Density Model for Short-Beaked Common Dolphin (*Delphinus delphis*) for the U.S. East Coast: Supplementary Report

Duke University Marine Geospatial Ecology Lab*

Model Version 3.1 - 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 Short-Beaked Common Dolphin (*Delphinus delphis*) for the U.S. East Coast Version 3.1, 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	2014-11-17	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.
3	2015-10-06	Switched our selection of the "best model" to the contemporaneous model, from the climatological model fitted to all segments (see Discussion). Updated the documentation.
3.1	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.) No changes to the other 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	306
NEFSC NARWSS Harbor Porpoise Survey	1999-1999	6	36	5
NEFSC North Atlantic Right Whale Sighting Survey	1999-2013	432	2330	581
NEFSC Shipboard Surveys	1995-2004	16	1143	173
NJDEP Aerial Surveys	2008-2009	11	60	5
NJDEP Shipboard Surveys	2008-2009	14	836	19
SEFSC Atlantic Shipboard Surveys	1992-2005	28	1731	37
SEFSC Mid Atlantic Tursiops Aerial Surveys	1995-2005	35	196	3
SEFSC Southeast Cetacean Aerial Surveys	1992-1995	8	42	0
UNCW Cape Hatteras Navy Surveys	2011-2013	19	125	12
UNCW Early Marine Mammal Surveys	2002-2002	18	98	5
UNCW Jacksonville Navy Surveys	2009-2013	66	402	0
UNCW Onslow Navy Surveys	2007-2011	49	282	1
UNCW Right Whale Surveys	2005-2008	114	586	26
Virginia Aquarium Aerial Surveys	2012-2014	9	53	16
Total		895	8332	1189

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	1189

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

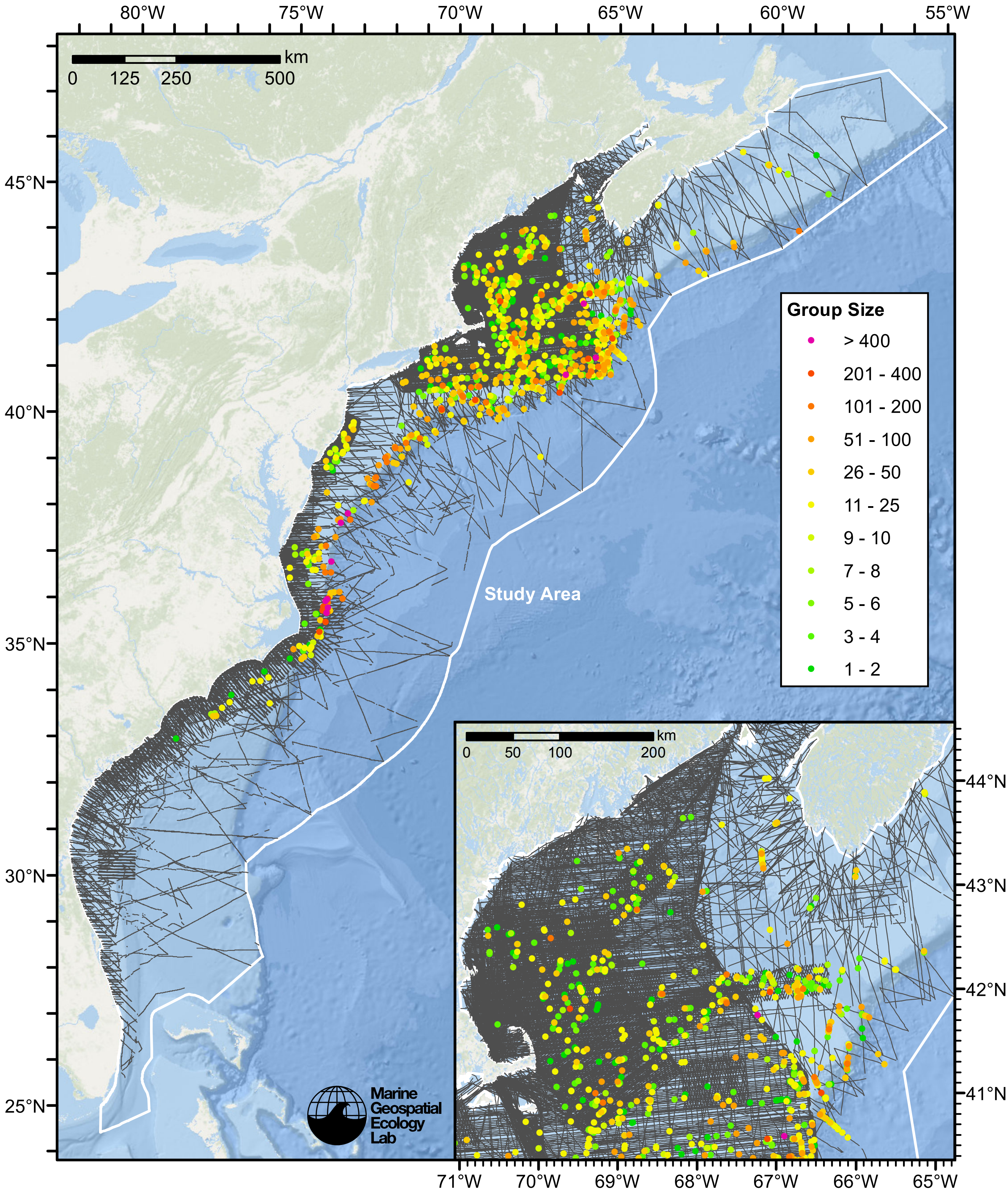


Figure 1: Short-beaked common dolphin sightings and survey tracklines.

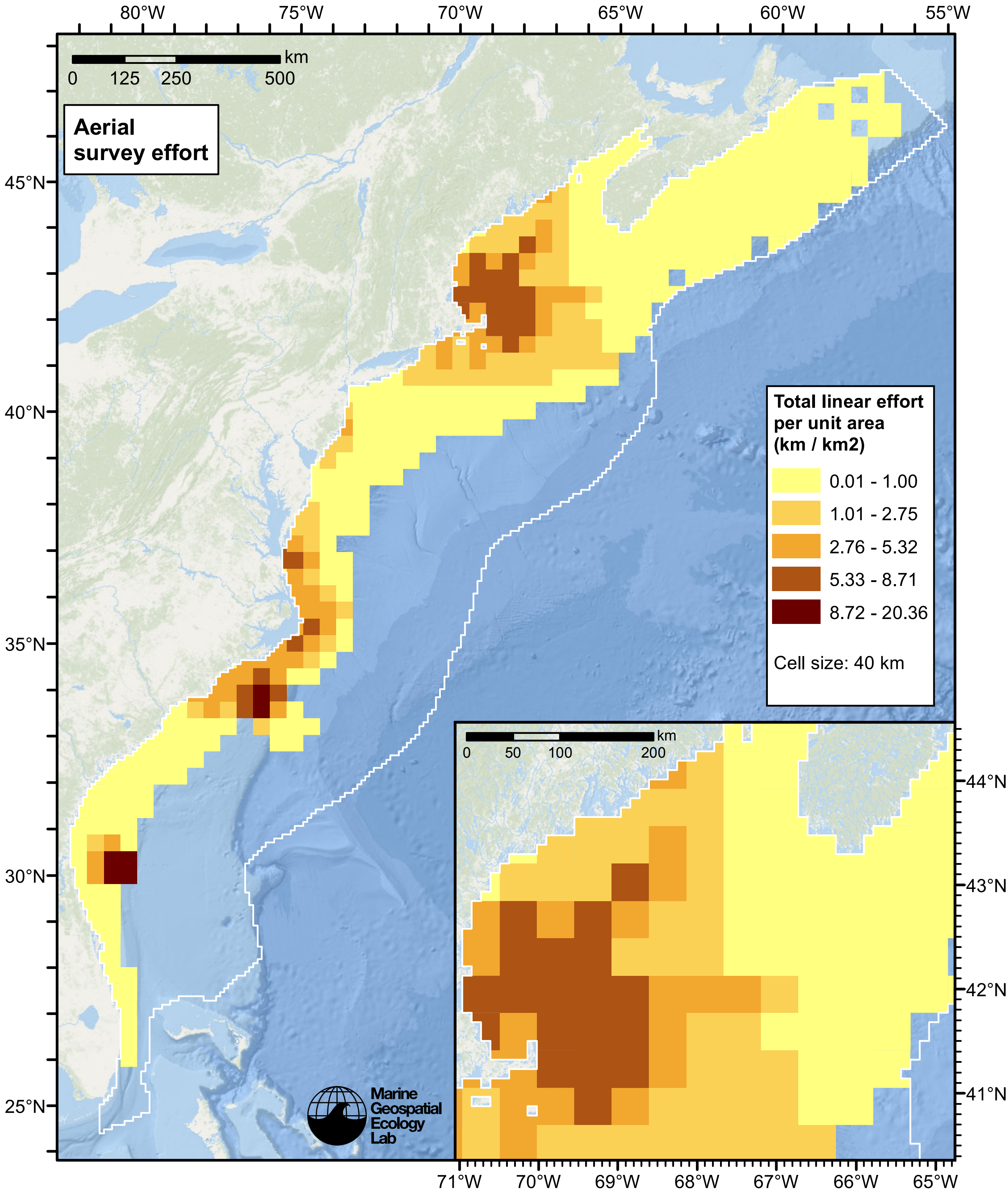


Figure 2: Aerial linear survey effort per unit area.

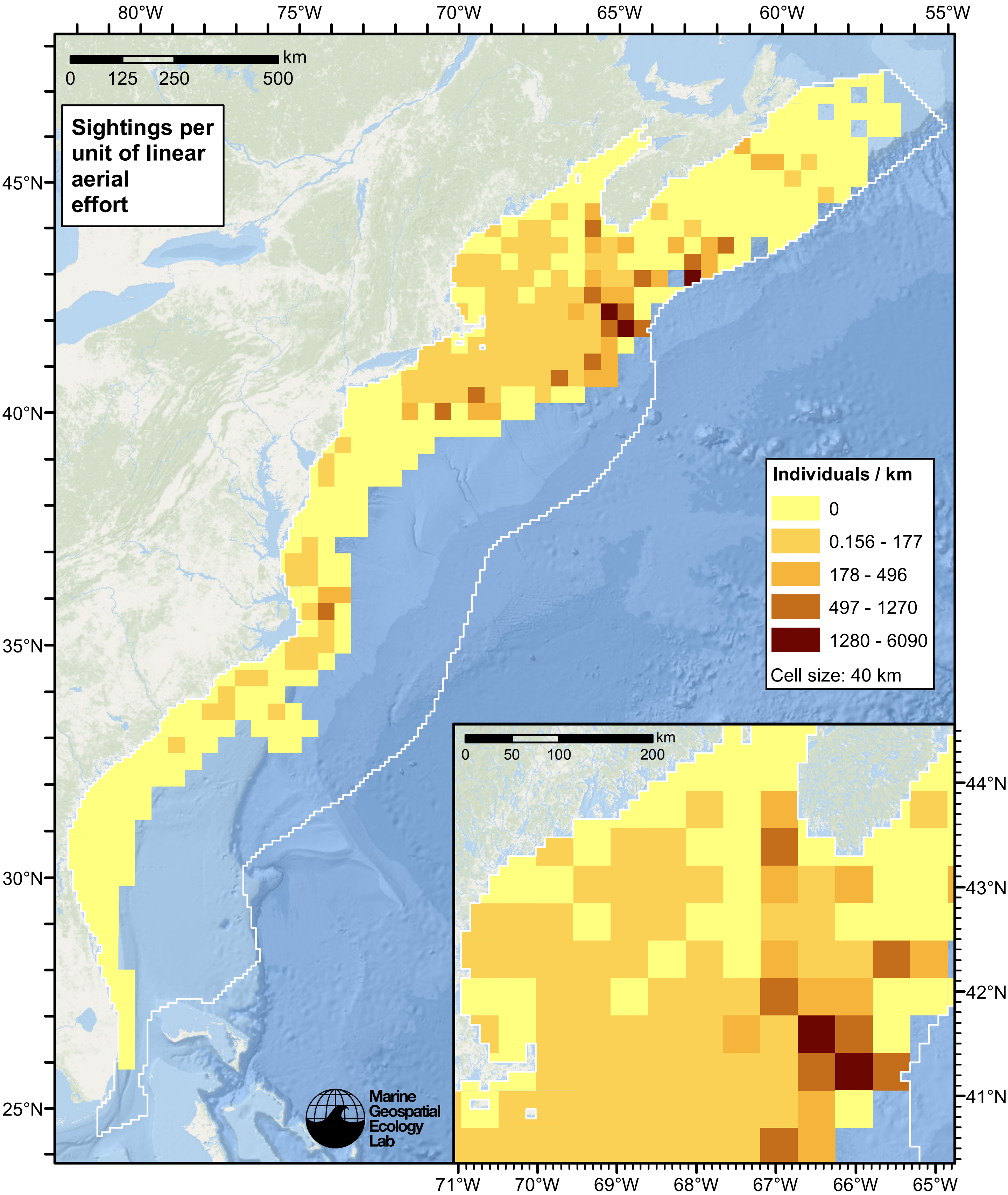


Figure 3: Short-beaked common dolphin sightings per unit aerial linear survey effort.

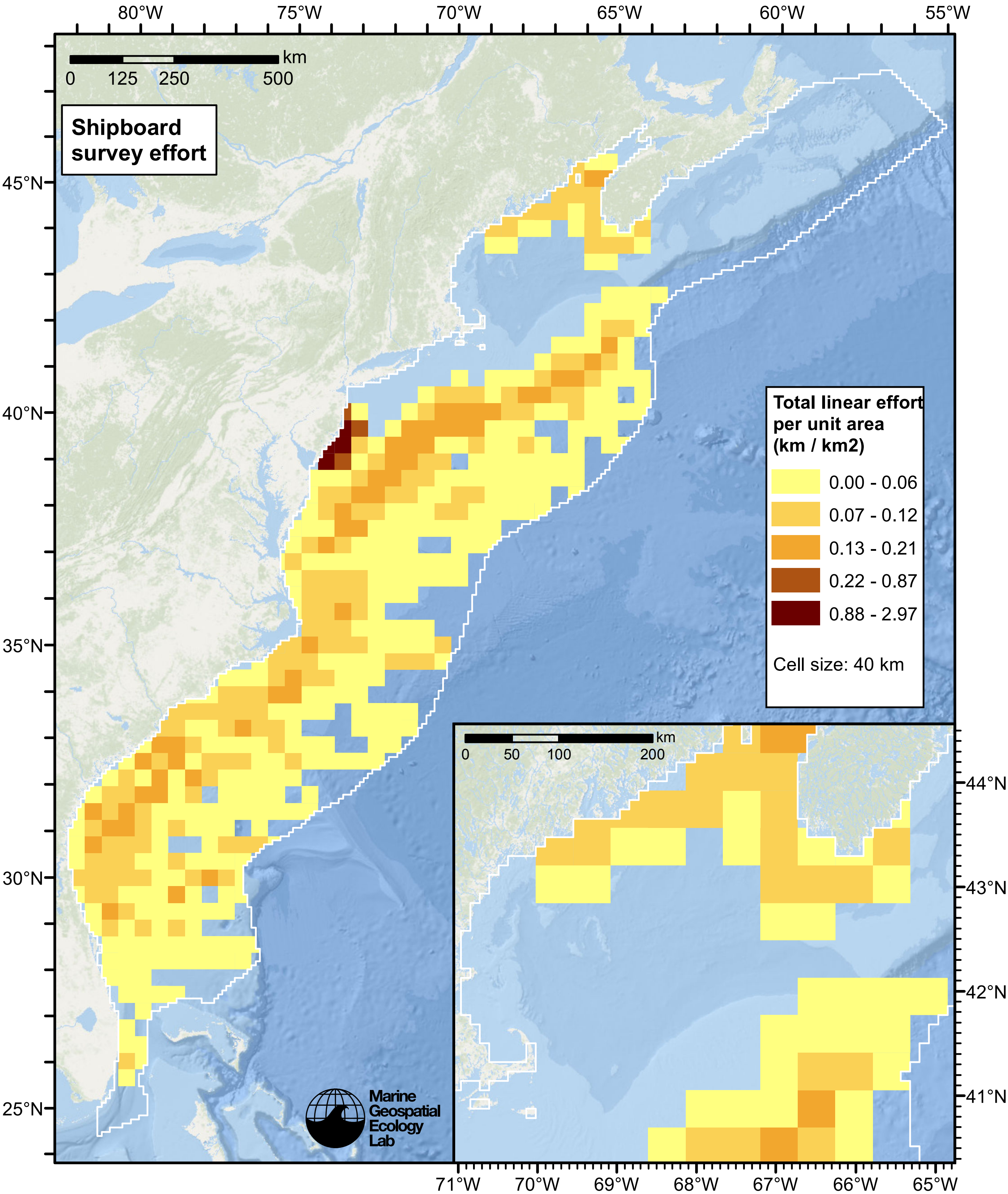


Figure 4: Shipboard linear survey effort per unit area.

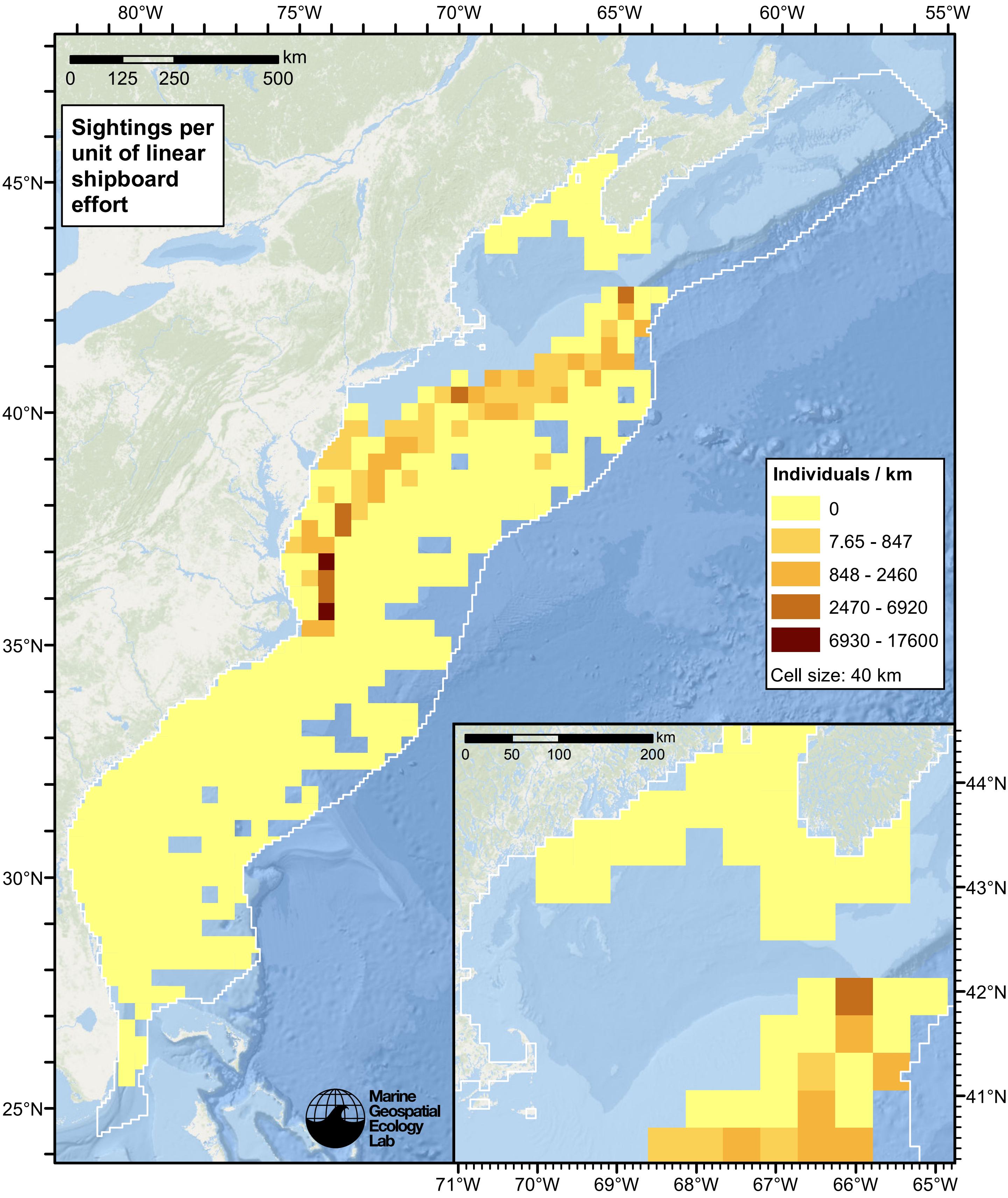


Figure 5: Short-beaked common dolphin sightings per unit shipboard linear survey effort.

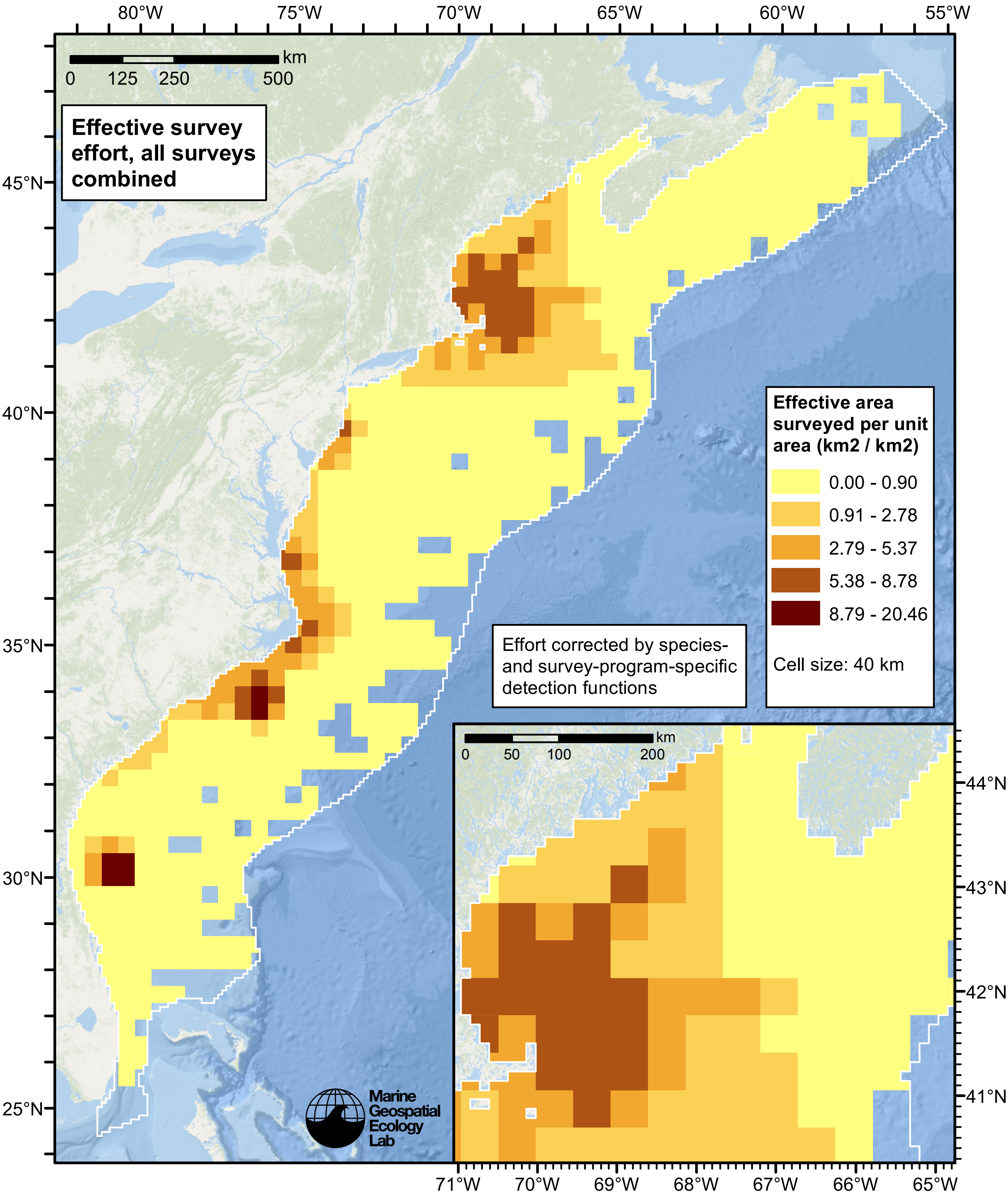


Figure 6: Effective survey effort per unit area, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

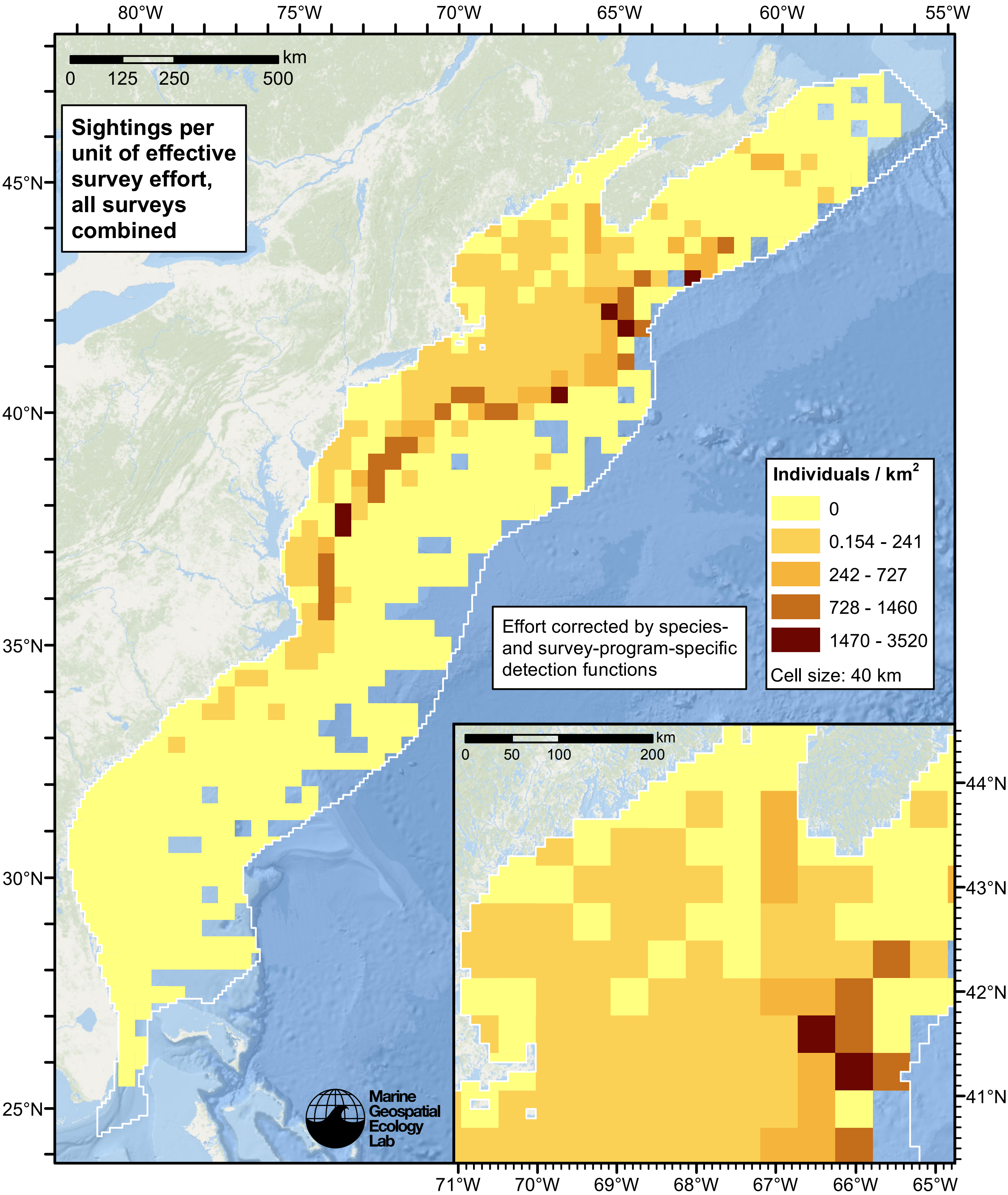


Figure 7: Short-beaked common dolphin sightings per unit of effective survey effort, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

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.

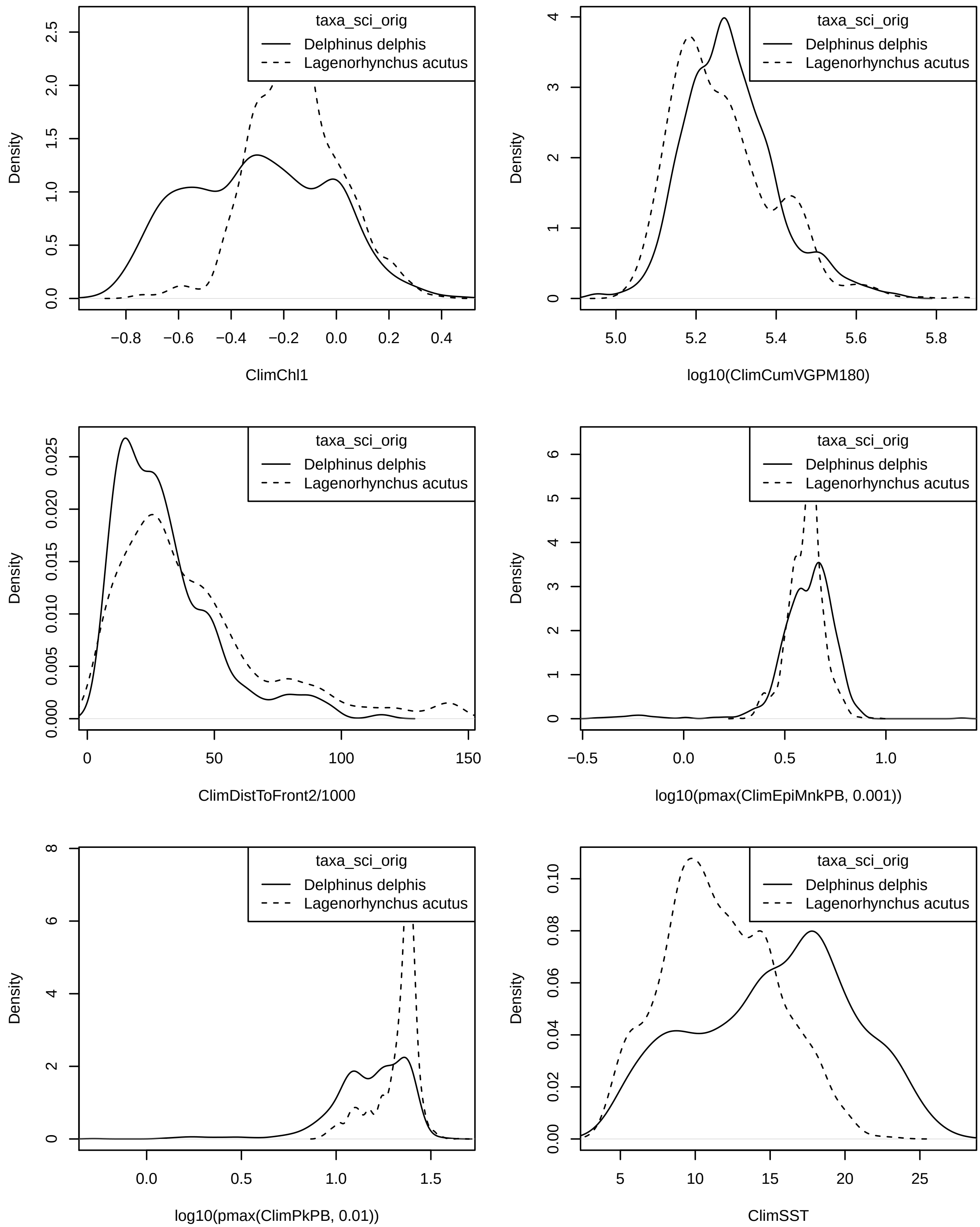
For the predictive model, we used the cforest classifier (Hothorn et al. 2006), an elaboration of the classic random forest classifier (Breiman, 2001). First, we trained a binary classifier using the sightings that reported definitive species identifications (e.g. "fin whale" and "sei whale"). The training 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).

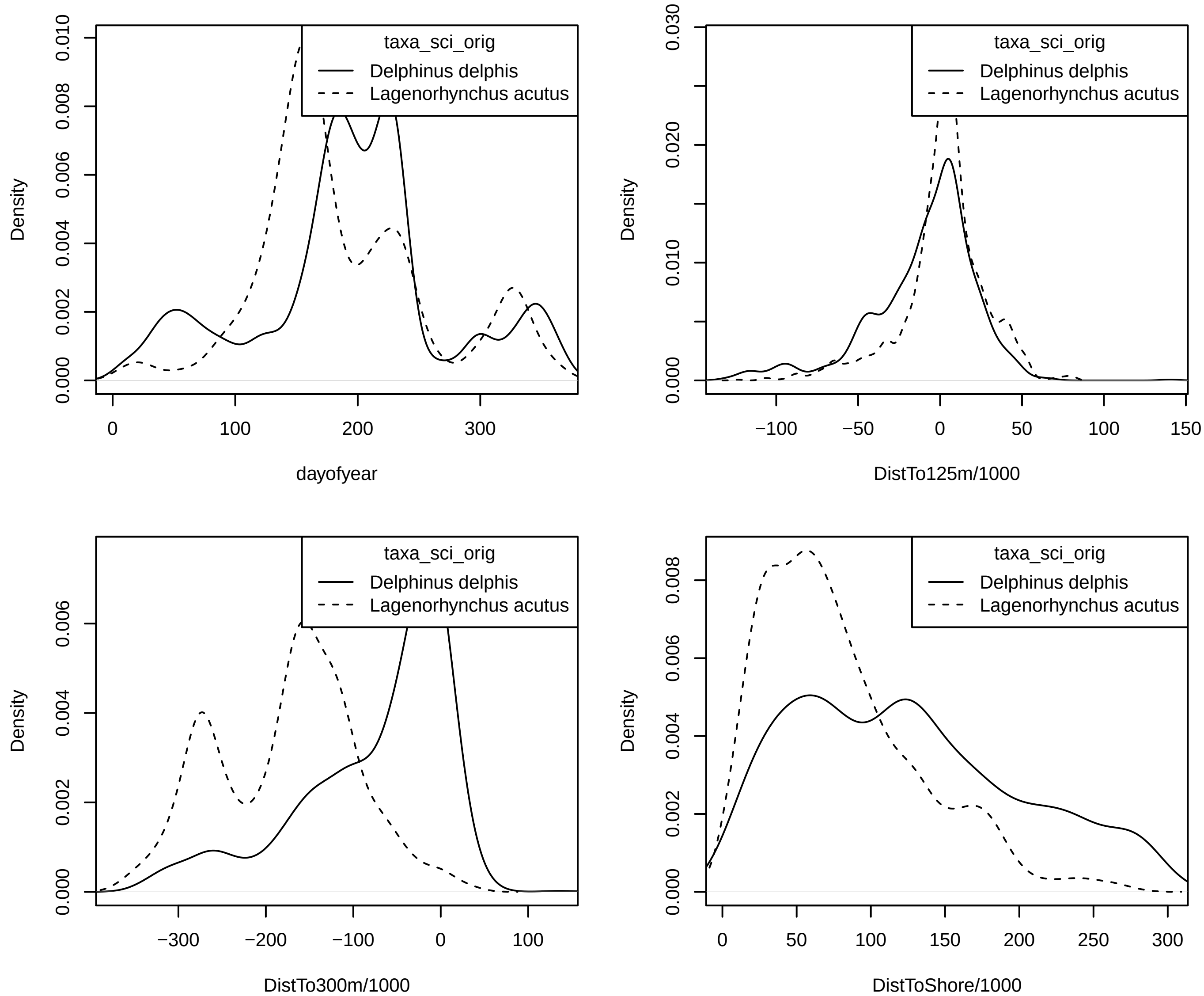
Then, for all sightings reporting the ambiguous identification, we reclassified the sighting as either one species or the other by processing the predictor values observed for that sighting through the fitted model. We then included the reclassified sightings in the detection functions and spatial models 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
log10(ClimCumVGPM180)
ClimDistToFront2/1000
log10(pmax(ClimEpiMnkPB, 0.001))
log10(pmax(ClimPkPB, 0.01))
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, dayofy
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
```

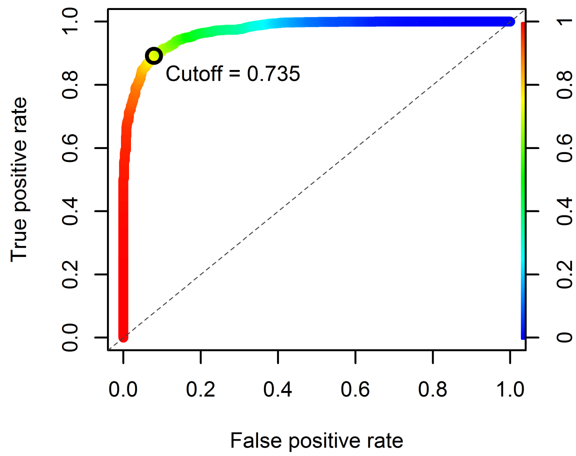


Figure 8: Receiver operating characteristic (ROC) curve illustrating the predictive performance of the model used to reclassify "Delphinus delphis/Lagenorhynchus acutus" sightings into one species or the other.

Reclassifications Performed

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

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.

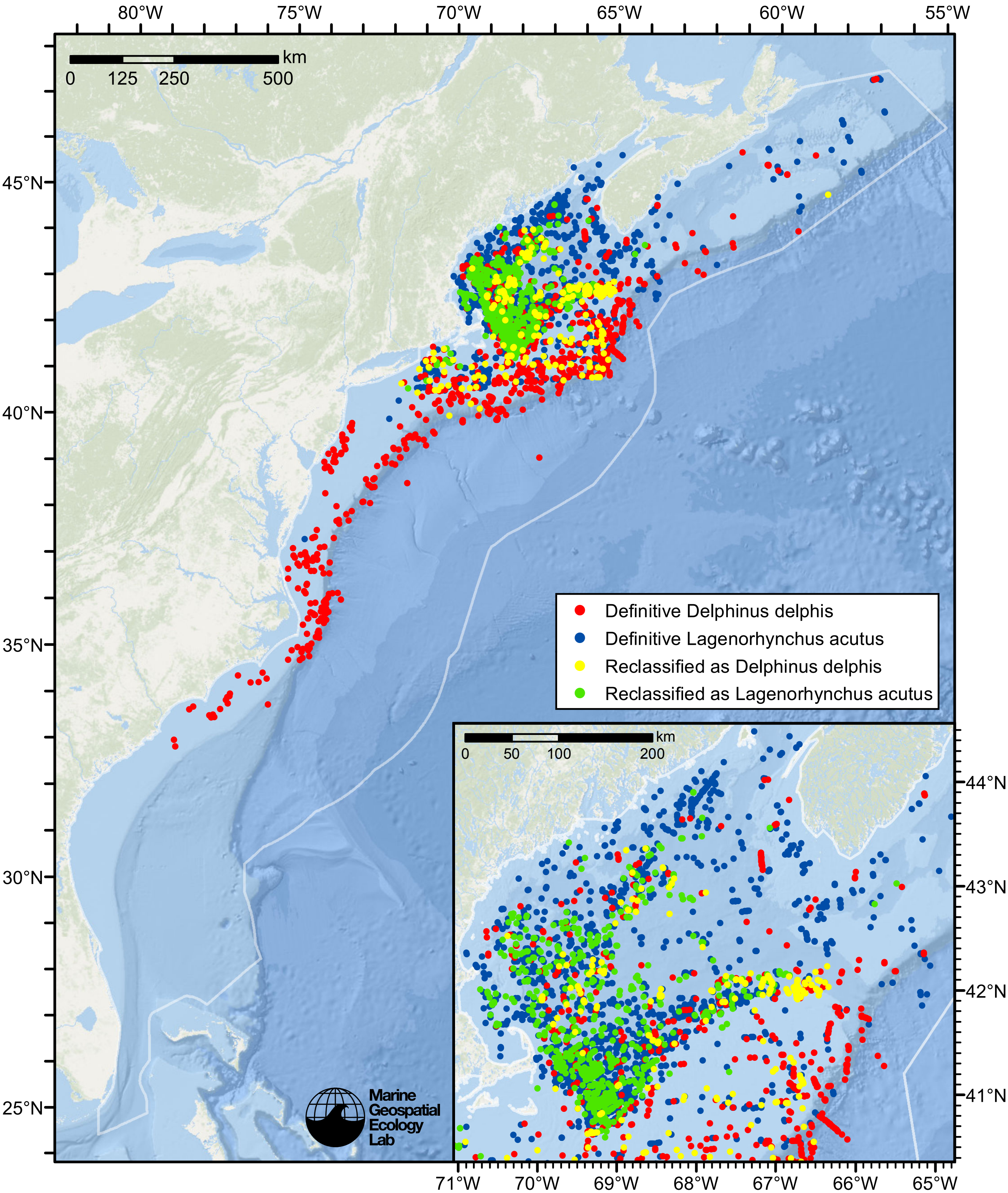


Figure 9: Definitive sightings used to train the model and ambiguous sightings reclassified by the model, by season.

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

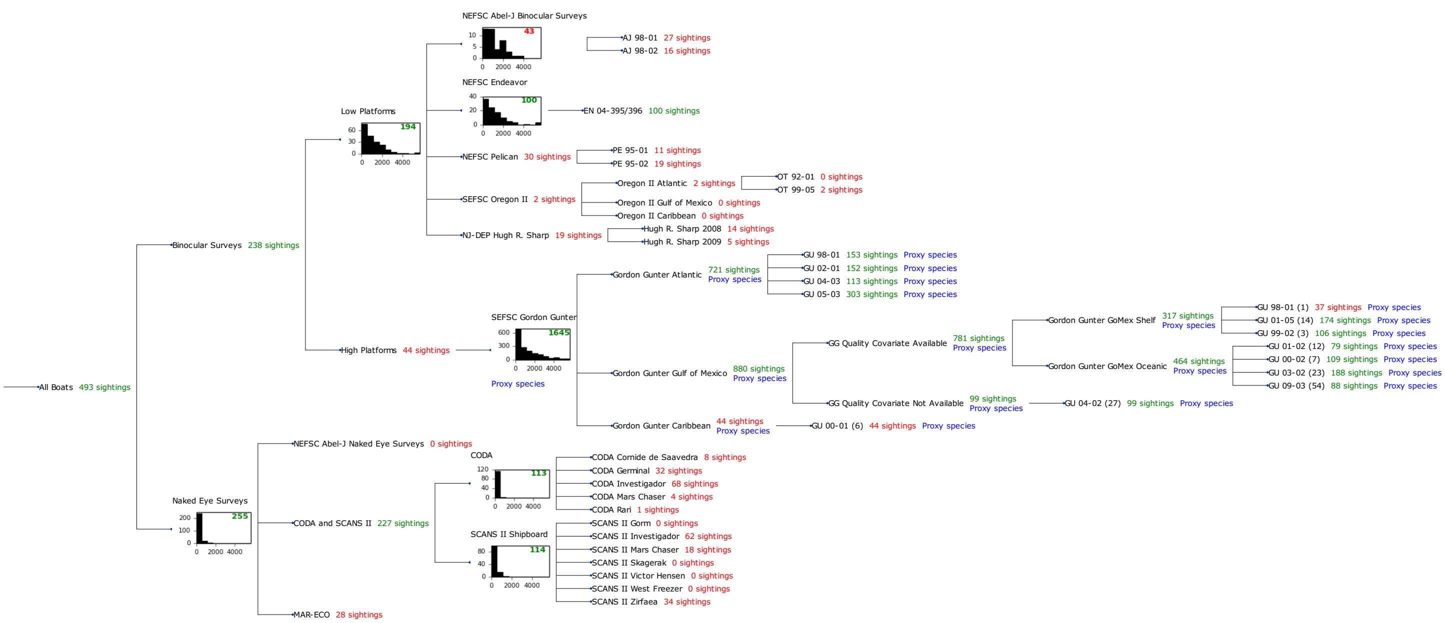


Figure 10: Detection hierarchy for shipboard surveys

Low Platforms

The sightings were right truncated at 4000m.

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

vessel	Vessel from which the observation was made. This covariate allows the detection function to account for vessel-specific biases, such as the height of the survey platform.

Table 5: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn	cos	3		Yes	0.00	1436
hr	poly	2		Yes	0.84	1258
hn				Yes	0.87	1665
hn			beaufort	Yes	1.34	1665
hn	cos	2		Yes	1.78	1553
hn			size	Yes	2.71	1665
hr	poly	4		Yes	2.85	1248
hn			beaufort, size	Yes	2.99	1667
hn			beaufort, vessel	Yes	4.79	1665
hn			vessel	Yes	6.70	1663
hr			beaufort, size	Yes	8.28	1750
hr			size	Yes	9.19	1368
hr				Yes	9.84	1793
hr			beaufort, vessel	Yes	10.52	1877
hr			beaufort, vessel, size	Yes	12.38	1849
hr			vessel	Yes	14.84	1560
hr			vessel, size	Yes	14.91	1351
hn	herm	4		No		
hr			beaufort	No		
hn			vessel, size	No		
hn			beaufort, vessel, size	No		

Table 6: Candidate detection functions for Low Platforms. The first one listed was selected for the density model.

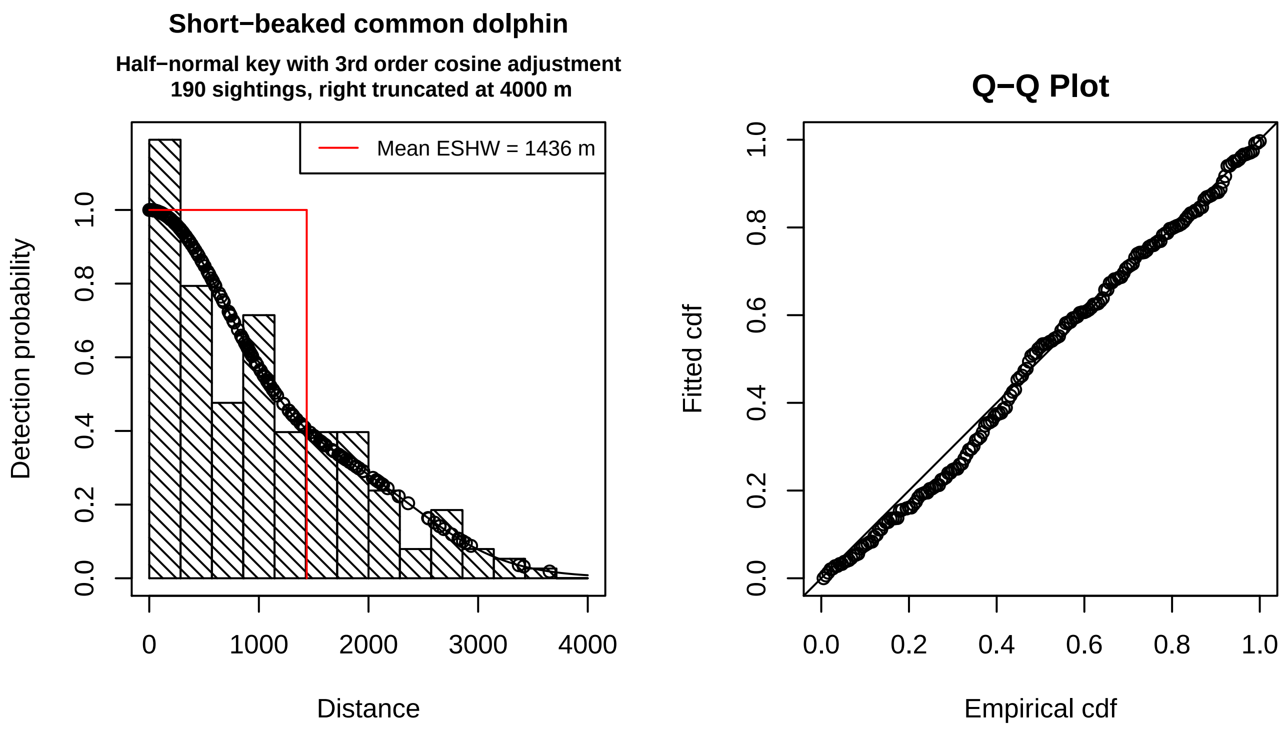


Figure 11: Detection function for Low Platforms that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  190
Distance range         :  0  -  4000
AIC                    :  3004.75

Detection function:
 Half-normal key function with cosine adjustment term of order 3

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 7.199788 0.05410986

Adjustment term parameter(s):
              estimate         se
cos, order 3 0.1668555 0.09835087


Monotonicity constraints were enforced.
                       Estimate          SE         CV
Average p             0.3590848  0.03366409 0.09374968
N in covered region 529.1228576 58.35301605 0.11028255

Monotonicity constraints were enforced.
```

Additional diagnostic plots:

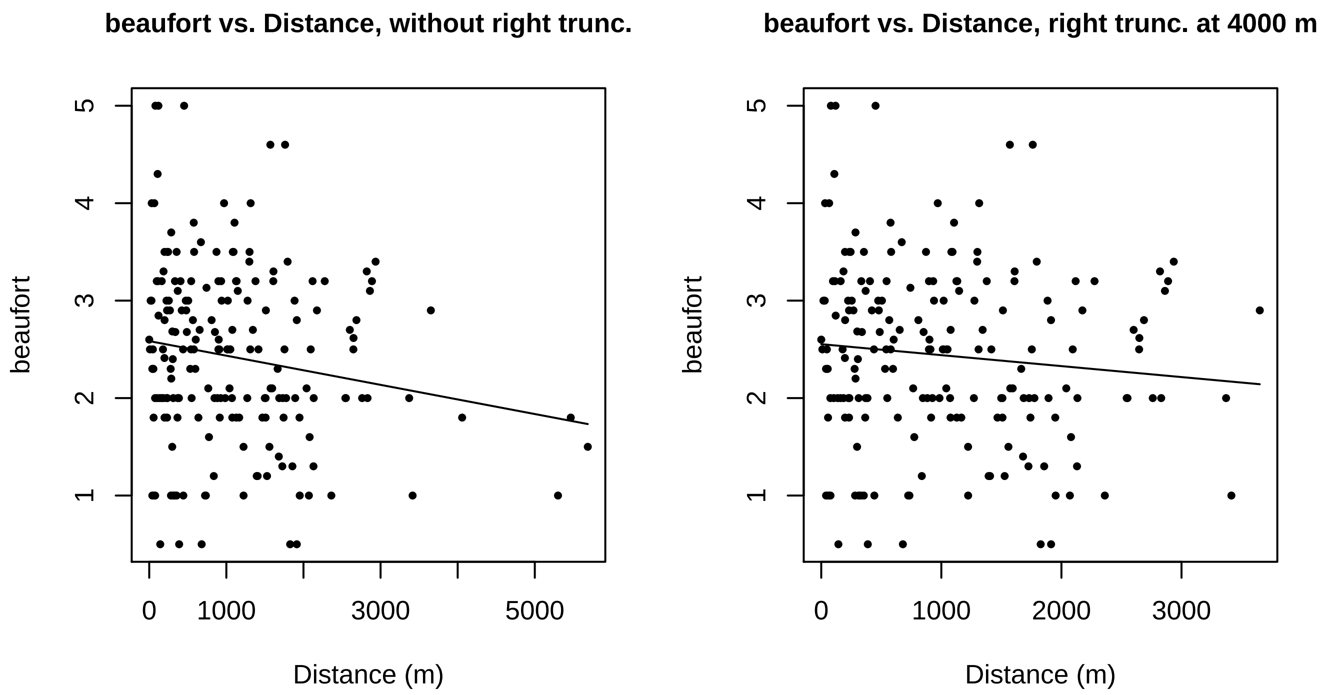


Figure 12: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

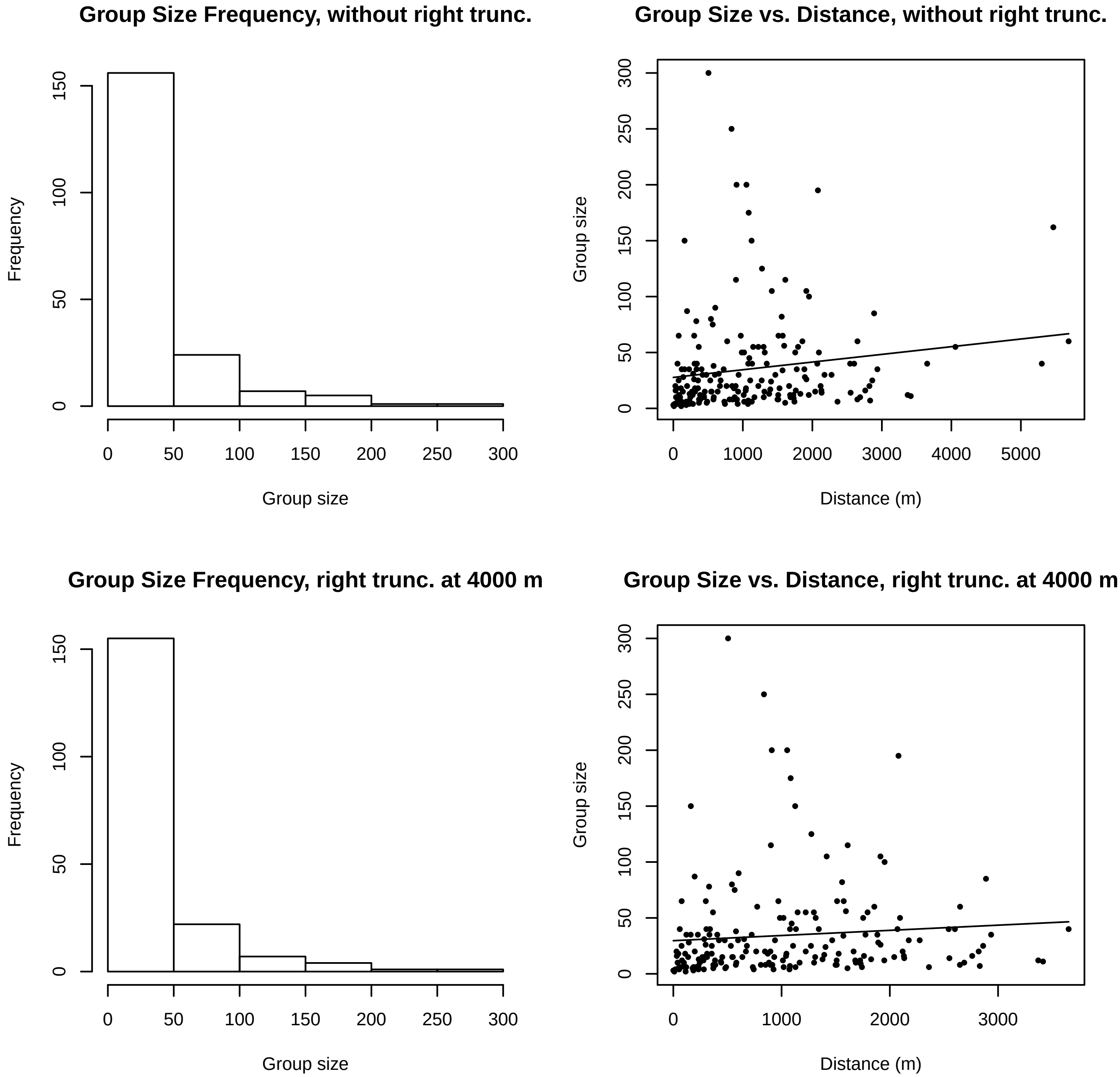


Figure 13: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NEFSC Abel-J Binocular Surveys

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

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn				Yes	0.00	1883
hn	cos	3		Yes	1.81	1719
hn	cos	2		Yes	1.99	1911
hn			size	Yes	2.48	2335
hr				Yes	3.13	2073
hr	poly	2		Yes	4.11	1816
hr	poly	4		Yes	4.27	1909
hr			size	Yes	4.96	1948
hn	herm	4		No		
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 8: Candidate detection functions for NEFSC Abel-J Binocular Surveys. The first one listed was selected for the density model.

