

Density Model for Pantropical Spotted Dolphin (*Stenella attenuata*) for the U.S. East Coast: Supplementary Report

Duke University Marine Geospatial Ecology Lab*

Model Version 2.3 - 2015-10-06

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:

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Revision History

Version	Date	Description of changes
1	2014-10-25	Initial version.
2	2014-11-13	Reconfigured detection hierarchy and adjusted NARWSS detection functions based on additional information from Tim Cole. Switched Slope and Abyss region to use uniform distribution of abundance, rather than a GAM with a single predictor variable. Updated documentation.
2.1	2015-03-06	Updated the documentation. No changes to the model.
2.2	2015-05-14	Updated calculation of CVs. Switched density rasters to logarithmic breaks. No changes to the model.
2.3	2015-10-06	Updated the documentation. No changes to the model.

*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	0
NEFSC NARWSS Harbor Porpoise Survey	1999-1999	6	36	0
NEFSC North Atlantic Right Whale Sighting Survey	1999-2013	432	2330	0
NEFSC Shipboard Surveys	1995-2004	16	1143	4
NJDEP Aerial Surveys	2008-2009	11	60	0
NJDEP Shipboard Surveys	2008-2009	14	836	0
SEFSC Atlantic Shipboard Surveys	1992-2005	28	1731	10
SEFSC Mid Atlantic Tursiops Aerial Surveys	1995-2005	35	196	2
SEFSC Southeast Cetacean Aerial Surveys	1992-1995	8	42	0
UNCW Cape Hatteras Navy Surveys	2011-2013	19	125	0
UNCW Early Marine Mammal Surveys	2002-2002	18	98	0
UNCW Jacksonville Navy Surveys	2009-2013	66	402	1
UNCW Onslow Navy Surveys	2007-2011	49	282	0
UNCW Right Whale Surveys	2005-2008	114	586	0
Virginia Aquarium Aerial Surveys	2012-2014	9	53	0
Total		895	8332	17

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	17

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

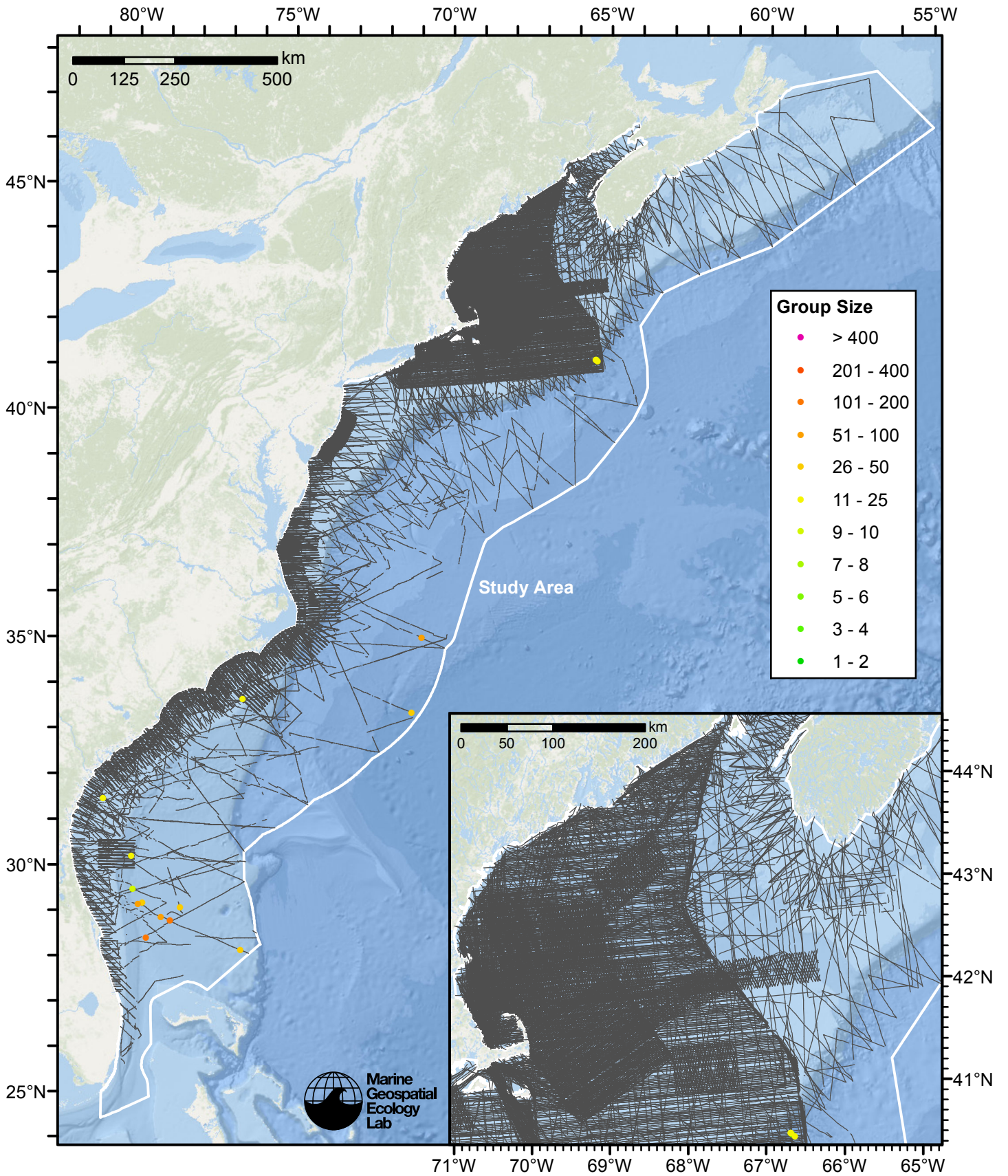


Figure 1: Pantropical spotted dolphin sightings and survey tracklines.

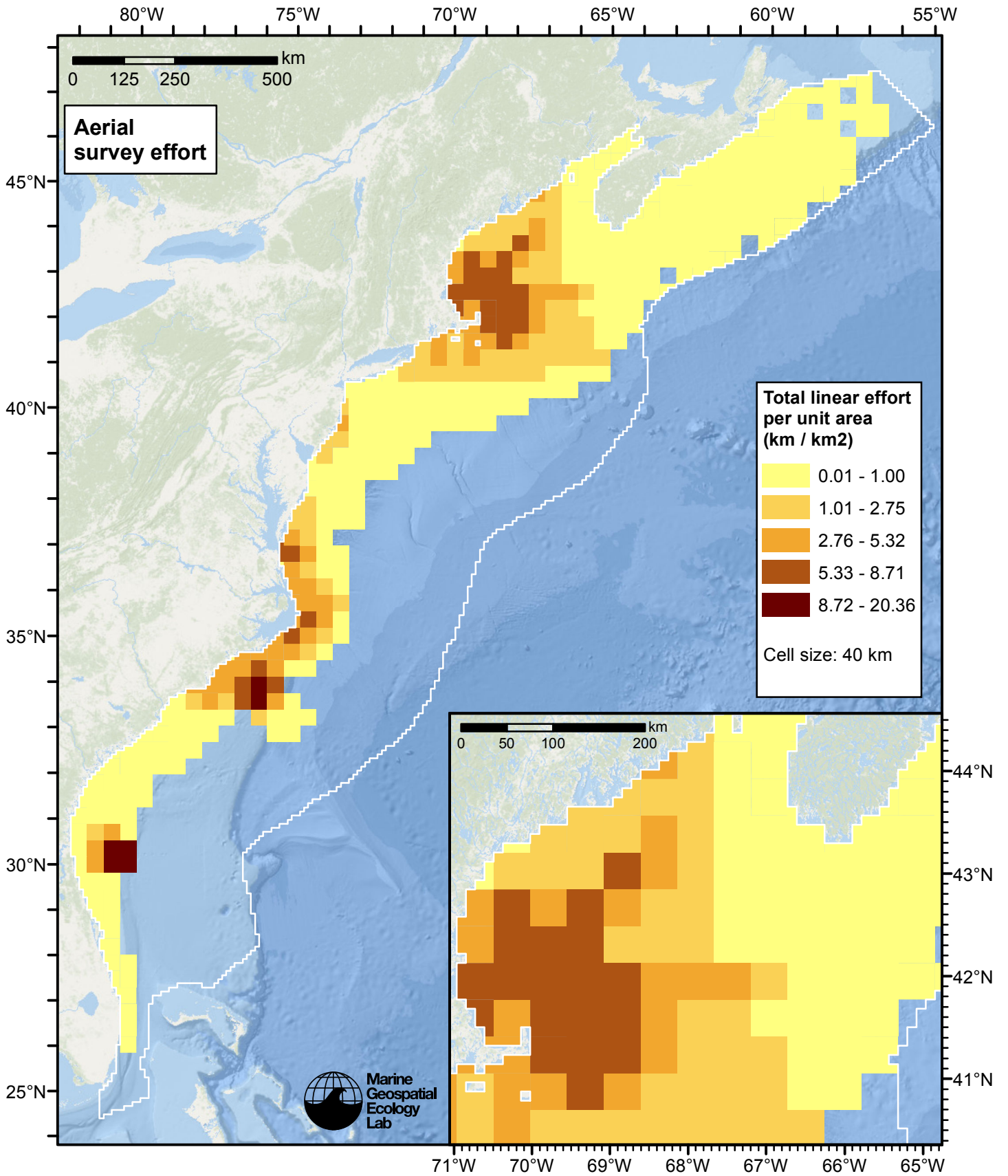


Figure 2: Aerial linear survey effort per unit area.

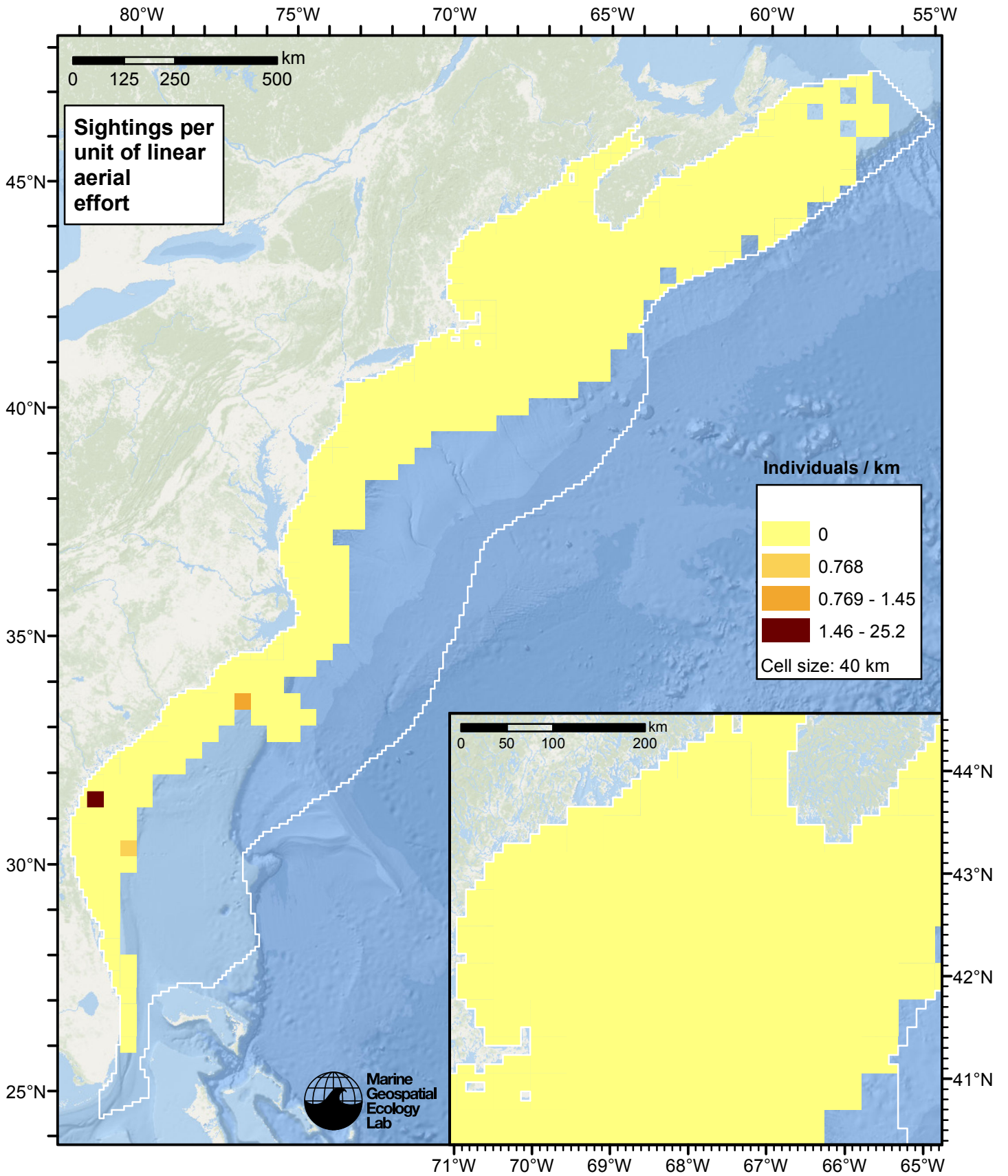


Figure 3: Pantropical spotted dolphin sightings per unit aerial linear survey effort.

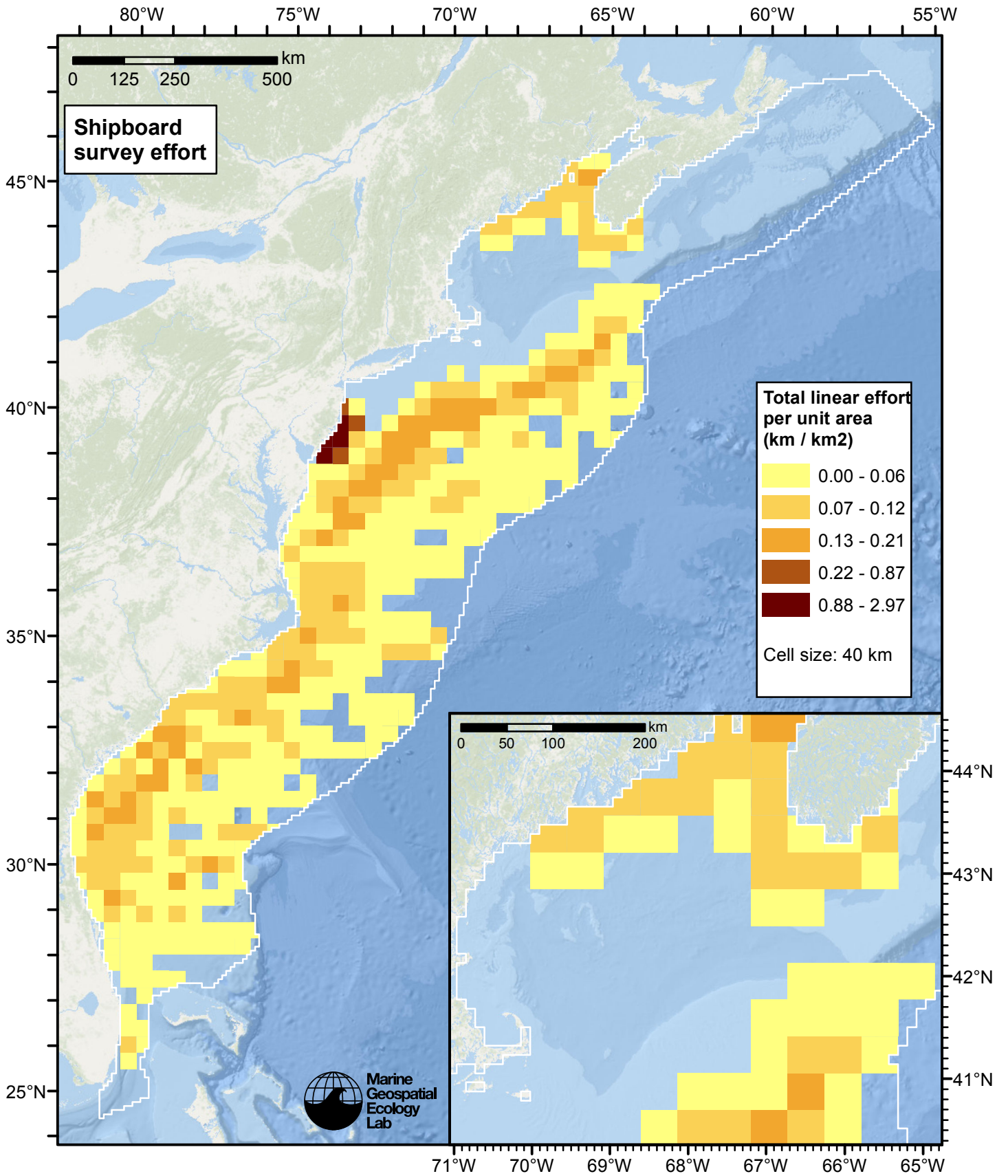


Figure 4: Shipboard linear survey effort per unit area.

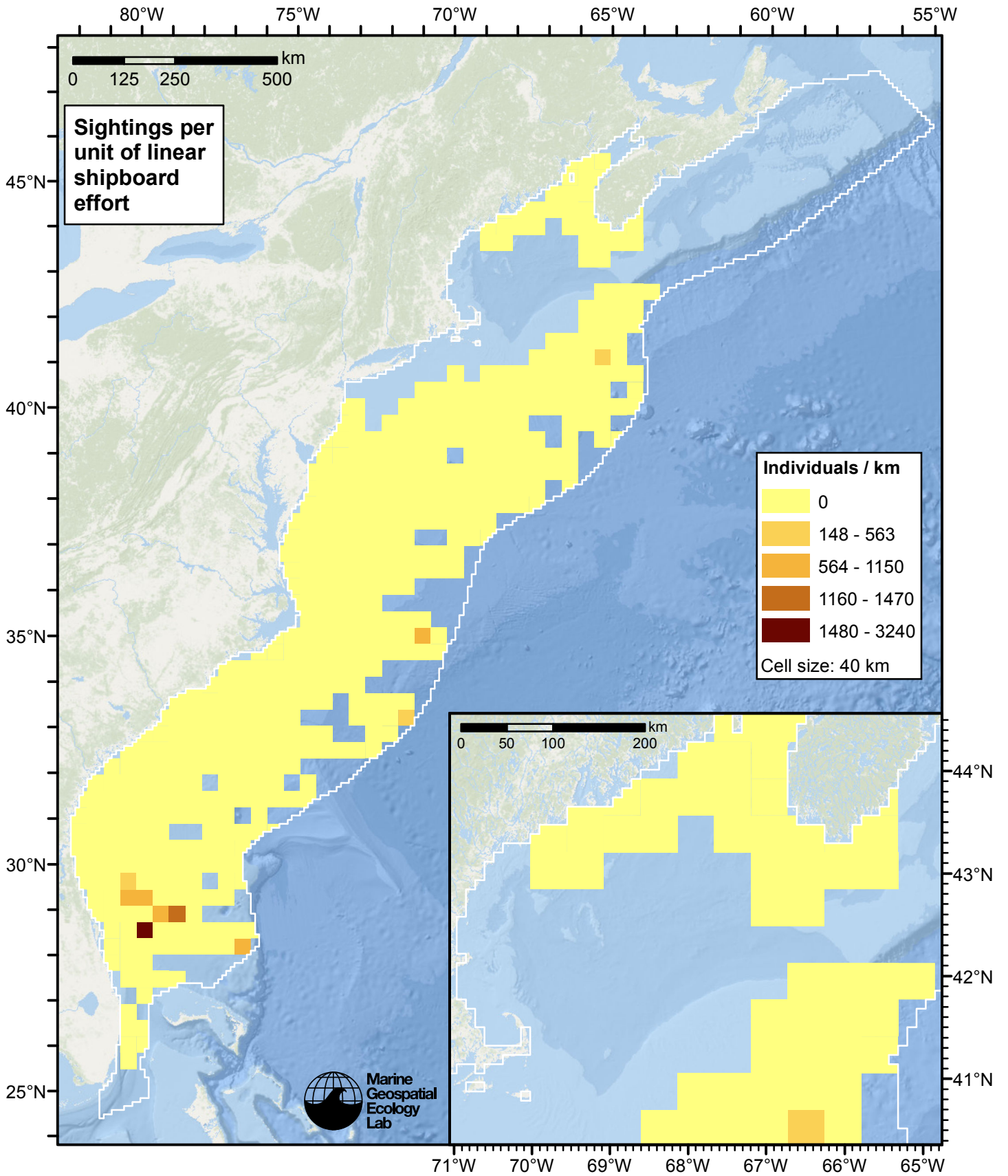


Figure 5: Pantropical spotted dolphin sightings per unit shipboard linear survey effort.

