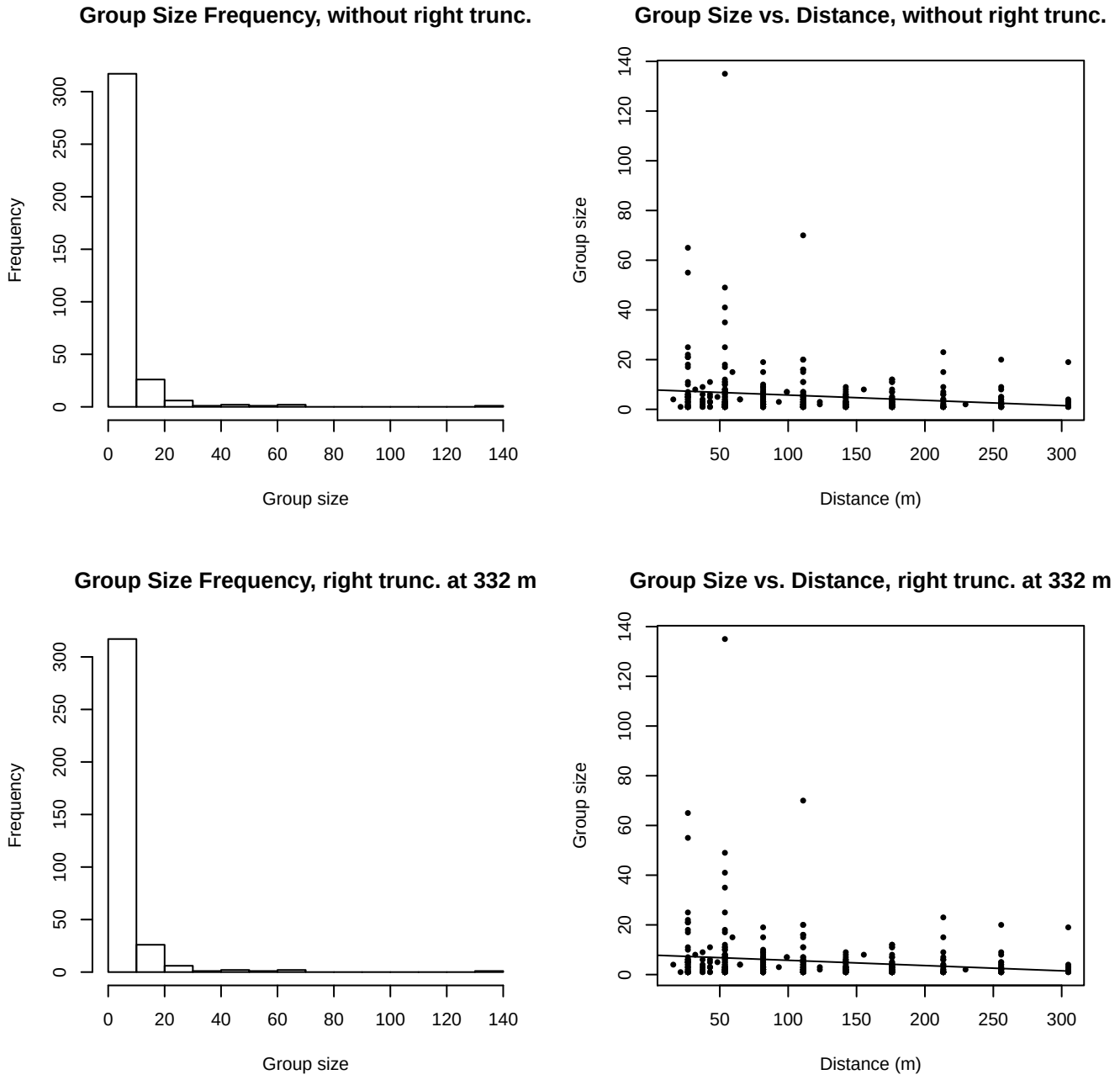


Figure 84: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Virginia Aquarium Surveys

Because this taxon was sighted too infrequently to fit a detection function to its sightings alone, we fit a detection function to the pooled sightings of several other species that we believed would exhibit similar detectability. These "proxy species" are listed below.

Reported By Observer	Common Name	n
Delphinus capensis	Long-beaked common dolphin	0
Delphinus delphis	Short-beaked common dolphin	16

Delphinus delphis/Lagenorhynchus acutus	Short-beaked common or Atlantic white-sided dolphin	0
Delphinus delphis/Stenella	Short-beaked common dolphin or Stenella spp.	0
Delphinus delphis/Stenella coeruleoalba	Short-beaked common or striped dolphin	0
Grampus griseus	Risso's dolphin	0
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	0
Lagenorhynchus albirostris	White-beaked dolphin	0
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	0
Stenella	Unidentified Stenella	0
Stenella attenuata	Pantropical spotted dolphin	0
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	0
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	0
Stenella frontalis/Tursiops truncatus	Atlantic spotted or Bottlenose dolphin	0
Stenella longirostris	Spinner dolphin	0
Steno bredanensis	Rough-toothed dolphin	0
Steno bredanensis/Tursiops truncatus	Bottlenose or rough-toothed dolphin	0
Tursiops truncatus	Bottlenose dolphin	67
Total		83

Table 57: Proxy species used to fit detection functions for Virginia Aquarium Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 1500m.

Covariate	Description
beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 58: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			quality, size	Yes	0.00	413
hr			quality	Yes	2.75	381
hr			size	Yes	2.86	408
hr				Yes	5.08	379

hr	poly	4		Yes	7.07	377
hr	poly	2		Yes	7.08	379
hn	cos	2		Yes	8.57	438
hn			quality, size	Yes	10.48	567
hn	cos	3		Yes	11.42	404
hn			quality	Yes	11.94	549
hn			beaufort, quality, size	Yes	12.28	569
hn			beaufort, quality	Yes	13.90	549
hn			beaufort, size	Yes	17.69	567
hn			beaufort	Yes	18.02	563
hn				Yes	18.13	562
hn			size	Yes	18.73	562
hn	herm	4		No		
hr			beaufort	No		
hr			beaufort, quality	No		
hr			beaufort, size	No		
hr			beaufort, quality, size	No		

Table 59: Candidate detection functions for Virginia Aquarium Surveys. The first one listed was selected for the density model.

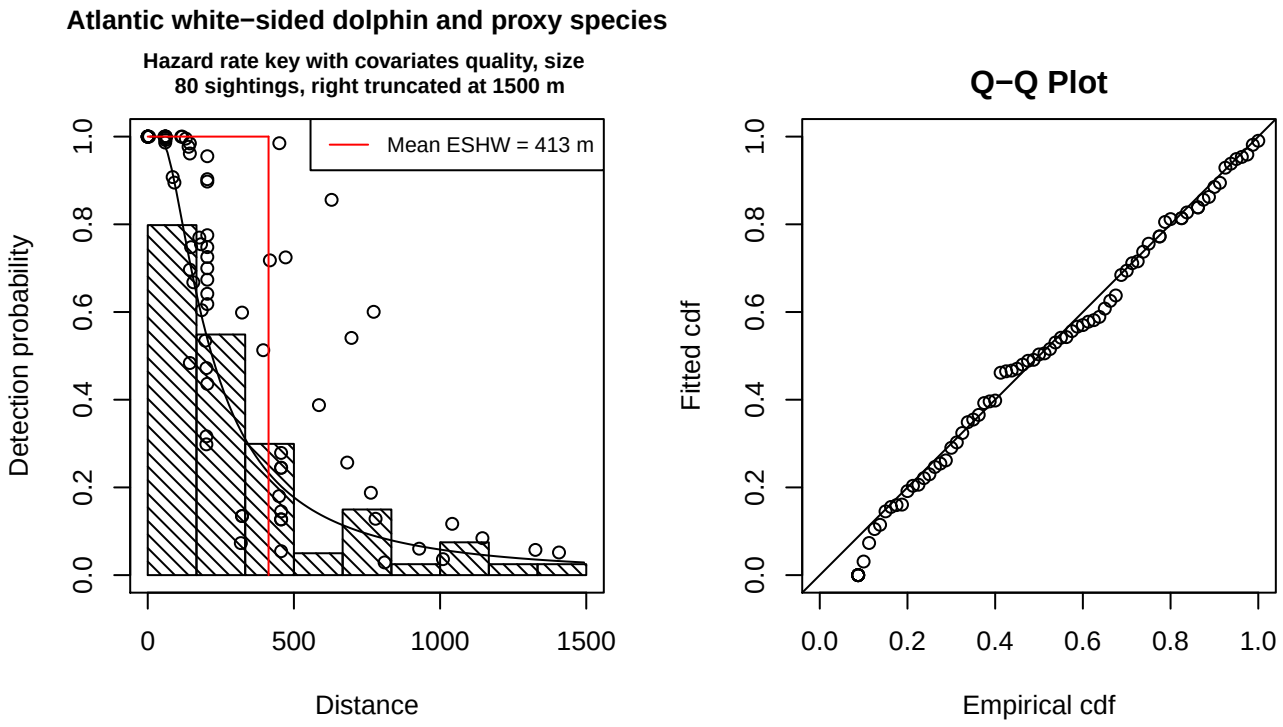


Figure 85: Detection function for Virginia Aquarium Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  80
Distance range         :  0  -  1500
AIC                    :  1076.058

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate        se
(Intercept)  5.6518239 0.3734155
quality     -0.3758731 0.1494911
size         0.3255962 0.2331376

Shape parameters:
             estimate        se
(Intercept) 0.6332354 0.1825191

                       Estimate          SE        CV
Average p             0.2217122  0.03813113 0.1719848
N in covered region 360.8280660 72.14728675 0.1999492
```

Additional diagnostic plots:

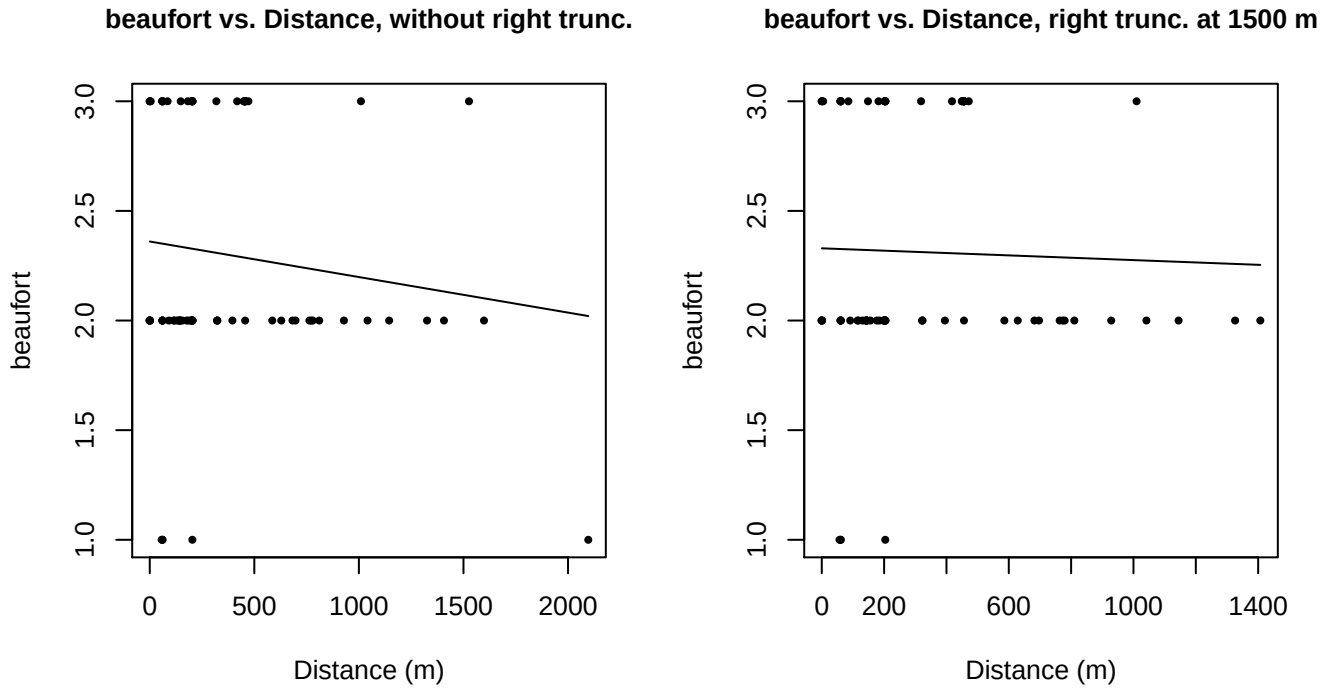


Figure 86: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

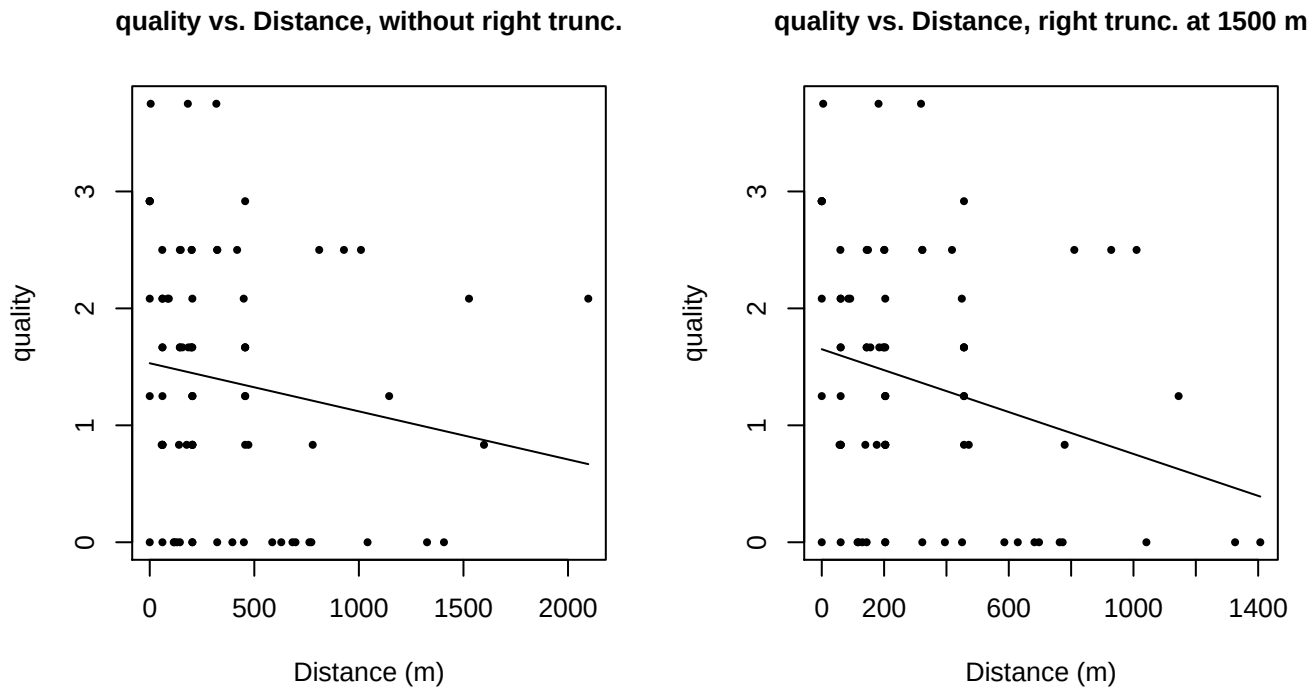


Figure 87: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

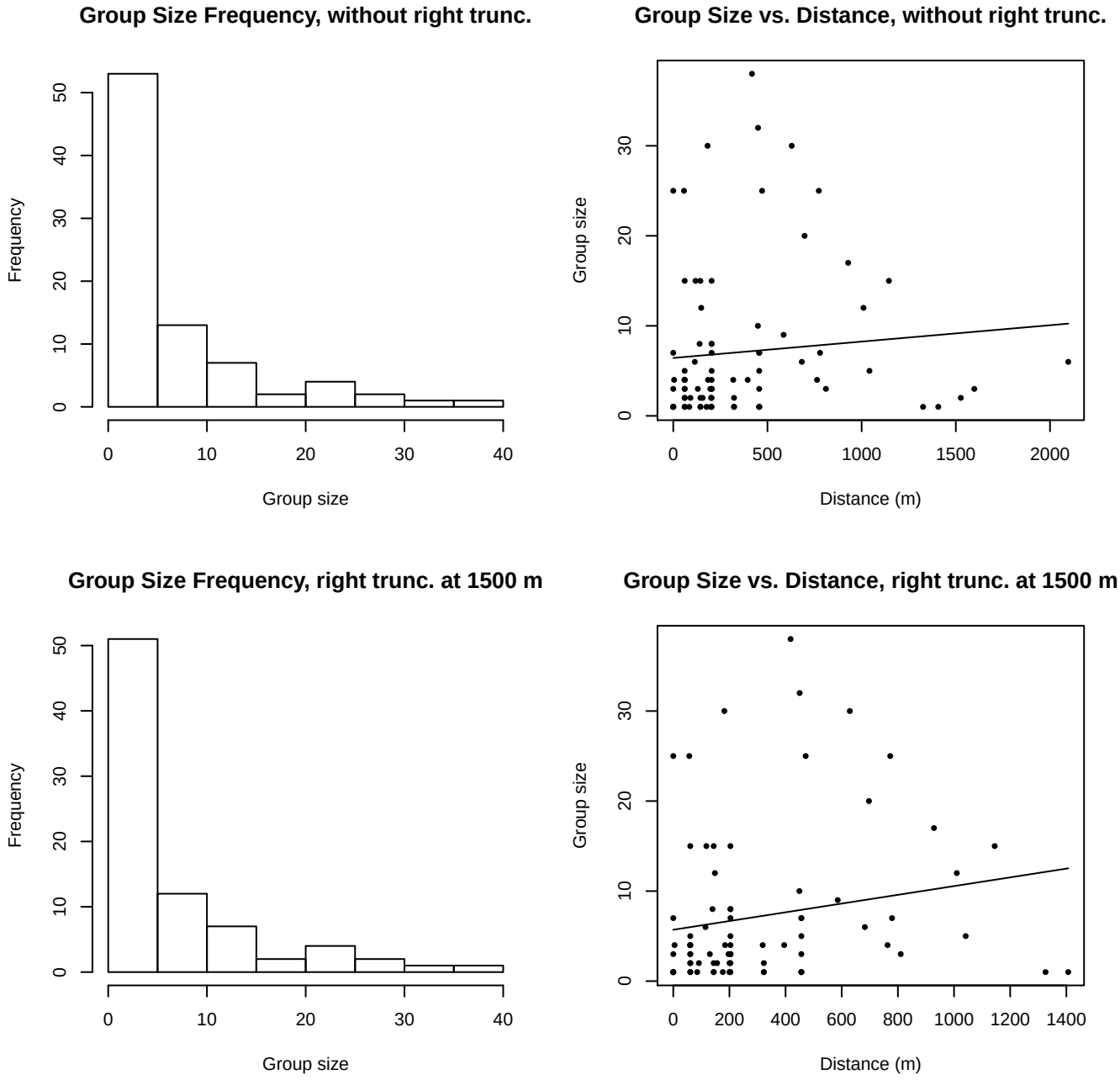


Figure 88: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NARWSS Grummans

The sightings were right truncated at 800m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 107 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances.

Covariate	Description

beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 60: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			quality, size	Yes	0.00	221
hr			quality	Yes	4.95	201
hr			size	Yes	5.81	216
hn			quality, size	Yes	12.34	226
hr				Yes	12.74	188
hn			size	Yes	13.55	223
hn	cos	2		Yes	13.85	146
hr	poly	4		Yes	14.66	186
hr	poly	2		Yes	14.74	188
hn			quality	Yes	25.97	214
hn				Yes	27.00	214
hn	herm	4		Yes	28.61	214
hn	cos	3		No		
hn			beaufort	No		
hr			beaufort	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, size	No		
hr			beaufort, size	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 61: Candidate detection functions for NARWSS Grummans. The first one listed was selected for the density model.

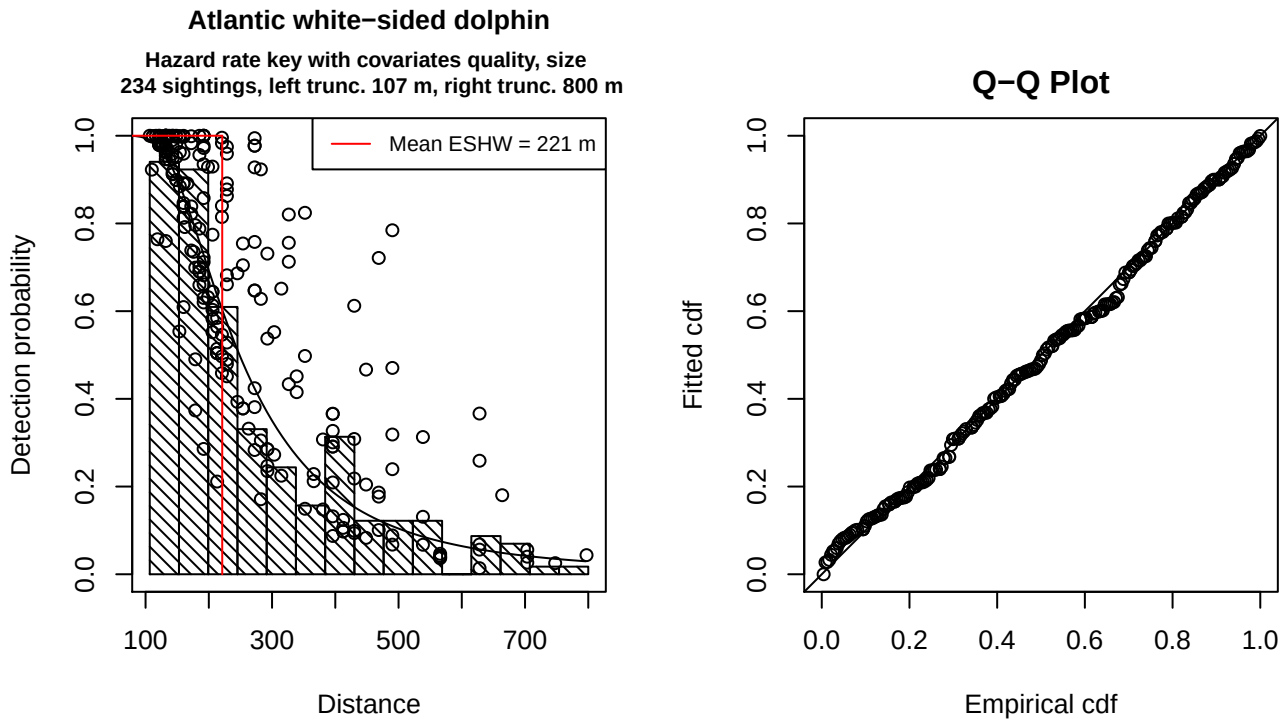


Figure 89: Detection function for NARWSS Grummans that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  234
Distance range         :  106.5979  -  800
AIC                    :  2821.406

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
             estimate         se
(Intercept)  5.5838747 0.13933619
quality     -0.2853959 0.10822779
size         0.2411057 0.08491289

Shape parameters:
            estimate        se
(Intercept)  1.11092 0.1144703

                     Estimate           SE        CV
Average p            0.235497   0.03532006 0.1499809
N in covered region 993.643067 160.02526879 0.1610490
```

Additional diagnostic plots:

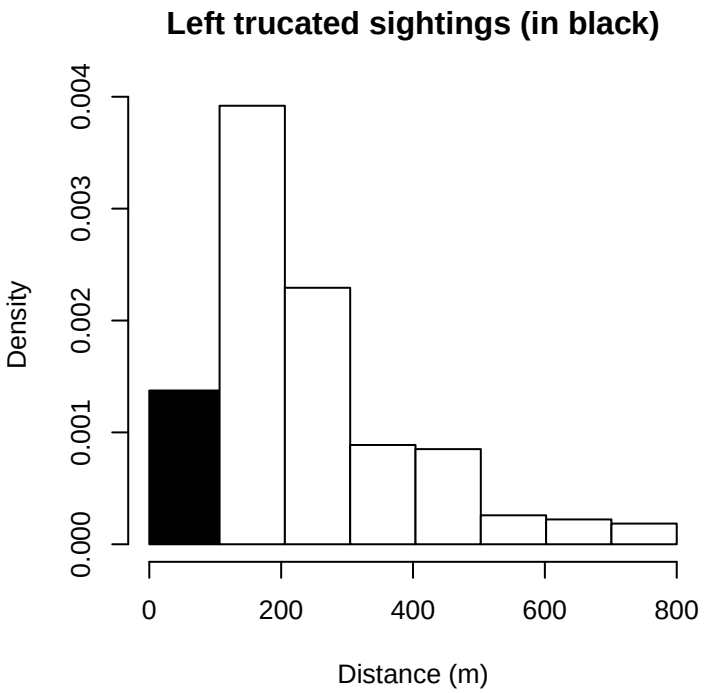


Figure 90: Density of sightings by perpendicular distance for NARWSS Grummans. Black bars on the left show sightings that were left truncated.