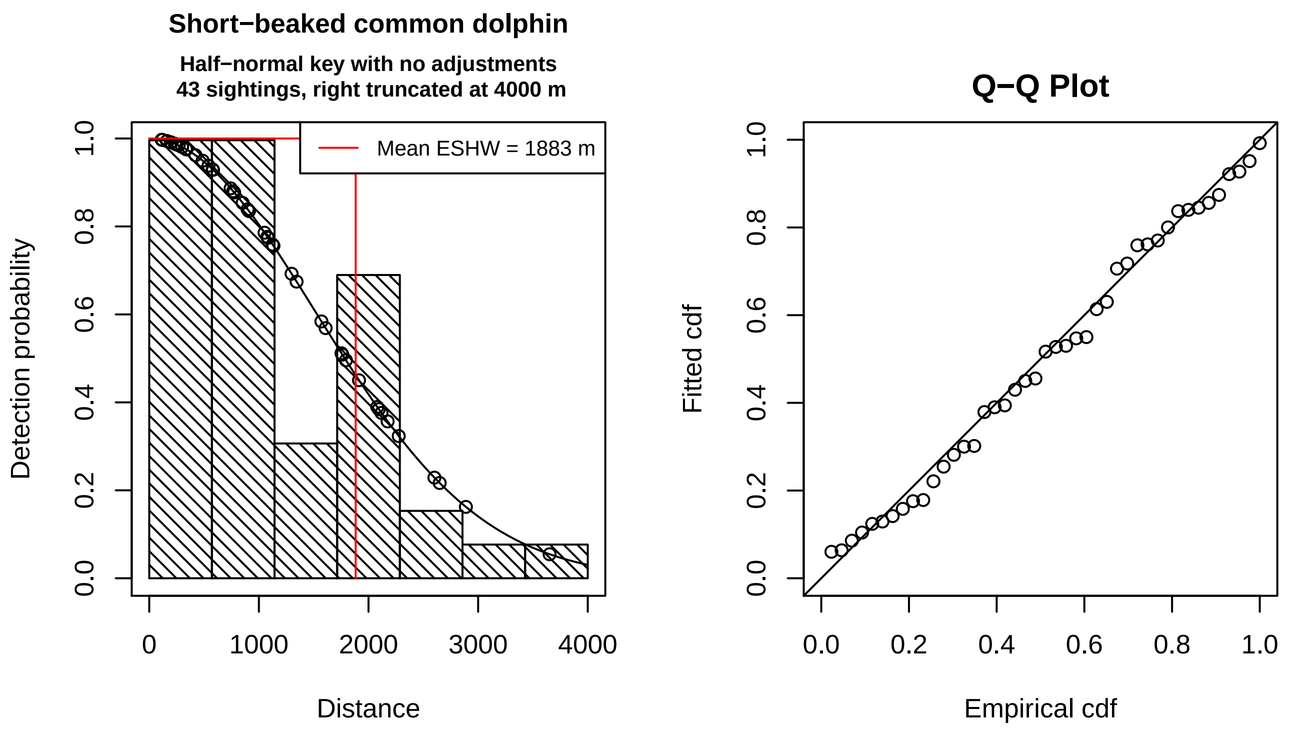


Figure 14: Detection function for NEFSC Abel-J Binocular Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  43
Distance range         :  0  -  4000
AIC                    :  690.6844

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept) 7.322976 0.1274395

                        Estimate          SE        CV
Average p              0.4706748  0.05608354 0.1191556
N in covered region 91.3581903 14.87426477 0.1628126
```

Additional diagnostic plots:

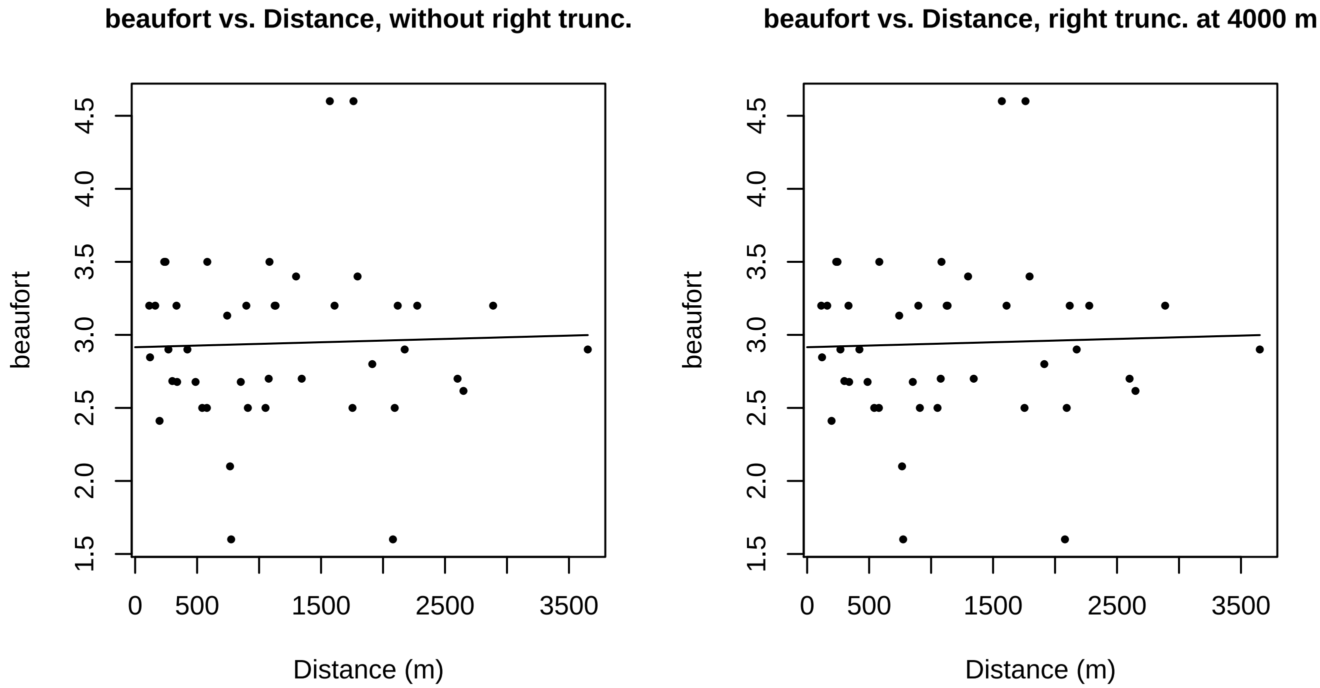


Figure 15: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

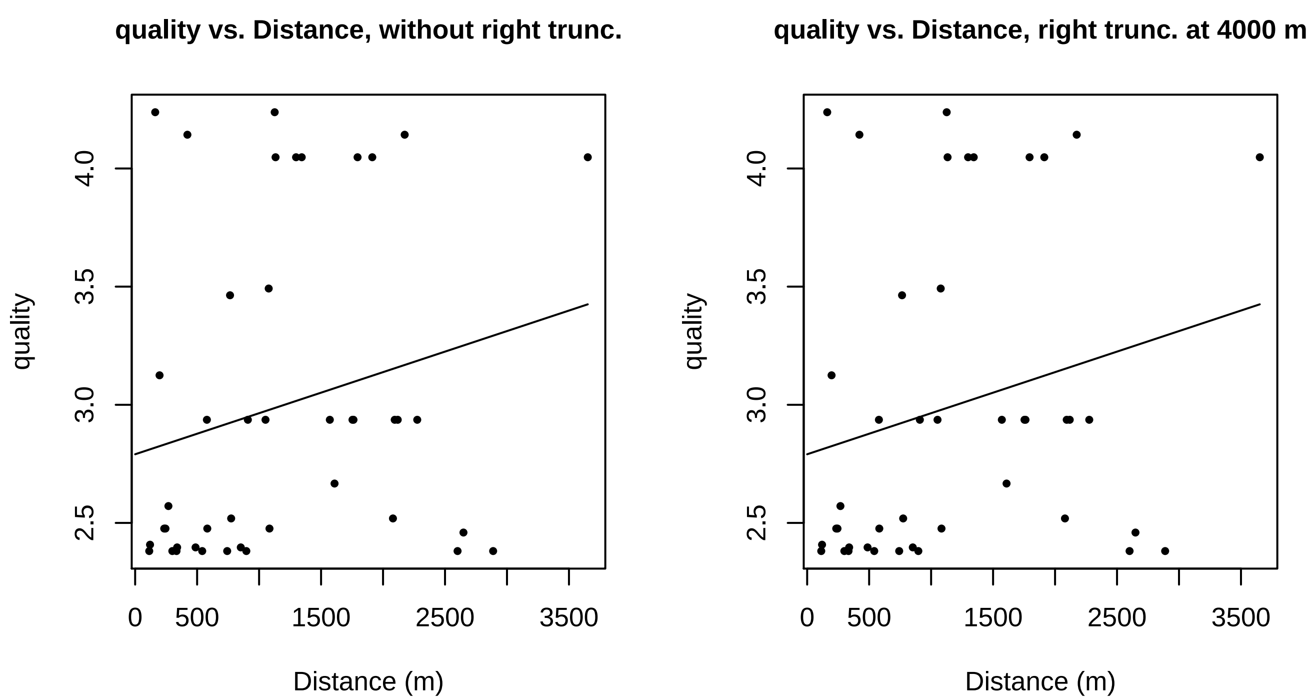


Figure 16: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

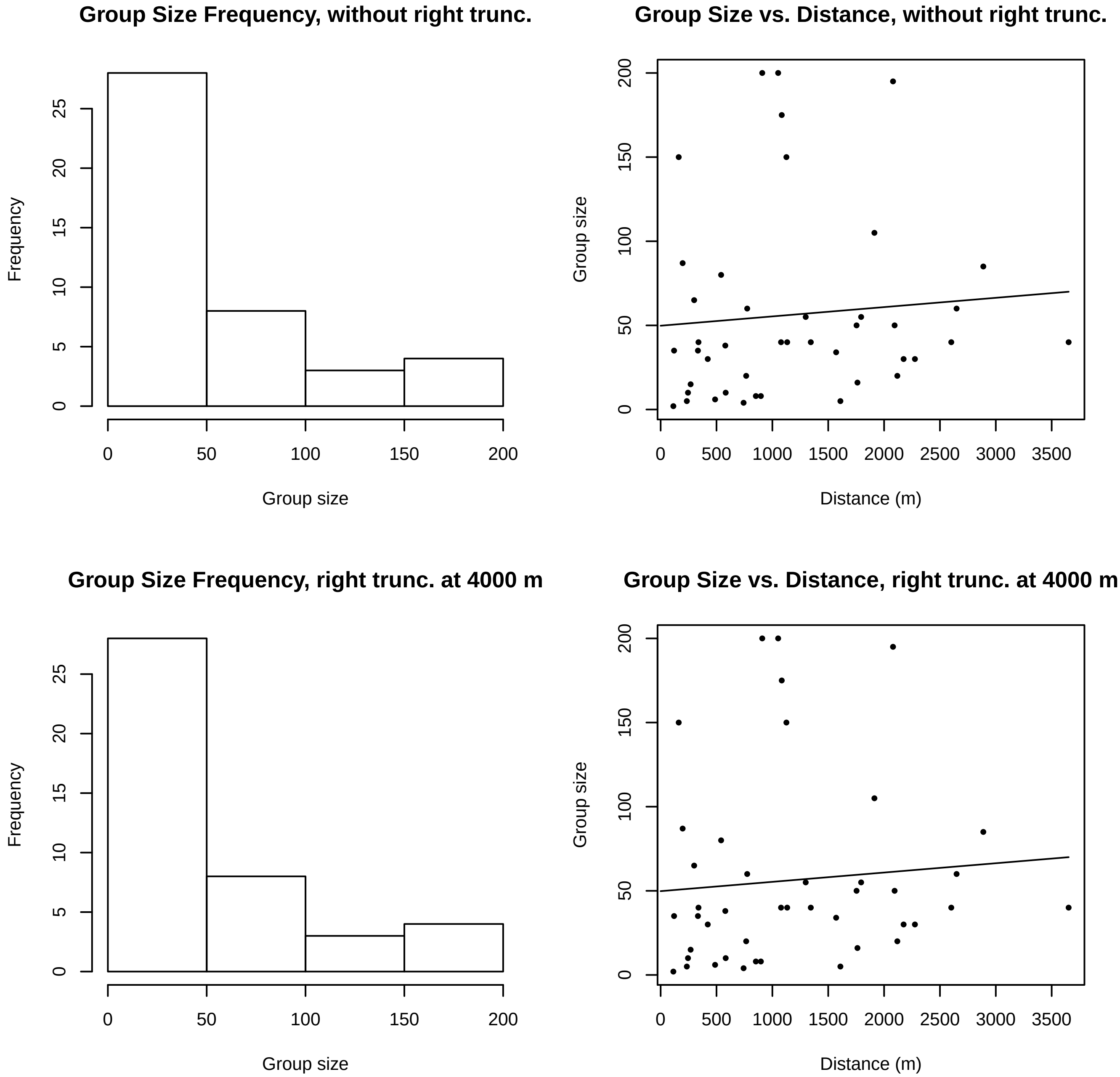


Figure 17: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NEFSC Endeavor

The sightings were right truncated at 3000m.

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				Yes	0.00	1638
hr			size	Yes	0.20	1120
hn	cos	2		Yes	1.28	1492
hn	cos	3		Yes	1.49	1493
hn			beaufort	Yes	1.53	1640
hr	poly	4		Yes	2.05	1177
hr			quality	Yes	2.11	1068
hr	poly	2		Yes	2.22	1225
hr			quality, size	Yes	2.62	1043
hr				Yes	2.66	1717
hr			beaufort	Yes	2.92	1823
hr			beaufort, size	Yes	4.83	1834
hr			beaufort, quality	Yes	4.92	1821
hr			beaufort, quality, size	Yes	6.87	1831
hn	herm	4		No		
hn			quality	No		
hn			size	No		
hn			beaufort, quality	No		
hn			beaufort, size	No		
hn			quality, size	No		
hn			beaufort, quality, size	No		

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

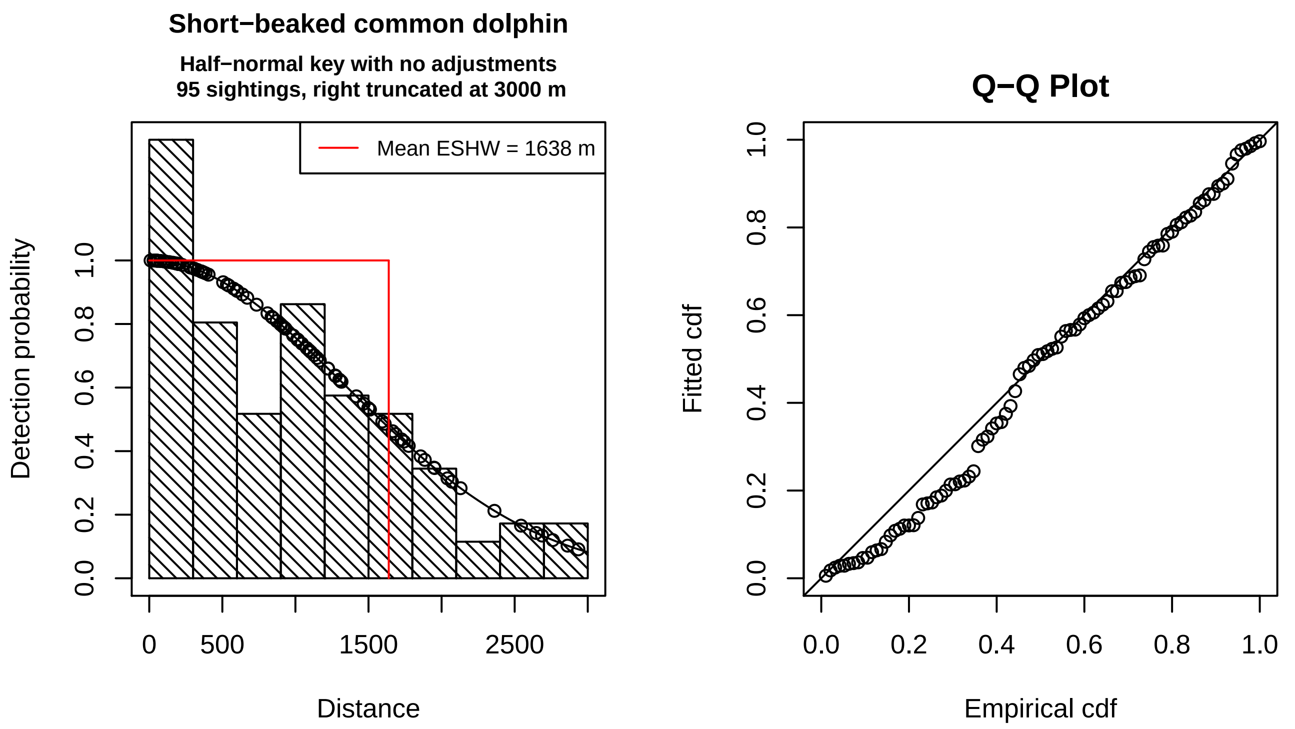


Figure 18: Detection function for NEFSC Endeavor that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  95
Distance range         :  0  -  3000
AIC                    :  1489.028

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 7.201324 0.09196094

                       Estimate          SE         CV
Average p             0.5461413  0.04268774 0.07816246
N in covered region 173.9476641 18.14969428 0.10433997
```

Additional diagnostic plots:

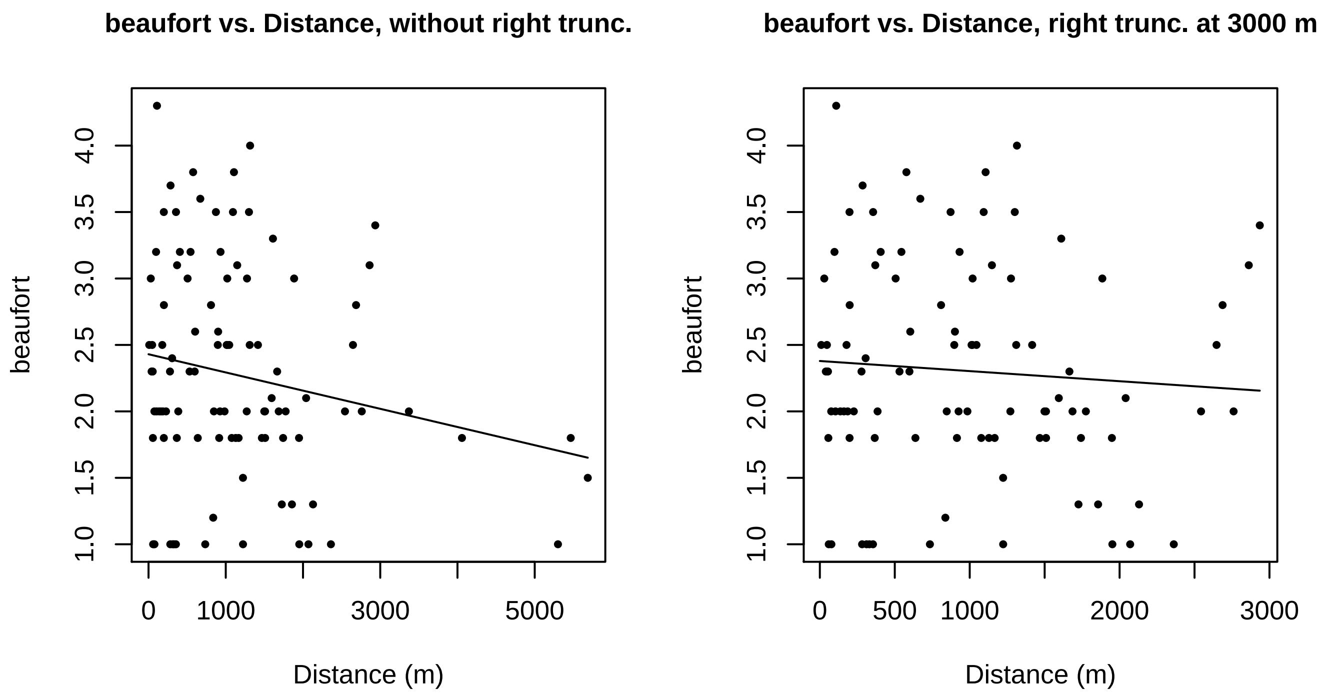


Figure 19: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

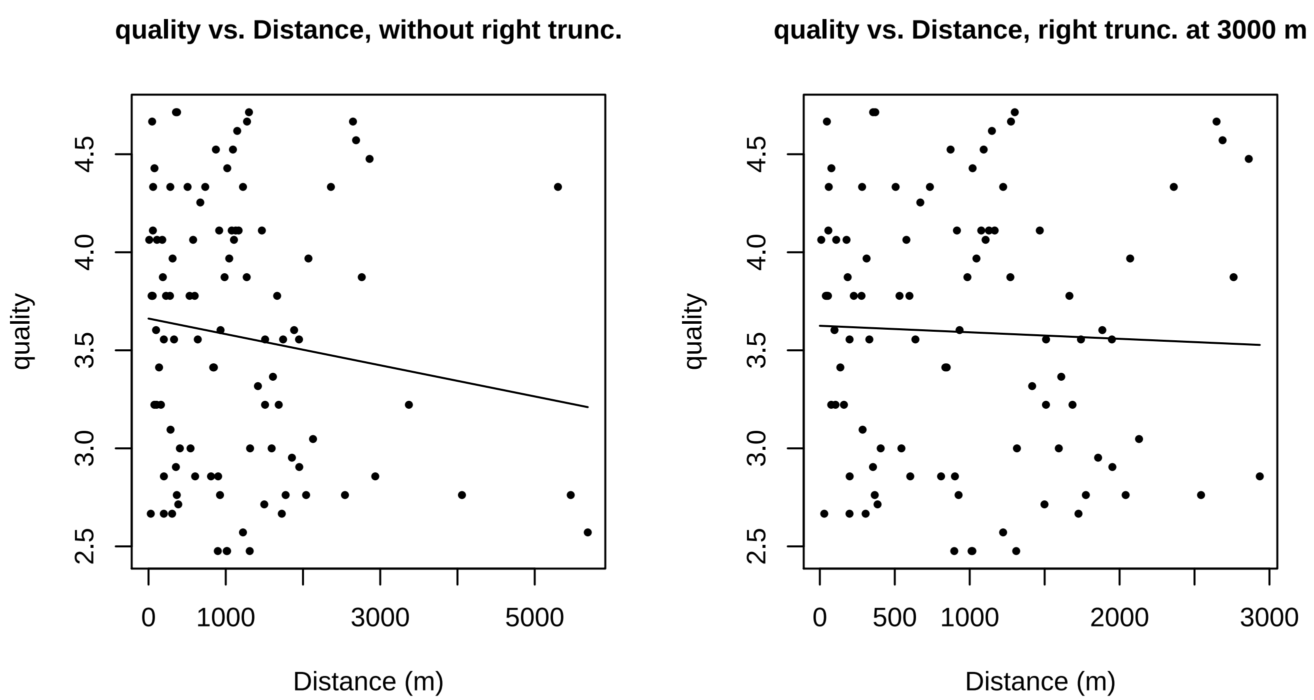


Figure 20: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

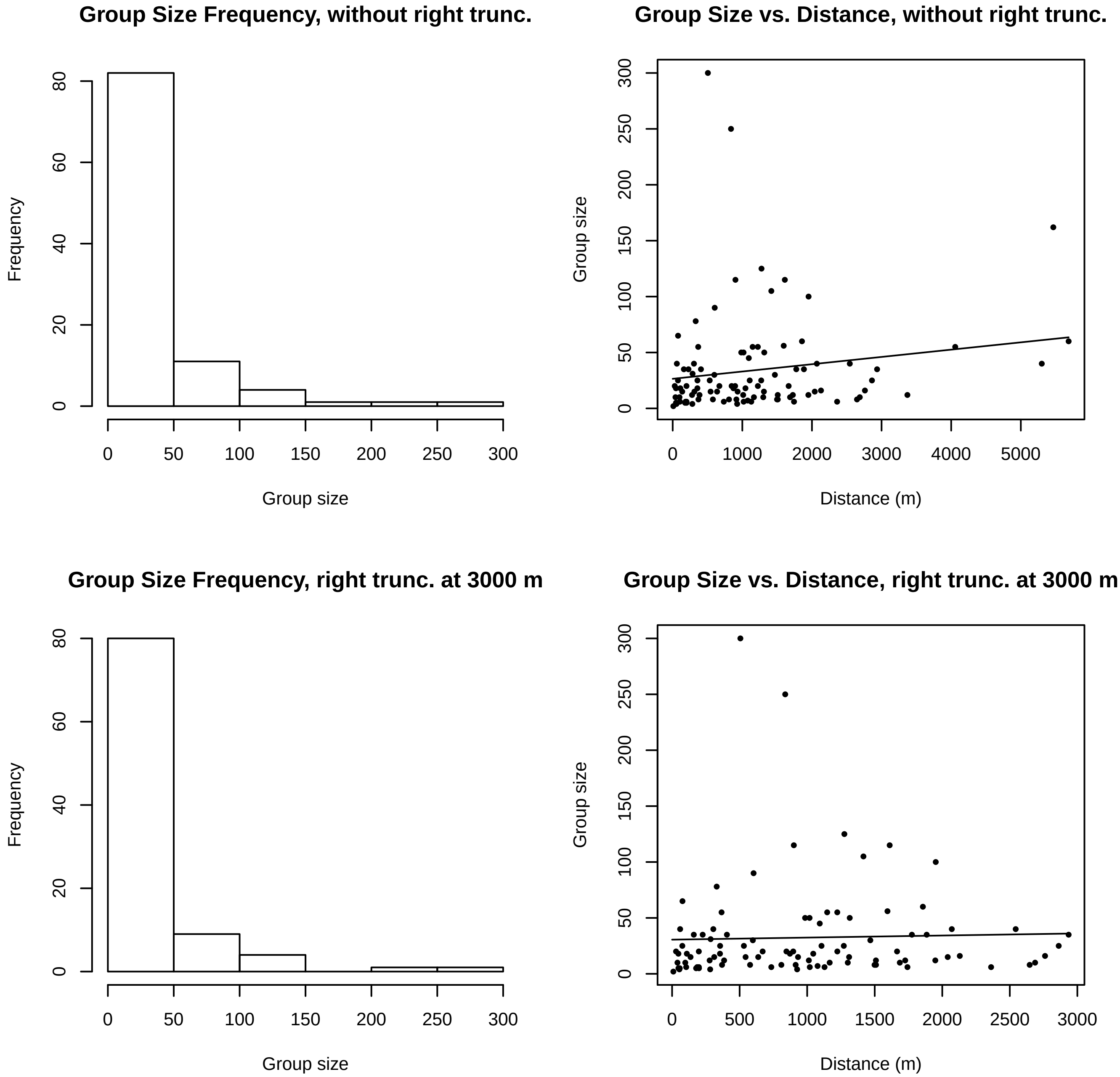


Figure 21: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SEFSC 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 11: 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 12: 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 13: Candidate detection functions for SEFSC Gordon Gunter. The first one listed was selected for the density model.

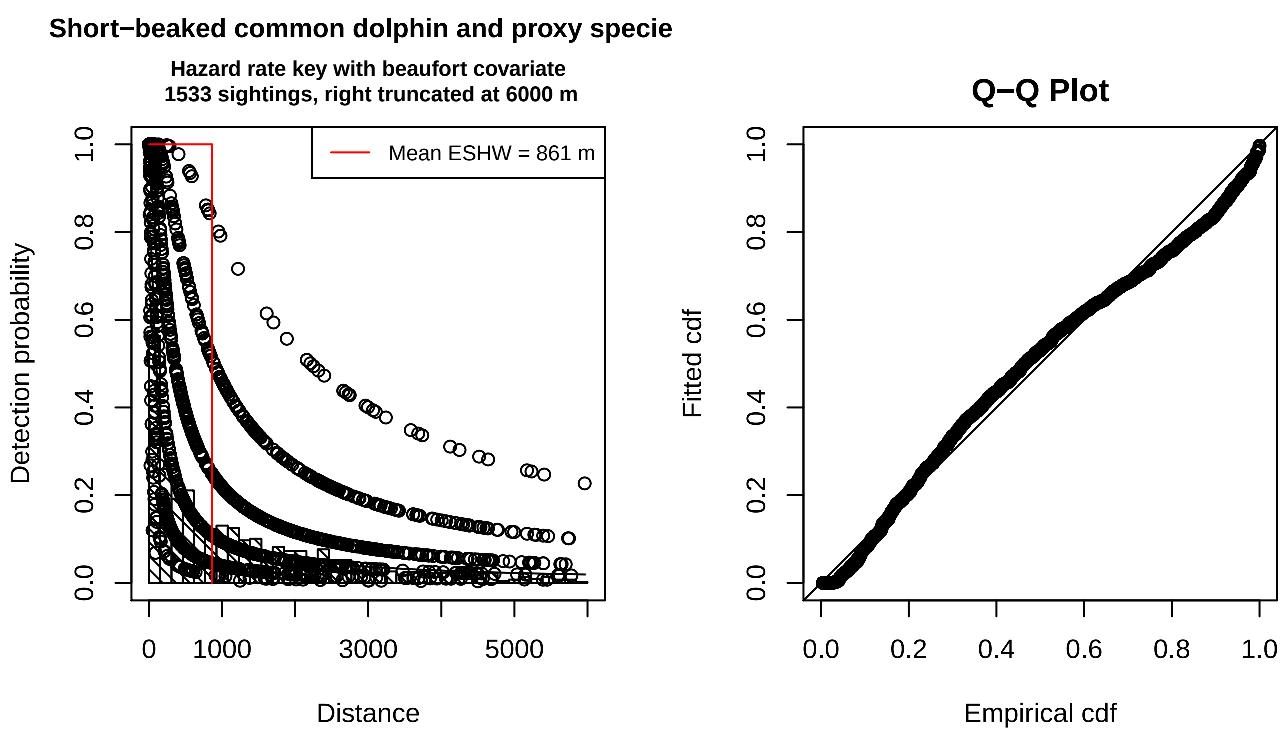


Figure 22: Detection function for SEFSC Gordon Gunter that was selected for the density model

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:

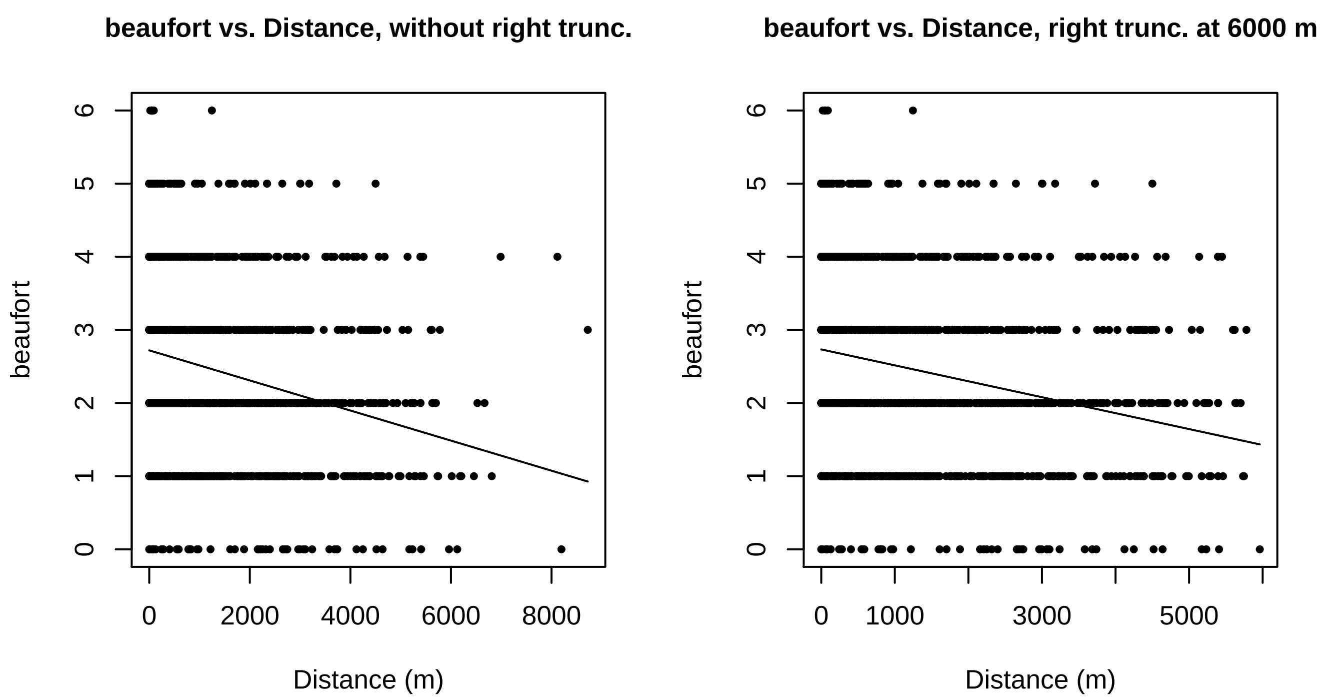


Figure 23: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

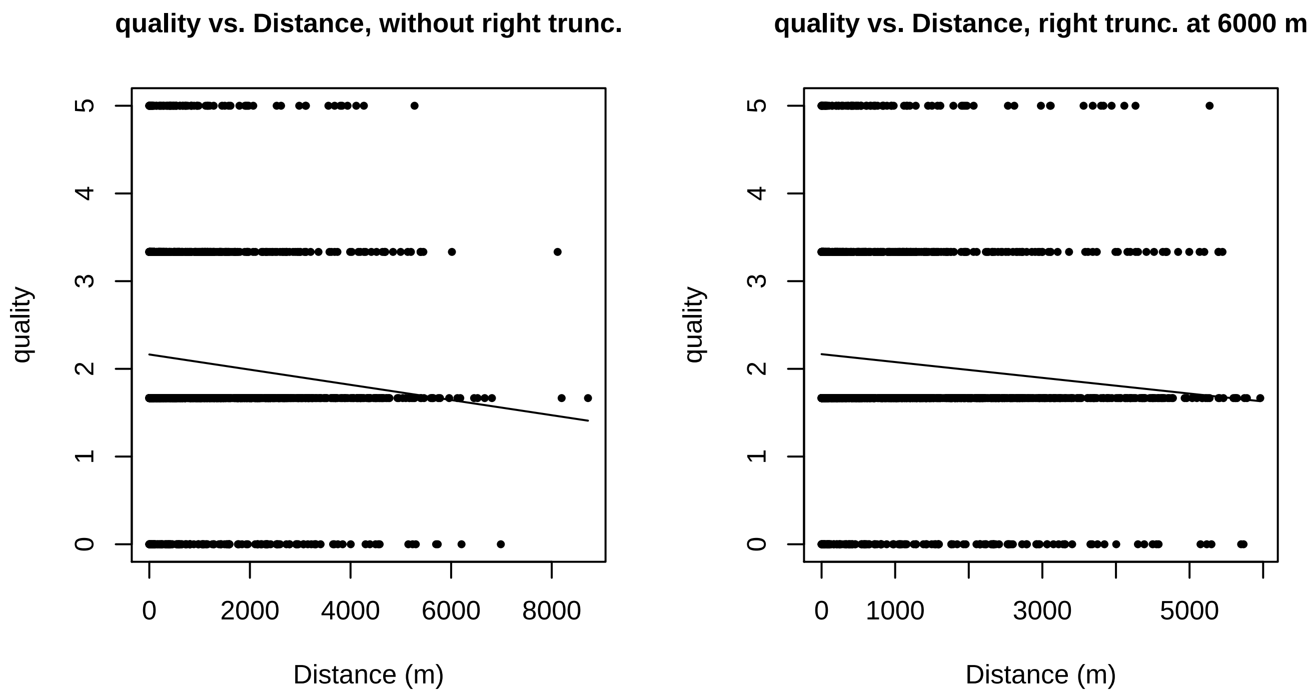


Figure 24: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

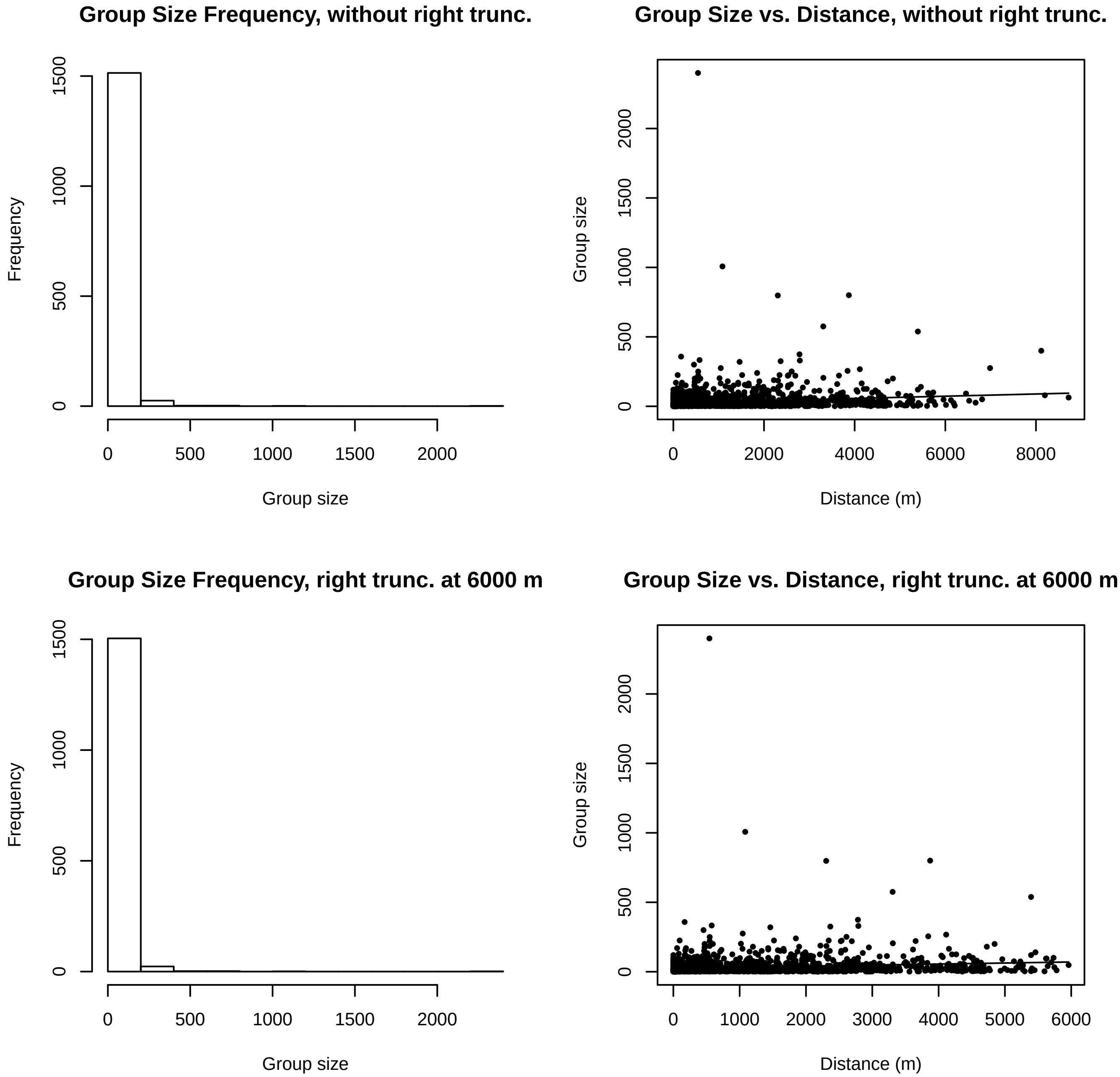


Figure 25: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Naked Eye Surveys

The sightings were right truncated at 1200m.

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

Table 14: 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	280
hr			beaufort	Yes	0.85	268
hr	poly	2		Yes	2.82	237
hn	cos	2		Yes	3.32	309
hr	poly	4		Yes	3.86	263
hr			size	Yes	3.96	292
hr				Yes	4.13	282
hn	cos	3		Yes	10.91	281
hn			size	Yes	25.70	388
hn			beaufort, size	Yes	27.66	388
hn				Yes	33.41	376
hn			beaufort	Yes	35.29	376
hn	herm	4		No		

Table 15: Candidate detection functions for Naked Eye Surveys. The first one listed was selected for the density model.

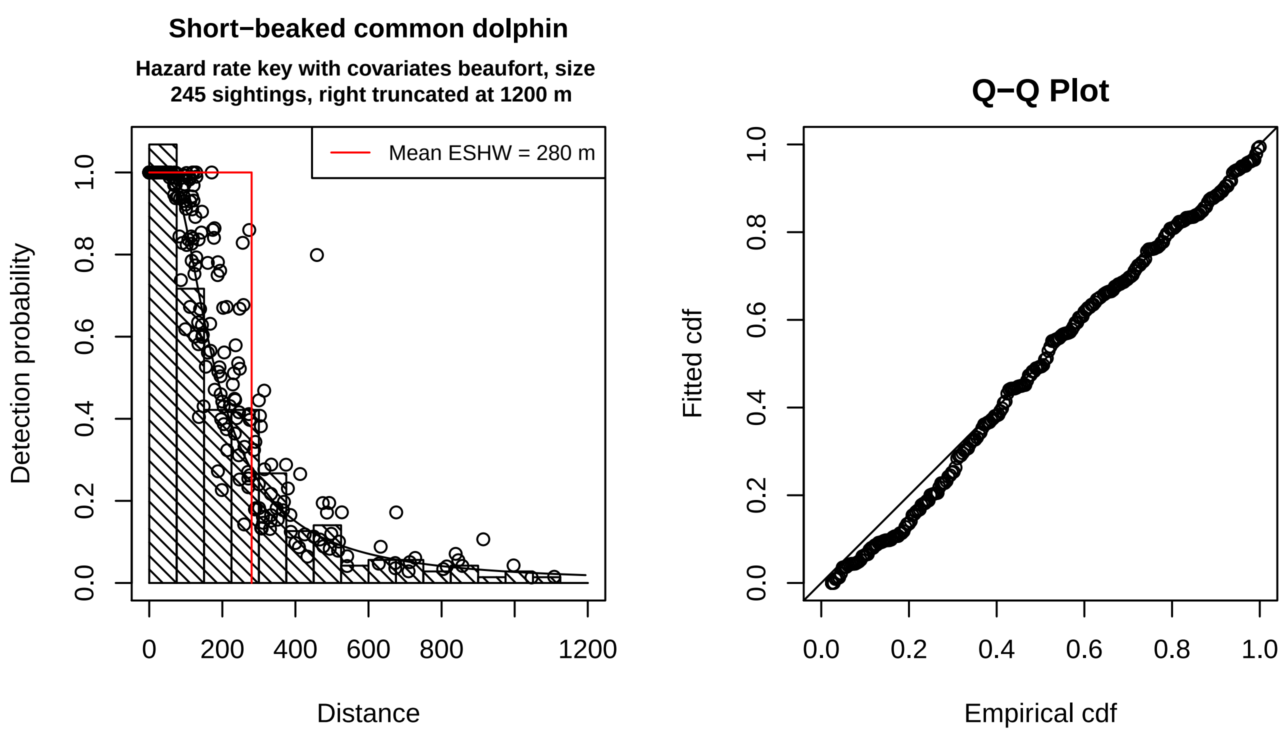


Figure 26: Detection function for Naked Eye Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
```

```
Number of observations :  245
Distance range         :  0  -  1200
AIC                    :  3119.322

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate         se
(Intercept)  5.3596438 0.24859979
beaufort    -0.1642021 0.07312133
size         0.3577323 0.16418866

Shape parameters:
             estimate        se
(Intercept) 0.7082958 0.1032291

                        Estimate           SE         CV
Average p              0.2152285   0.01810298 0.08411051
N in covered region 1138.3248376 115.81987129 0.10174589
```

Additional diagnostic plots:

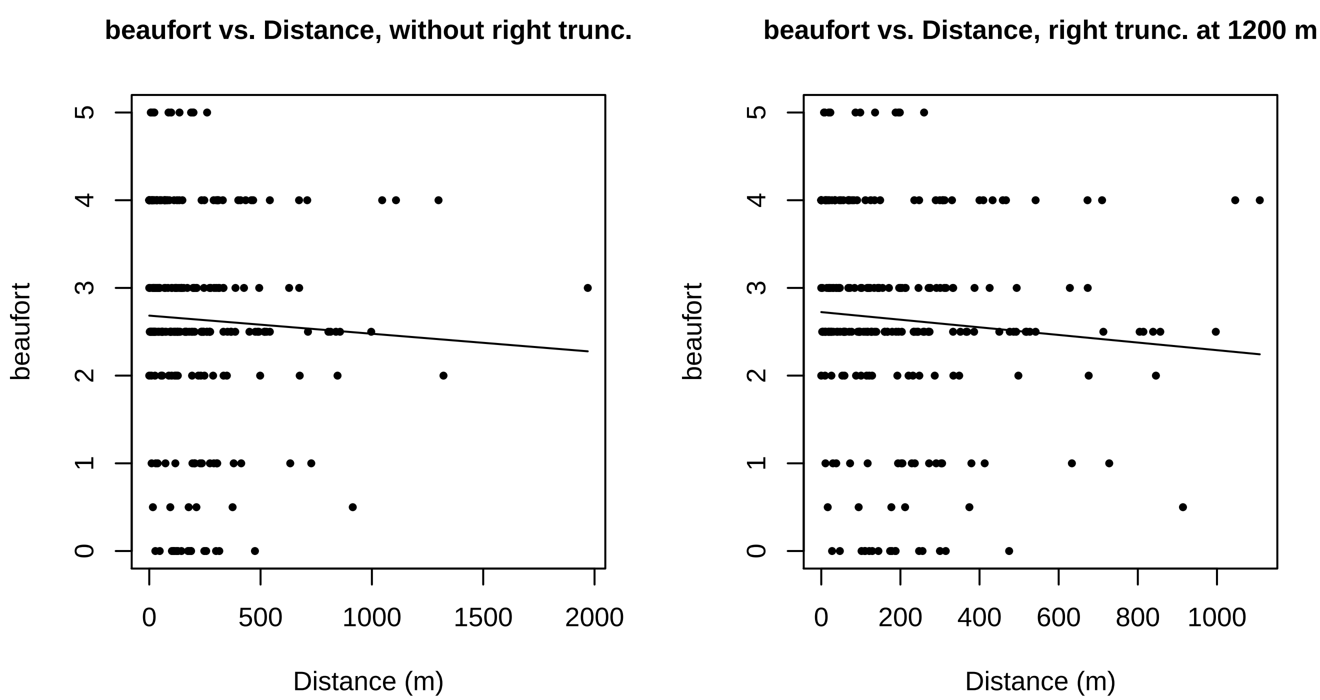


Figure 27: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

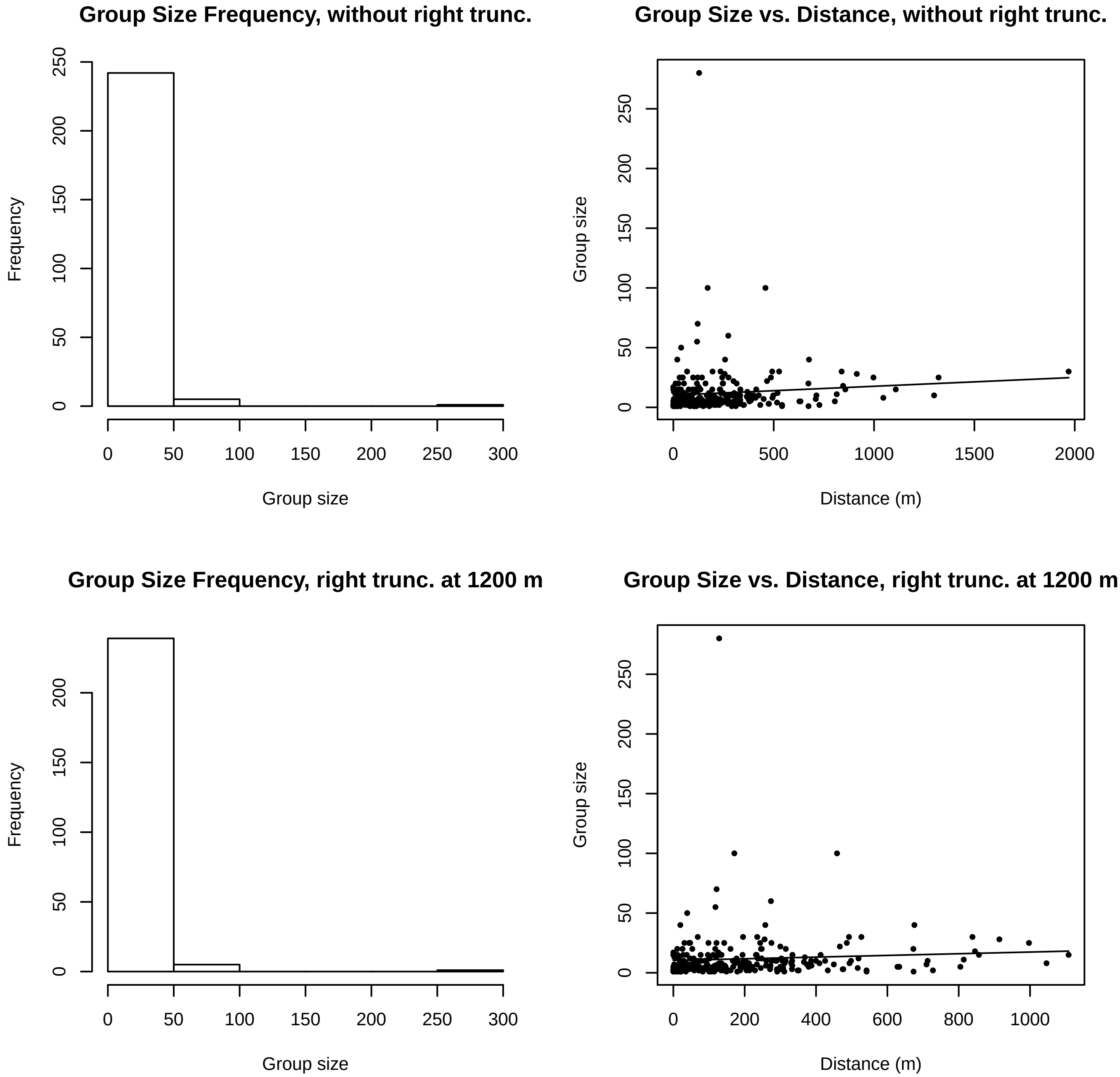


Figure 28: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

CODA

The sightings were right truncated at 600m.

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 16: 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	192
hr			quality, size	Yes	1.60	198
hr			beaufort, size	Yes	2.00	192
hr				Yes	5.31	167
hr			quality	Yes	5.93	178
hr			beaufort	Yes	7.08	171
hr	poly	4		Yes	7.11	164
hr	poly	2		Yes	7.24	164
hn	cos	2		Yes	8.25	212
hn	cos	3		Yes	13.48	204
hn			size	Yes	17.72	282
hn			quality	Yes	18.51	280
hn			quality, size	Yes	18.52	280
hn				Yes	18.58	281
hn			beaufort, size	Yes	19.46	282
hn	herm	4		Yes	20.33	281
hn			beaufort	Yes	20.46	281
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 17: Candidate detection functions for CODA. The first one listed was selected for the density model.

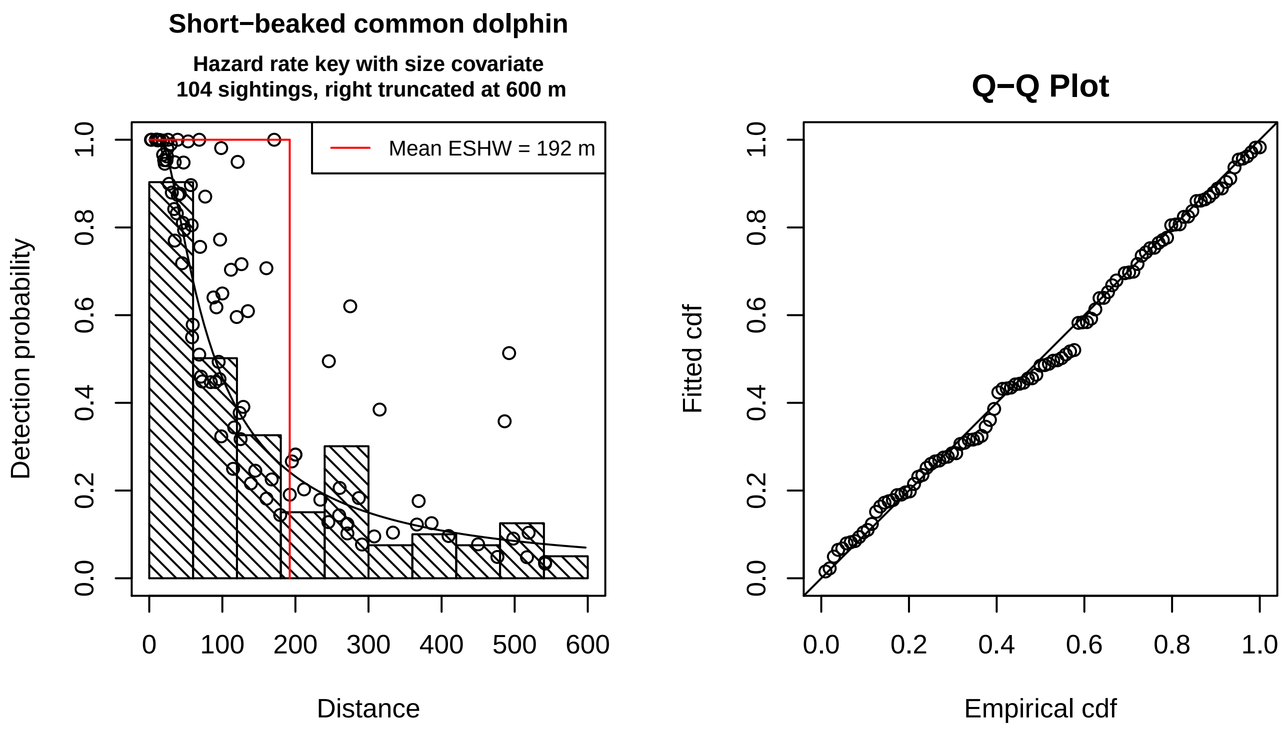


Figure 29: Detection function for CODA that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  104
Distance range         :  0  -  600
AIC                    :  1253.884

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept) 3.759157 0.4865157
size        1.164316 0.5454890

Shape parameters:
             estimate       se
(Intercept) 0.3157106 0.185555

                        Estimate         SE        CV
Average p              0.2609576  0.0534943 0.2049923
N in covered region 398.5321205 88.8455084 0.2229319
```

Additional diagnostic plots:

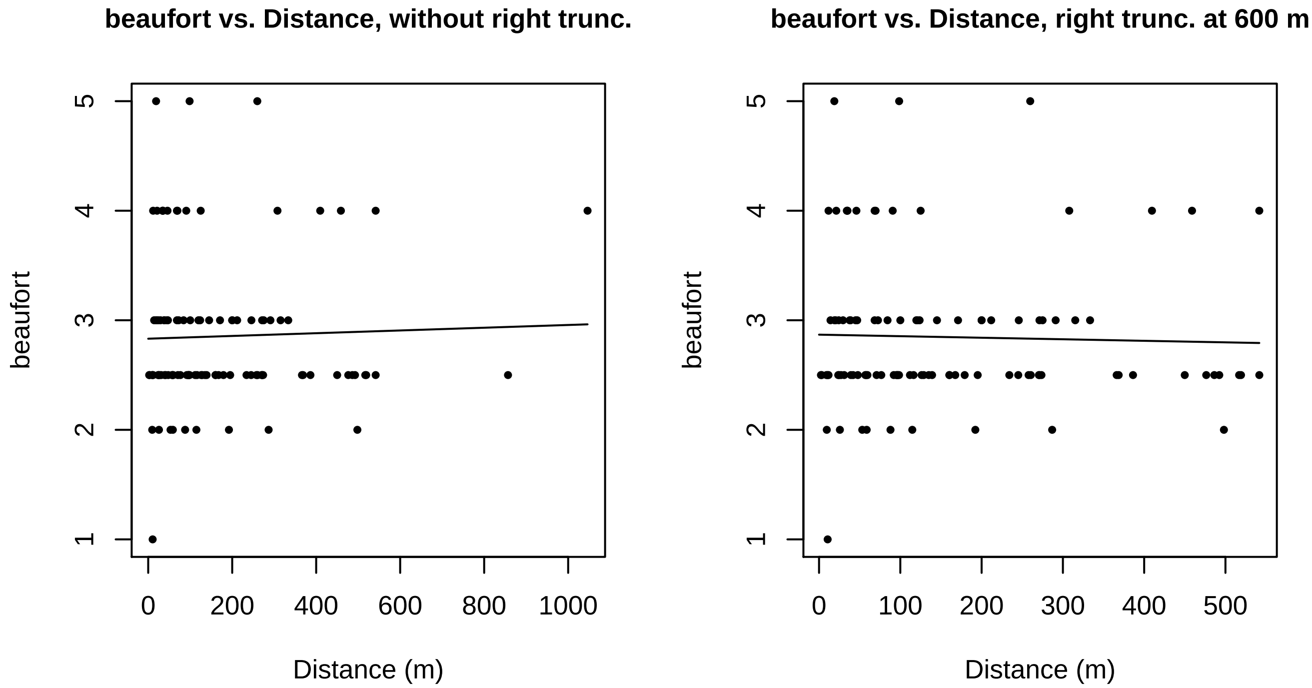


Figure 30: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

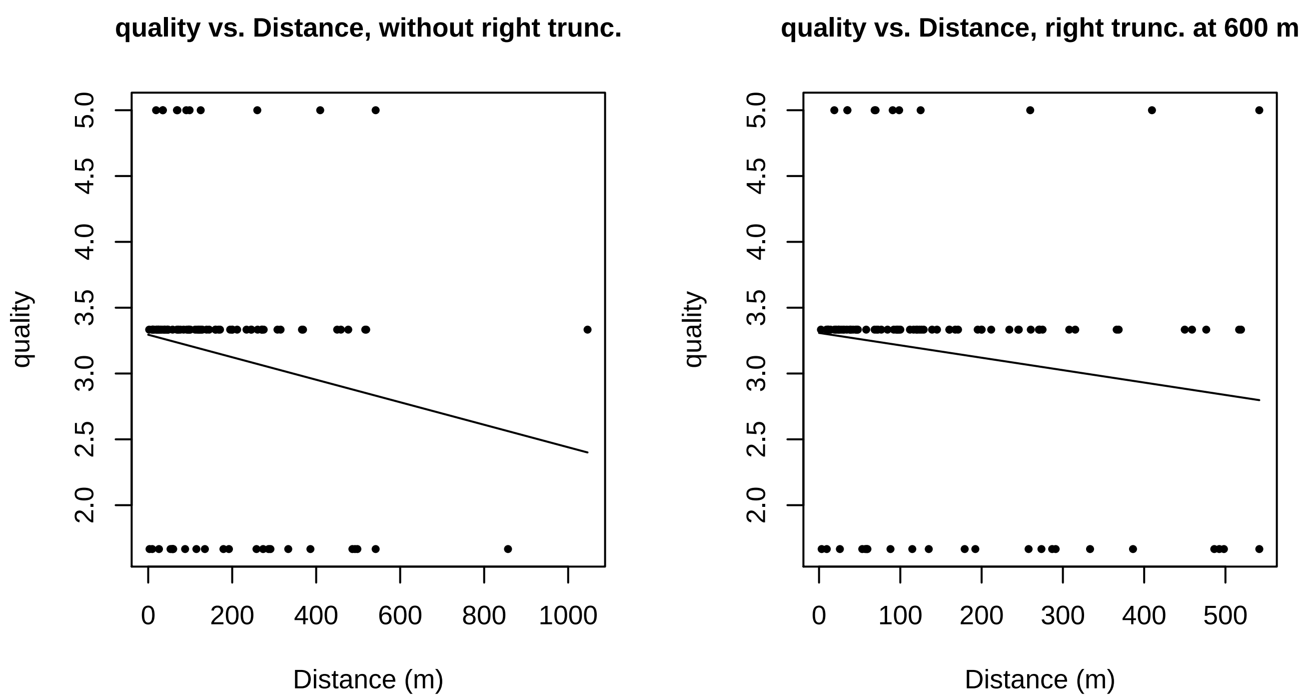


Figure 31: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

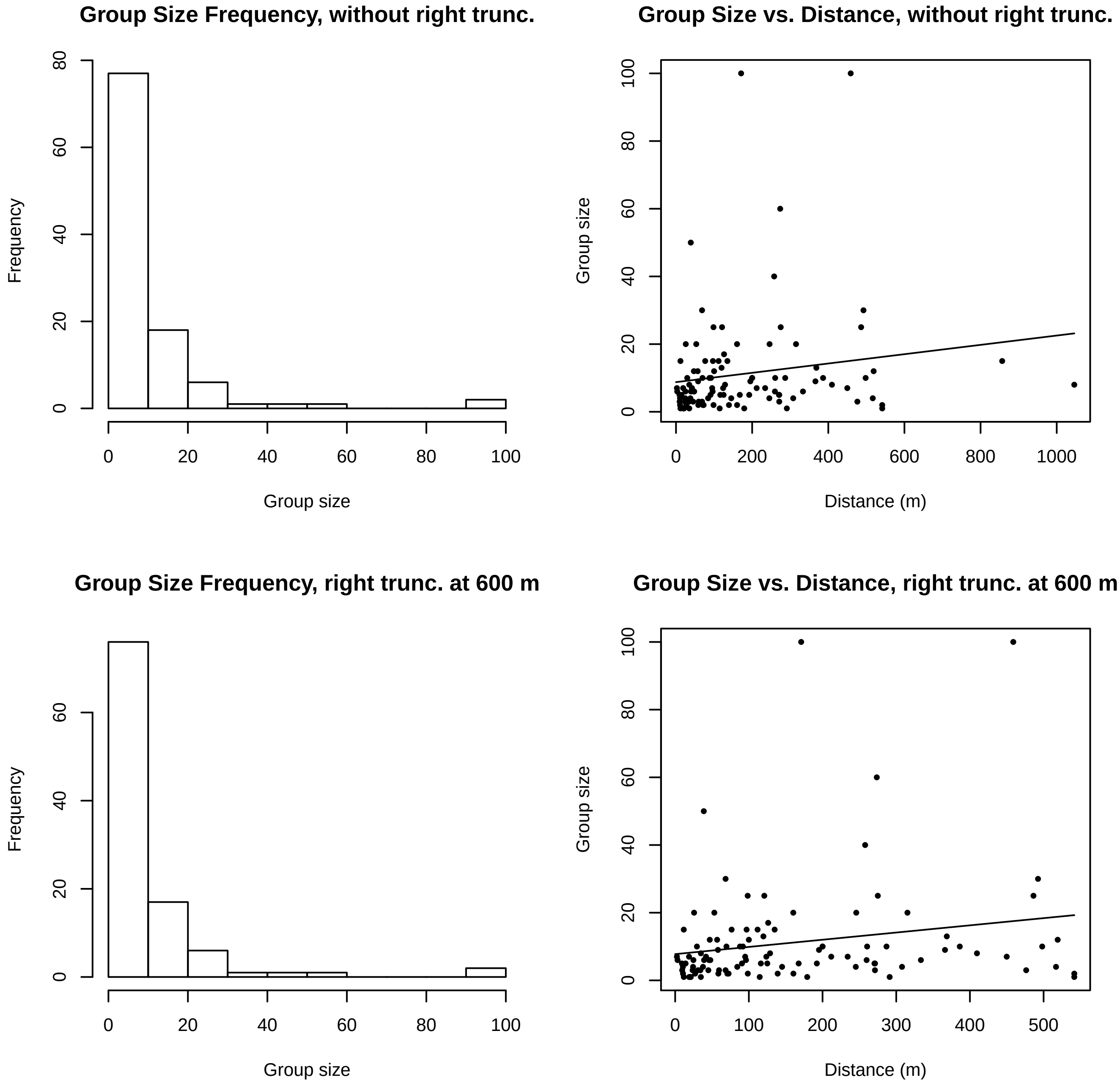


Figure 32: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

SCANS II Shipboard

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

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn	cos	2		Yes	0.00	322
hr				Yes	1.87	376
hr			quality	Yes	3.43	367
hr			beaufort	Yes	3.78	372
hr	poly	2		Yes	3.87	376
hr	poly	4		Yes	3.87	376
hn			size	Yes	5.96	451
hn				Yes	10.99	437
hn	cos	3		Yes	12.34	396
hn	herm	4		Yes	12.70	436
hn			beaufort	No		
hn			quality	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 19: Candidate detection functions for SCANS II Shipboard. The first one listed was selected for the density model.