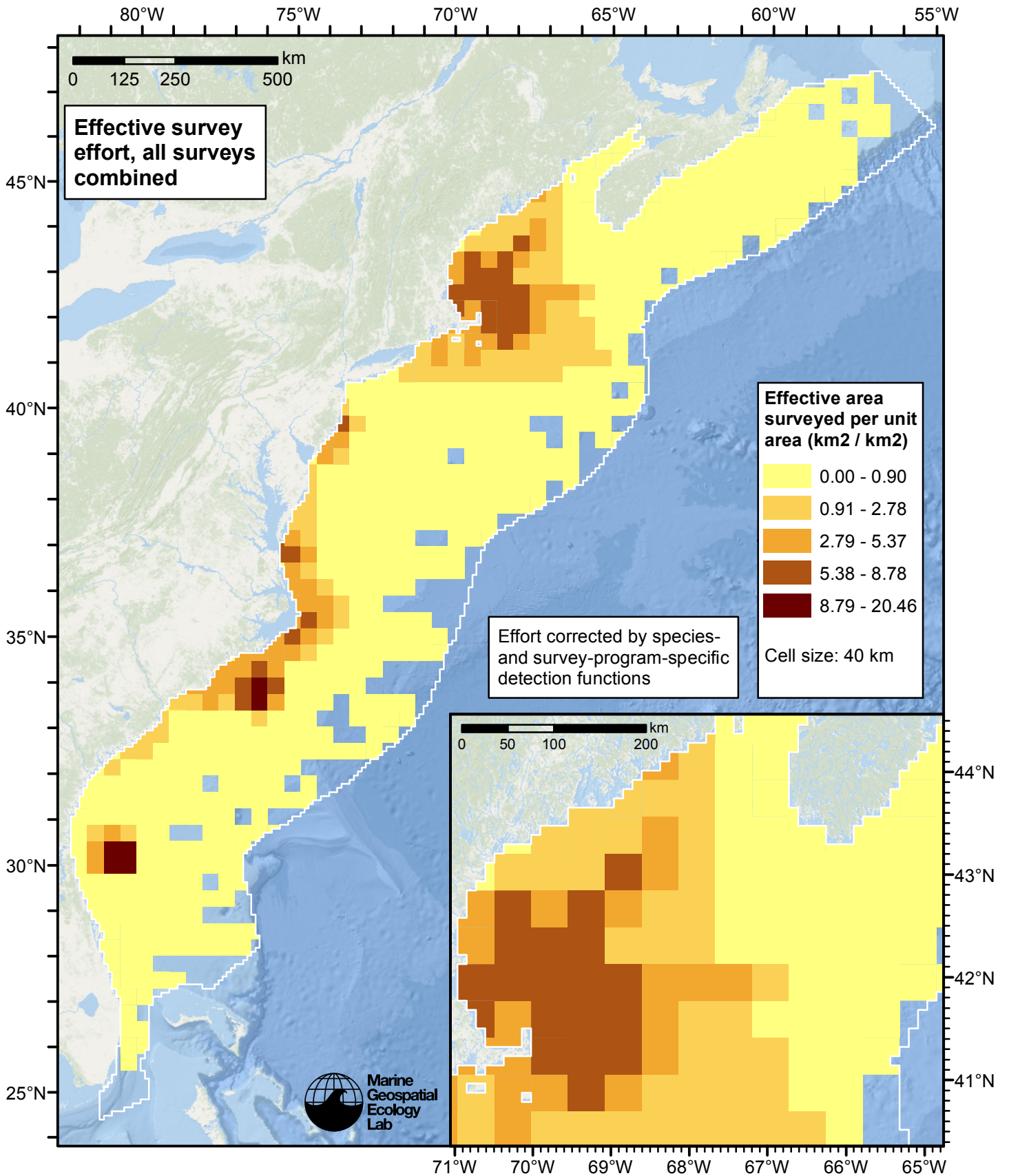


Figure 6: Effective survey effort per unit area, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

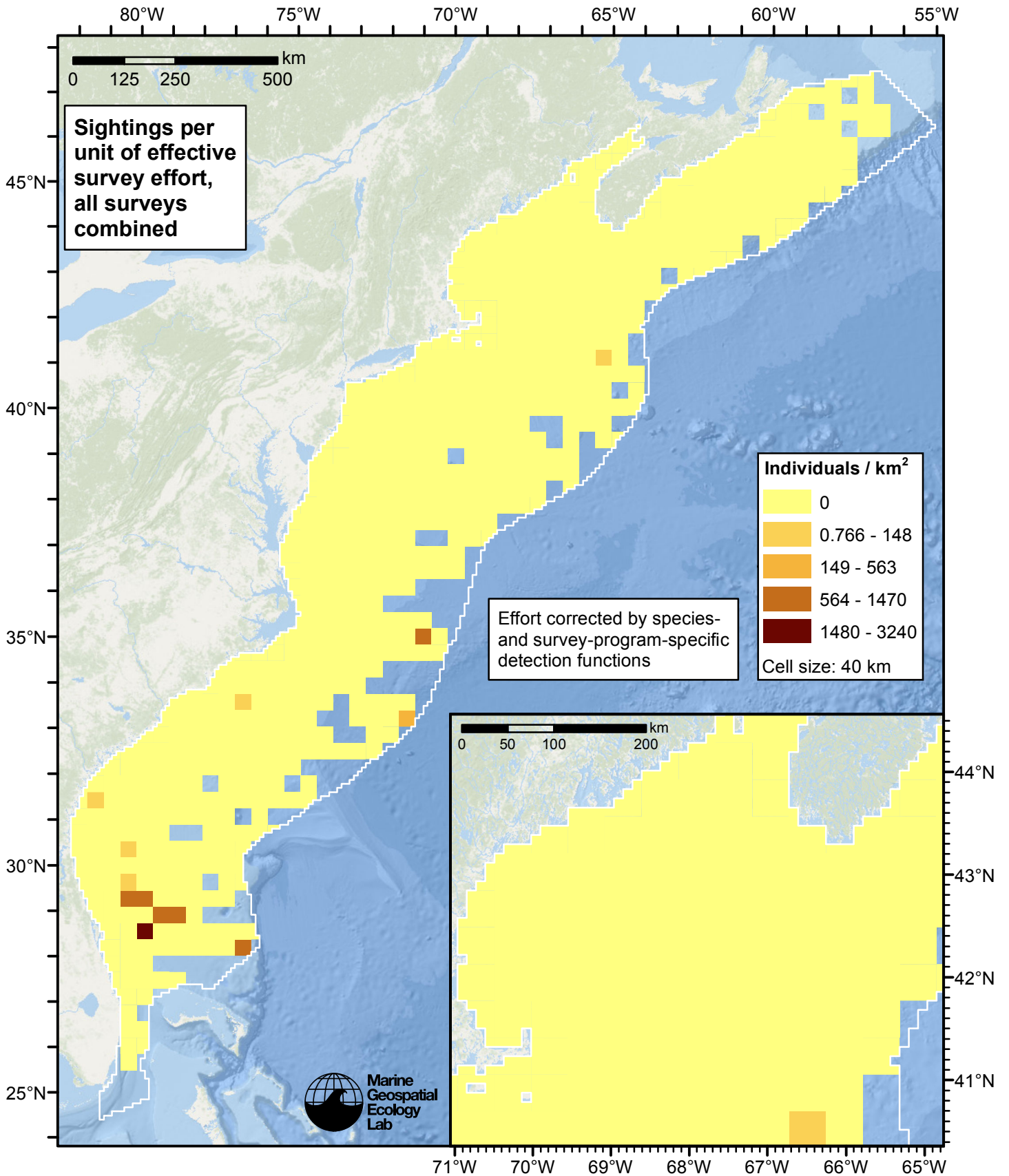


Figure 7: Pantropical spotted dolphin sightings per unit of effective survey effort, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

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) receives 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

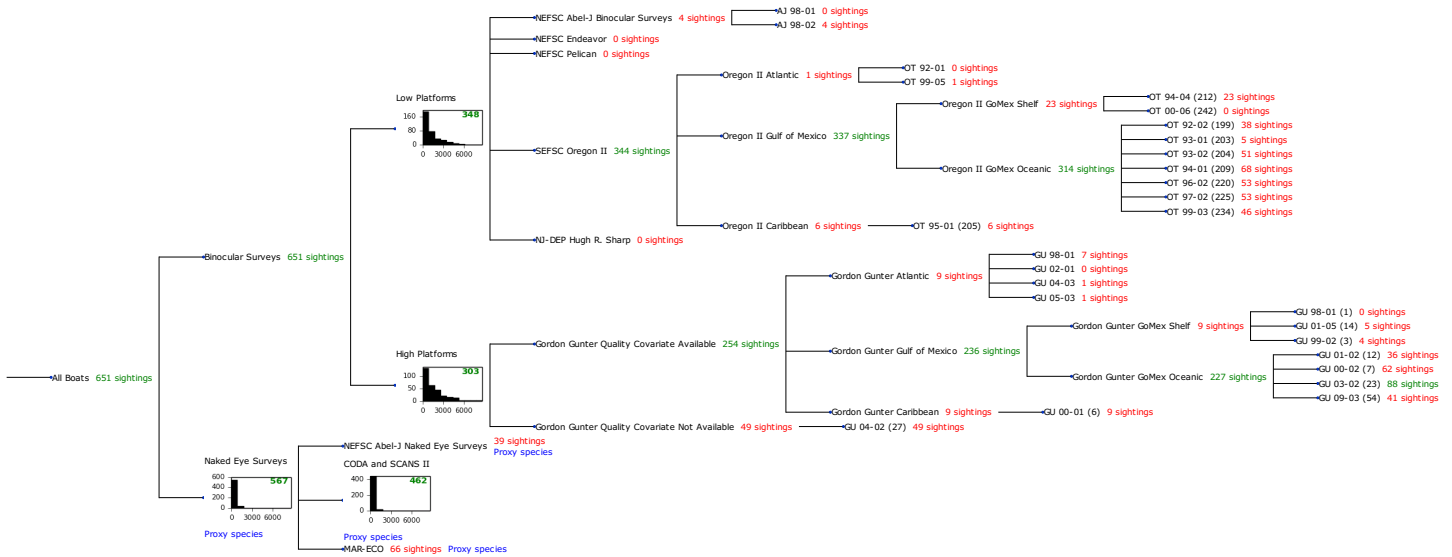


Figure 8: Detection hierarchy for shipboard surveys

Low Platforms

The sightings were right truncated at 5000m.

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

Table 4: 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	1817
hr			size	Yes	0.58	1713
hr				Yes	53.23	728
hr			beaufort	Yes	53.57	742
hn	cos	2		Yes	78.00	1593
hn			beaufort, size	Yes	83.97	2182
hn			size	Yes	84.86	2174
hn	cos	3		Yes	87.93	1485
hn				Yes	123.93	2109
hn			beaufort	Yes	124.03	2108
hn	herm	4		Yes	125.00	2104
hr	poly	2		No		
hr	poly	4		No		

Table 5: Candidate detection functions for Low Platforms. The first one listed was selected for the density model.

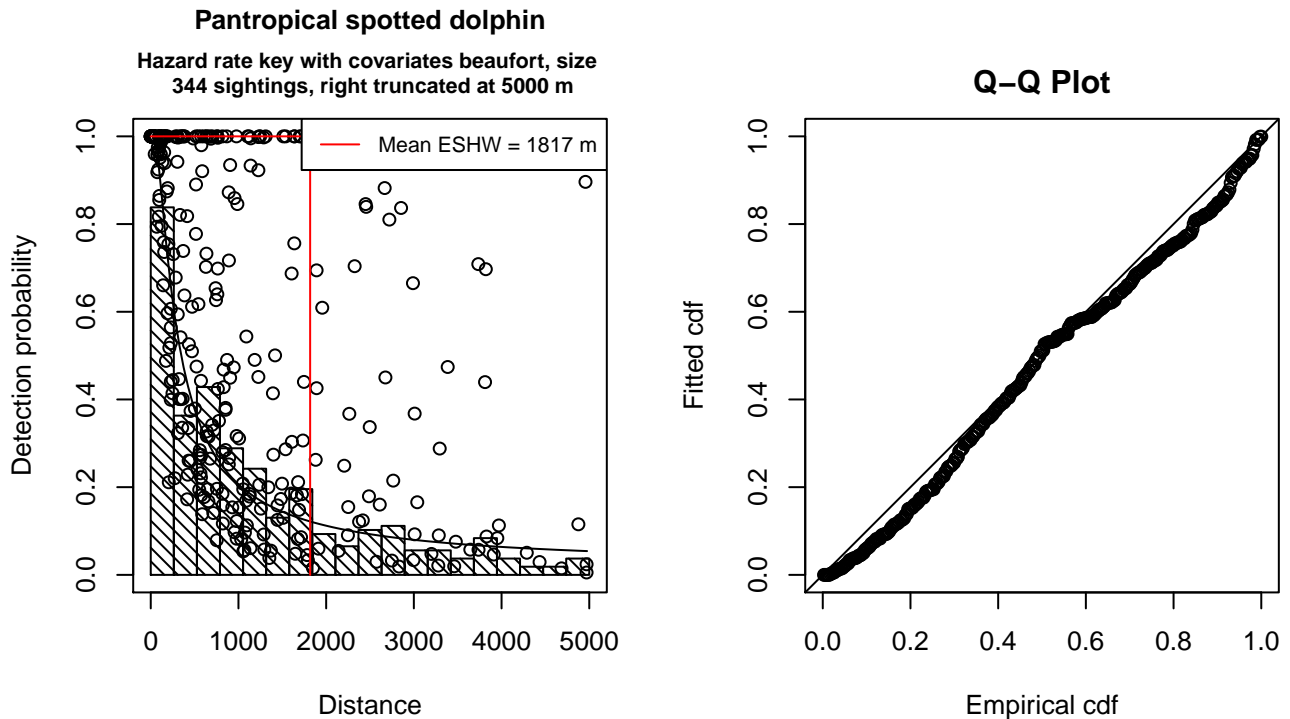


Figure 9: Detection function for Low Platforms that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 344
 Distance range : 0 - 5000
 AIC : 5477.79

Detection function:
 Hazard-rate key function

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	5.1390917	0.32755835
beaufort	-0.1542072	0.07613888
size	2.3802017	0.34732806

Shape parameters:

	estimate	se
(Intercept)	0.3576001	0.08845056

	Estimate	SE	CV
Average p	0.1686068	0.02024788	0.1200893
N in covered region	2040.2498708	269.16384121	0.1319269

Additional diagnostic plots:

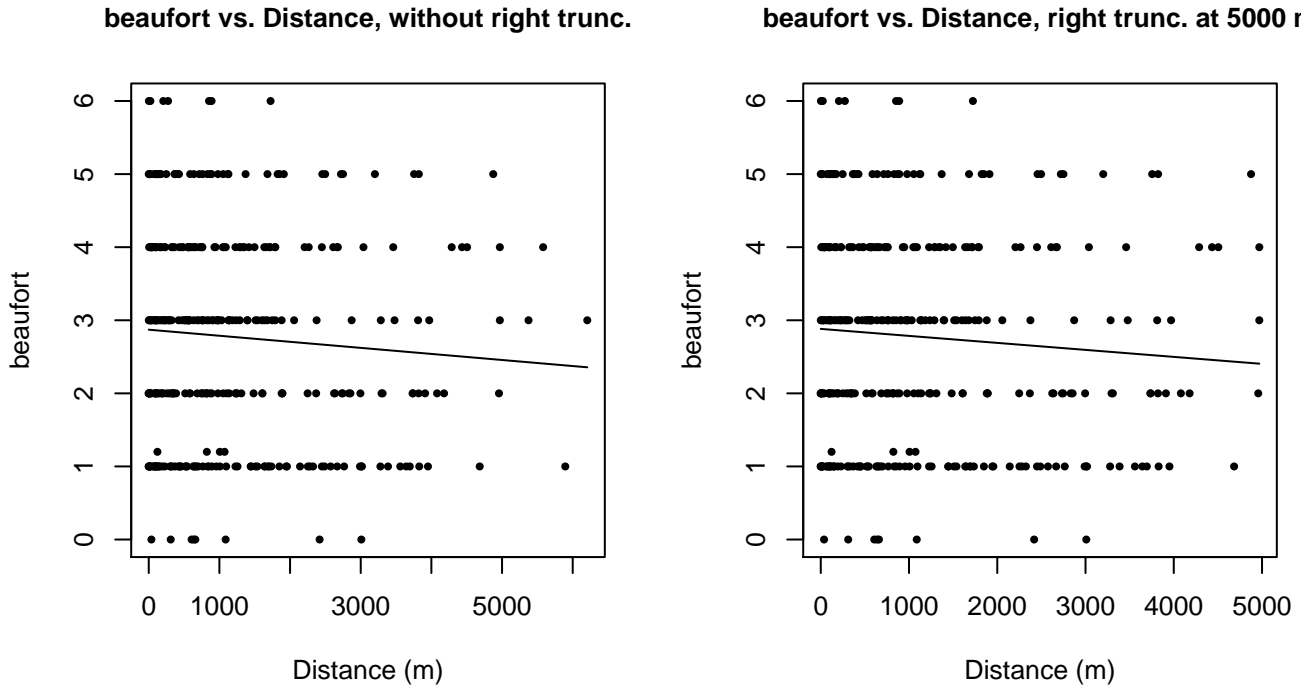
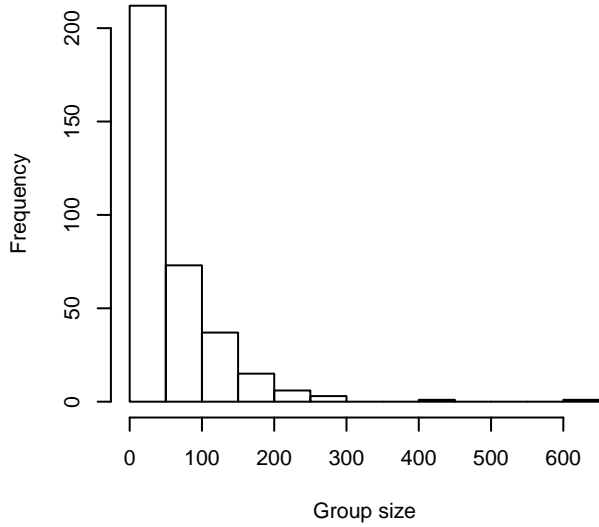
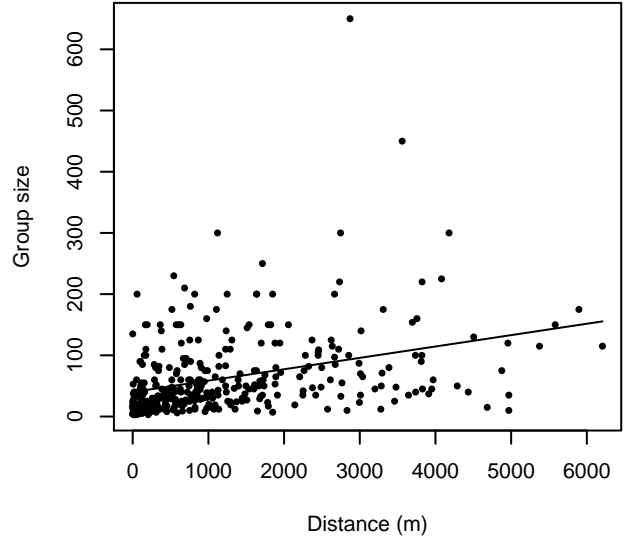


Figure 10: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

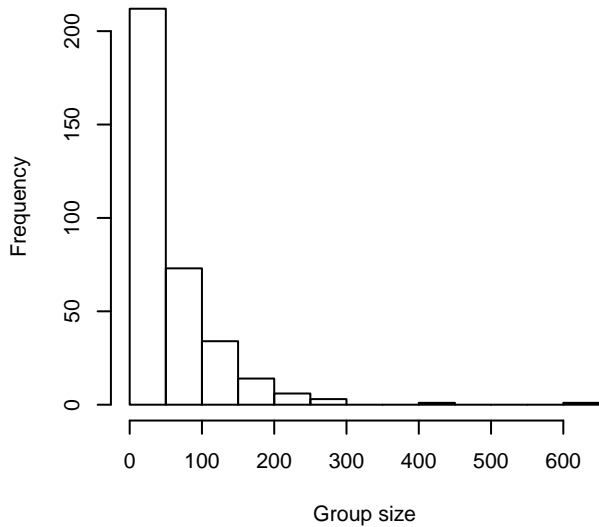
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 5000 m



Group Size vs. Distance, right trunc. at 5000 m

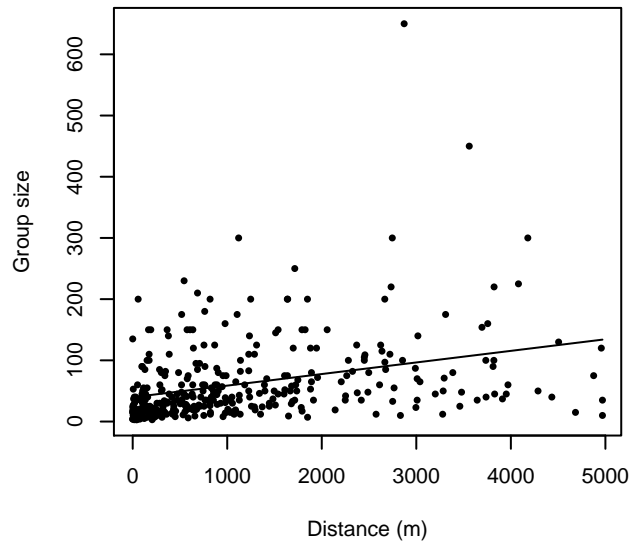


Figure 11: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

High Platforms

The sightings were right truncated at 6000m.

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

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

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	1404
hr			size	Yes	21.82	924
hr			beaufort	Yes	24.65	1013
hr	poly	4		Yes	42.14	827
hn			beaufort, size	Yes	42.29	2609
hr				Yes	46.56	726
hn			beaufort	Yes	69.58	2498
hn	cos	2		Yes	74.34	1977
hn	cos	3		Yes	80.32	1865
hn			size	Yes	88.70	2521
hn				Yes	99.38	2502
hn	herm	4		Yes	100.85	2496
hr	poly	2		No		

Table 7: Candidate detection functions for High Platforms. The first one listed was selected for the density model.