Figure 91: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

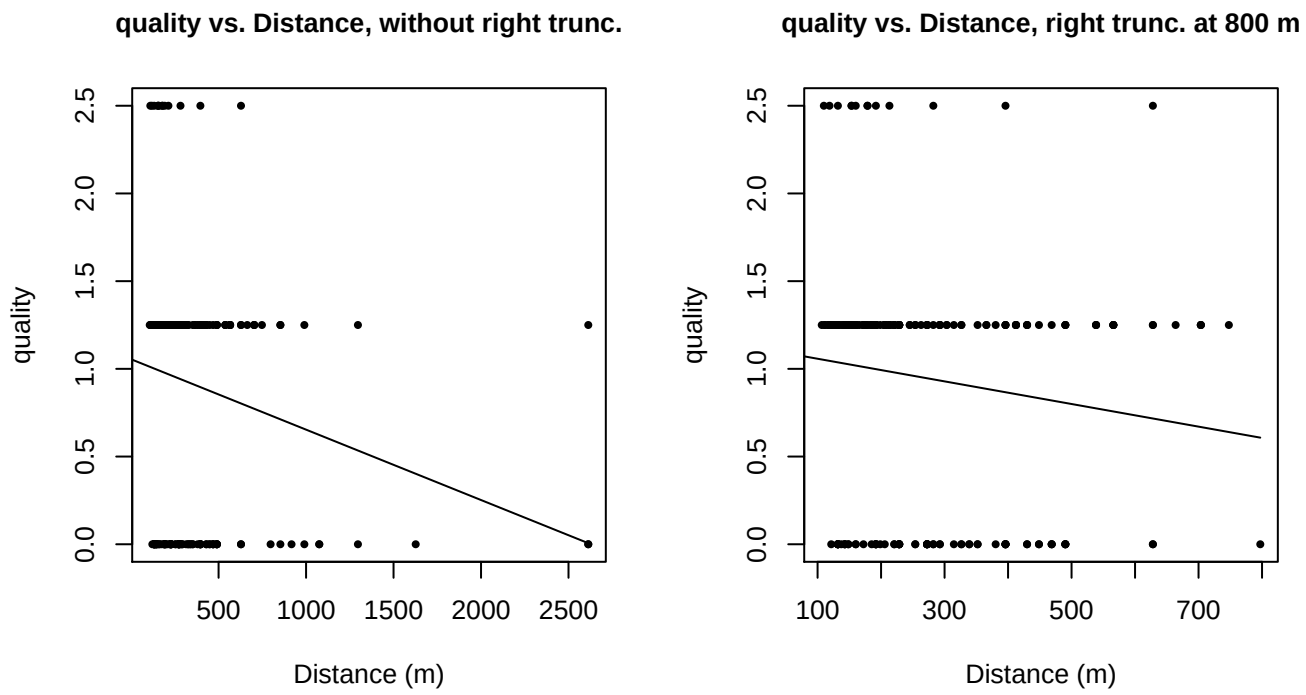


Figure 92: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

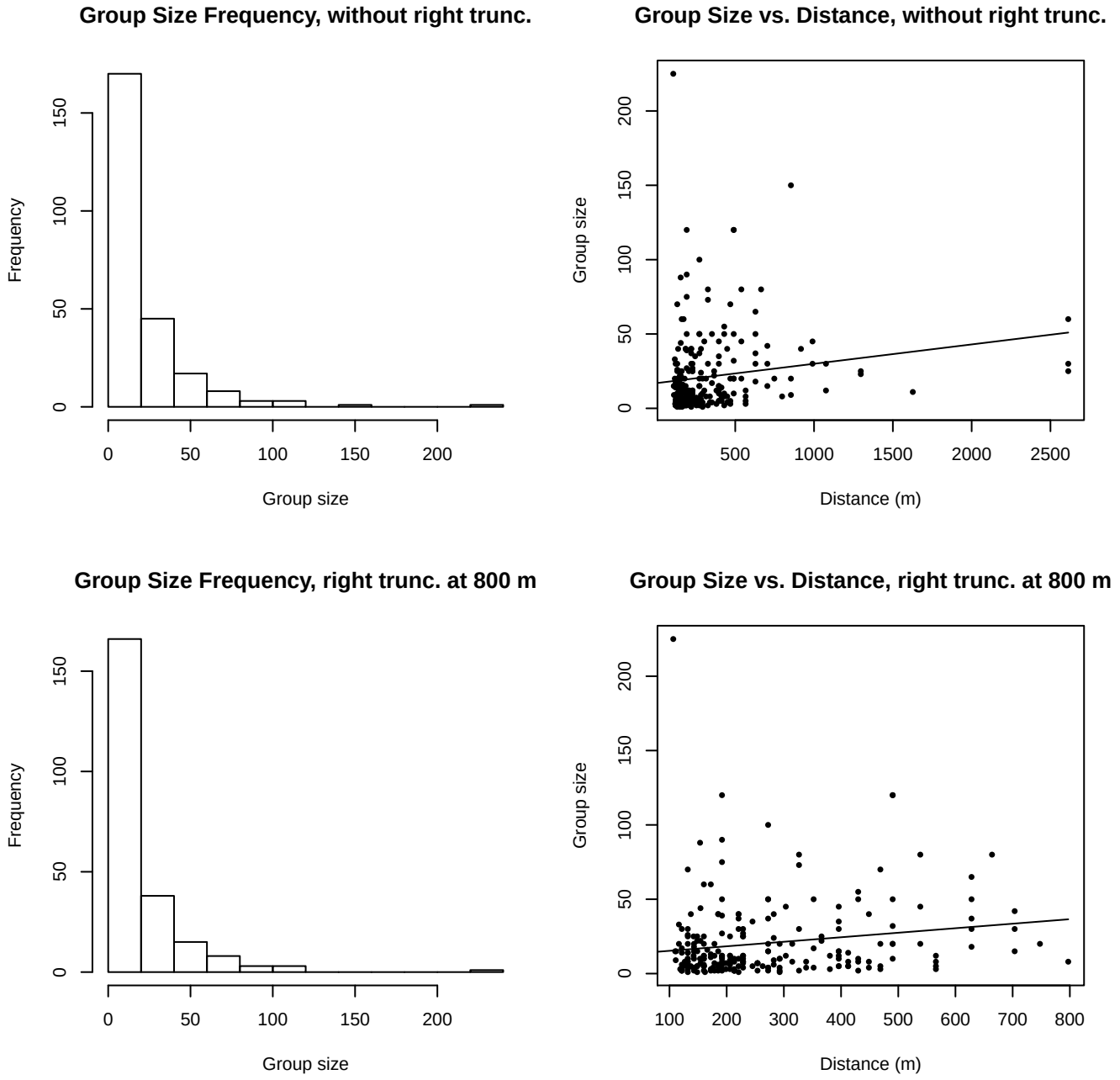


Figure 93: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NARWSS Twin Otters

The sightings were right truncated at 2500m. Due to a reduced frequency of sightings close to the trackline that plausibly resulted from the behavior of the observers and/or the configuration of the survey platform, the sightings were left truncted as well. Sightings closer than 160 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances. The vertical sighting angles were heaped at 10 degree increments up to 80 degrees and 1 degree increments thereafter, so the candidate detection functions were fitted using linear bins scaled accordingly.

Covariate	Description

beaufort	Beaufort sea state.
quality	Survey-specific index of the quality of observation conditions, utilizing relevant factors other than Beaufort sea state (see methods).
size	Estimated size (number of individuals) of the sighted group.

Table 62: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	471
hr			quality, size	Yes	2.35	466
hr	poly	2		Yes	4.56	438
hr	poly	4		Yes	5.38	449
hr			beaufort	Yes	10.57	466
hr				Yes	10.95	461
hr			quality	Yes	12.95	461
hn	cos	2		Yes	17.98	425
hn	cos	3		Yes	38.04	357
hn			size	Yes	103.14	500
hn			beaufort, size	Yes	104.01	500
hn			quality, size	Yes	104.63	500
hn			beaufort, quality, size	Yes	105.82	500
hn			beaufort	Yes	119.95	498
hn				Yes	120.66	498
hn	herm	4		Yes	121.76	498
hn			beaufort, quality	Yes	121.93	498
hn			quality	Yes	122.28	498
hr			size	No		
hr			beaufort, quality	No		
hr			beaufort, quality, size	No		

Table 63: Candidate detection functions for NARWSS Twin Otters. The first one listed was selected for the density model.

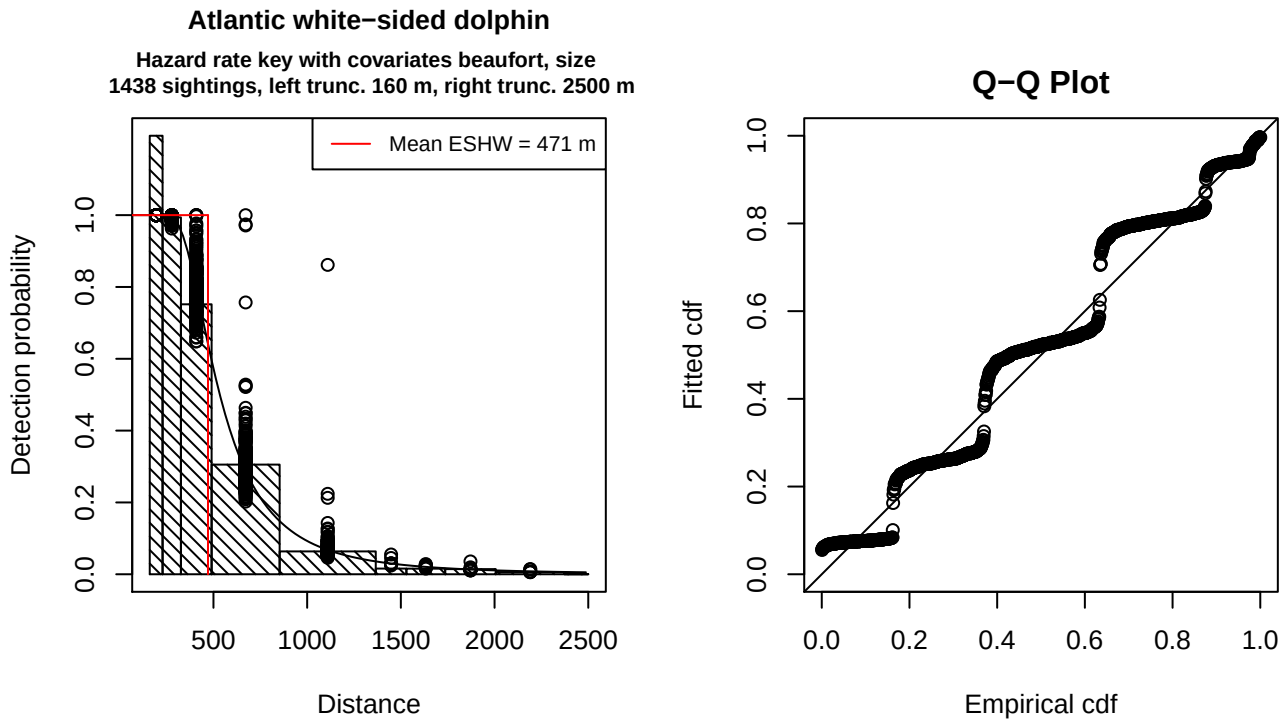


Figure 94: Detection function for NARWSS Twin Otters that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1438
Distance range         :  160.0674  -  2500
AIC                    :  4829.159

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
               estimate         se
(Intercept)  6.22302535 0.07117184
beaufort    -0.04599510 0.02900356
size         0.08434032 0.02730089

Shape parameters:
            estimate         se
(Intercept) 1.155304 0.04242395