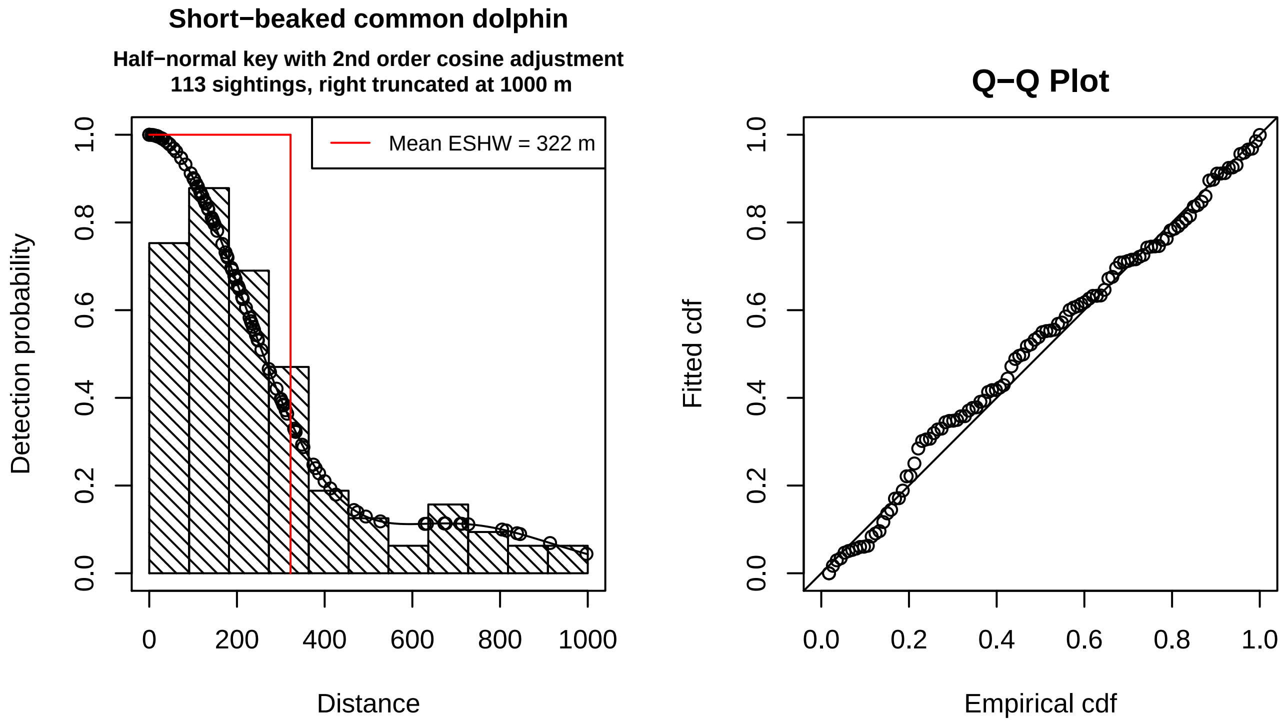


Figure 33: Detection function for SCANS II Shipboard that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  113
Distance range         :  0  -  1000
AIC                    :  1473.649

Detection function:
 Half-normal key function with cosine adjustment term of order 2

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.989493 0.07985869

Adjustment term parameter(s):
              estimate       se
cos, order 2 0.5650613 0.134987


Monotonicity constraints were enforced.
                       Estimate          SE         CV
Average p             0.3222314  0.02780618 0.08629259
N in covered region 350.6796971 40.66125072 0.11594983

Monotonicity constraints were enforced.
```

Additional diagnostic plots:

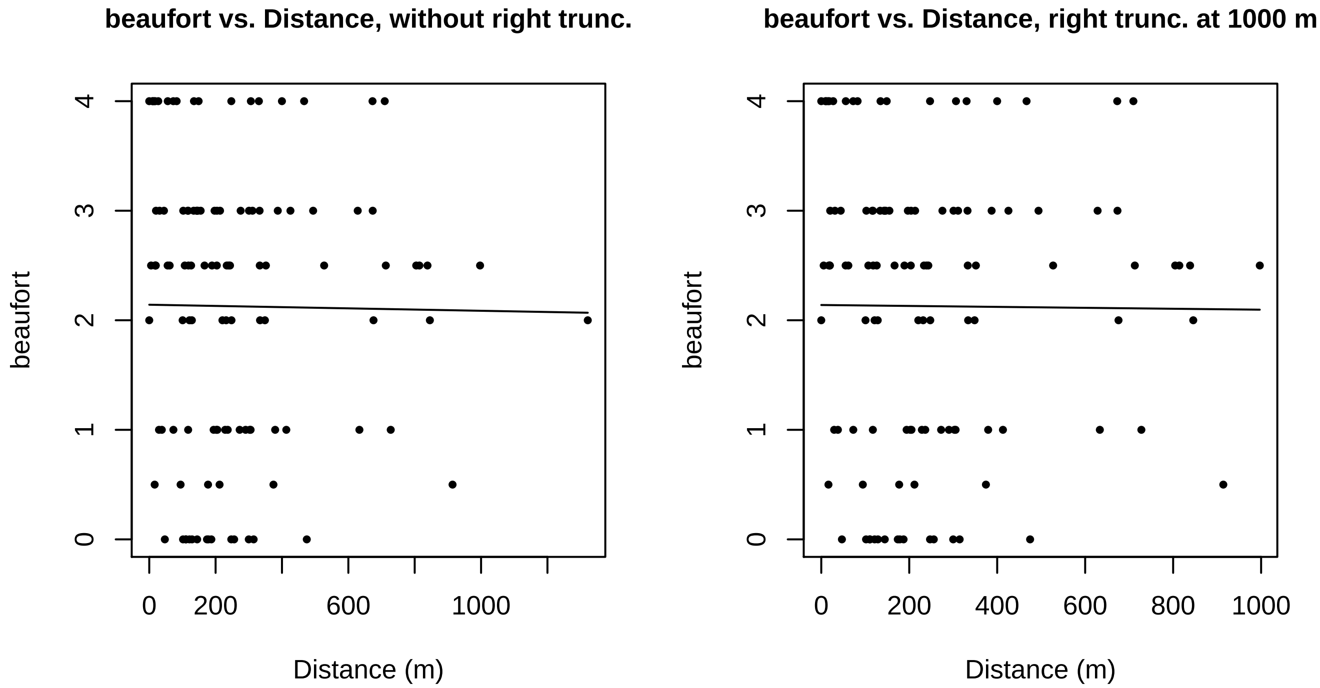


Figure 34: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

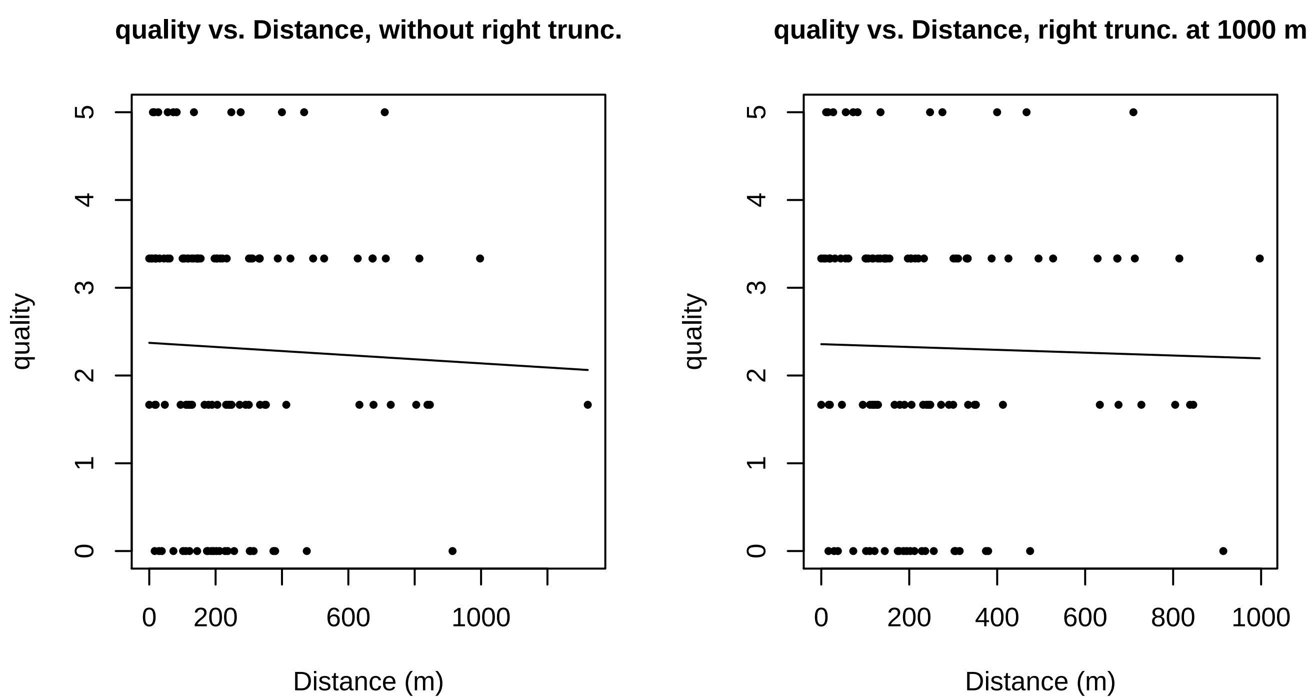


Figure 35: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

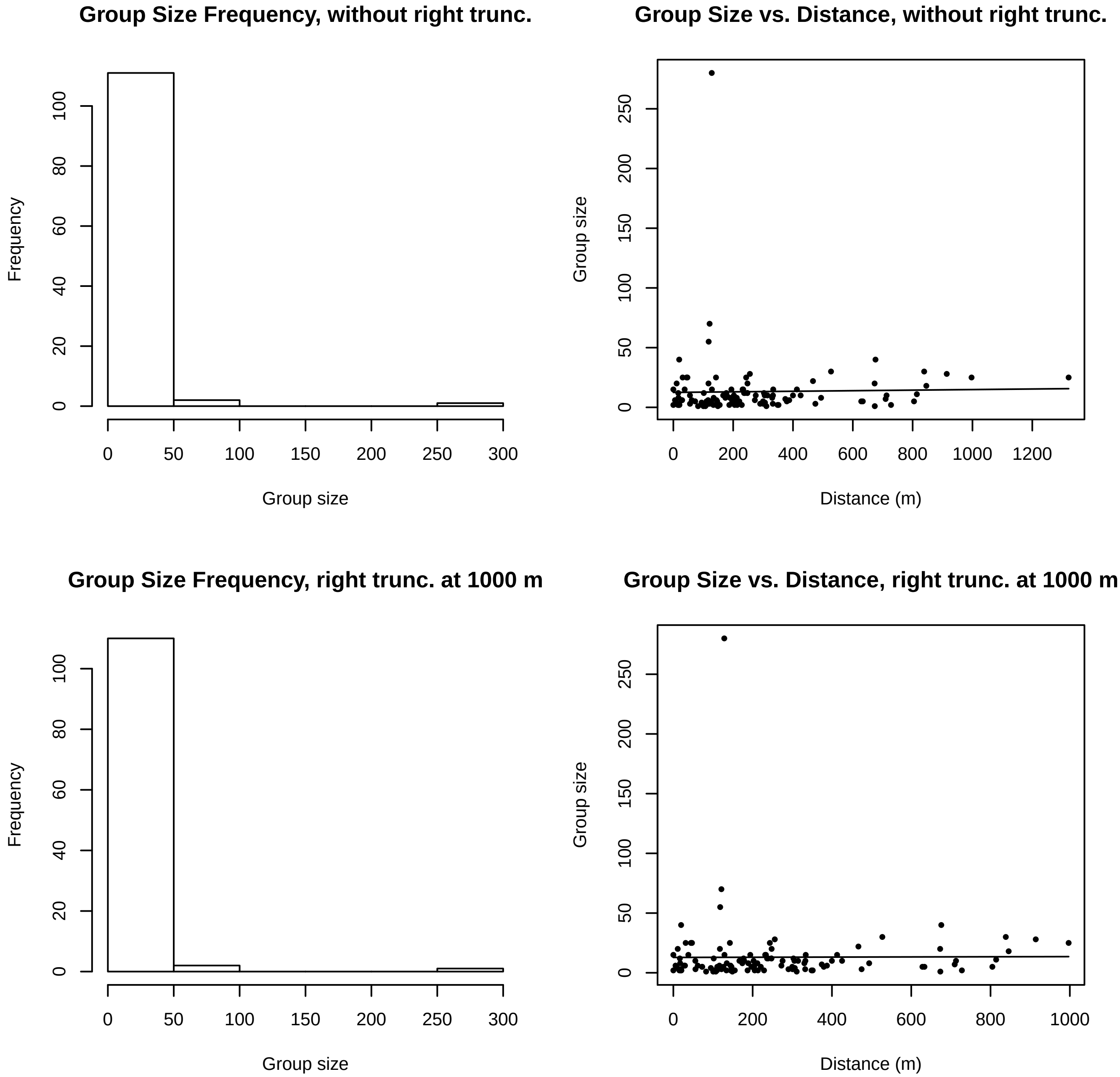


Figure 36: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Aerial Surveys

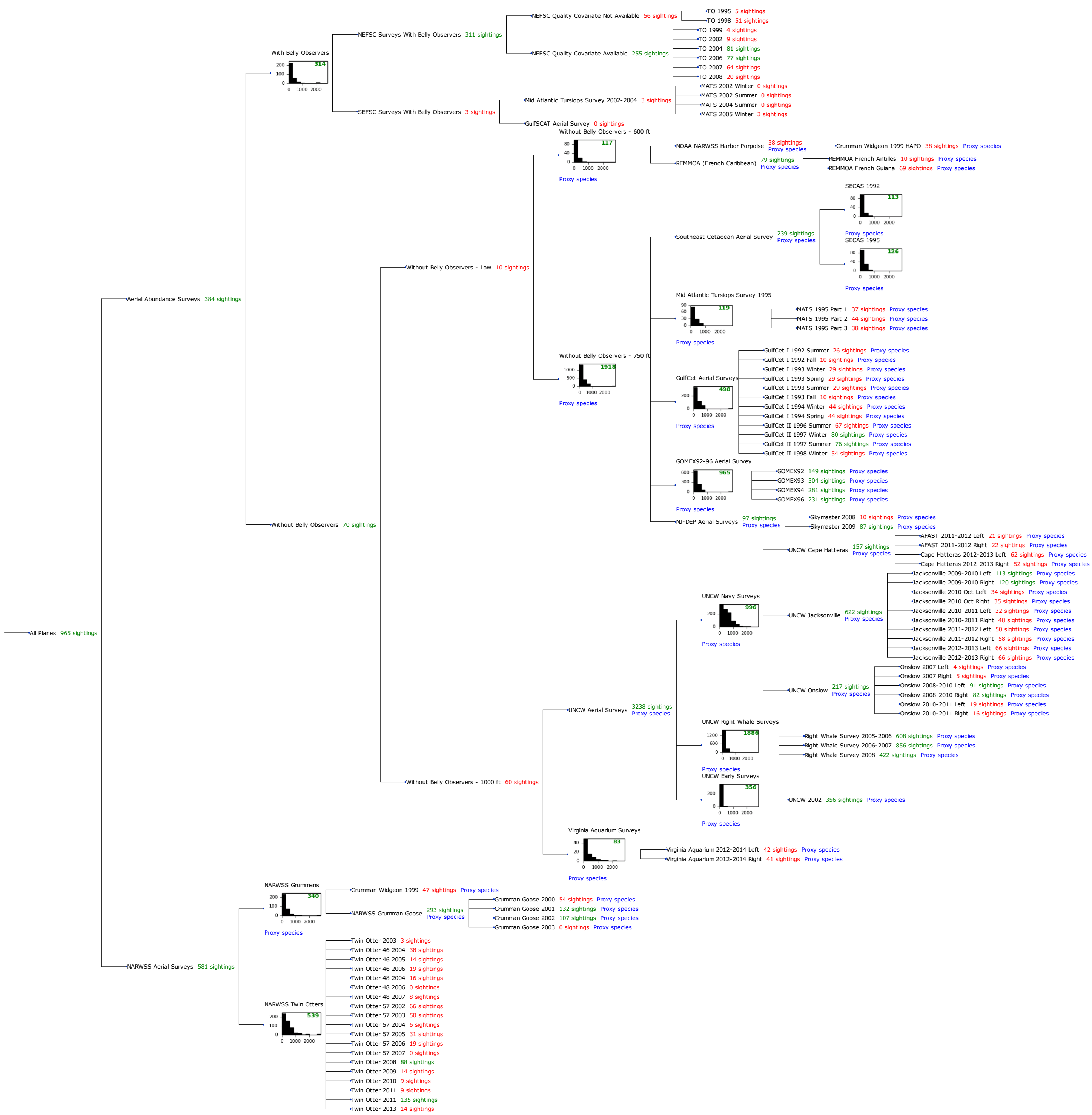


Figure 37: Detection hierarchy for aerial surveys

With Belly Observers

The sightings were right truncated at 1100m.

Covariate	Description

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

Table 20: 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	425
hr				Yes	25.80	369
hn	cos	2		Yes	26.72	321
hr	poly	4		Yes	27.05	365
hr	poly	2		Yes	27.53	363
hr			beaufort	Yes	27.56	370
hn	cos	3		Yes	34.34	324
hn			beaufort	Yes	36.56	374
hn				Yes	37.35	375
hn	herm	4		No		
hn			size	No		
hn			beaufort, size	No		
hr			beaufort, size	No		

Table 21: Candidate detection functions for With Belly Observers. The first one listed was selected for the density model.

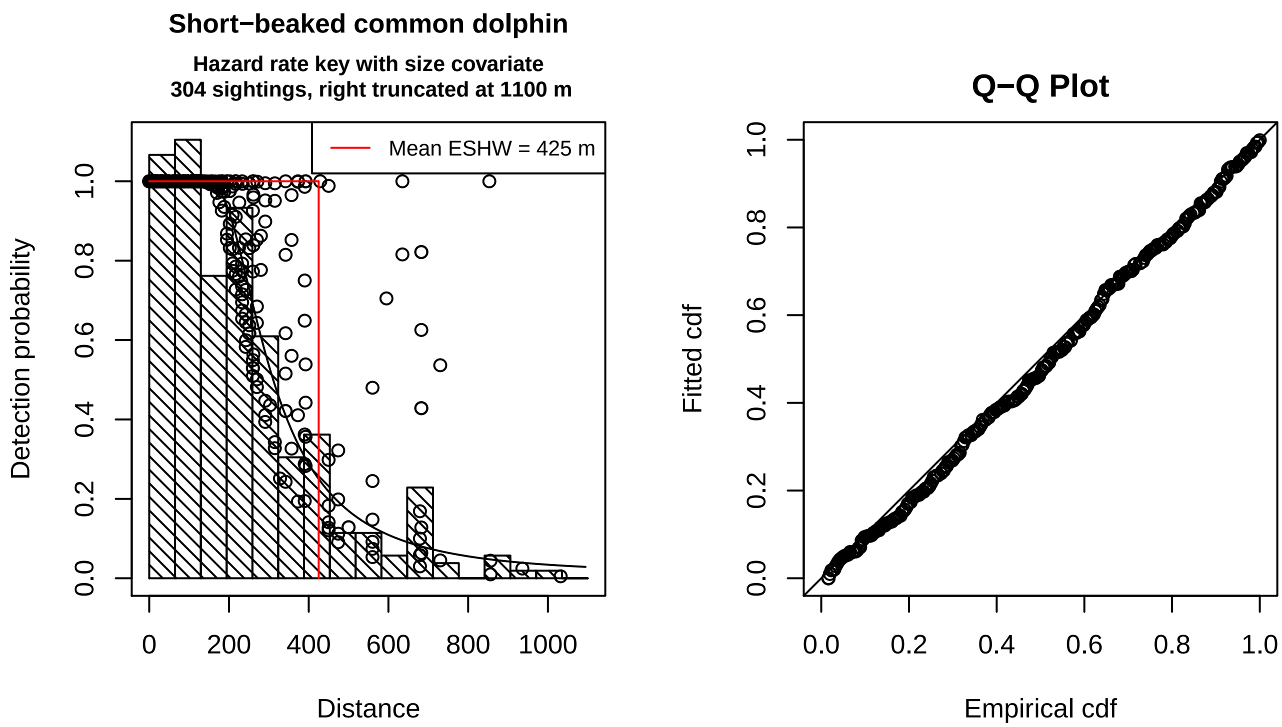


Figure 38: Detection function for With Belly Observers that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  304
Distance range         :  0  -  1100
AIC                    :  3871.122

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.436441 0.08438971
size        2.279323 0.43323128

Shape parameters:
            estimate        se
(Intercept) 1.290295 0.1051851

                       Estimate          SE         CV
Average p             0.3405743  0.01711267 0.05024652
N in covered region 892.6098687 62.12780798 0.06960242
```

Additional diagnostic plots:

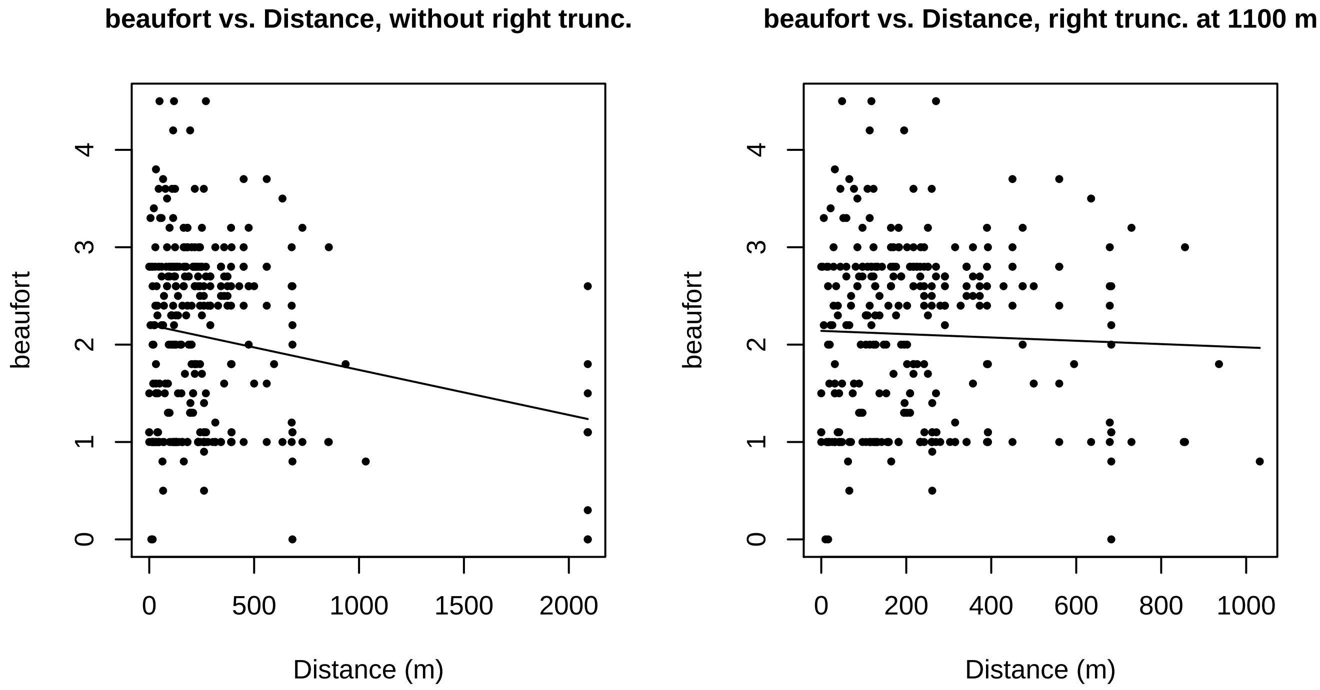


Figure 39: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

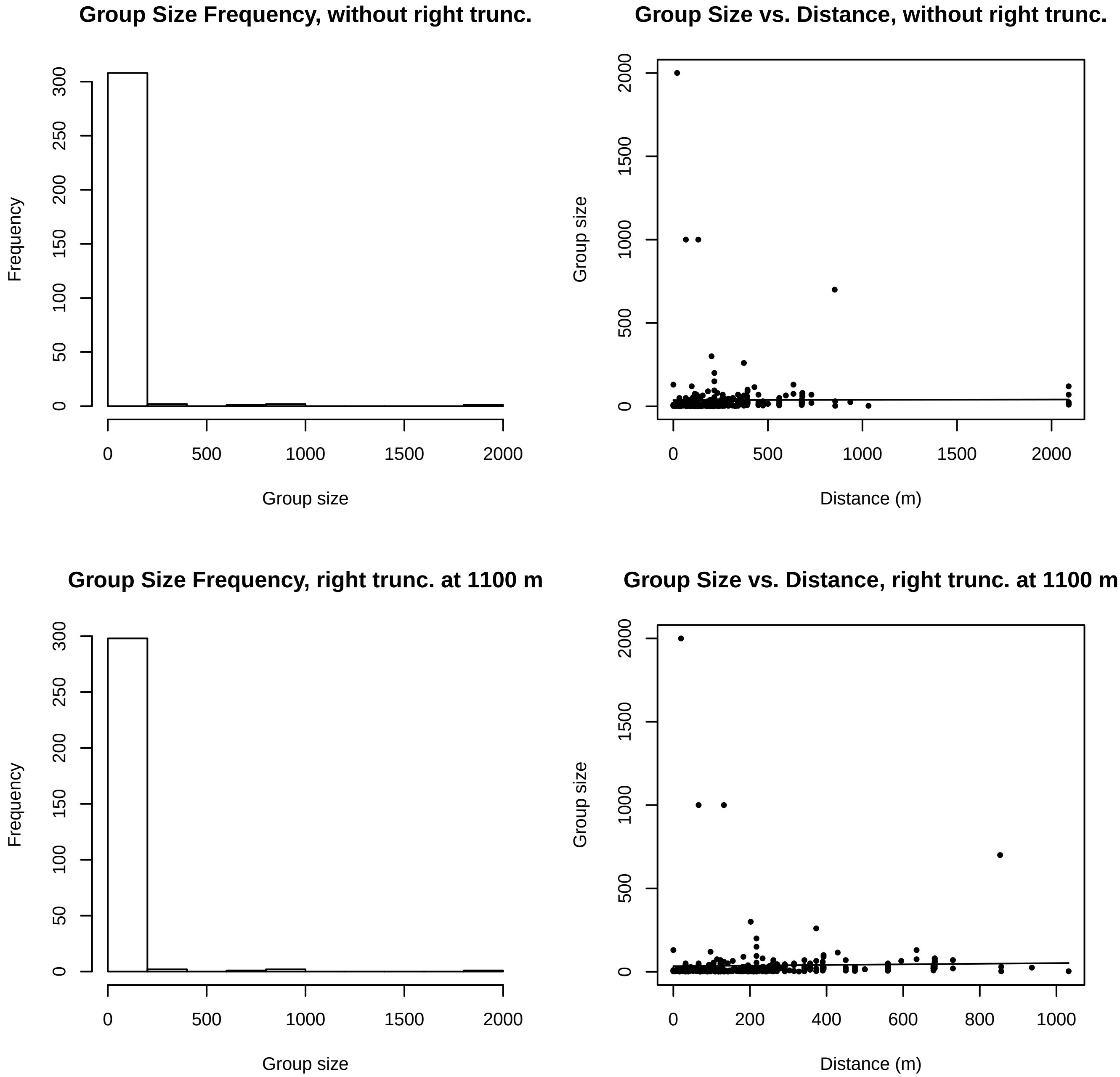


Figure 40: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Without Belly Observers - 600 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	3
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	4
Lagenorhynchus acutus	Atlantic white-sided dolphin	31
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	4
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	70
Total		117

Table 22: Proxy species used to fit detection functions for Without Belly Observers - 600 ft. The number of sightings, n, is before truncation.

The sightings were right truncated at 600m.

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				Yes	0.00	273
hr				Yes	0.47	313
hn	cos	3		Yes	0.63	294
hn	cos	2		Yes	1.46	297
hn	herm	4		Yes	1.66	292
hn			beaufort	Yes	1.82	273

hn			size	Yes	1.98	273
hr	poly	4		Yes	2.01	305
hr			beaufort	Yes	2.15	308
hr	poly	2		Yes	2.38	298
hn			beaufort, size	Yes	3.80	273
hr			size	No		
hr			beaufort, size	No		

Table 24: Candidate detection functions for Without Belly Observers - 600 ft. The first one listed was selected for the density model.

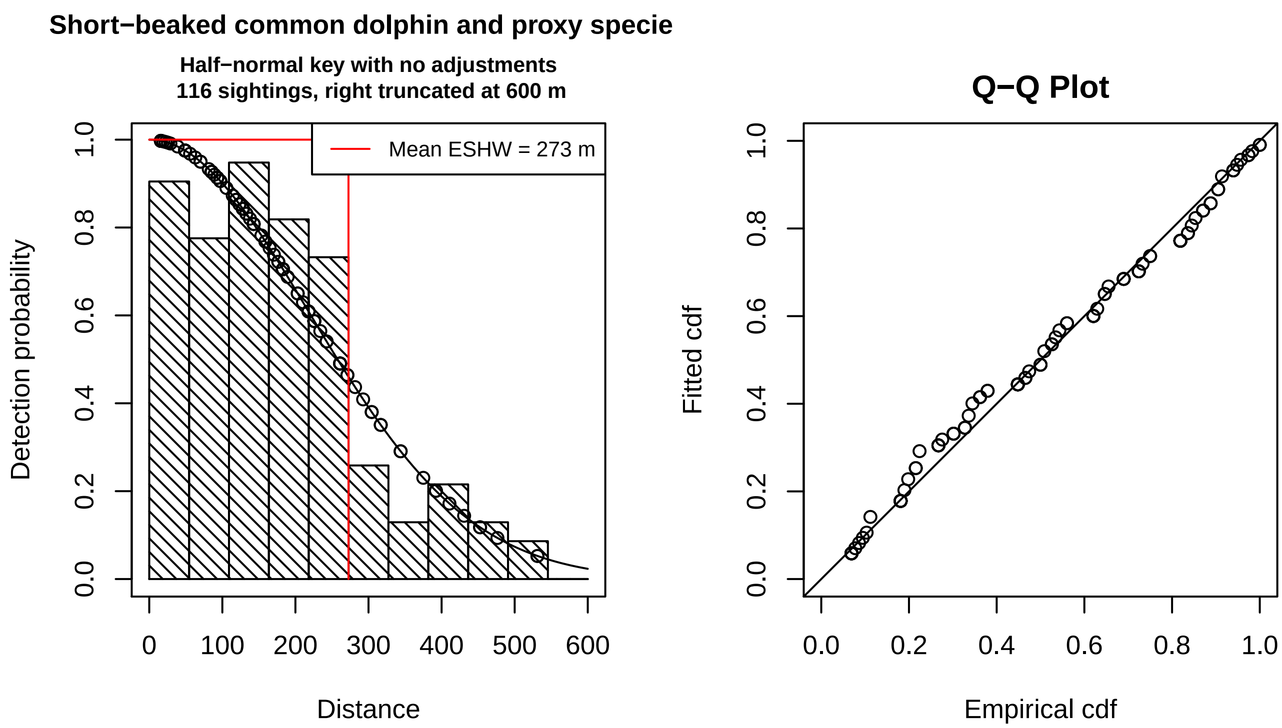


Figure 41: Detection function for Without Belly Observers - 600 ft that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  116
Distance range         :  0  -  600
AIC                    :  1413.111