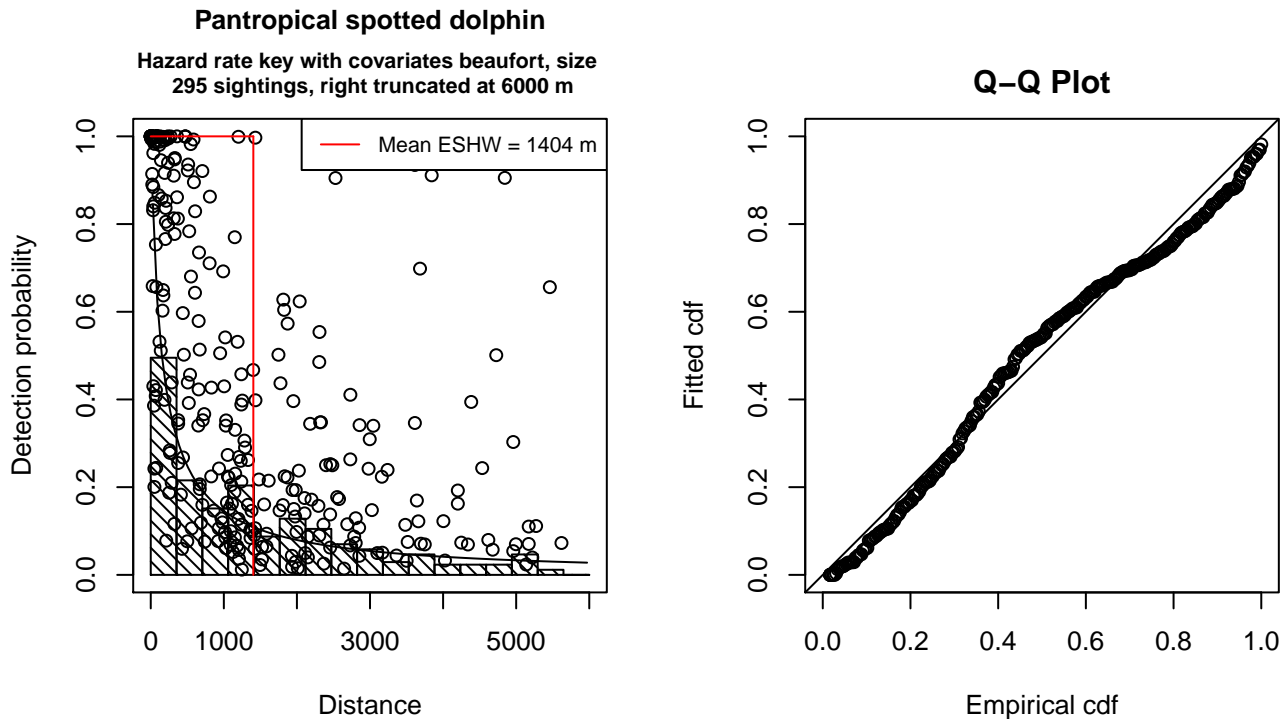


Figure 12: Detection function for High Platforms that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 295
 Distance range : 0 - 6000
 AIC : 4806.309

Detection function:
 Hazard-rate key function

Detection function parameters
 Scale Coefficients:

	estimate	se
(Intercept)	6.3719618	0.4029306
beaufort	-0.6896037	0.1256594
size	0.9673811	0.1774448

Shape parameters:

	estimate	se
(Intercept)	0.1127456	0.08968933

	Estimate	SE	CV
Average p	0.1010828	0.01972899	0.1951765
N in covered region	2918.3989143	595.17837580	0.2039400

Additional diagnostic plots:

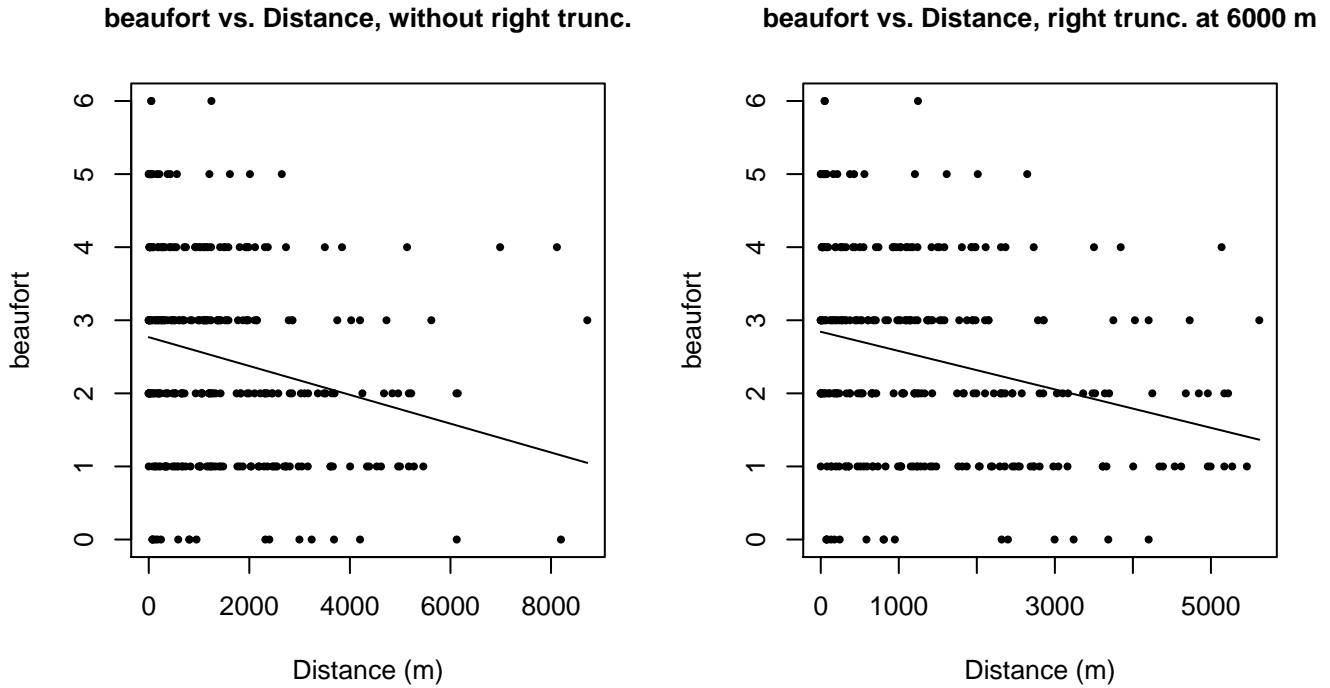


Figure 13: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

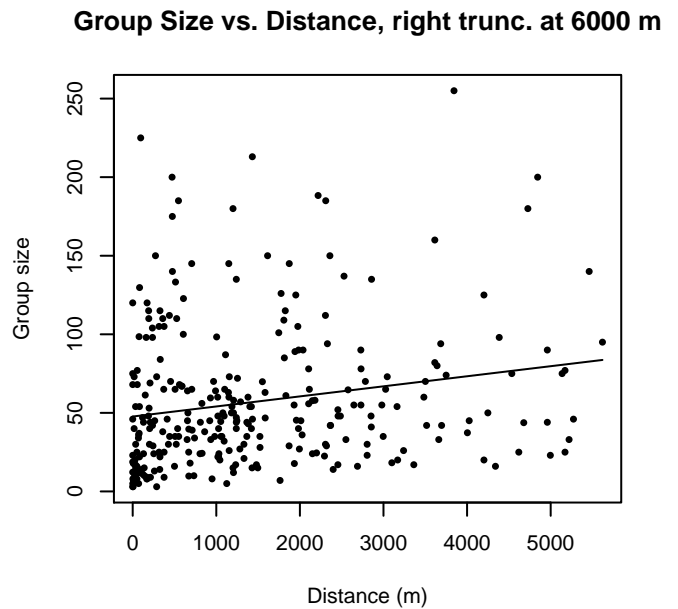
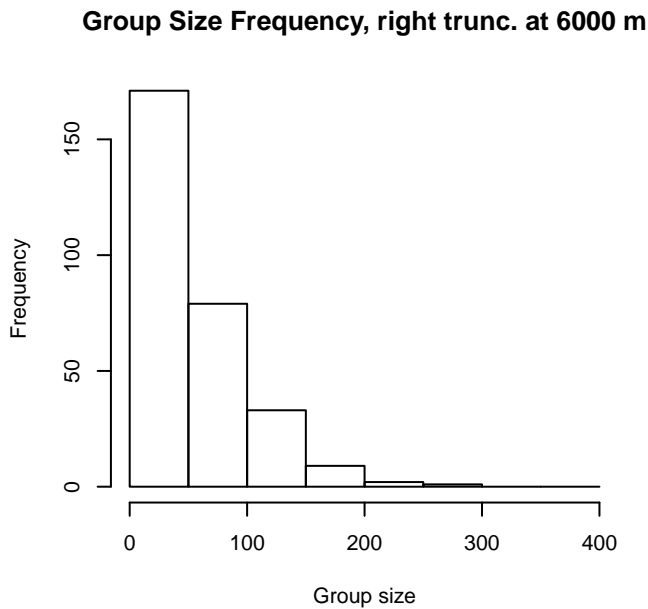
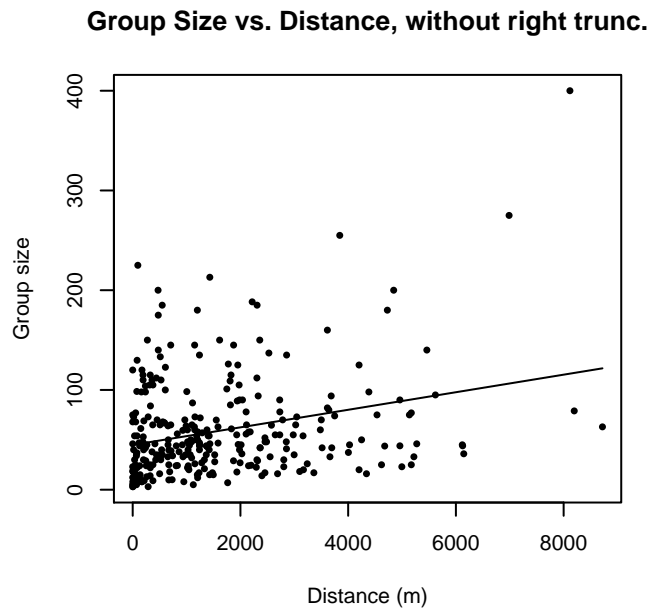
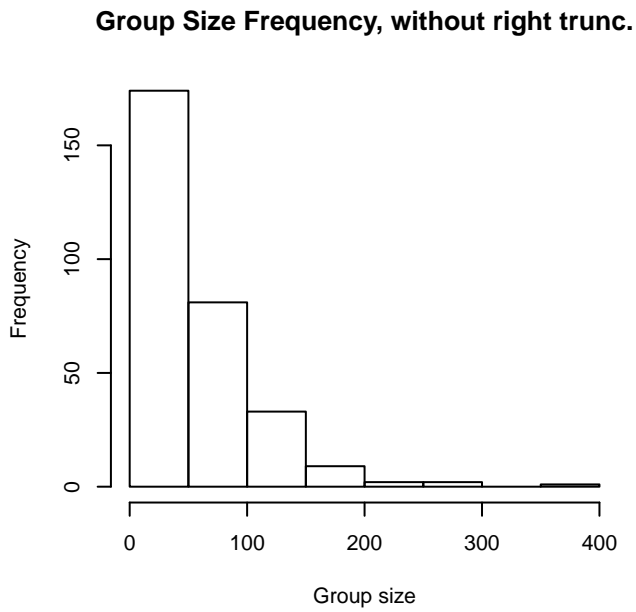


Figure 14: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Naked Eye 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
<i>Delphinus capensis</i>	Long-beaked common dolphin	0
<i>Delphinus delphis</i>	Short-beaked common dolphin	255

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	72
Grampus griseus	Risso’s dolphin	9
Grampus griseus/Tursiops truncatus	Risso’s or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser’s dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	102
Lagenorhynchus albirostris	White-beaked dolphin	36
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	4
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	48
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	41
Total		567

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

The sightings were right truncated at 1000m.

Covariate	Description
beaufort	Beaufort sea state.
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)
hr			beaufort, size	Yes	0.00	329
hr			beaufort	Yes	5.52	306
hr			size	Yes	7.76	330
hr	poly	2		Yes	8.35	253
hr	poly	4		Yes	11.34	266
hn	cos	2		Yes	14.63	339

hr			Yes	14.95	308
hn	cos	3	Yes	29.74	330
hn		beaufort, size	Yes	33.37	434
hn		size	Yes	39.64	433
hn		beaufort	Yes	47.43	427
hn			Yes	53.26	426
hn	herm	4	Yes	54.28	425

Table 10: Candidate detection functions for Naked Eye Surveys. The first one listed was selected for the density model.

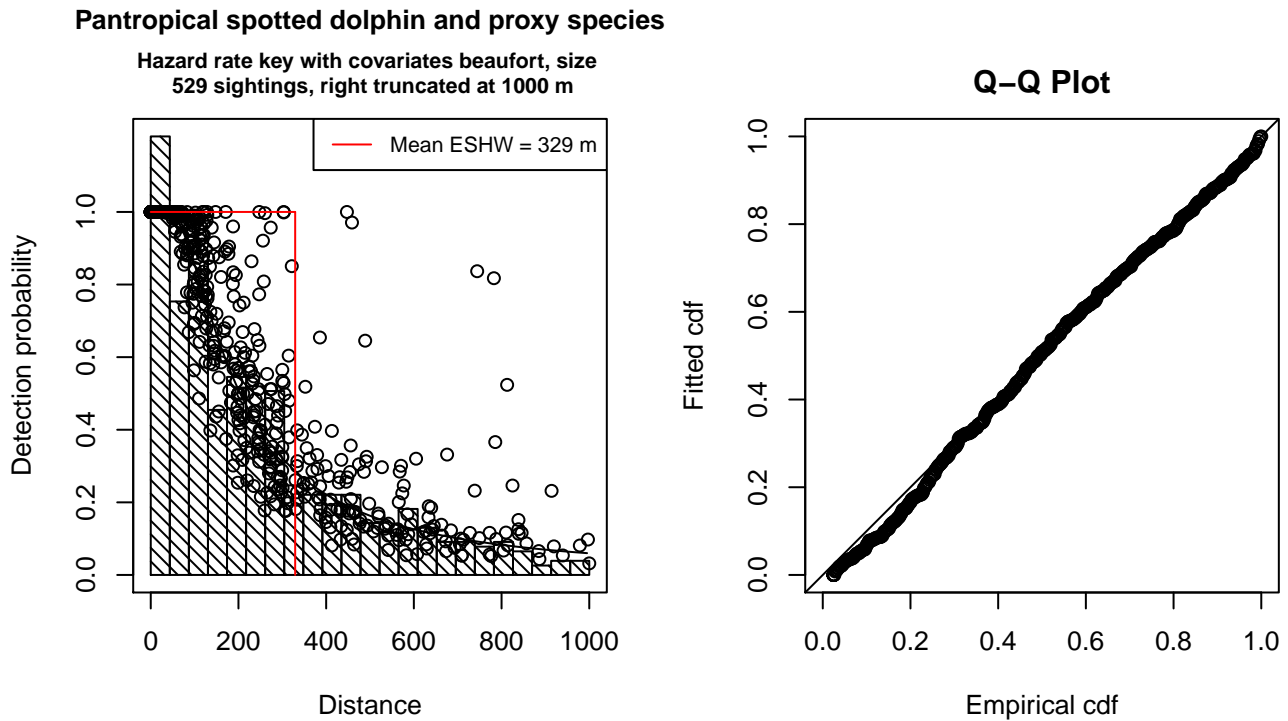


Figure 15: Detection function for Naked Eye Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations : 529
Distance range       : 0 - 1000
AIC                  : 6866.942
```