                        Estimate           SE         CV
Average p              0.1858489 6.473284e-03 0.03483091
N in covered region 7737.4698220 3.265445e+02 0.04220301
```

Additional diagnostic plots:

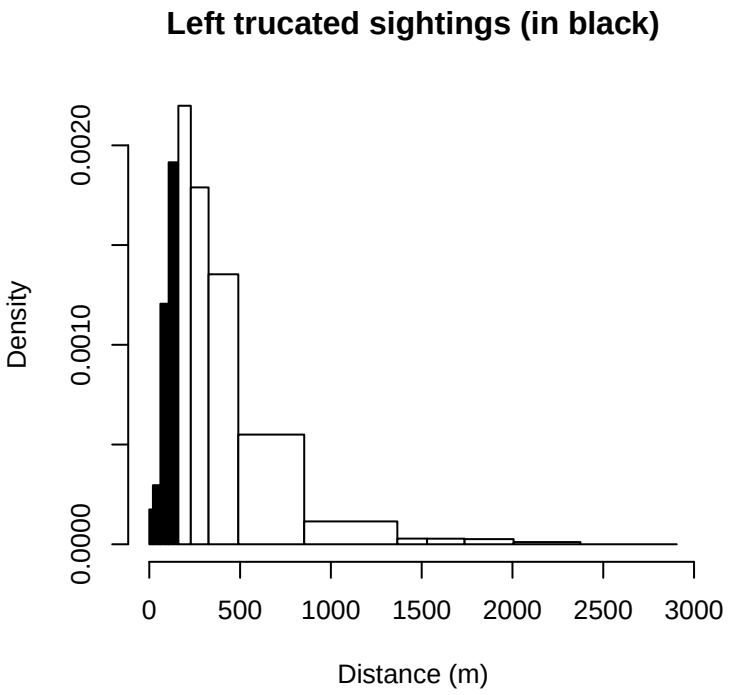


Figure 95: Density of sightings by perpendicular distance for NARWSS Twin Otters. Black bars on the left show sightings that were left truncated.

Figure 96: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

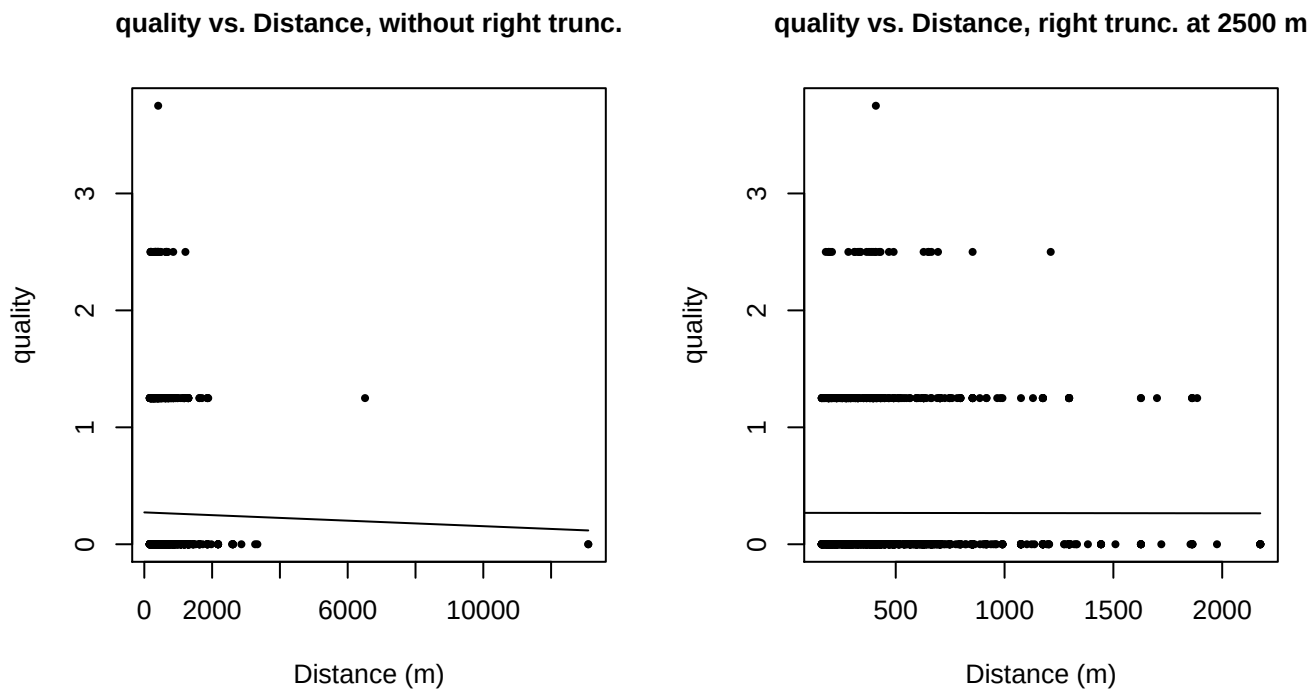


Figure 97: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

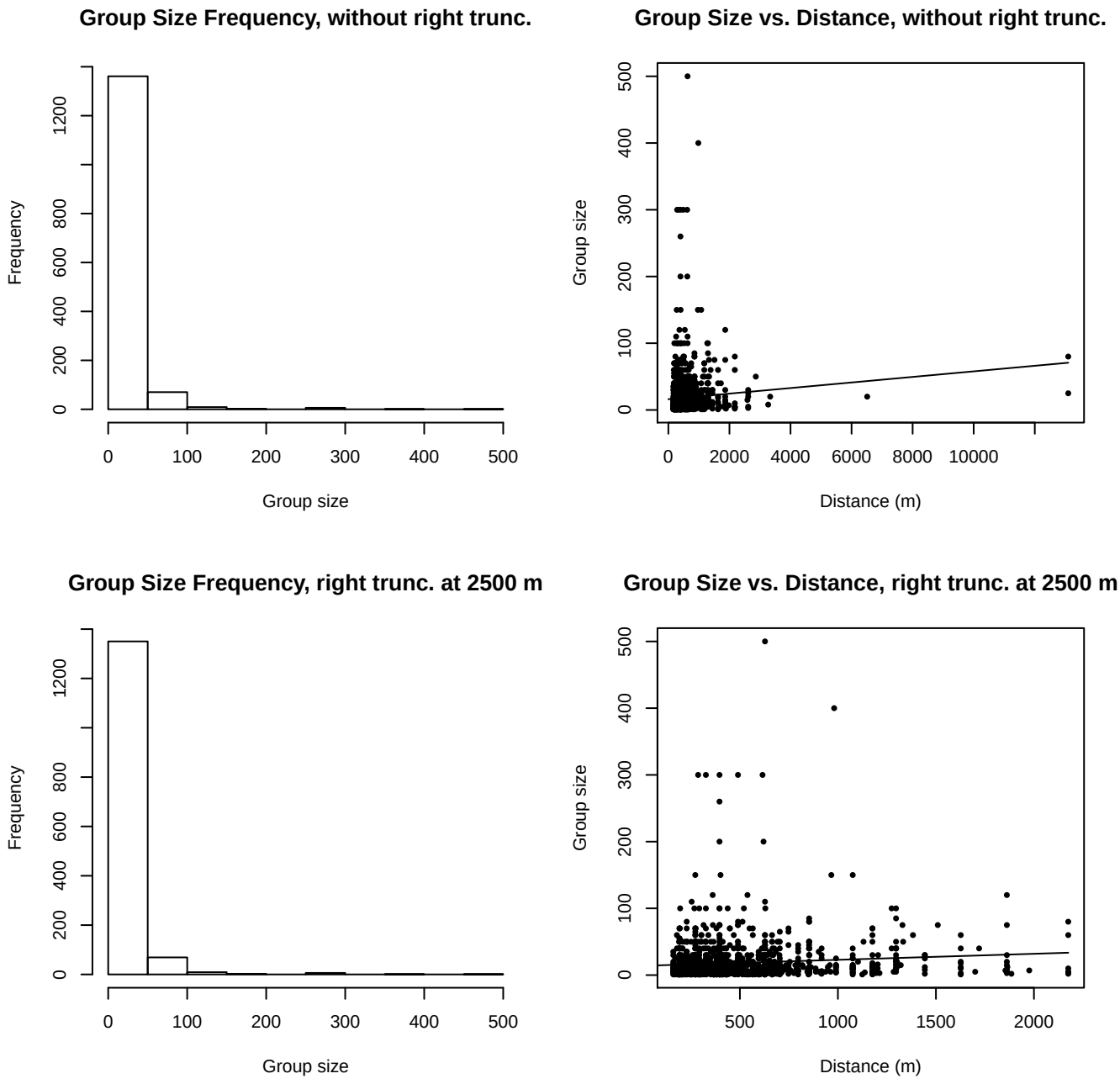


Figure 98: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

g(0) Estimates

Platform	Surveys	Group Size	*g(0)*	Biases Addressed	Source
Shipboard	Binocular Surveys	1-20	0.856	Perception	Barlow and Forney (2007)
		>20	0.970	Perception	Barlow and Forney (2007)
Shipboard	Naked Eye Surveys	Any	0.27	Perception	Palka (2006)
Aerial	All	1-5	0.43	Both	Palka (2006)
		>5	0.960	Both	Carretta et al. (2000)

Table 64: Estimates of *g(0)* used in this density model.

For shipboard surveys that utilized bigeye binoculars, we were unable to locate species-specific g(0) estimates in the literature. Instead, we utilized Barlow and Forney's (2007) estimates for delphinids, produced from several years of dual-team surveys that used similar binoculars and protocols to the surveys in our study. This study provided separate estimates for small and large groups, but pooled sightings of several species together to provide a generic estimate for all delphinids, due to sample-size limitations. To our knowledge, there is no species-specific shipboard g(0) estimate that treats small and large groups separately, so we believe Barlow and Forney (2007) provide the best general- purpose alternative. Their estimate accounted for perception bias but not availability bias; dive times for dolphins are short enough that availability bias is not expected to be significant for dolphins observed from shipboard surveys. Only 3 groups were sighted by shipboard surveys that used bigeye binoculars, so the choice of g(0) for these sightings has a negligible effect on the final abundance estimate.

For shipboard surveys that used naked eye observations, we used Palka's (2006) survey-specific g(0) estimate for the 1999 Abel-J naked eye survey. We used the estimate for the upper team, which was the primary team and the one for which we had sightings. This estimate used a dual-team methodology and accounted perception bias but not availability bias. We also used this estimate with the European naked eye surveys, which did not publish g(0) estimates. (The European surveys were not used in the East Coast model documented here, but may have been used in the AFTT model. Please consult the AFTT model documentation for more information.)

For aerial surveys, we were unable to locate species-specific g(0) estimates in the literature. For small groups, defined here as 1-5 individuals, we used Palka's (2006) estimate of g(0) for groups of 1-5 small cetaceans, estimated from two years of aerial surveys using the Hiby (1999) circle-back method. This estimate accounted for both availability and perception bias, but pooled sightings of several species together to provide a generic estimate for all delphinids, due to sample-size limitations. For large groups, defined here as greater than 5 individuals, Palka (2006) assumed that g(0) was 1. When we discussed this with NOAA SWFSC reviewers, they agreed that it was safe to assume that the availability bias component of g(0) was 1 but insisted that perception bias should be slightly less than 1, because it was possible to miss large groups. We agreed to take a conservative approach and obtained our g(0) for large groups from Carretta et al. (2000), who estimated g(0) for both small and large groups of delphinids. We used Carretta et al.'s g(0) estimate for groups of 1-25 individuals (0.960), rather than their larger one for more than 25 individuals (0.994), to account for the fact that we were using Palka's definition of large groups as those with more than 5 individuals.

Density Models

Atlantic white-sided dolphins occur in temperate and sub-polar waters of the North Atlantic (Waring et al. 2014). In the western North Atlantic they occur mainly over the shelf, from central West Greenland as far south as North Carolina. Although stranding records have been reported as far south as Georgia (Waring et al. 2014), the southernmost sighting reported by our surveys was off Virginia, and all of the others were from New York and waters to the north. Given that the species is not reported to occupy warm-water habitat, we split the study area at the at the north wall of the Gulf Stream, separating the cold northern waters, representing probable habitat, from warm southern waters, which we assumed were unoccupied.

Palka et al. (1997) reported that spatiotemporal patterns in sightings and strandings indicate seasonal shifts in Atlantic white-sided dolphin distribution, suggesting a more northerly distribution in summer and southerly in winter, but did not report

evidence of specific, large- scale migrations that would warrant defining multiple seasons under our modeling methodology. Accordingly, we fitted a single, year-round model that incorporated all available survey data north of the Gulf Stream.

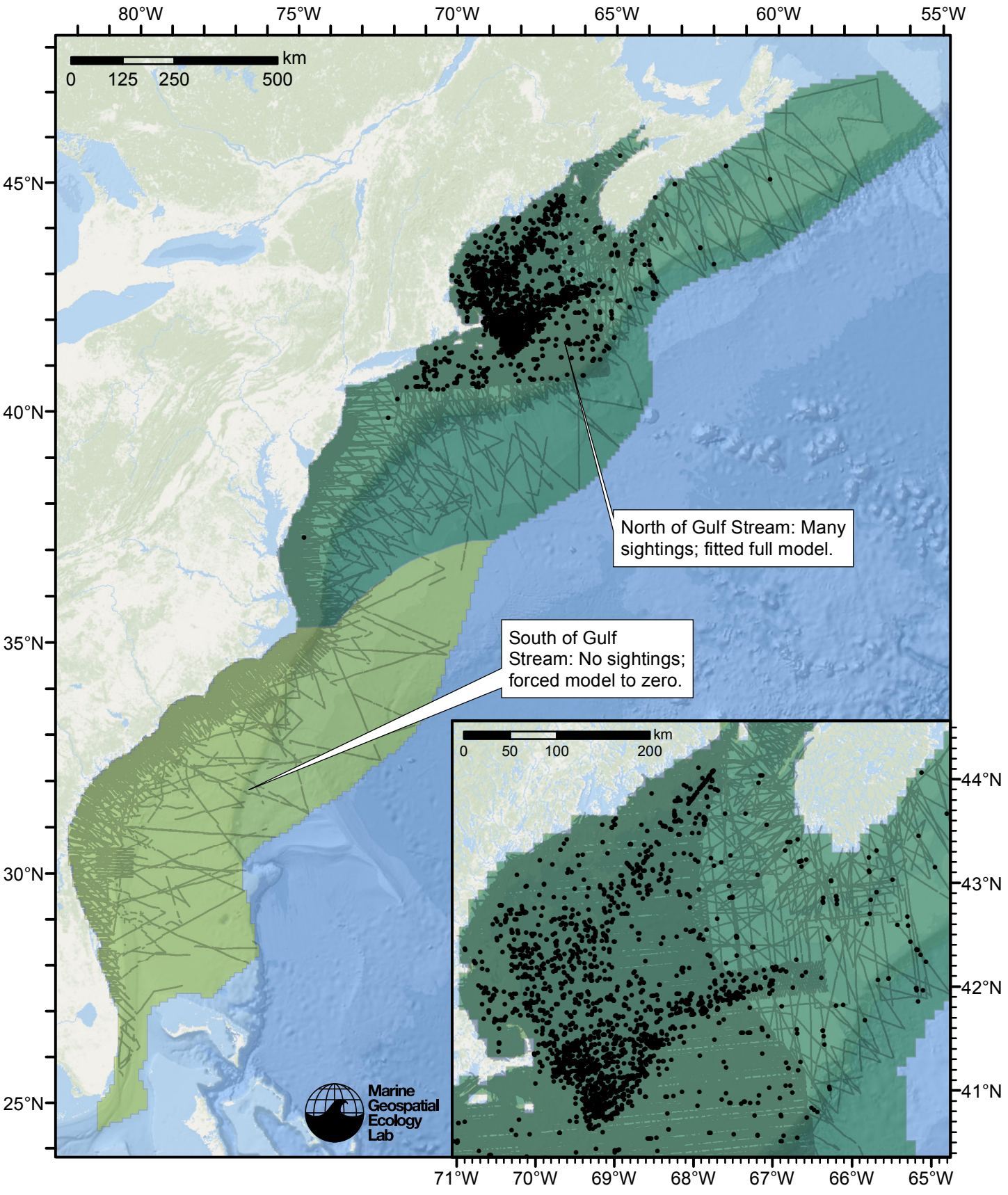


Figure 99: Atlantic white-sided dolphin density model schematic. All on-effort sightings are shown, including those that were truncated when detection functions were fitted.

Climatological Model

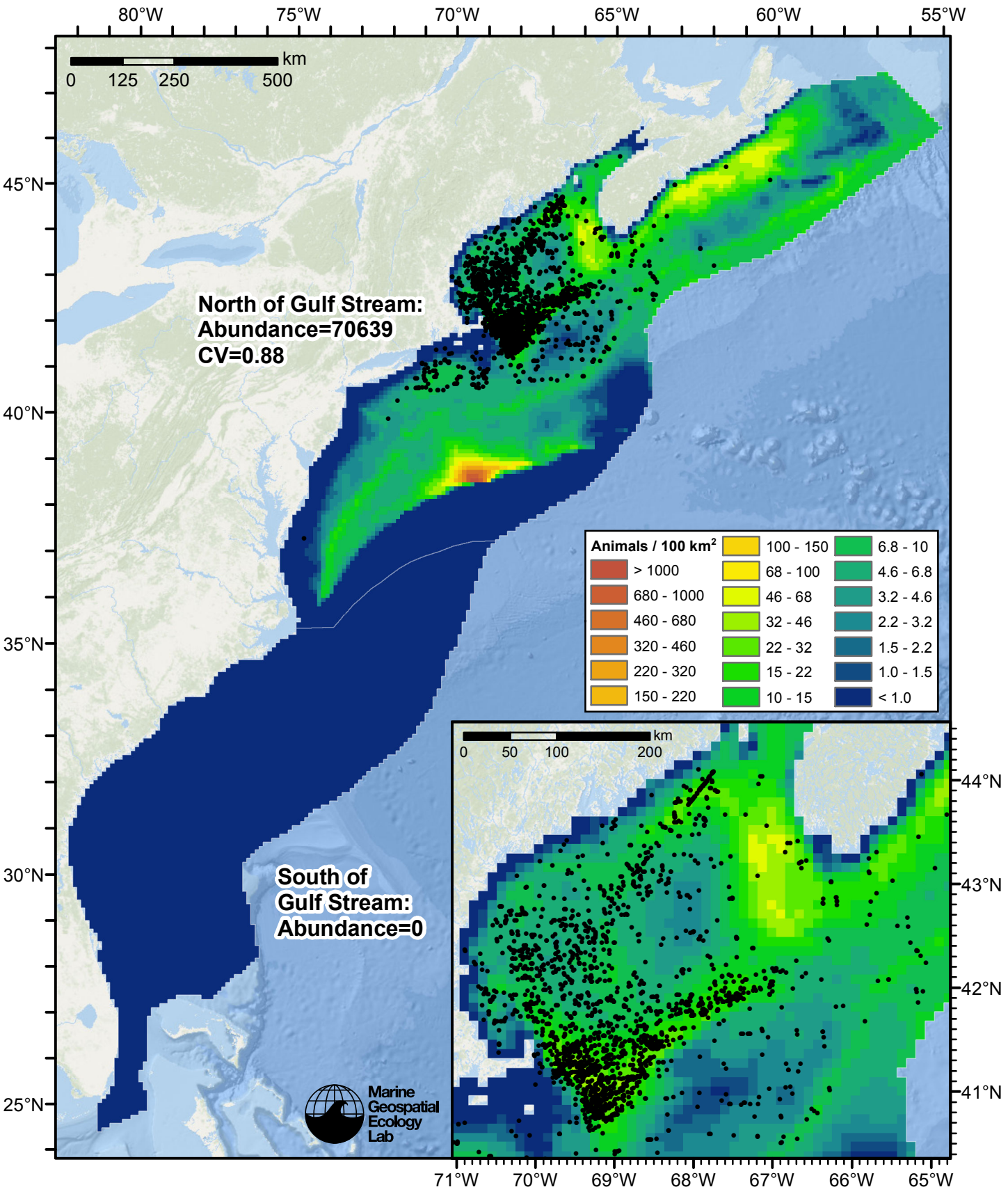


Figure 100: Atlantic white-sided dolphin density predicted by the climatological model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

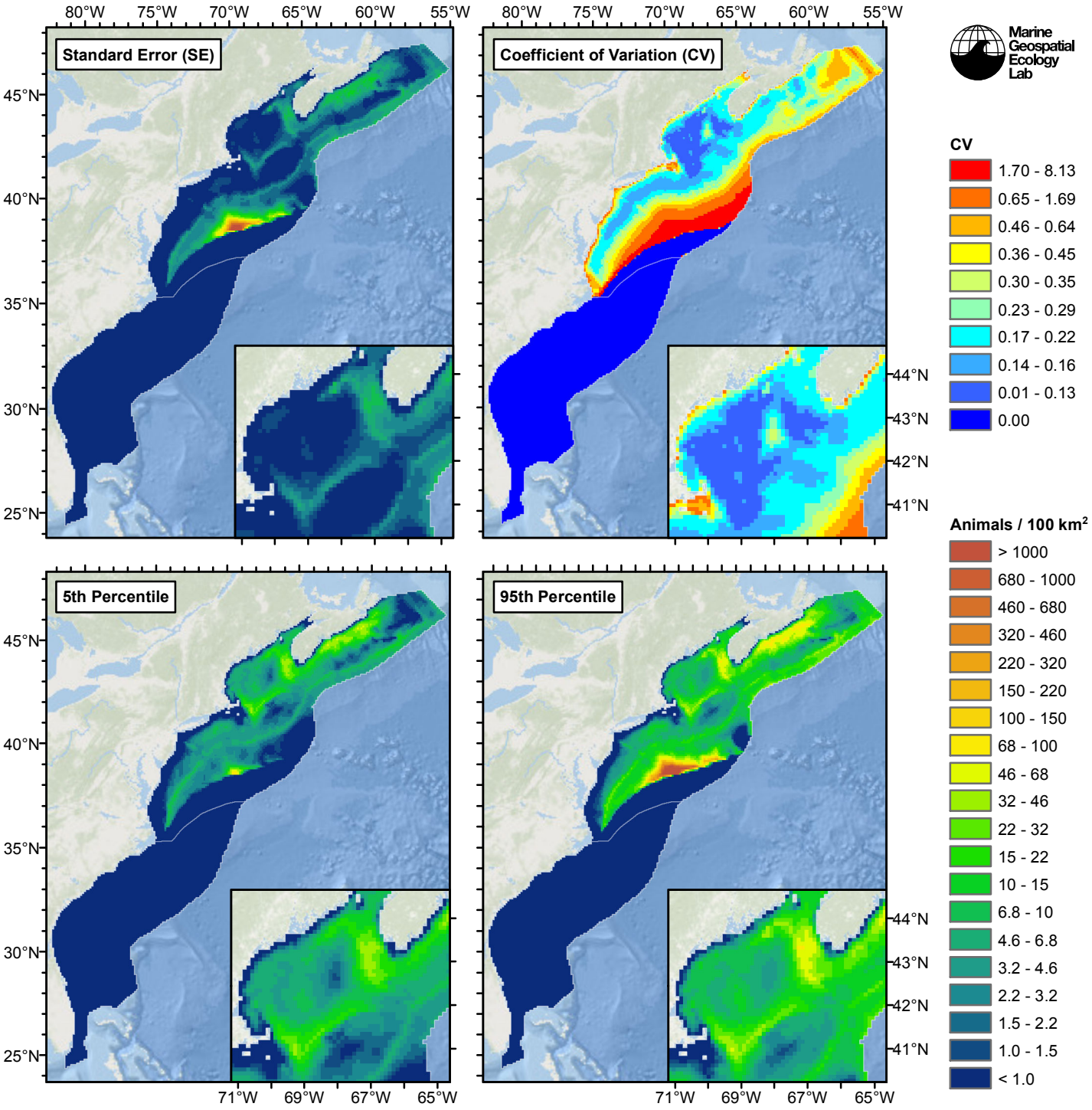


Figure 101: Estimated uncertainty for the climatological model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

North of Gulf Stream

Statistical output

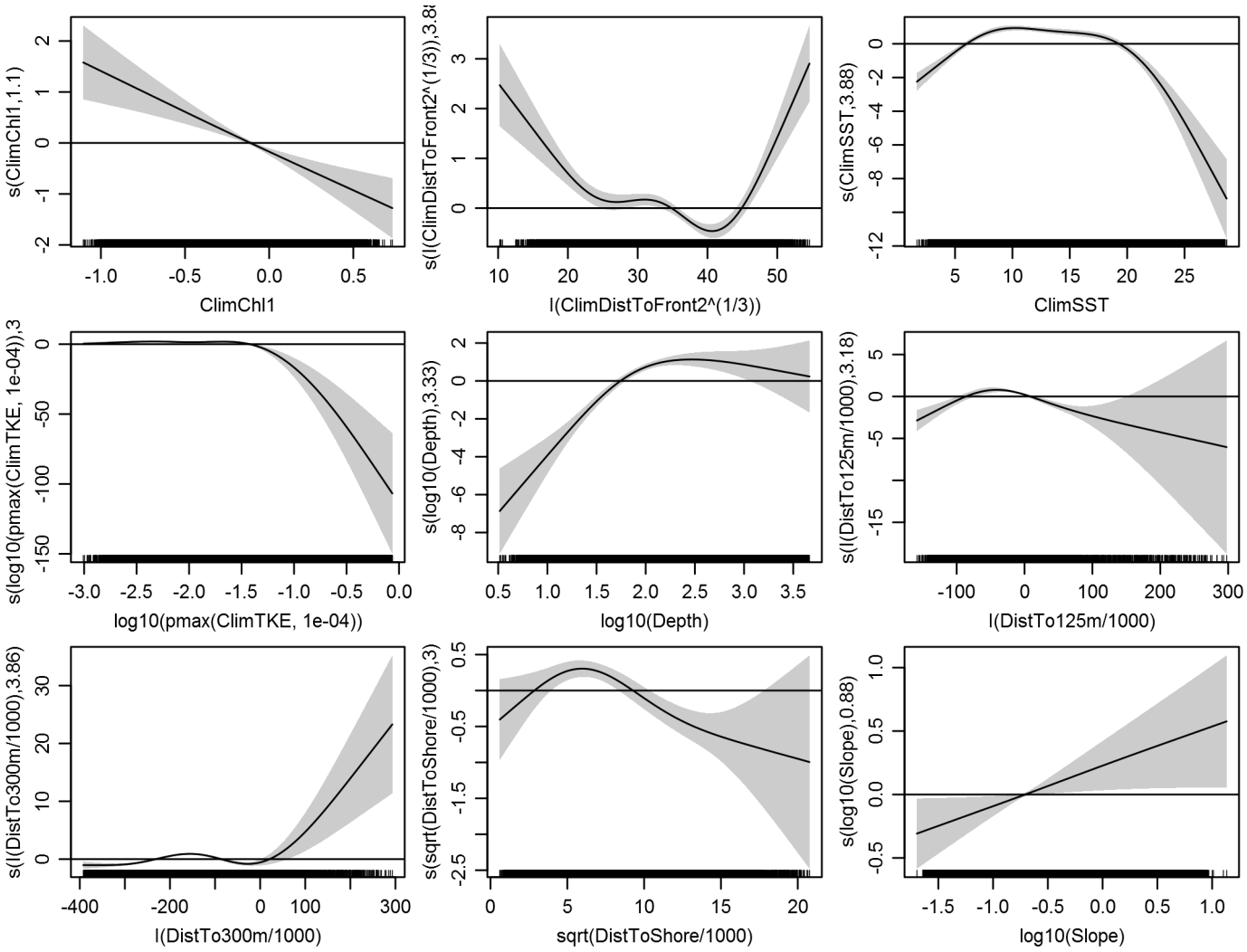
```
Rscript.exe: This is mgcv 1.8-3. For overview type 'help("mgcv-package")'.


Family: Tweedie(p=1.411)
```

```
Link function: log

Formula:
abundance ~ offset(log(area_km2)) + s(log10(Depth), bs = "ts",
    k = 5) + s(sqrt(DistToShore/1000), bs = "ts", k = 5) + s(log10(Slope),
    bs = "ts", k = 5) + s(I(DistTo125m/1000), bs = "ts", k = 5) +
    s(I(DistTo300m/1000), bs = "ts", k = 5) + s(ClimSST, bs = "ts",
    k = 5) + s(I(ClimDistToFront2^(1/3)), bs = "ts", k = 5) +
    s(log10(pmax(ClimTKE, 1e-04)), bs = "ts", k = 5) + s(ClimChl1,
    bs = "ts", k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -5.3805     0.3312  -16.25   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                                edf Ref.df      F  p-value
s(log10(Depth))               3.3314      4 28.029  < 2e-16 ***
s(sqrt(DistToShore/1000))     2.9986      4  9.564 1.92e-09 ***
s(log10(Slope))               0.8768      4  1.374  0.00965 **
s(I(DistTo125m/1000))         3.1800      4 19.685  < 2e-16 ***
s(I(DistTo300m/1000))         3.8583      4 57.392  < 2e-16 ***
s(ClimSST)                    3.8830      4 50.482  < 2e-16 ***
s(I(ClimDistToFront2^(1/3)))  3.8823      4 23.220  < 2e-16 ***
s(log10(pmax(ClimTKE, 1e-04))) 3.8497     4  7.669 1.81e-06 ***
s(ClimChl1)                   1.1005      4  6.925 6.62e-08 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.0207   Deviance explained = 22.7%
-REML =  13446  Scale est. = 122.84    n = 64653

All predictors were significant. This is the final model.
Creating term plots.
Diagnostic output from gam.check():

Method: REML   Optimizer: outer newton
full convergence after 19 iterations.
Gradient range [-6.08371e-06,2.043216e-06]
(score 13446.29 & scale 122.8353).
Hessian positive definite, eigenvalue range [0.3395185,3128.647].
Model rank =  37 / 37