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.388383 0.07654643
```

```
                       Estimate          SE         CV
Average p              0.4543498  0.03299346 0.07261686
N in covered region 255.3098755 25.50172372 0.09988538
```

Additional diagnostic plots:

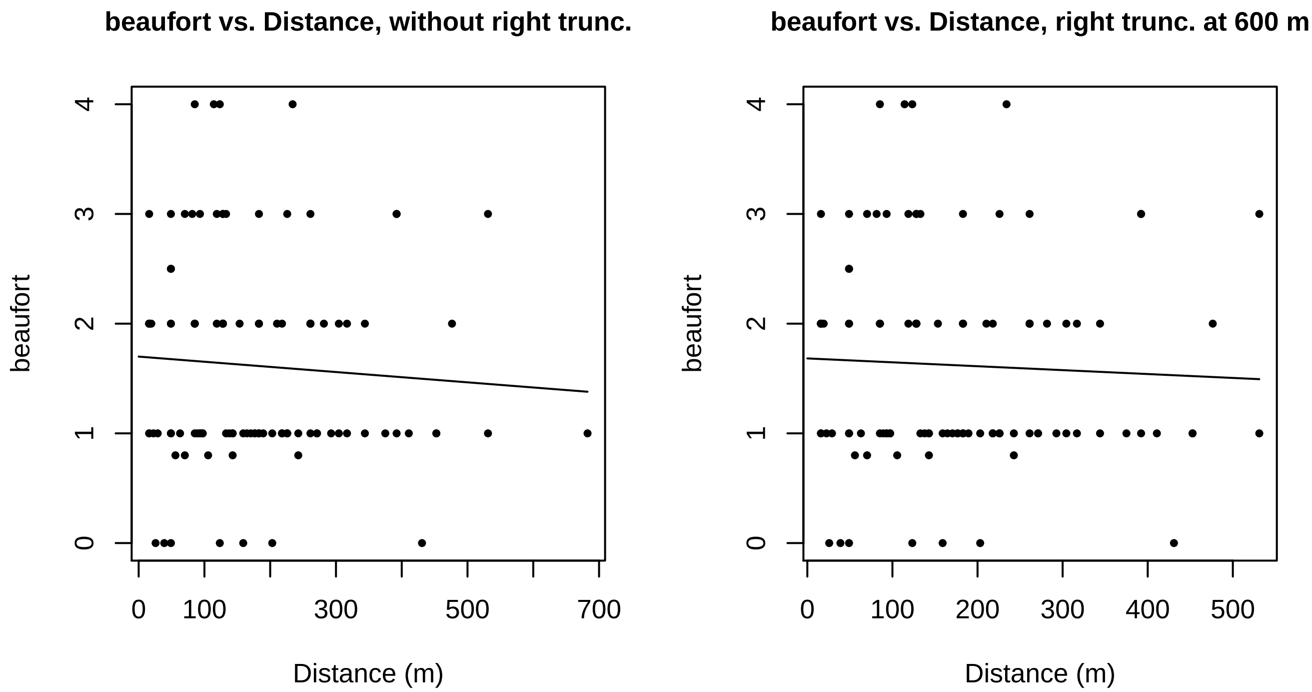


Figure 42: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

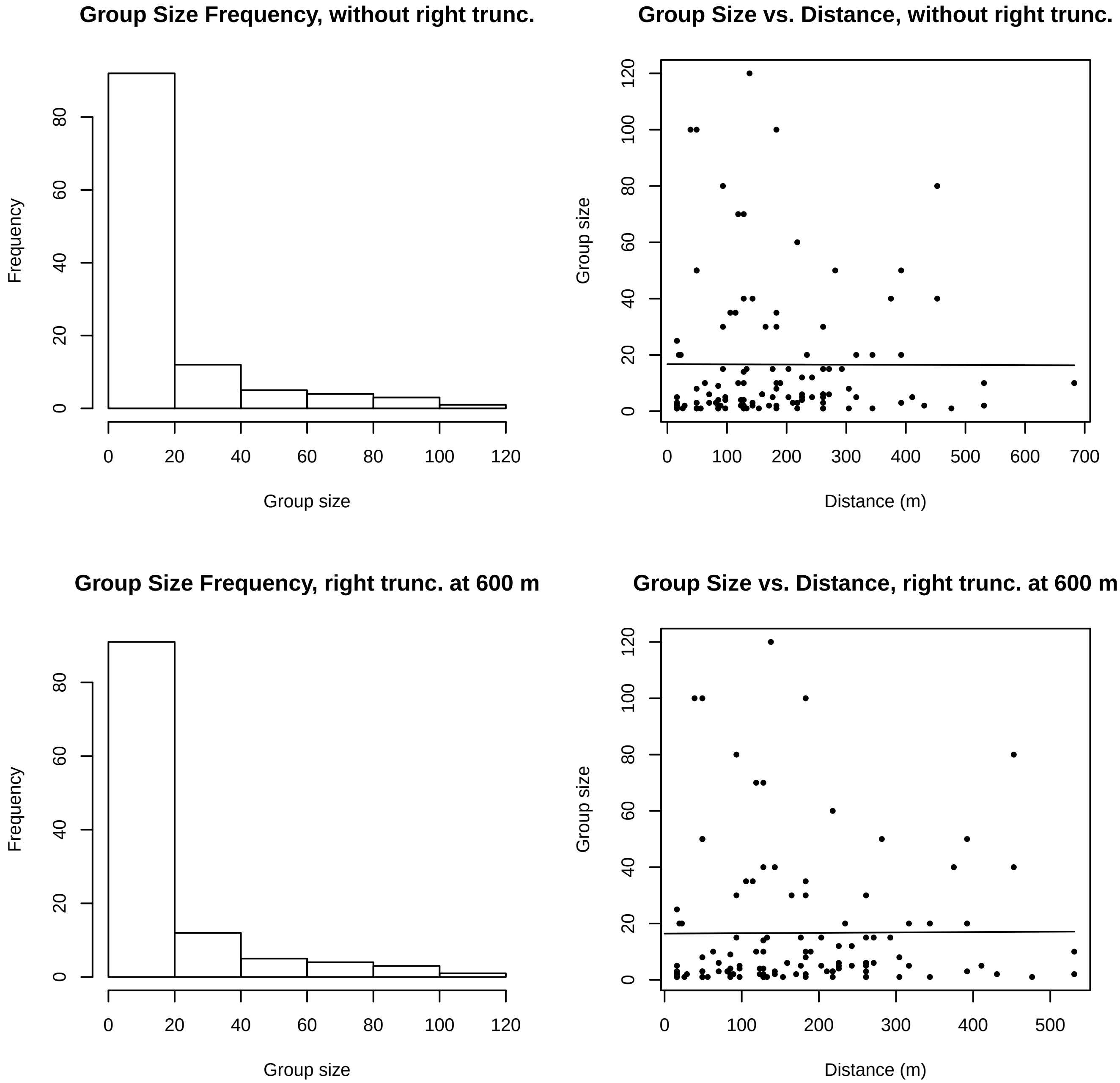


Figure 43: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Without Belly Observers - 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 25: 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 26: 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	2		Yes	10.40	388

hr	poly	4		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 27: Candidate detection functions for Without Belly Observers - 750 ft. The first one listed was selected for the density model.

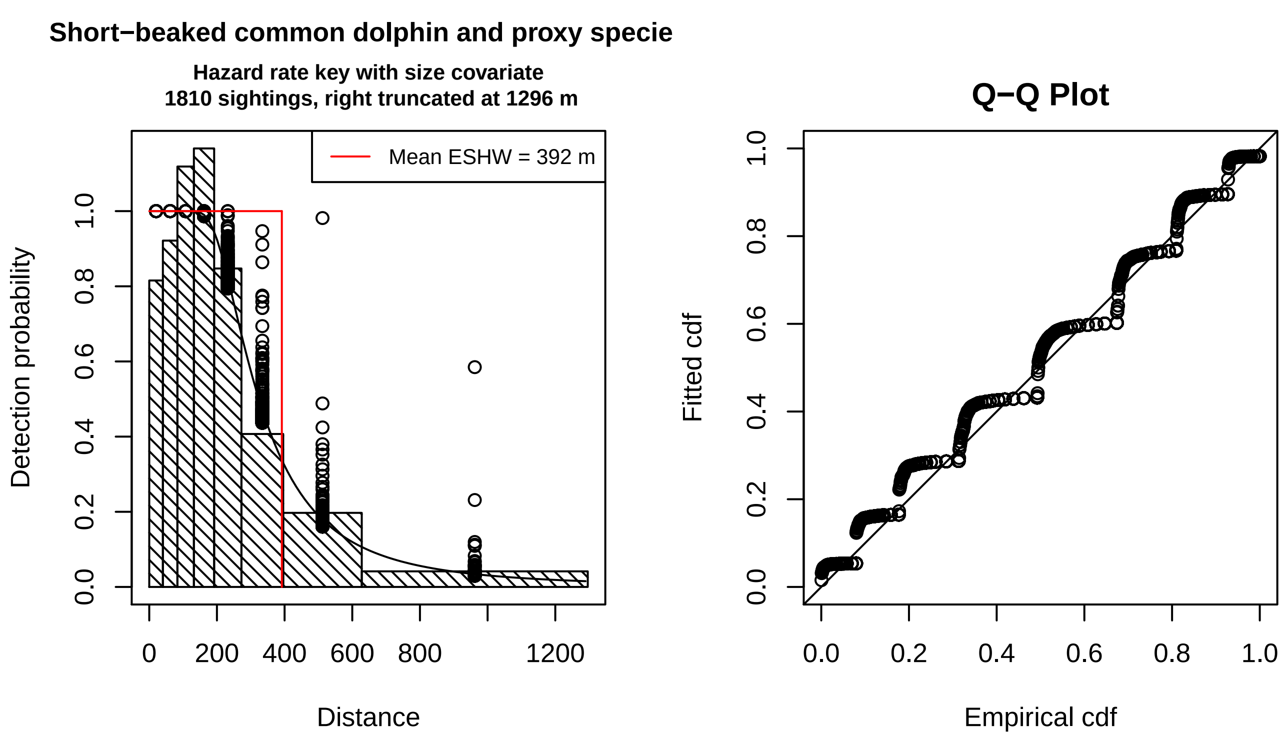


Figure 44: Detection function for Without Belly Observers - 750 ft that was selected for the density model

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:

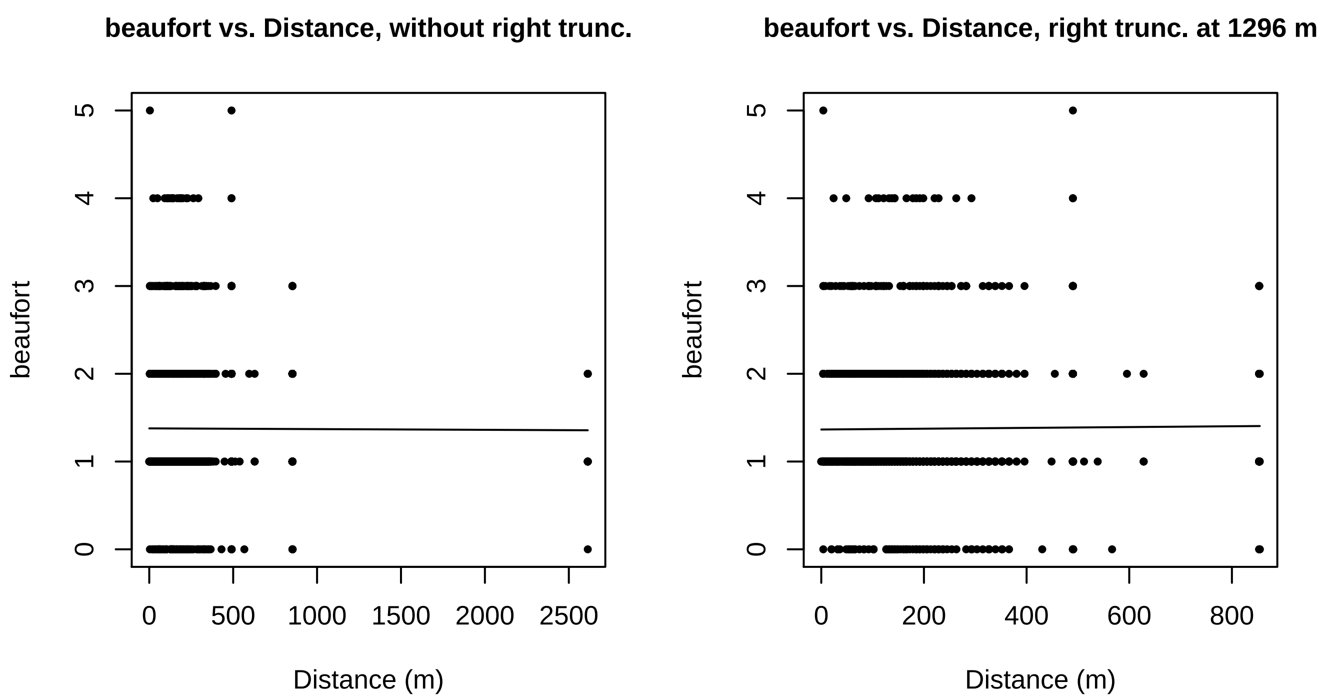


Figure 45: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

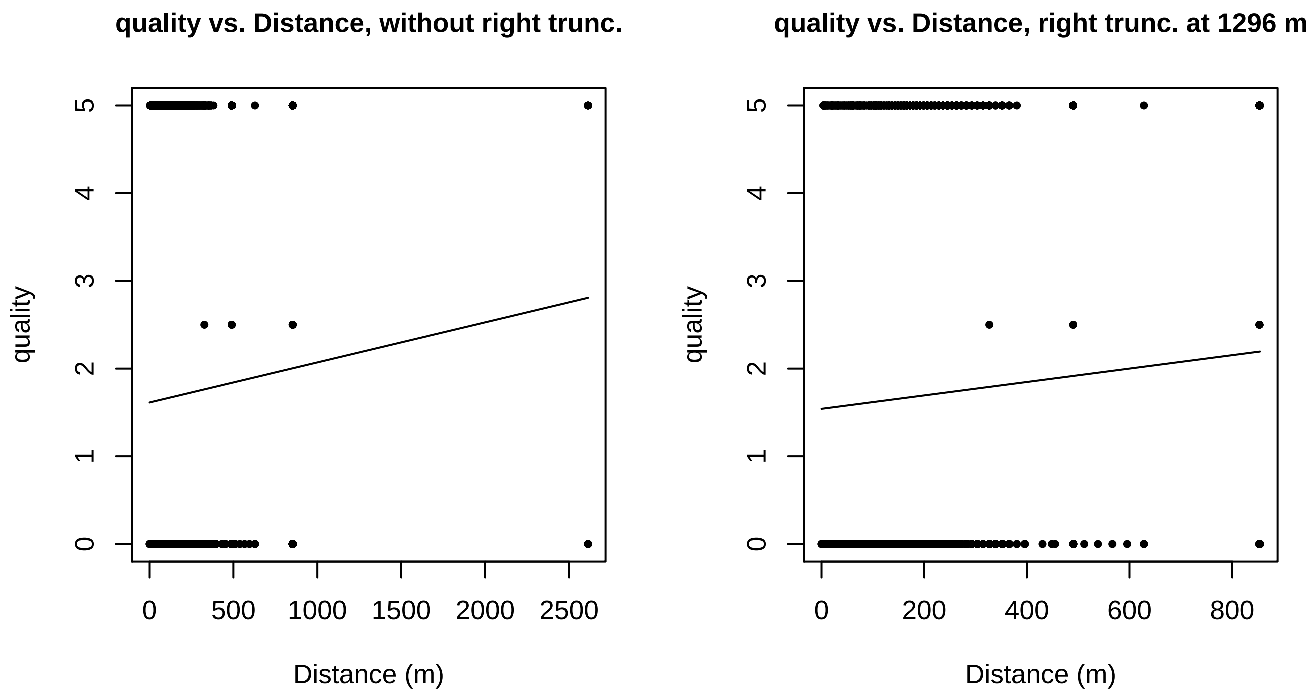


Figure 46: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

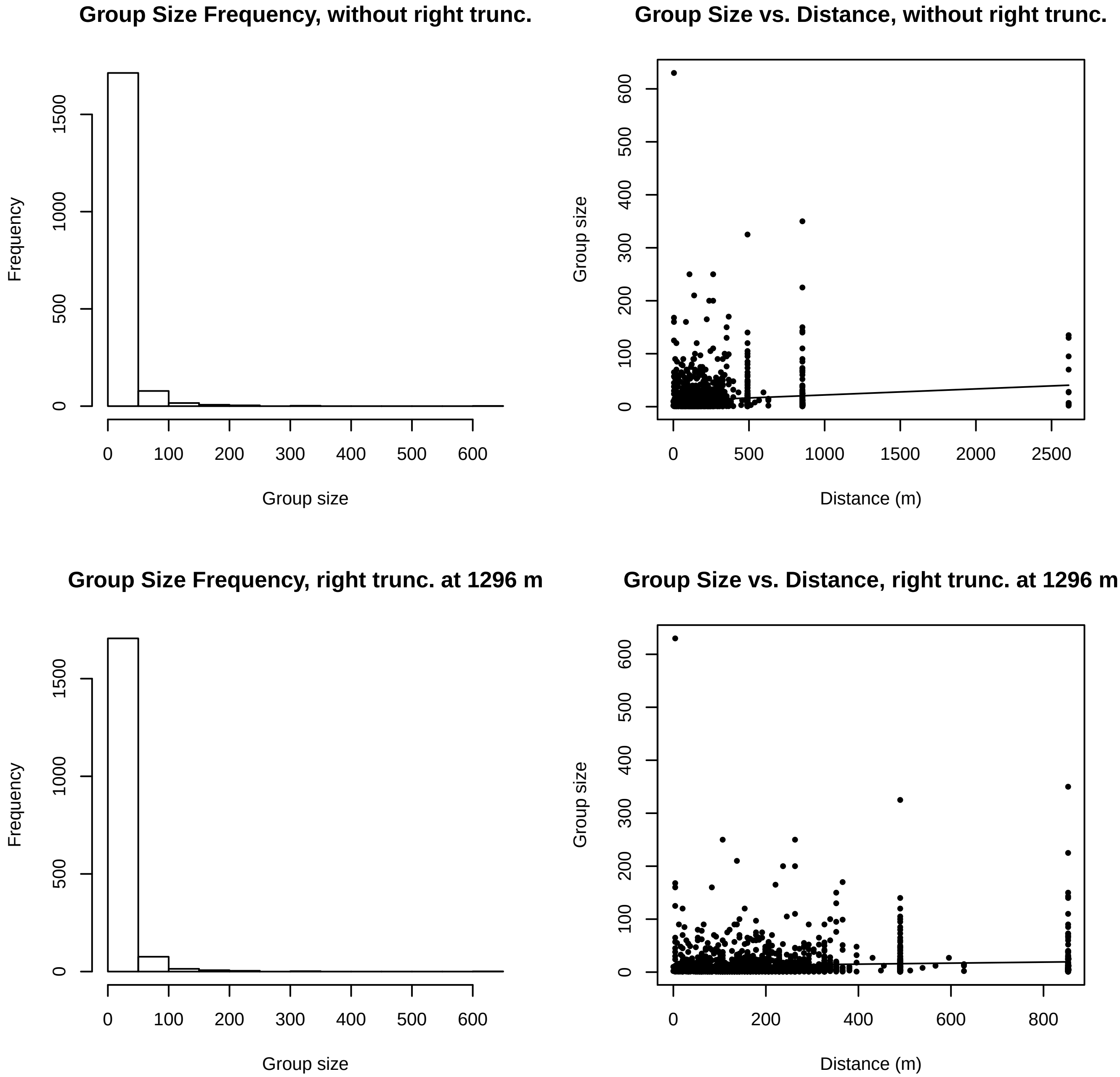


Figure 47: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 28: 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 29: 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	23.46	182
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			size	No		
hn			beaufort, size	No		

Table 30: Candidate detection functions for SE_secas92. The first one listed was selected for the density model.

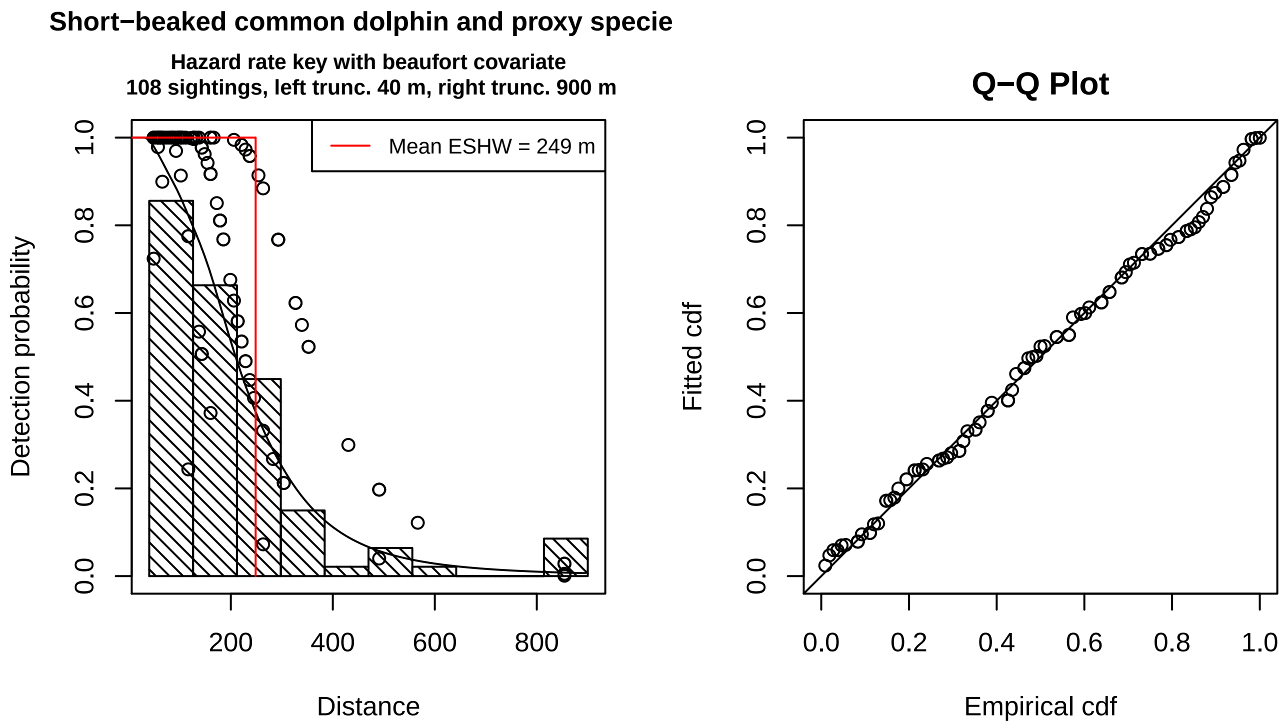


Figure 48: Detection function for SE_secas92 that was selected for the density model

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:

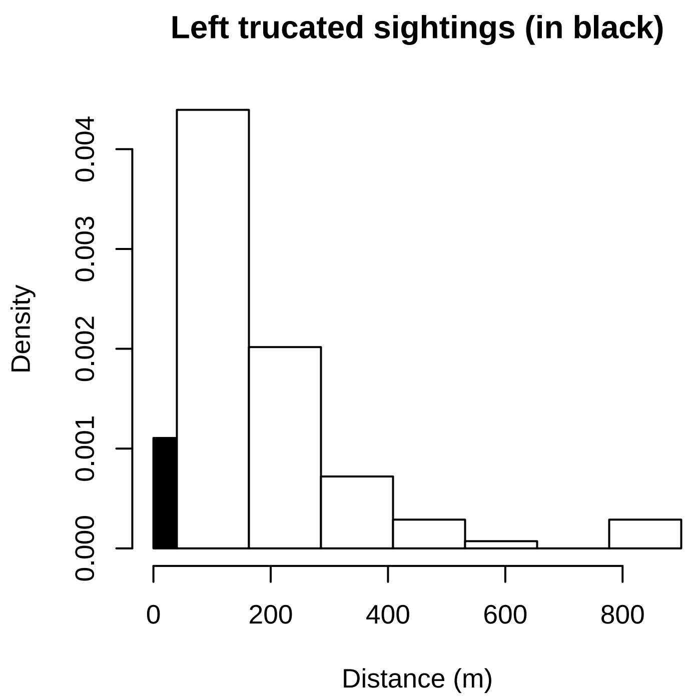


Figure 49: Density of sightings by perpendicular distance for SE_secas92. Black bars on the left show sightings that were left truncated.

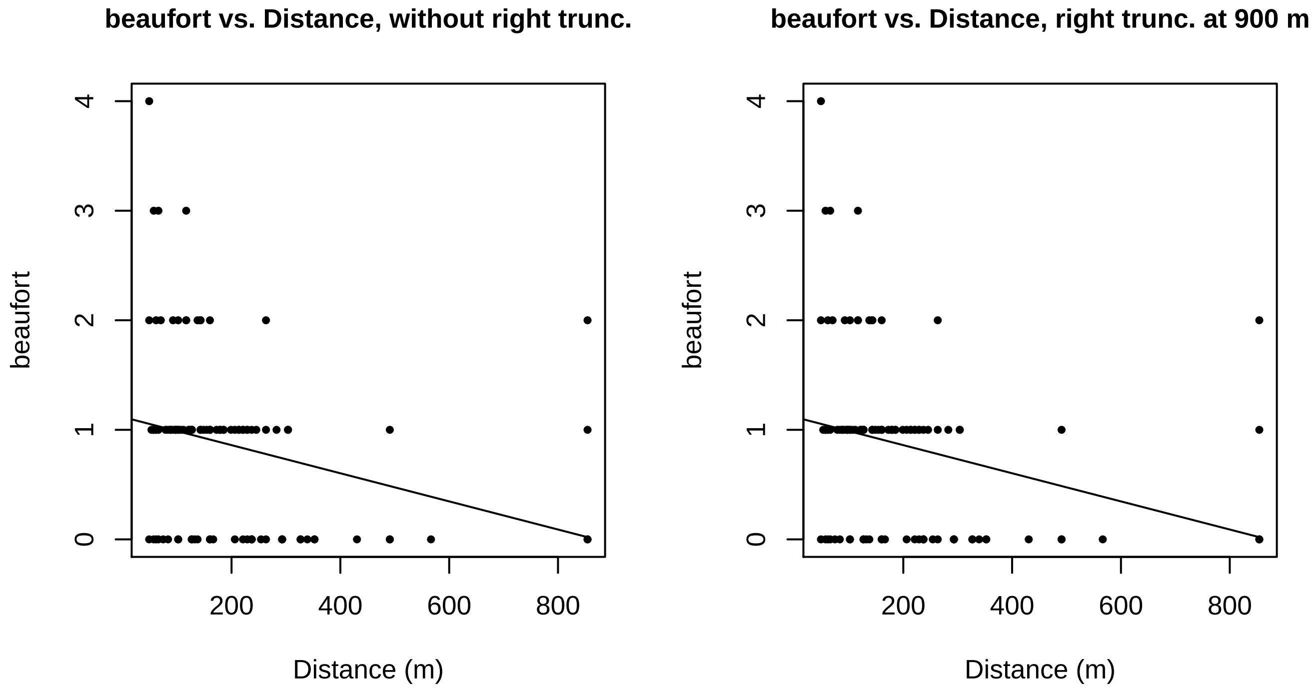


Figure 50: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

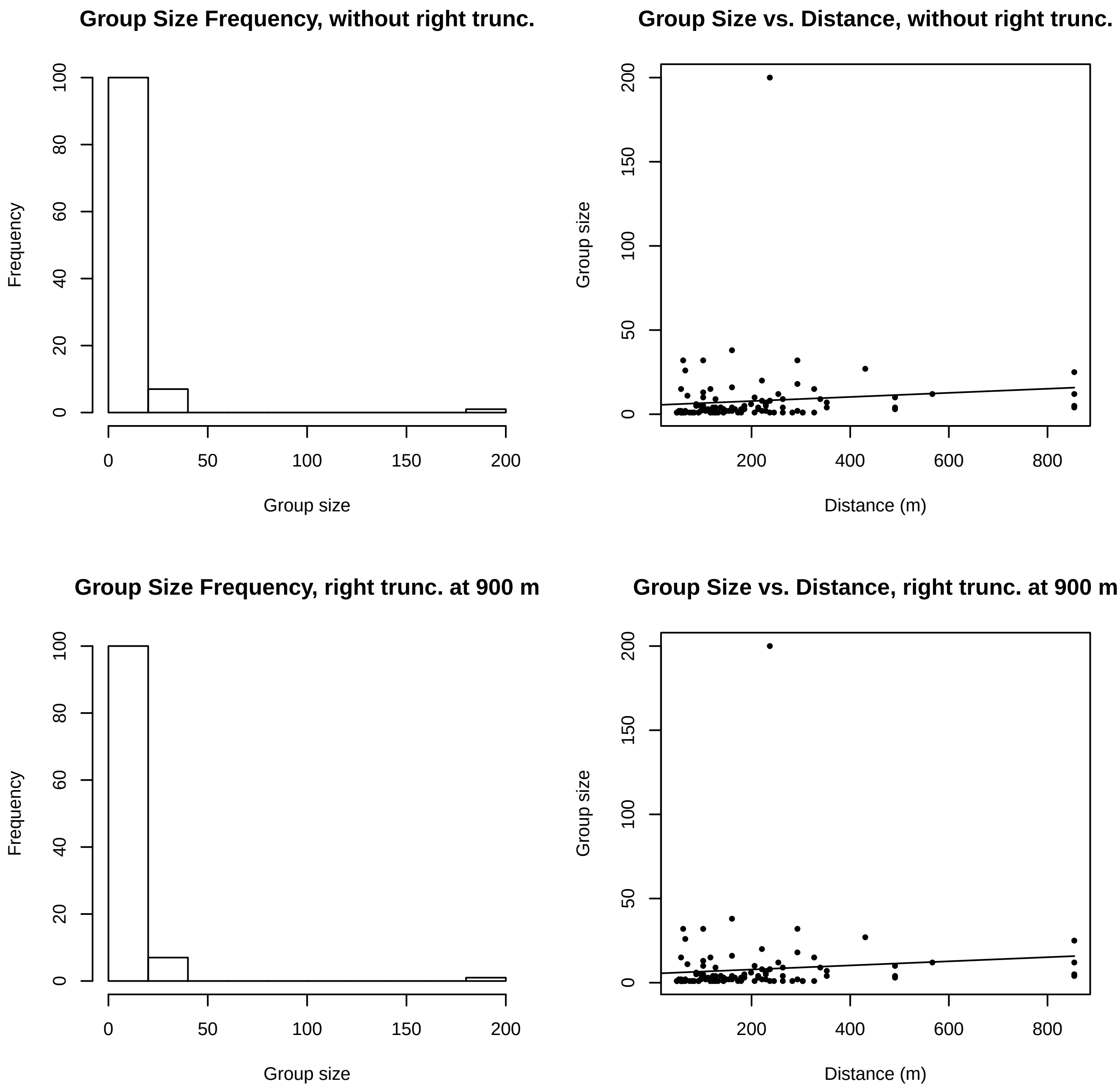


Figure 51: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 31: 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 32: 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 33: Candidate detection functions for SE_secas95. The first one listed was selected for the density model.

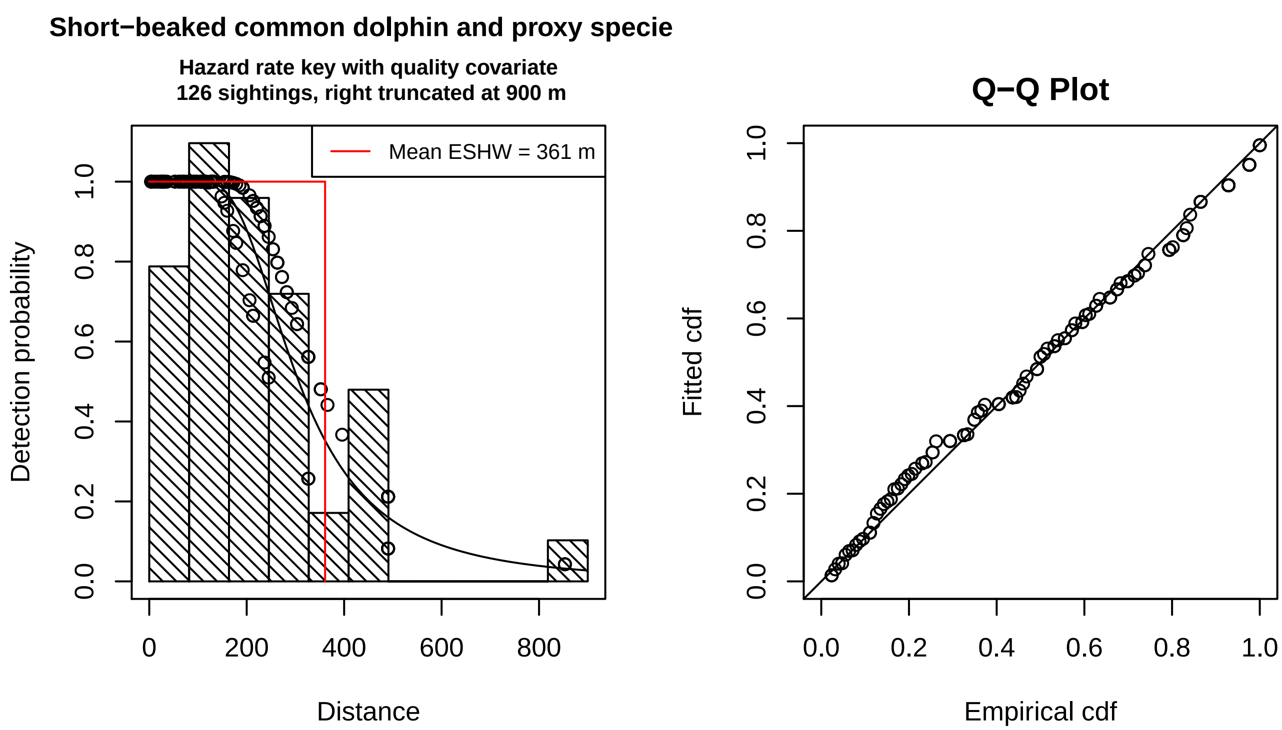


Figure 52: Detection function for SE_secas95 that was selected for the density model

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:

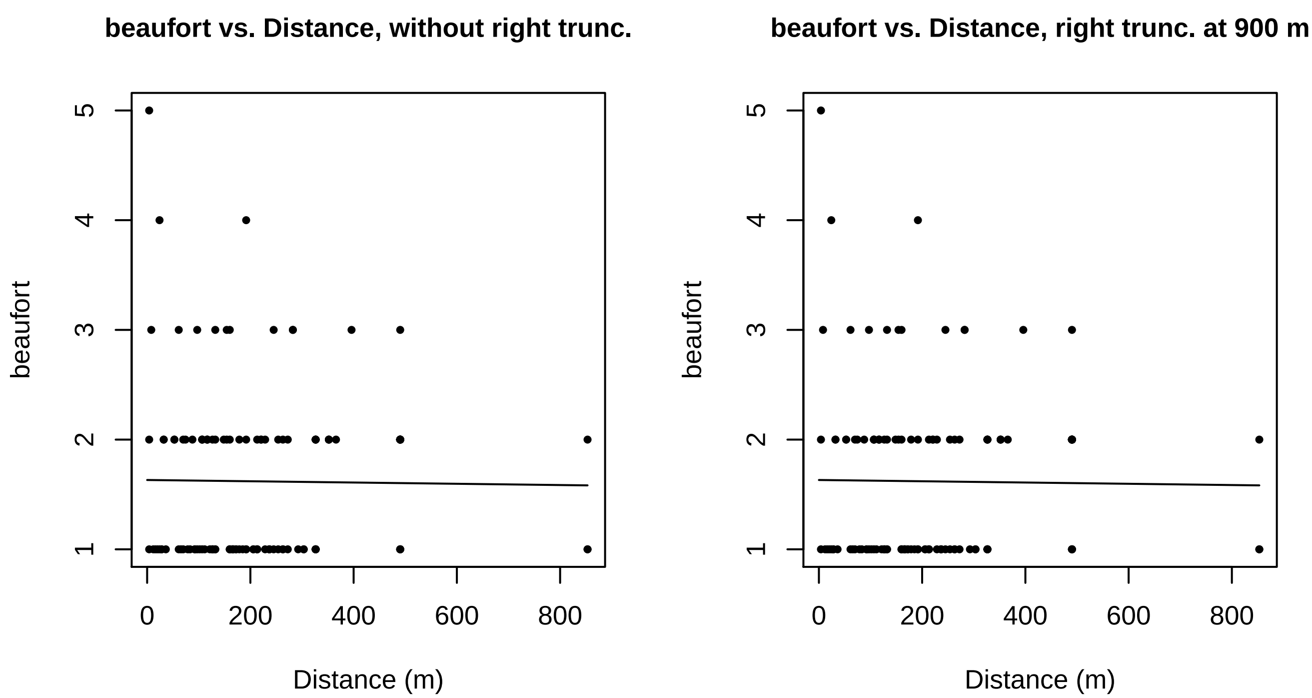


Figure 53: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

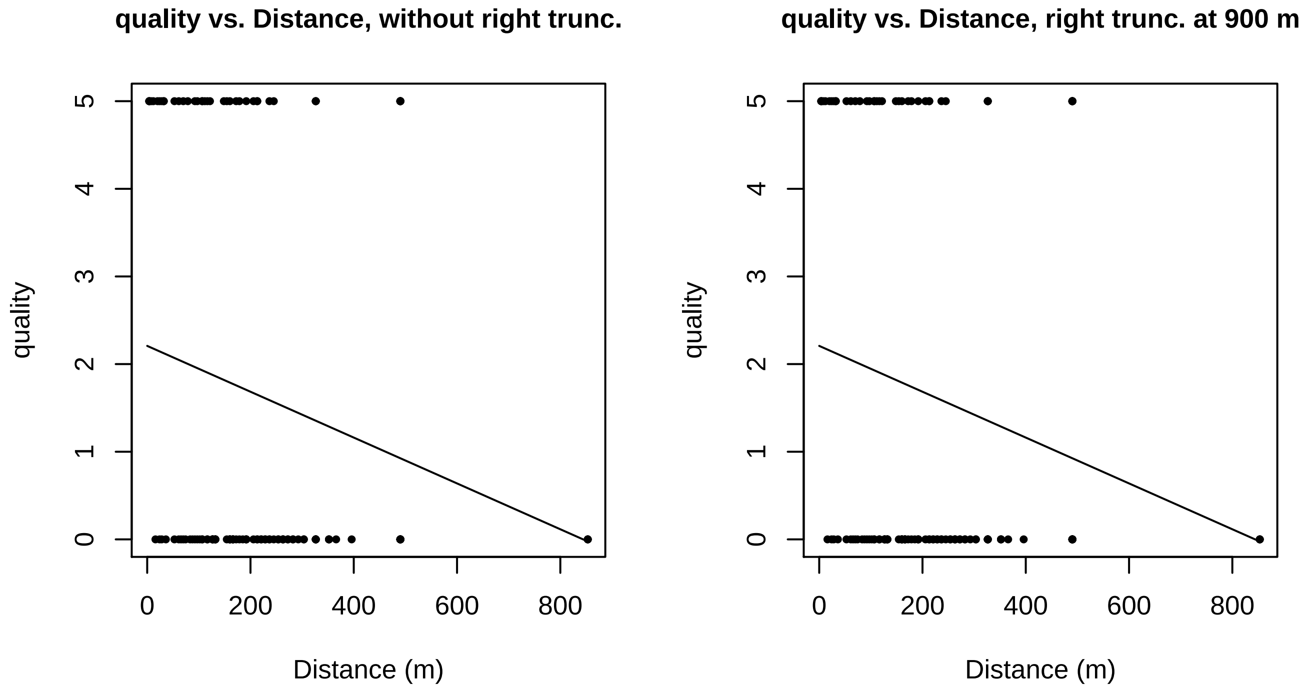


Figure 54: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

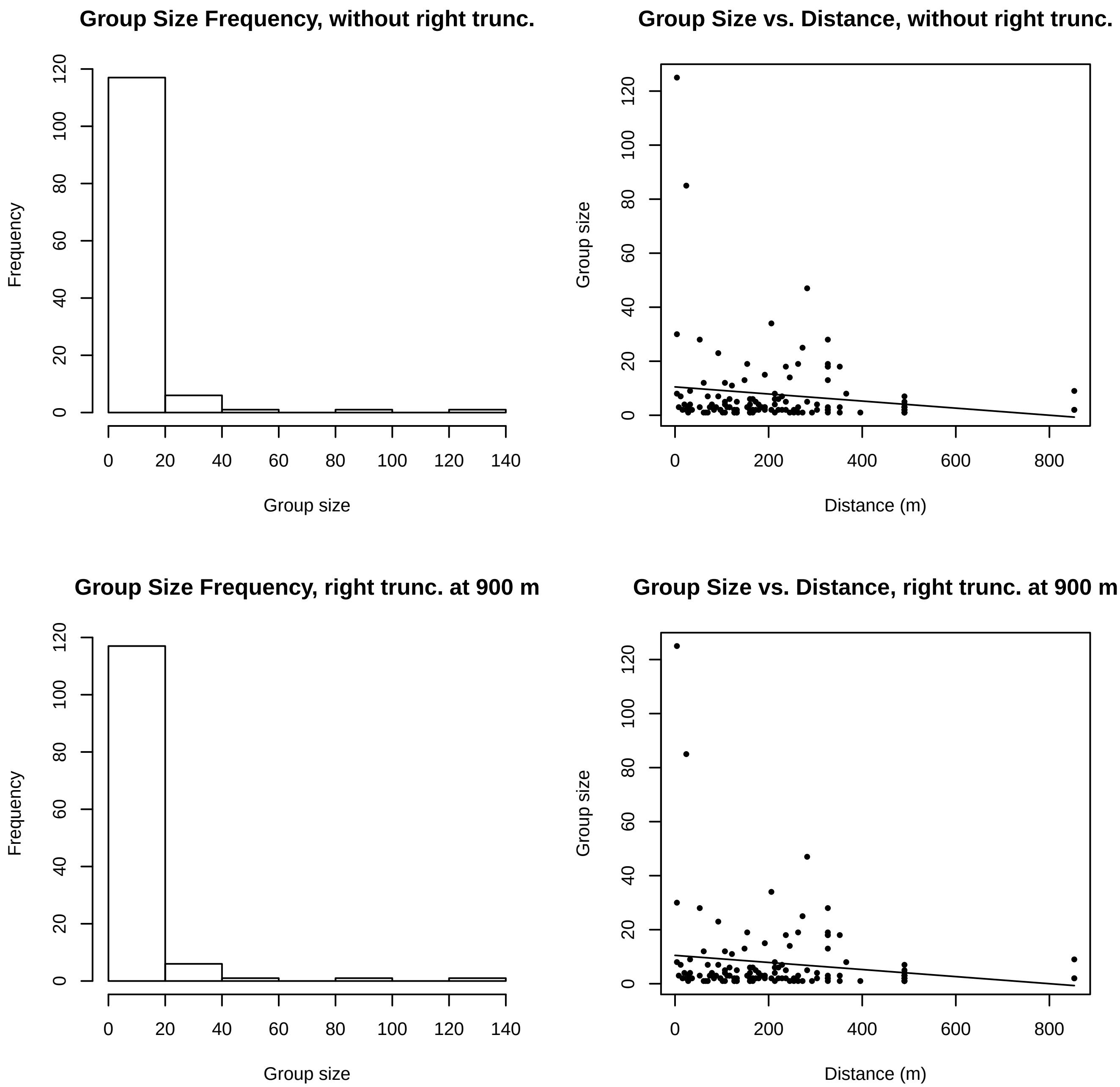


Figure 55: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 34: 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 35: 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			size	Yes	1.63	420

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

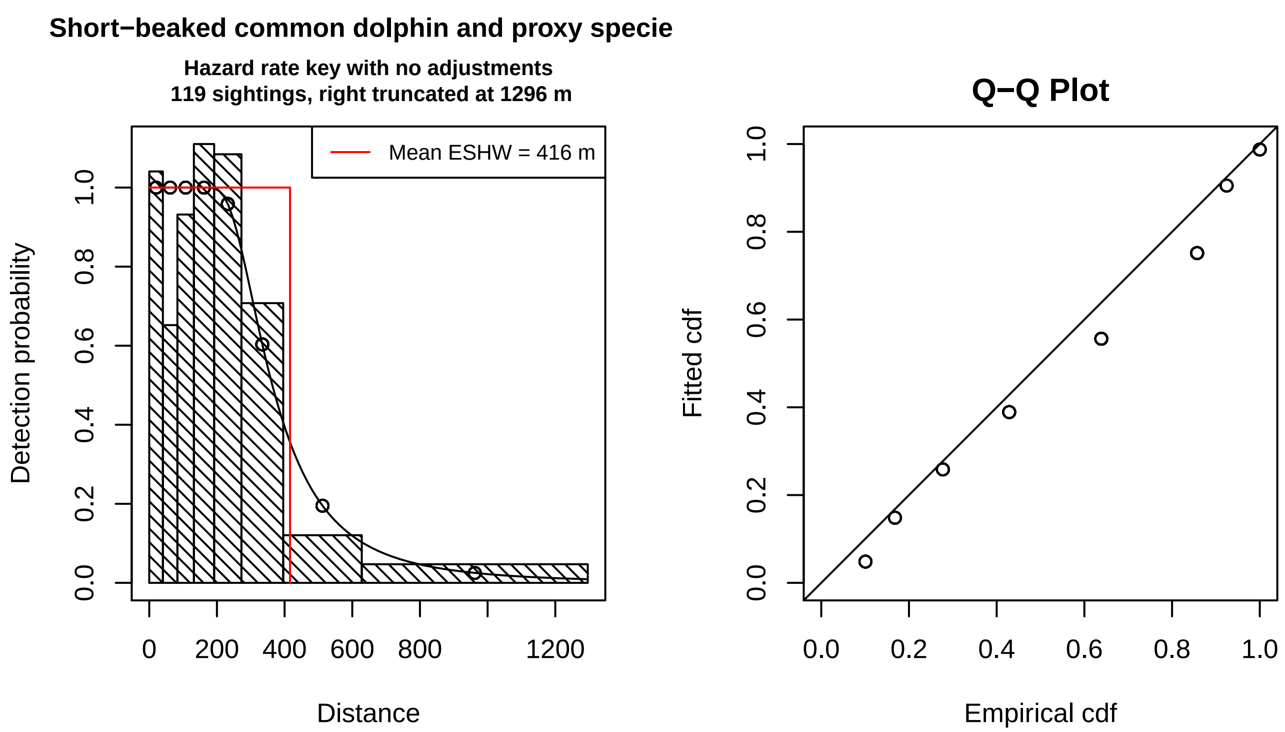


Figure 56: Detection function for Mid Atlantic Tursiops Survey 1995 that was selected for the density model

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:

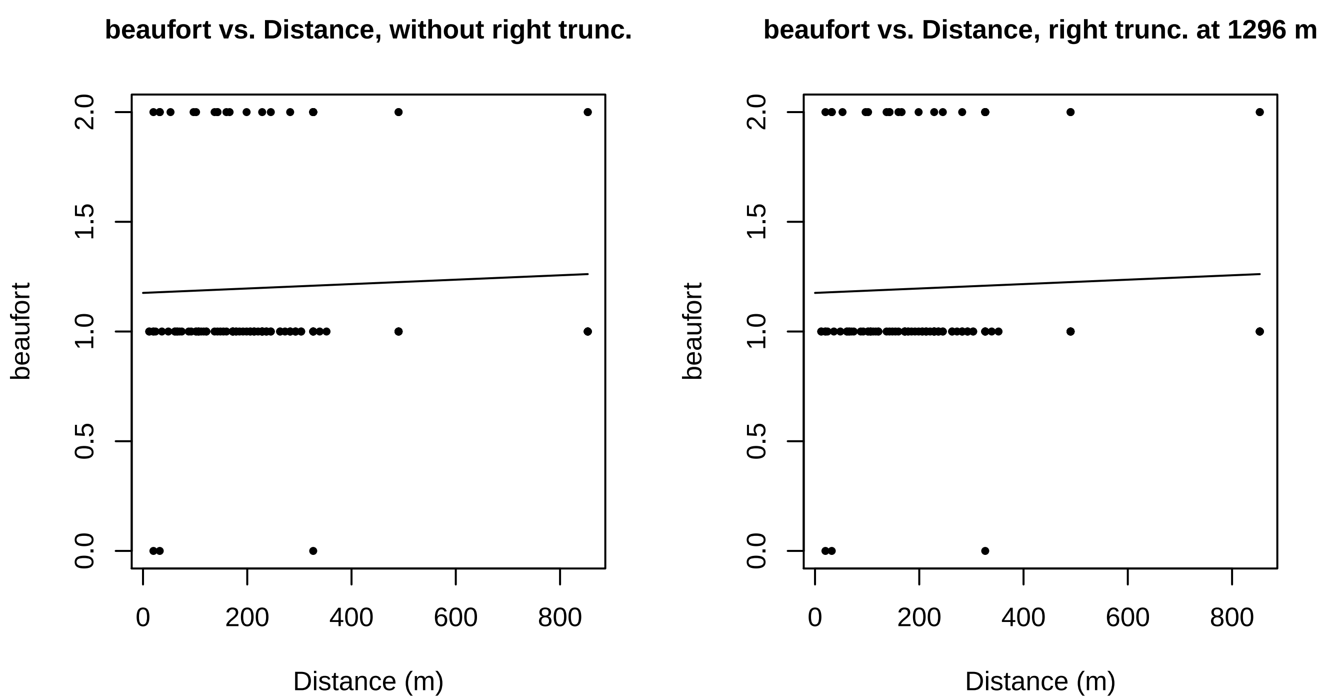


Figure 57: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

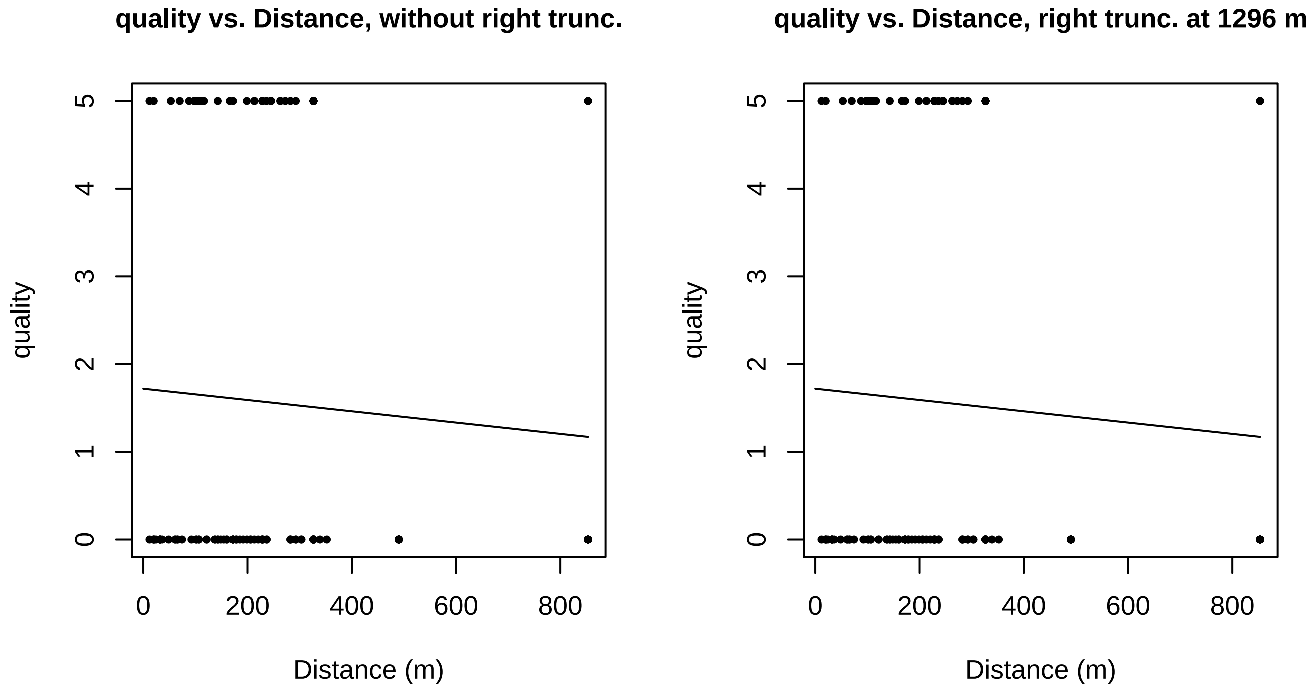


Figure 58: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

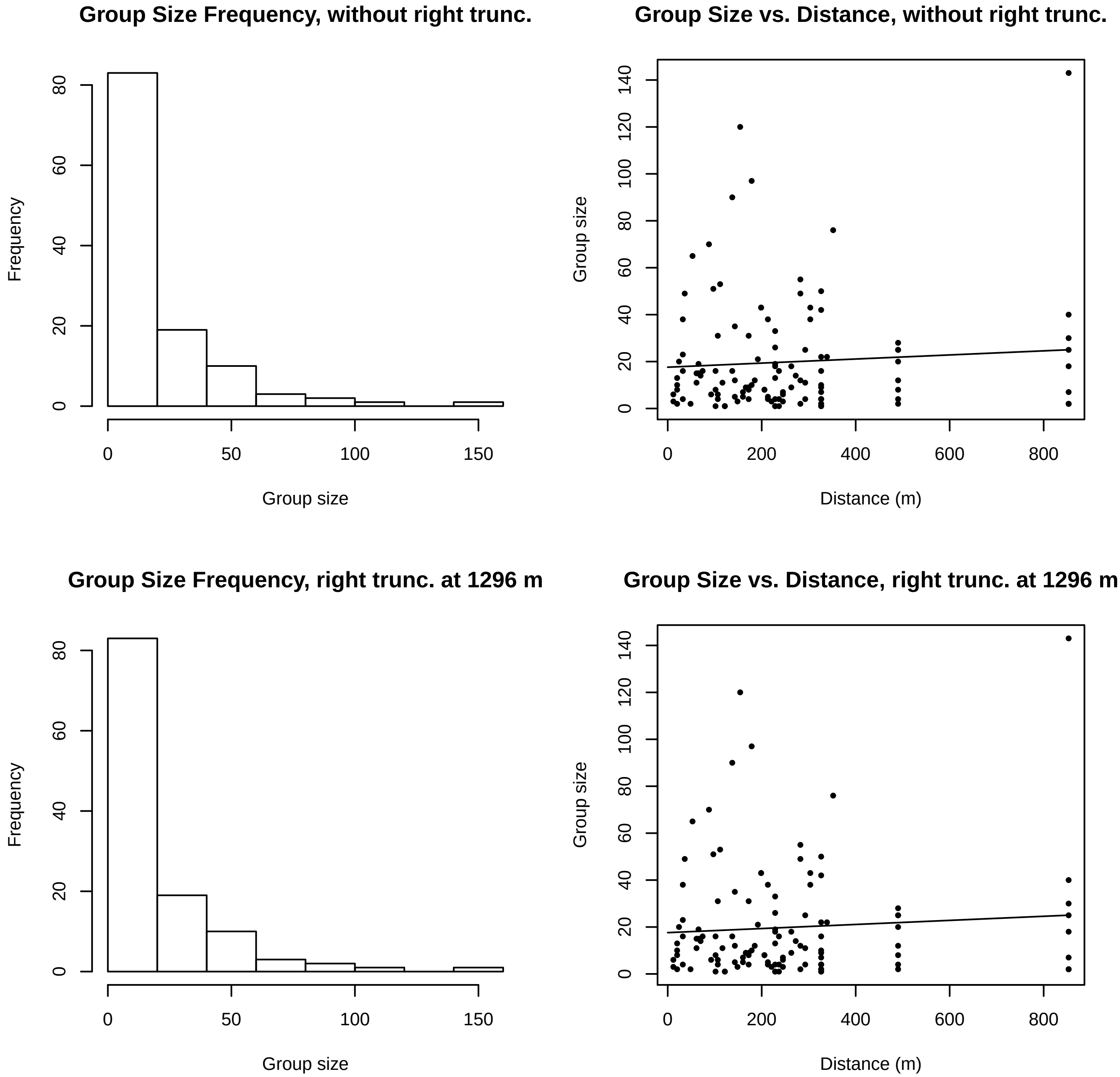


Figure 59: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 37: 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 38: 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 39: Candidate detection functions for GulfCet Aerial Surveys. The first one listed was selected for the density model.

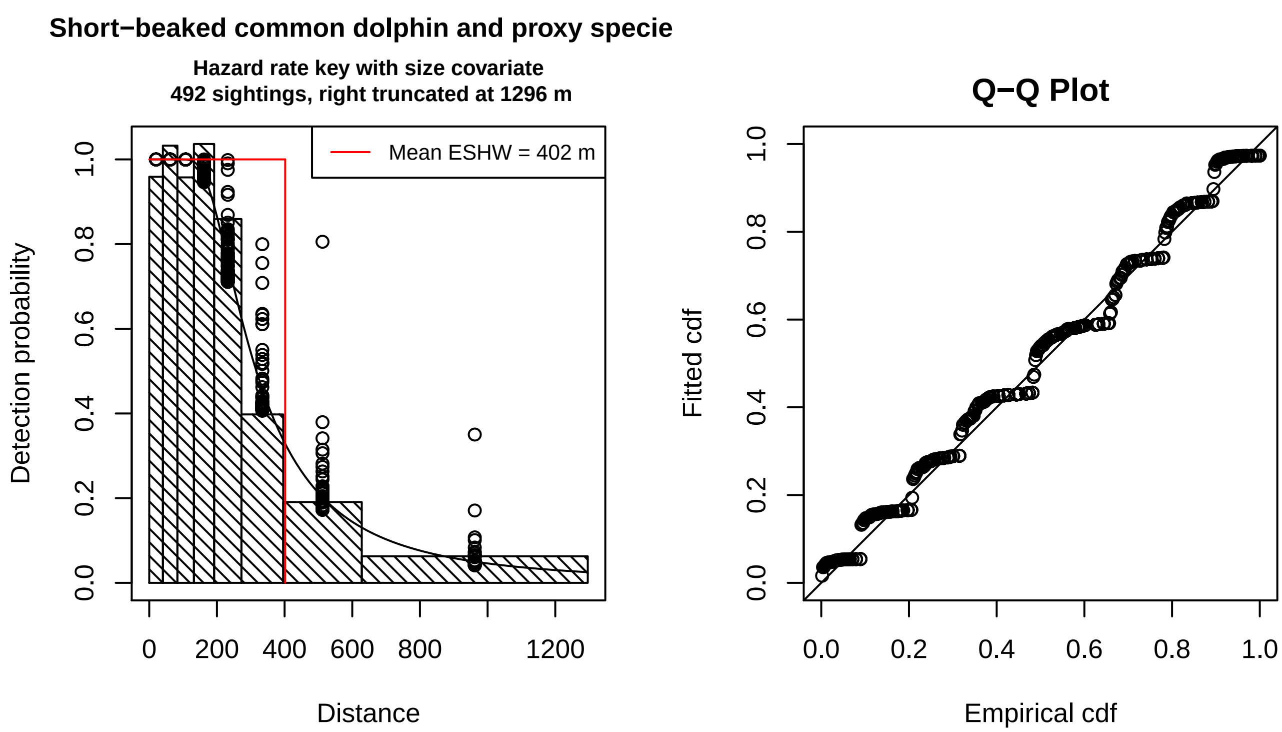


Figure 60: Detection function for GulfCet Aerial Surveys that was selected for the density model

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:

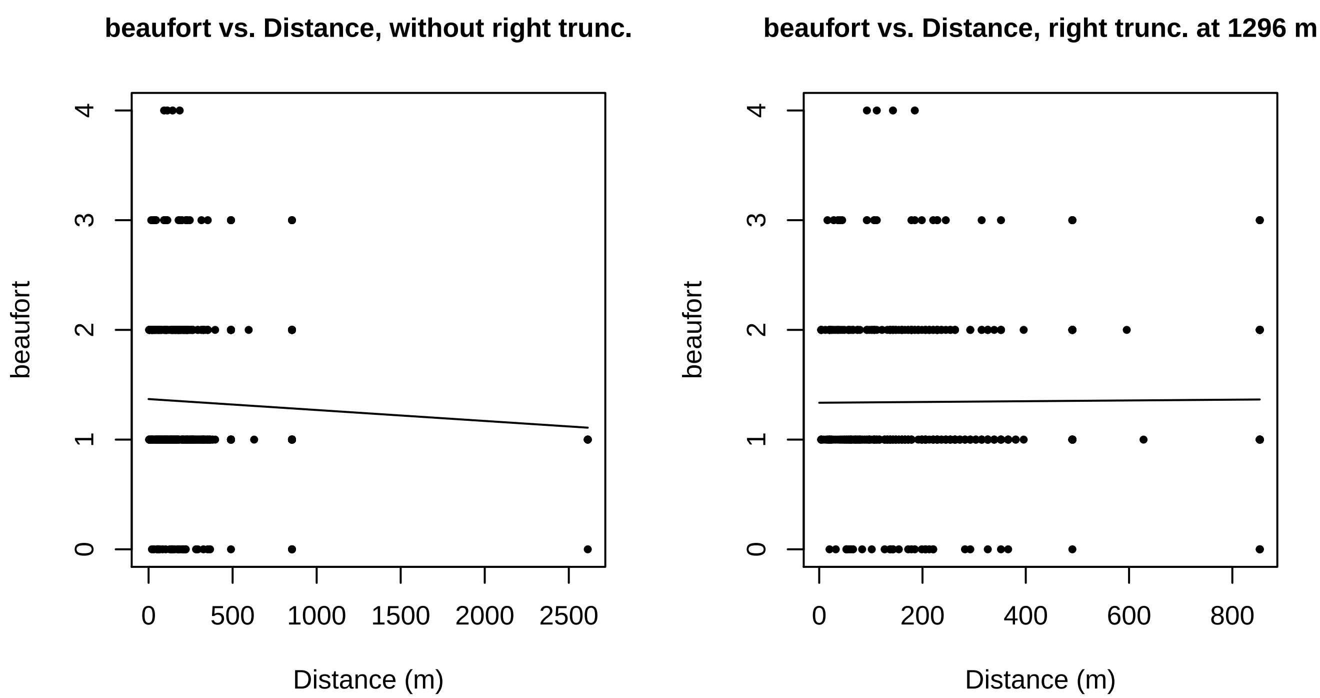


Figure 61: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

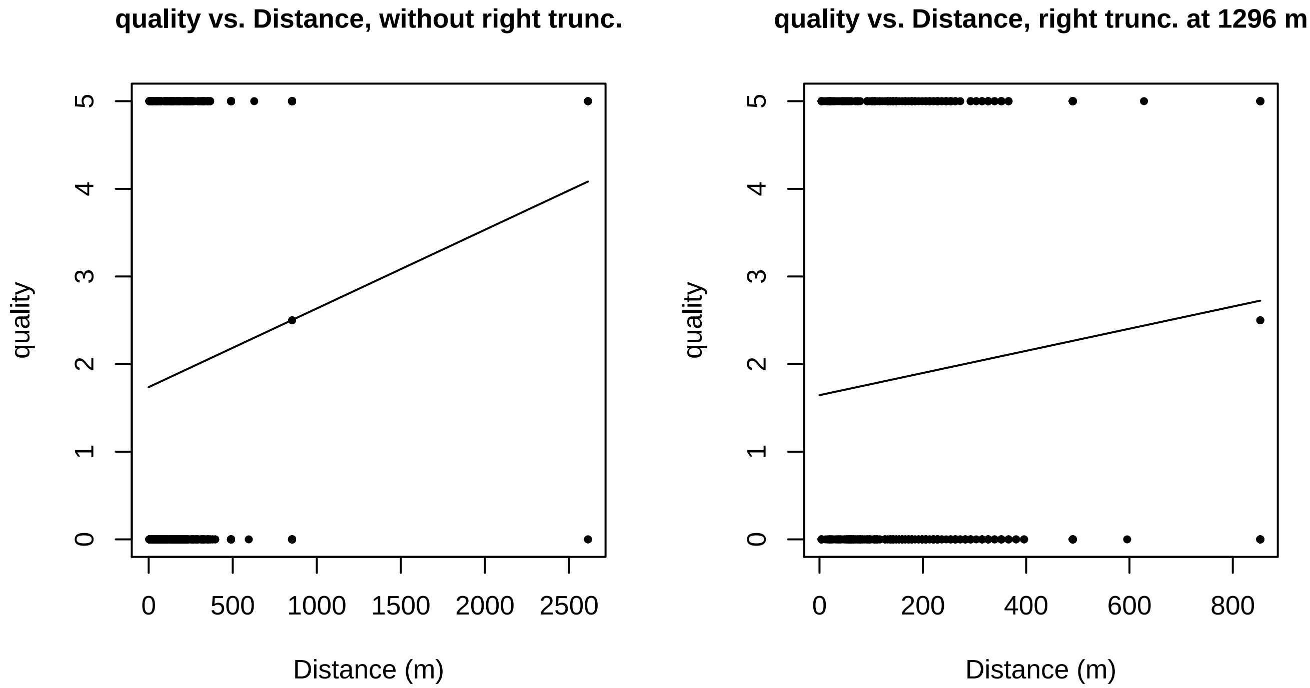


Figure 62: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

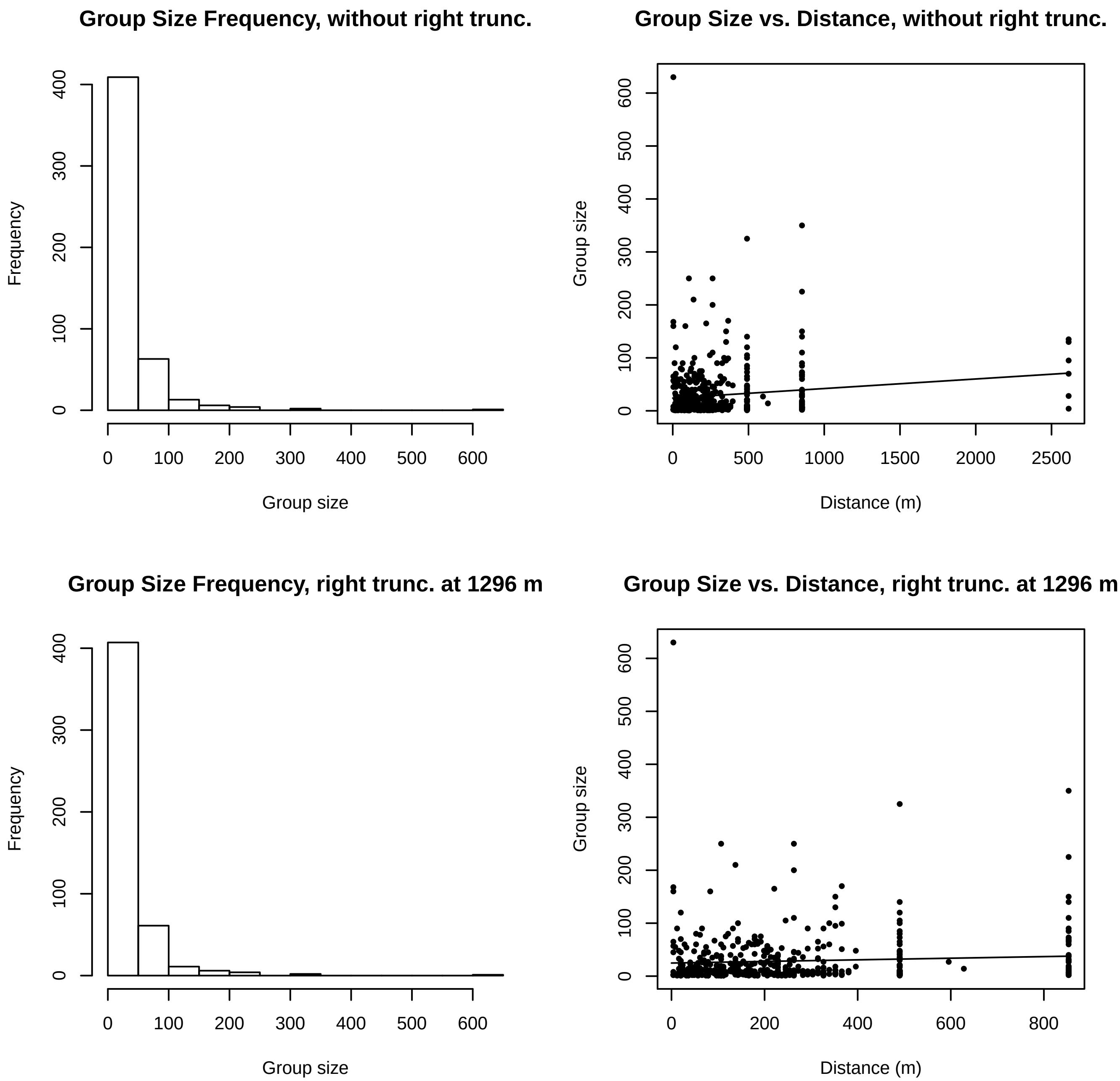


Figure 63: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 40: 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 41: 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 42: Candidate detection functions for GOMEX92-96 Aerial Survey. The first one listed was selected for the density model.

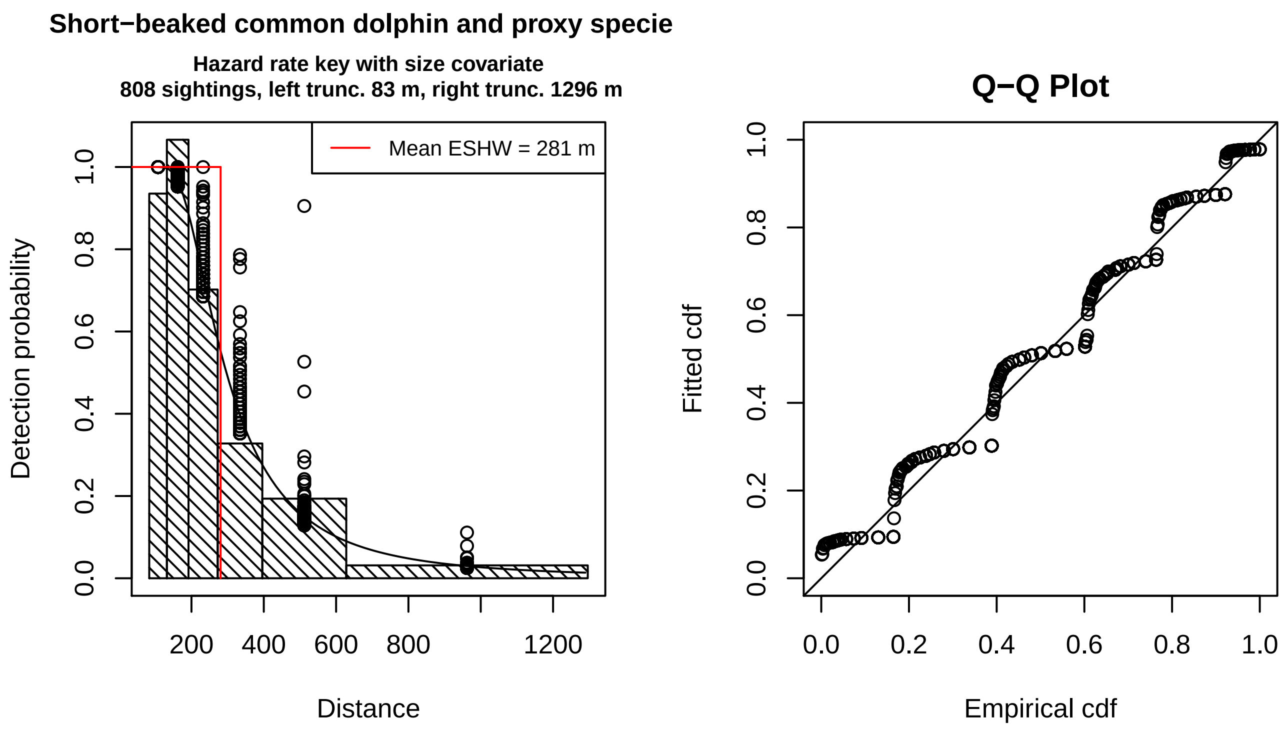


Figure 64: Detection function for GOMEX92-96 Aerial Survey that was selected for the density model

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:

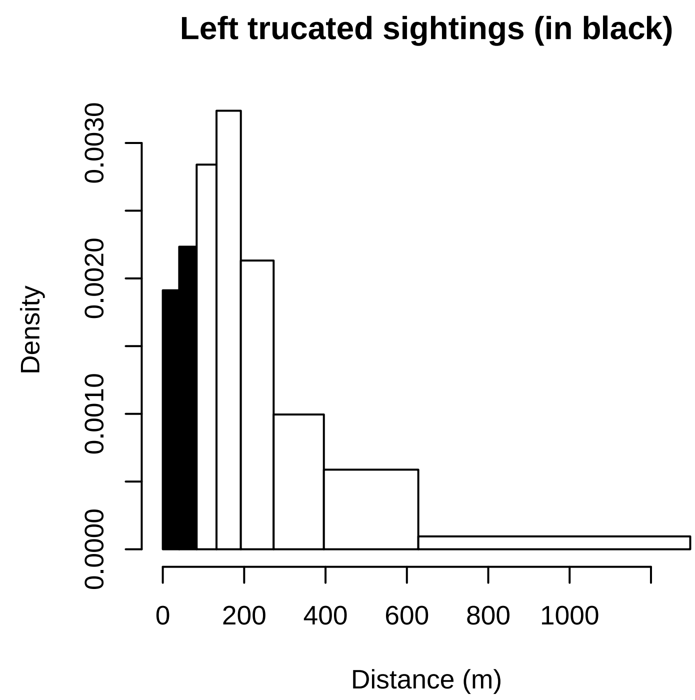


Figure 65: Density of sightings by perpendicular distance for GOMEX92-96 Aerial Survey. Black bars on the left show sightings that were left truncated.

Figure 66: 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.

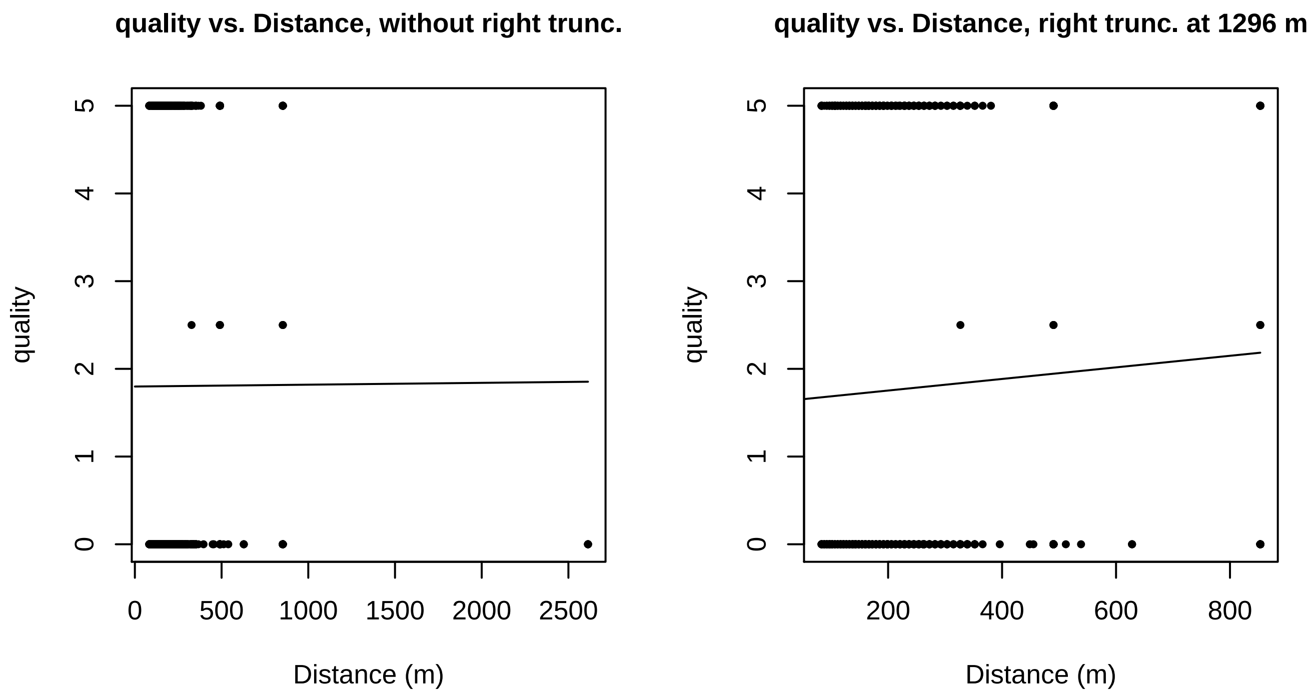


Figure 67: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

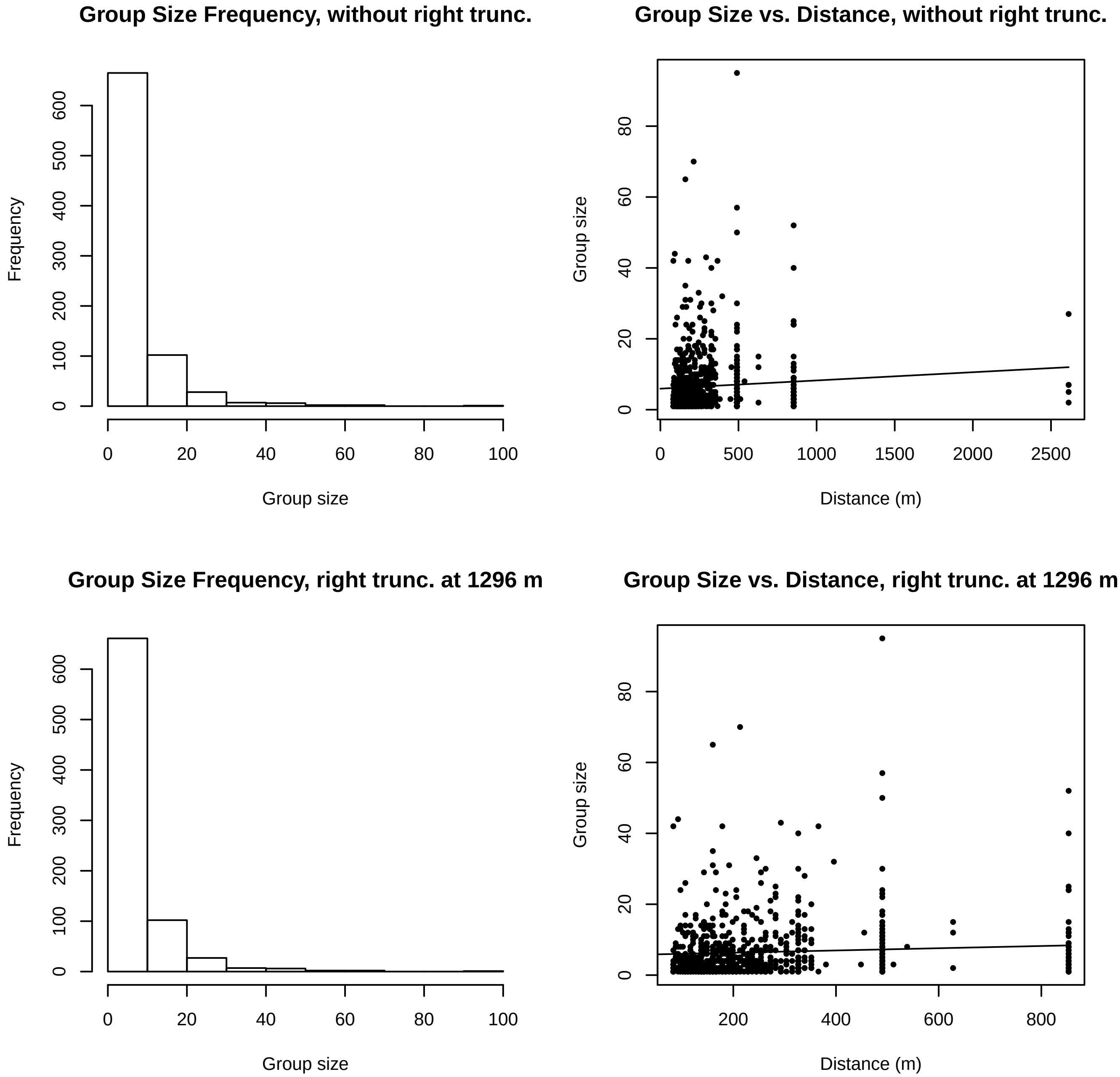


Figure 68: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 43: 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 44: 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	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
hn	herm	4		No		
hr			beaufort	No		
hr			beaufort, quality	No		

Table 45: Candidate detection functions for UNCW Navy Surveys. The first one listed was selected for the density model.

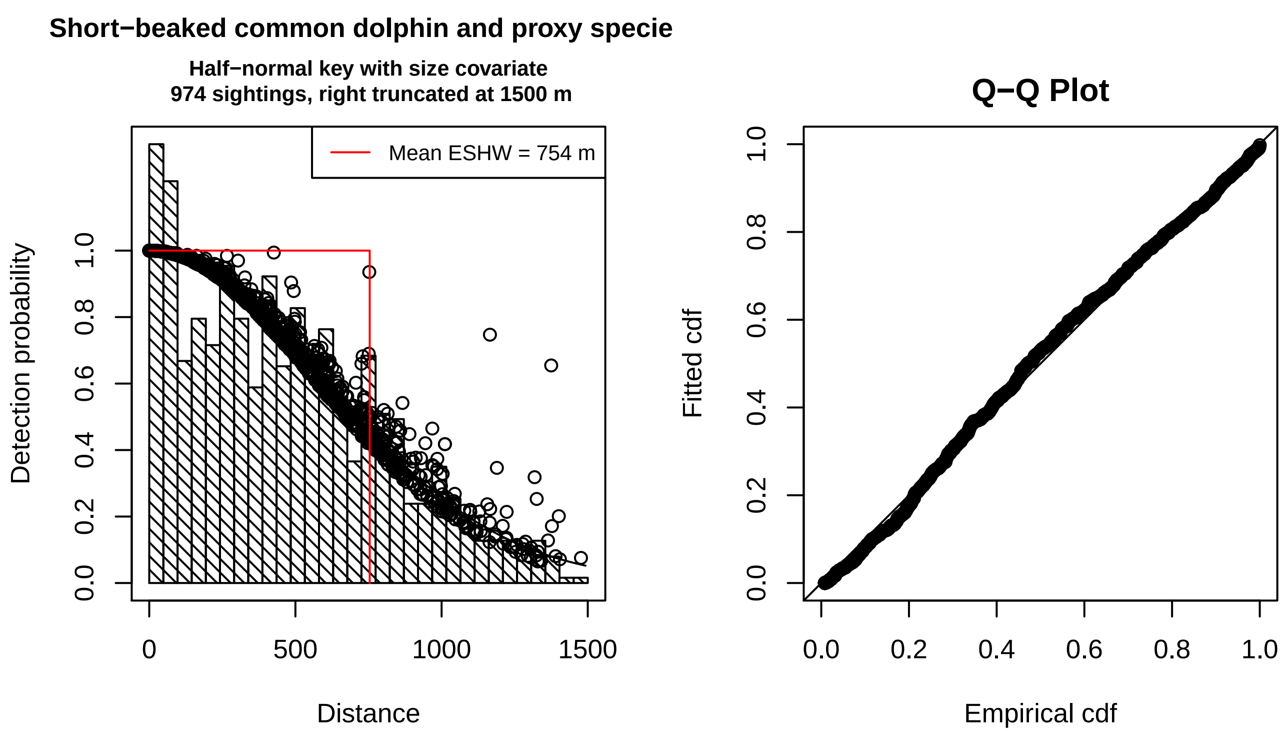


Figure 69: Detection function for UNCW Navy Surveys that was selected for the density model

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 70: 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.

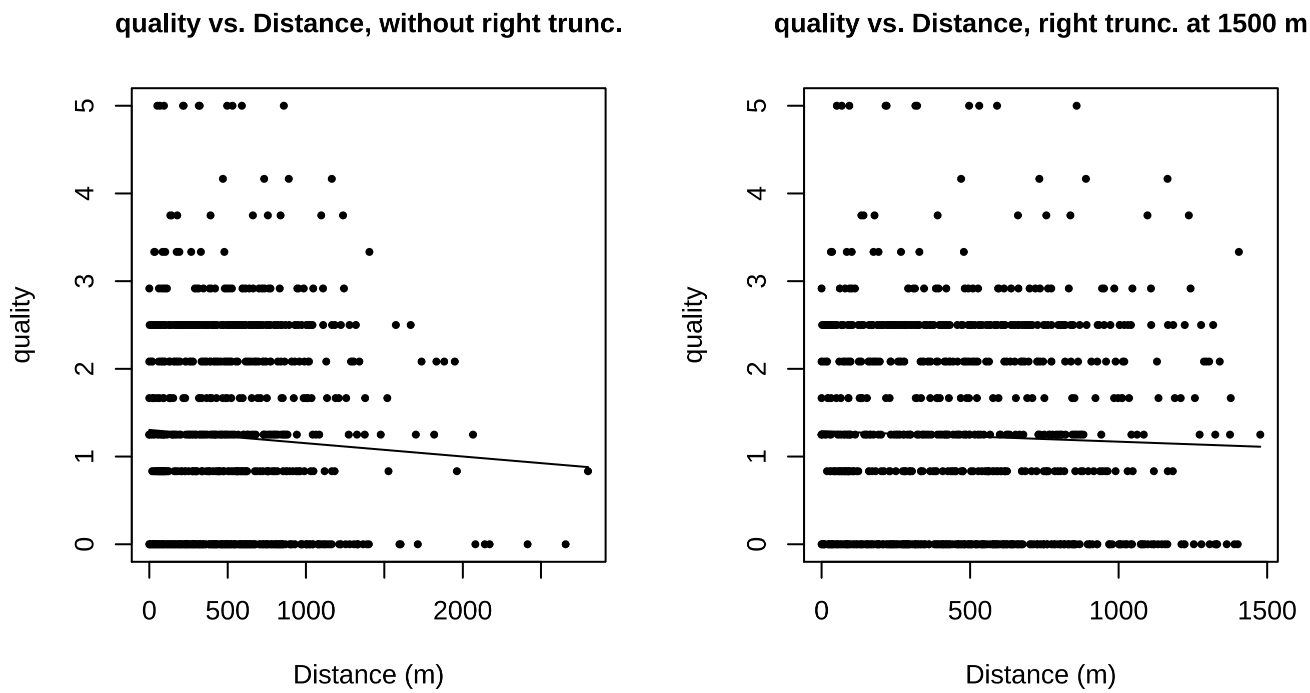


Figure 71: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

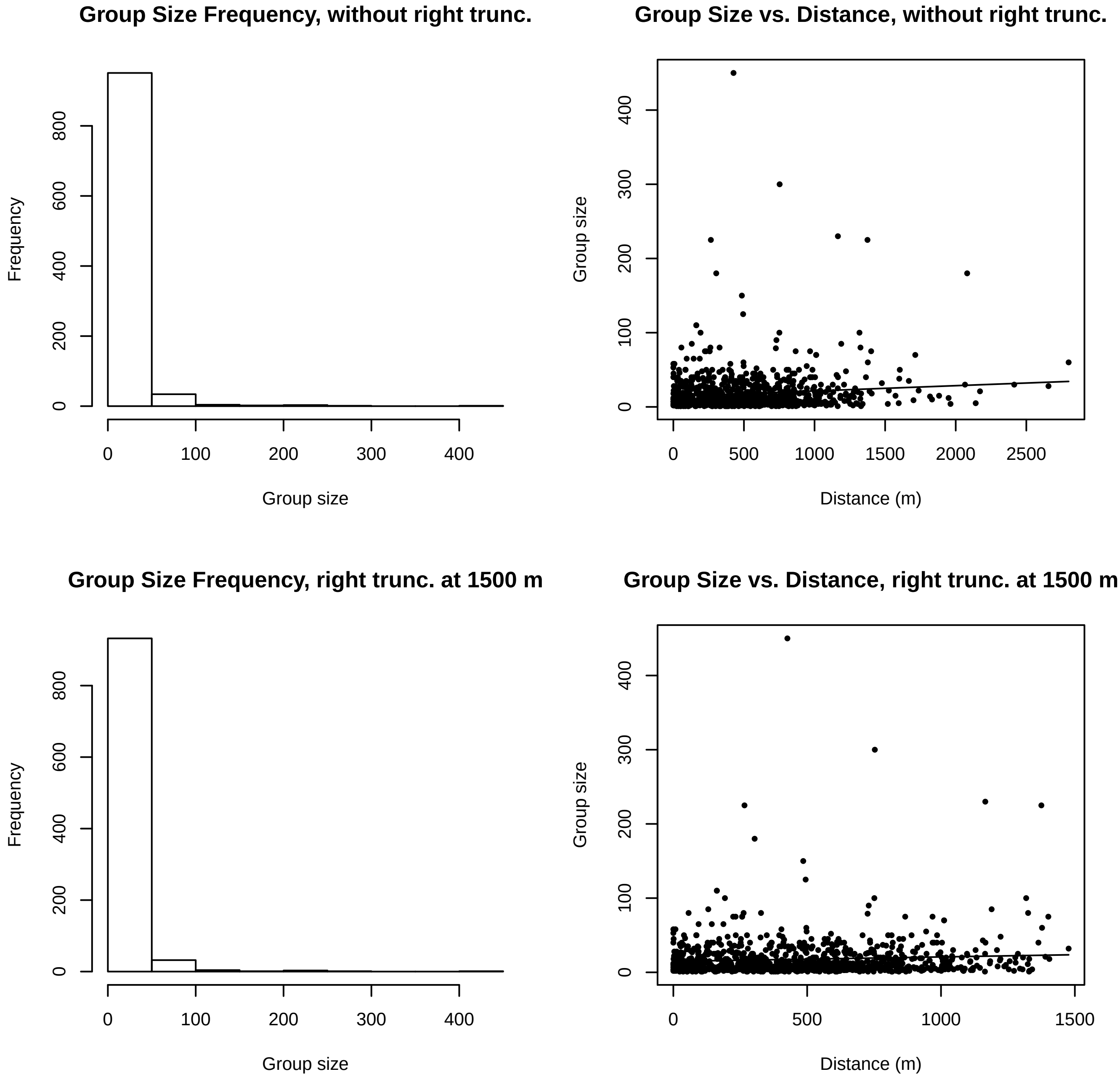


Figure 72: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 46: 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 47: 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 48: Candidate detection functions for UNCW Right Whale Surveys. The first one listed was selected for the density model.

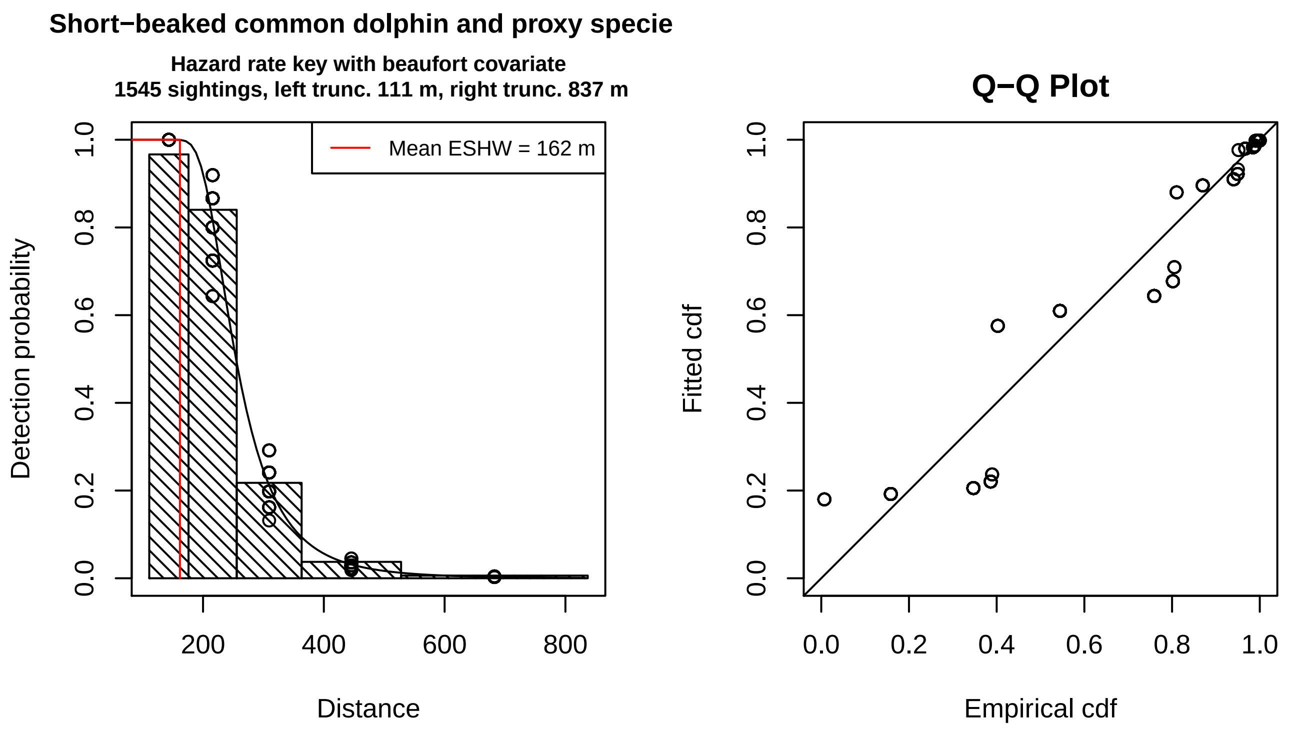


Figure 73: Detection function for UNCW Right Whale Surveys that was selected for the density model

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:

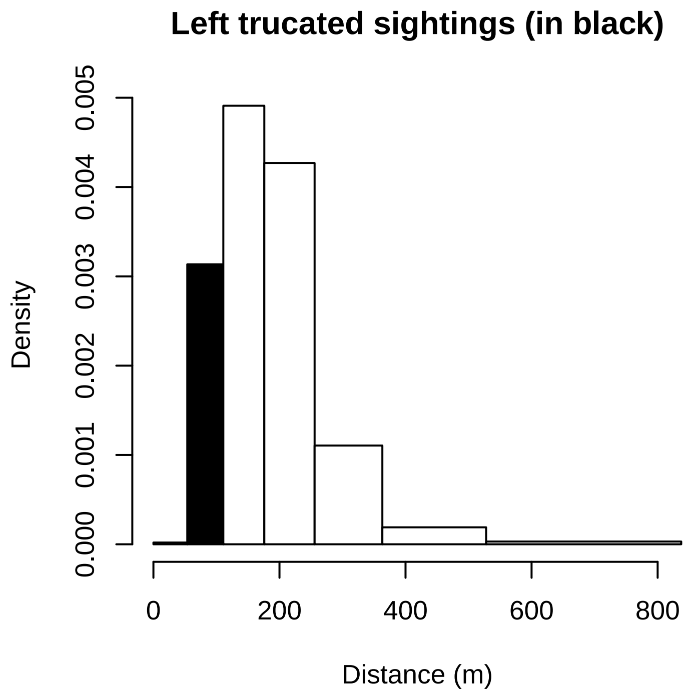


Figure 74: Density of sightings by perpendicular distance for UNCW Right Whale Surveys. Black bars on the left show sightings that were left truncated.

Figure 75: 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.

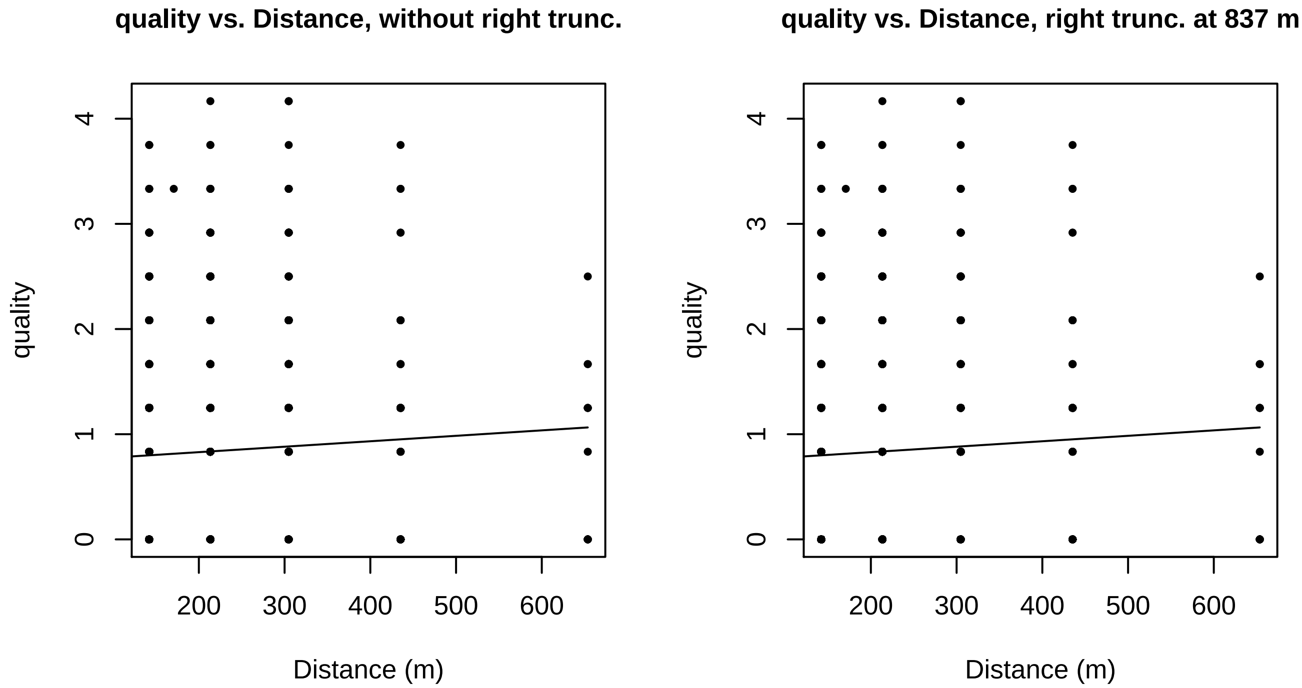


Figure 76: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

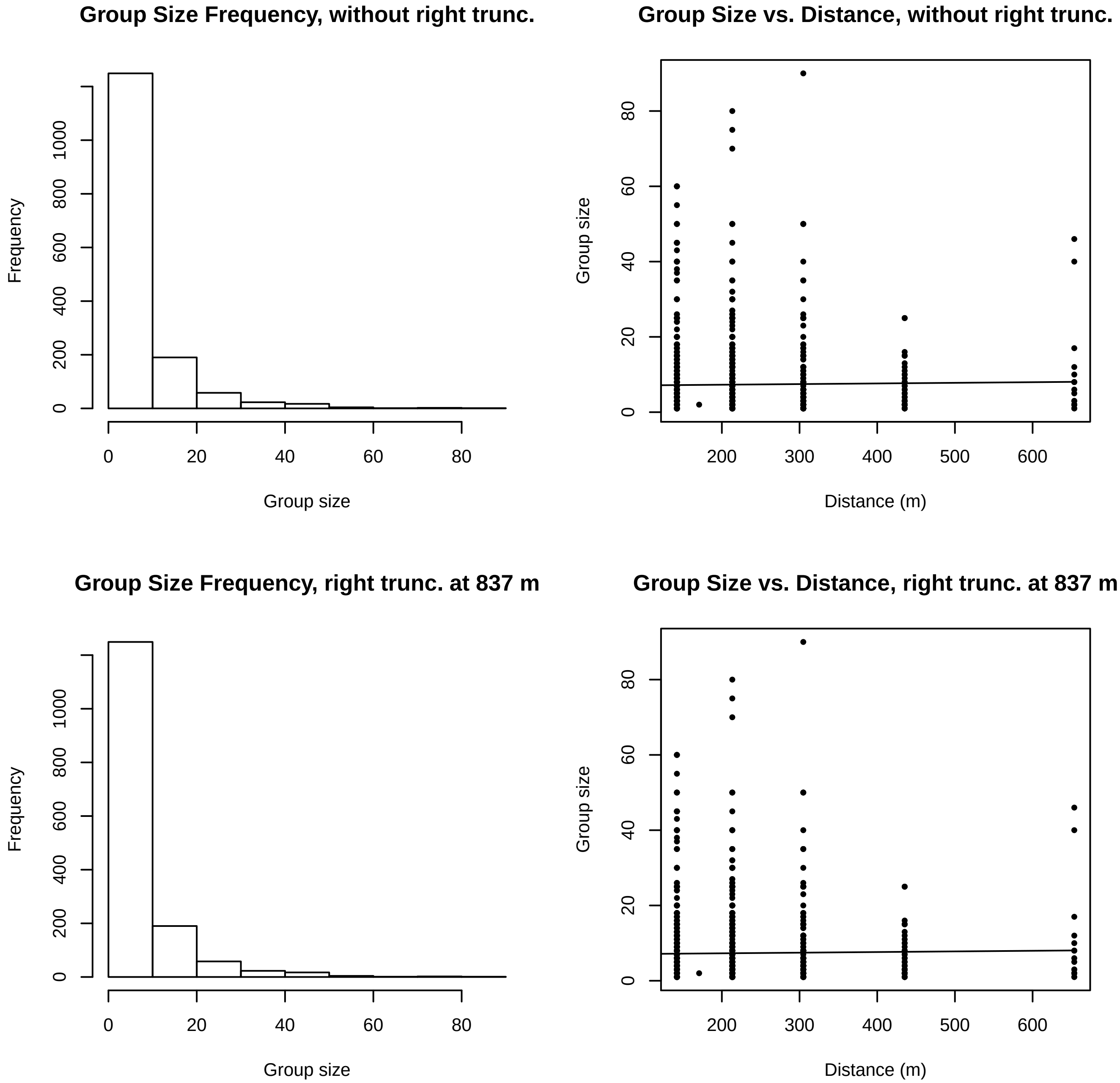


Figure 77: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 49: 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 50: 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 51: Candidate detection functions for UNCW Early Surveys. The first one listed was selected for the density model.

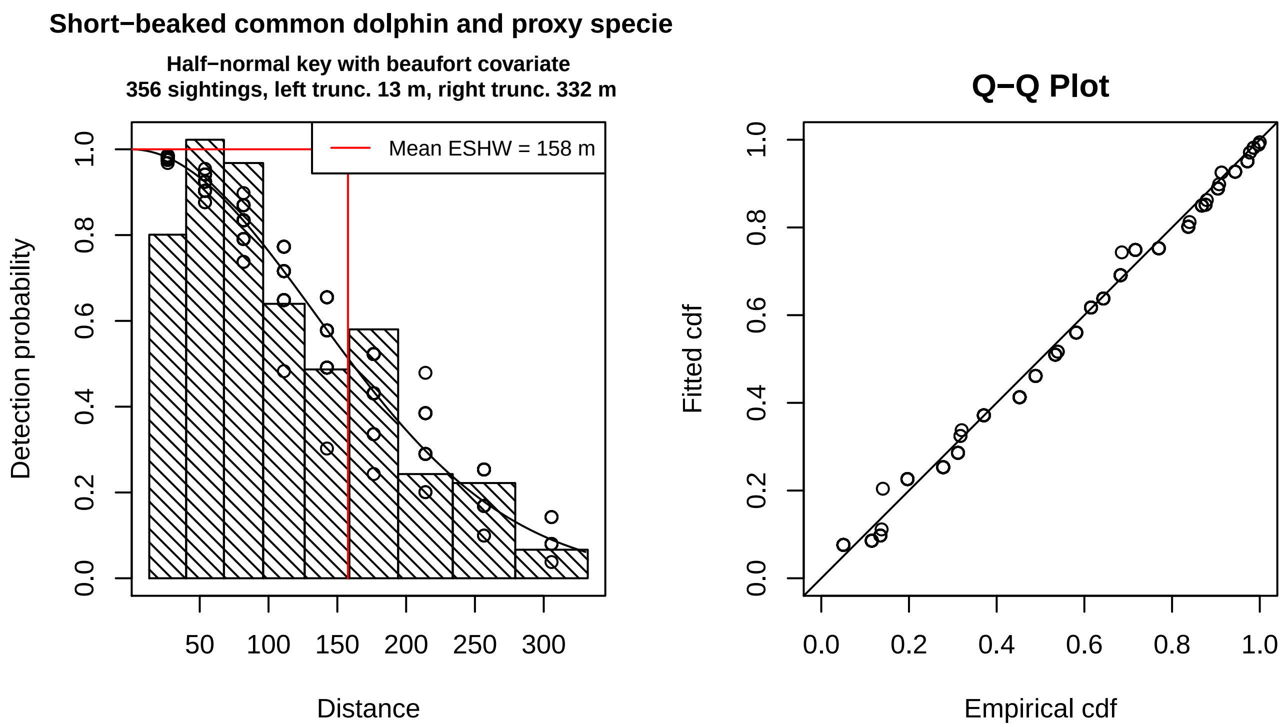


Figure 78: Detection function for UNCW Early Surveys that was selected for the density model

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:

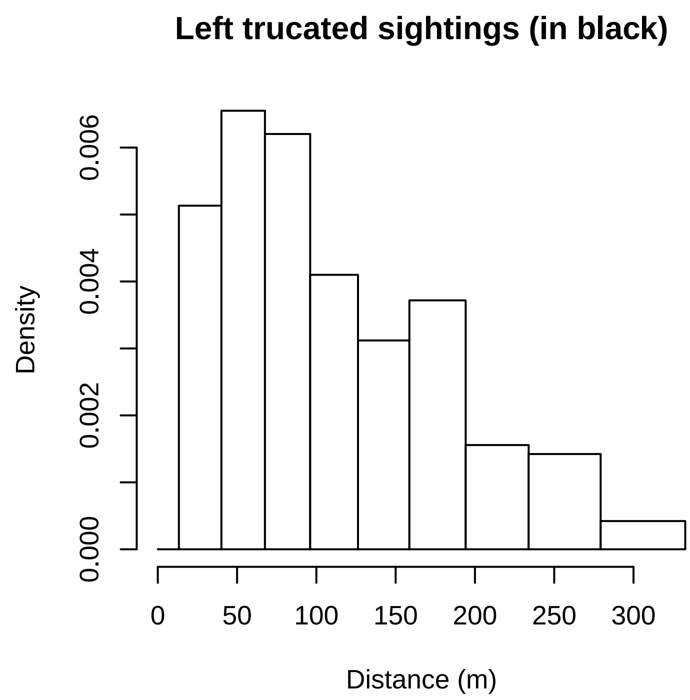


Figure 79: Density of sightings by perpendicular distance for UNCW Early Surveys. Black bars on the left show sightings that were left truncated.

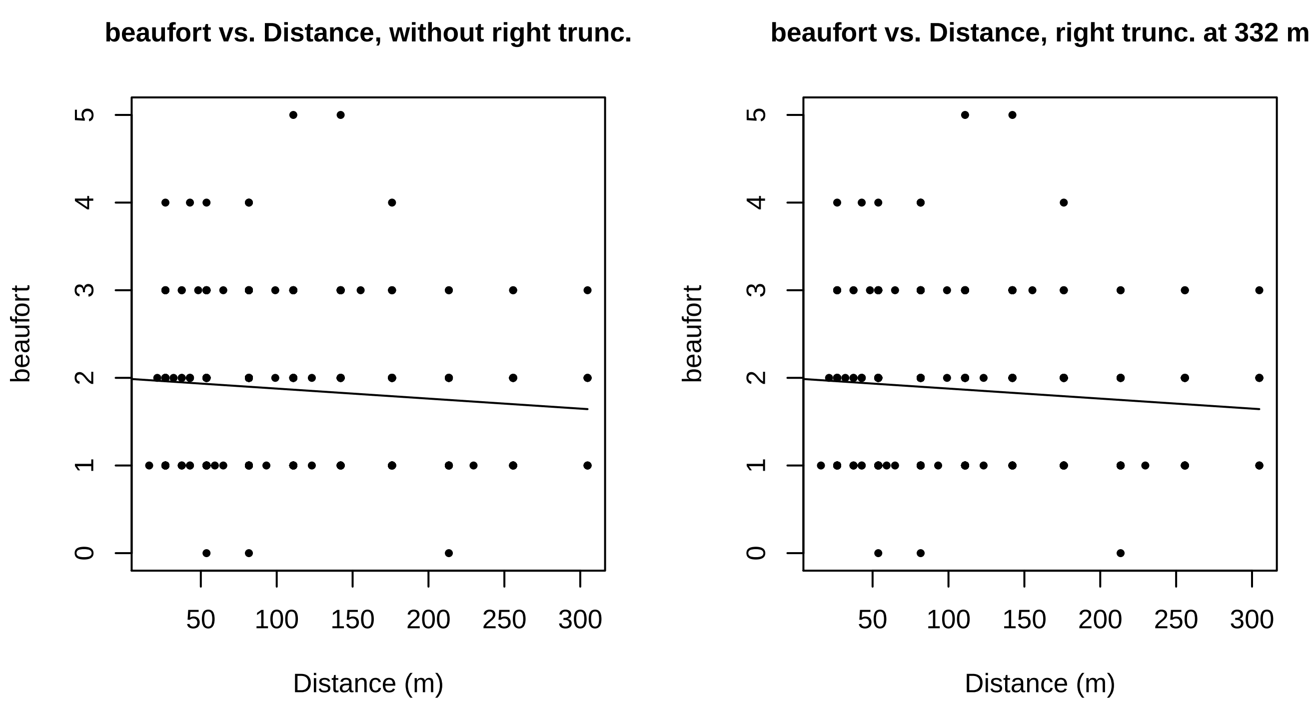


Figure 80: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

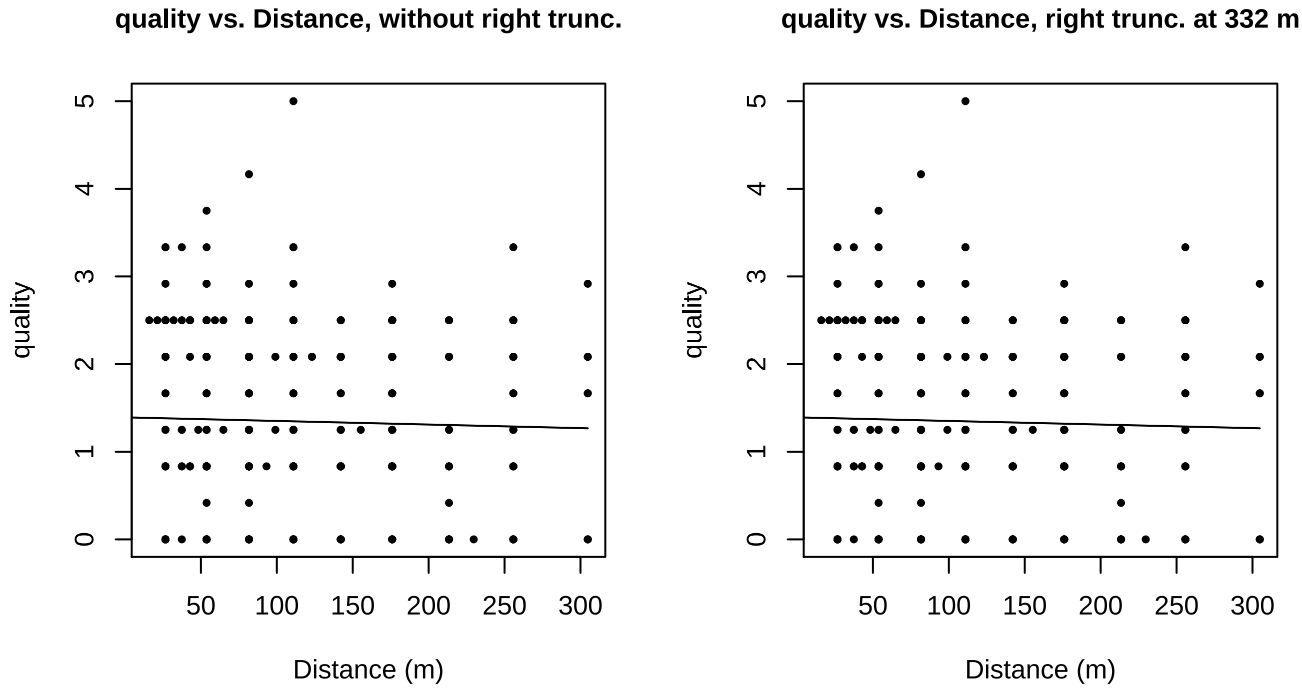


Figure 81: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

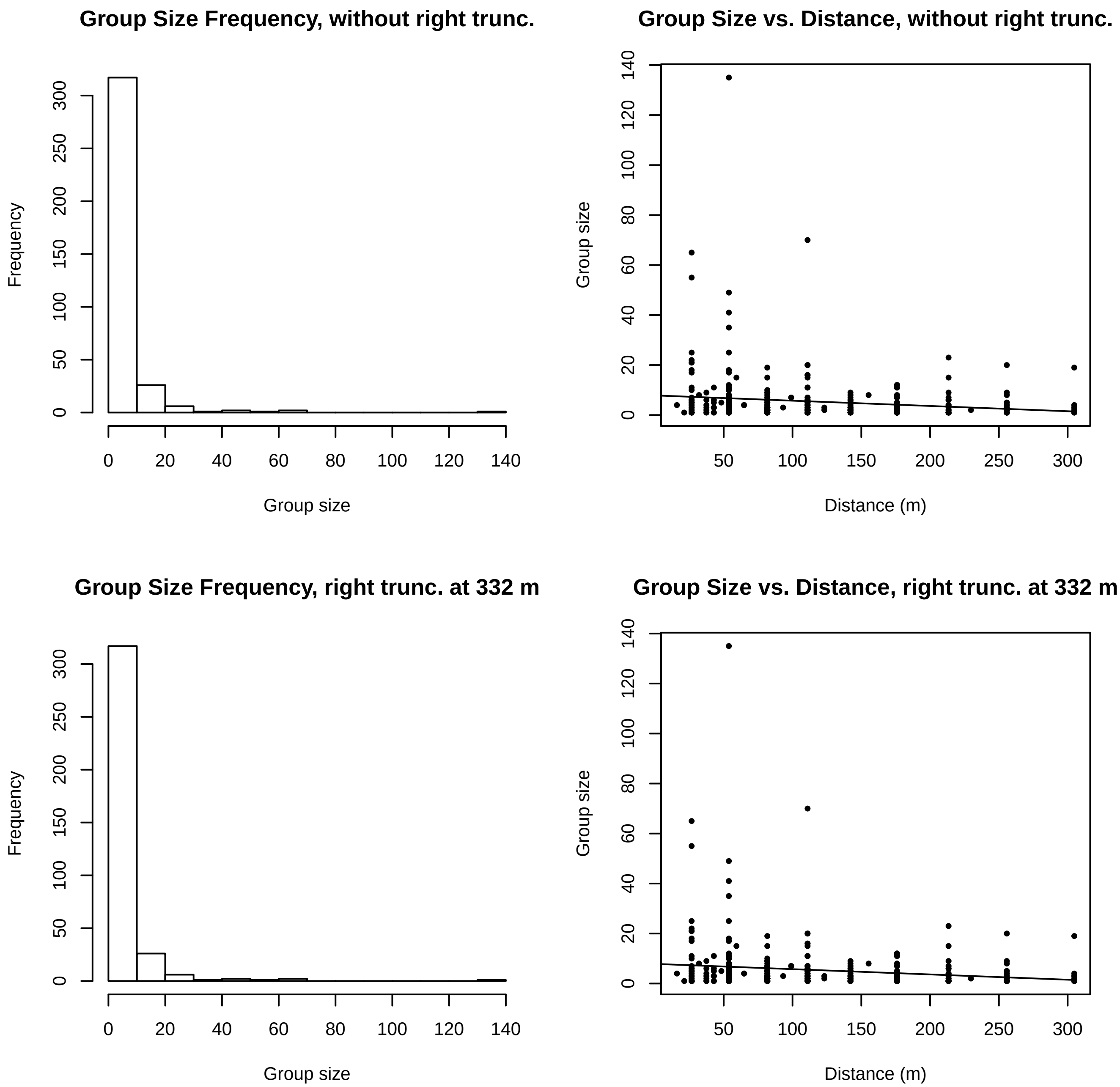


Figure 82: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 52: 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 53: 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 54: Candidate detection functions for Virginia Aquarium Surveys. The first one listed was selected for the density model.

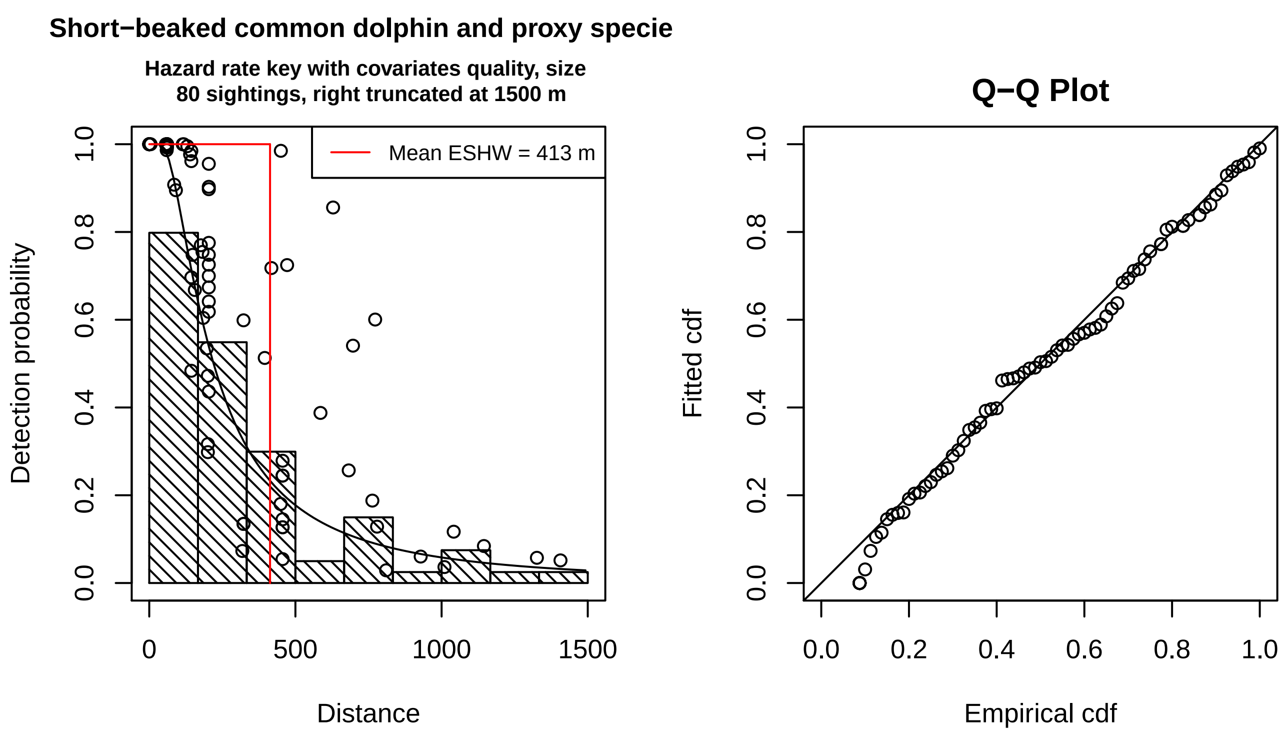


Figure 83: Detection function for Virginia Aquarium Surveys that was selected for the density model

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:

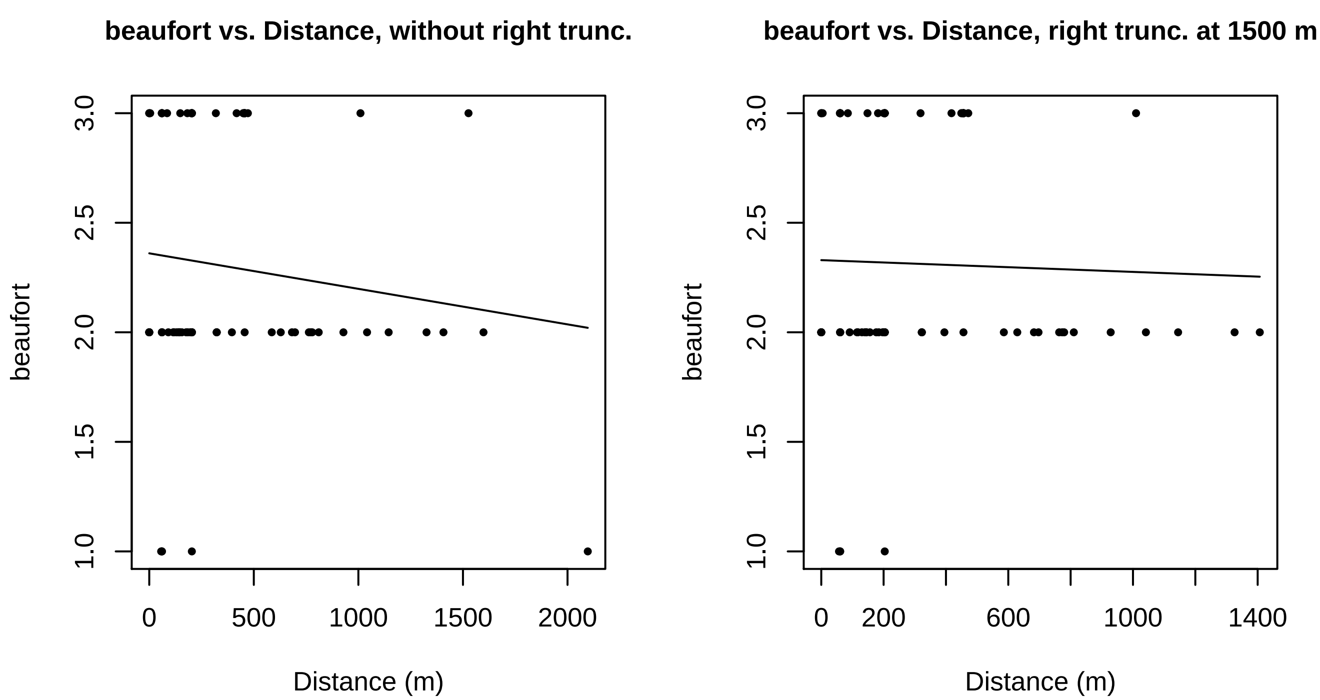


Figure 84: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

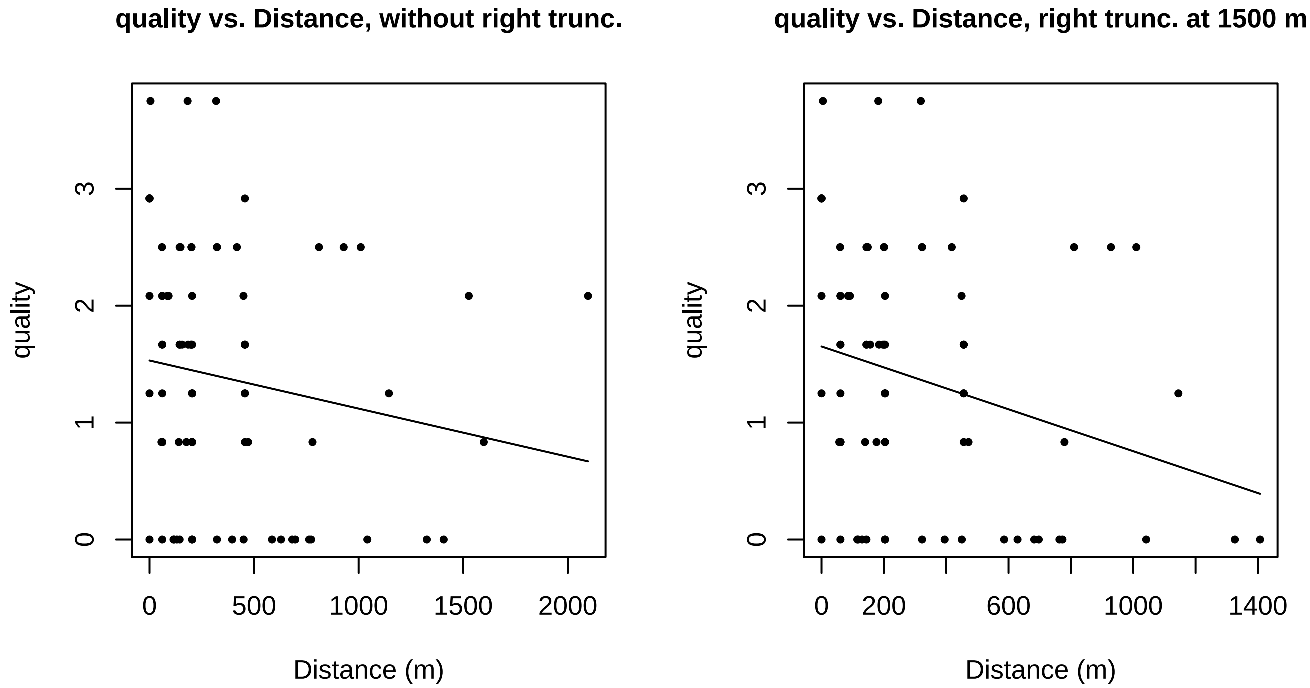


Figure 85: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

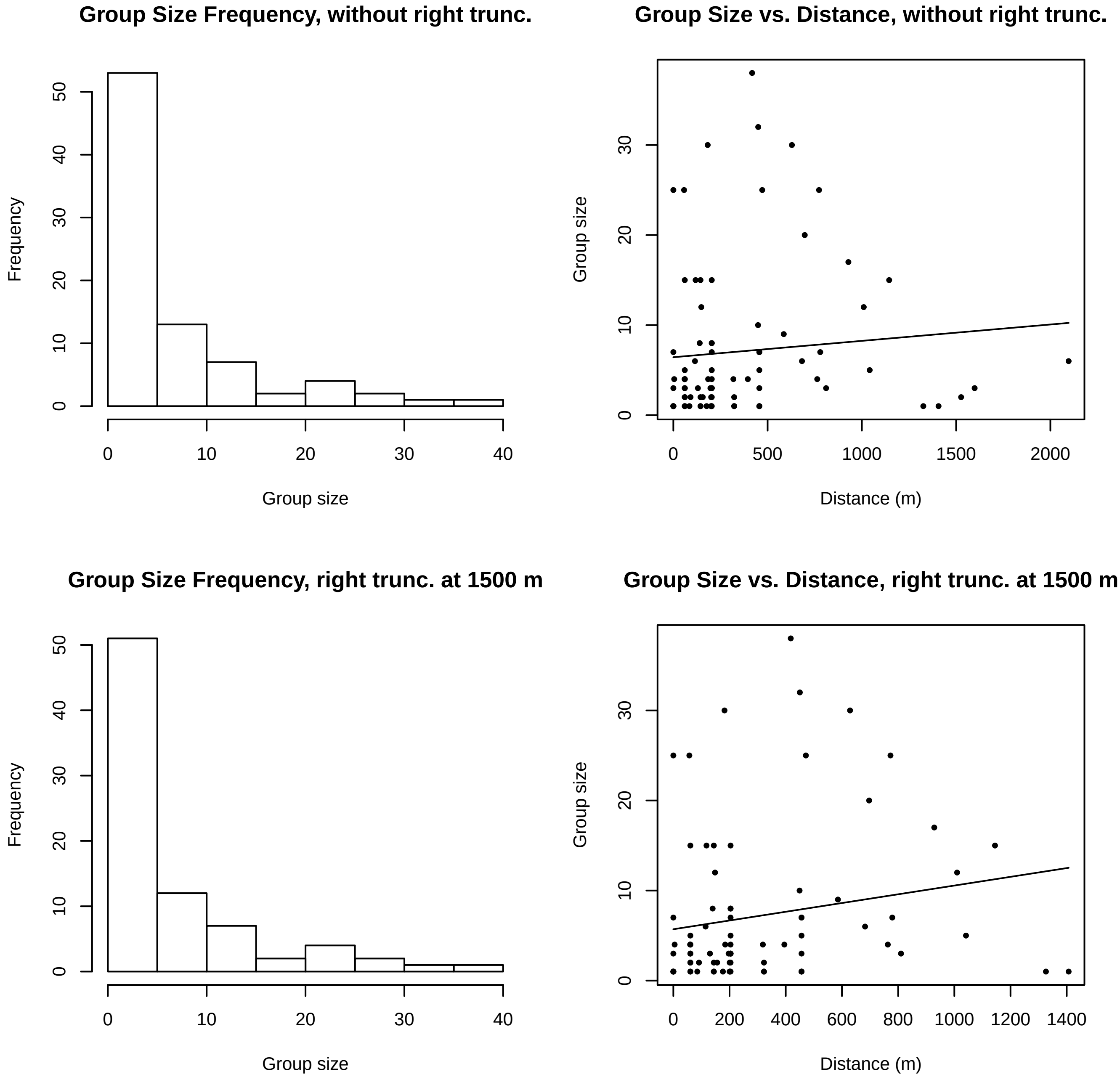


Figure 86: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NARWSS Grummans

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	42

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	288
Lagenorhynchus albirostris	White-beaked dolphin	3
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	1
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	6
Total		340

Table 55: Proxy species used to fit detection functions for NARWSS Grummans. The number of sightings, n, is before truncation.

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 56: 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	235

hr			size	Yes	5.95	231
hr			beaufort, size	Yes	7.81	233
hr			quality	Yes	11.76	213
hn			size	Yes	14.26	231
hn			quality, size	Yes	14.51	233
hn			beaufort, size	Yes	16.23	231
hr				Yes	20.06	203
hn	cos	2		Yes	20.08	154
hr	poly	4		Yes	21.78	200
hr			beaufort	Yes	22.05	204
hr	poly	2		Yes	22.06	203
hn				Yes	33.54	223
hn			quality	Yes	33.86	223
hn	herm	4		Yes	35.13	222
hn	cos	3		No		
hn			beaufort	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hn			beaufort, quality, size	No		
hr			beaufort, quality, size	No		

Table 57: Candidate detection functions for NARWSS Grummans. The first one listed was selected for the density model.

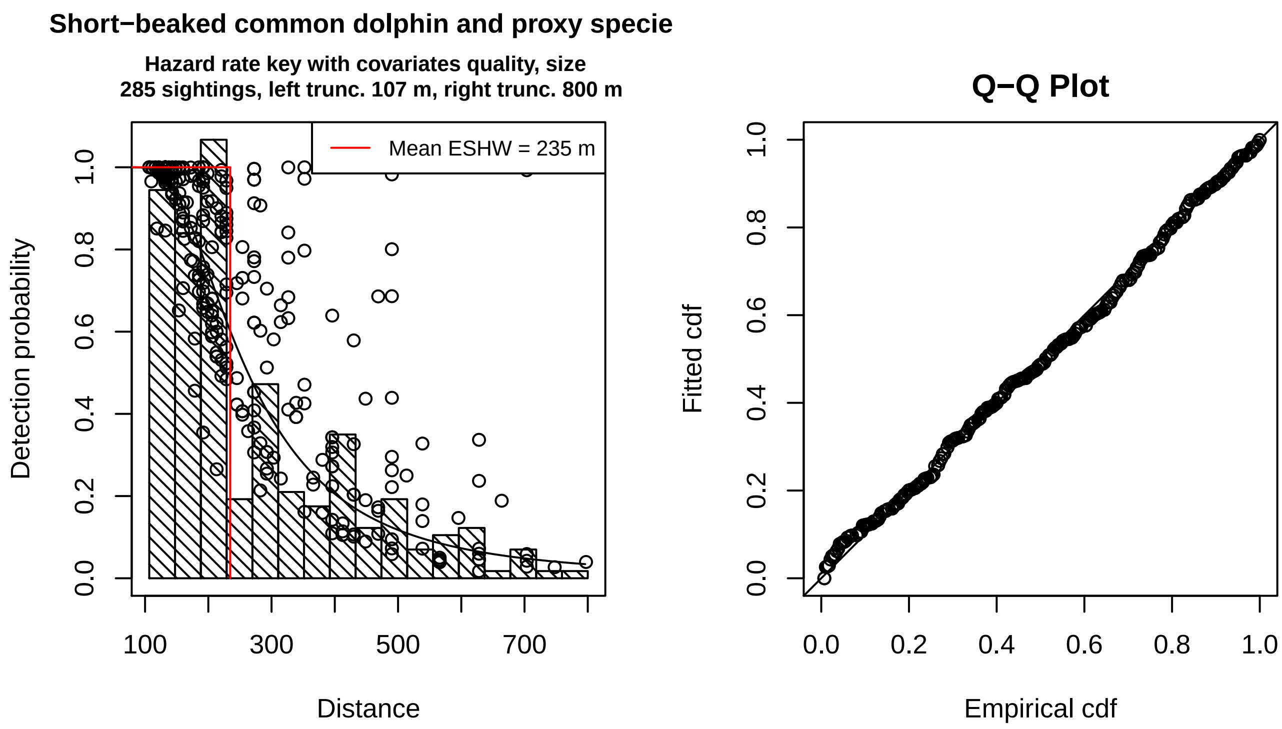


Figure 87: Detection function for NARWSS Grummans that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  285
Distance range         :  106.5979  -  800
AIC                    :  3450.827

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate         se
(Intercept)  5.5620259 0.12398130
quality     -0.2408179 0.09290192
size         0.2953779 0.09400126

Shape parameters:
            estimate        se
(Intercept) 1.119906 0.1056045

                        Estimate           SE        CV
Average p              0.2541682   0.03062592 0.1204947
N in covered region 1121.3045461 147.37019002 0.1314274
```