```
Detection function:
Hazard-rate key function
```

```
Detection function parameters
Scale Coefficients:
      estimate      se
(Intercept) 5.4796299 0.21489966
beaufort    -0.2095913 0.06594519
```

size 0.5152091 0.16341040

Shape parameters:

	estimate	se
(Intercept)	0.4966405	0.08804302

	Estimate	SE	CV
Average p	0.2987683	0.02050381	0.06862779
N in covered region	1770.6030180	138.21190973	0.07805923

Additional diagnostic plots:

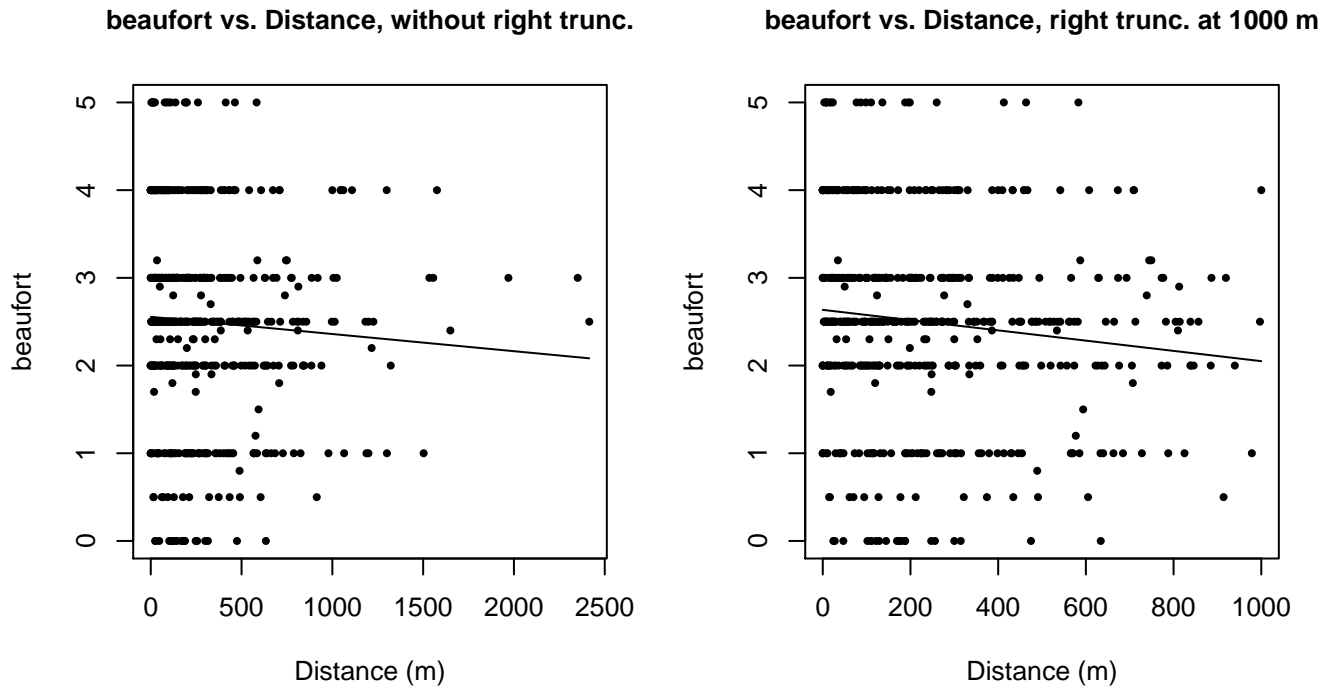


Figure 16: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

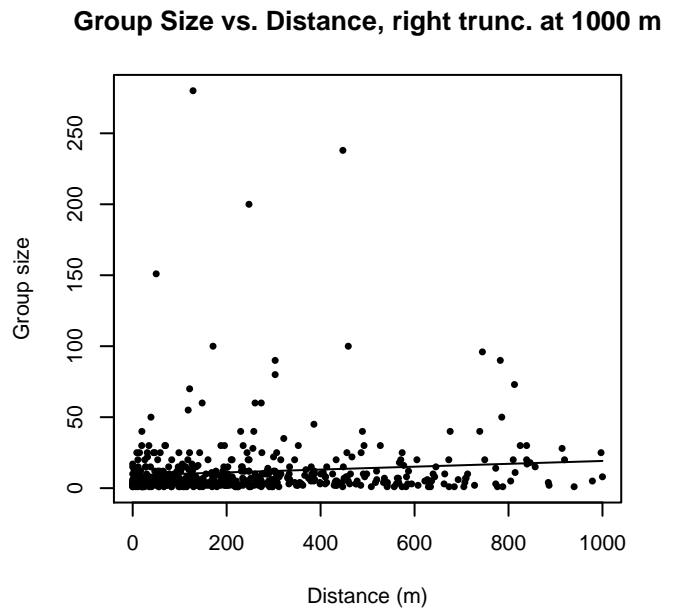
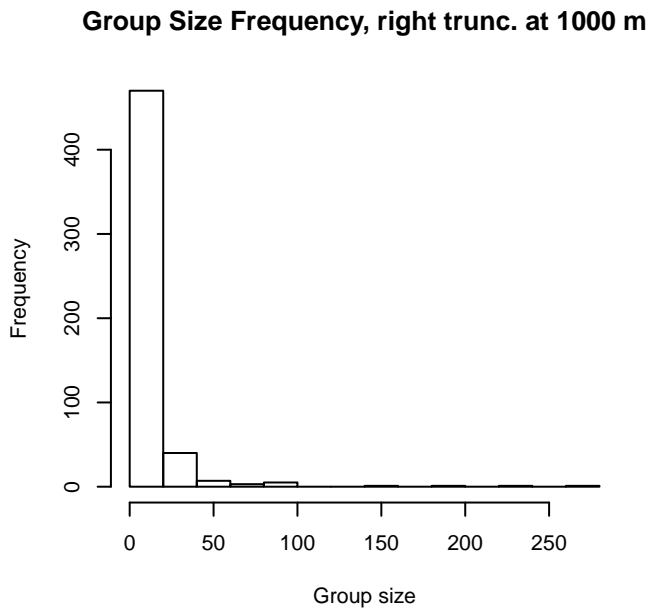
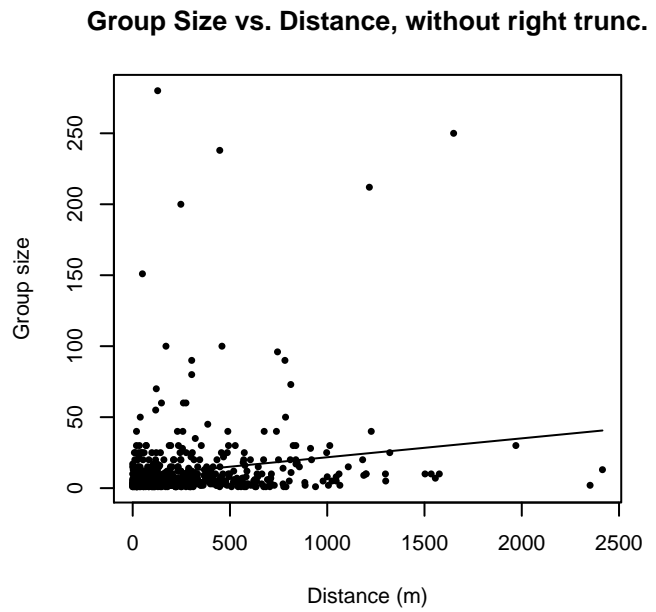
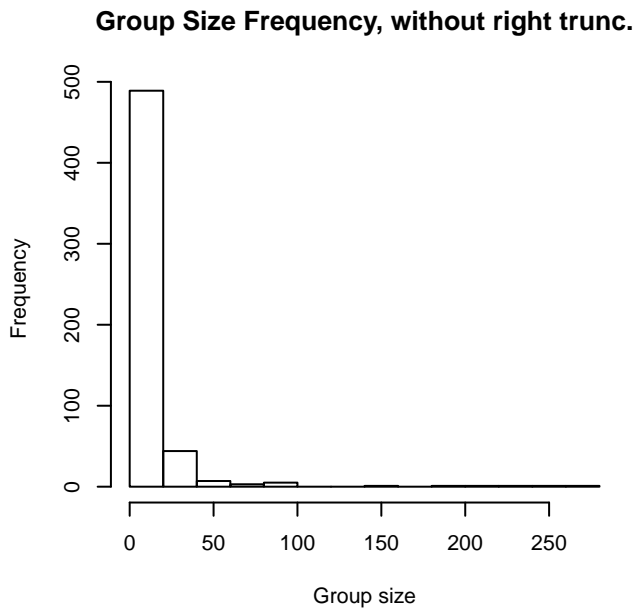


Figure 17: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

CODA and SCANS II

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

Reported By Observer	Common Name	n
<i>Delphinus capensis</i>	Long-beaked common dolphin	0
<i>Delphinus delphis</i>	Short-beaked common dolphin	227

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	57
Grampus griseus	Risso’s dolphin	9
Grampus griseus/Tursiops truncatus	Risso’s or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser’s dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	56
Lagenorhynchus albirostris	White-beaked dolphin	32
Lagenorhynchus albirostris/Lagenorhynchus acutus	White-beaked or white-sided dolphin	4
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	36
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	41
Total		462

Table 11: Proxy species used to fit detection functions for CODA and SCANS II. The number of sightings, n , is before truncation.

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 12: 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	326
hr			quality	Yes	0.85	325
hr	poly	2		Yes	2.85	257
hr			beaufort, size	Yes	3.50	319

hr			beaufort	Yes	4.73	315
hr	poly	4		Yes	5.08	288
hn	cos	2		Yes	5.71	335
hr			size	Yes	6.16	322
hr				Yes	7.78	319
hn	cos	3		Yes	15.49	324
hn			quality, size	Yes	21.34	416
hn			beaufort, size	Yes	22.76	417
hn			beaufort, quality, size	Yes	23.17	416
hn			quality	Yes	25.50	413
hn			size	Yes	26.46	418
hn			beaufort, quality	Yes	27.47	413
hn			beaufort	Yes	28.47	414
hn				Yes	32.88	414
hn	herm	4		Yes	34.17	413
hr			beaufort, quality	No		
hr			beaufort, quality, size	No		

Table 13: Candidate detection functions for CODA and SCANS II. The first one listed was selected for the density model.

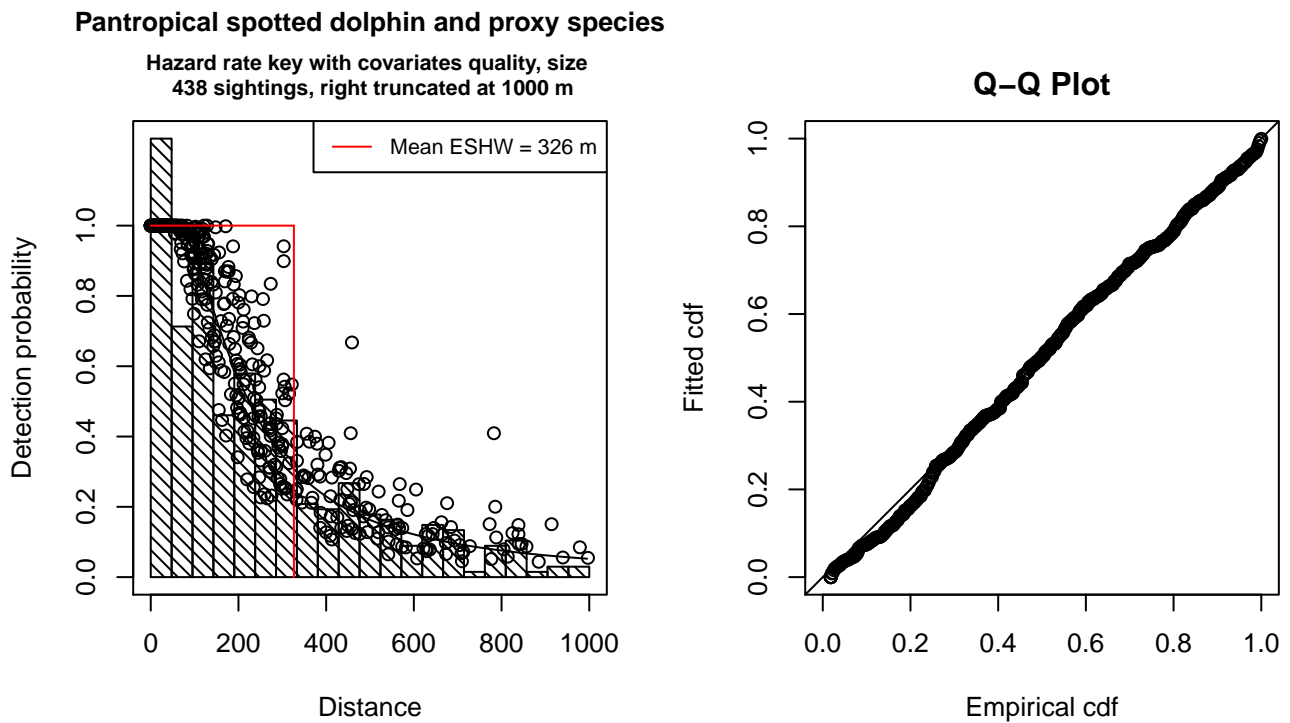


Figure 18: Detection function for CODA and SCANS II that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 438
Distance range : 0 - 1000
AIC : 5674.066

Detection function:

Hazard-rate key function

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	5.4624136	0.17286880
quality	-0.1426257	0.05036964
size	0.2194236	0.11538504

Shape parameters:

	estimate	se
(Intercept)	0.5741026	0.09733169

	Estimate	SE	CV
Average p	0.3097732	0.02170451	0.07006582
N in covered region	1413.9378602	114.19755693	0.08076561

Additional diagnostic plots:

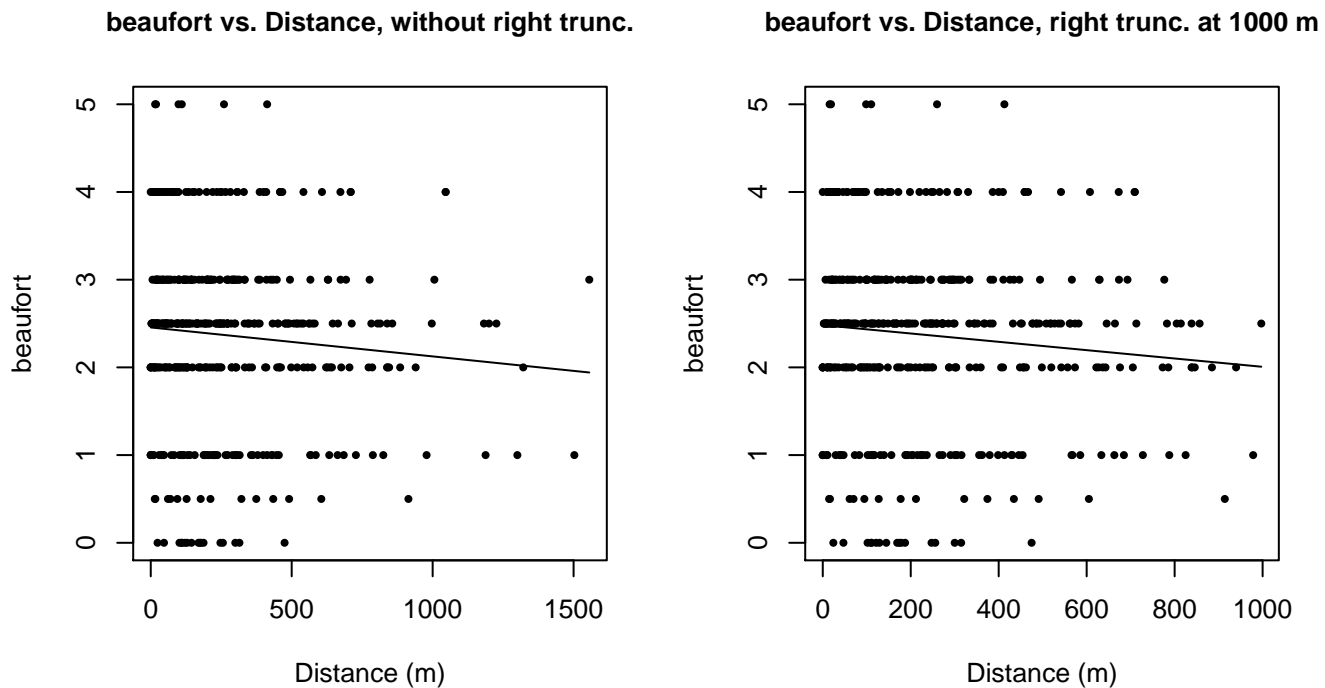
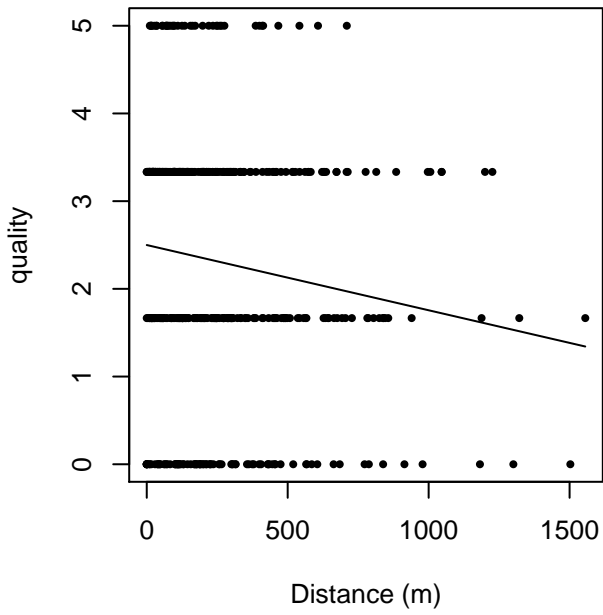


Figure 19: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 1000 m

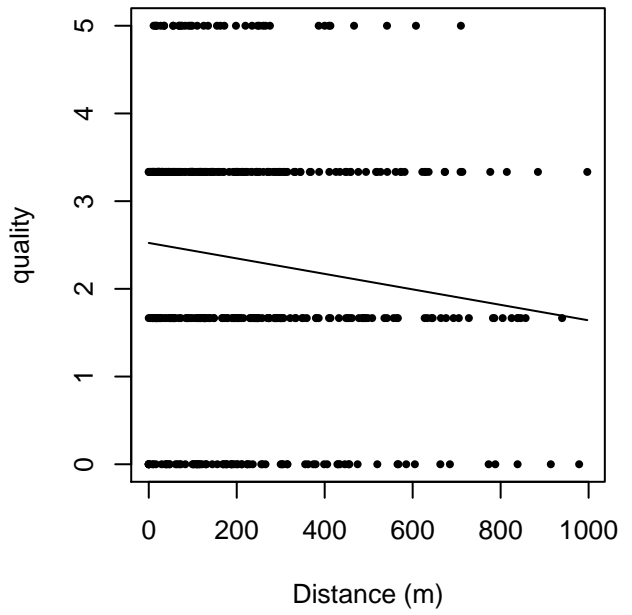
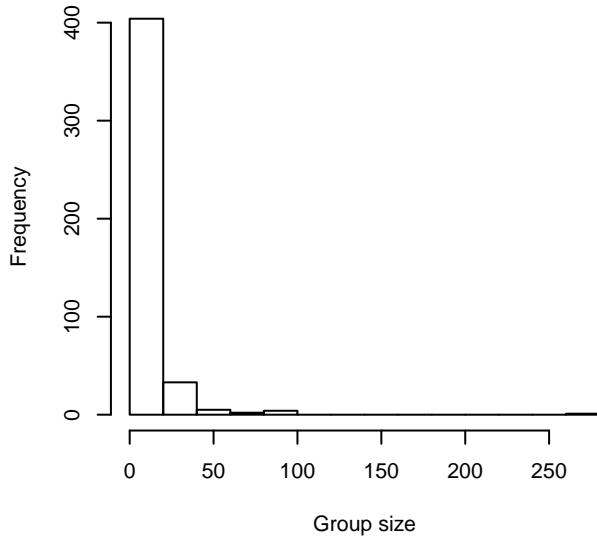
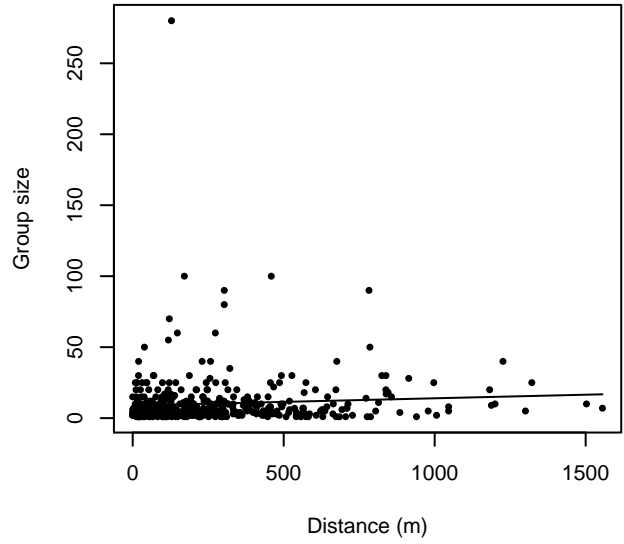


Figure 20: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

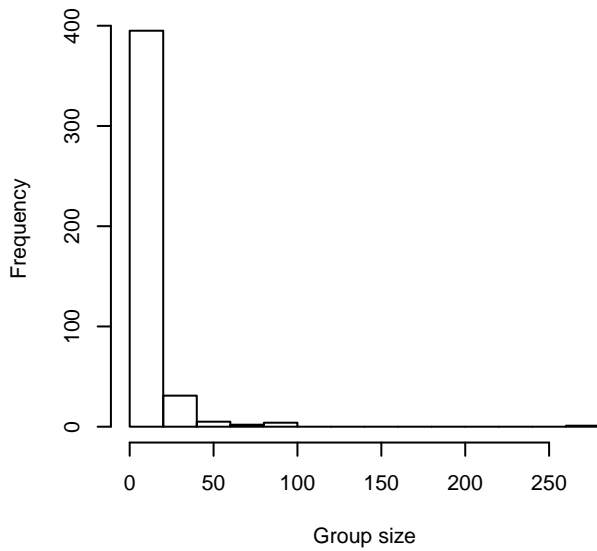
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 1000 m



Group Size vs. Distance, right trunc. at 1000 m

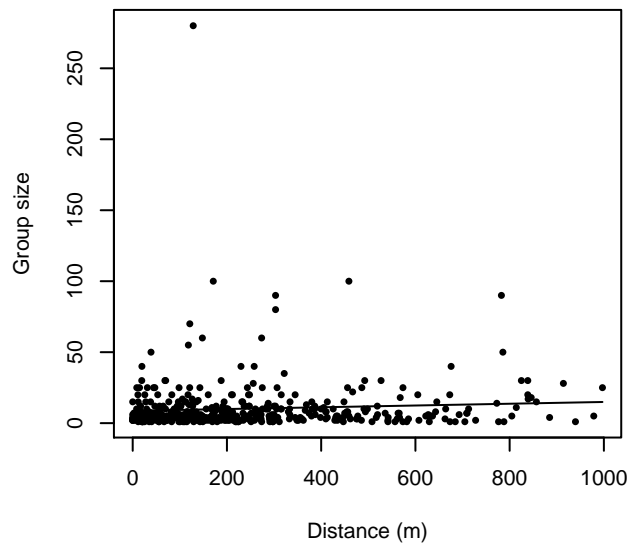


Figure 21: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Aerial Surveys

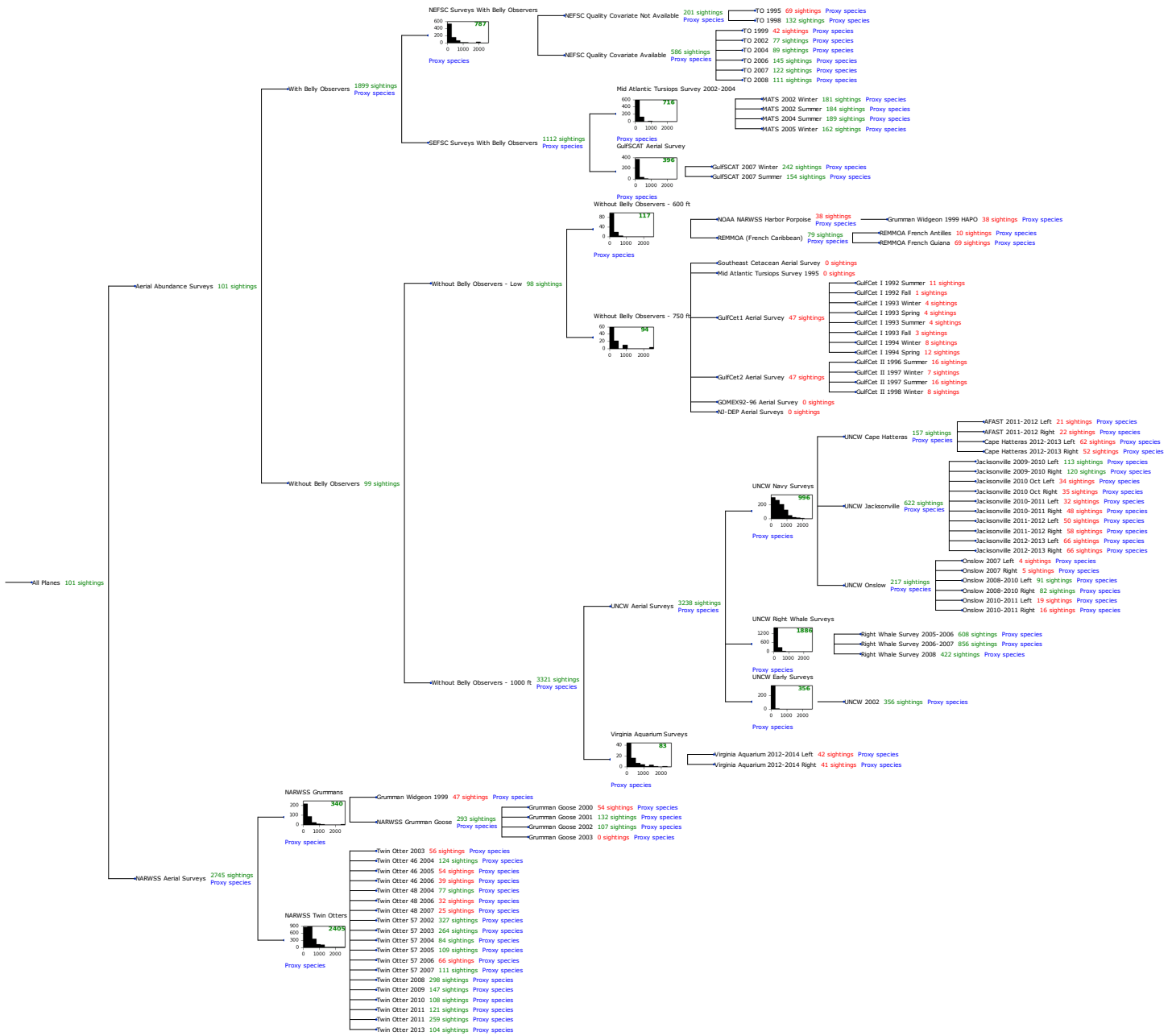


Figure 22: Detection hierarchy for aerial surveys

NEFSC Surveys With Belly Observers

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	311
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	148
Grampus griseus/Tursiops truncatus	Risso’s or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser’s dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	220
Lagenorhynchus albirostris	White-beaked dolphin	5
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	2
Stenella frontalis	Atlantic spotted dolphin	2
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	99
Total		787

Table 14: Proxy species used to fit detection functions for NEFSC Surveys With Belly Observers. The number of sightings, n , is before truncation.

The sightings were right truncated at 1000m.

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

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

Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			size	Yes	0.00	380
hr	poly	4		Yes	18.20	354
hr				Yes	20.16	359
hr	poly	2		Yes	20.32	350
hn	cos	2		Yes	20.44	311
hn			size	Yes	25.50	370
hn	cos	3		Yes	37.76	322

hn			Yes	43.60	364
hn	herm	4	Yes	45.08	363
hr		beaufort	No		
hn		beaufort	No		
hr		beaufort, size	No		
hn		beaufort, size	No		

Table 16: Candidate detection functions for NEFSC Surveys With Belly Observers. The first one listed was selected for the density model.

Pantropical spotted dolphin and proxy species

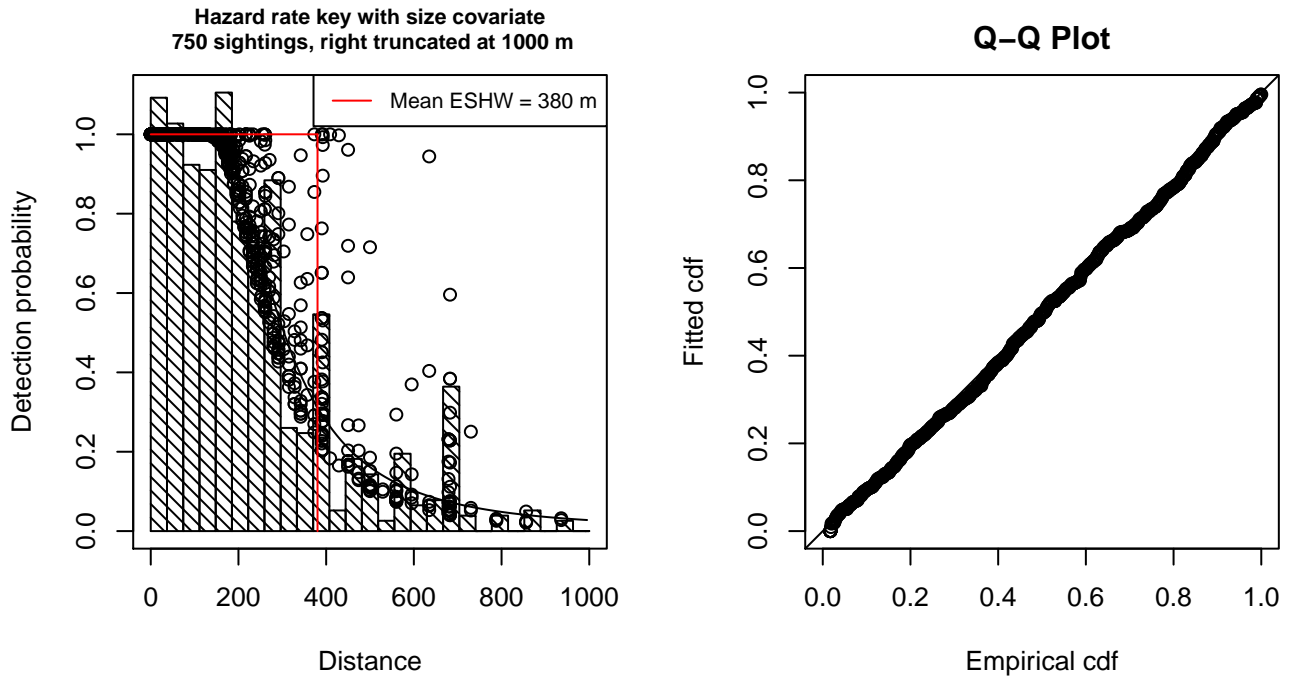


Figure 23: Detection function for NEFSC Surveys With Belly Observers that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations : 750
Distance range       : 0 - 1000
AIC                  : 9547.646
```

```
Detection function:
Hazard-rate key function
```

```
Detection function parameters
Scale Coefficients:
      estimate      se
(Intercept) 5.4723464 0.05875051
size       0.4895925 0.09092657
```