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                                k'   edf k-index p-value
s(log10(Depth))               4.000 3.331   0.607    0.00
s(sqrt(DistToShore/1000))     4.000 2.999   0.628    0.01
s(log10(Slope))               4.000 0.877   0.641    0.02
s(I(DistTo125m/1000))         4.000 3.180   0.646    0.08
s(I(DistTo300m/1000))         4.000 3.858   0.655    0.14
s(ClimSST)                    4.000 3.883   0.639    0.02
s(I(ClimDistToFront2^(1/3)))  4.000 3.882   0.657    0.22
s(log10(pmax(ClimTKE, 1e-04))) 4.000 3.850  0.636    0.02
s(ClimChl1)                   4.000 1.100   0.654    0.10
```

Predictors retained during the model selection procedure: Depth, DistToShore, Slope, DistTo125m, DistTo300m, ClimSST, ClimDistToFront2, ClimTKE, ClimChl1

Predictors dropped during the model selection procedure:

Model term plots



Diagnostic plots

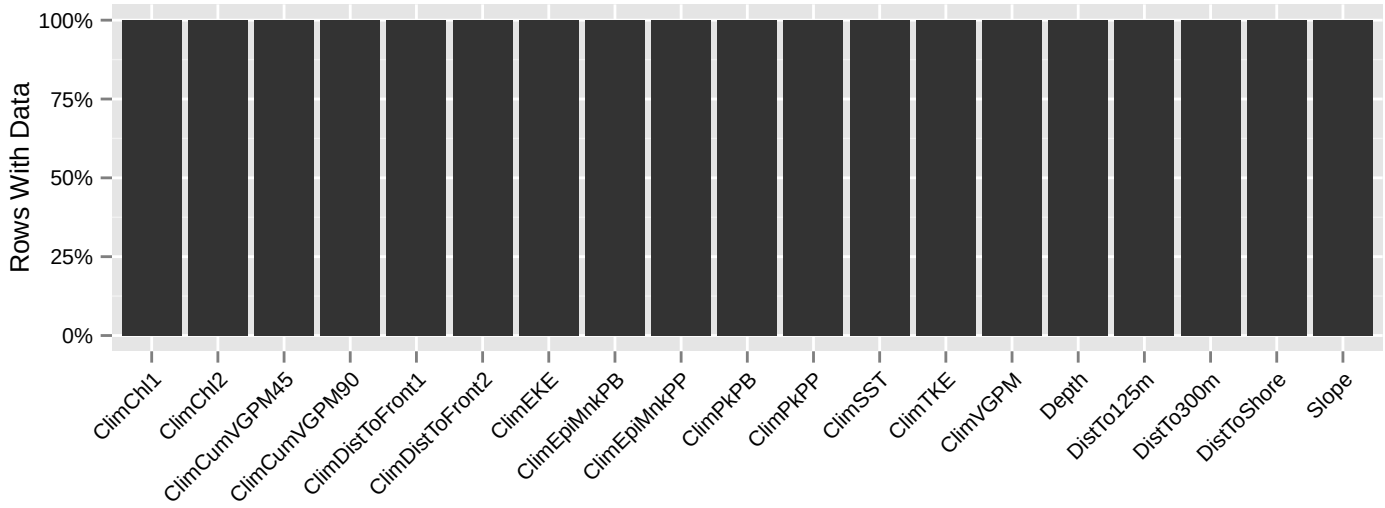


Figure 102: Segments with predictor values for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to assess how many segments would be lost by including a given predictor in a model.

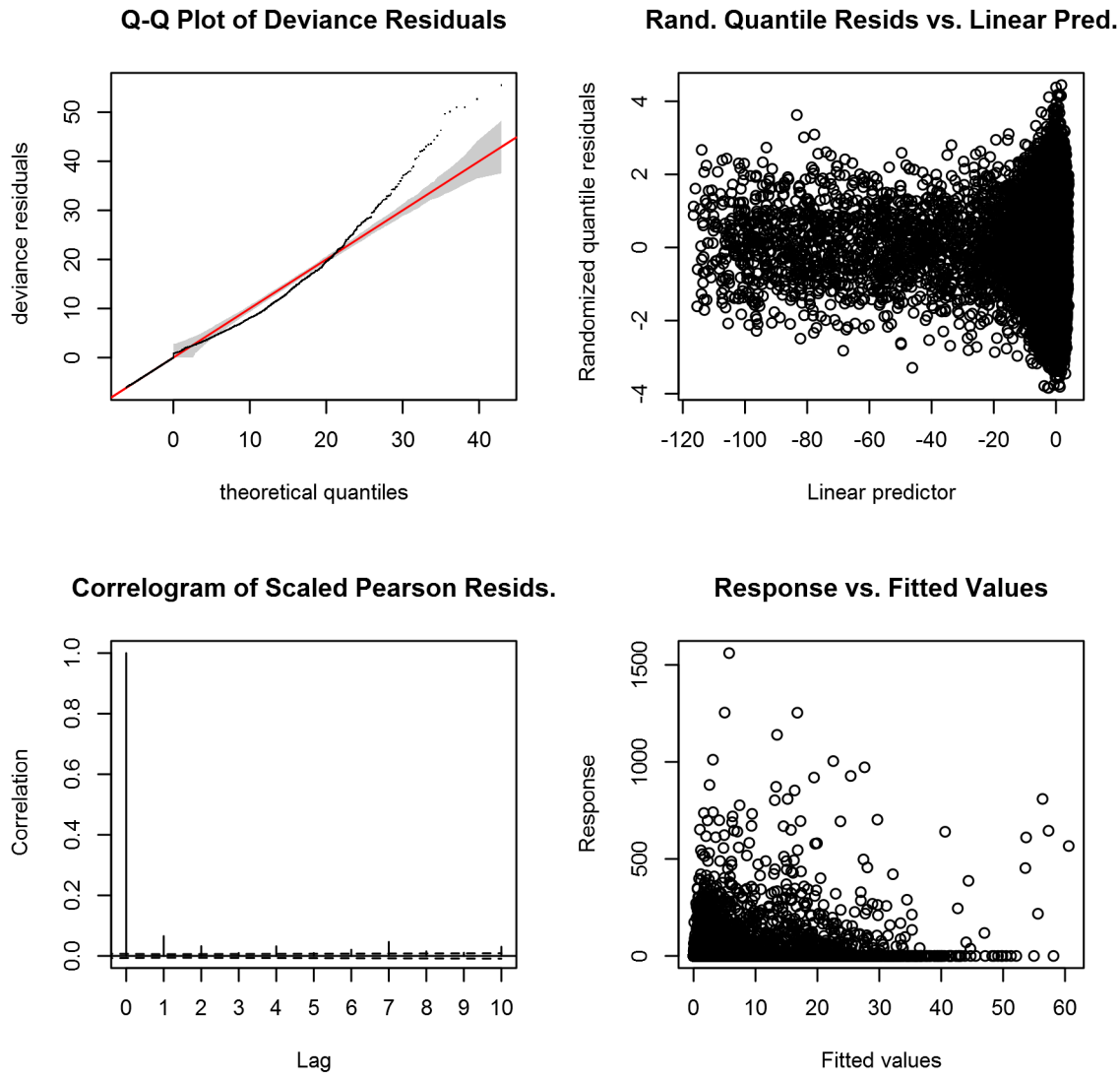


Figure 103: Statistical diagnostic plots for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream.

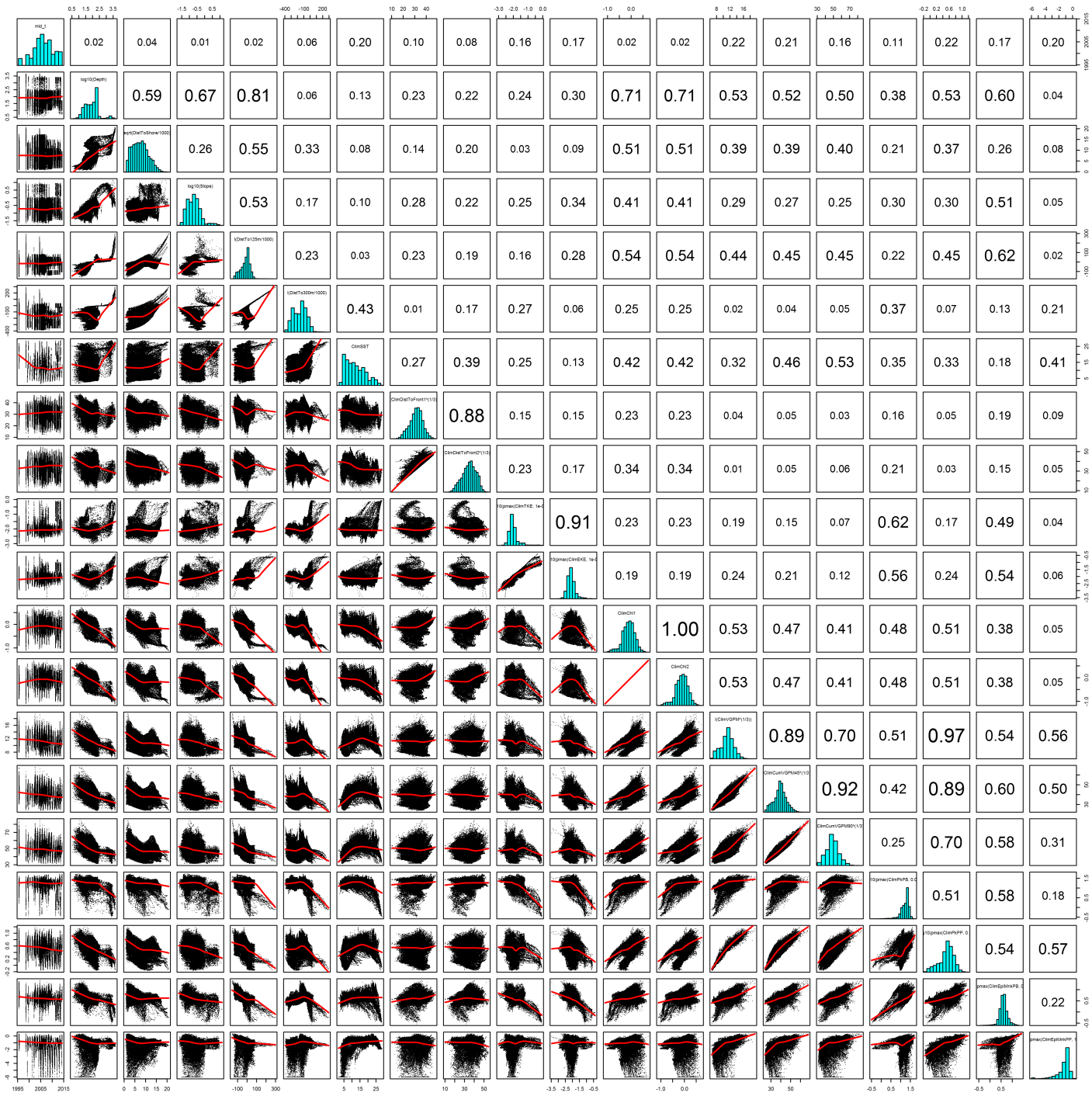


Figure 104: Scatterplot matrix for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

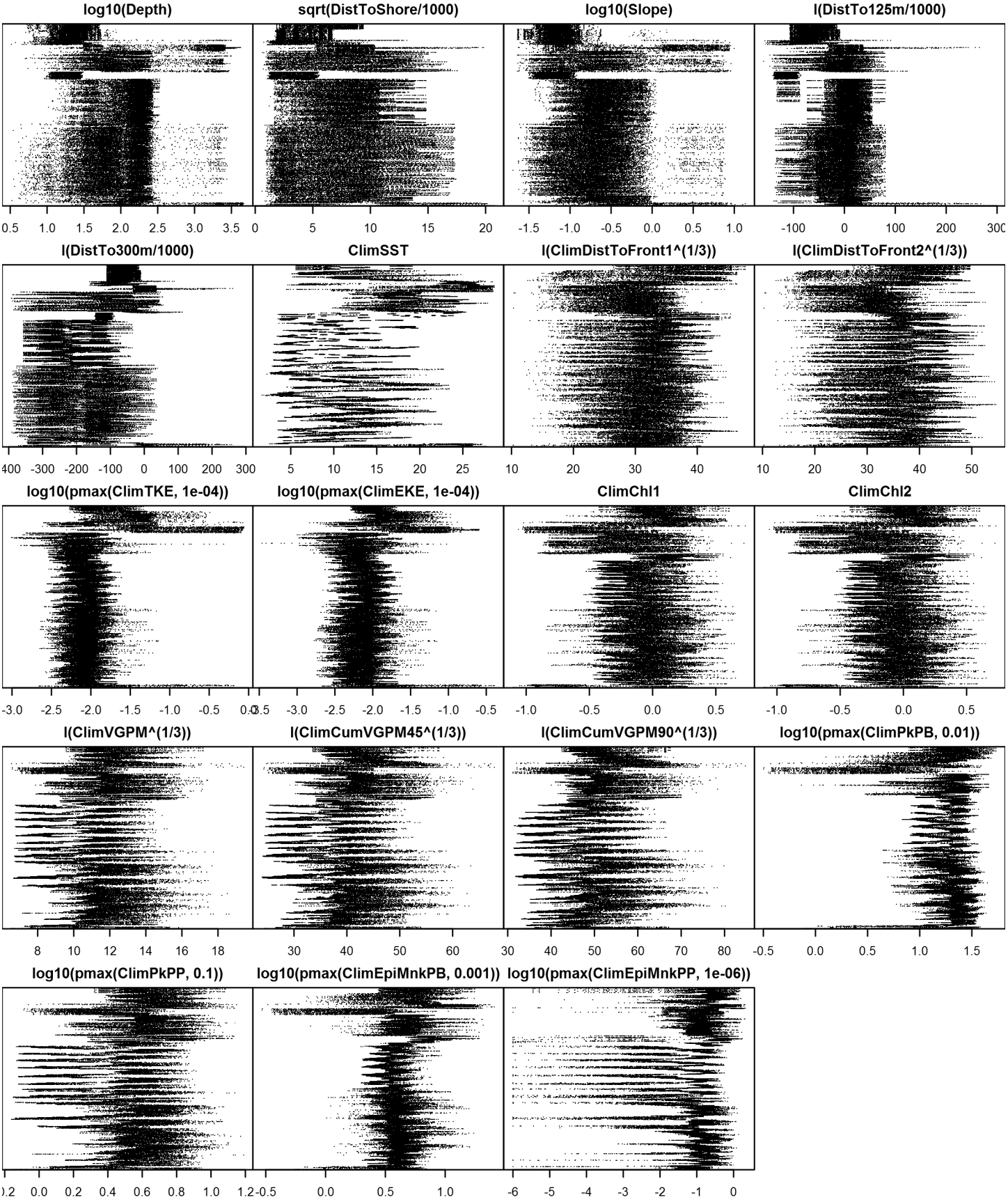


Figure 105: Dotplot for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

South of Gulf Stream

Density assumed to be 0 in this region.

Contemporaneous Model

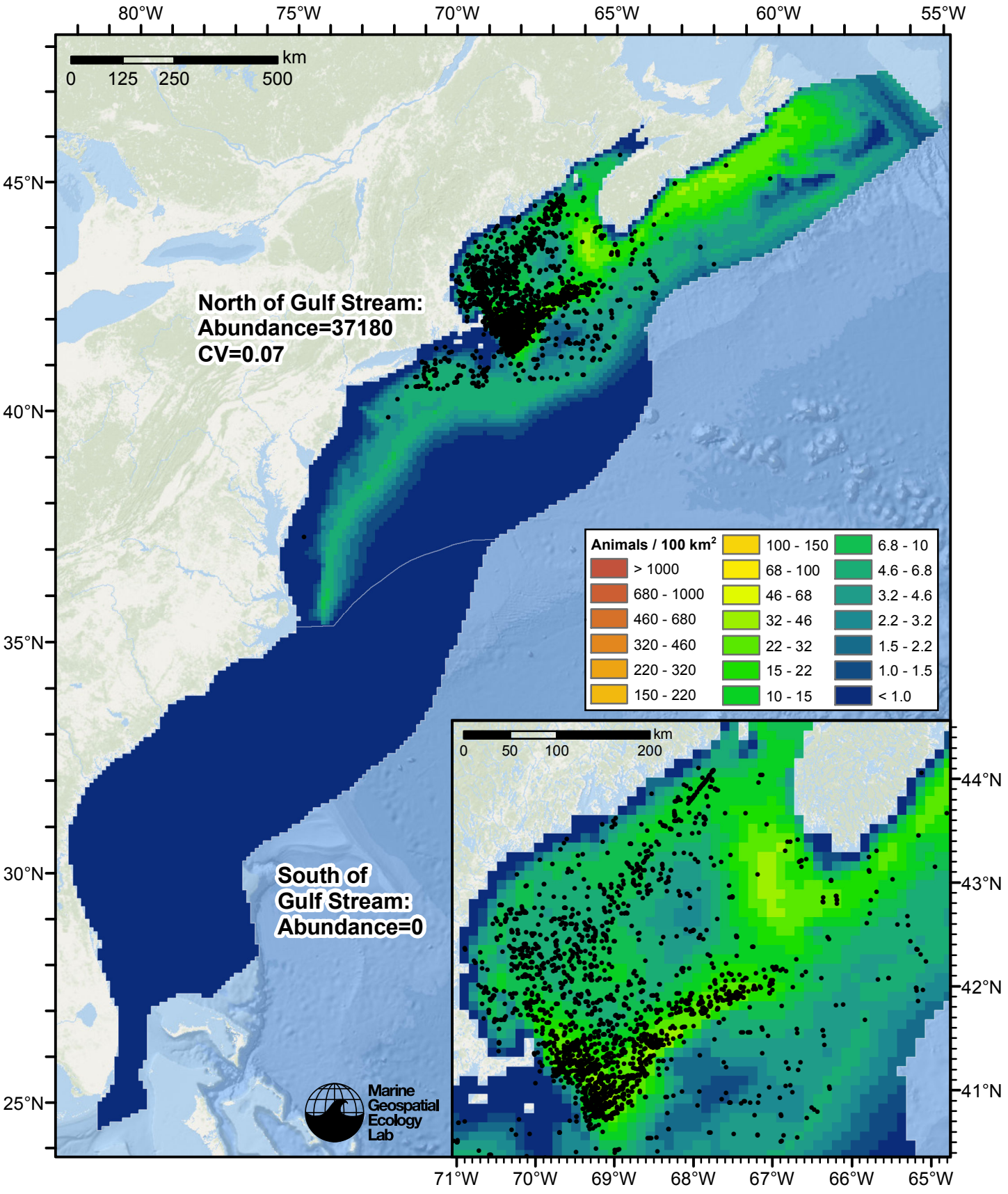


Figure 106: Atlantic white-sided dolphin density predicted by the contemporaneous model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

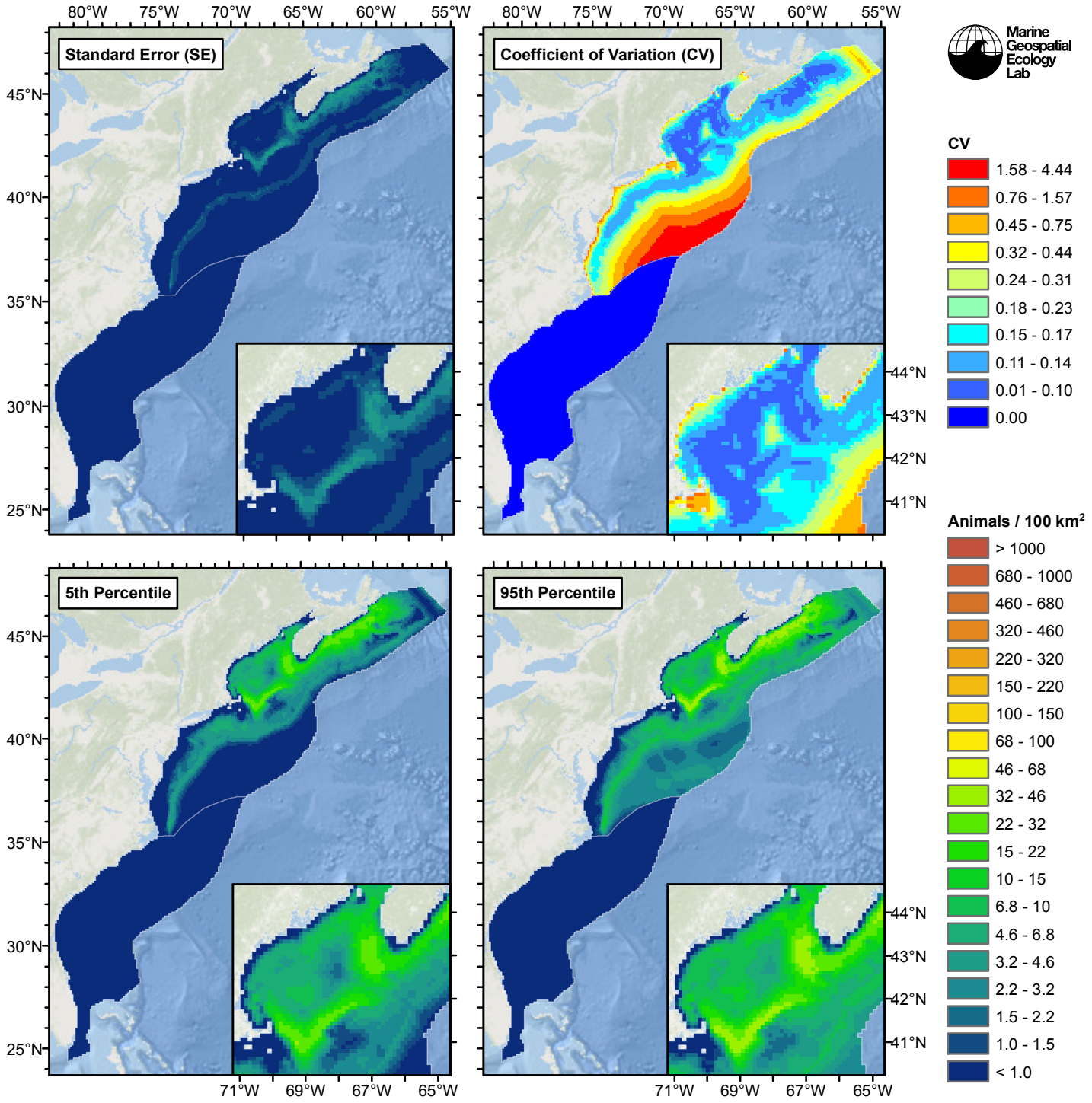


Figure 107: Estimated uncertainty for the contemporaneous model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

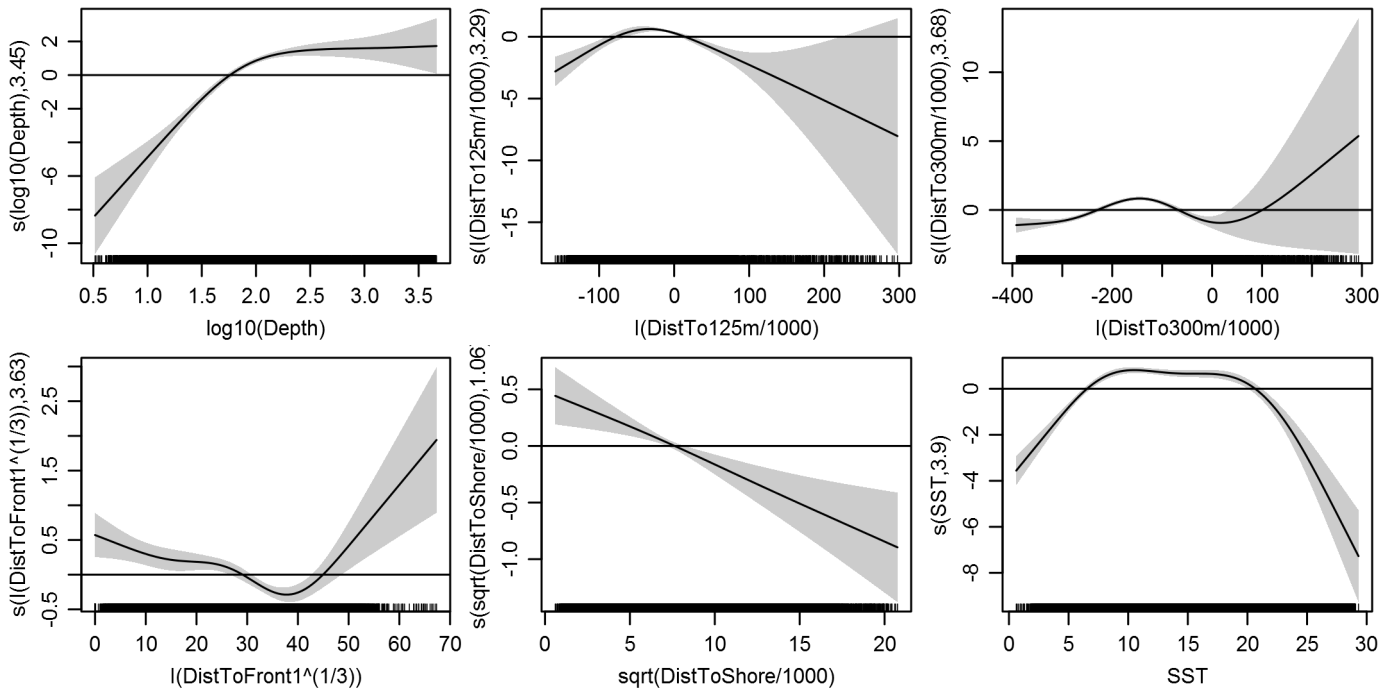
North of Gulf Stream

Statistical output

```
Rscript.exe: This is mgcv 1.8-3. For overview type 'help("mgcv-package")'.


Family: Tweedie(p=1.415)
```

```
Link function: log

Formula:
abundance ~ offset(log(area_km2)) + s(log10(Depth), bs = "ts",
    k = 5) + s(sqrt(DistToShore/1000), bs = "ts", k = 5) + s(I(DistTo125m/1000),
    bs = "ts", k = 5) + s(I(DistTo300m/1000), bs = "ts", k = 5) +
    s(SST, bs = "ts", k = 5) + s(I(DistToFront1^(1/3)), bs = "ts",
    k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -3.76930    0.06478  -58.19   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                            edf Ref.df     F  p-value
s(log10(Depth))           3.455      4 50.28  < 2e-16 ***
s(sqrt(DistToShore/1000)) 1.062      4  4.28 2.06e-05 ***
s(I(DistTo125m/1000))     3.288      4 21.72  < 2e-16 ***
s(I(DistTo300m/1000))     3.681      4 55.09  < 2e-16 ***
s(SST)                    3.901      4 58.92  < 2e-16 ***
s(I(DistToFront1^(1/3)))  3.629      4 10.87 1.37e-09 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.0154   Deviance explained = 20.2%
-REML =  13496  Scale est. = 126.19    n = 64653

All predictors were significant. This is the final model.
Creating term plots.
Diagnostic output from gam.check():

Method: REML   Optimizer: outer newton
full convergence after 11 iterations.
Gradient range [-0.002240854,0.002537826]
(score 13496.12 & scale 126.1874).
Hessian positive definite, eigenvalue range [0.3730057,3118.229].
Model rank =  25 / 25

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                             k'   edf k-index p-value
s(log10(Depth))           4.000 3.455   0.642    0.02
s(sqrt(DistToShore/1000)) 4.000 1.062   0.658    0.12
s(I(DistTo125m/1000))     4.000 3.288   0.642    0.02
s(I(DistTo300m/1000))     4.000 3.681   0.665    0.28
s(SST)                    4.000 3.901   0.654    0.06
s(I(DistToFront1^(1/3)))  4.000 3.629   0.676    0.84

Predictors retained during the model selection procedure: Depth, DistToShore, DistTo125m,
DistTo300m, SST, DistToFront1