Additional diagnostic plots:

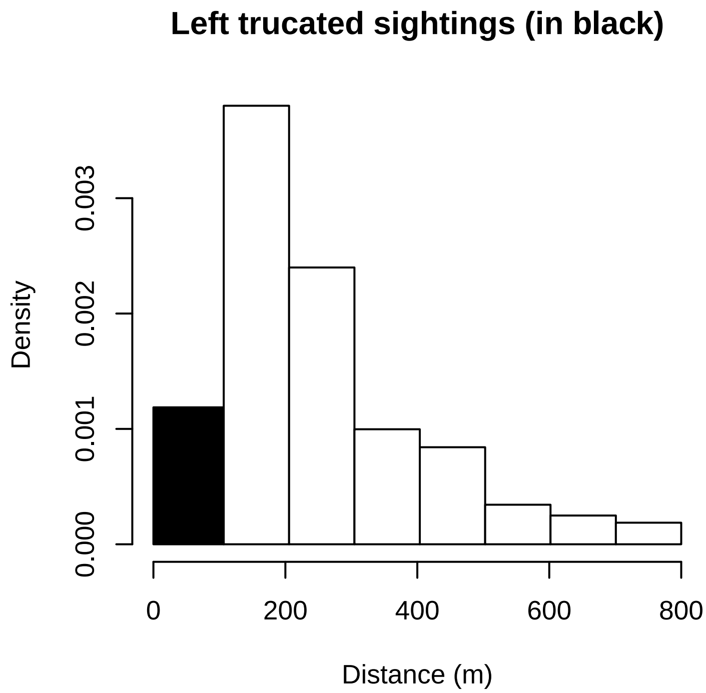


Figure 88: Density of sightings by perpendicular distance for NARWSS Grummans. Black bars on the left show sightings that were left truncated.