Shape parameters:

	estimate	se
(Intercept)	1.119282	0.06987517

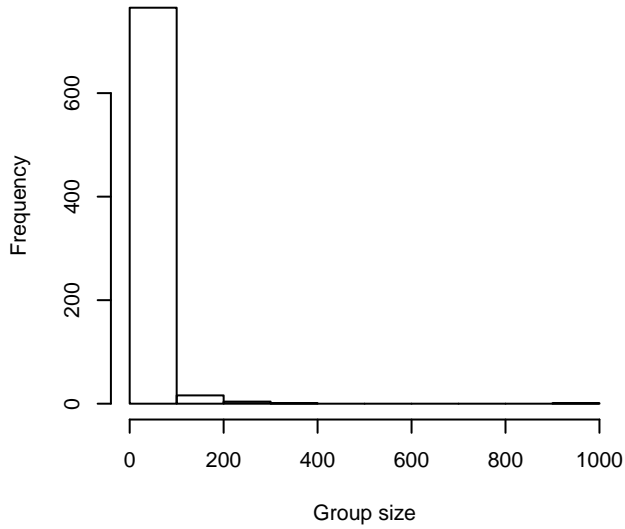
	Estimate	SE	CV
Average p	0.3611704	0.01276499	0.03534340
N in covered region	2076.5823459	95.75938663	0.04611394

Additional diagnostic plots:

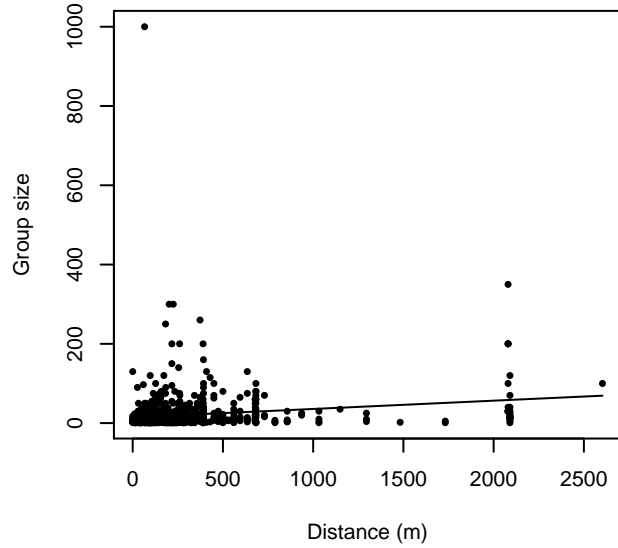


Figure 24: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

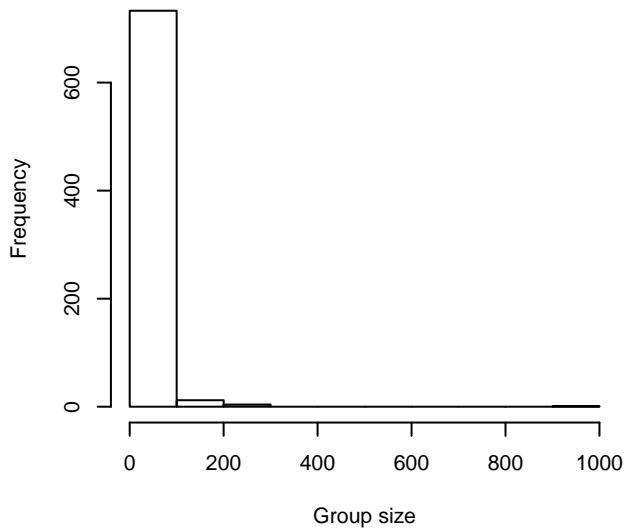
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 1000 m



Group Size vs. Distance, right trunc. at 1000 m

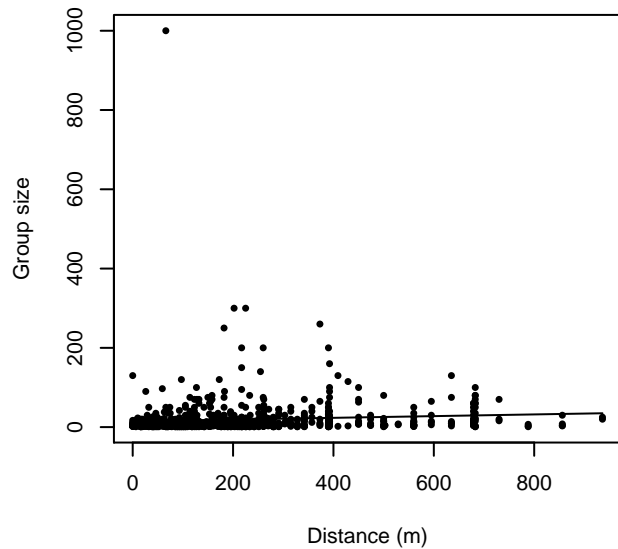


Figure 25: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Mid Atlantic Tursiops Survey 2002-2004

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	3

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	4
Stenella attenuata	Pantropical spotted dolphin	2
Stenella attenuata/frontalis	Pantropical or Atlantic spotted dolphin	0
Stenella clymene	Clymene dolphin	1
Stenella coeruleoalba	Striped dolphin	0
Stenella frontalis	Atlantic spotted dolphin	107
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	599
Total		716

Table 17: Proxy species used to fit detection functions for Mid Atlantic Tursiops Survey 2002-2004. 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 18: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

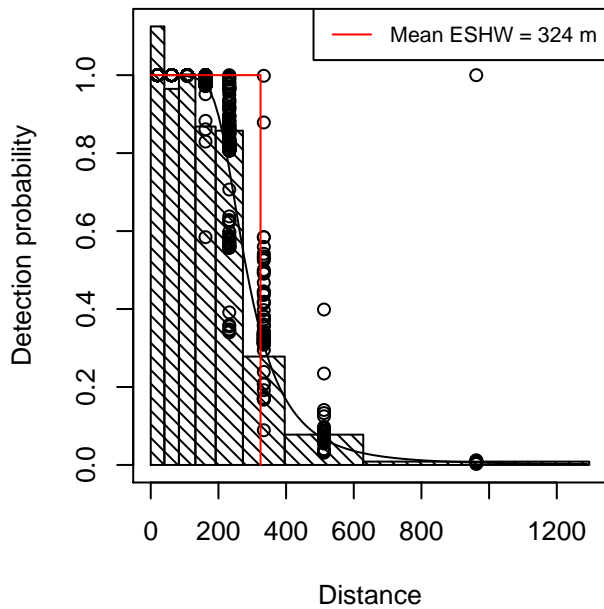
Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hr			beaufort, size	Yes	0.00	324
hr			beaufort	Yes	7.23	320
hr			size	Yes	15.09	325

hr				Yes	19.48	320
hr	poly	4		Yes	21.50	320
hn			beaufort, size	Yes	24.61	291
hn			beaufort, quality, size	Yes	26.60	291
hn	cos	2		Yes	30.32	279
hn			beaufort	Yes	31.08	289
hn			beaufort, quality	Yes	33.08	289
hn			size	Yes	40.66	292
hn	cos	3		Yes	41.28	267
hn			quality, size	Yes	42.57	292
hn				Yes	44.74	289
hn			quality	Yes	46.65	289
hn	herm	4		Yes	46.67	289
hr	poly	2		No		
hr			quality	No		
hr			beaufort, quality	No		
hr			quality, size	No		
hr			beaufort, quality, size	No		

Table 19: Candidate detection functions for Mid Atlantic Tursiops Survey 2002-2004. The first one listed was selected for the density model.

Pantropical spotted dolphin and proxy species

Hazard rate key with covariates beaufort, size
715 sightings, right truncated at 1296 m



Q-Q Plot

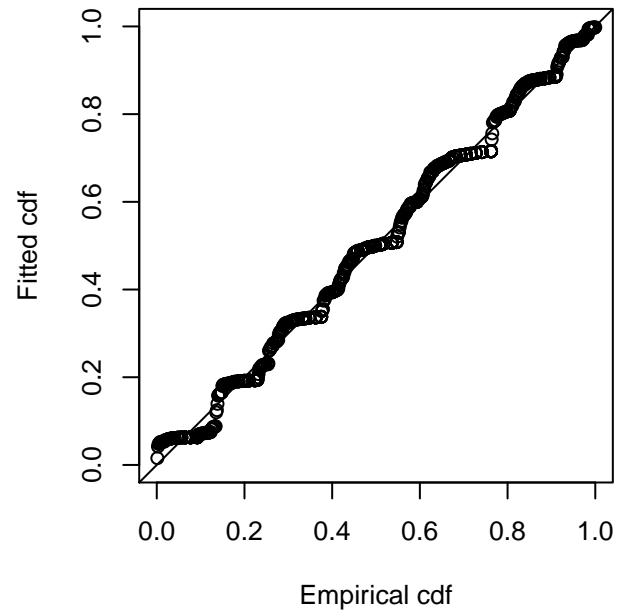


Figure 26: Detection function for Mid Atlantic Tursiops Survey 2002-2004 that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 715
Distance range : 0 - 1296
AIC : 2772.63

Detection function:

Hazard-rate key function

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	5.7365141	0.06710784
beaufort	-0.1711703	0.03981217
size	0.3005678	0.11350774

Shape parameters:

	estimate	se
(Intercept)	1.410097	0.06849596

	Estimate	SE	CV
Average p	0.2428843	7.461501e-03	0.03072039
N in covered region	2943.7878981	1.320799e+02	0.04486732

Additional diagnostic plots:

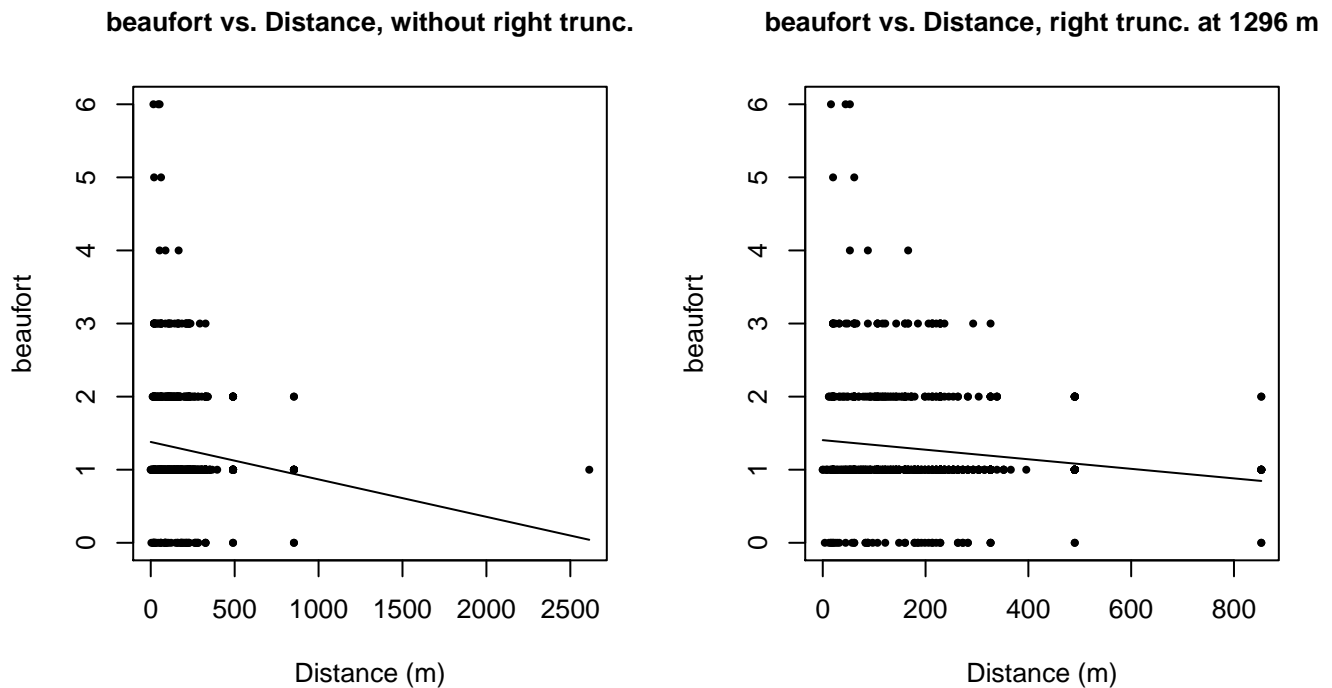
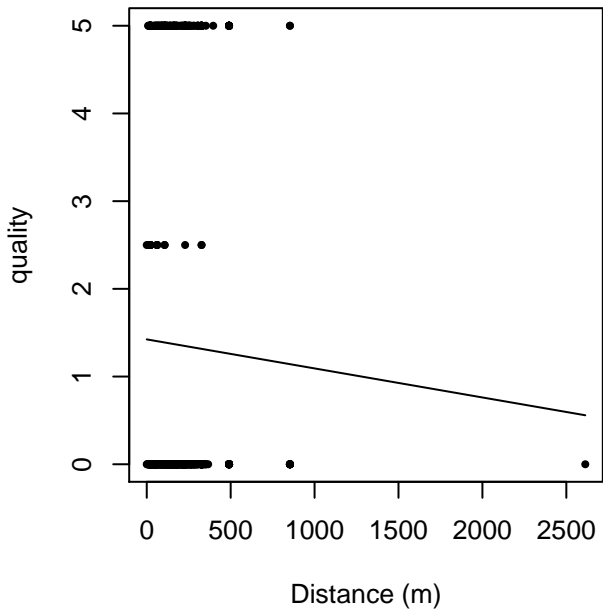


Figure 27: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 1296 m

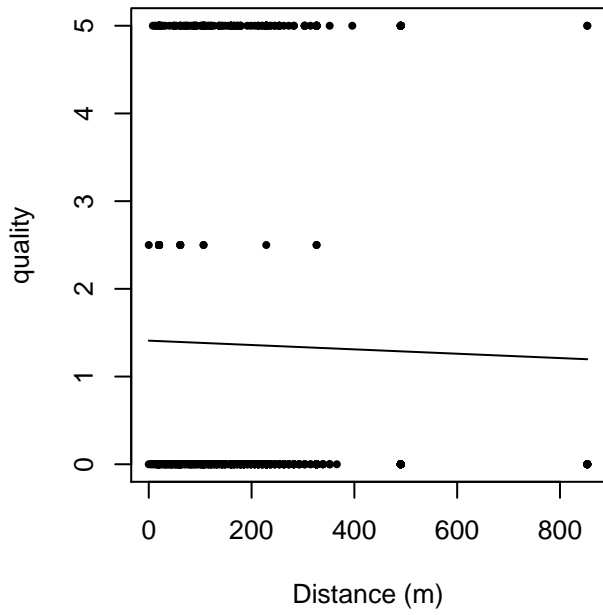


Figure 28: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

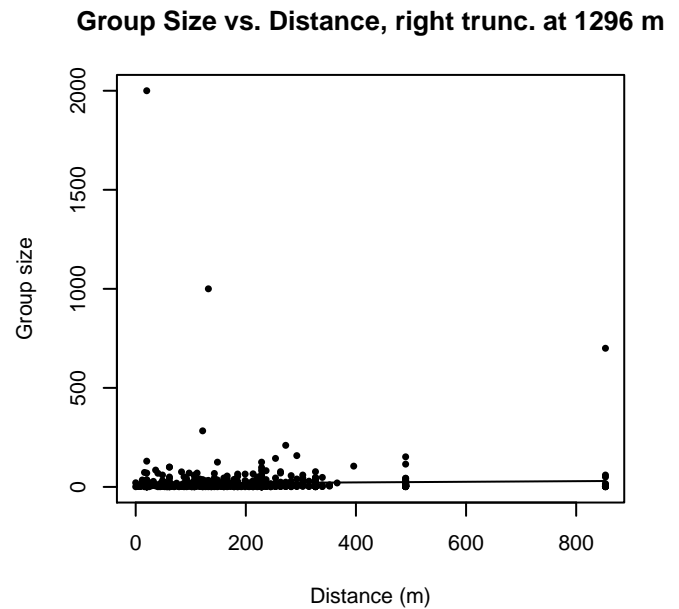
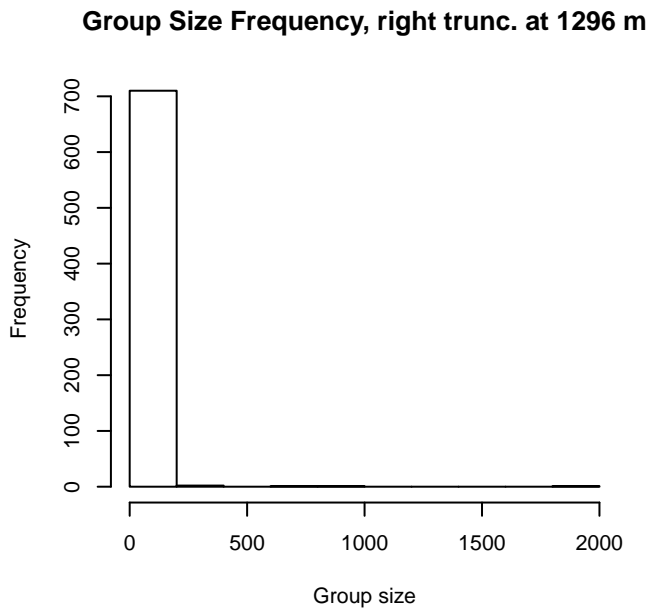
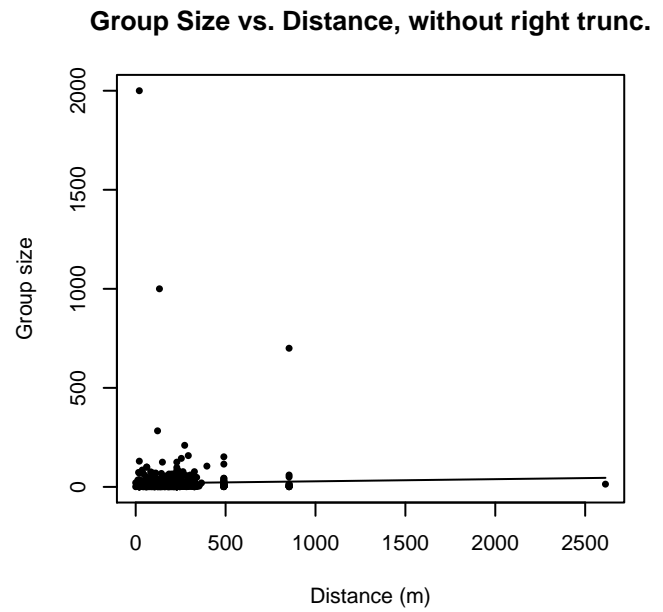
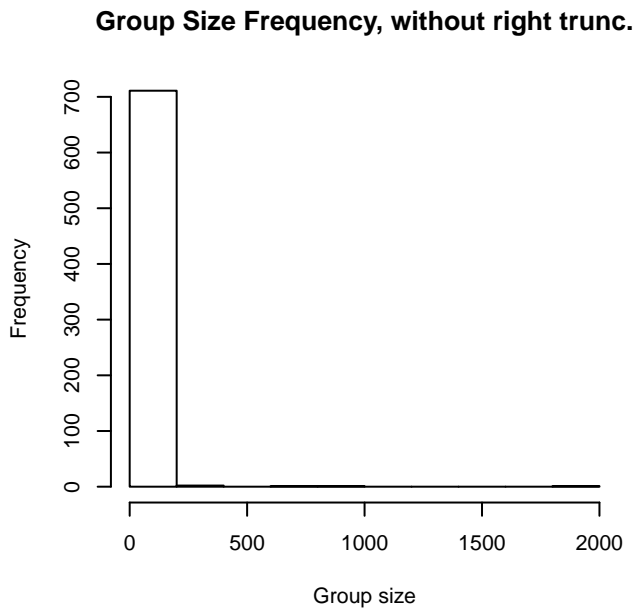


Figure 29: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

GulfSCAT 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	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	15
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	381
Total		396

Table 20: Proxy species used to fit detection functions for GulfSCAT Aerial Survey. The number of sightings, n , is before truncation.

The sightings were right truncated at 400m.