Predictors dropped during the model selection procedure: Slope
```

Model term plots



Diagnostic plots

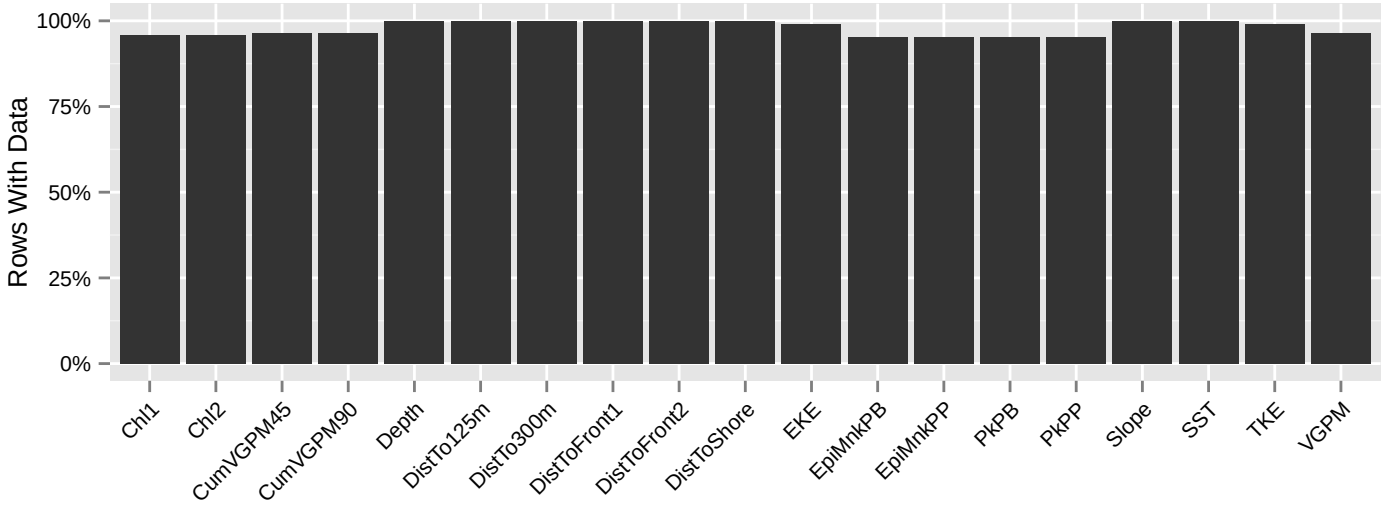


Figure 108: Segments with predictor values for the Atlantic white-sided dolphin Contemporaneous model, North of Gulf Stream. This plot is used to assess how many segments would be lost by including a given predictor in a model.

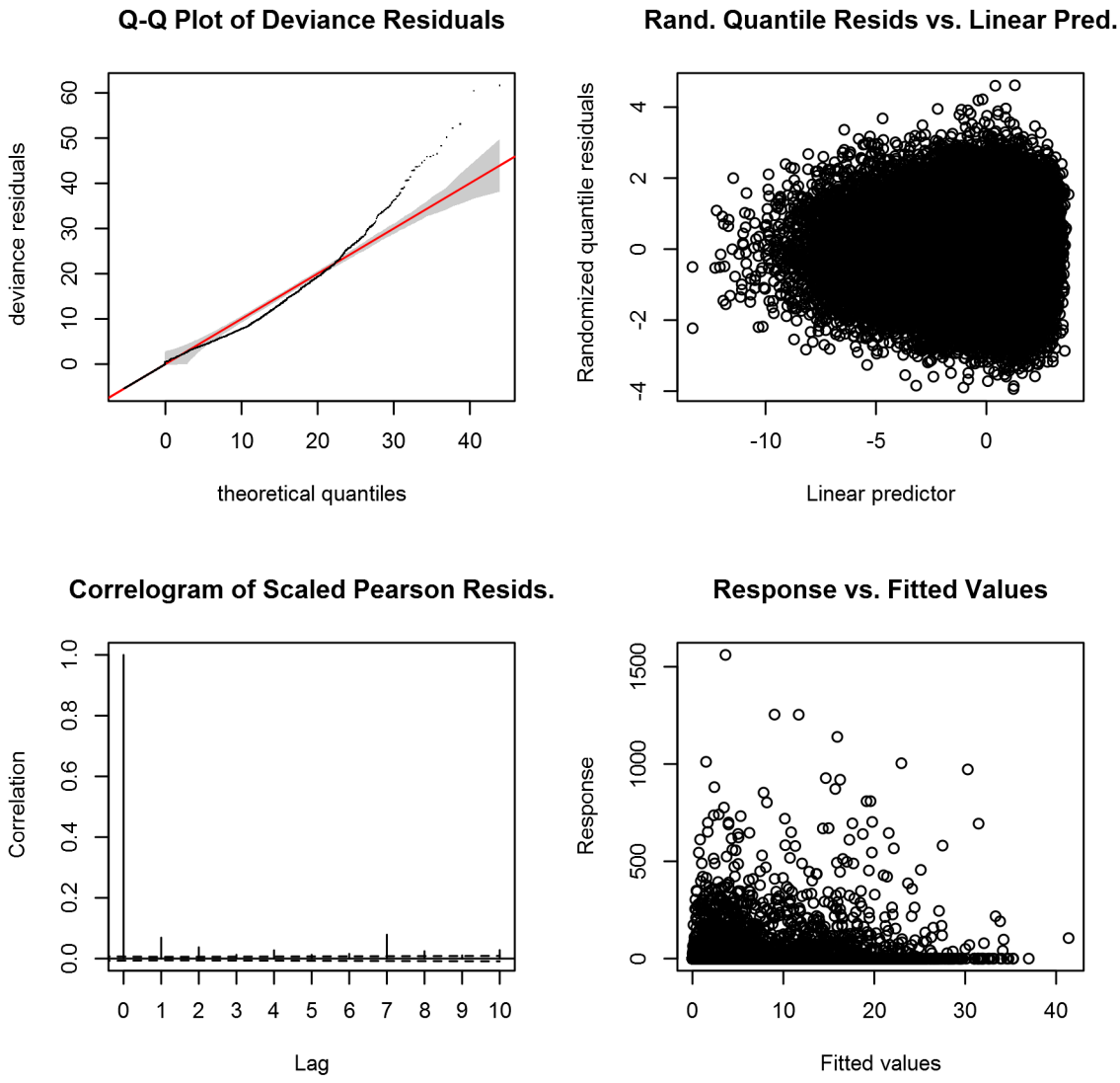


Figure 109: Statistical diagnostic plots for the Atlantic white-sided dolphin Contemporaneous model, North of Gulf Stream.

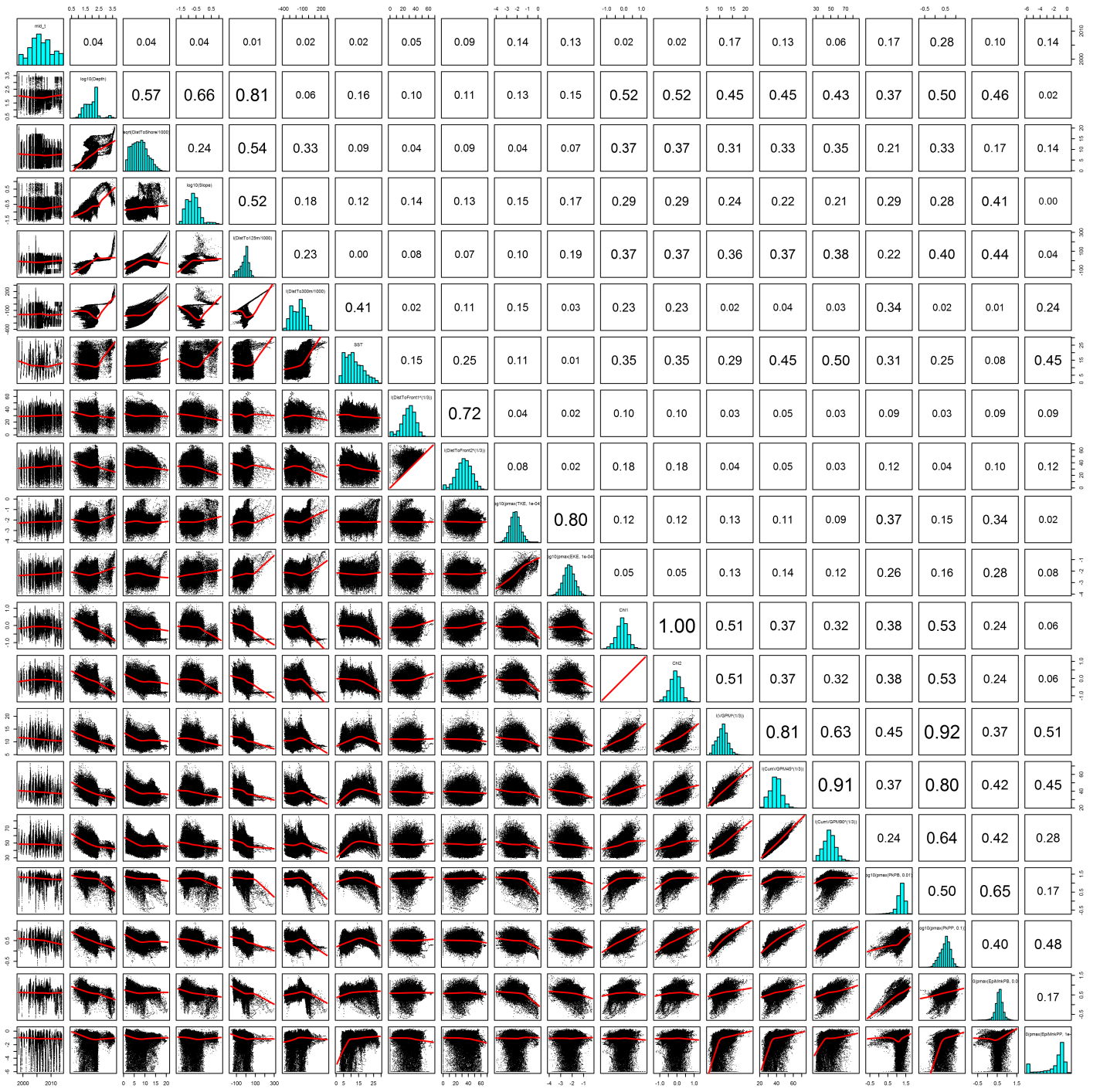


Figure 110: Scatterplot matrix for the Atlantic white-sided dolphin Contemporaneous model, North of Gulf Stream. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

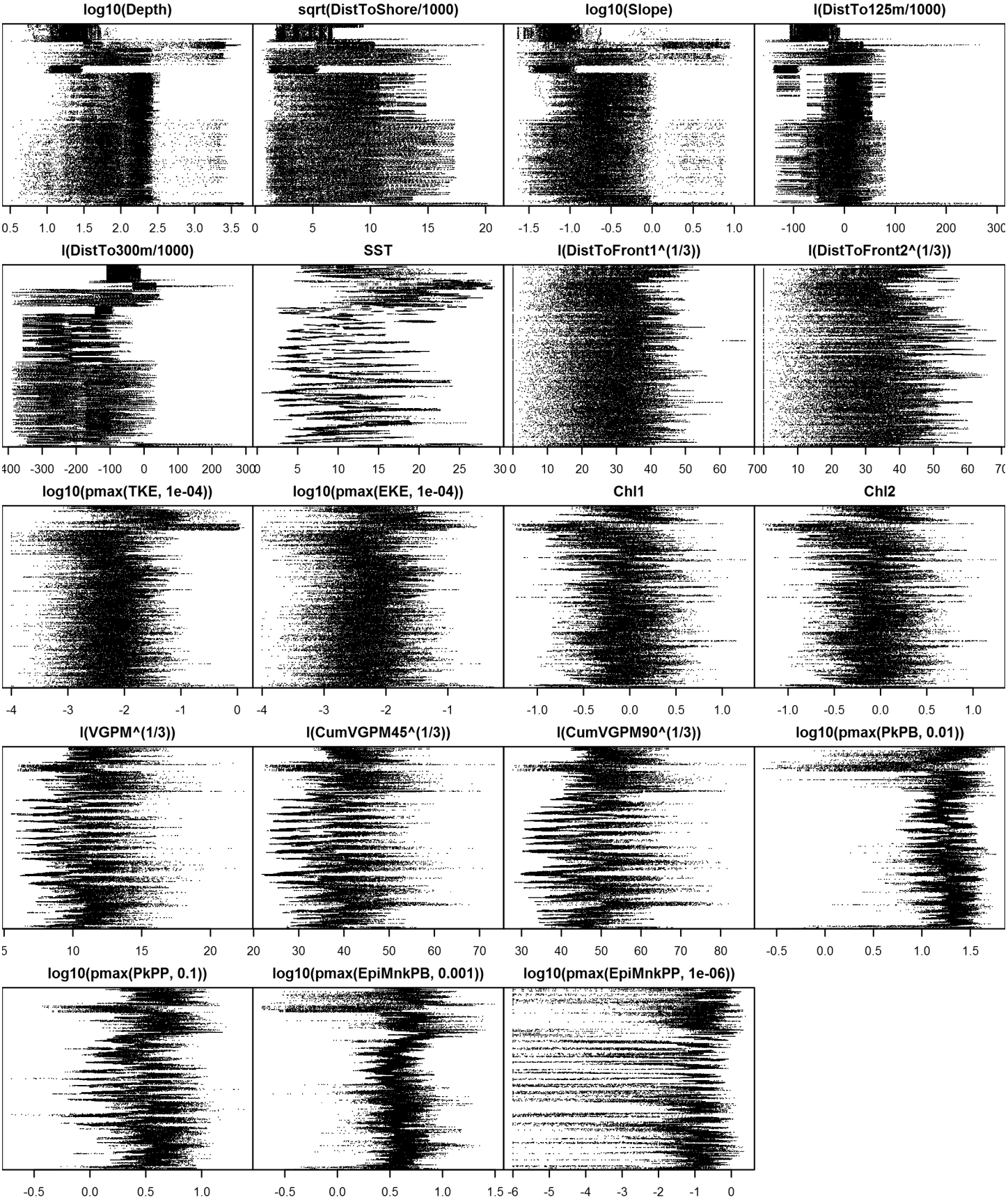


Figure 111: Dotplot for the Atlantic white-sided dolphin Contemporaneous model, North of Gulf Stream. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

South of Gulf Stream

Density assumed to be 0 in this region.

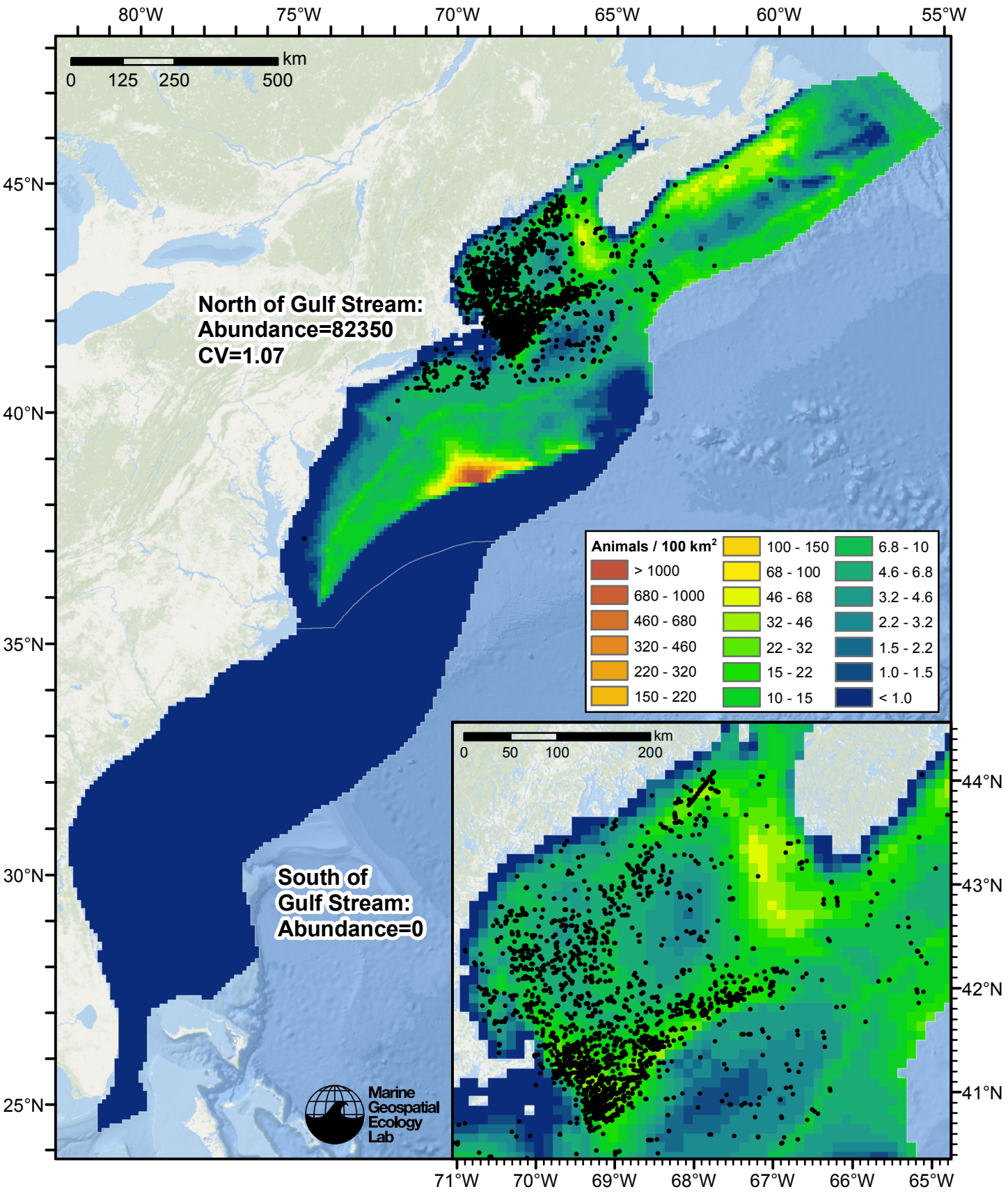


Figure 112: Atlantic white-sided dolphin density predicted by the climatological same segments model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

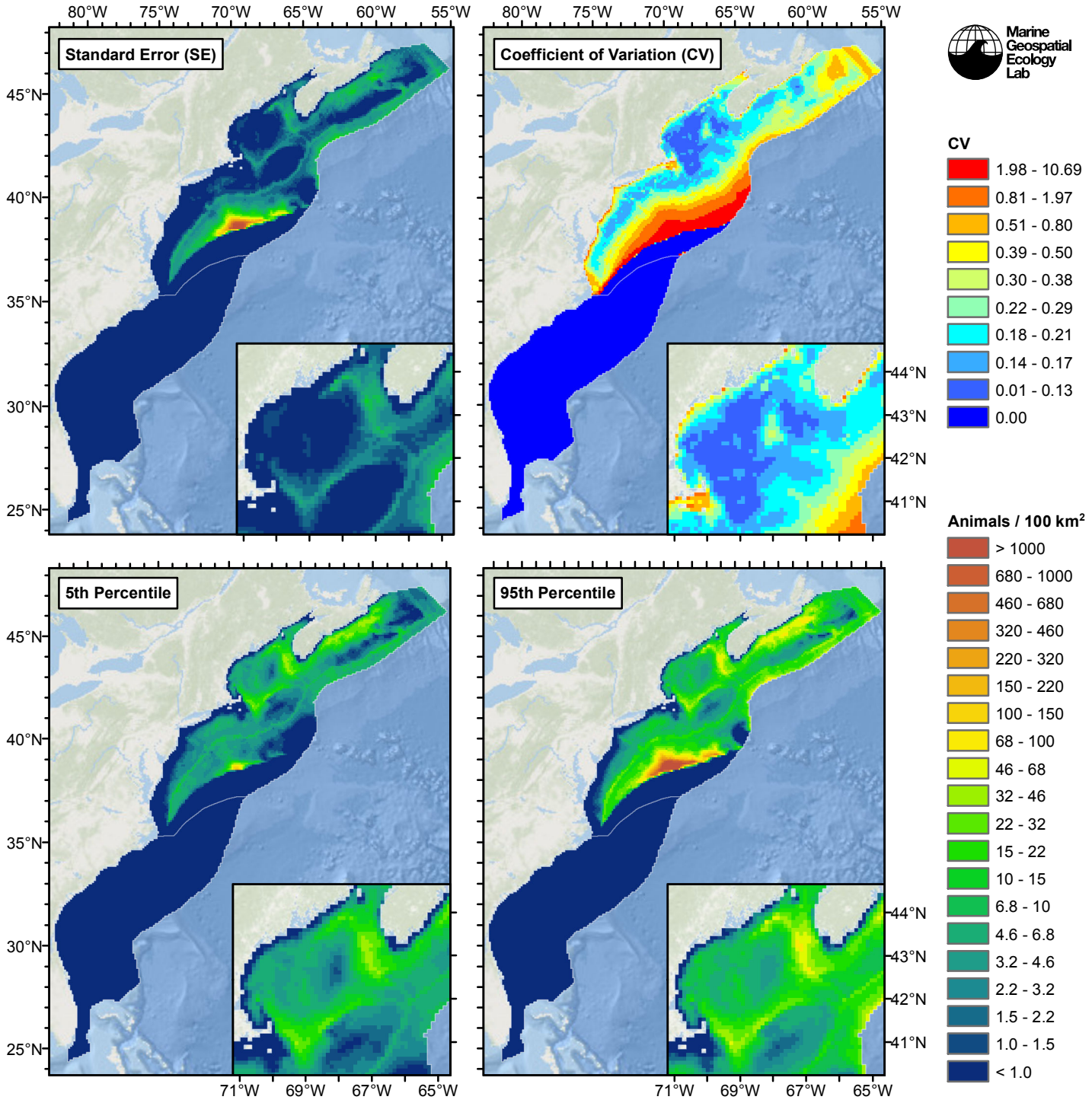


Figure 113: Estimated uncertainty for the climatological same segments model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

North of Gulf Stream

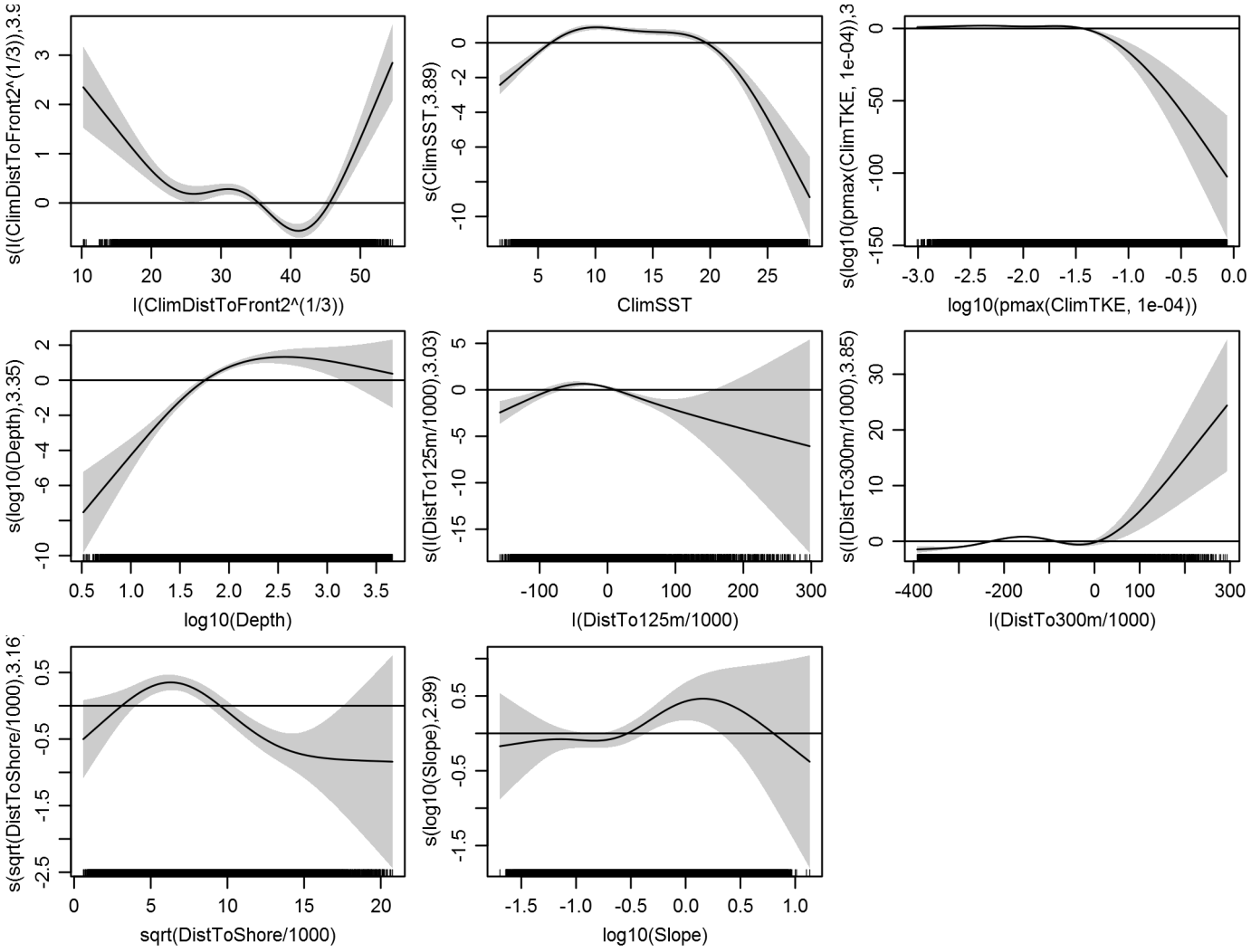
Statistical output

```
Rscript.exe: This is mgcv 1.8-3. For overview type 'help("mgcv-package")'.


Family: Tweedie(p=1.412)
```

```
Link function: log

Formula:
abundance ~ offset(log(area_km2)) + s(log10(Depth), bs = "ts",
    k = 5) + s(sqrt(DistToShore/1000), bs = "ts", k = 5) + s(log10(Slope),
    bs = "ts", k = 5) + s(I(DistTo125m/1000), bs = "ts", k = 5) +
    s(I(DistTo300m/1000), bs = "ts", k = 5) + s(ClimSST, bs = "ts",
    k = 5) + s(I(ClimDistToFront2^(1/3)), bs = "ts", k = 5) +
    s(log10(pmax(ClimTKE, 1e-04)), bs = "ts", k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -5.3059     0.3251  -16.32   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Approximate significance of smooth terms:
                                edf Ref.df      F  p-value
s(log10(Depth))               3.346      4 32.145  < 2e-16 ***
s(sqrt(DistToShore/1000))     3.164      4 13.311 7.53e-13 ***
s(log10(Slope))               2.993      4  3.319  0.00179 **
s(I(DistTo125m/1000))         3.034      4 16.089 1.05e-15 ***
s(I(DistTo300m/1000))         3.851      4 56.441  < 2e-16 ***
s(ClimSST)                    3.893      4 47.902  < 2e-16 ***
s(I(ClimDistToFront2^(1/3)))  3.904      4 23.888  < 2e-16 ***
s(log10(pmax(ClimTKE, 1e-04))) 3.840     4  8.594 2.96e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.0193   Deviance explained = 22.5%
-REML =  13458  Scale est. = 123.23    n = 64653

All predictors were significant. This is the final model.
Creating term plots.
Diagnostic output from gam.check():

Method: REML   Optimizer: outer newton
full convergence after 14 iterations.
Gradient range [-2.073795e-05,1.005096e-06]
(score 13458.26 & scale 123.2328).
Hessian positive definite, eigenvalue range [0.3997358,3123.266].
Model rank =  33 / 33

Basis dimension (k) checking results. Low p-value (k-index<1) may
indicate that k is too low, especially if edf is close to k'.