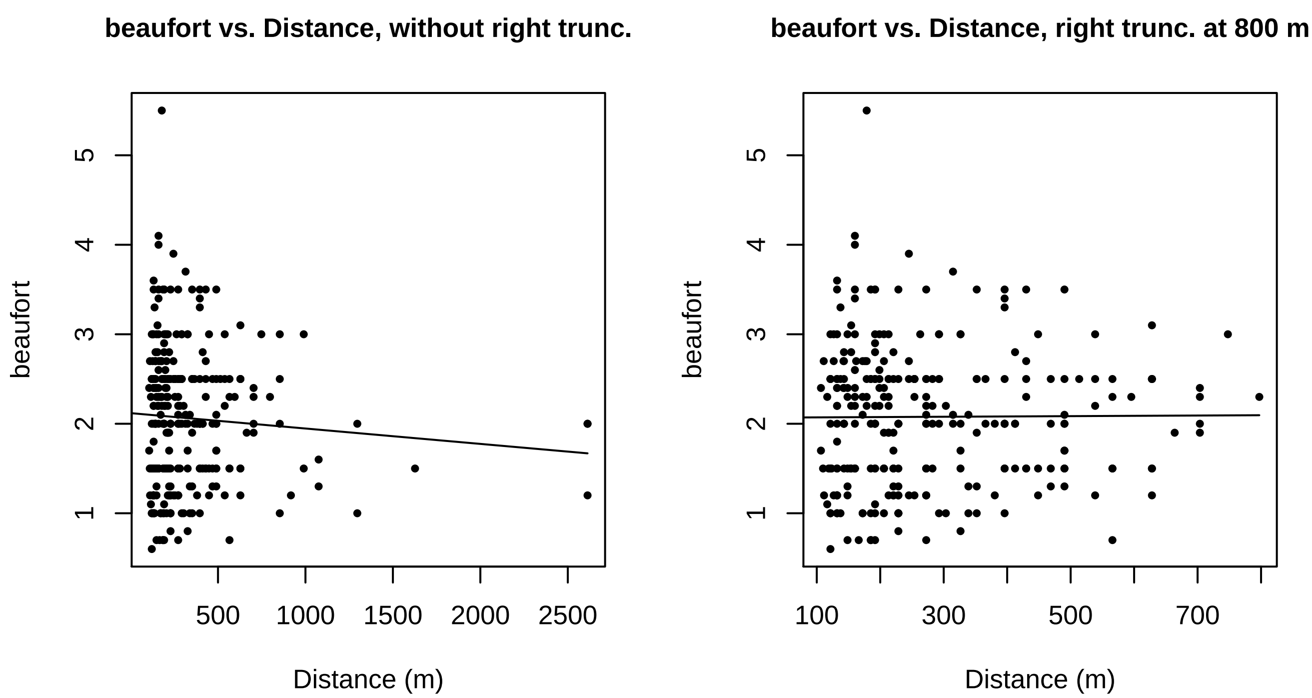


Figure 89: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

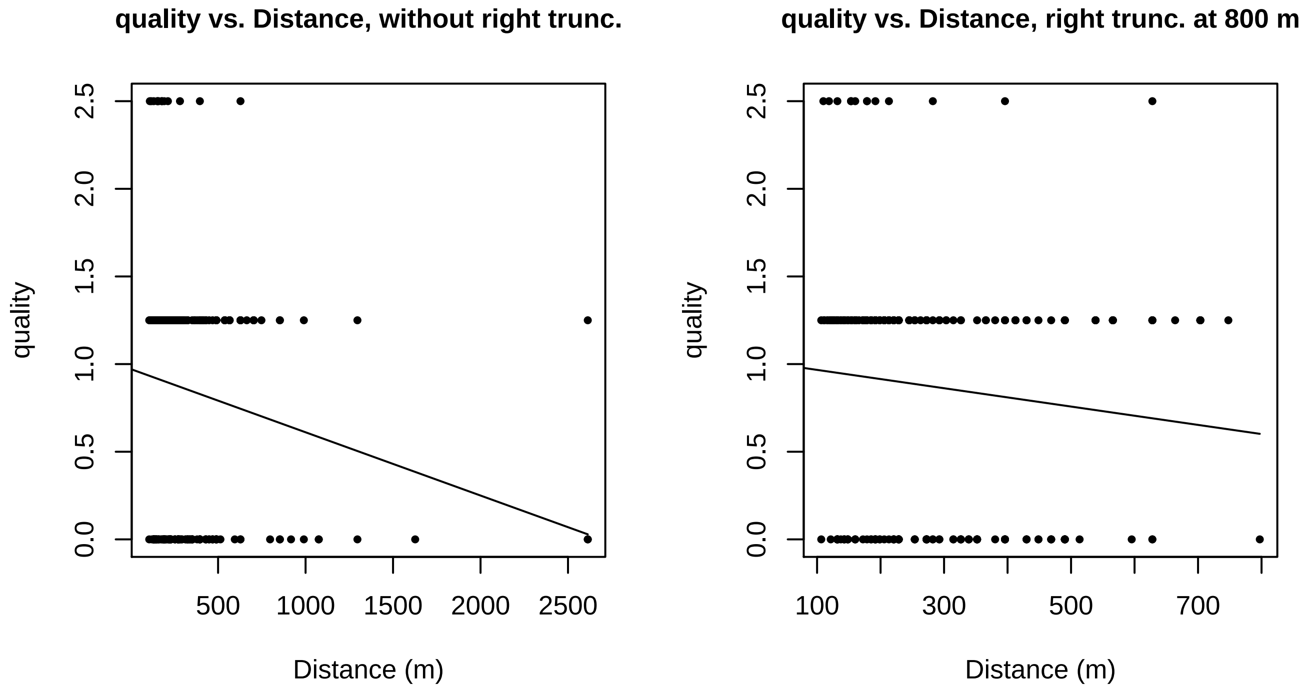


Figure 90: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

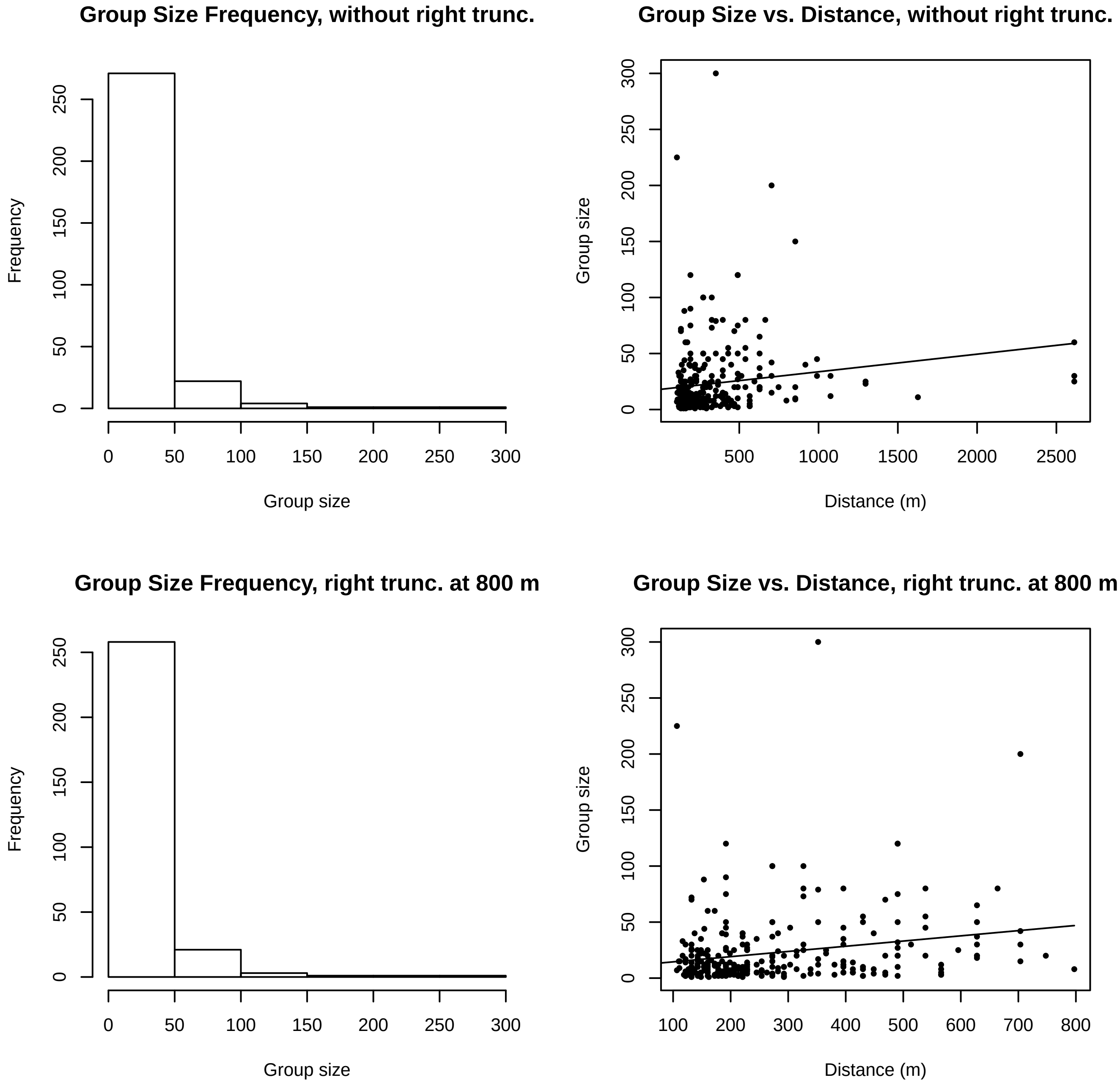


Figure 91: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 58: 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	478
hr			beaufort	Yes	6.33	439
hr	poly	2		Yes	7.15	388
hr			size	Yes	7.15	457
hr	poly	4		Yes	7.73	405
hr			quality, size	Yes	8.87	455
hr				Yes	11.78	423
hr			quality	Yes	13.42	420
hn	cos	3		Yes	14.61	358
hn	cos	2		Yes	17.89	448
hn			beaufort, size	Yes	44.11	545
hn			beaufort, quality, size	Yes	45.86	546
hn			size	Yes	46.60	544
hn			quality, size	Yes	48.25	545
hn				Yes	54.50	542
hn			beaufort	Yes	54.63	542
hn	herm	4		Yes	56.18	542
hn			quality	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hr			beaufort, quality, size	No		

Table 59: Candidate detection functions for NARWSS Twin Otters. The first one listed was selected for the density model.

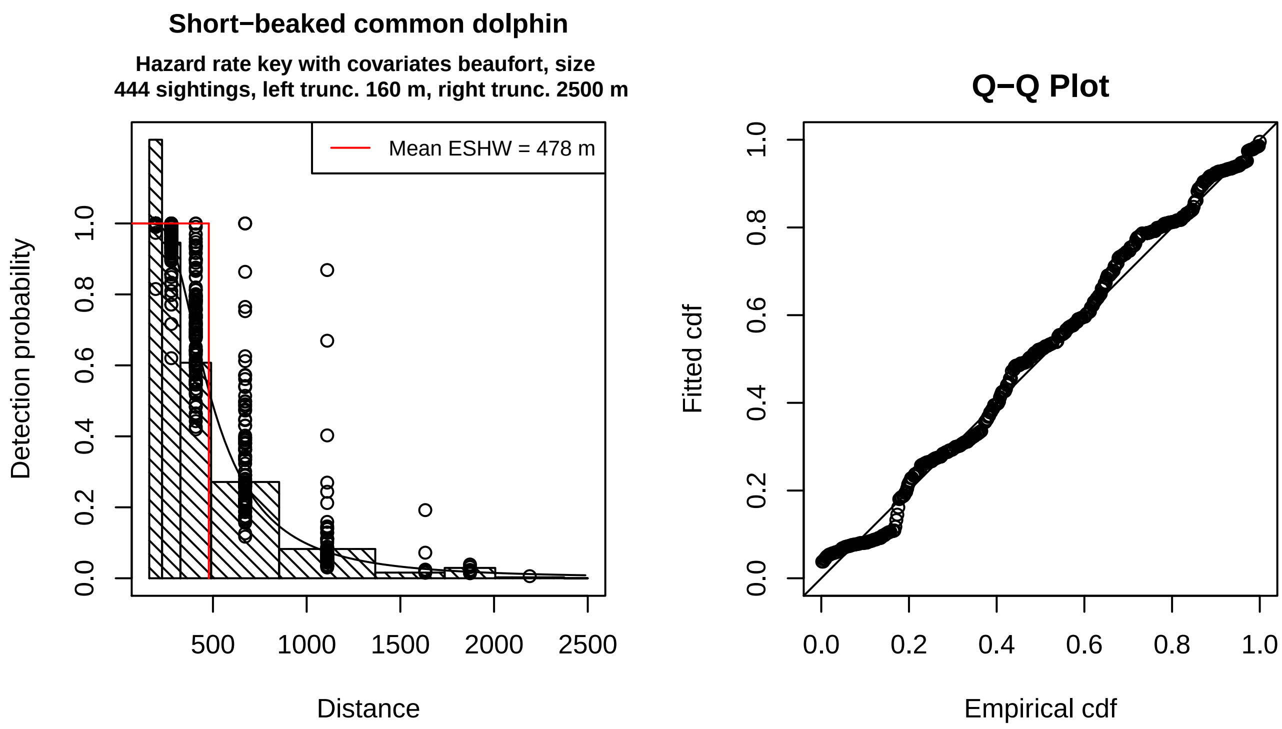


Figure 92: Detection function for NARWSS Twin Otters that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  444
Distance range         :  160.0674  -  2500
AIC                    :  1535.306

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate         se
(Intercept)  6.4500595 0.16406785
beaufort    -0.2023108 0.06983548
size         0.2404588 0.06895694

Shape parameters:
            estimate         se
(Intercept) 1.060185 0.07385327

                        Estimate           SE         CV
Average p              0.1749012   0.01386137 0.07925257
N in covered region 2538.5753526 229.53838311 0.09042016
```

Additional diagnostic plots:

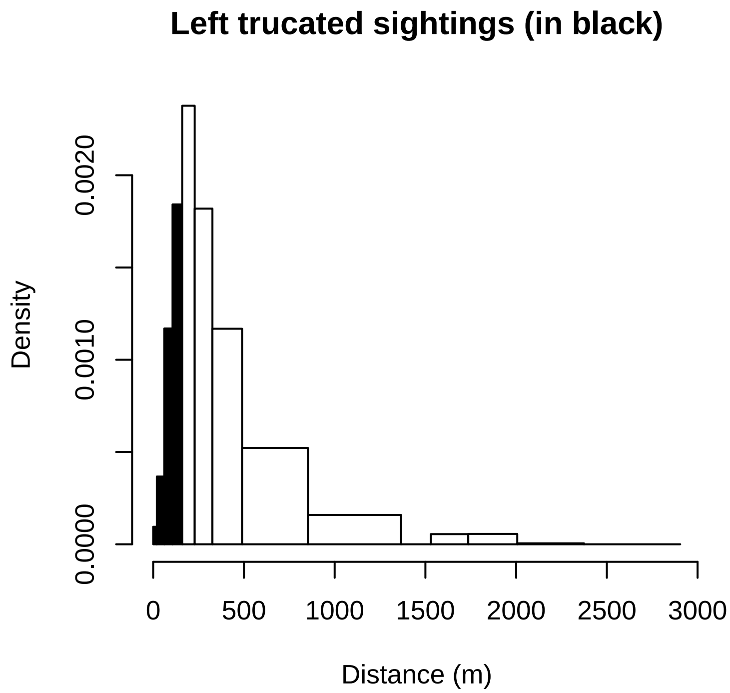


Figure 93: Density of sightings by perpendicular distance for NARWSS Twin Otters. Black bars on the left show sightings that were left truncated.

Figure 94: 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.

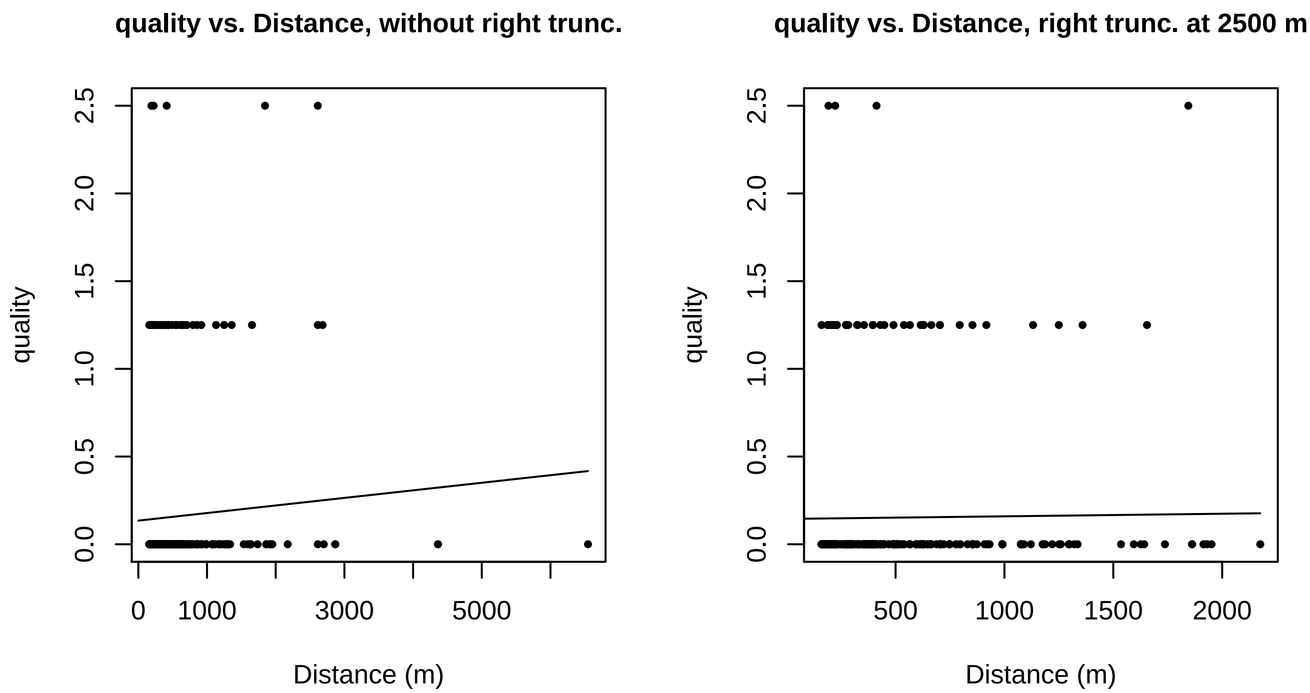


Figure 95: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

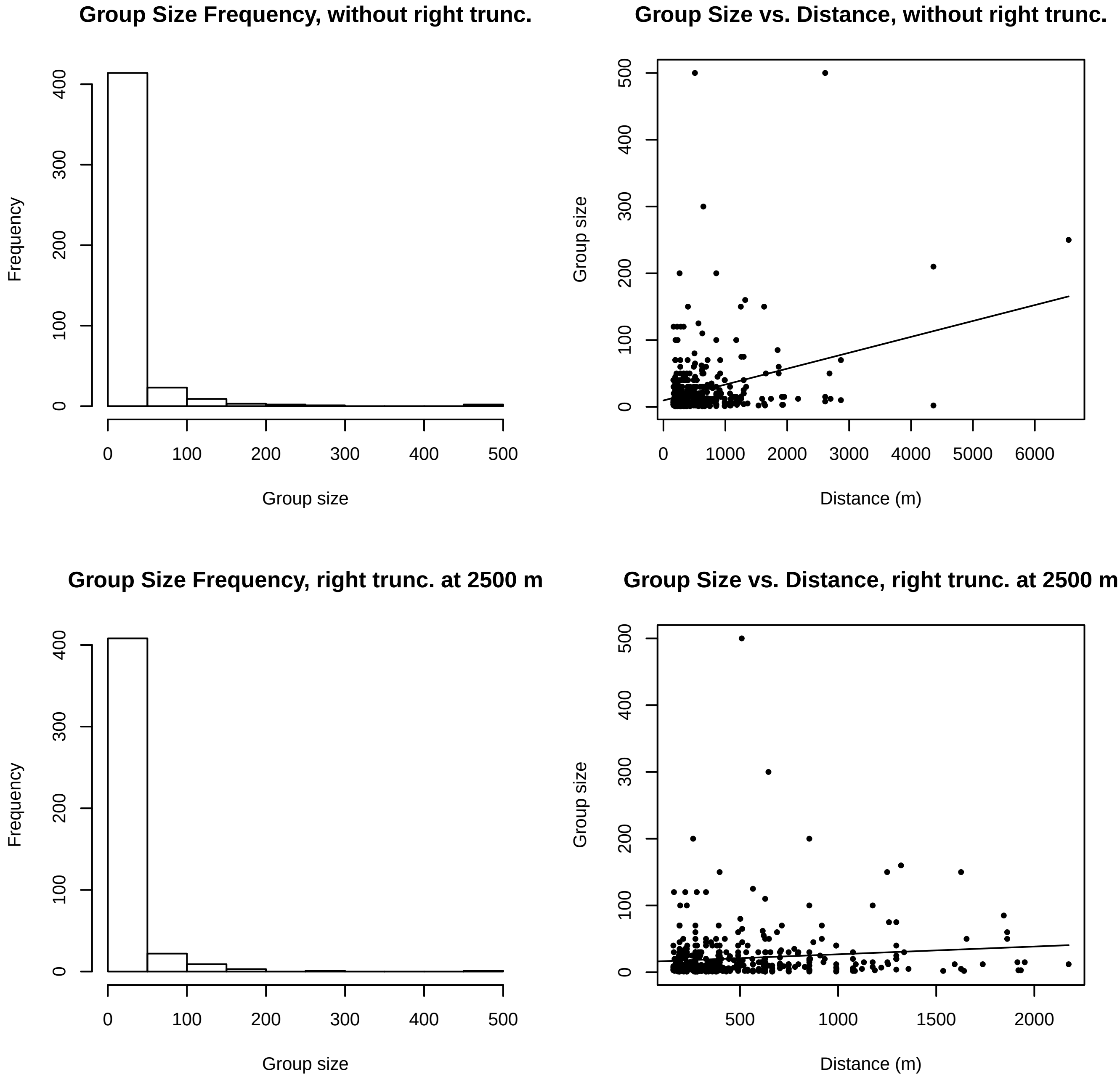


Figure 96: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

g(0) Estimates

Platform	Surveys	Group Size	*g(0)*	Biases Addressed	Source
Shipboard	All	1-20	0.856	Perception	Barlow and Forney (2007)
		>20	0.970	Perception	Barlow and Forney (2007)
Shipboard	NEFSC Abel-J Binocular Surveys	Any	0.76	Perception	Palka (2006)
Shipboard	NEFSC Endeavor	Any	0.64	Perception	Palka (2006)
Aerial	All	1-5	0.43	Both	Palka (2006)
		>5	0.960	Both	Carretta et al. (2000)

Table 60: Estimates of *g(0)* used in this density model.

For shipboard surveys other than the NOAA NEFSC cruises for which Palka (2006) provided survey-specific estimates of g(0), 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.

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

Short-beaked common dolphins are widely distributed in temperate and sub-tropical waters (Waring et al. 2014). At the time of this writing, Jefferson et al. (2009) provided the most recent comprehensive review of their distribution in the western North Atlantic. According to this study, in recent decades off the North American east coast, short-beaked common dolphins were found mainly in cooler waters, ranging between the 200m and 2000m isobaths from at least Cape Hatteras north to 47-50 N off the Canadian coast. This may be a change from the first half of the 20th century, in which short-beaked common dolphins were believed to be more common in the waters of the southeast U.S. as far south as Florida; the shift may be related to changes in water temperature, or prey distributions resulting from oceanographic changes, or displacement by Stenella species (Jefferson et al. 2009).

Jefferson et al. (2009) described seasonal movements in our study area as follows. From January to May, short-beaked common dolphins regularly range north only as far as Georges Bank, then shift northwards in summer as waters warm into the Gulf of Maine, Scotian Shelf, and prominent bottom escarpments such as the Flemish Cap. They are extremely rare in the Bay of Fundy at all times but are common in slope waters of Nova Scotia in late summer and autumn and are frequently seen near the "Gully" canyon at this time. Concurrent with Jefferson et al.'s (2009) review but not considered by it, Lawson and Gosselin (2009) reported 198 sightings of short-beaked common dolphins in a survey of the Scotian Shelf in July-August 2007, and 2 more near Cape Breton, and ultimately estimated the abundance for this area during the survey to be 171,680, the most of any cetacean sighted (Lawson and Gosselin 2011).

The surveys incorporated into our modeling study, spanning 1992-2014, reported over 1000 sightings of short-beaked common dolphins. Most of the sightings were reported between New York and Canada, reflecting both the species' habitat and a bias in survey effort, with 75% of the sightings reported by NOAA aerial surveys of the northeast U.S. and southeast Canada. Shipboard surveys reported sightings along the shelf break and slope from Cape Hatteras to Georges Bank, the northernmost extent of shipboard effort. Smaller-scale shipboard and aerial surveys reported clusters of sightings in areas south of New England, including New Jersey, Virginia, North Carolina, and even one sighting off South Carolina. Given the heterogeneity in survey effort, it is not trivial to discern a pattern in distribution from the sightings alone, although a sightings-per-unit-effort map (Fig. 7) suggests highest density along the shelf break and slope, consistent with the habitat descriptions from the literature.

We could find no description in the literature of a broad scale migration that would indicate a clear seasonal switch in the species' relationship to environmental covariates (as with baleen whales migrating between cold feeding grounds and warm calving grounds). Given that, and that sightings were reported across the study area–both north and south of Cape Hatteras, and both on and off the continental shelf–we fitted a single, year-round model that incorporated all available survey data.

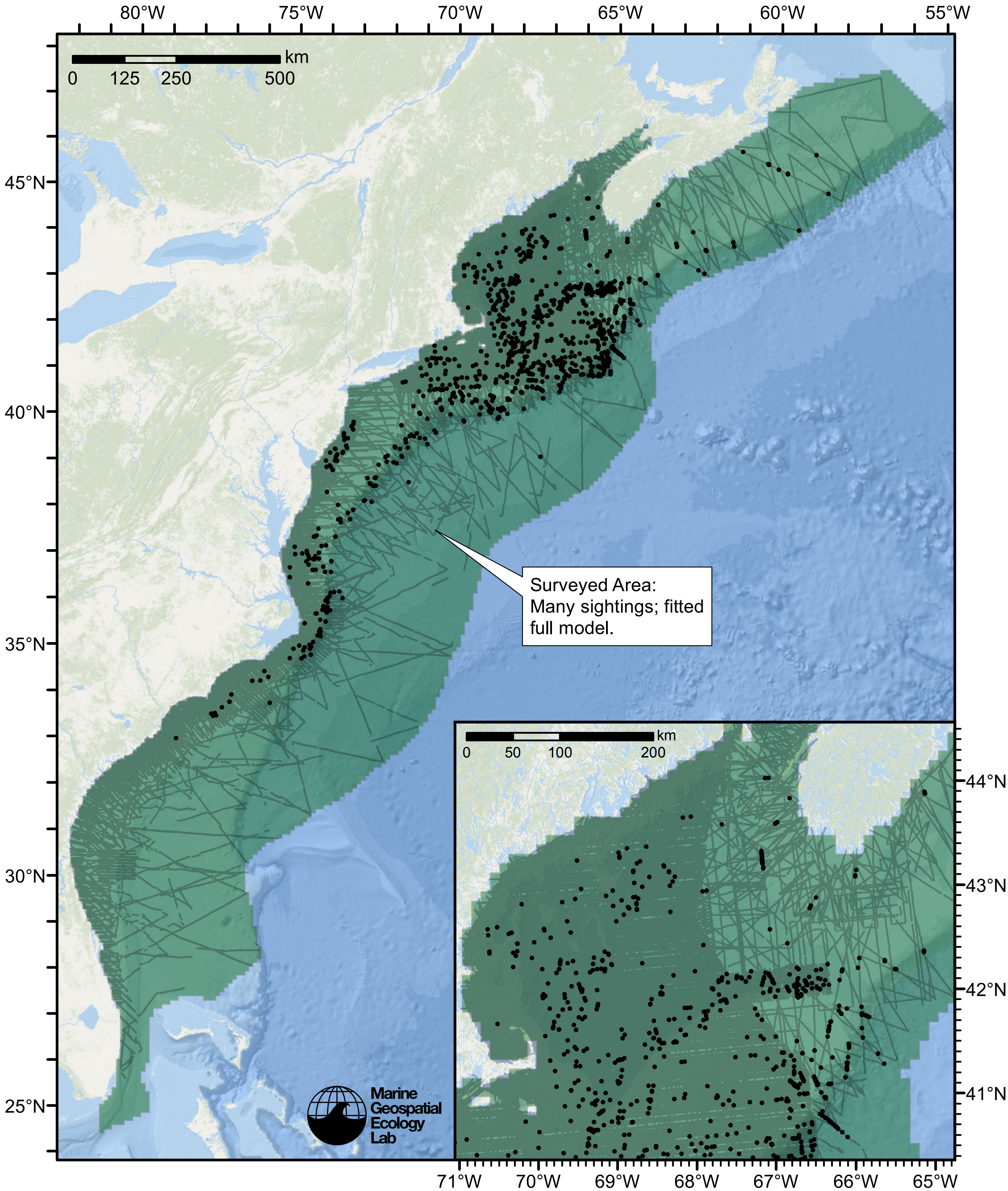


Figure 97: Short-beaked common dolphin density model schematic. All on-effort sightings are shown, including those that were truncated when detection functions were fitted.

Climatological Model

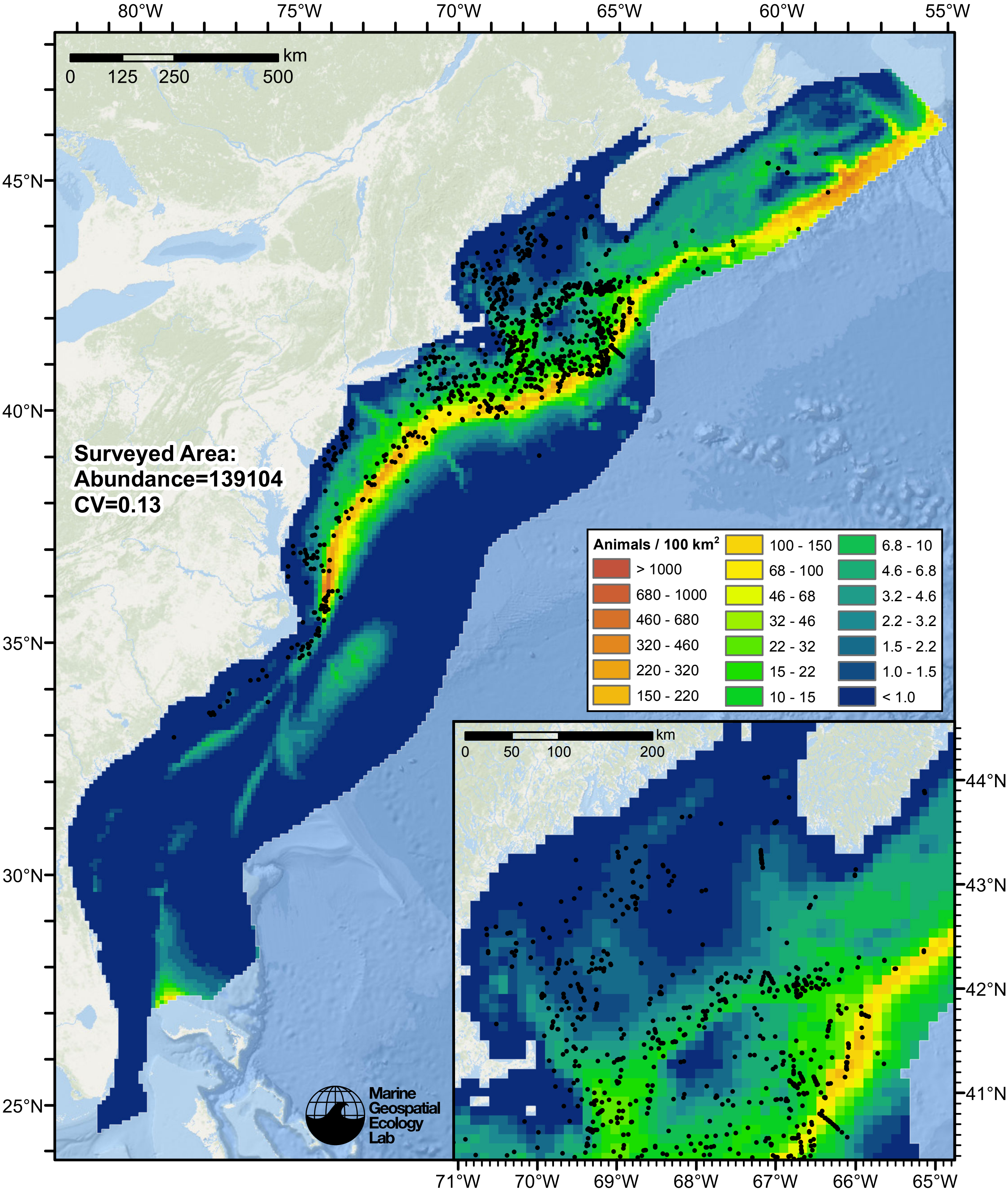


Figure 98: Short-beaked common dolphin density predicted by the climatological model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

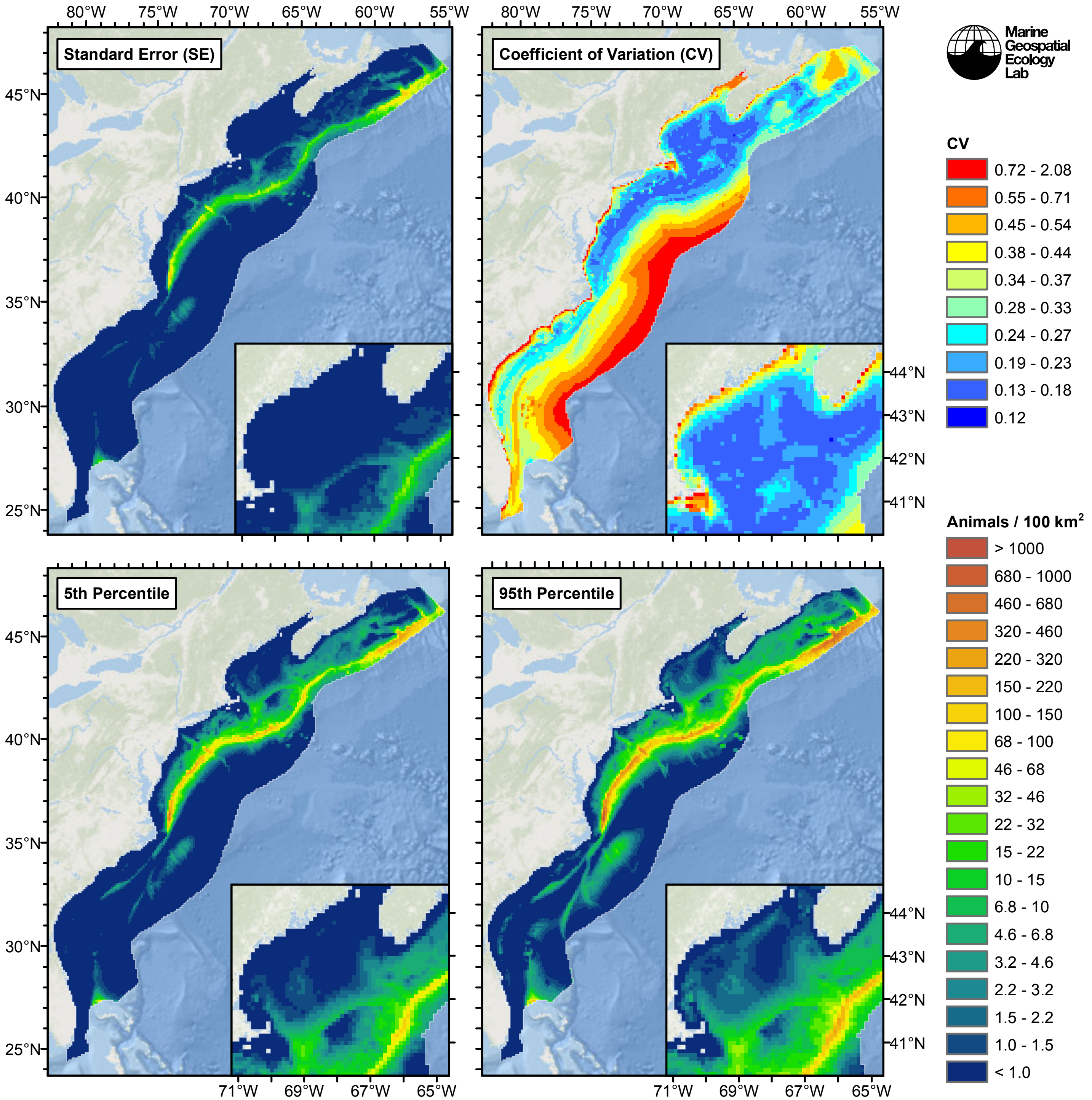


Figure 99: Estimated uncertainty for the climatological model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

Surveyed Area

Statistical output

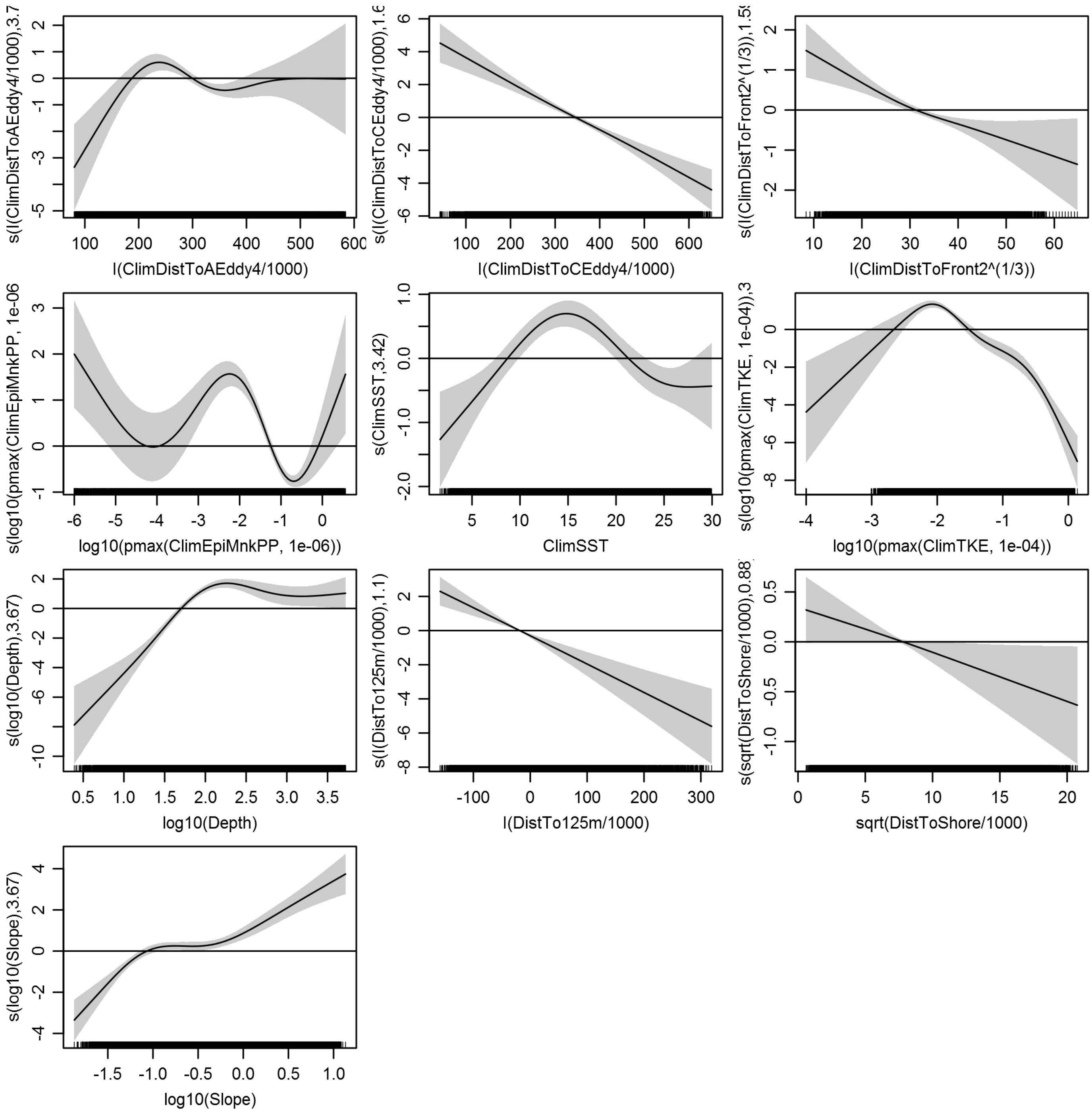
```
Rscript.exe: This is mgcv 1.8-3. For overview type 'help("mgcv-package")'.


Family: Tweedie(p=1.454)
```

```
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(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(I(ClimDistToAEddy4/1000), bs = "ts", k = 5) +
    s(I(ClimDistToCEddy4/1000), bs = "ts", k = 5) + s(log10(pmax(ClimEpiMnkPP,
    1e-06)), bs = "ts", k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) -5.06632    0.08069  -62.79   <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))                  3.673      4 39.754  < 2e-16 ***
s(sqrt(DistToShore/1000))        0.882      4  1.201    0.015 *
s(log10(Slope))                  3.669      4 29.440  < 2e-16 ***
s(I(DistTo125m/1000))            1.099      4  8.207 2.27e-09 ***
s(ClimSST)                       3.422      4 12.791 6.96e-12 ***
s(I(ClimDistToFront2^(1/3)))     1.589      4  7.609 1.12e-08 ***
s(log10(pmax(ClimTKE, 1e-04)))   3.769      4 69.733  < 2e-16 ***
s(I(ClimDistToAEddy4/1000))      3.711      4  8.674 5.03e-08 ***
s(I(ClimDistToCEddy4/1000))      1.676      4 22.581  < 2e-16 ***
s(log10(pmax(ClimEpiMnkPP, 1e-06))) 3.911      4 39.661  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.00017   Deviance explained = 47.3%
-REML = 8164.8  Scale est. = 193.69    n = 104236

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 15 iterations.
Gradient range [-1.623369e-05,9.717921e-06]
(score 8164.76 & scale 193.6904).
Hessian positive definite, eigenvalue range [0.04377653,1783.525].
Model rank =  41 / 41

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 3.673   0.573    0.00
s(sqrt(DistToShore/1000))        4.000 0.882   0.620    0.24
s(log10(Slope))                  4.000 3.669   0.594    0.00
s(I(DistTo125m/1000))            4.000 1.099   0.611    0.06
s(ClimSST)                       4.000 3.422   0.622    0.36
s(I(ClimDistToFront2^(1/3)))     4.000 1.589   0.618    0.22
s(log10(pmax(ClimTKE, 1e-04)))   4.000 3.769   0.598    0.00
```

```
s(I(ClimDistToAEddy4/1000))         4.000 3.711   0.607    0.06
s(I(ClimDistToCEddy4/1000))         4.000 1.676   0.619    0.24
s(log10(pmax(ClimEpiMnkPP, 1e-06))) 4.000 3.911   0.616    0.14
```

```
Predictors retained during the model selection procedure: Depth, DistToShore, Slope, DistTo125m,
ClimSST, ClimDistToFront2, ClimTKE, ClimDistToAEddy4, ClimDistToCEddy4, ClimEpiMnkPP

Predictors dropped during the model selection procedure:
```

Model term plots



Diagnostic plots

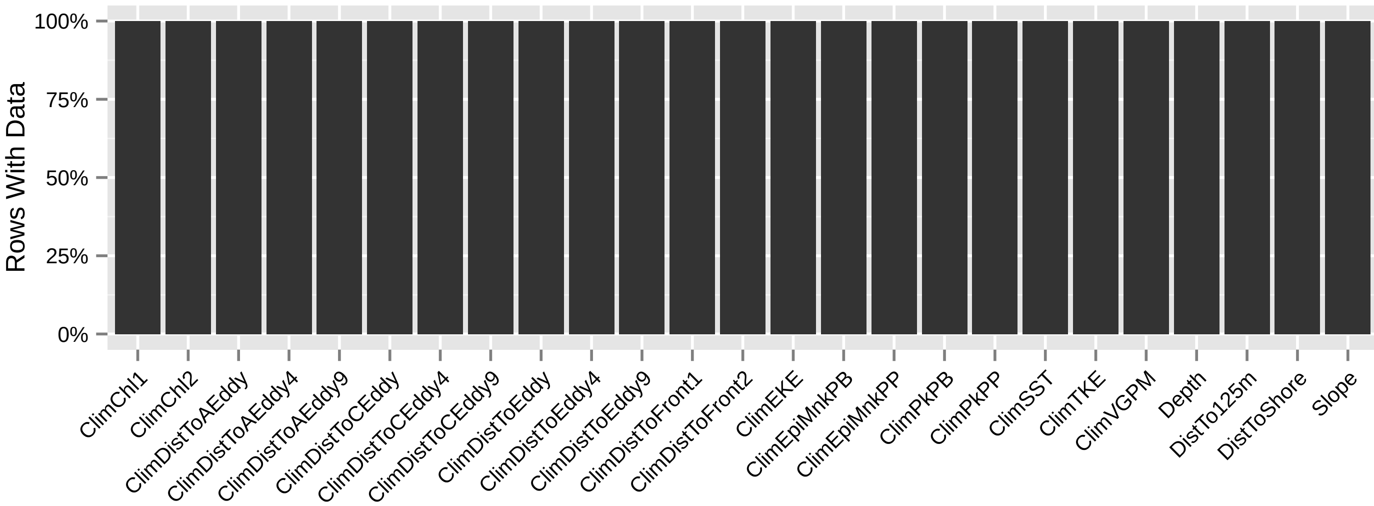


Figure 100: Segments with predictor values for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to assess how many segments would be lost by including a given predictor in a model.

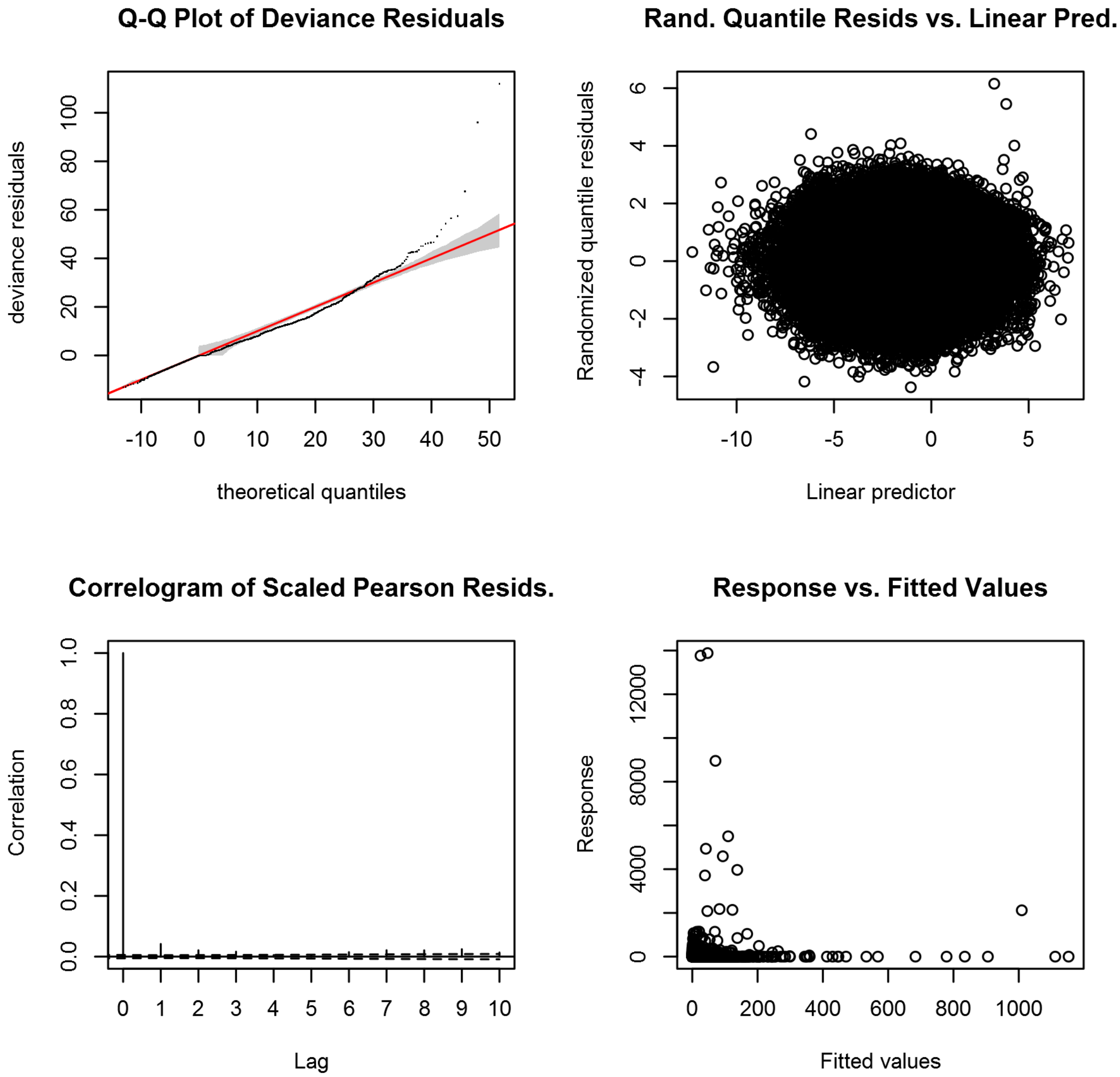


Figure 101: Statistical diagnostic plots for the Short-beaked common dolphin Climatological model, Surveyed Area.

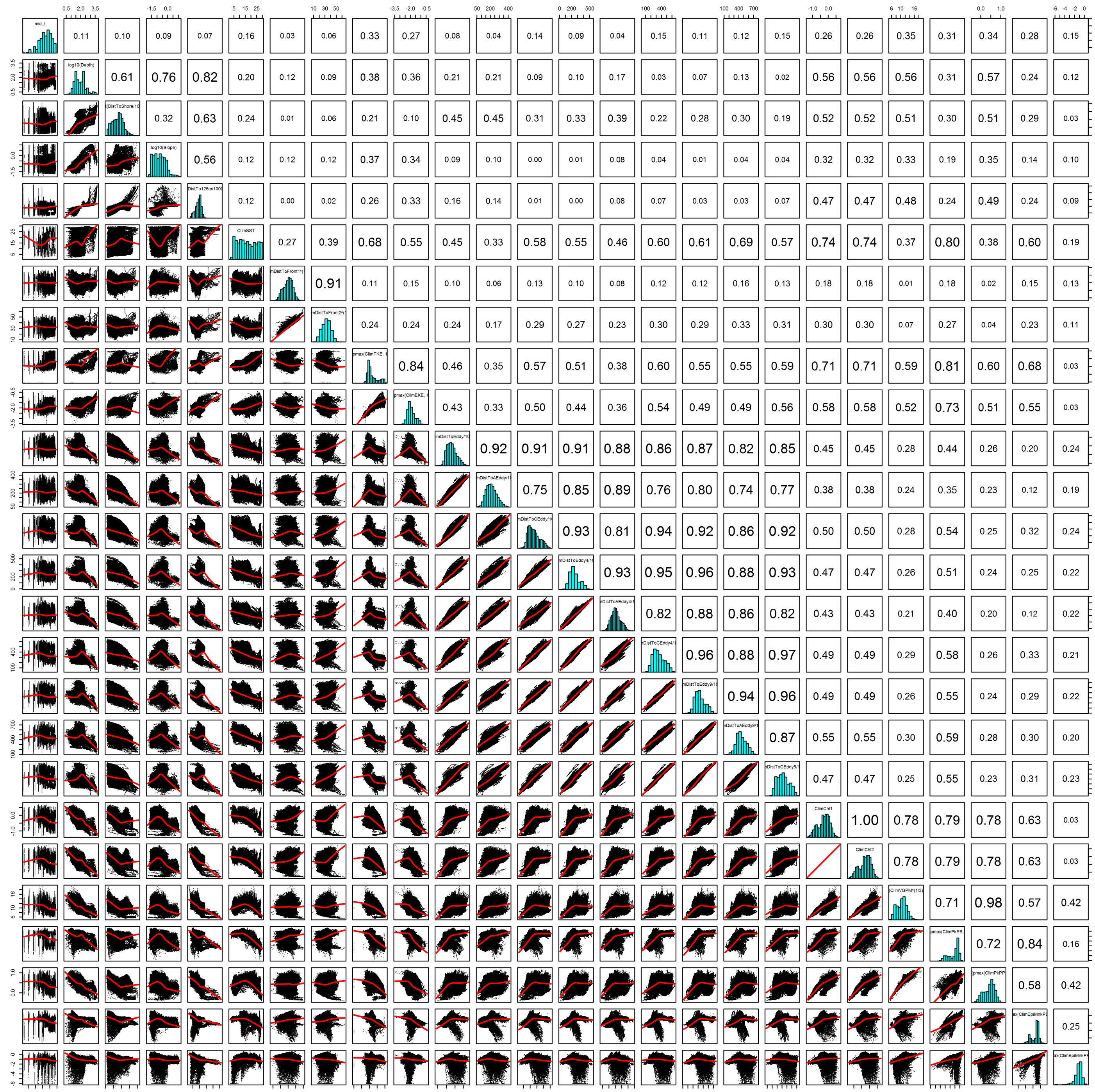


Figure 102: Scatterplot matrix for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

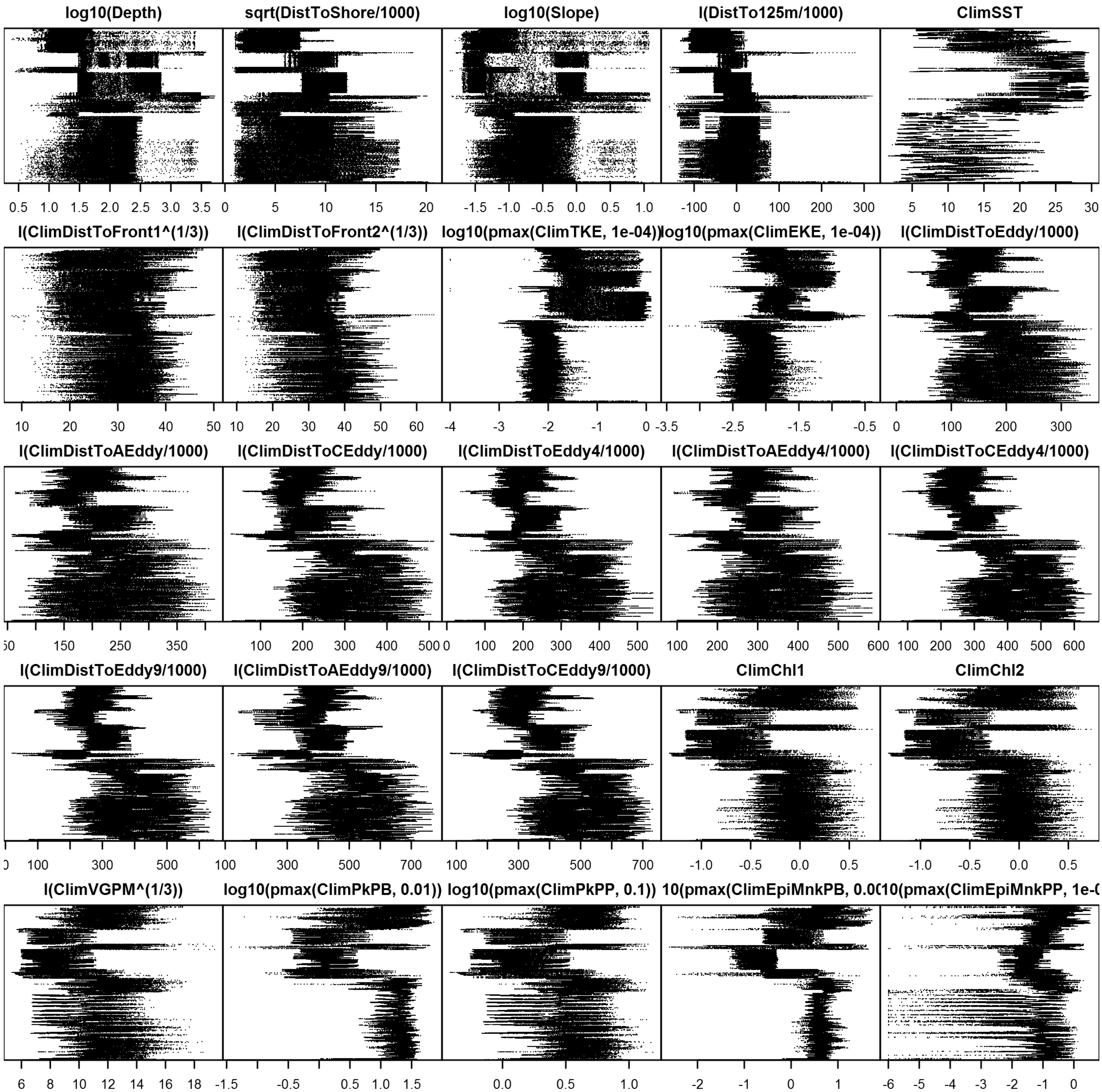


Figure 103: Dotplot for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

Contemporaneous Model

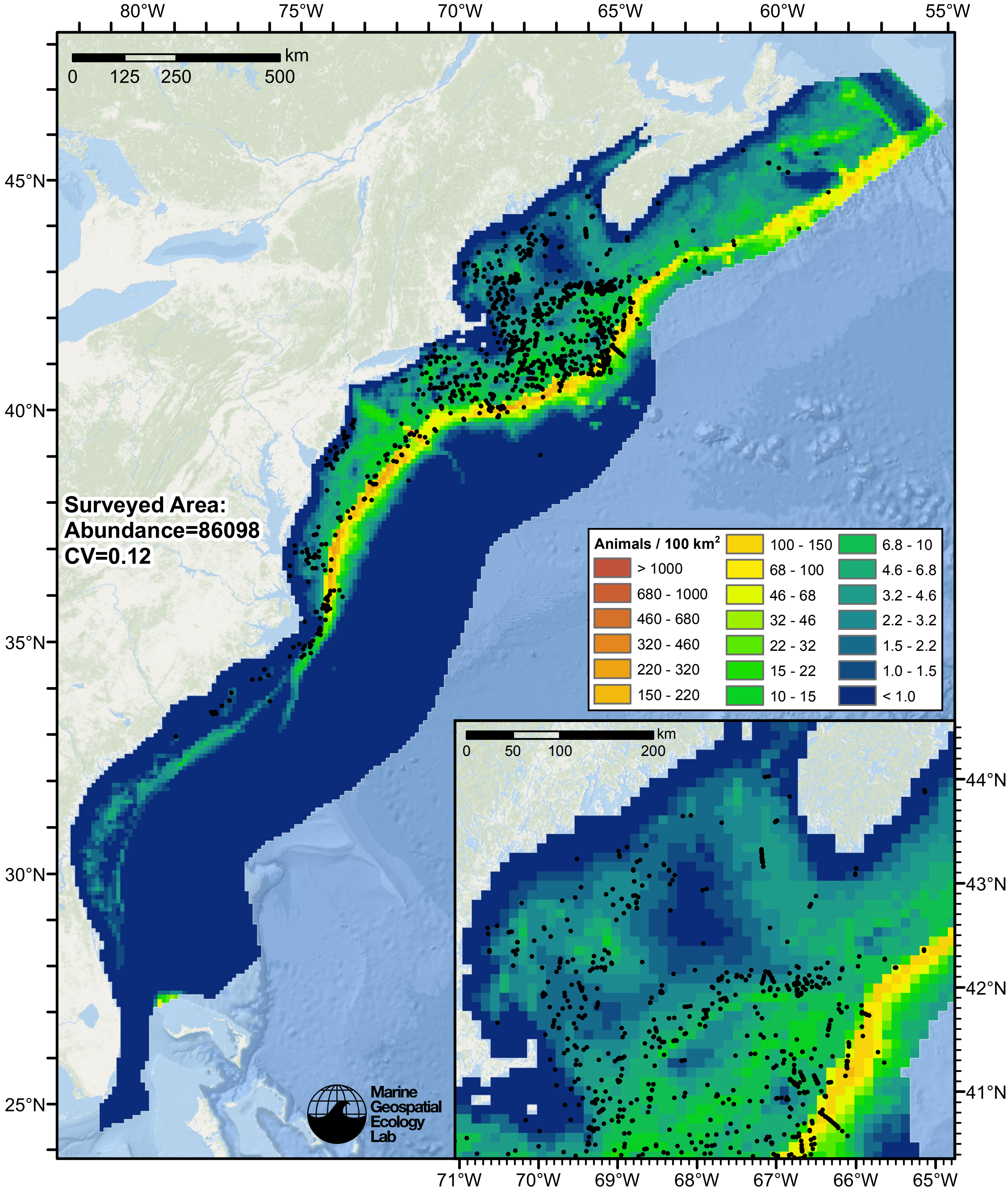


Figure 104: Short-beaked common dolphin density predicted by the contemporaneous model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

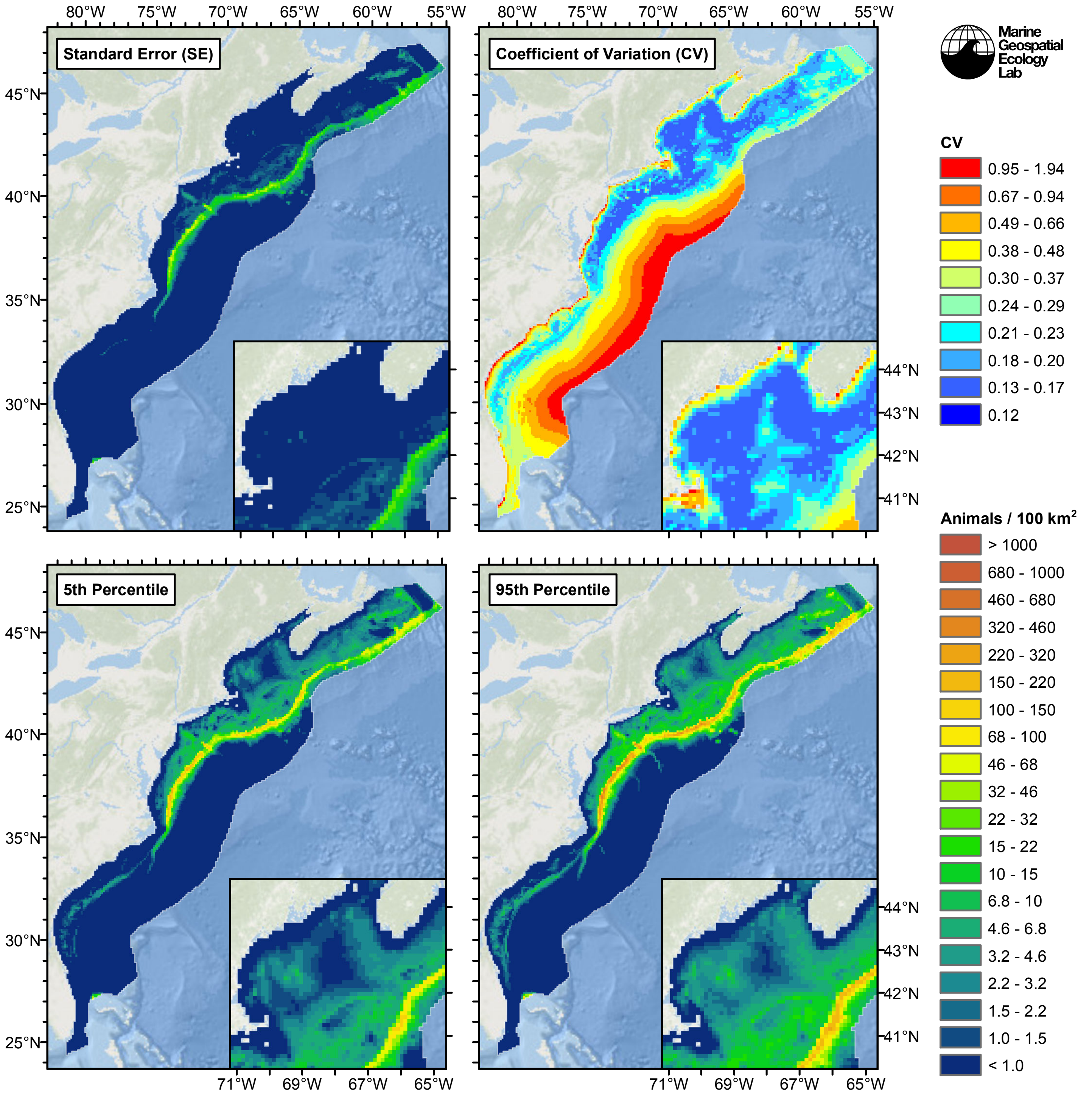


Figure 105: Estimated uncertainty for the contemporaneous model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

Surveyed Area

Statistical output

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


Family: Tweedie(p=1.456)
```