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

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

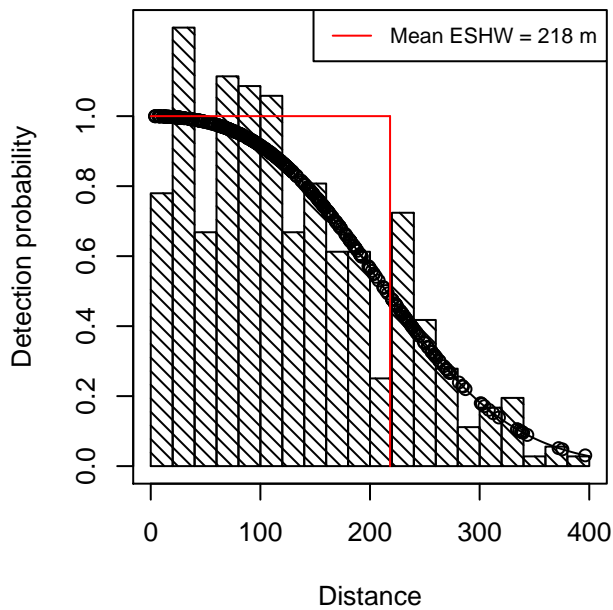
Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn	herm	4		Yes	0.00	218
hn	cos	2		Yes	0.09	221
hn				Yes	0.90	199
hn			size	Yes	2.21	199

hn	cos	3	Yes	2.37	209
hr	poly	2	Yes	2.39	218
hr	poly	4	Yes	2.47	223
hr			Yes	4.46	230
hr		size	Yes	5.04	232
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 22: Candidate detection functions for GulfSCAT Aerial Survey. The first one listed was selected for the density model.

Pantropical spotted dolphin and proxy species

Half-normal key with 4th order Hermite polynomial adj.
392 sightings, right truncated at 400 m



Q-Q Plot

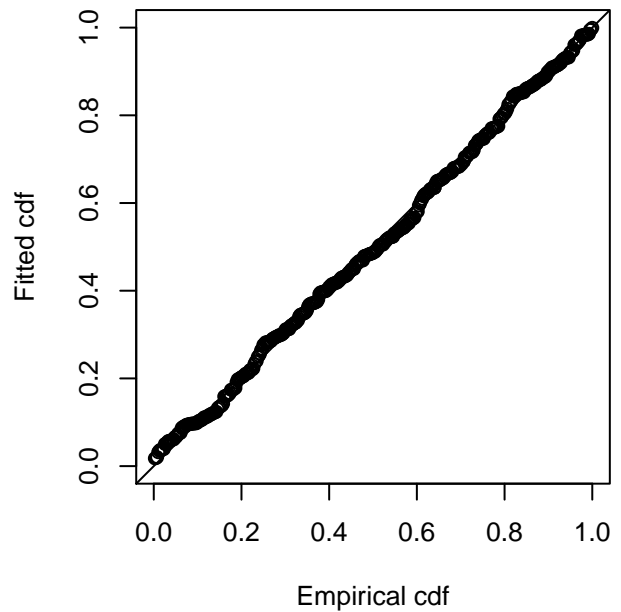


Figure 30: Detection function for GulfSCAT Aerial Survey that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 392
Distance range : 0 - 400
AIC : 4505.917

Detection function:

Half-normal key function with Hermite polynomial adjustment term of order 4

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	4.855658	0.0741652

Adjustment term parameter(s):

	estimate	se
herm, order 4	-0.04125642	0.01270664

Monotonicity constraints were enforced.

	Estimate	SE	CV
Average p	0.5457537	0.04201324	0.07698205
N in covered region	718.2727866	60.45889329	0.08417261

Monotonicity constraints were enforced.

Additional diagnostic plots:

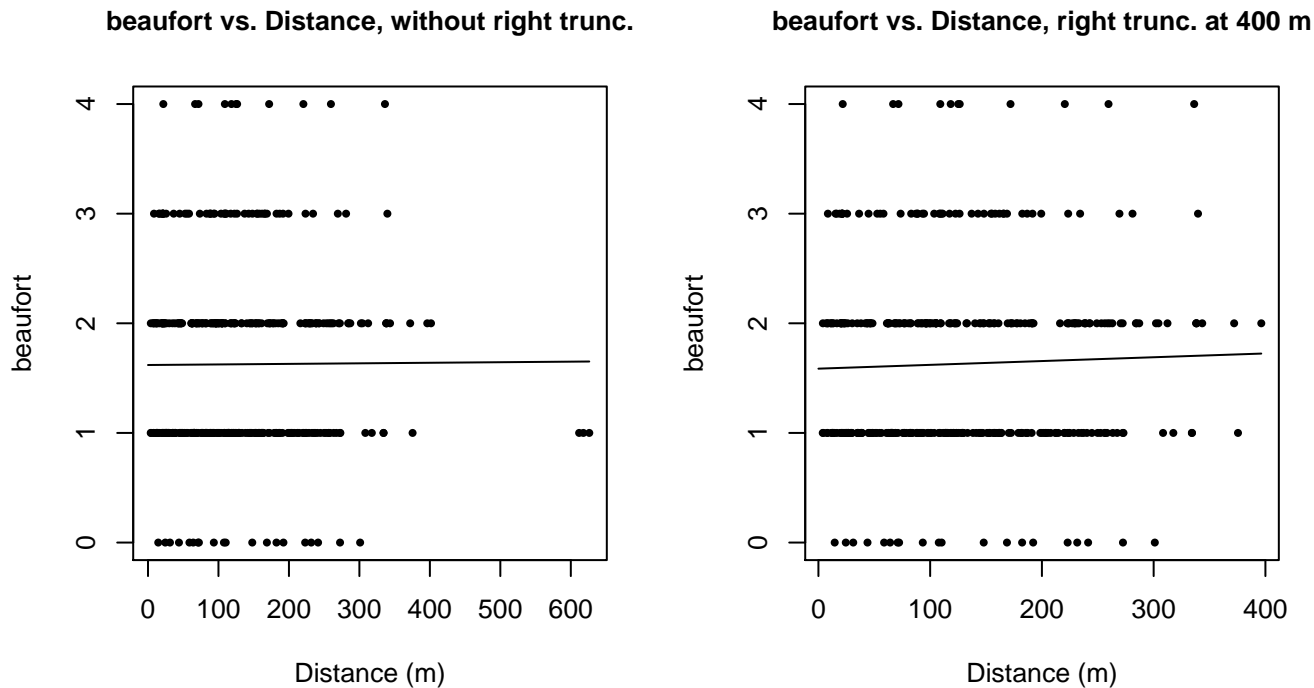
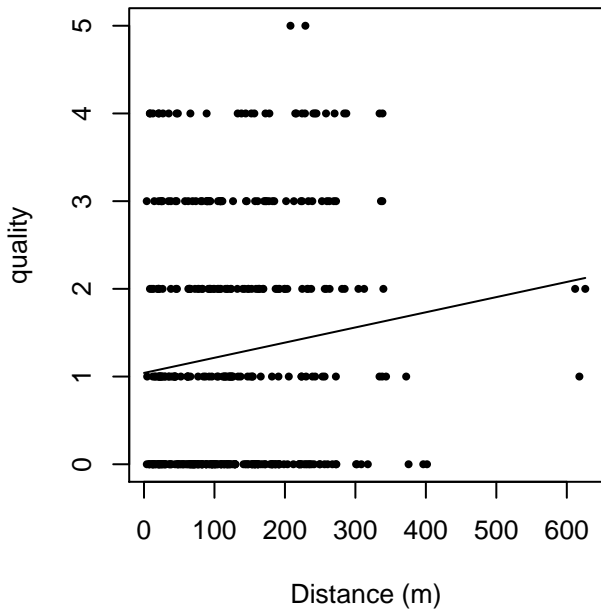


Figure 31: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 400 m

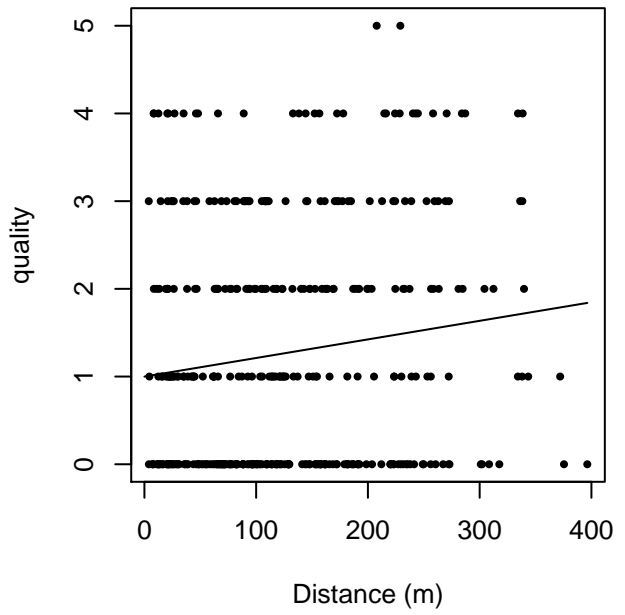


Figure 32: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

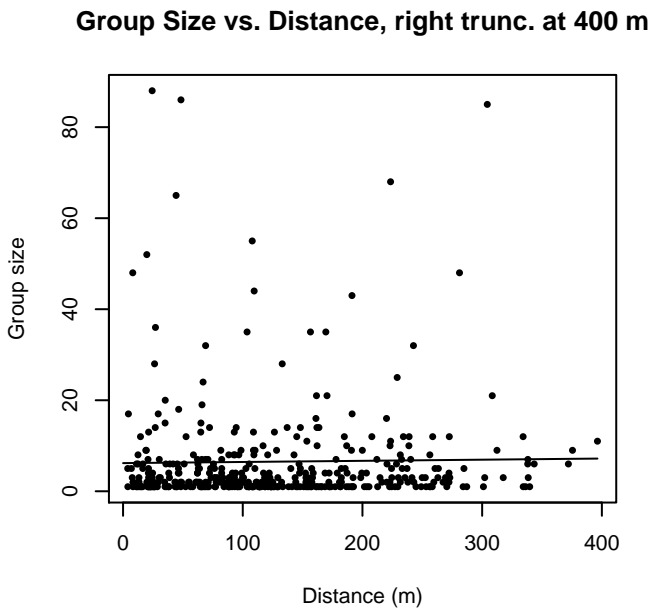
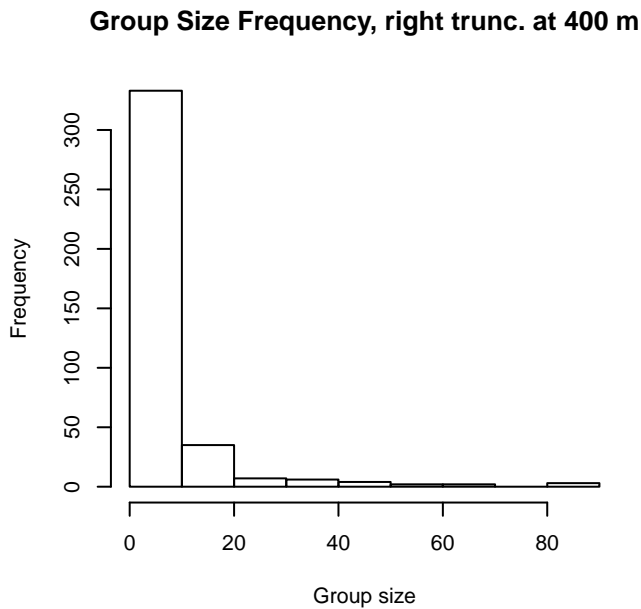
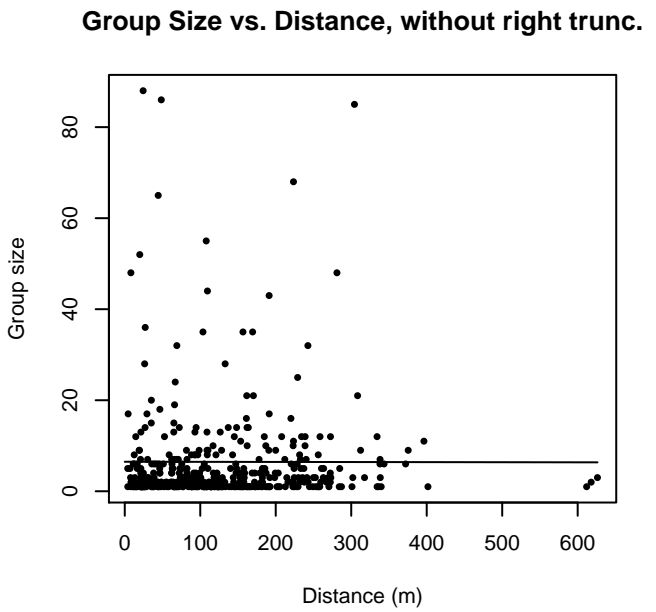
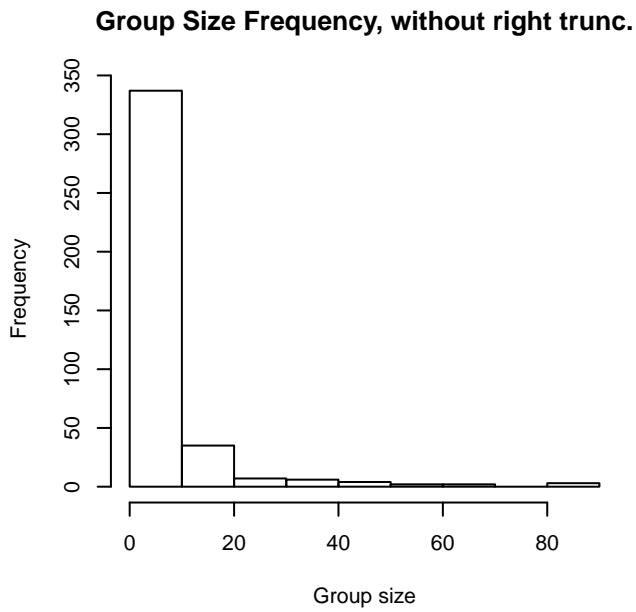


Figure 33: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 23: 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 24: 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 25: Candidate detection functions for Without Belly Observers - 600 ft. The first one listed was selected for the density model.

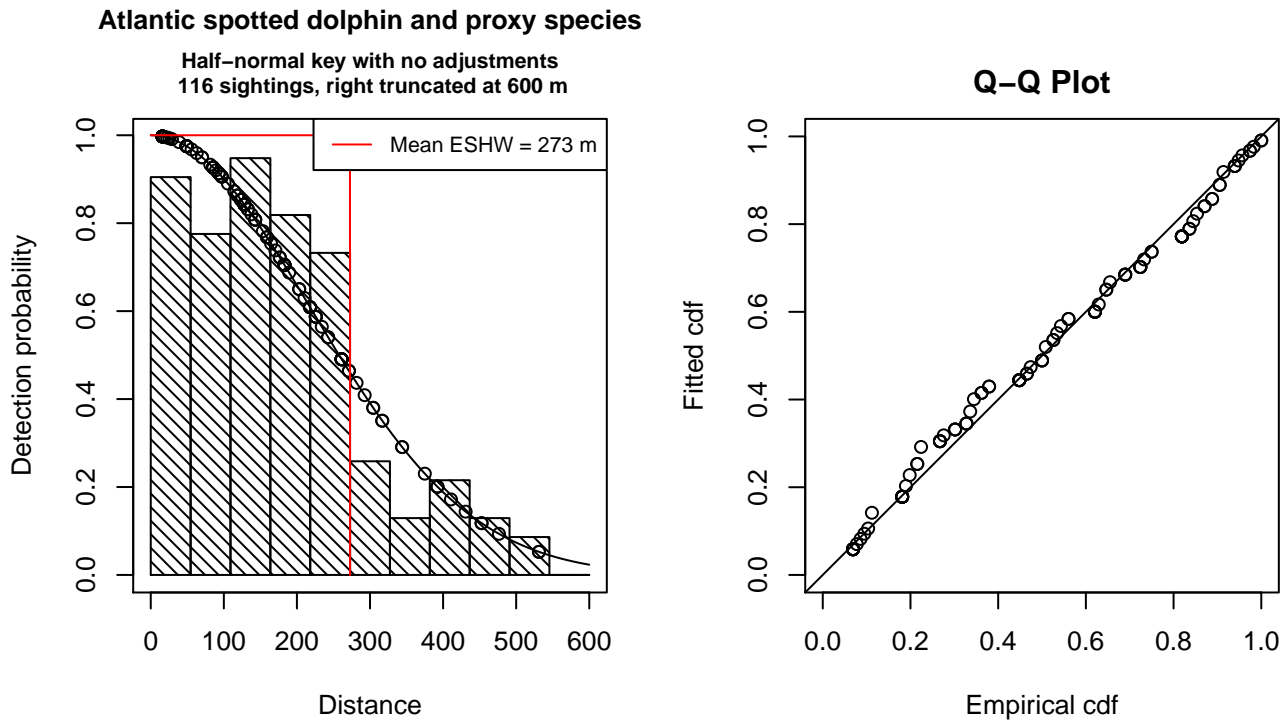


Figure 34: Detection function for Without Belly Observers - 600 ft that was selected for the density model

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:

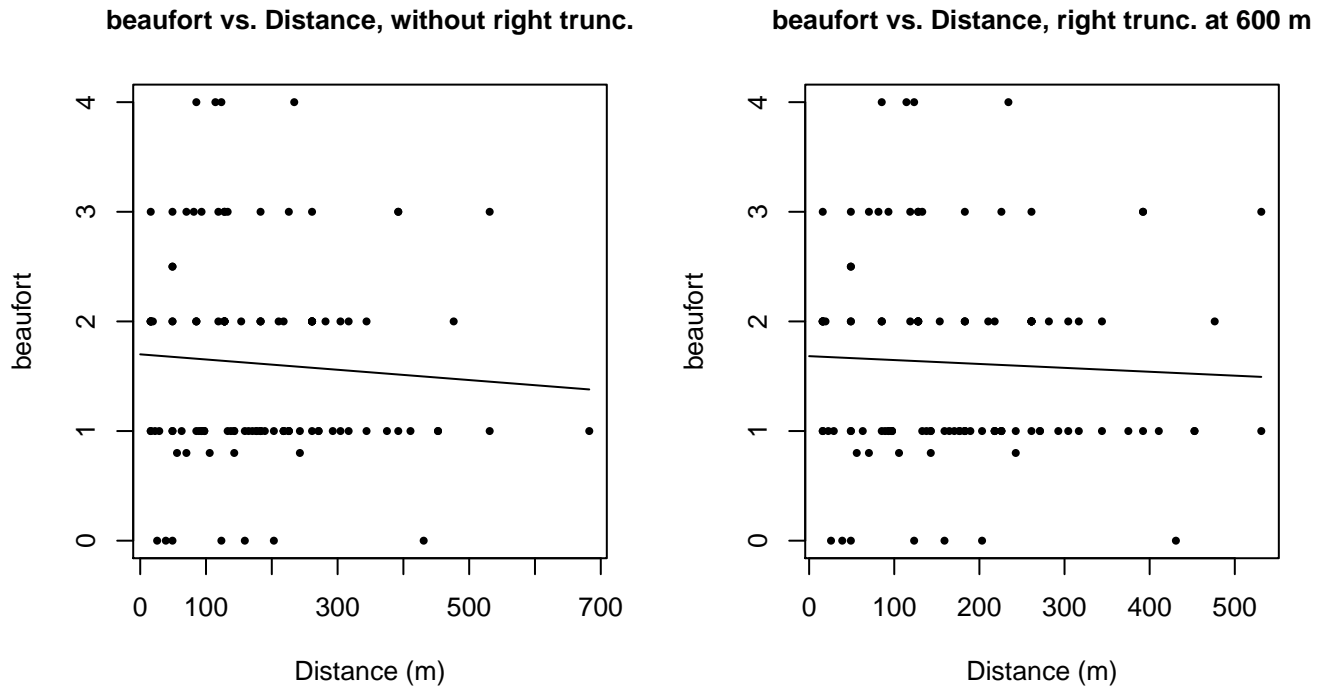
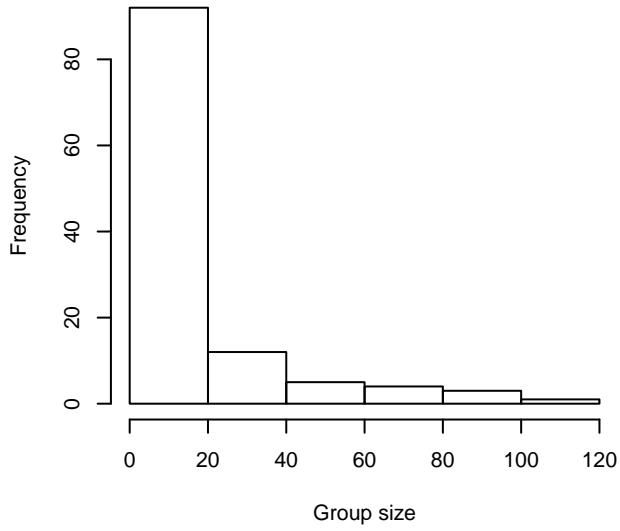
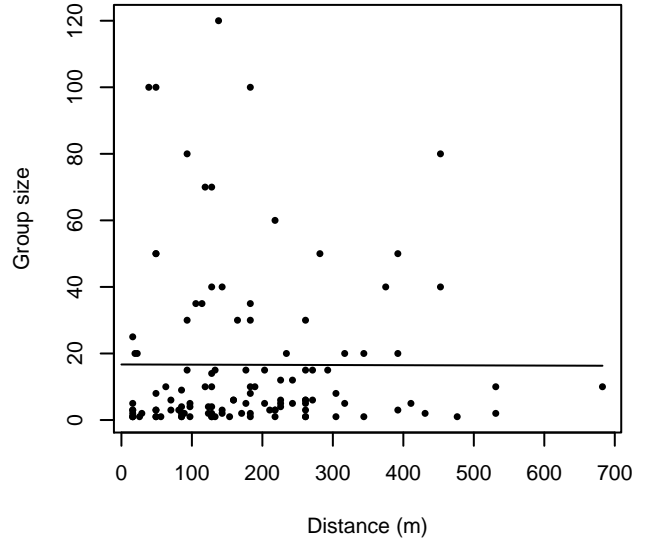


Figure 35: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

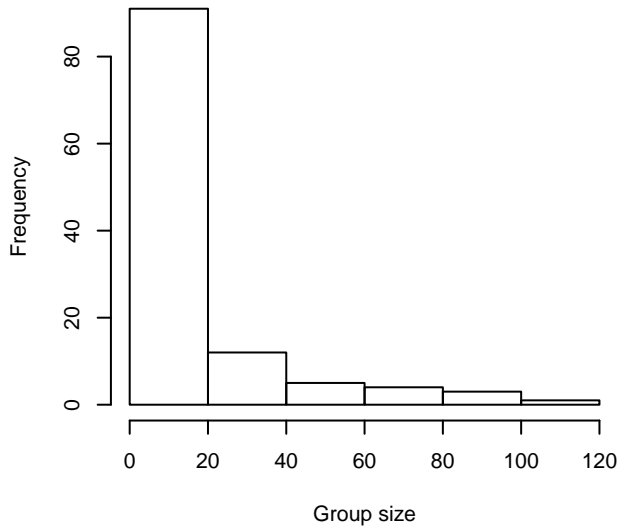
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 600 m



Group Size vs. Distance, right trunc. at 600 m

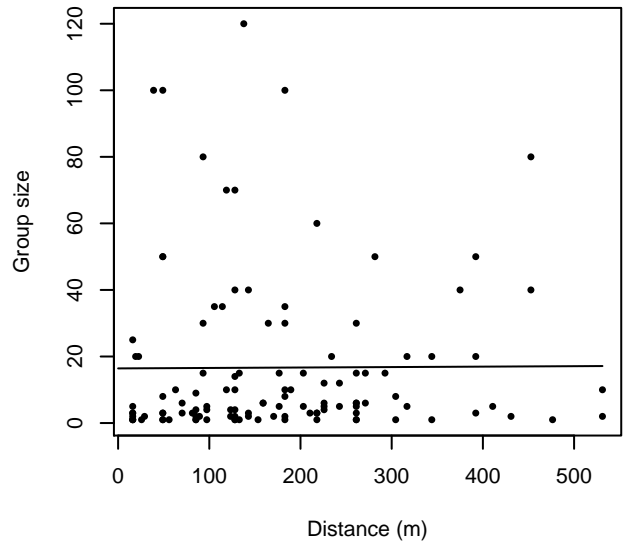


Figure 36: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

Without Belly Observers - 750 ft

The sightings were right truncated at 900m.