                                k'   edf k-index p-value
s(log10(Depth))               4.000 3.346   0.705    0.01
s(sqrt(DistToShore/1000))     4.000 3.164   0.712    0.02
s(log10(Slope))               4.000 2.993   0.700    0.01
s(I(DistTo125m/1000))         4.000 3.034   0.700    0.02
s(I(DistTo300m/1000))         4.000 3.851   0.711    0.04
s(ClimSST)                    4.000 3.893   0.713    0.06
s(I(ClimDistToFront2^(1/3)))  4.000 3.904   0.725    0.20
s(log10(pmax(ClimTKE, 1e-04))) 4.000 3.840  0.678    0.00

Predictors retained during the model selection procedure: Depth, DistToShore, Slope, DistTo125m,
DistTo300m, ClimSST, ClimDistToFront2, ClimTKE
```

```
Predictors dropped during the model selection procedure:
```

Model term plots



Diagnostic plots

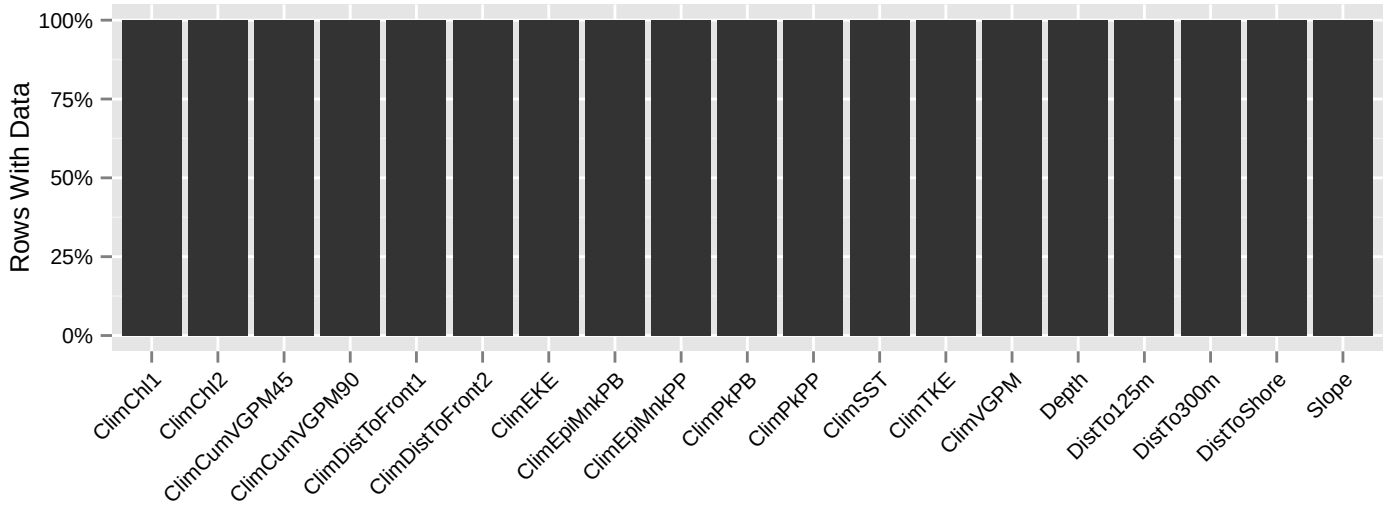


Figure 114: Segments with predictor values for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to assess how many segments would be lost by including a given predictor in a model.

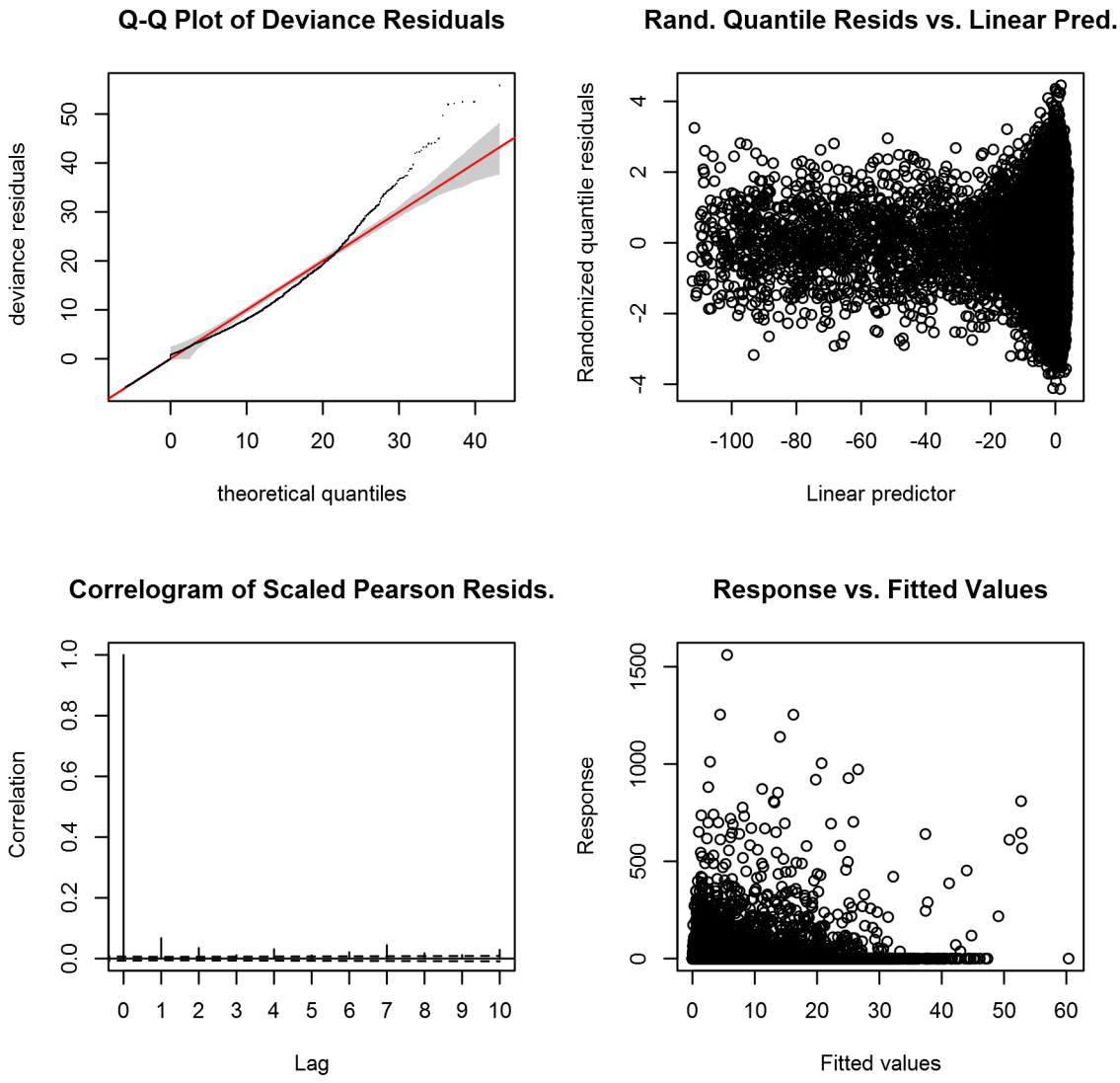


Figure 115: Statistical diagnostic plots for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream.

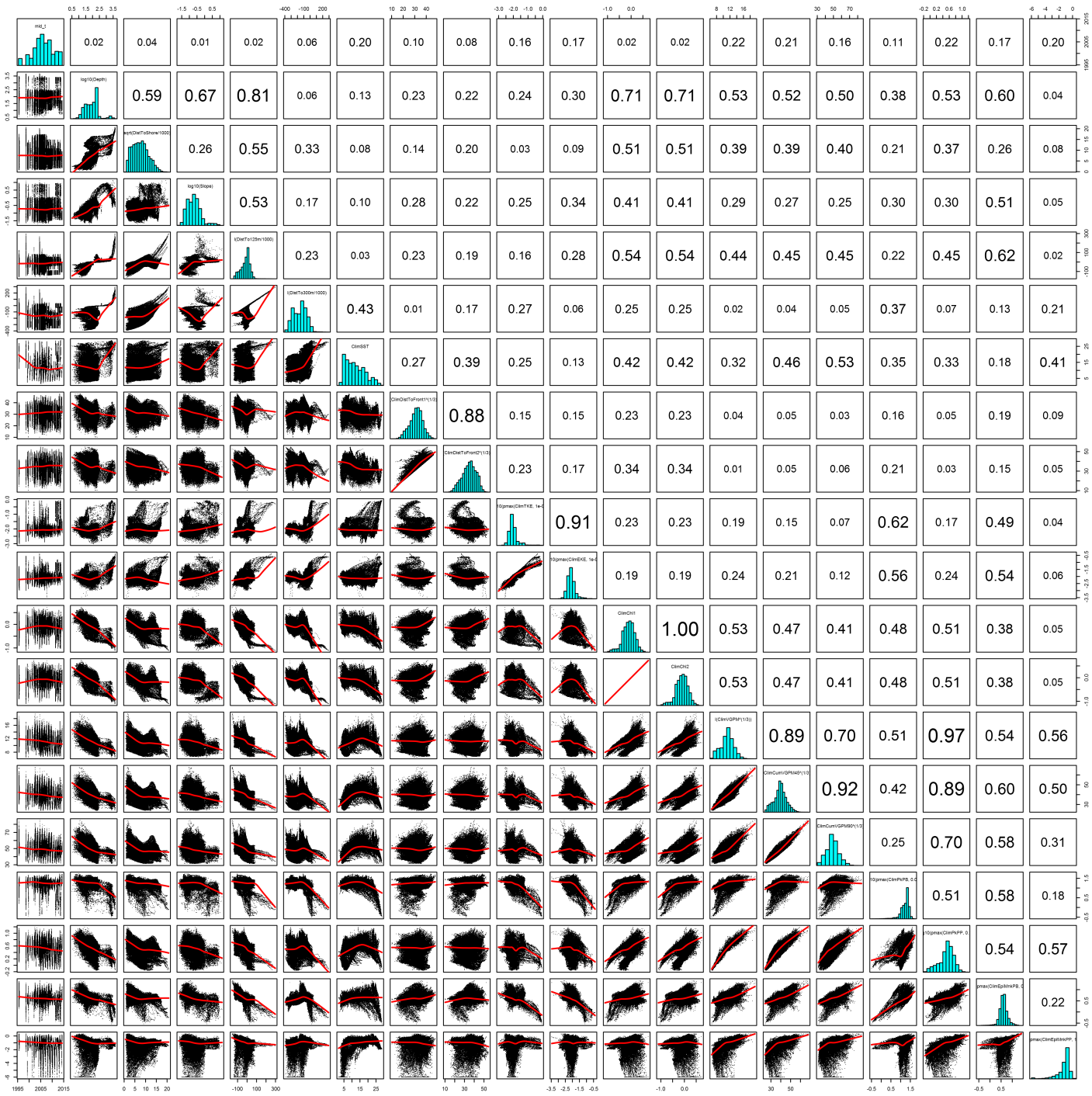


Figure 116: Scatterplot matrix for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

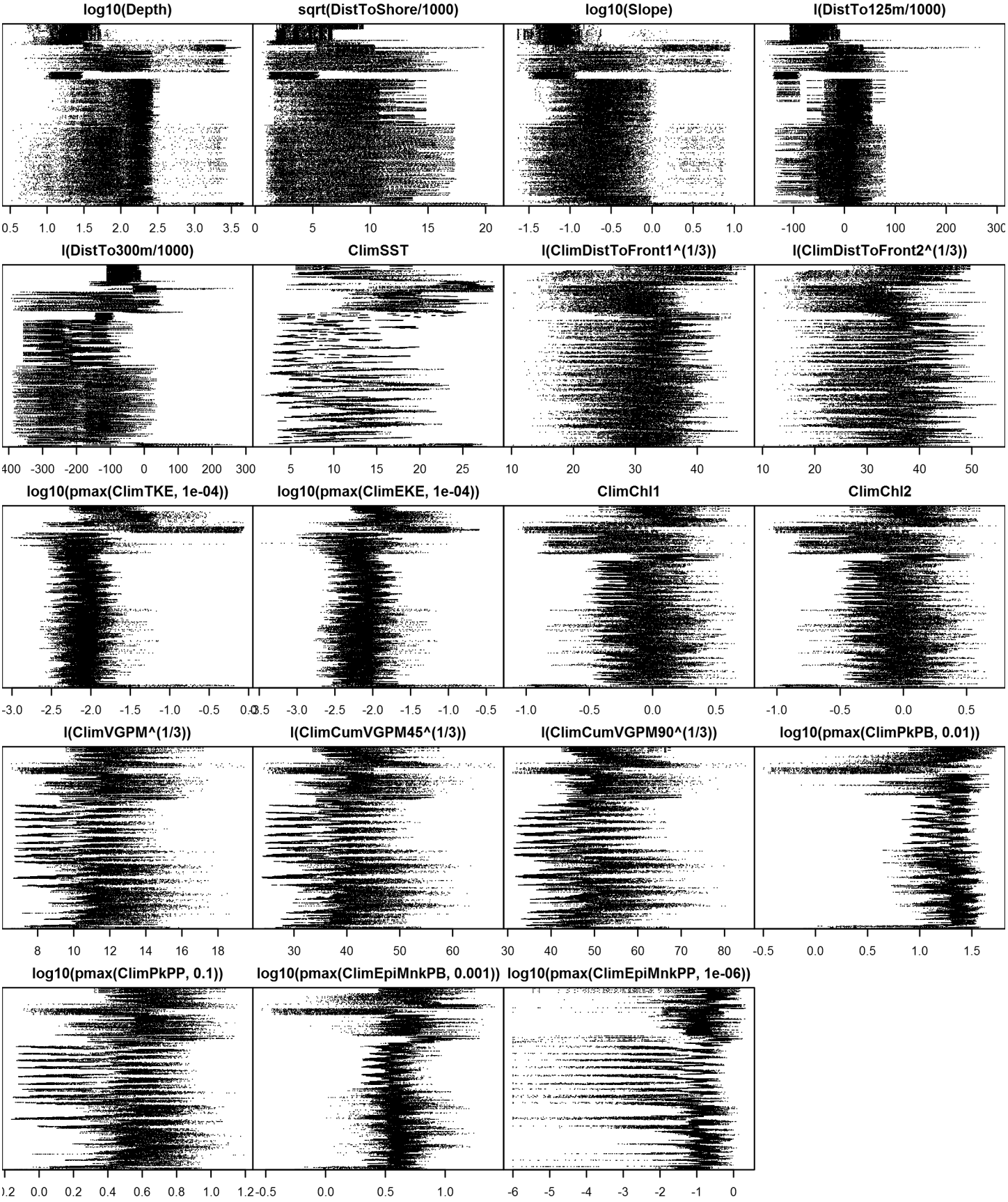


Figure 117: Dotplot for the Atlantic white-sided dolphin Climatological model, North of Gulf Stream. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

South of Gulf Stream

Density assumed to be 0 in this region.

Model Comparison

Spatial Model Performance

The table below summarizes the performance of the candidate spatial models that were tested. The first model contained only physiographic predictors. Subsequent models added additional suites of predictors of based on when they became available via remote sensing.

For each model, three versions were fitted; the % Dev Expl columns give the % deviance explained by each one. The "climatological" models were fitted to 8-day climatologies of the environmental predictors. Because the environmental predictors were always available, no segments were lost, allowing these models to consider the maximal amount of survey data. The "contemporaneous" models were fitted to day-of-sighting images of the environmental predictors; these were smoothed to reduce data loss due to clouds, but some segments still failed to retrieve environmental values and were lost. Finally, the "climatological same segments" models fitted climatological predictors to the segments retained by the contemporaneous model, so that the explantory power of the two types of predictors could be directly compared. For each of the three models, predictors were selected independently via shrinkage smoothers; thus the three models did not necessarily utilize the same predictors.

Predictors derived from ocean currents first became available in January 1993 after the launch of the TOPEX/Poseidon satellite; productivity predictors first became available in September 1997 after the launch of the SeaWiFS sensor. Contemporaneous and climatological same segments models considering these predictors usually suffered data loss. Date Range shows the years spanned by the retained segments. The Segments column gives the number of segments retained; % Lost gives the percentage lost.

Predictors	Climatol % Dev Expl	Contemp % Dev Expl	Climatol Same Segs % Dev Expl	Segments	% Lost	Date Range
Phys	14.9			64653		1995-2014
Phys+SST	21.1	20.2	21.1	64653	0.0	1995-2014
Phys+SST+Curr	22.5	20.2	22.5	64653	0.0	1995-2014
Phys+SST+Curr+Prod	22.7	19.9	22.0	61516	4.9	1998-2013

Table 65: Deviance explained by the candidate density models.