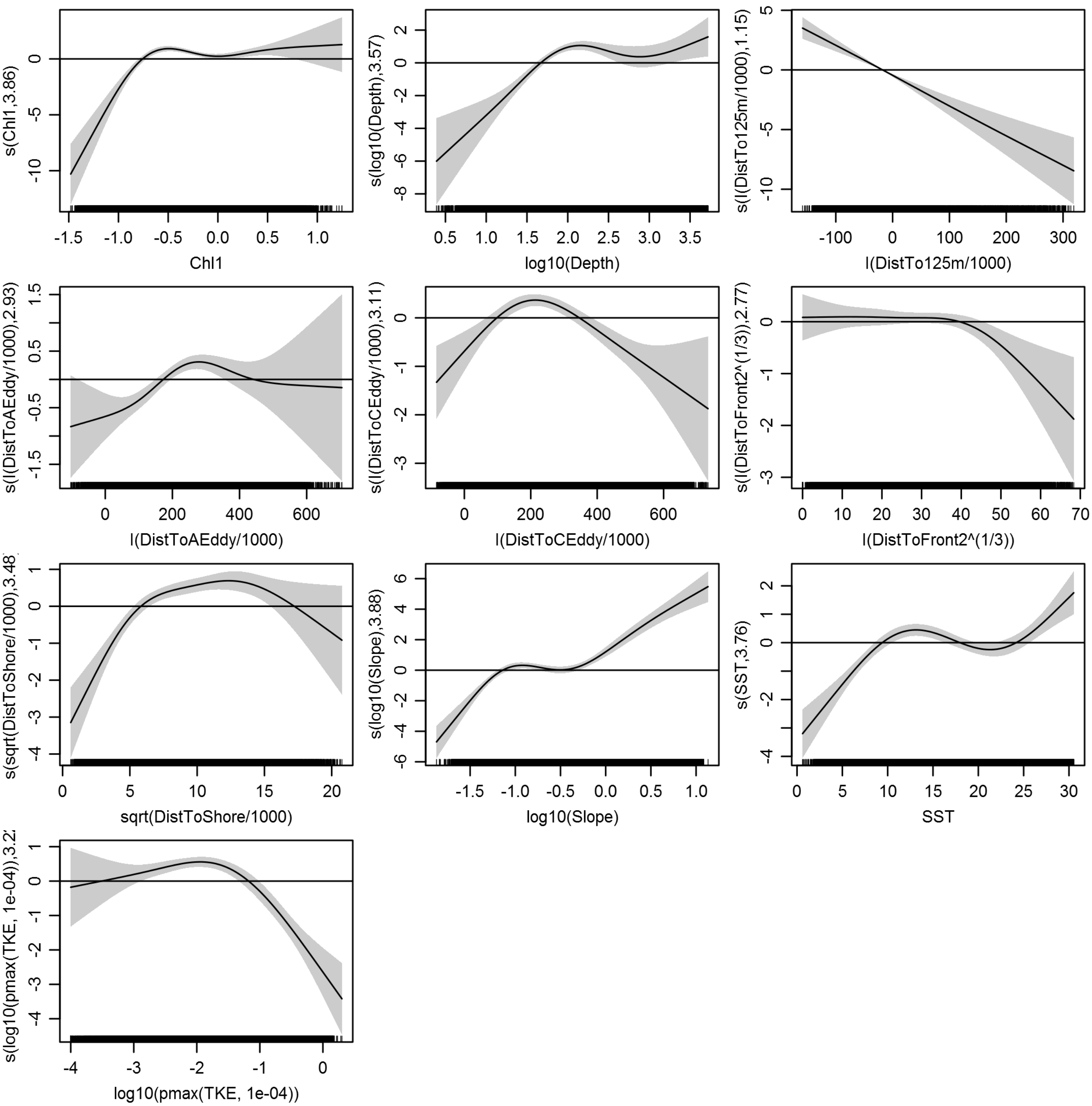
```
Link function: log

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(SST, bs = "ts", k = 5) + s(I(DistToFront2^(1/3)), bs = "ts",
    k = 5) + s(log10(pmax(TKE, 1e-04)), bs = "ts", k = 5) + s(I(DistToAEddy/1000),
    bs = "ts", k = 5) + s(I(DistToCEddy/1000), bs = "ts", k = 5) +
    s(Chl1, bs = "ts", k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -4.9883     0.0896  -55.68   <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))            3.571      4 19.152  < 2e-16 ***
s(sqrt(DistToShore/1000))  3.482      4 14.696 1.39e-13 ***
s(log10(Slope))            3.877      4 55.057  < 2e-16 ***
s(I(DistTo125m/1000))      1.155      4 16.818  < 2e-16 ***
s(SST)                     3.757      4 25.710  < 2e-16 ***
s(I(DistToFront2^(1/3)))   2.768      4  2.822  0.00496 **
s(log10(pmax(TKE, 1e-04))) 3.219      4 19.523  < 2e-16 ***
s(I(DistToAEddy/1000))     2.927      4  7.223 3.90e-07 ***
s(I(DistToCEddy/1000))     3.110      4 10.740 2.86e-10 ***
s(Chl1)                    3.863      4 18.815 4.23e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.00565   Deviance explained = 44.9%
-REML = 7888.7  Scale est. = 206.31    n = 99604

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 13 iterations.
Gradient range [-3.84193e-06,2.147191e-06]
(score 7888.671 & scale 206.3142).
Hessian positive definite, eigenvalue range [0.1333892,1709.492].
Model rank =  41 / 41

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 3.571   0.688    0.04
s(sqrt(DistToShore/1000))  4.000 3.482   0.688    0.03
s(log10(Slope))            4.000 3.877   0.666    0.02
s(I(DistTo125m/1000))      4.000 1.155   0.708    0.18
s(SST)                     4.000 3.757   0.705    0.10
s(I(DistToFront2^(1/3)))   4.000 2.768   0.718    0.62
s(log10(pmax(TKE, 1e-04))) 4.000 3.219   0.702    0.11
s(I(DistToAEddy/1000))     4.000 2.927   0.725    0.94
```

s(I(DistToCEddy/1000))	4.000	3.110	0.720	0.76
s(Chl1)	4.000	3.863	0.692	0.00

Predictors retained during the model selection procedure: Depth, DistToShore, Slope, DistTo125m, SST, DistToFront2, TKE, DistToAEddy, DistToCEddy, Chl1

Predictors dropped during the model selection procedure:

Model term plots



Diagnostic plots

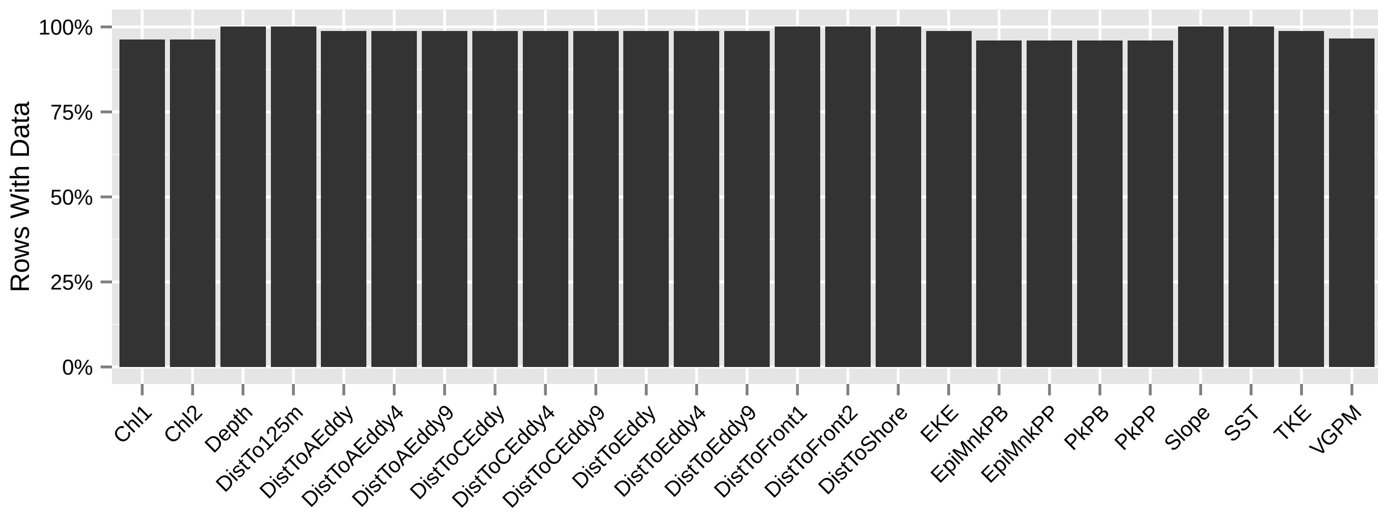


Figure 106: Segments with predictor values for the Short-beaked common dolphin Contemporaneous model, Surveyed Area. This plot is used to assess how many segments would be lost by including a given predictor in a model.

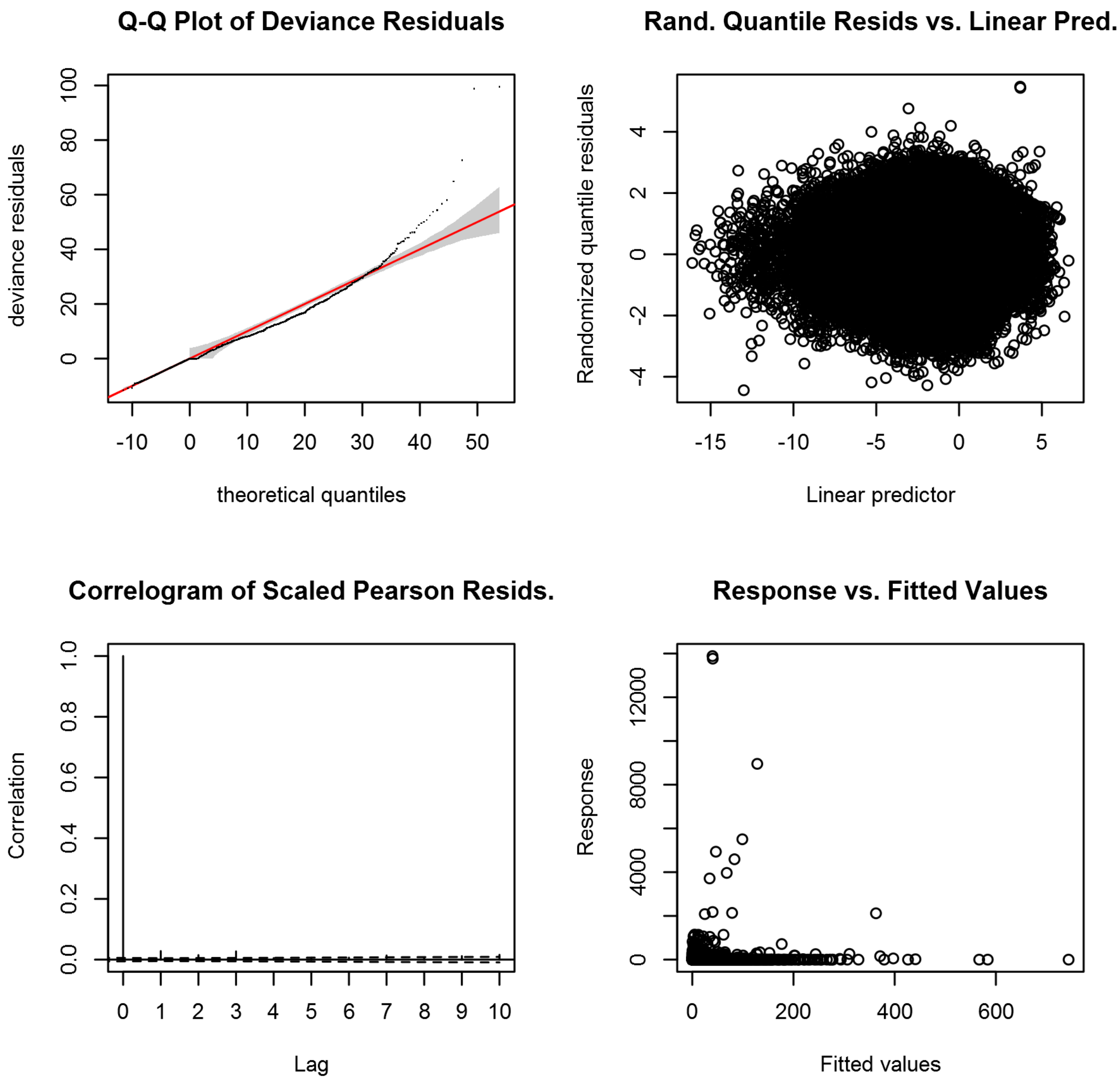


Figure 107: Statistical diagnostic plots for the Short-beaked common dolphin Contemporaneous model, Surveyed Area.

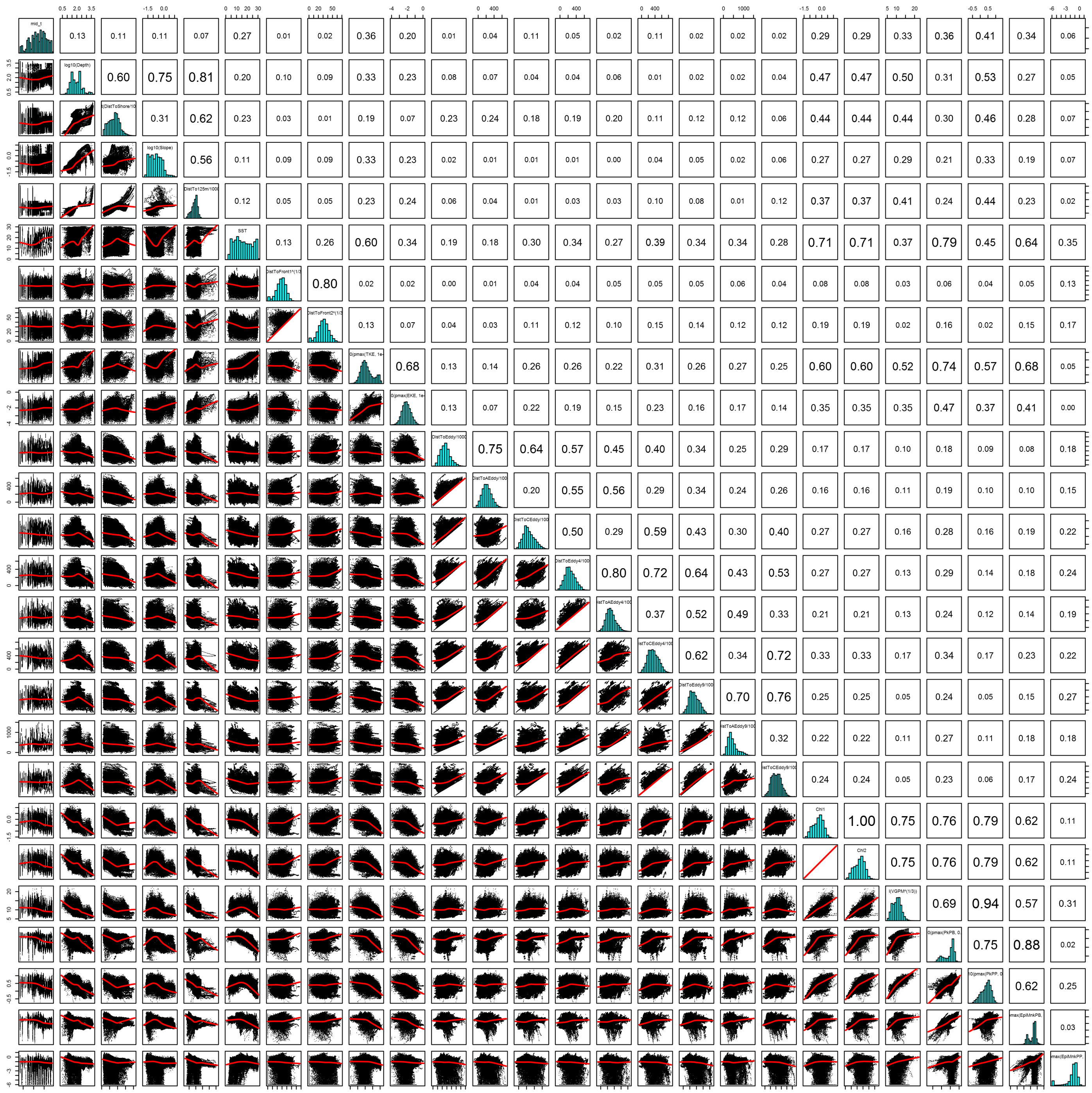


Figure 108: Scatterplot matrix for the Short-beaked common dolphin Contemporaneous model, Surveyed Area. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

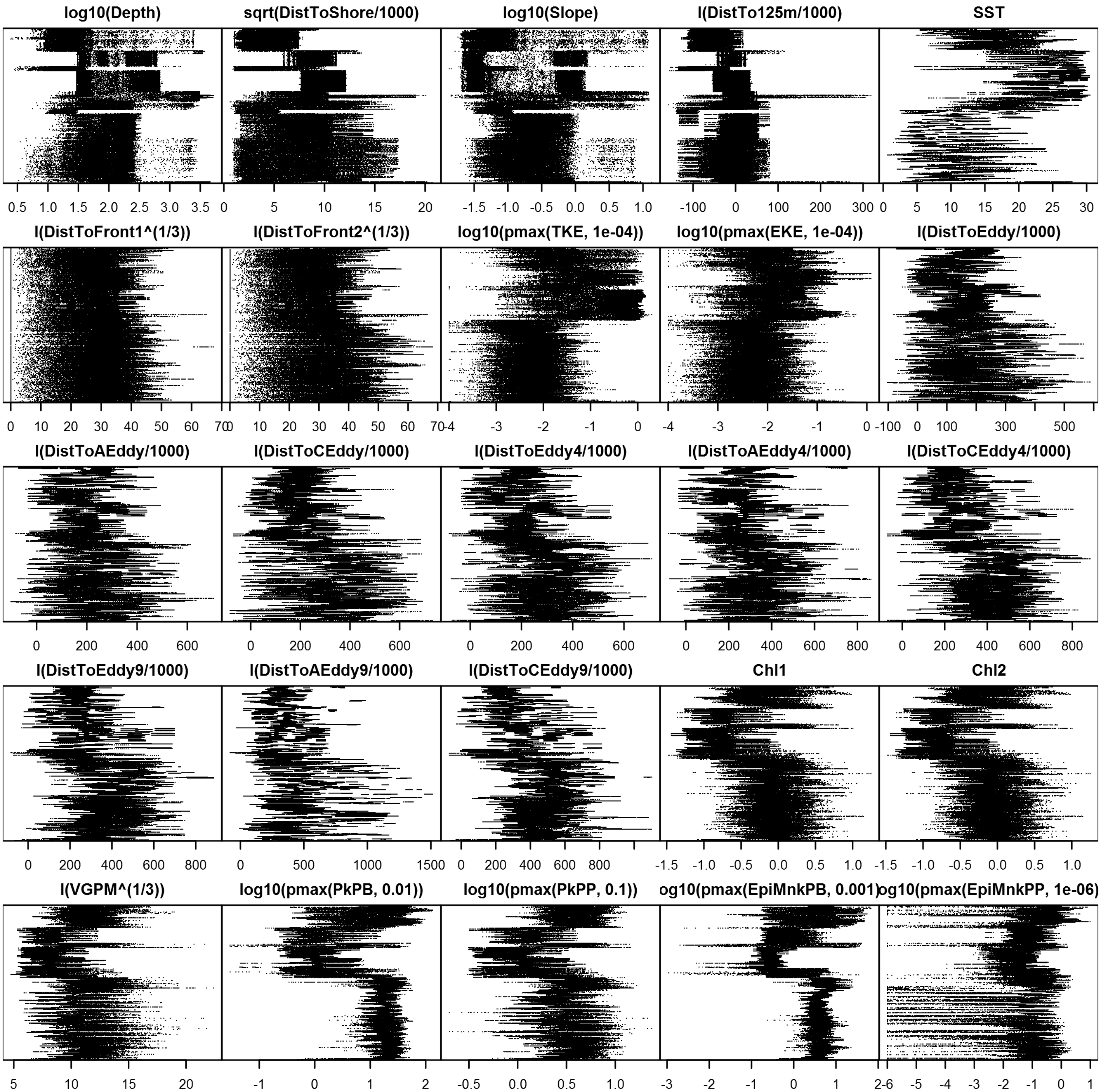


Figure 109: Dotplot for the Short-beaked common dolphin Contemporaneous model, Surveyed Area. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

Climatological Same Segments Model

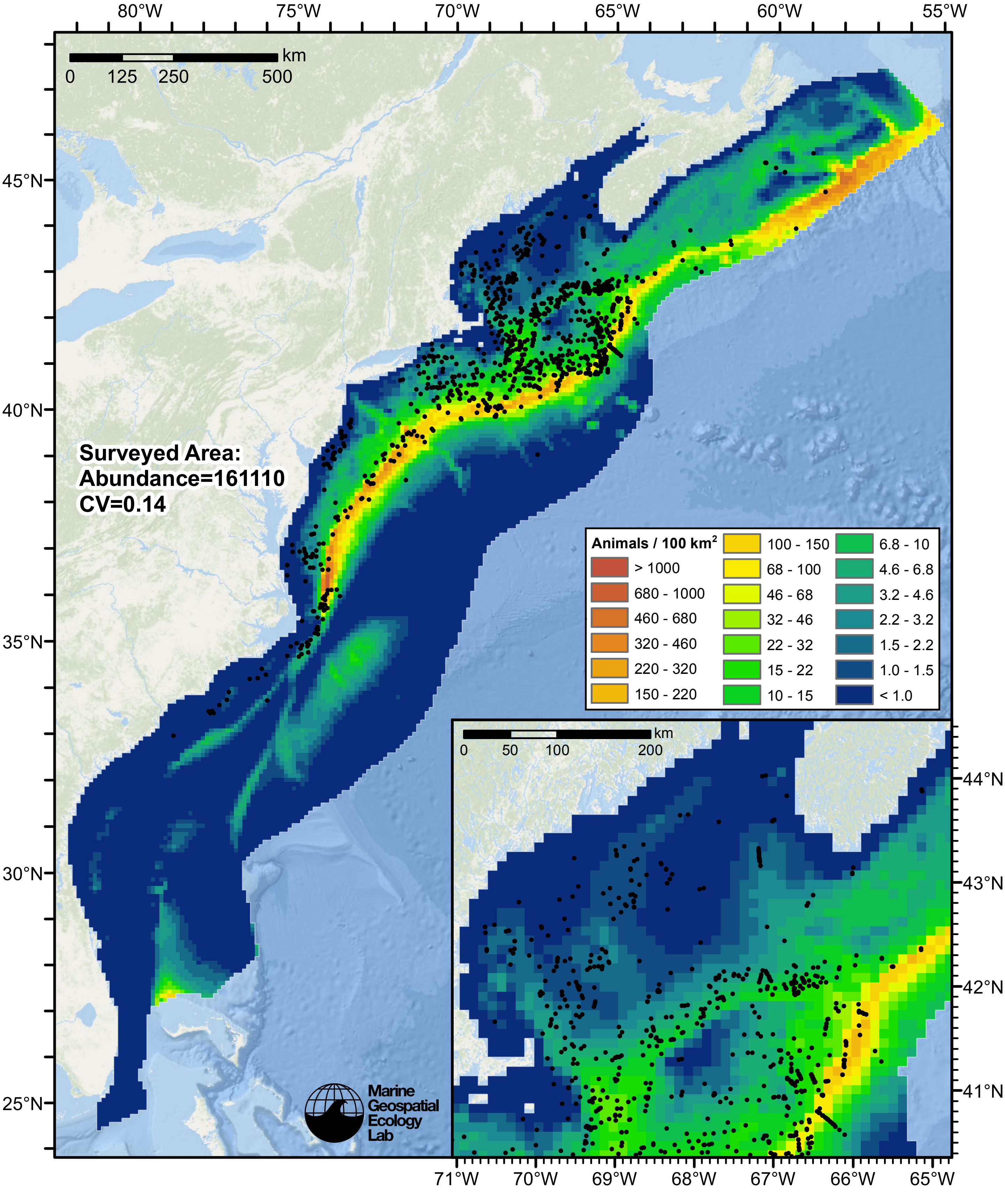


Figure 110: Short-beaked common dolphin density predicted by the climatological same segments model that explained the most deviance. Pixels are 10x10 km. The legend gives the estimated individuals per pixel; breaks are logarithmic. Abundance for each region was computed by summing the density cells occuring in that region.

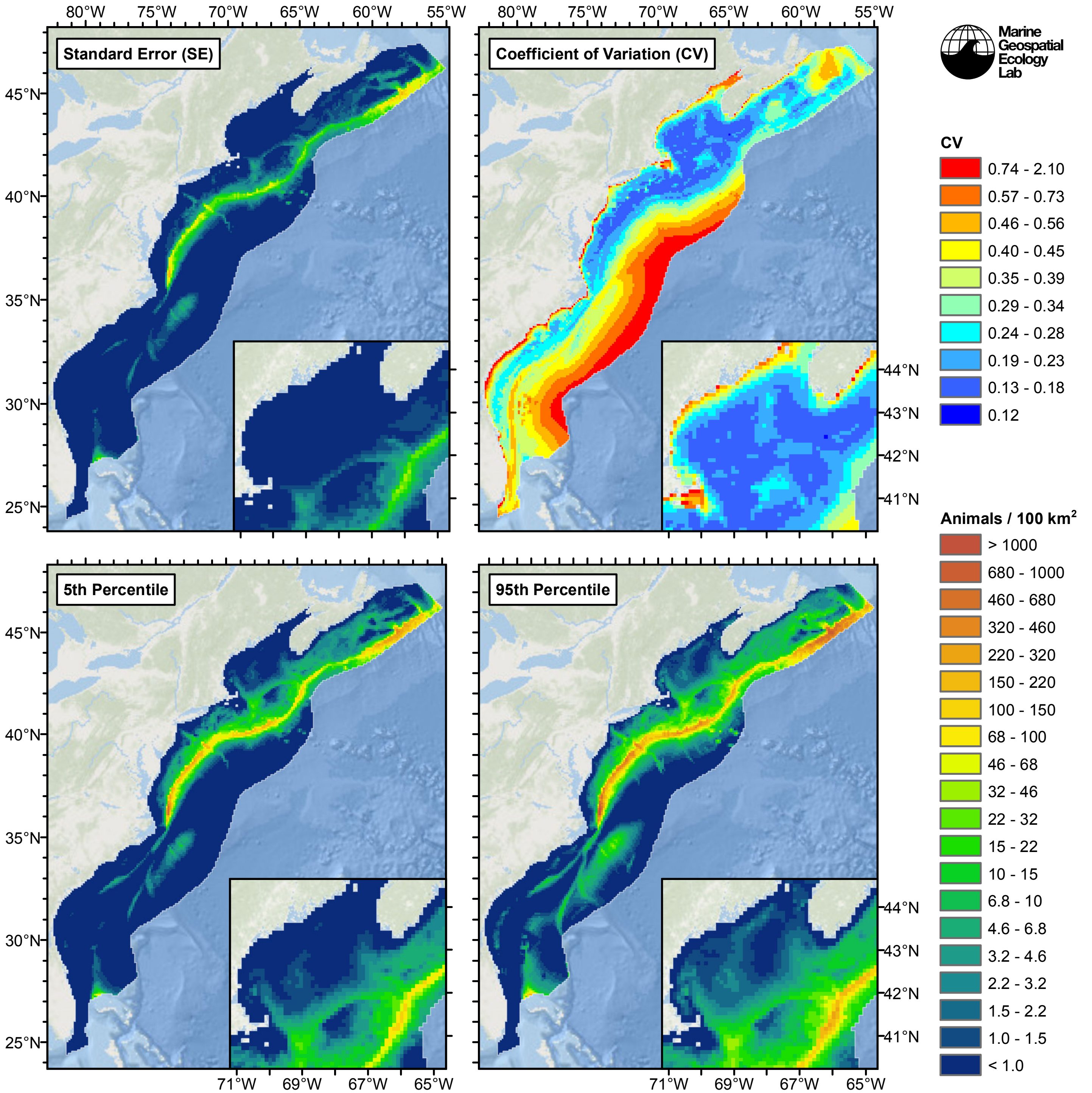


Figure 111: Estimated uncertainty for the climatological same segments model that explained the most deviance. These estimates only incorporate the statistical uncertainty estimated for the spatial model (by the R mgcv package). They do not incorporate uncertainty in the detection functions, g(0) estimates, predictor variables, and so on.

Surveyed Area

Statistical output

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


Family: Tweedie(p=1.449)
```

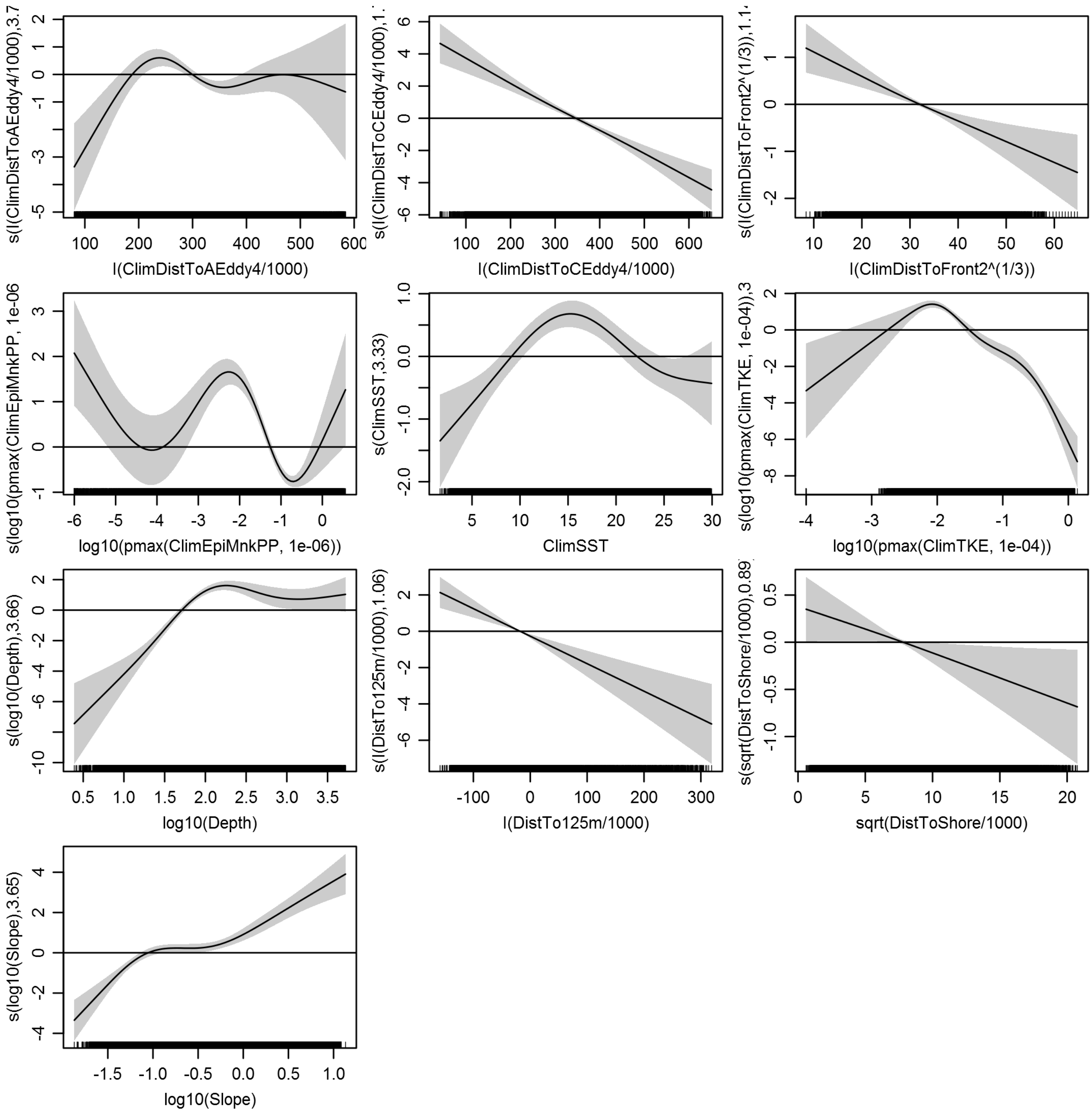
```
Link function: log

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(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(I(ClimDistToAEddy4/1000), bs = "ts", k = 5) +
    s(I(ClimDistToCEddy4/1000), bs = "ts", k = 5) + s(log10(pmax(ClimEpiMnkPP,
    1e-06)), bs = "ts", k = 5)

Parametric coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -5.0456     0.0824  -61.23   <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))                 3.6618      4 35.676  < 2e-16 ***
s(sqrt(DistToShore/1000))       0.8921      4  1.322   0.0111 *
s(log10(Slope))                 3.6522      4 30.063  < 2e-16 ***
s(I(DistTo125m/1000))           1.0580      4  6.597 7.98e-08 ***
s(ClimSST)                      3.3275      4 11.711 5.03e-11 ***
s(I(ClimDistToFront2^(1/3)))    1.1424      4  6.267 2.42e-07 ***
s(log10(pmax(ClimTKE, 1e-04)))  3.7531      4 71.727  < 2e-16 ***
s(I(ClimDistToAEddy4/1000))     3.7054      4  8.791 4.00e-08 ***
s(I(ClimDistToCEddy4/1000))     1.6979      4 21.996  < 2e-16 ***
s(log10(pmax(ClimEpiMnkPP, 1e-06))) 3.9124      4 41.096  < 2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  -0.00584   Deviance explained =   48%
-REML = 7798.4  Scale est. = 194.09    n = 99604

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 18 iterations.
Gradient range [-4.894175e-05,2.808689e-05]
(score 7798.387 & scale 194.0897).
Hessian positive definite, eigenvalue range [0.2635356,1702.938].
Model rank =  41 / 41

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 3.662   0.670    0.02
s(sqrt(DistToShore/1000))       4.000 0.892   0.663    0.00
s(log10(Slope))                 4.000 3.652   0.666    0.04
s(I(DistTo125m/1000))           4.000 1.058   0.677    0.09
s(ClimSST)                      4.000 3.327   0.692    0.46
s(I(ClimDistToFront2^(1/3)))    4.000 1.142   0.667    0.03
s(log10(pmax(ClimTKE, 1e-04)))  4.000 3.753   0.674    0.04
```

```
s(I(ClimDistToAEddy4/1000))          4.000 3.705   0.699    0.86
s(I(ClimDistToCEddy4/1000))          4.000 1.698   0.684    0.12
s(log10(pmax(ClimEpiMnkPP, 1e-06))) 4.000 3.912   0.694    0.58
```