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				Yes	0.00	385
hr			size	Yes	0.66	398
hn	cos	2		Yes	1.33	340
hr	poly	2		Yes	2.00	385
hr	poly	4		Yes	2.62	358
hn			size	Yes	10.29	486
hn			beaufort, size	Yes	11.10	501
hn				Yes	11.72	481
hn			quality, size	Yes	12.19	487
hn	cos	3		Yes	12.60	506
hn			beaufort, quality, size	Yes	12.84	502
hn	herm	4		Yes	13.03	479
hn			beaufort	Yes	13.51	481
hr			beaufort	No		
hn			quality	No		
hr			quality	No		
hn			beaufort, quality	No		
hr			beaufort, quality	No		
hr			beaufort, size	No		
hr			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.

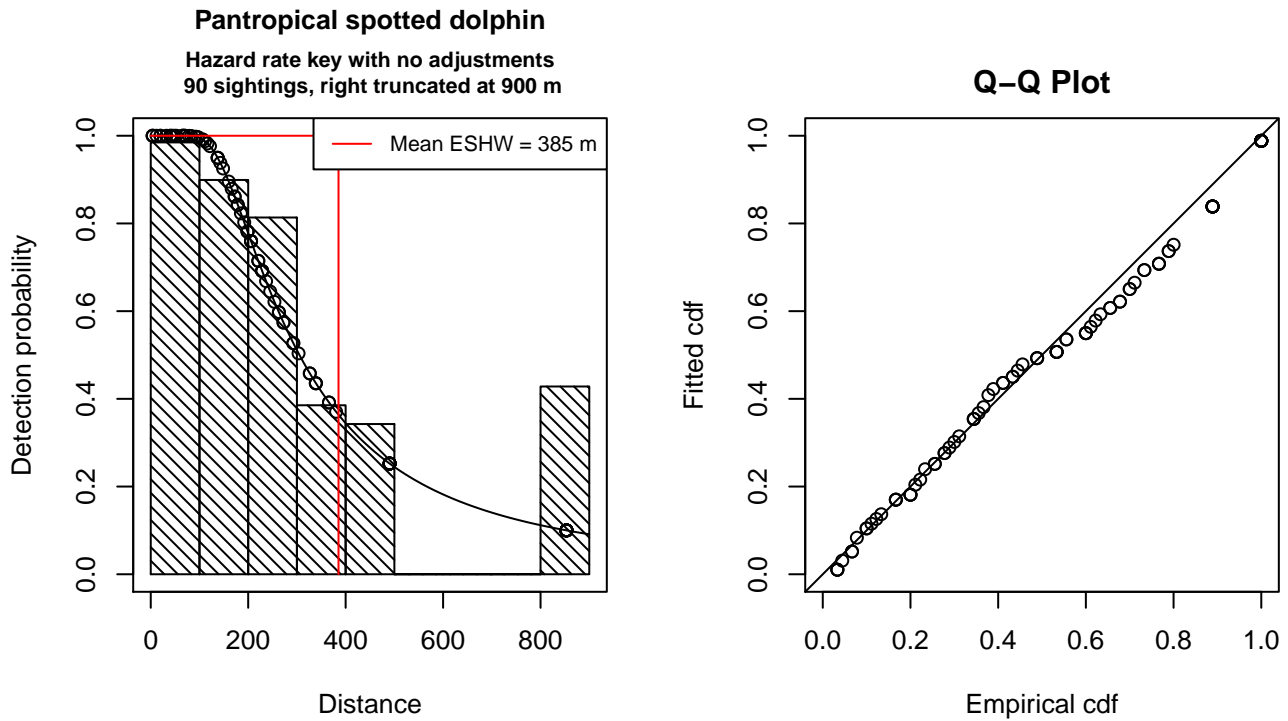


Figure 37: Detection function for Without Belly Observers - 750 ft that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 90
 Distance range : 0 - 900
 AIC : 1179.815

Detection function:
 Hazard-rate key function

Detection function parameters
 Scale Coefficients:
 estimate se
 (Intercept) 5.520789 0.2463792

Shape parameters:
 estimate se
 (Intercept) 0.605147 0.2145303

	Estimate	SE	CV
Average p	0.4281779	0.06414965	0.1498201
N in covered region	210.1929997	35.67070764	0.1697045

Additional diagnostic plots:

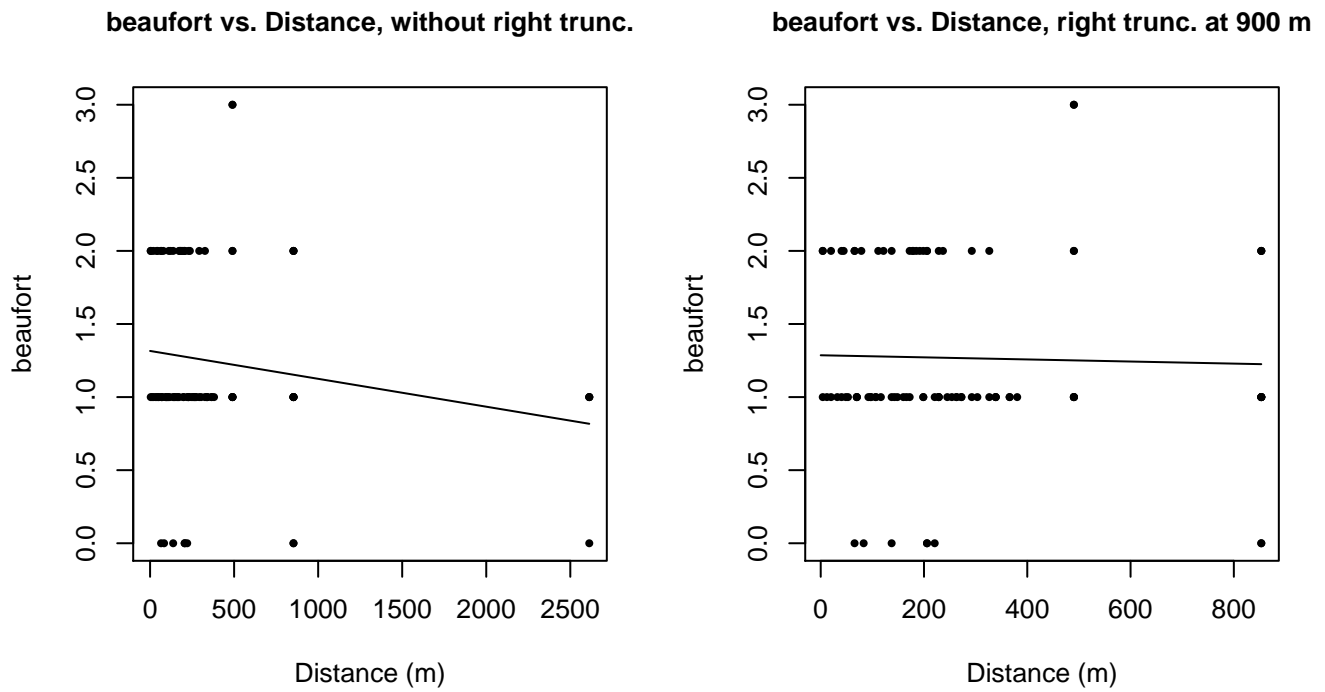


Figure 38: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

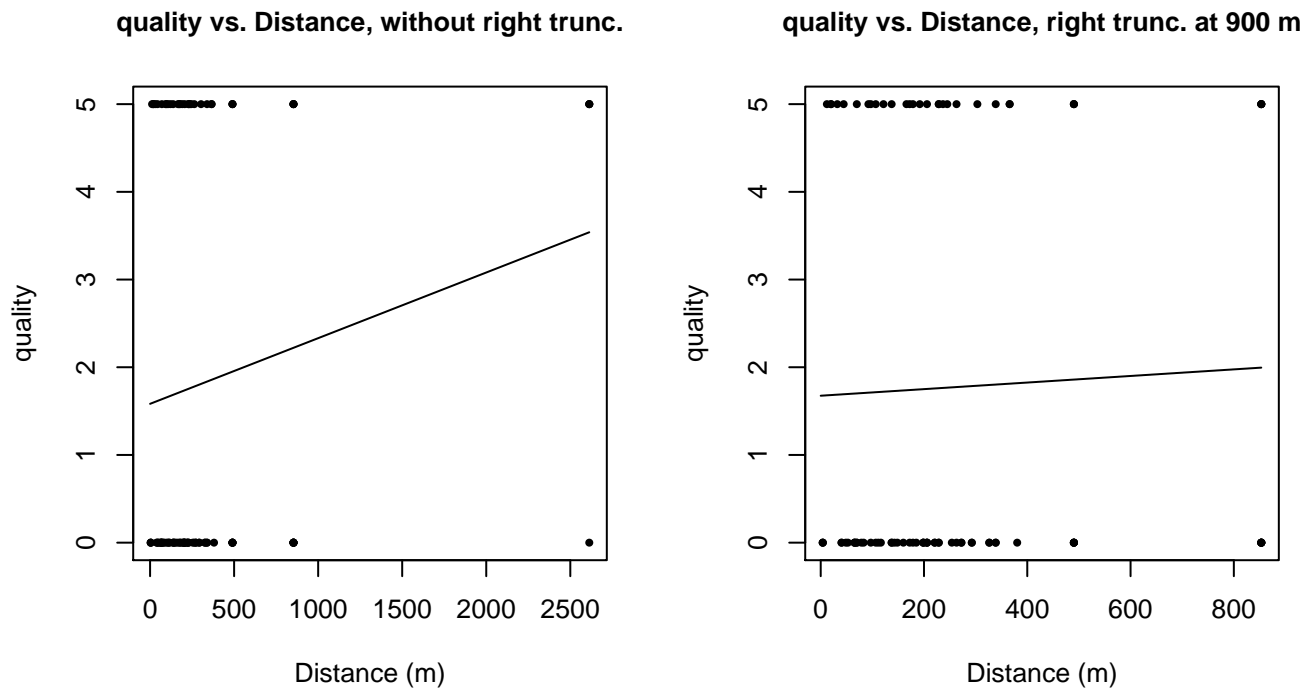
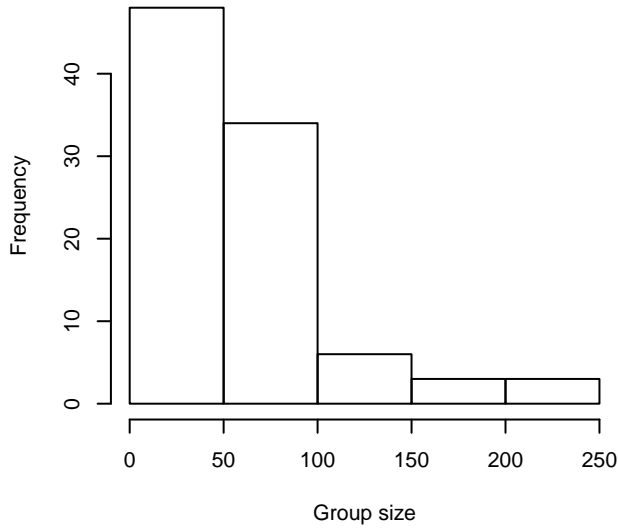
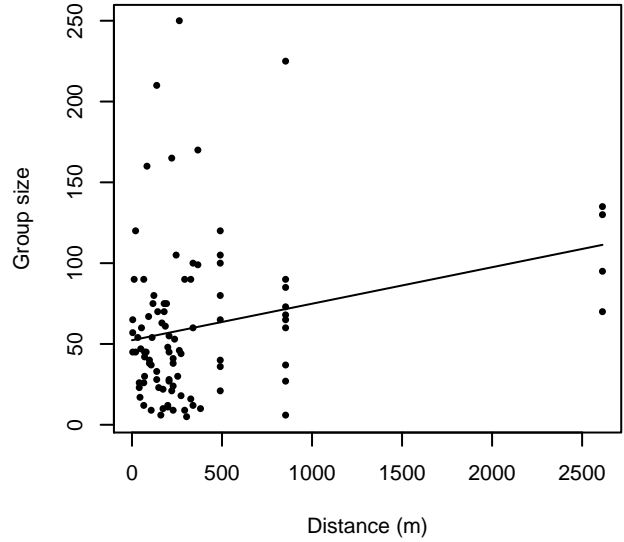


Figure 39: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

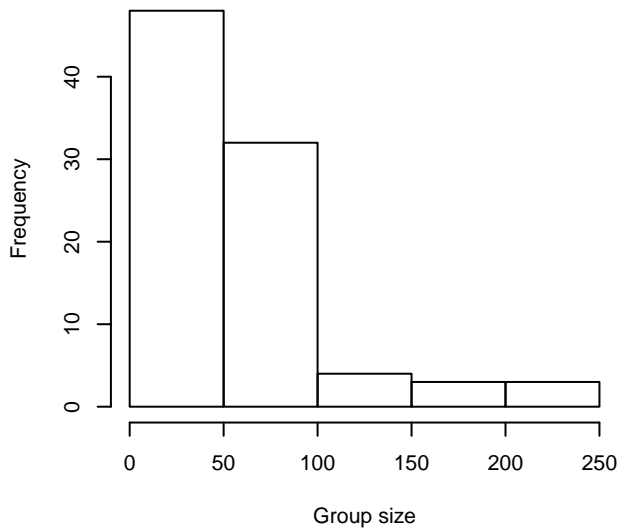
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 900 m



Group Size vs. Distance, right trunc. at 900 m

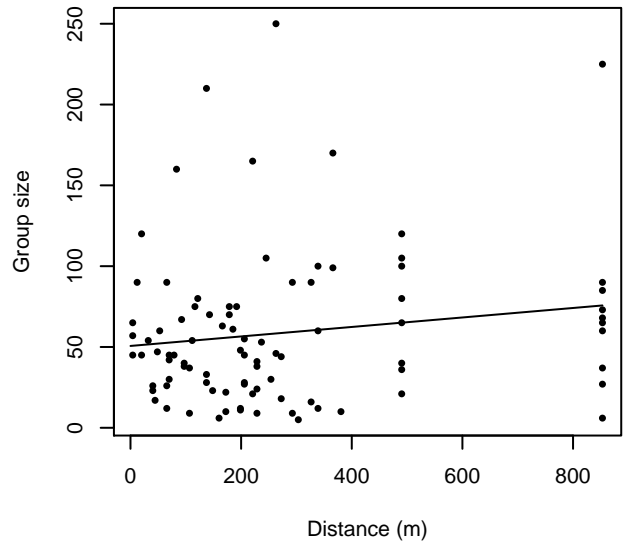


Figure 40: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 28: 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 29: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

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

hn	herm	4		Yes	5.14	794
hn	cos	2		Yes	6.16	795
hn				Yes	6.29	753
hn			quality	Yes	7.21	753
hn	cos	3		Yes	8.04	736
hn			beaufort	Yes	8.22	753
hn			beaufort, quality	Yes	9.12	753
hr	poly	4		Yes	9.77	841
hr			size	Yes	10.21	901
hr			quality, size	Yes	10.93	900
hr			beaufort, size	Yes	12.21	901
hr			beaufort, quality, size	Yes	12.93	900
hr				Yes	16.65	887
hr			quality	Yes	17.68	886
hr	poly	2		Yes	18.65	887
hr			beaufort	No		
hr			beaufort, quality	No		

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

Pantropical spotted dolphin and proxy species

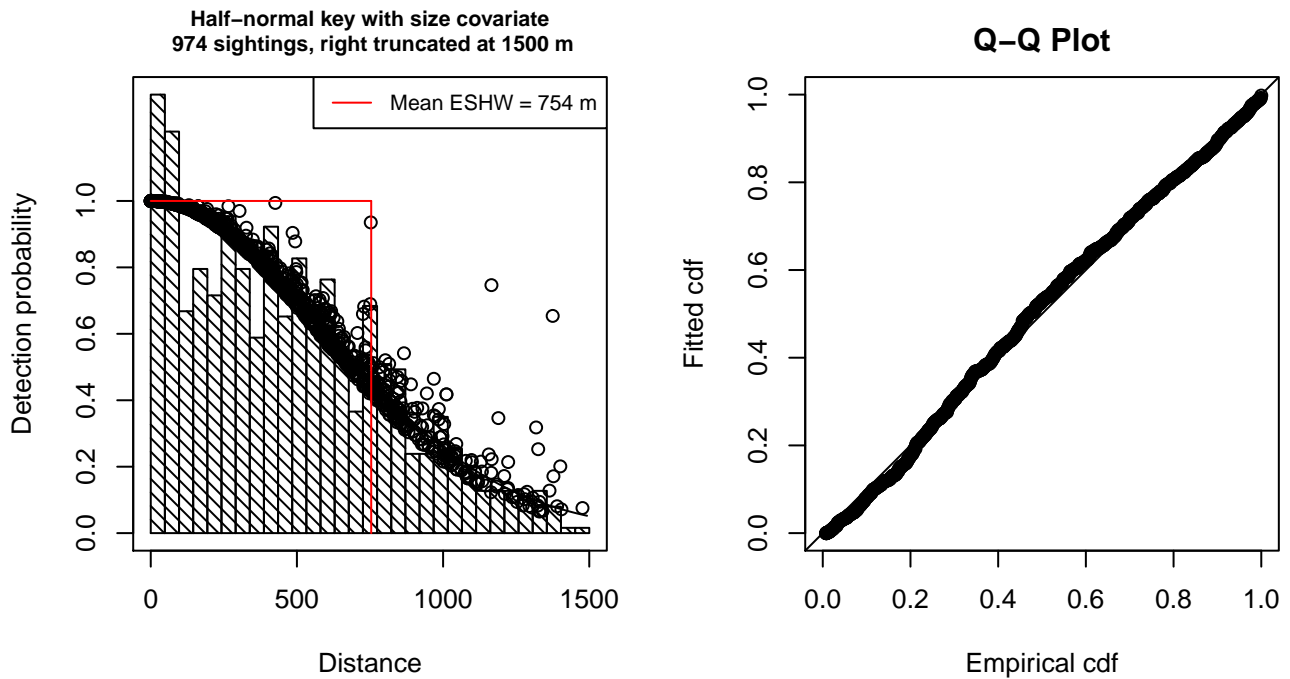


Figure 41: Detection function for UNCW Navy Surveys that was selected for the density model

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)	6.3390621	0.04000783
size	0.1171238	0.05081044

	Estimate	SE	CV
Average p	0.4997492	0.0133791	0.02677164
N in covered region	1948.9777925	68.4482329	0.03512007

Additional diagnostic plots:

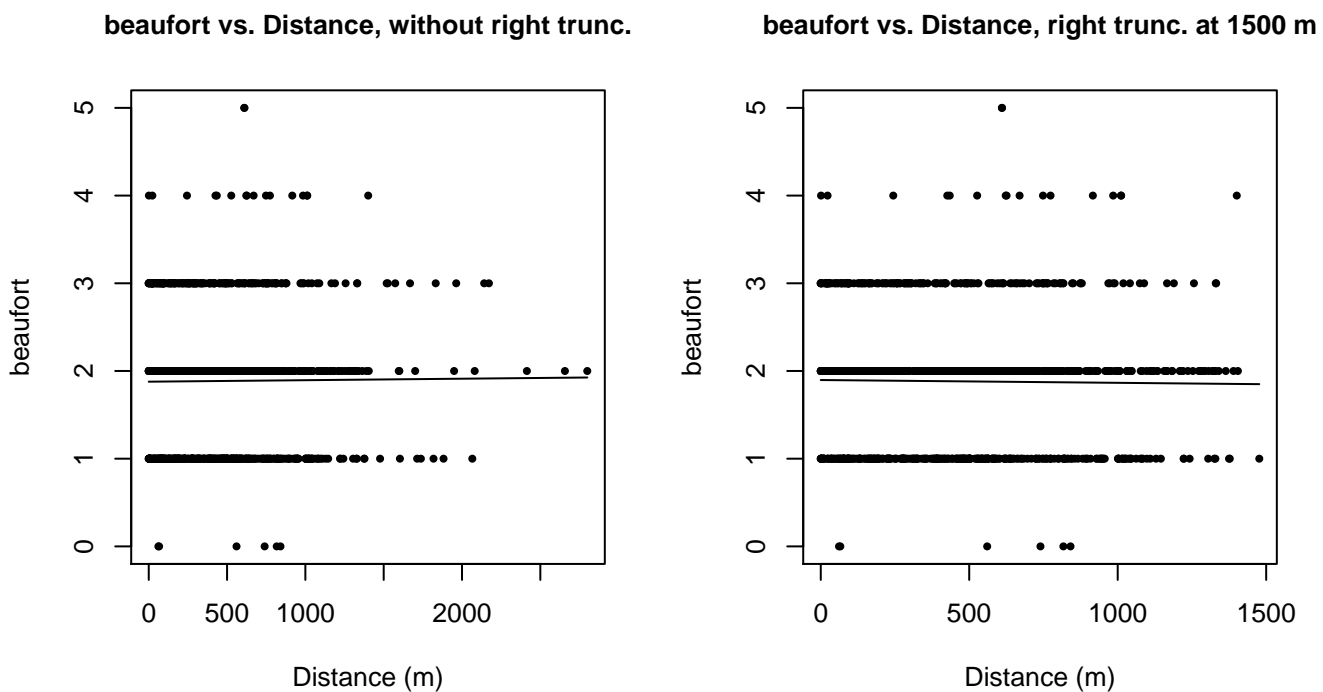
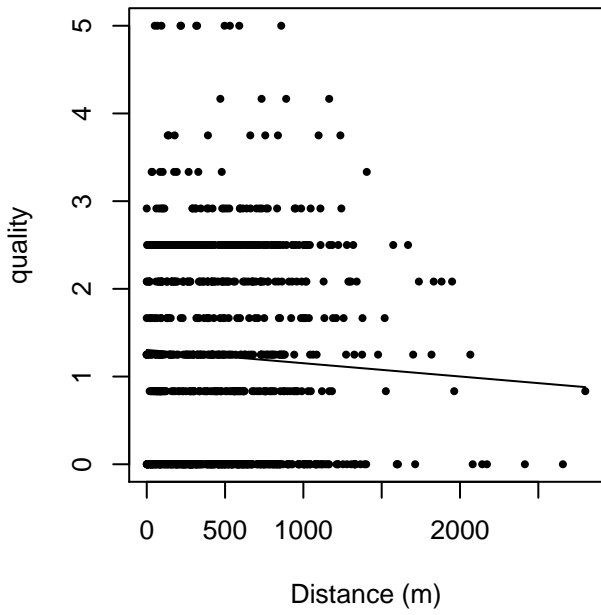