Abundance Estimates

The table below shows the estimated mean abundance (number of animals) within the study area, for the models that explained the most deviance for each model type. Mean abundance was calculated by first predicting density maps for a series of time steps, then computing the abundance for each map, and then averaging the abundances. For the climatological models, we used 8-day climatologies, resulting in 46 abundance maps. For the contemporaneous models, we used daily images, resulting in 365 predicted abundance maps per year that the prediction spanned. The Dates column gives the dates to which the estimates apply. For our models, these are the years for which both survey data and remote sensing data were available.

The Assumed g(0)=1 column specifies whether the abundance estimate assumed that detection was certain along the survey trackline. Studies that assumed this did not correct for availability or perception bias, and therefore underestimated abundance. The In our models column specifies whether the survey data from the study was also used in our models. If not, the study provides a completely independent estimate of abundance.

Dates	Model or study	Estimated abundance	CV	Assumed g(0)=1	In our models

1995-2014	Climatological model	70639	0.88	No	
1995-2014	Contemporaneous model*	37180	0.07	No	
1995-2014	Climatological same segments model	82350	1.07	No	
Jun-Aug 2011	Central Virginia to lower Bay of Fundy (Waring et al. 2014)	48819	0.61	No	No
Jul-Aug 2007	Scotian Shelf to Northern Labrador (Lawson and Gosselin 2011)	24422	0.49	No	No
August 2006	Southern Gulf of Maine to Bay of Fundy and Gulf of St. Lawrence (Waring et al. 2014)	17594	0.30	No	Yes

Table 66: Estimated mean abundance within the study area. We selected the model marked with * as our best estimate of the abundance and distribution of this taxon. For comparison, independent abundance estimates from NOAA technical reports and/or the scientific literature are shown. Please see the Discussion section below for our evaluation of our models compared to the other estimates. Note that our abundance estimates are averaged over the whole year, while the other studies may have estimated abundance for specific months or seasons. Our coefficients of variation (CVs) underestimate the true uncertainty in our estimates, as they only incorporated the uncertainty of the GAM stage of our models. Other sources of uncertainty include the detection functions and g(0) estimates. It was not possible to incorporate these into our CVs without undertaking a computationally-prohibitive bootstrap; we hope to attempt that in a future version of our models.

Density Maps

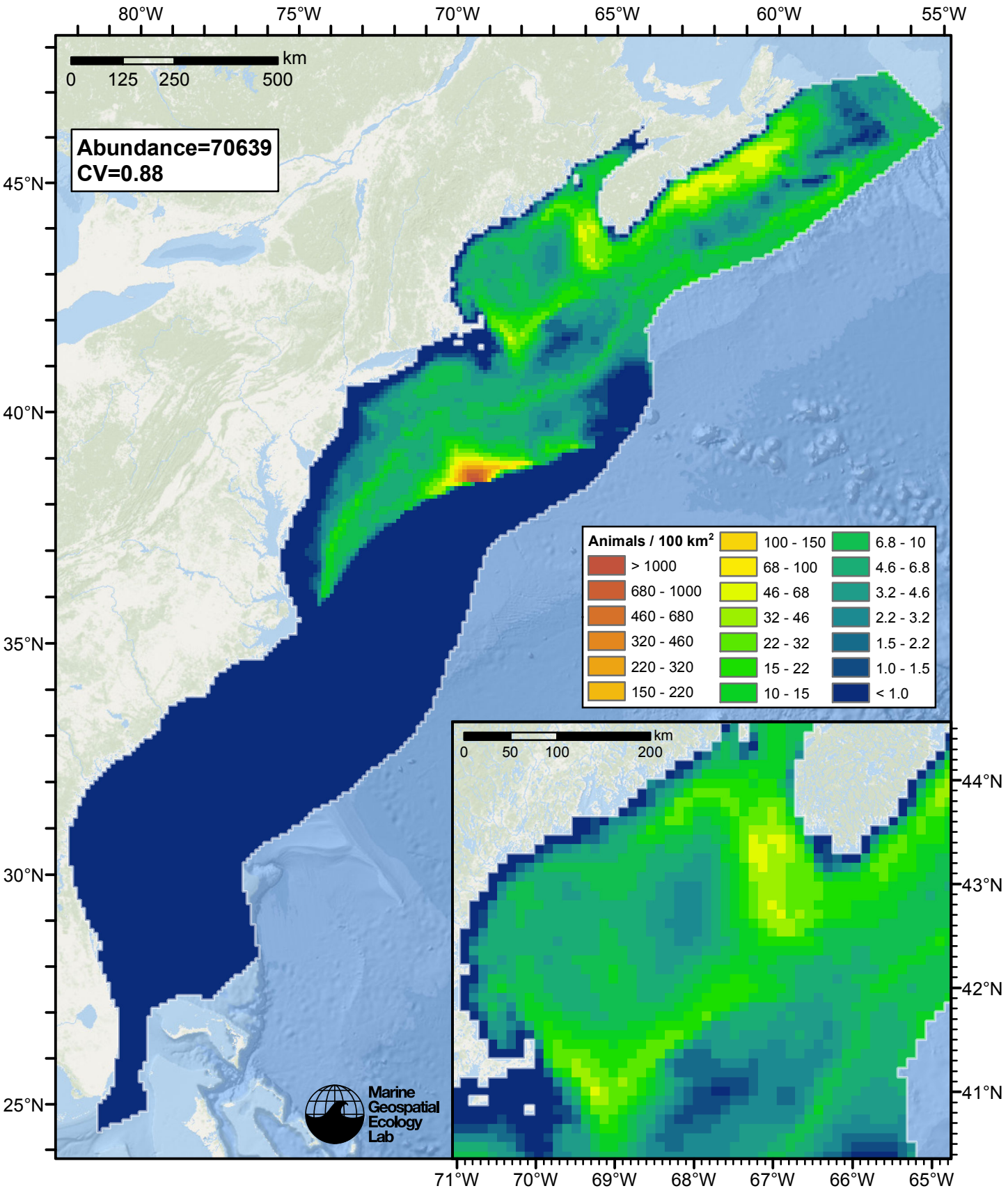


Figure 118: Atlantic white-sided dolphin density and abundance predicted by the climatological model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

Contemporaneous Model

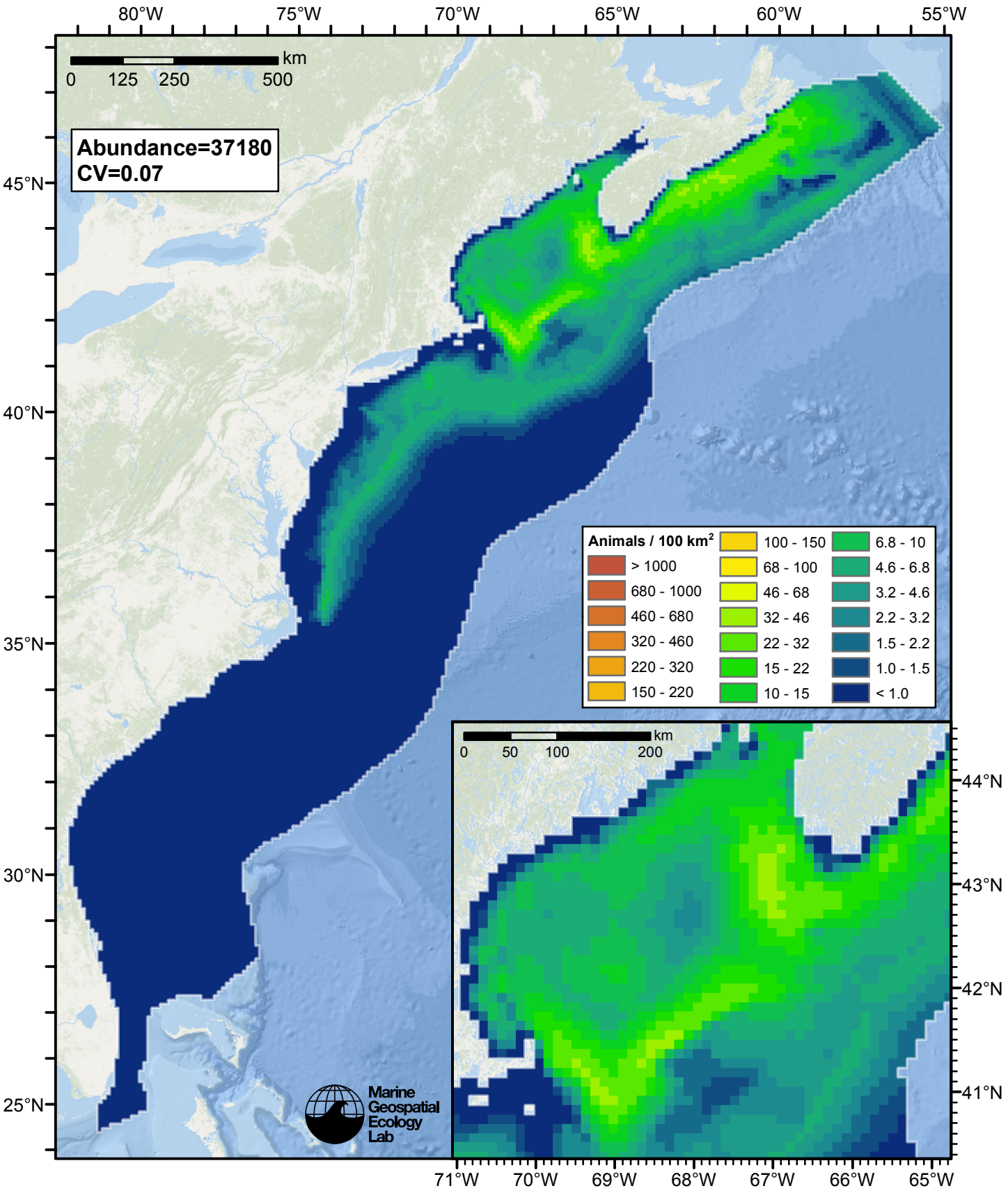


Figure 119: Atlantic white-sided dolphin density and abundance predicted by the contemporaneous model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

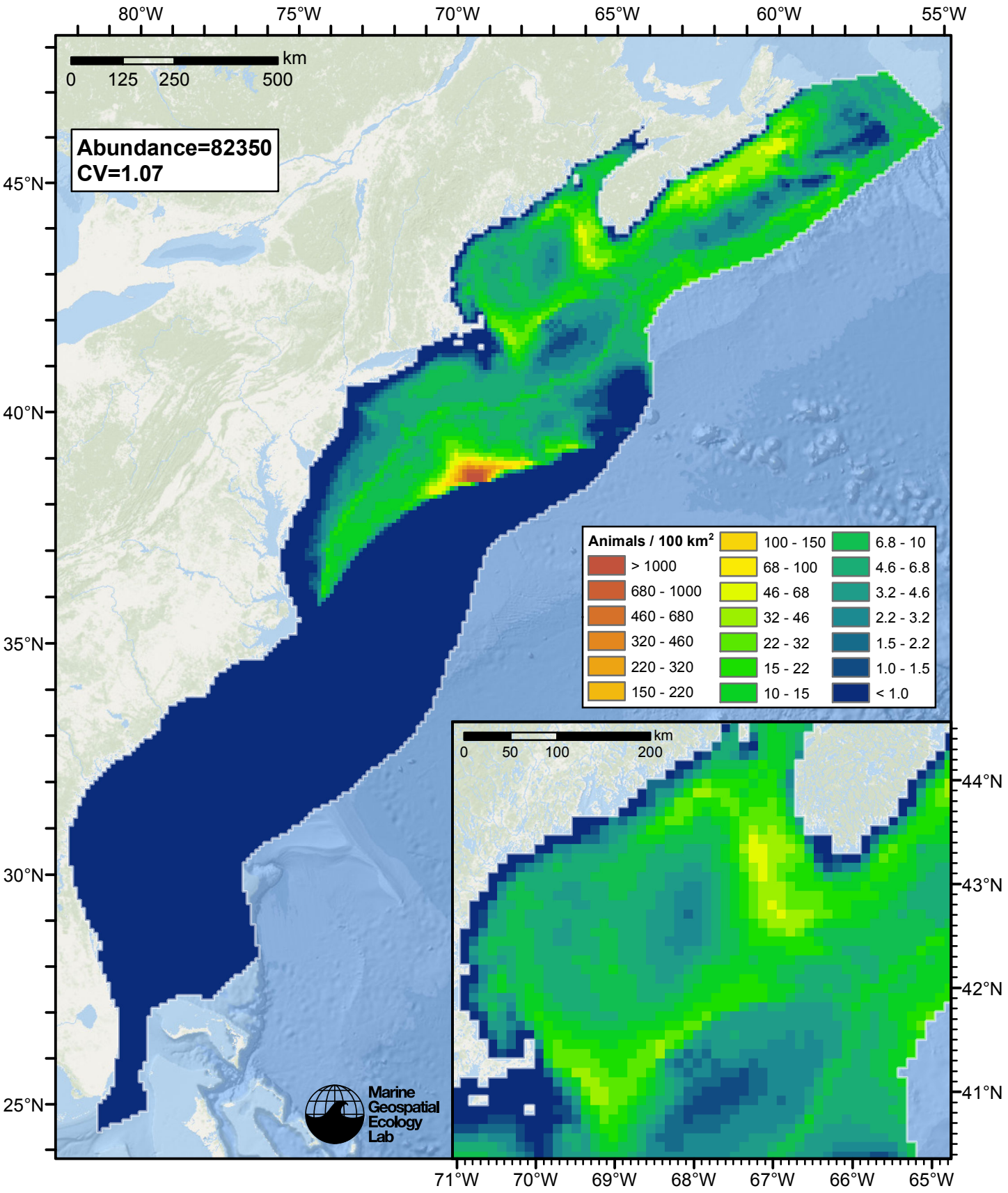


Figure 120: Atlantic white-sided dolphin density and abundance predicted by the climatological same segments model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

Temporal Variability

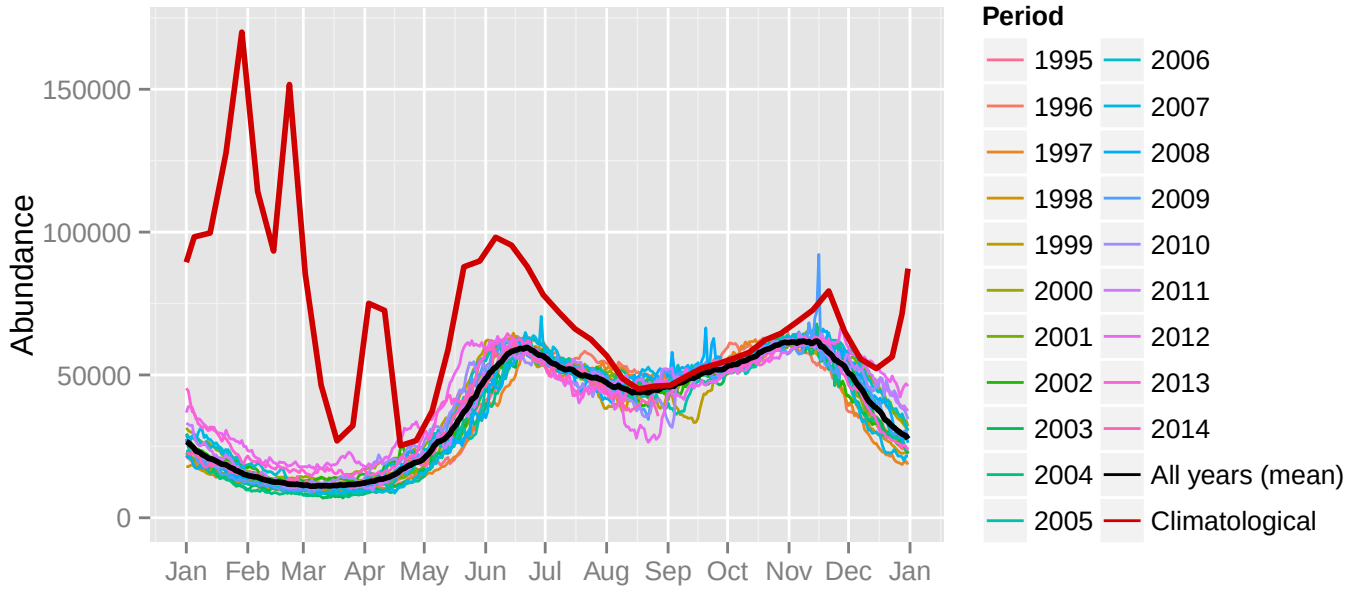


Figure 121: Comparison of Atlantic white-sided dolphin abundance predicted at a daily time step for different time periods. Individual years were predicted using contemporaneous models. "All years (mean)" averages the individual years, giving the mean annual abundance of the contemporaneous model. "Climatological" was predicted using the climatological model. The results for the climatological same segments model are not shown.