```
Predictors retained during the model selection procedure: Depth, DistToShore, Slope, DistTo125m,
ClimSST, ClimDistToFront2, ClimTKE, ClimDistToAEddy4, ClimDistToCEddy4, ClimEpiMnkPP
```

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

Model term plots



Diagnostic plots

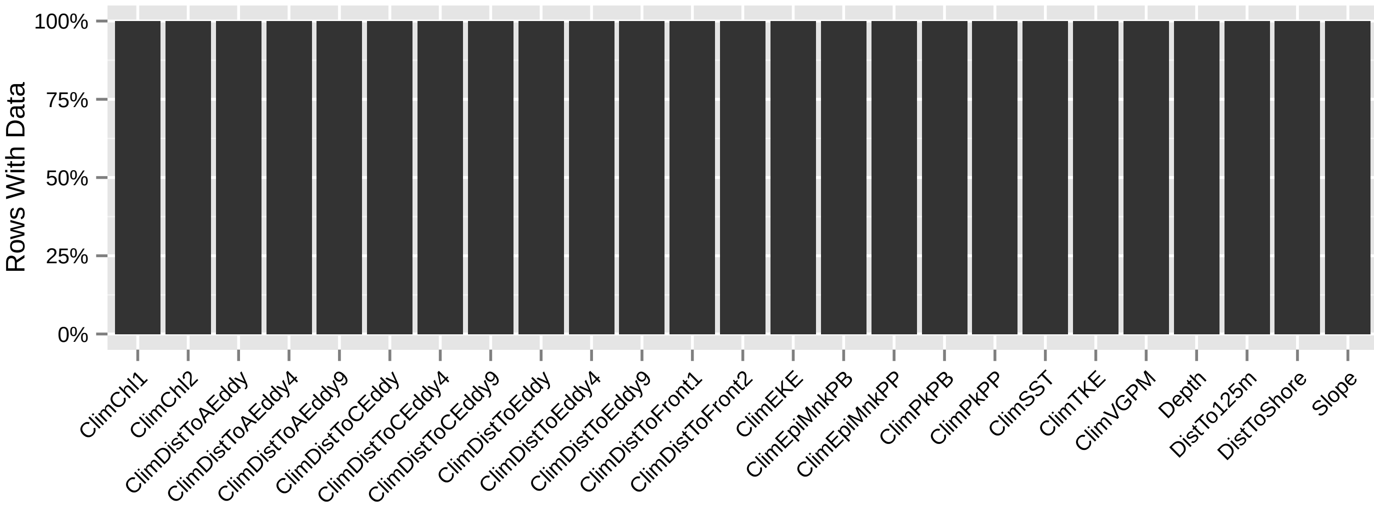


Figure 112: Segments with predictor values for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to assess how many segments would be lost by including a given predictor in a model.

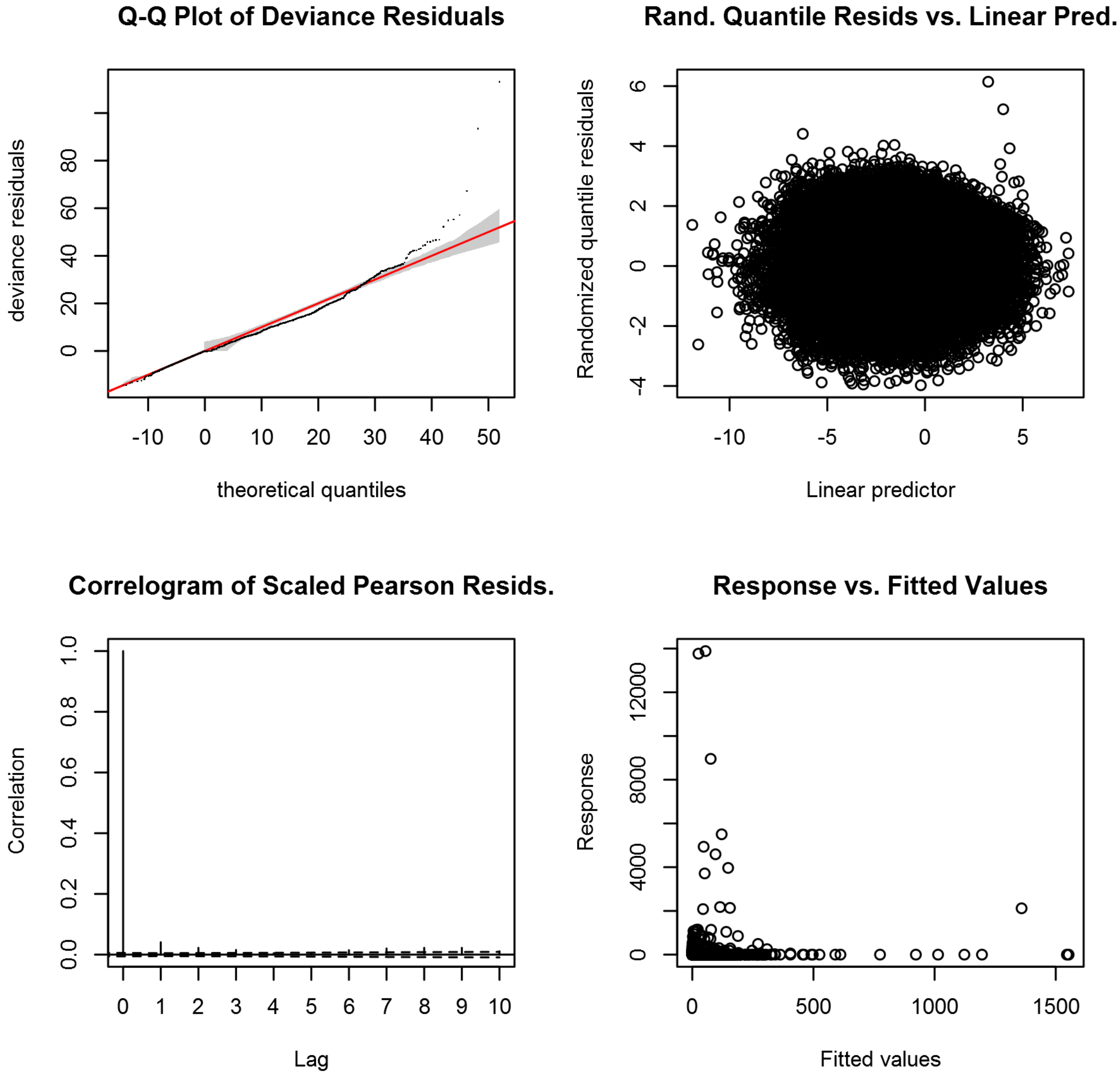


Figure 113: Statistical diagnostic plots for the Short-beaked common dolphin Climatological model, Surveyed Area.

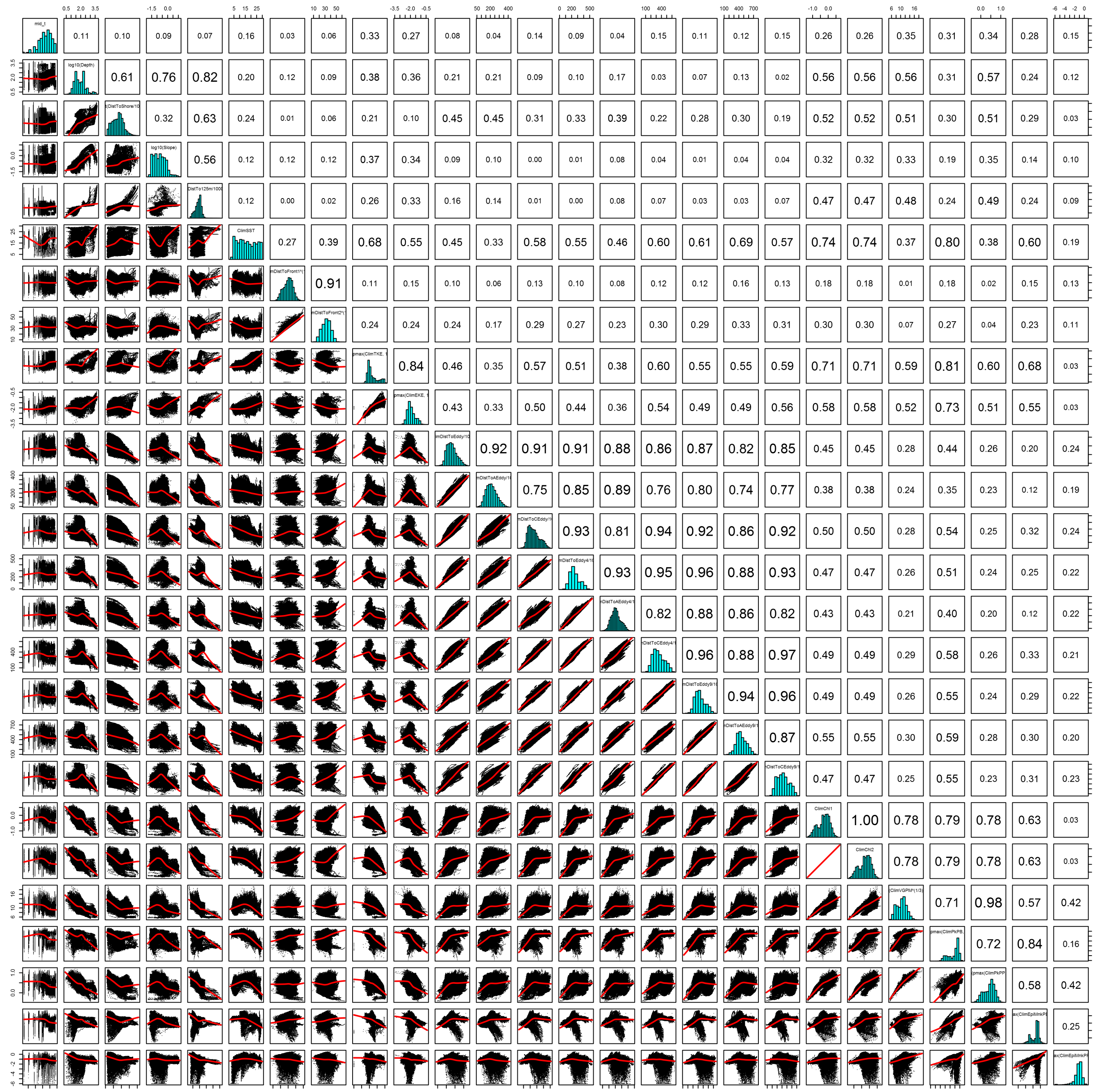


Figure 114: Scatterplot matrix for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to inspect the distribution of predictors (via histograms along the diagonal), simple correlation between predictors (via pairwise Pearson coefficients above the diagonal), and linearity of predictor correlations (via scatterplots below the diagonal). This plot is best viewed at high magnification.

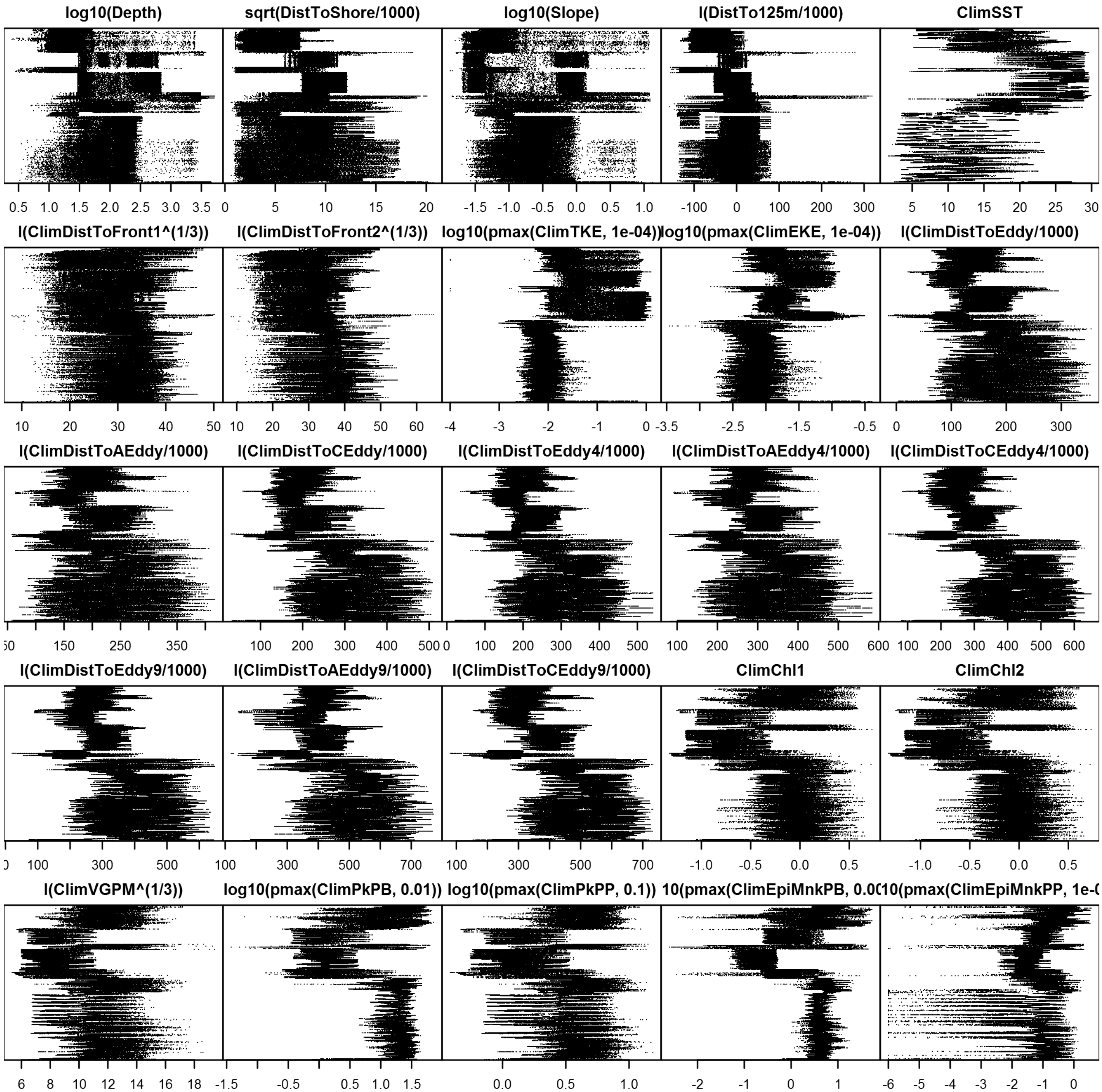


Figure 115: Dotplot for the Short-beaked common dolphin Climatological model, Surveyed Area. This plot is used to check for suspicious patterns and outliers in the data. Points are ordered vertically by transect ID, sequentially in time.

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	34.8			104236		1992-2014
Phys+SST	37.5	38.0	37.5	104236	0.0	1992-2014
Phys+SST+Curr	44.5	42.7	44.4	102911	1.3	1995-2013
Phys+SST+Curr+Prod	47.3	44.9	48.0	99604	4.4	1998-2013

Table 61: 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
1992-2014	Climatological model	139104	0.13	No	
1998-2013	Contemporaneous model*	86098	0.12	No	
1992-2014	Climatological same segments model	161110	0.14	No	

Jun-Aug 2011	Central Virginia to lower Bay of Fundy (Waring et al. 2014)	67191	0.29	No	No
Jun-Aug 2011	Central Florida to central Virginia (Waring et al. 2014)	2993	0.87	No	No
Jun-Aug 2011	Central Florida to lower Bay of Fundy, combined	70184	0.28	No	No
Jul-Aug 2007	Scotian Shelf to Northern Labrador (Lawson and Gosselin 2011)	173486	0.55	No	No
August 2006	Southern Gulf of Maine to Bay of Fundy and Gulf of St. Lawrence (Waring et al. 2014)	84000	0.36	No	Yes

Table 62: 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

Climatological Model

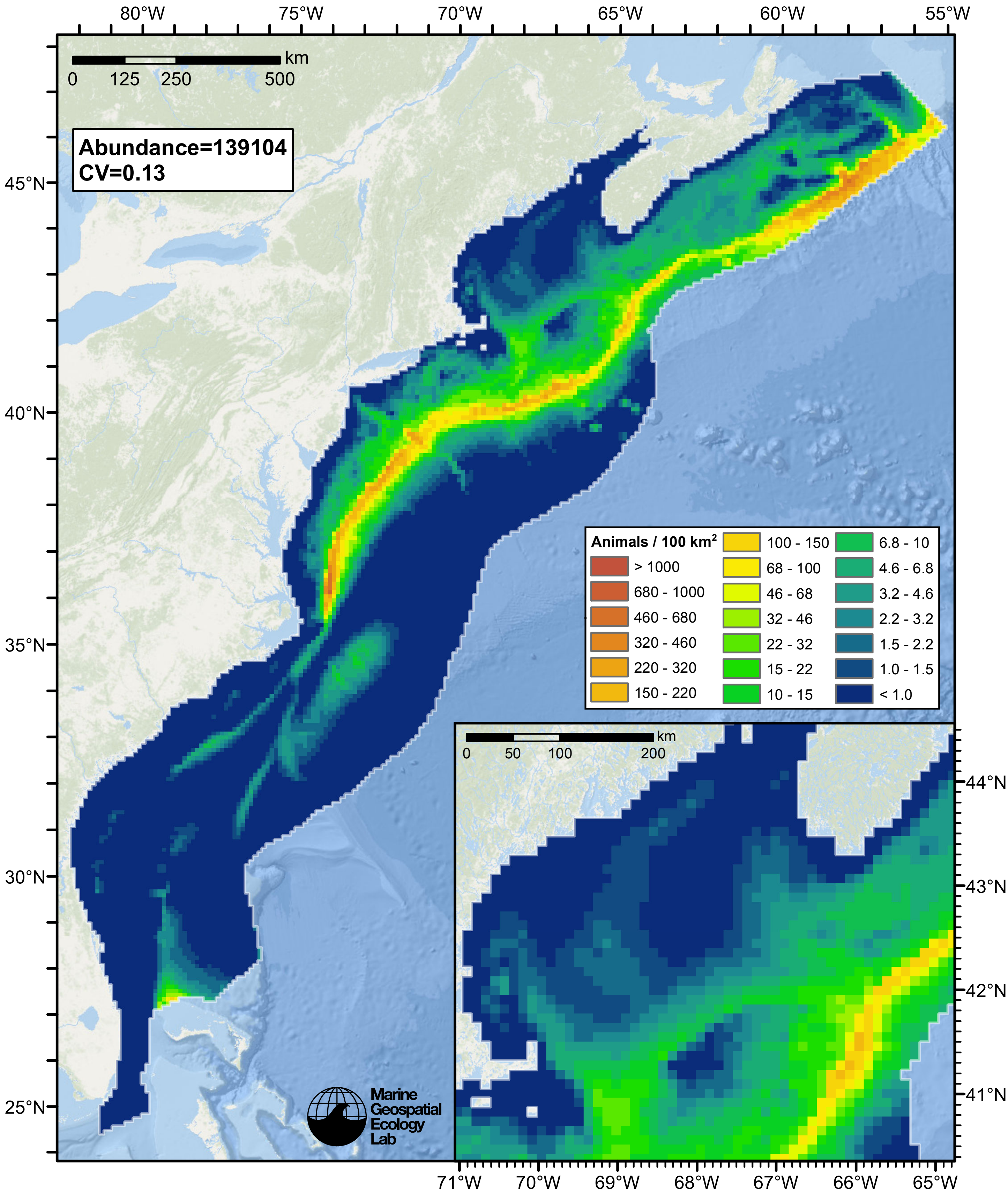


Figure 116: Short-beaked common dolphin density and abundance predicted by the climatological model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

Contemporaneous Model

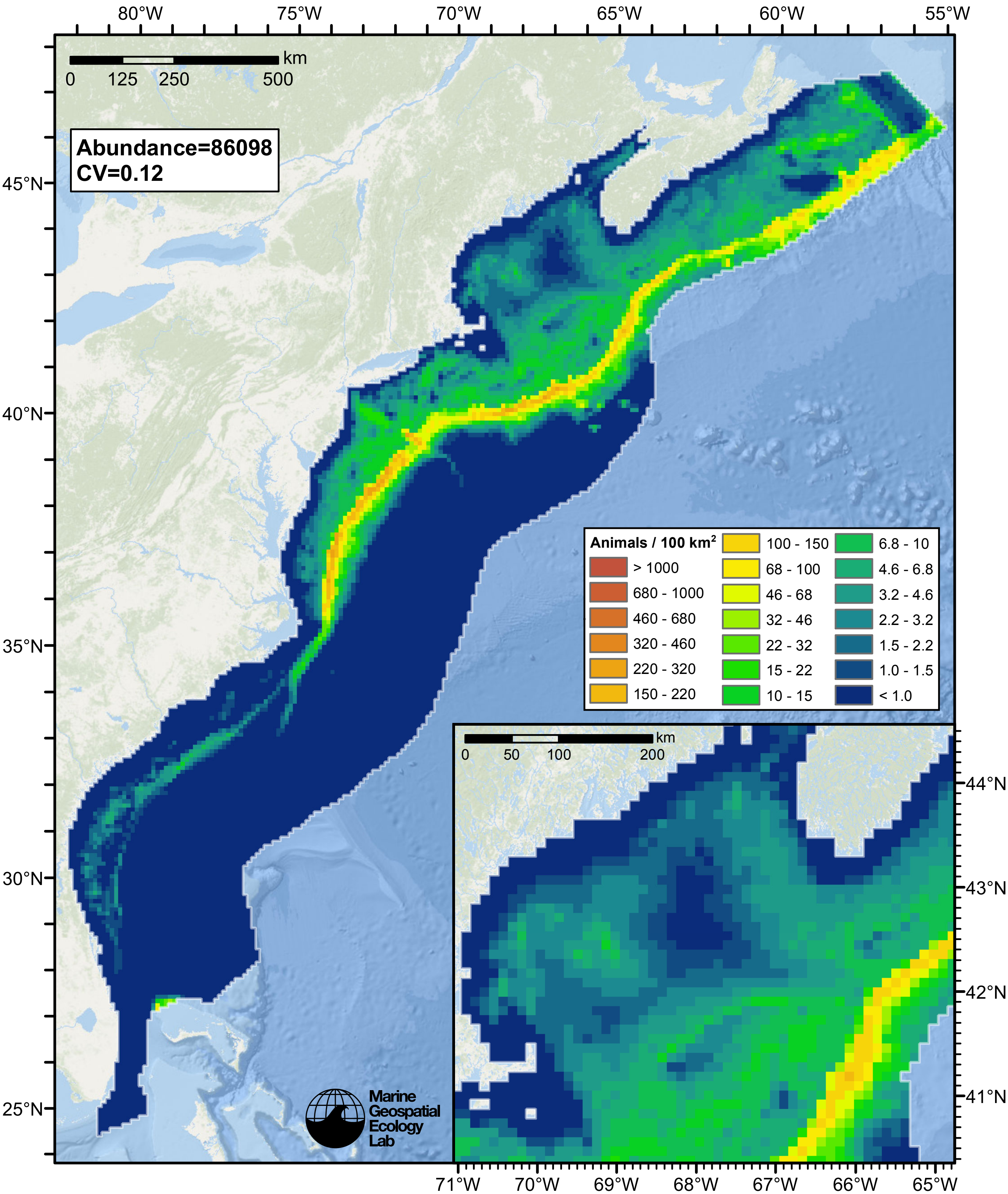


Figure 117: Short-beaked common dolphin density and abundance predicted by the contemporaneous model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

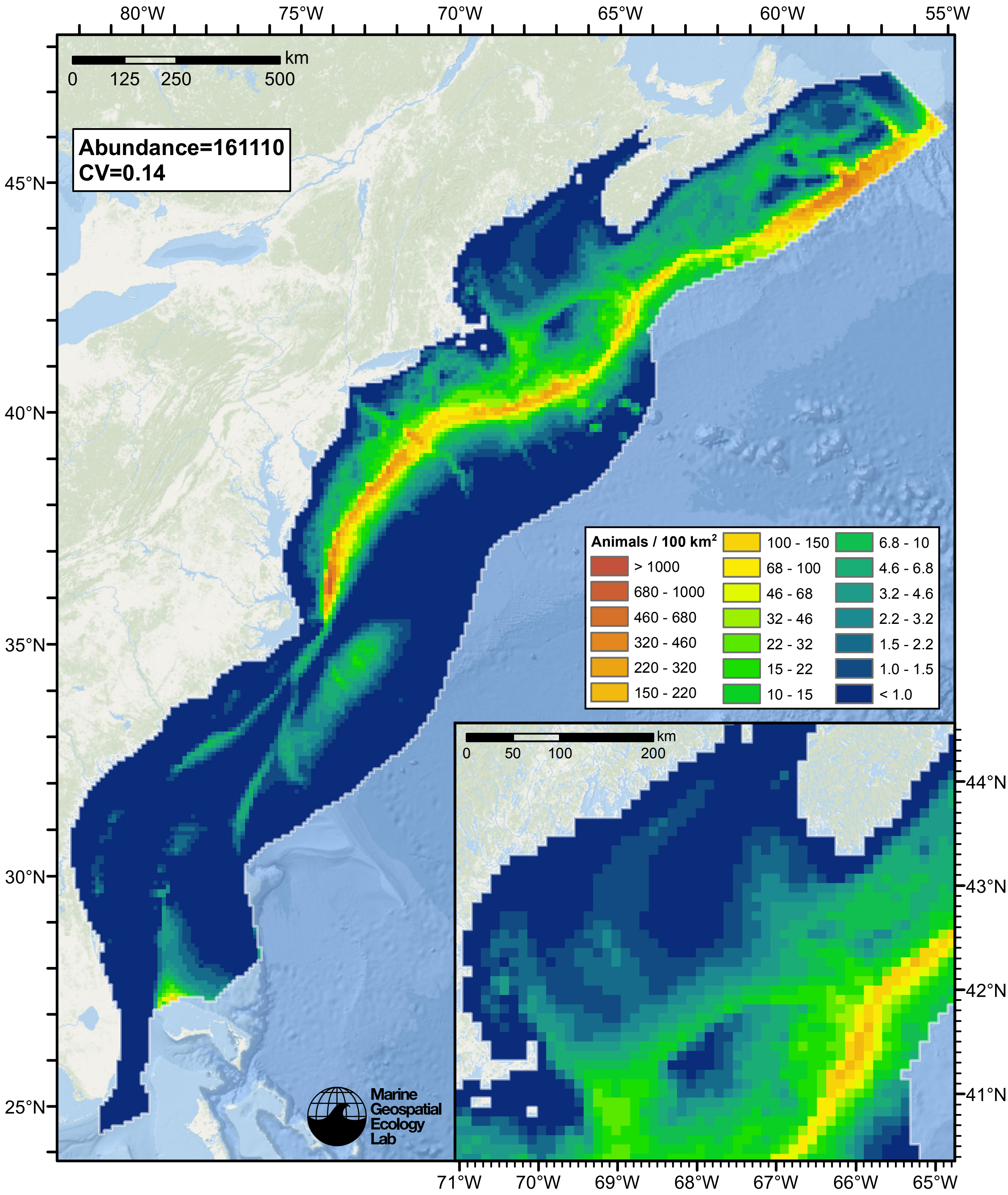


Figure 118: Short-beaked common dolphin density and abundance predicted by the climatological same segments model that explained the most deviance. Regions inside the study area (white line) where the background map is visible are areas we did not model (see text).

Temporal Variability

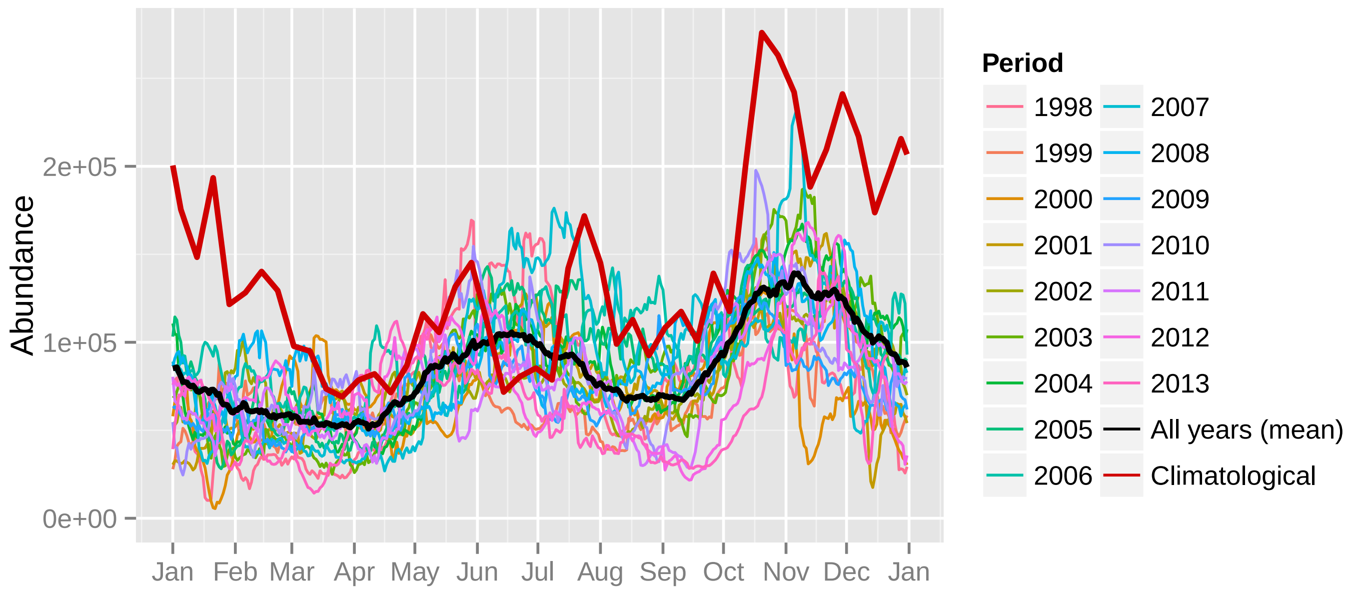


Figure 119: Comparison of Short-beaked common dolphin abundance predicted at a daily time step for different time periods. Individual years were predicted using contemporaneous models. "All years (mean)" averages the individual years, giving the mean annual abundance of the contemporaneous model. "Climatological" was predicted using the climatological model. The results for the climatological same segments model are not shown.

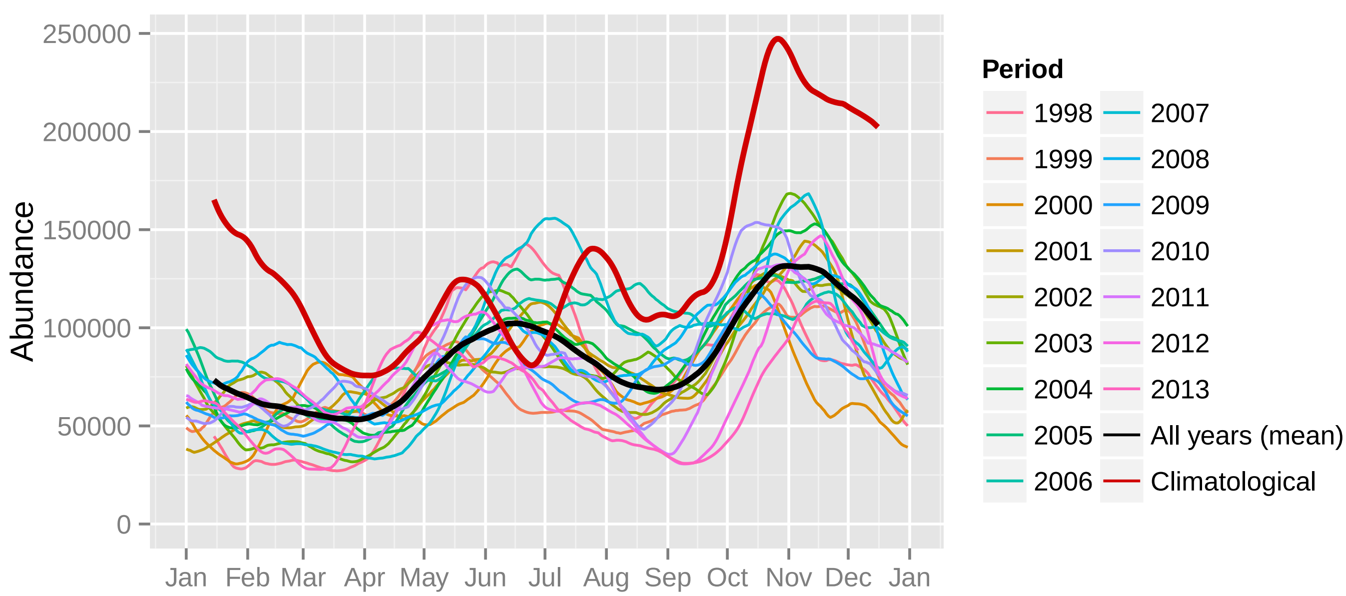
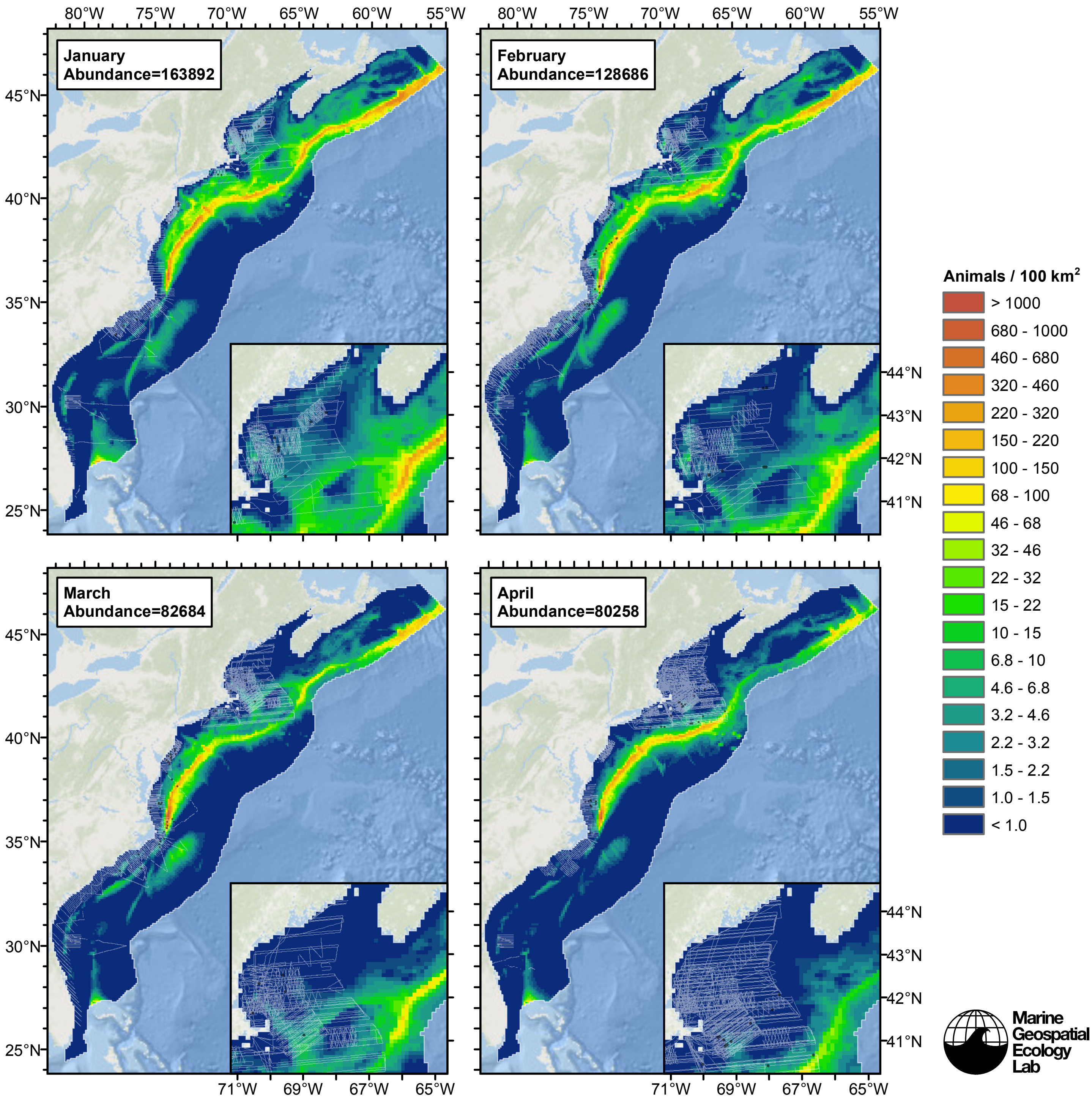
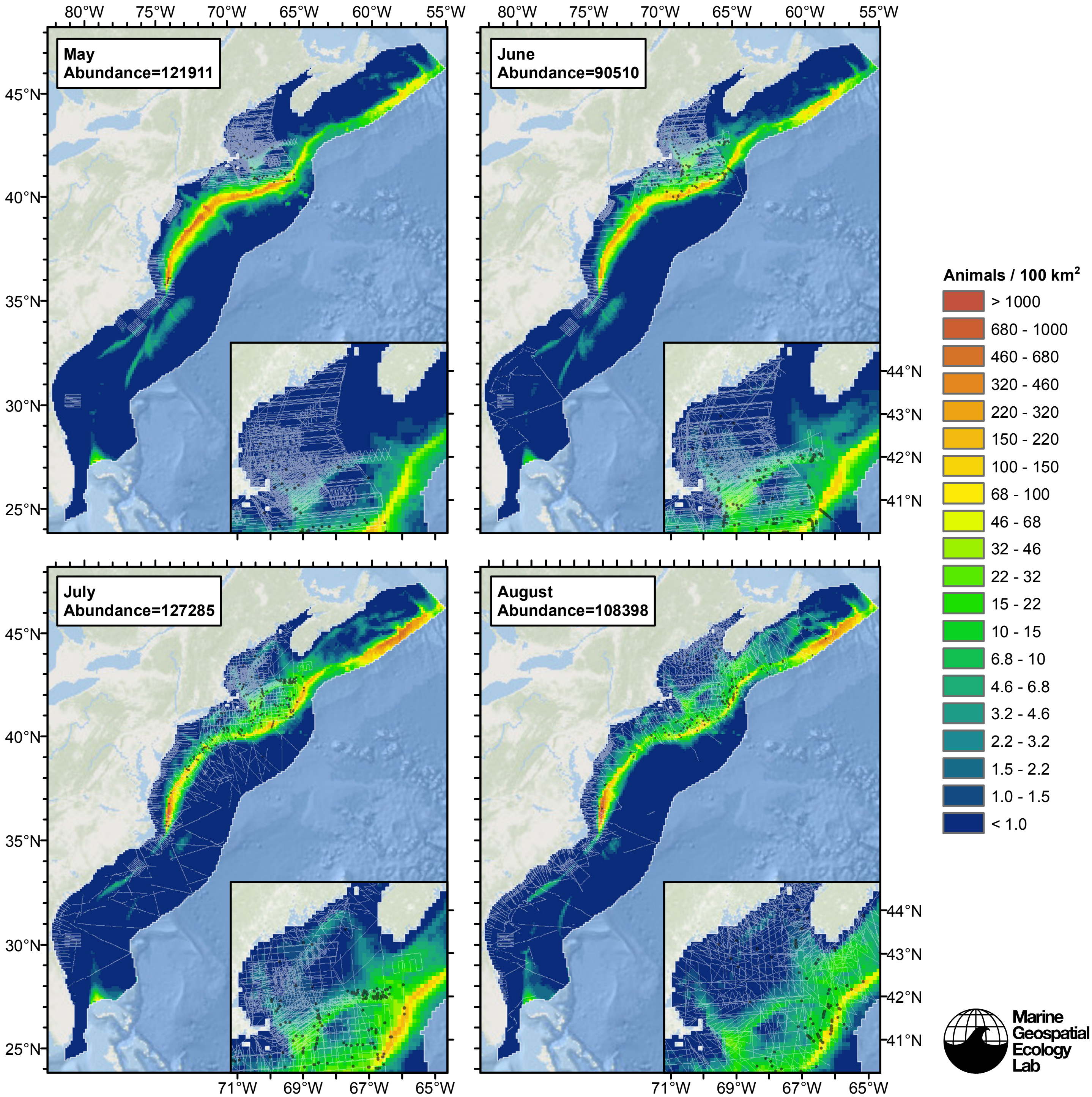


Figure 120: The same data as the preceding figure, but with a 30-day moving average applied.

Climatological Model




May
Abundance=121911
June
Abundance=90510
July
Abundance=127285
August
Abundance=108398
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
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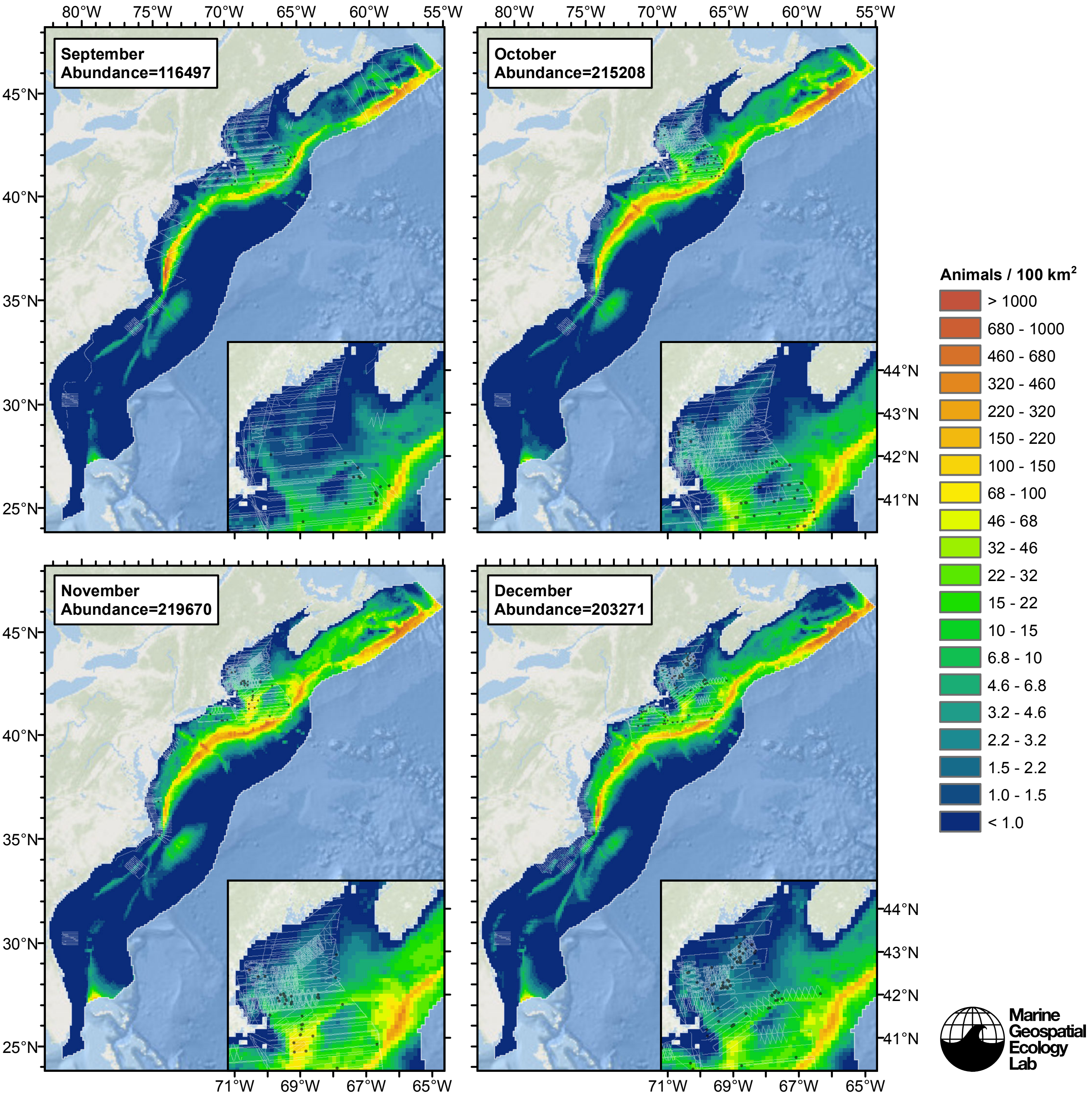
September
Abundance=116497
October
Abundance=215208
November
Abundance=219670
December
Abundance=203271
80°W
75°W
70°W
65°W
60°W
55°W
45°N
40°N
35°N
30°N
25°N
44°N
43°N
42°N
41°N
71°W
69°W
67°W
65°W
Animals / 100 km²
> 1000
680 - 1000
460 - 680
320 - 460
220 - 320
150 - 220
100 - 150
68 - 100
46 - 68
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
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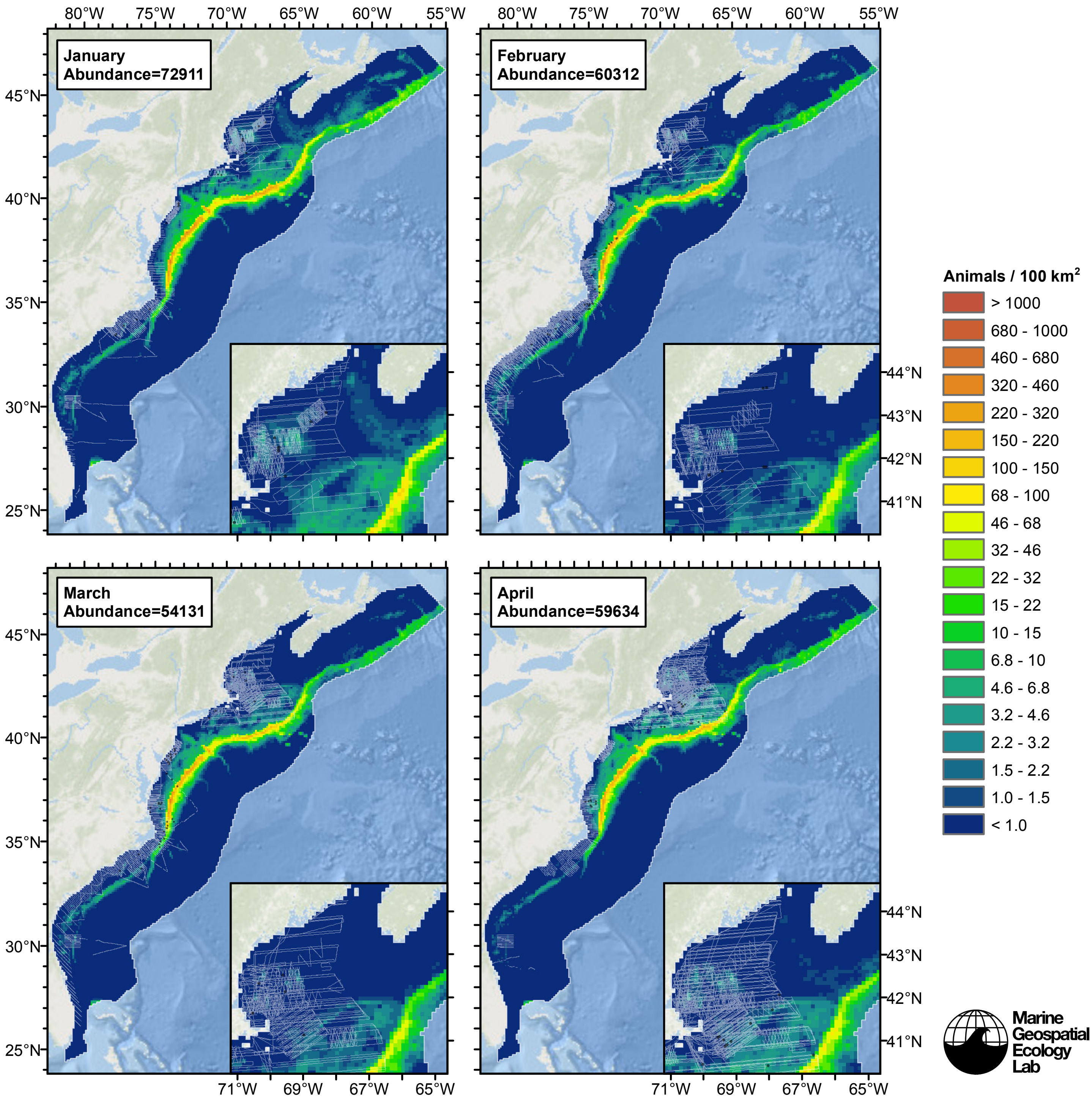
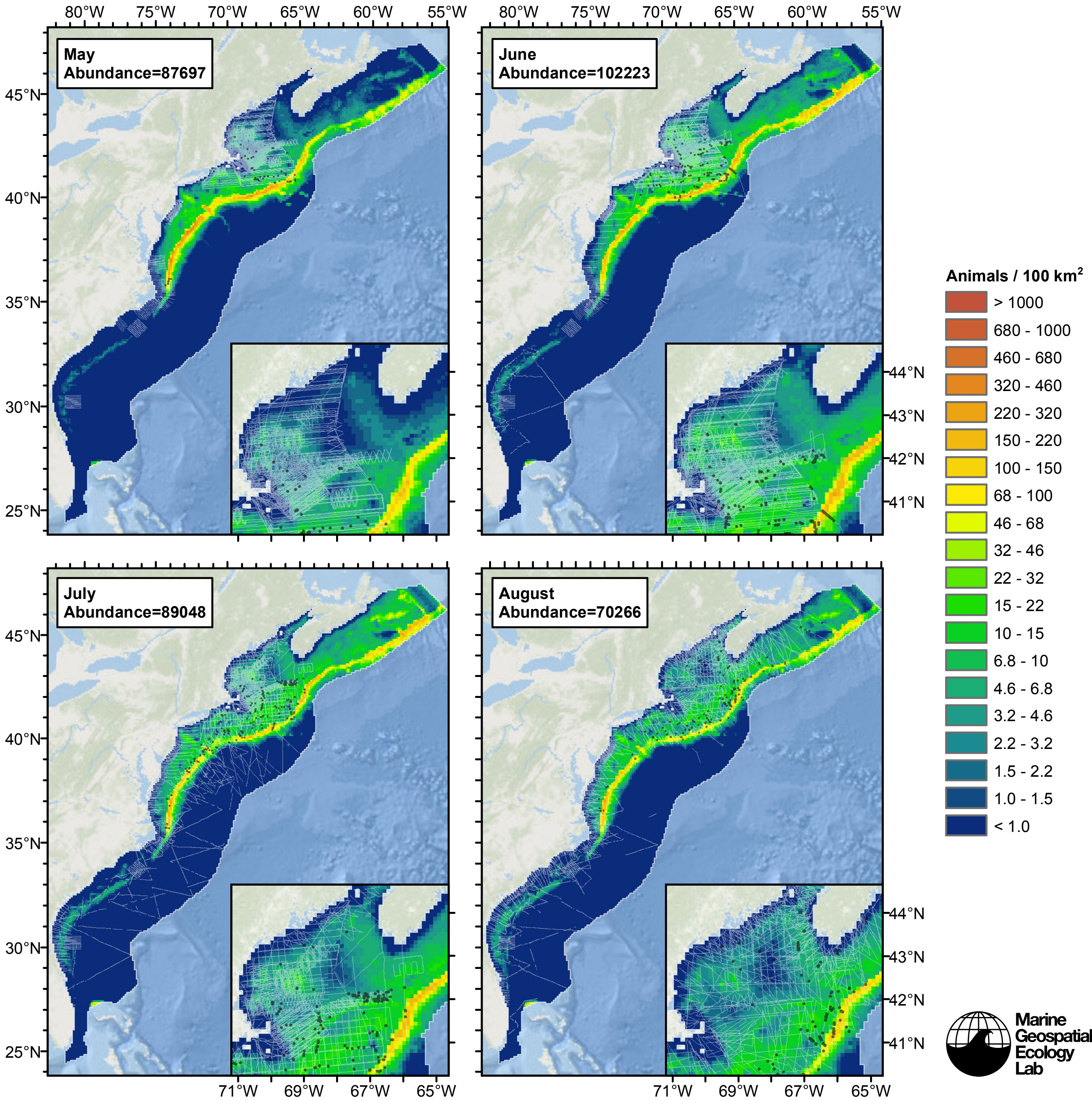
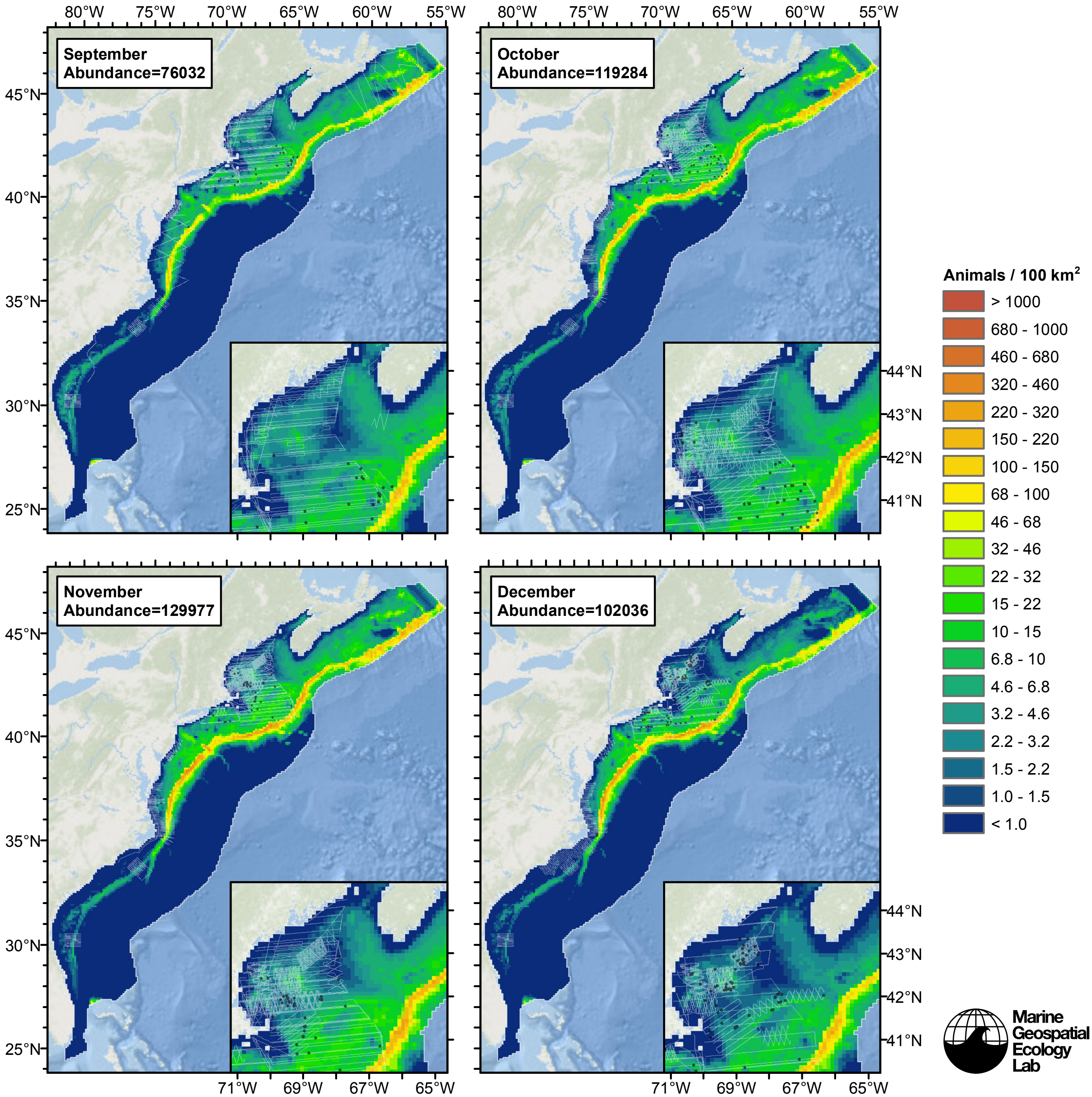
Ecology
Lab

Contemporaneous Model




May
Abundance=87697
June
Abundance=102223
July
Abundance=89048
August
Abundance=70266
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 km^2
> 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=76032
October
Abundance=119284
November
Abundance=129977
December
Abundance=102036
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
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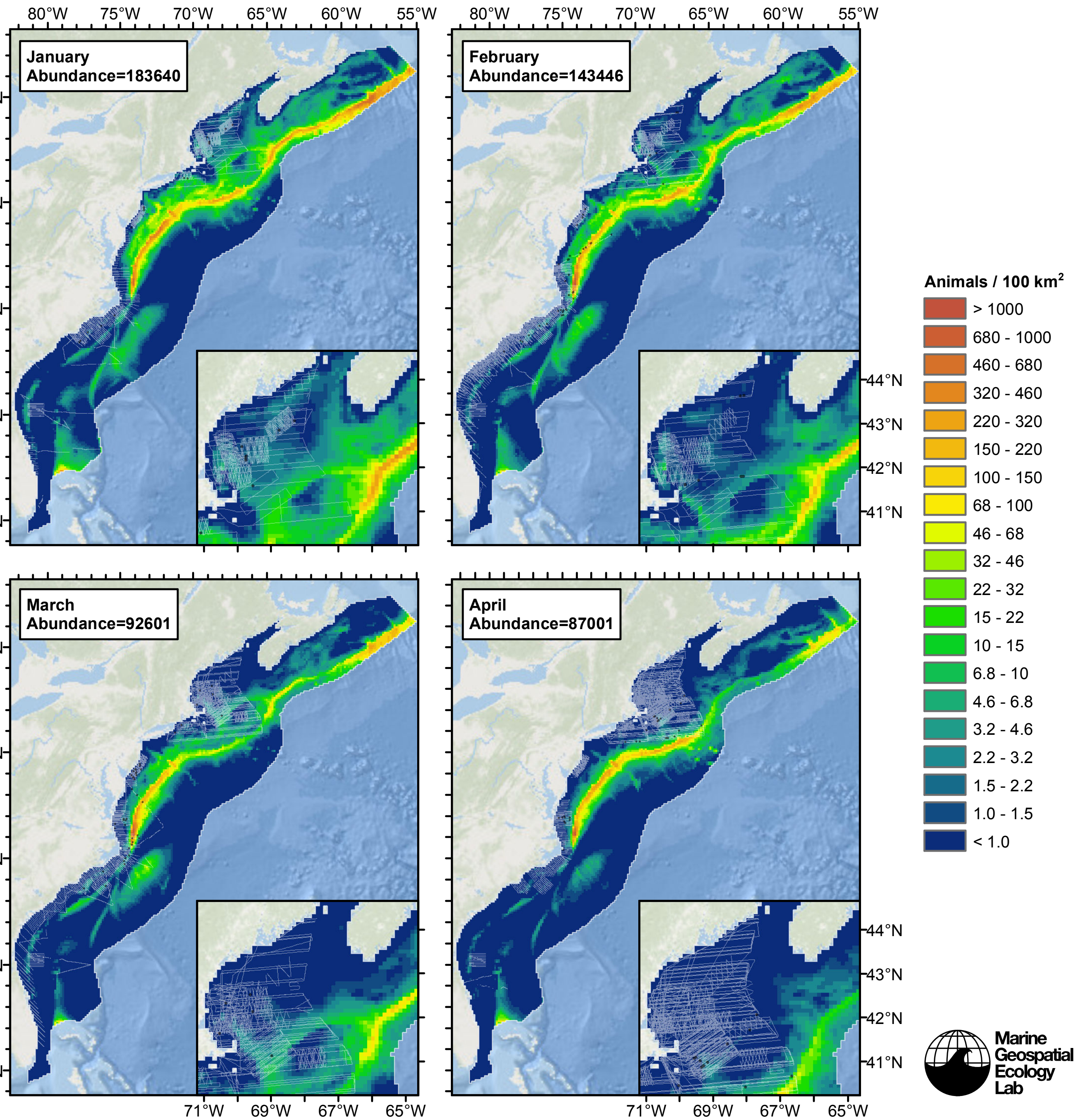
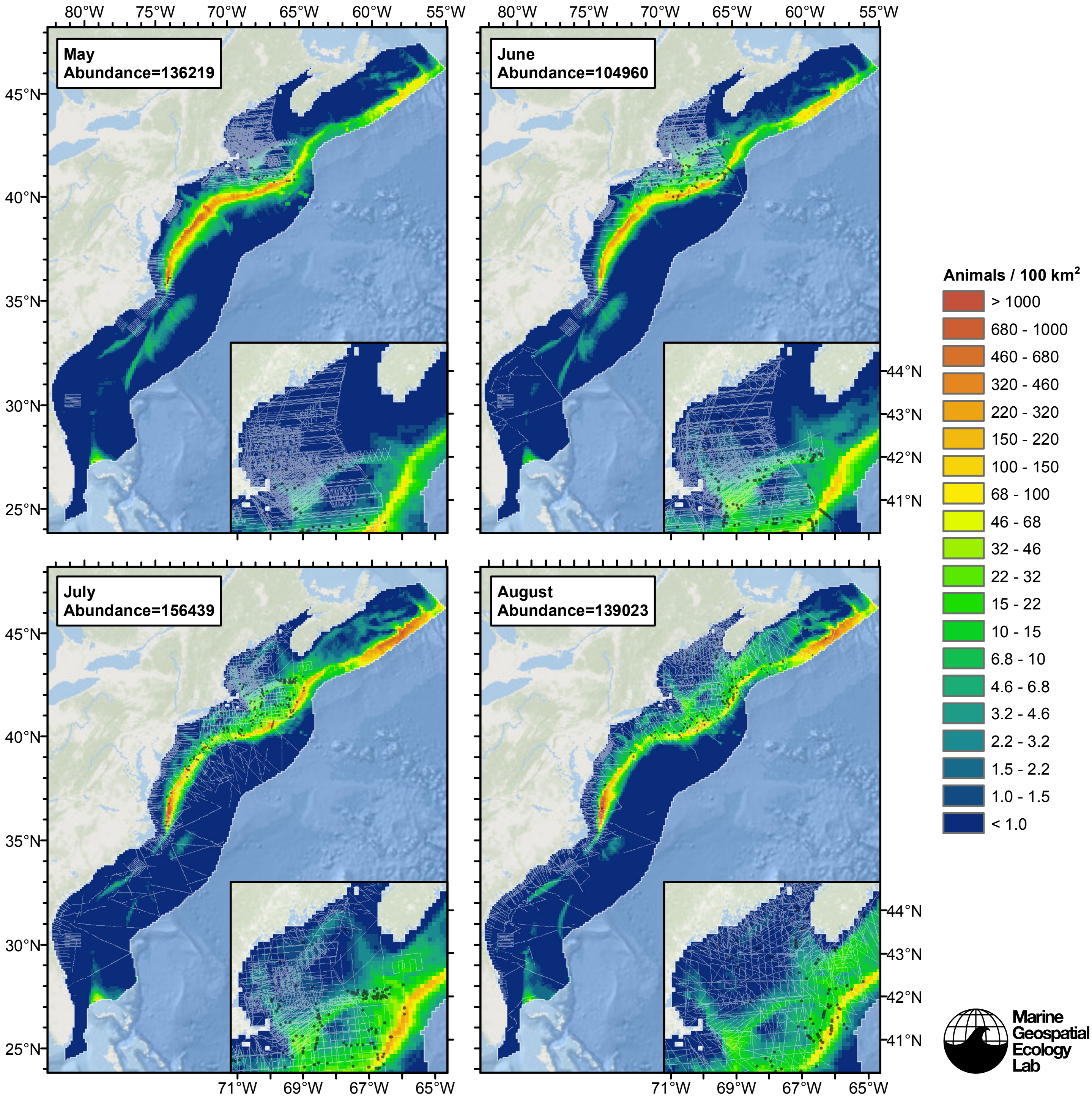
Ecology
Lab

Climatological Same Segments Model




May
Abundance=136219
June
Abundance=104960
July
Abundance=156439
August
Abundance=139023
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 km^2
> 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
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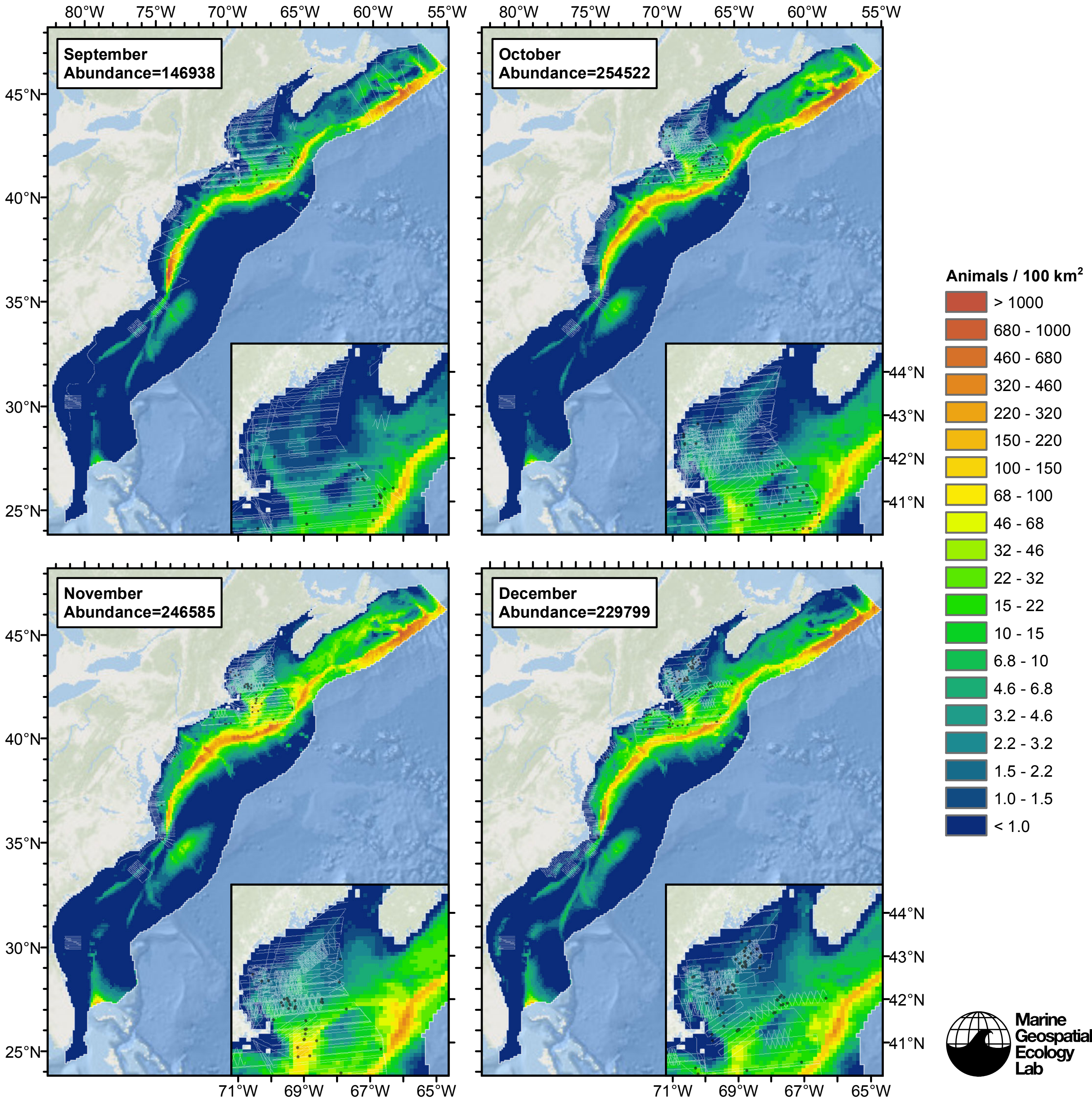

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Discussion

When models included only physiographic covariates, sea surface temperature (SST), and distance to the closest SST front, the model fitted to contemporaneous estimates of dynamic predictors (SST and distance to SST front) explained slightly more deviance than the model fitted to climatological estimates. But when covariates related to ocean currents and biological productivity were introduced, the climatological models explained more deviance.

Barring problems, and all else being equal, if the climatological model fitted to the contemporaneous model's segments explains more deviance, our standard procedure is to select the climatological model fitted to all segments, under the rationale that climatological estimates outperformed contemporaneous estimates, and we should on principle select the climatological model fitted to all segments rather than the one fitted to the contemporaneous model's segments, because it contains more data.

But for this species, the climatological models exhibited temporal variability in total abundance that we do not believe is realistic (Fig. 119), with abundance rising 50% from April to May (which may be OK), then falling 25% in June, rising 40% in July, then almost doubling from September to October, going from 116,497 to 215,208.

This oscillation suggests the model is overfitted. The large amount of survey data, the large number of sightings, and the complex pattern in short-beaked common dolphin distribution yielded the most complex models of all the taxa we studied. The contemporaneous model exhibited complexity similar to the climatological models–all models retained 10 covariates and discarded none–but did not display such high temporal variability, showing gradual month-to-month changes in abundance (averaged across all years) and only two peaks instead of three (Figs. 119, 120). The temporal stability of this model is more realistic. On the basis of that, and because it exhibited a slightly lower CV around the total abundance estimate, we selected the contemporaneous model as our best estimate of short-beaked common dolphin distribution and abundance.

When summarized at a monthly timestep, the model predicted spatiotemporal shifts in density that matched the seasonal pattern described by Jefferson et al. (2009), with low density in the Gulf of Maine and Scotian Shelf from January-April, a rise in May, sustained higher density from June-November, and a fall in December (see Temporal Variability section above). 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.

Our total abundance estimate averaged across the June-August period was 87,179, which is higher than NOAA's most recent estimate of 70,184 in 2011, but NOAA's estimate did not include the Scotian Shelf. Thus we consider these two estimates to be in agreement for the region of Florida to the lower Bay of Fundy. As of this writing, the most recent NOAA stock assessment report for this species (Waring et al. 2014) estimated the stock size at 173,486, based on an aerial survey of Canadian shelf waters conducted in July and August of 2007 (Lawson and Gosselin 2009, 2011). NOAA selected this estimate on the basis that "it covered more of the common dolphin range than the other surveys".

Of this estimate, 171,680 dolphins were estimated to be present on the Scotian Shelf–a huge number relative to our own estimate and NOAA's most recent estimate that covered this area, 84,000 in 2006. One possible explanation is that the Canadian analysis assumed a g(0) value that was substantially lower than our study or NOAA's; because abundance scales inversely with g(0), a lower g(0) yields a higher abundance. Our reading of Lawson and Gosselin (2011) is that they applied g(0)=0.309 to all sightings, based on unpublished data from D. Palka, referencing Palka (2005a). We could not locate this g(0) estimate in Palka (2005a). In any case, for our study we utilized g(0) estimates from Palka (2006), which estimated g(0)=0.43 for groups of 1-5 small cetaceans, and assumed g(0)=1 for groups of 6 or greater. Our reading of Lawson and Gosselin (2011) is that they did not apply g(0)=1 to large groups, but instead used g(0)=0.309 for all groups, regardless of size. In our analysis, 71% of the short-beaked common dolphin sightings were of groups of 6 or more individuals. Lawson and Gosselin (2009) reported 200 sightings of common dolphins totaling 2985 individuals, for a mean group size of 14.9. Lawson and Gosselin (2011) estimated an abundance of 53,049 for the Scotian Shelf, not correcting for g(0), then applied g(0)=0.309 to obtain an estimate of 171,680. If Palka's (2006) logic were followed, the abundance estimate for the Scotian Shelf would have been much smaller–probably closer to 53,049 than 171,680–assuming our reading of Lawson' and Gosselin's methodology is correct.

In any case, there is no doubt that the Canadian study suggests density of short-beaked common dolphins was very high on the Scotian Shelf in summer of 2007. Lawson and Gosselin (2009) reported 198 sightings of short-beaked common dolphins on the Scotian Shelf–nearly 17% the number of sightings reported for the entire 1992-2014 period by all of the surveys we utilized, combined. And, as noted, they estimated an abundance of 53,049 for the Scotian Shelf without correcting for availability or perception bias. This uncorrected value is still large but represents a minimum estimate, confirming that density was high even if the g(0) question is set aside. To try to account for this high density in our study, we made several attempts to contact J. Lawson regarding the in the hope of incorporating the Canadian survey into our models, but we received no response. We remain hopeful that a collaboration can be established in the future, and that the Canadian survey may be incorporated into a new version of our models.

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