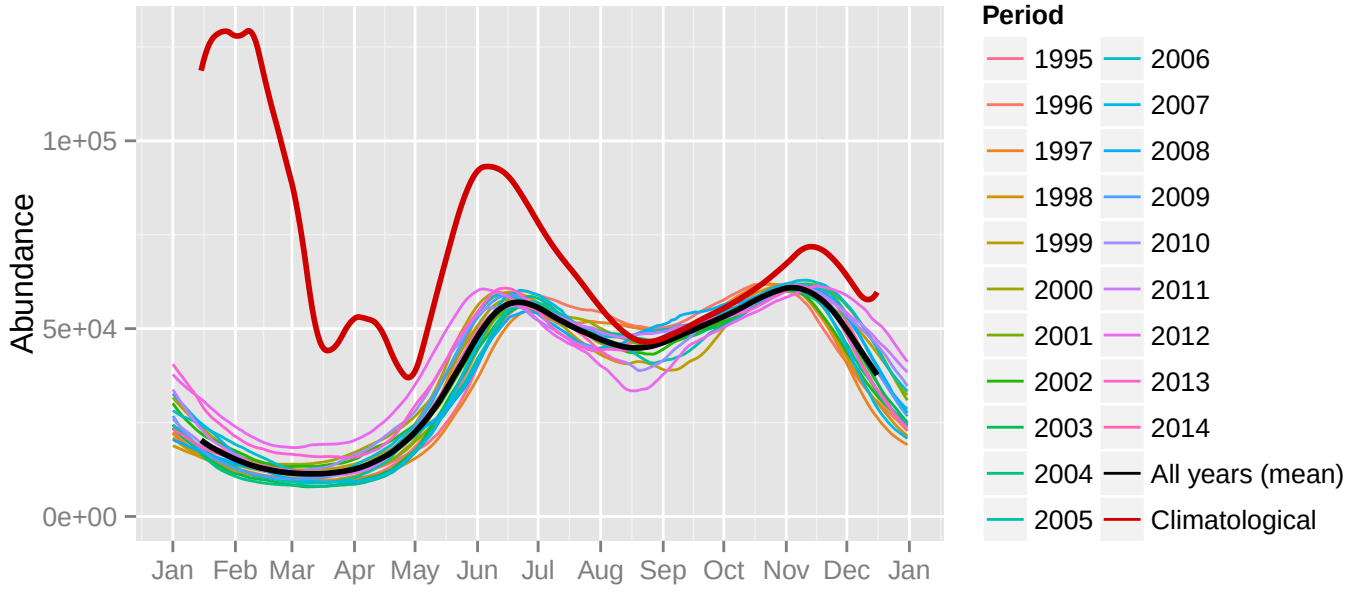
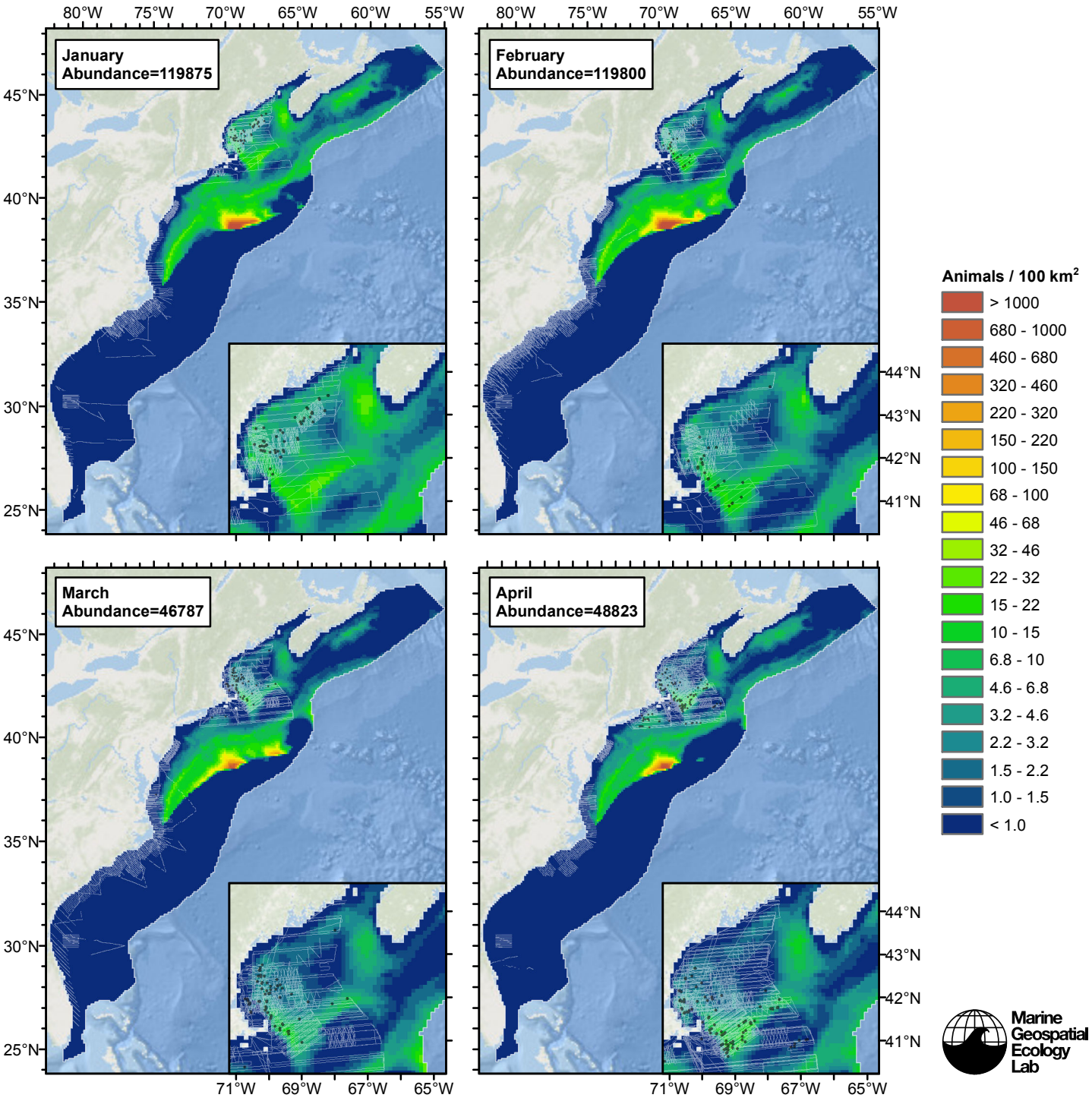
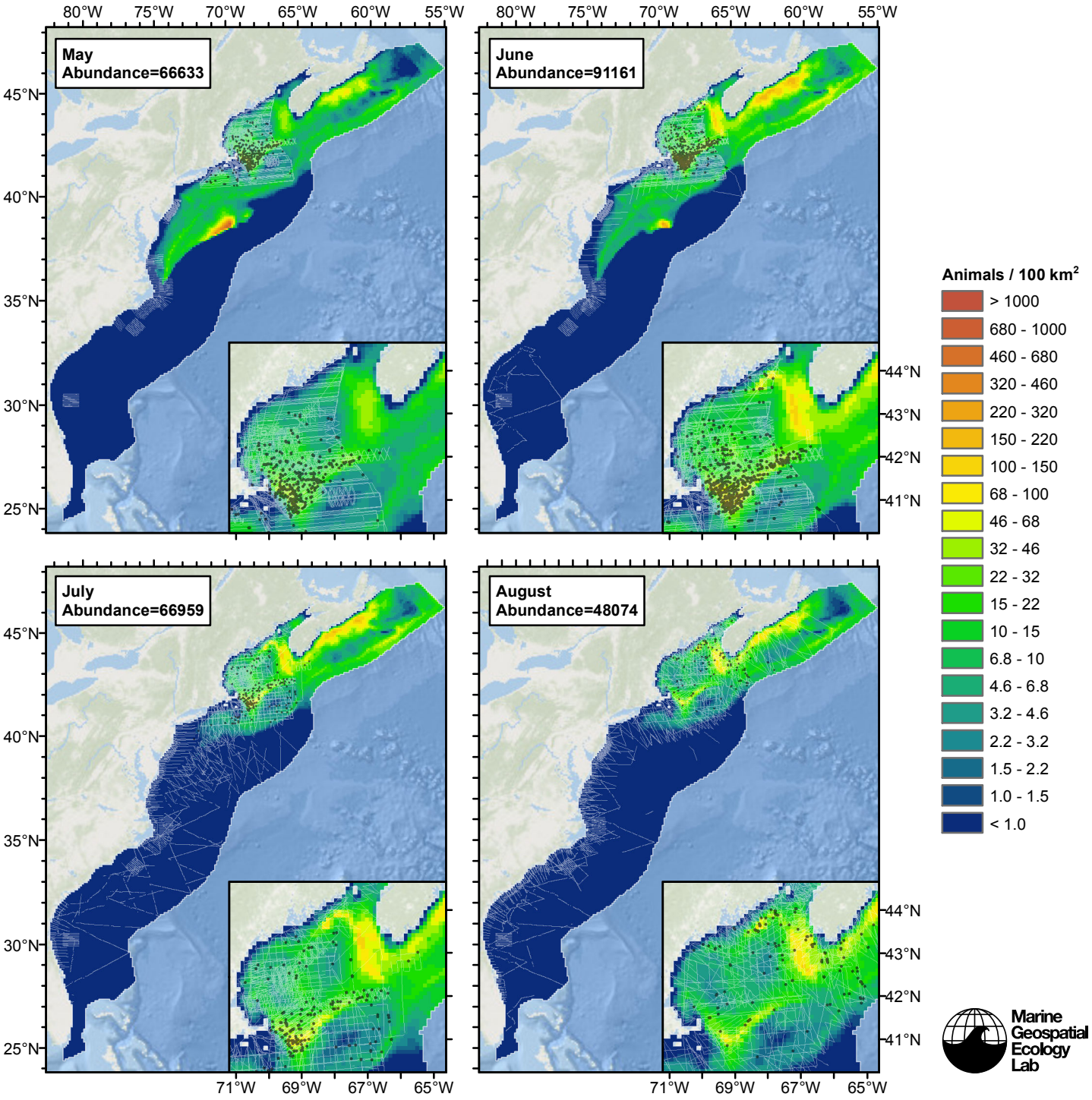
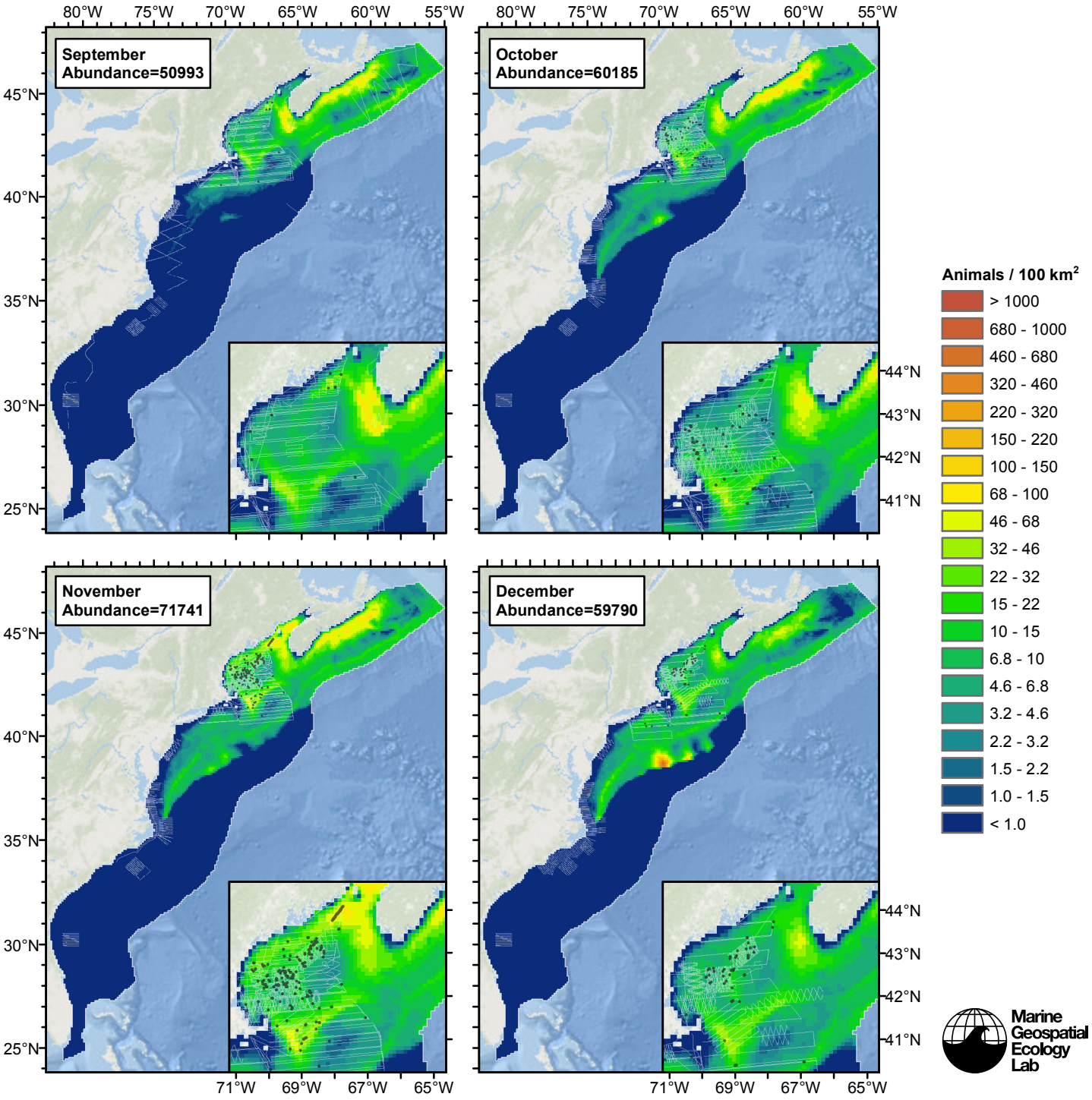


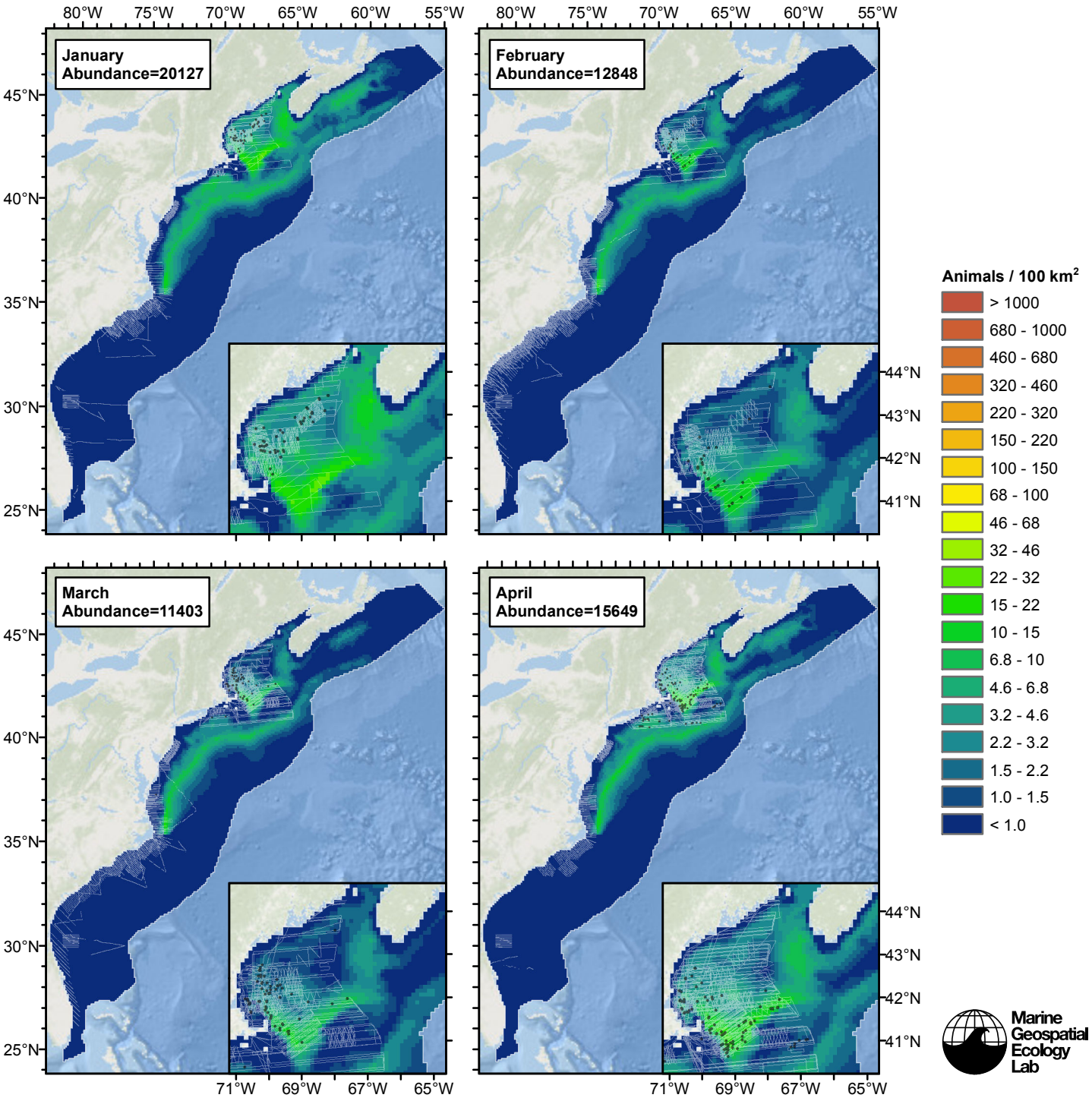
Figure 122: The same data as the preceding figure, but with a 30-day moving average applied.

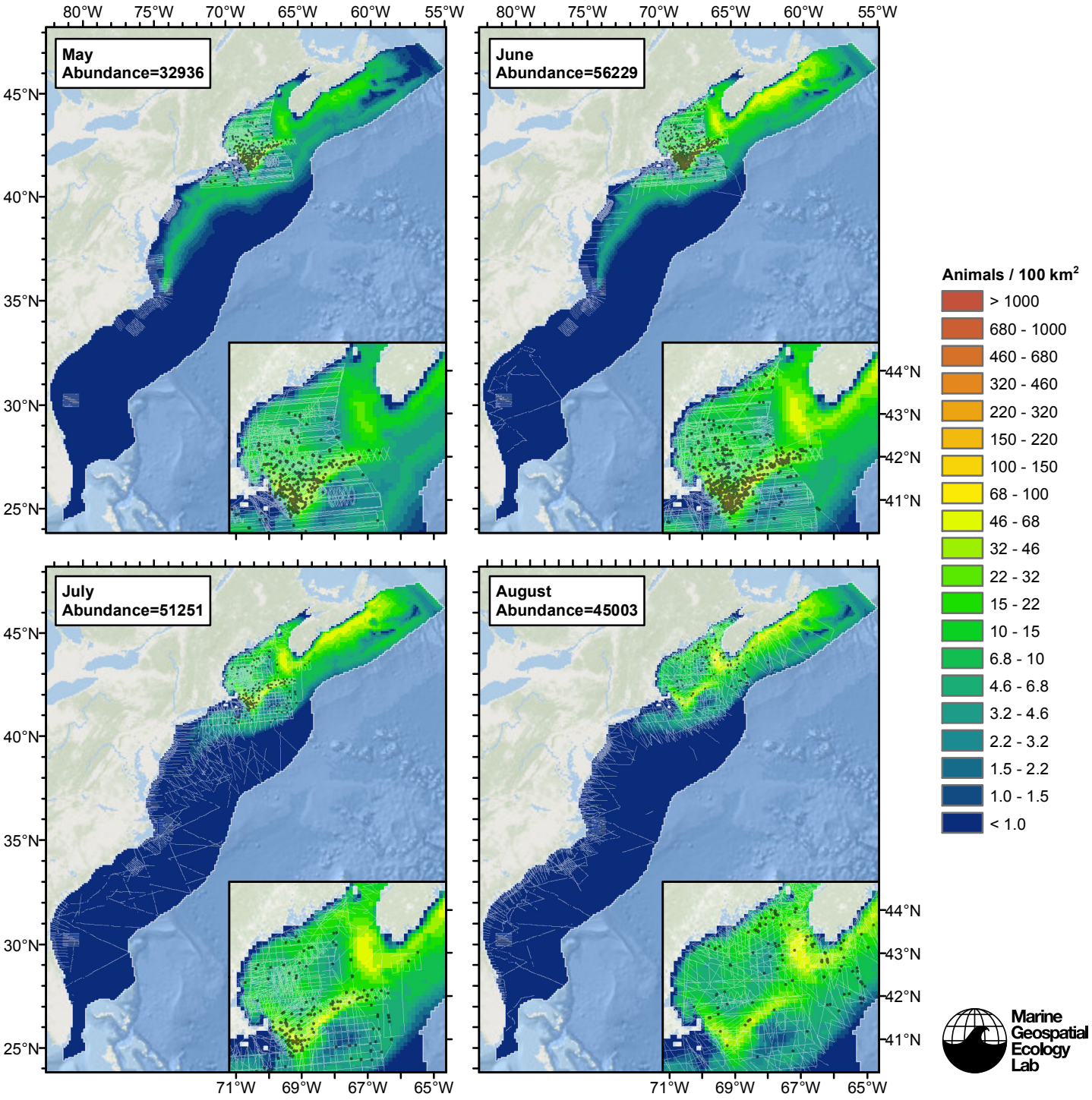

January
Abundance=119875
February
Abundance=119800
March
Abundance=46787
April
Abundance=48823
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab

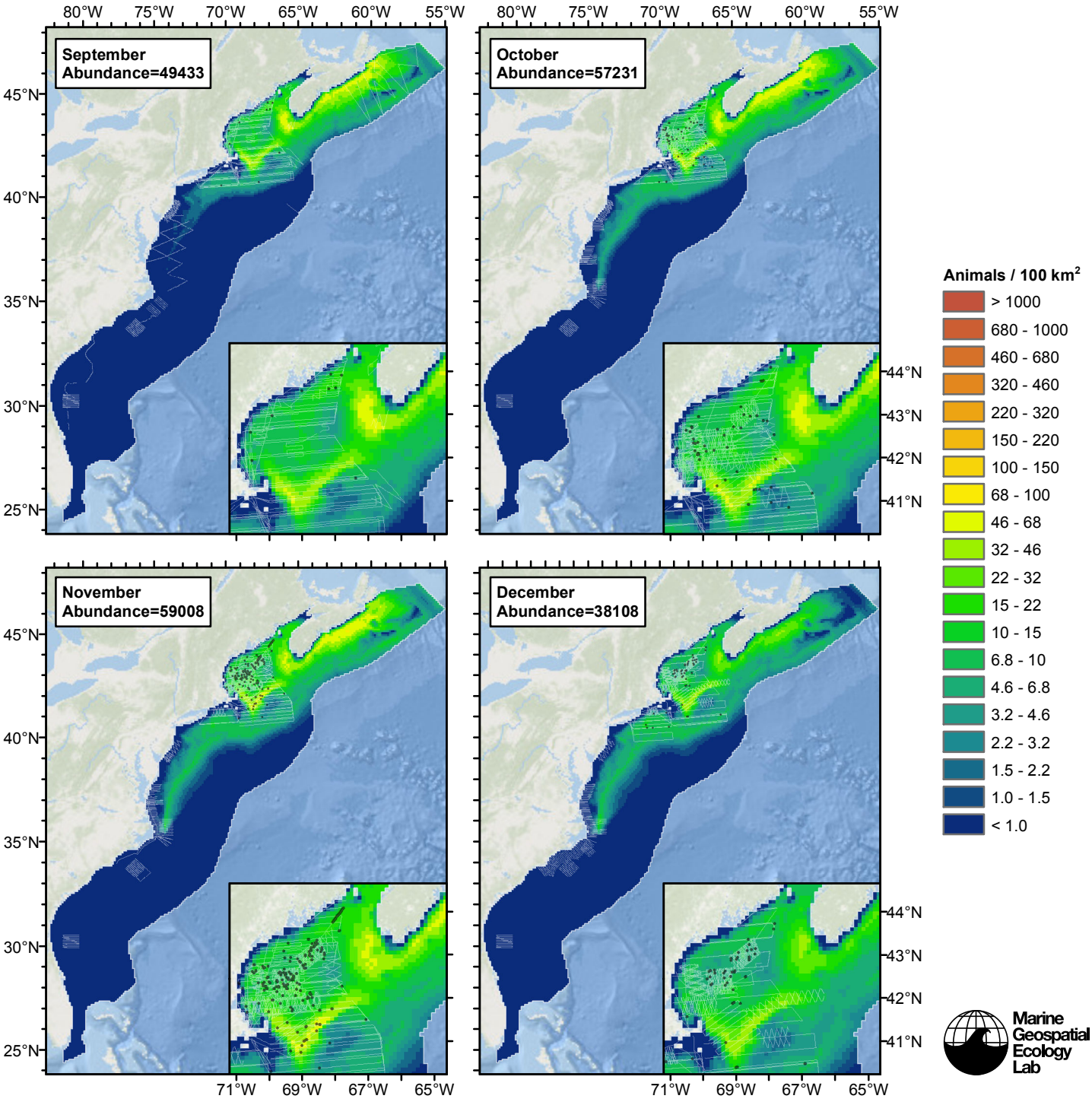

May
Abundance=66633
June
Abundance=91161
July
Abundance=66959
August
Abundance=48074
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab


September
Abundance=50993
October
Abundance=60185
November
Abundance=71741
December
Abundance=59790
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab

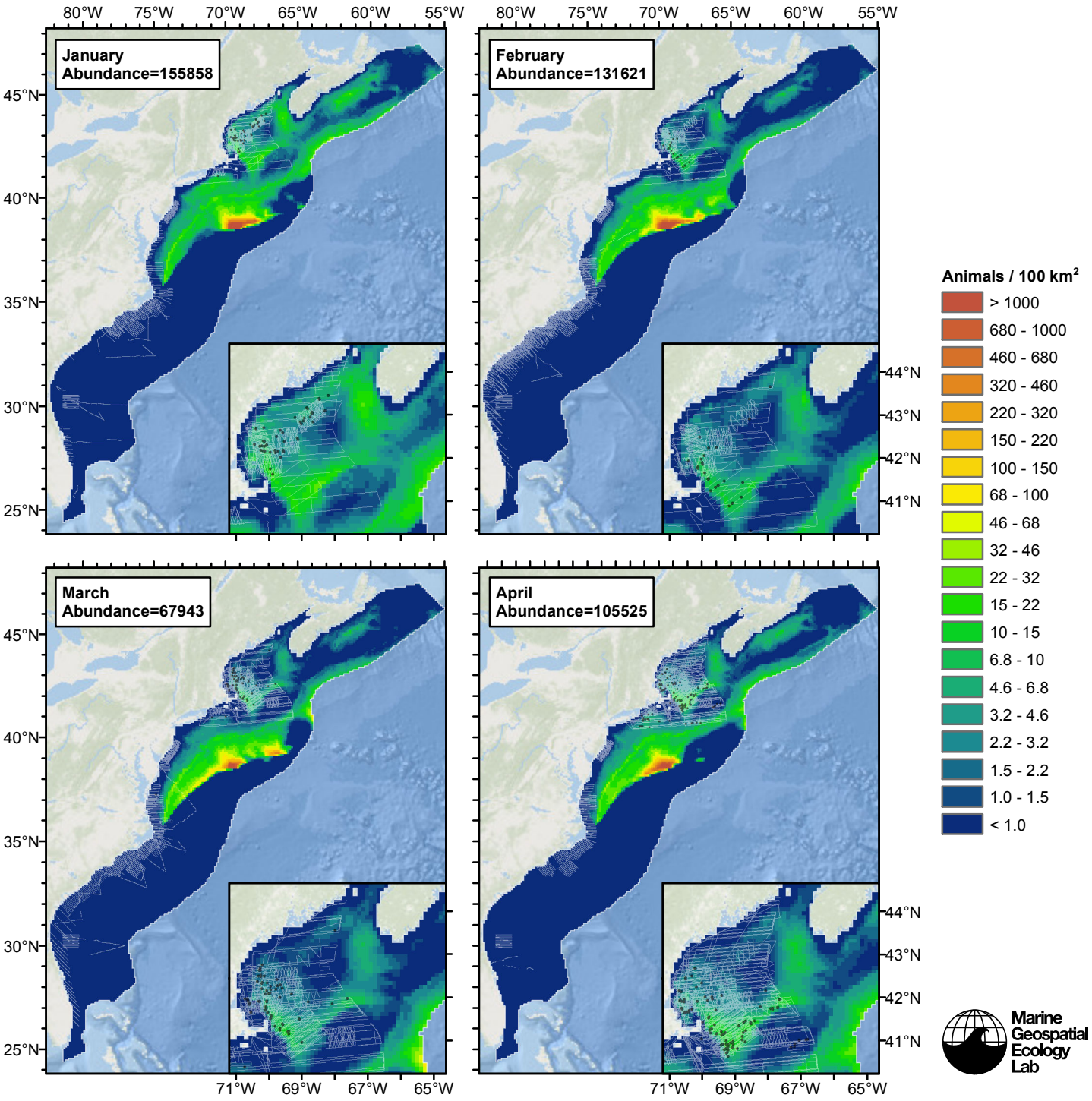
Contemporaneous Model

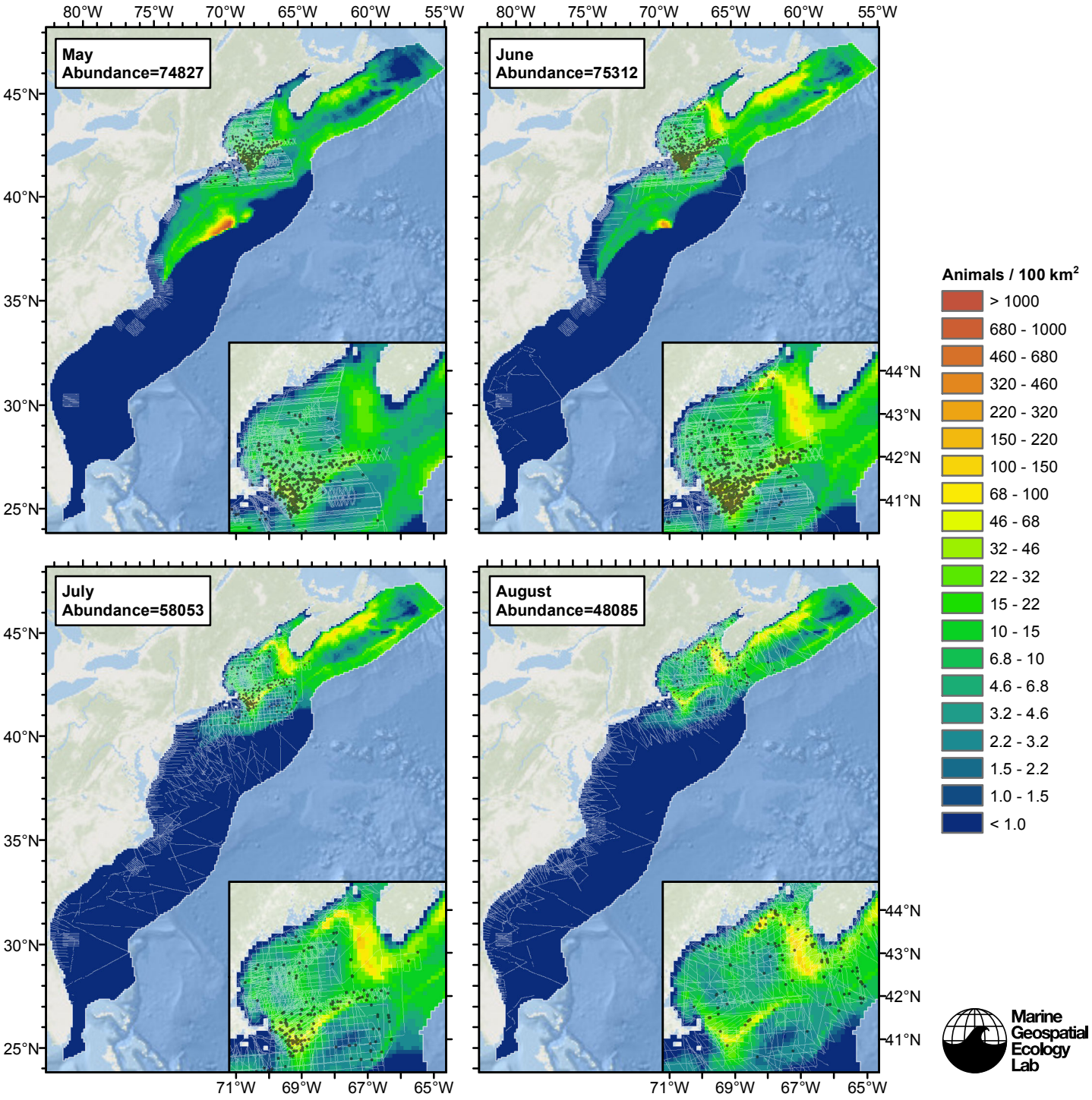


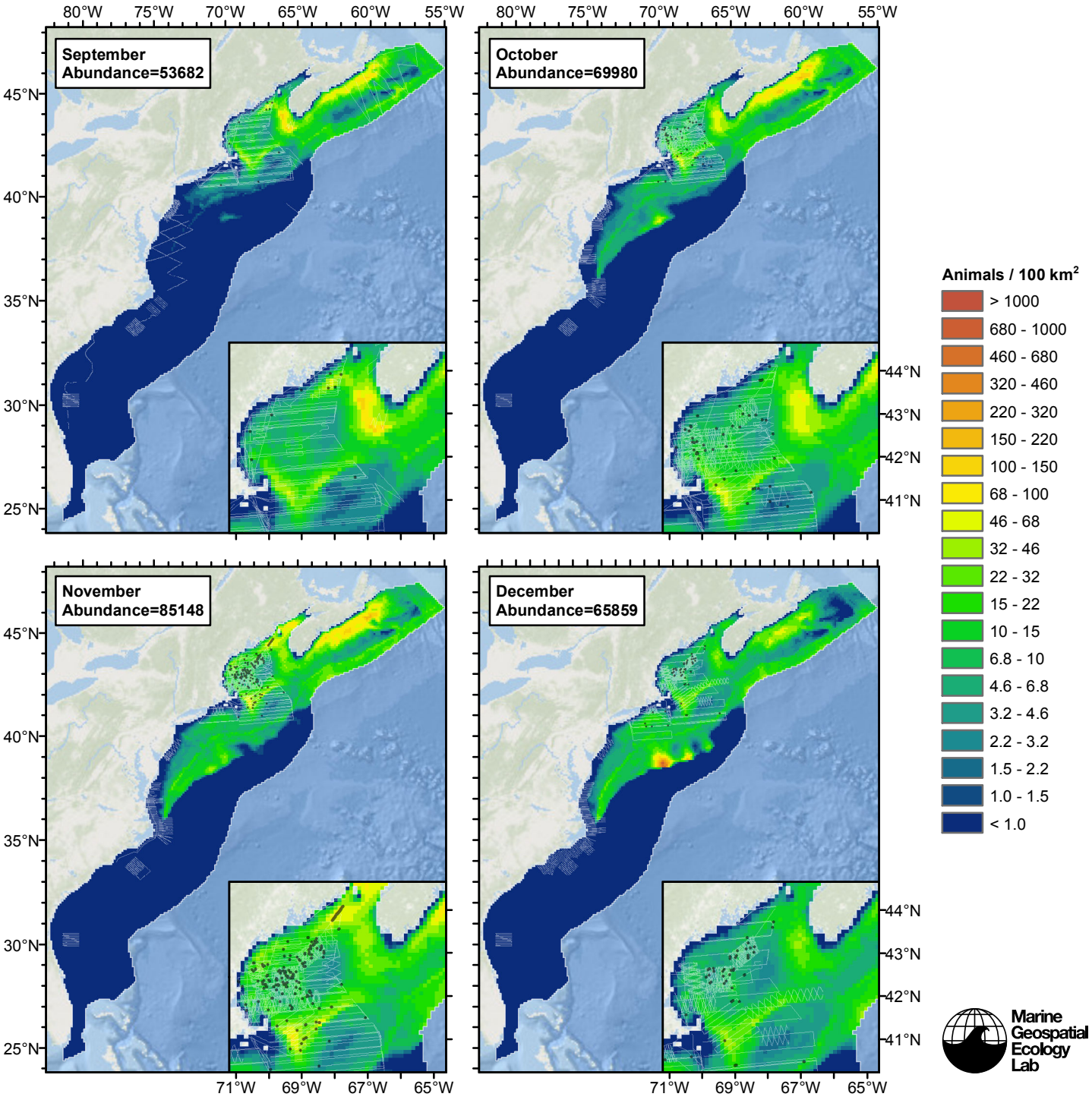

May
Abundance=32936
June
Abundance=56229
July
Abundance=51251
August
Abundance=45003
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab


September
Abundance=49433
October
Abundance=57231
November
Abundance=59008
December
Abundance=38108
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab

Climatological Same Segments Model




May
Abundance=74827
June
Abundance=75312
July
Abundance=58053
August
Abundance=48085
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
32 - 46
22 - 32
15 - 22
10 - 15
6.8 - 10
4.6 - 6.8
3.2 - 4.6
2.2 - 3.2
1.5 - 2.2
1.0 - 1.5
< 1.0
Marine
Geospatial
Ecology
Lab



Discussion

Although models built with climatological predictors explained more deviance than models built with contemporaneous predictors, the predictions from the climatological models showed a large hotspot of density off the shelf southeast of New York. This prediction was obviously spurious, and the CVs of the climatological models were very high (Table 65). Due to these problems, we selected the model that used contemporaneous predictors as our best estimate of Atlantic white-sided dolphin density and abundance.

When summarized at a monthly timestep, the model's predictions showed a northern shift in density in summer and southern shift in winter. While the timing of this shift did not exactly match the that suggested by Palka et al. (1997), the general pattern was consistent. Given this general match between model predictions and what has been reported in the literature, we

offer density predictions for this species at monthly temporal resolution.

Waring et al. (2014) summarized evidence for three stock units–Gulf of Maine, Gulf of St. Lawrence and Labrador Sea stocks–and noted that visual surveys, stranding records, and bycatch data indicate relatively low density on the Scotian Shelf during summer. We caution that our model predictions are not consistent with this finding; our model predicts density along the inner half of the Scotian Shelf similar to that of the Gulf of Maine. Survey effort was sparse along the Scotian Shelf relative to the Gulf of Maine. To try to improve coverage, we made several attempts to contact J. Lawson regarding the Canadian TNASS survey that was conducted along the Scotian Shelf and waters north in 2007, in the hope of incorporating it into our models, but we received no response. We remain hopeful that a collaboration can be established in the future, and that the Canadian TNASS data may be incorporated into a new version of our models.

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