Figure 42: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 1500 m

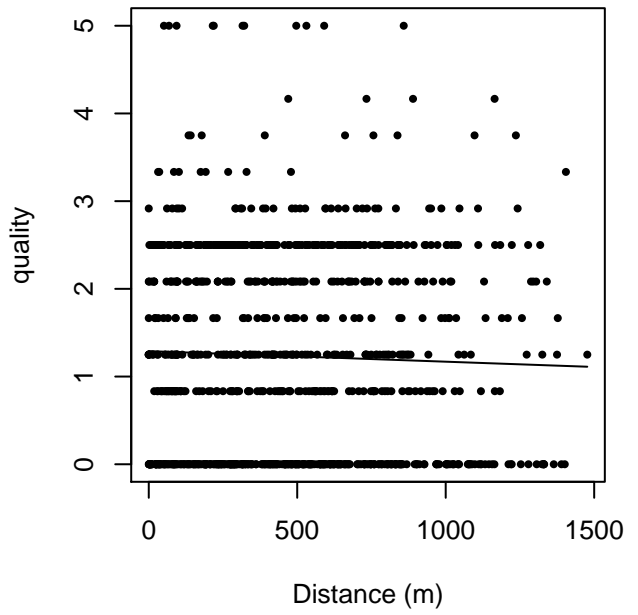
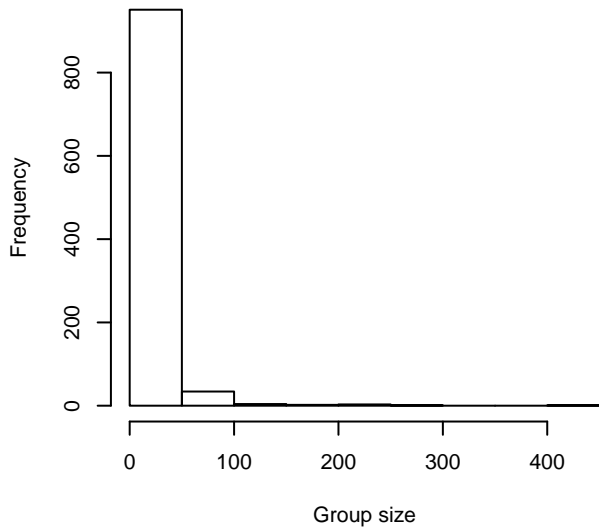
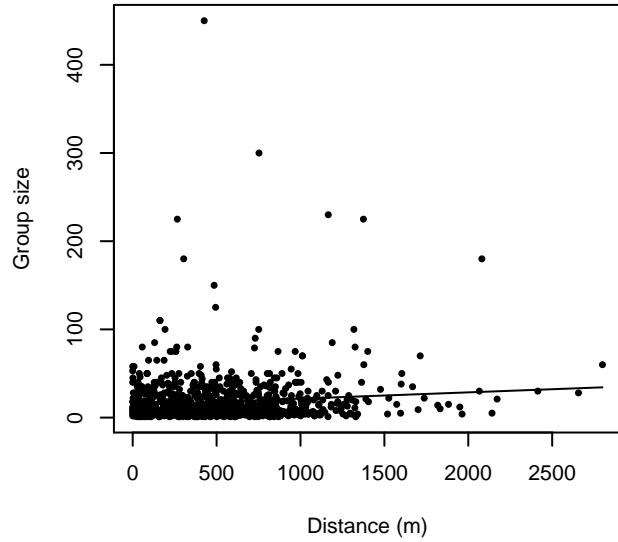


Figure 43: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

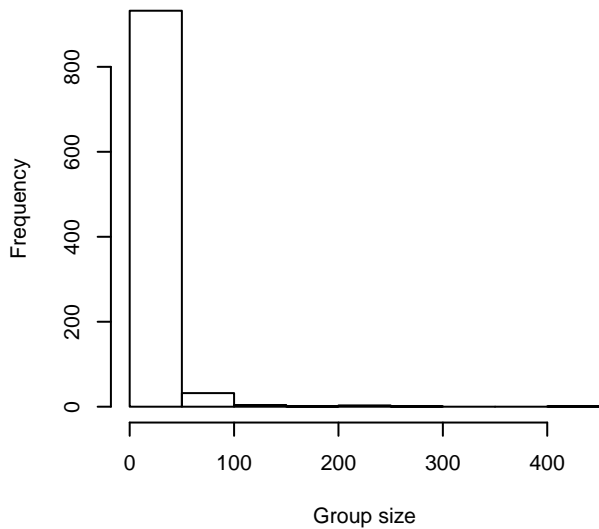
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 1500 m



Group Size vs. Distance, right trunc. at 1500 m

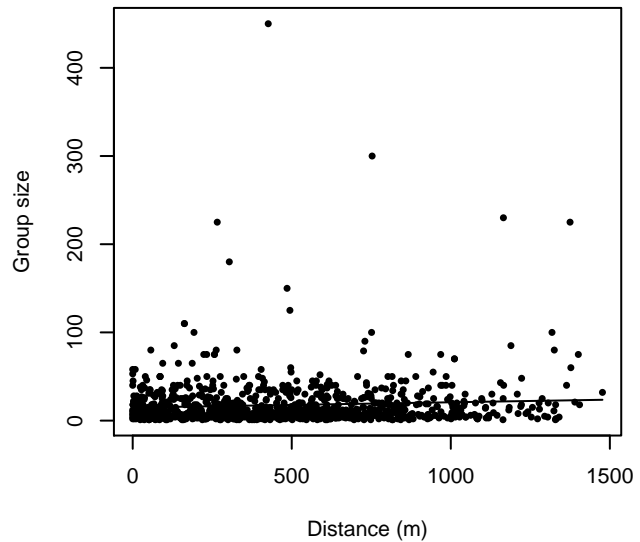


Figure 44: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 31: 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 truncated as well. Sightings closer than 111 m to the trackline were omitted from the analysis, and it was assumed that 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 32: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

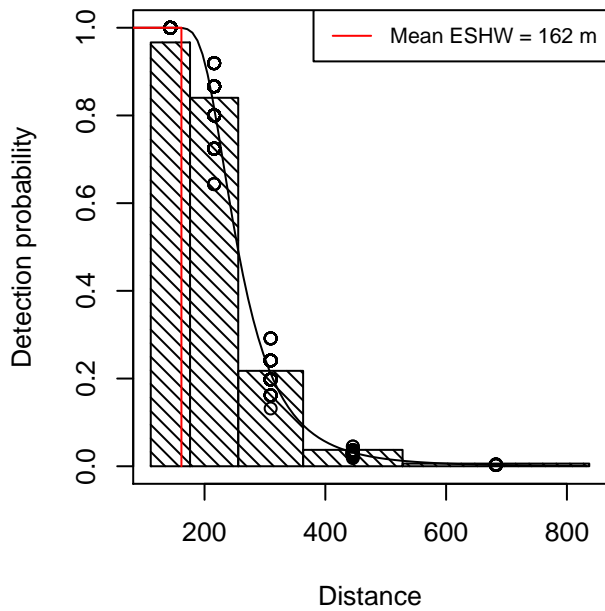
Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
-----	------------	-------	------------	-----------	--------------	---------------

hr			beaufort	Yes	0.00	162
hr			beaufort, size	Yes	1.38	162
hr				Yes	2.22	161
hr	poly	2		Yes	4.22	161
hr	poly	4		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 33: Candidate detection functions for UNCW Right Whale Surveys. The first one listed was selected for the density model.

Pantropical spotted dolphin and proxy species

Hazard rate key with beaufort covariate
1545 sightings, left trunc. 111 m, right trunc. 837 m



Q-Q Plot

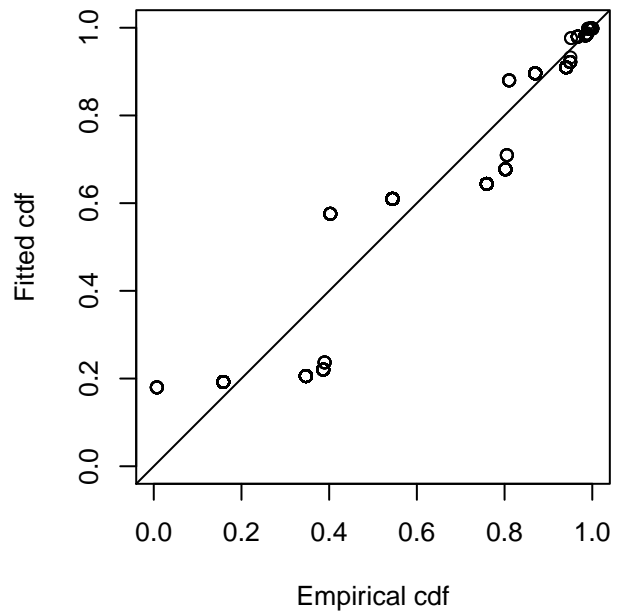


Figure 45: Detection function for UNCW Right Whale Surveys that was selected for the density model

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:

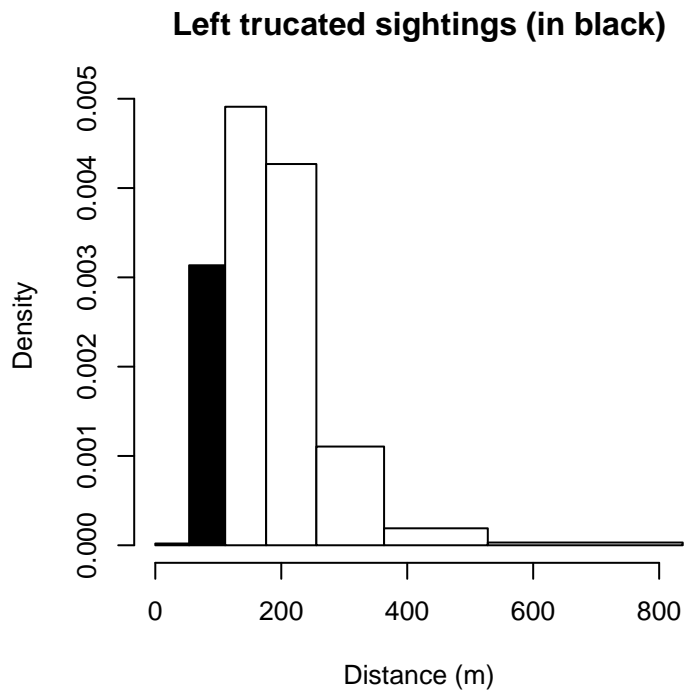


Figure 46: Density of sightings by perpendicular distance for UNCW Right Whale Surveys. Black bars on the left show sightings that were left truncated.

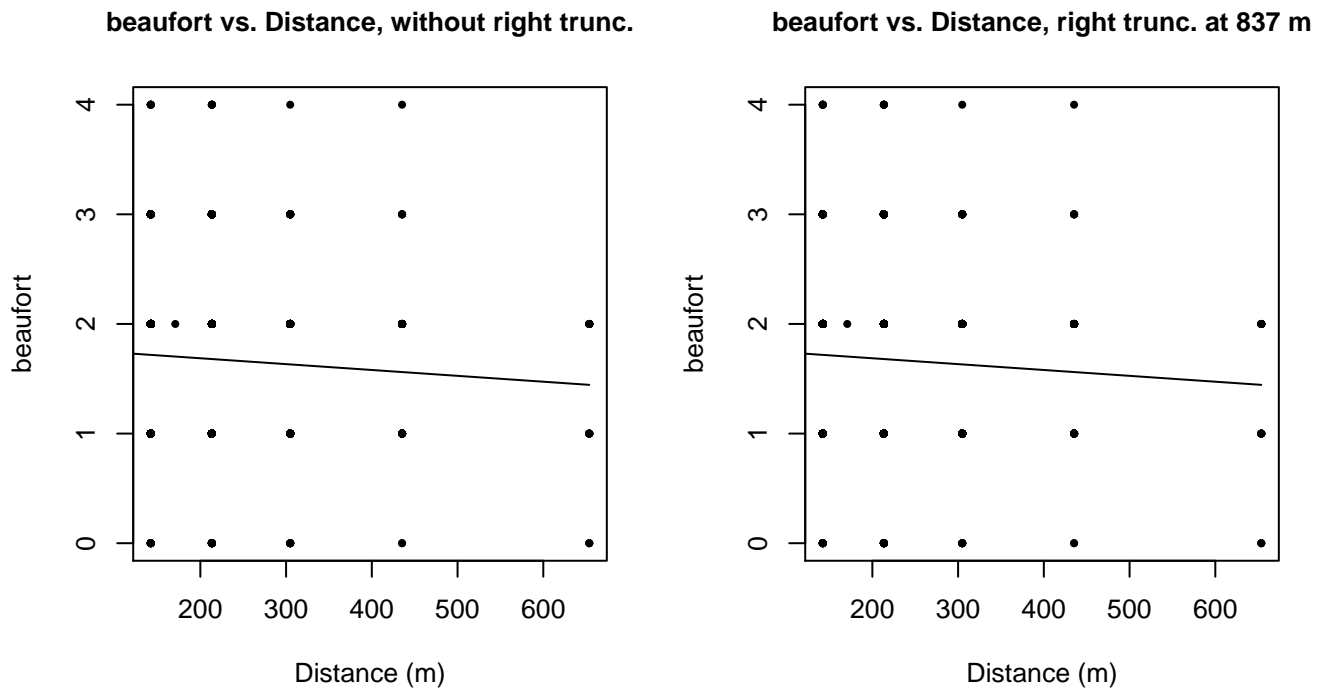
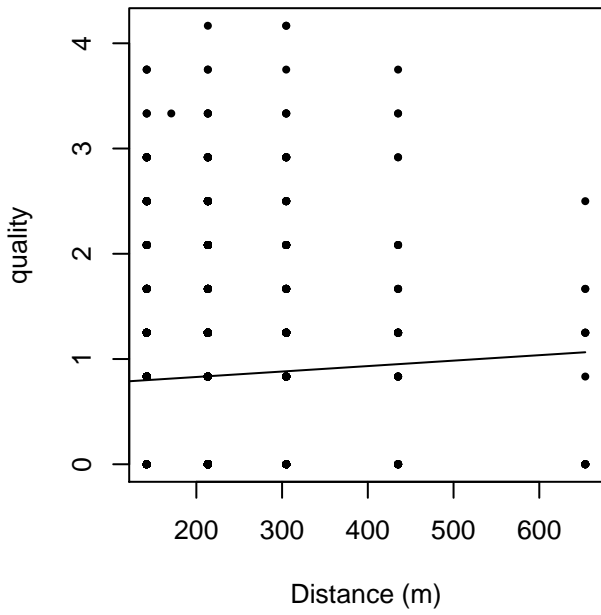


Figure 47: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 837 m

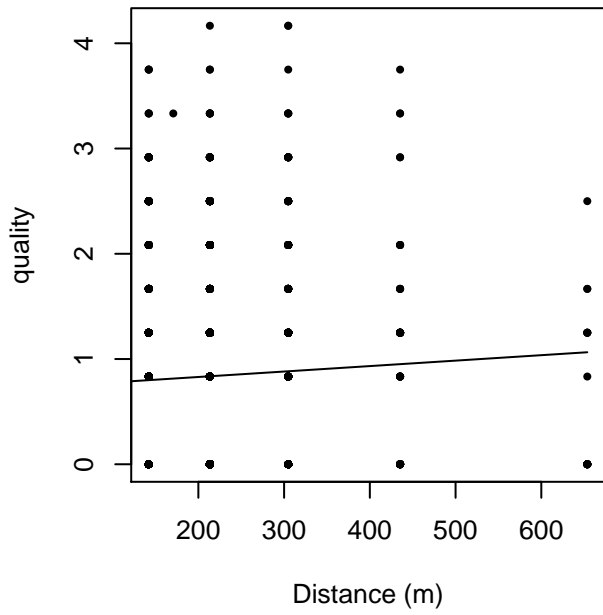
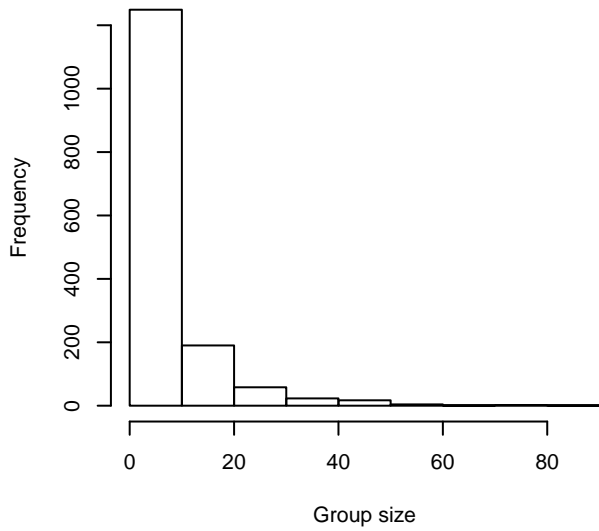
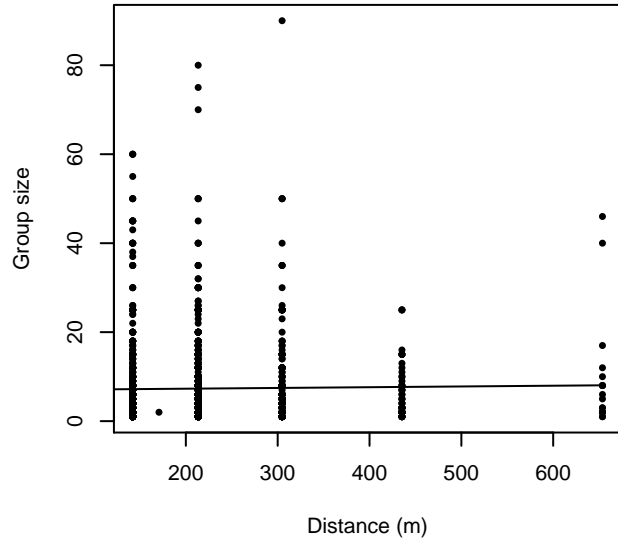


Figure 48: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

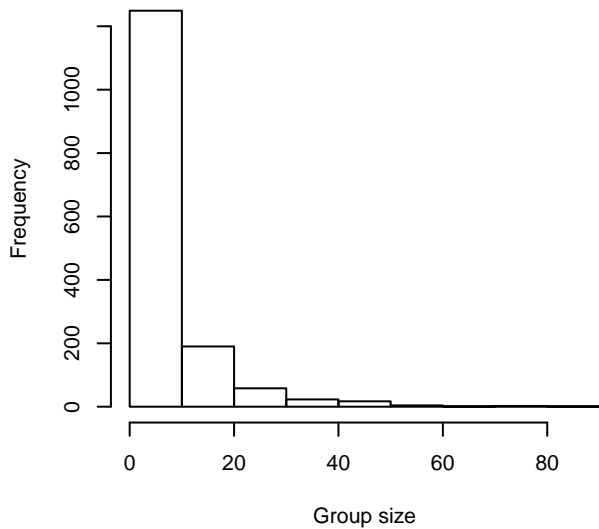
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 837 m



Group Size vs. Distance, right trunc. at 837 m

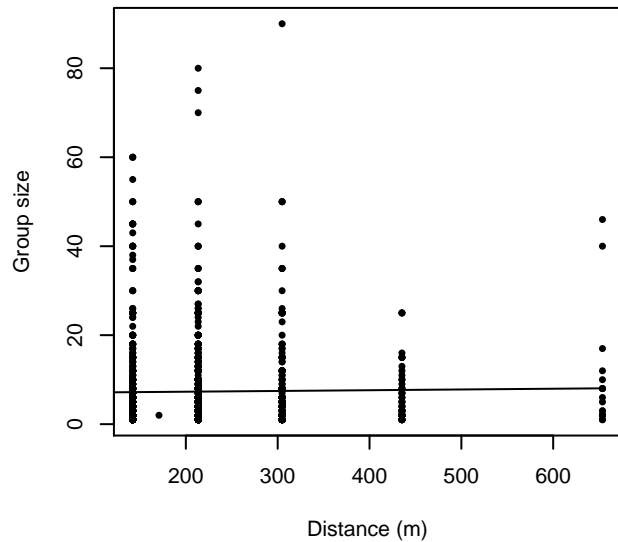


Figure 49: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 34: 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 truncated as well. Sightings closer than 13 m to the trackline were omitted from the analysis, and it was assumed that 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 35: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

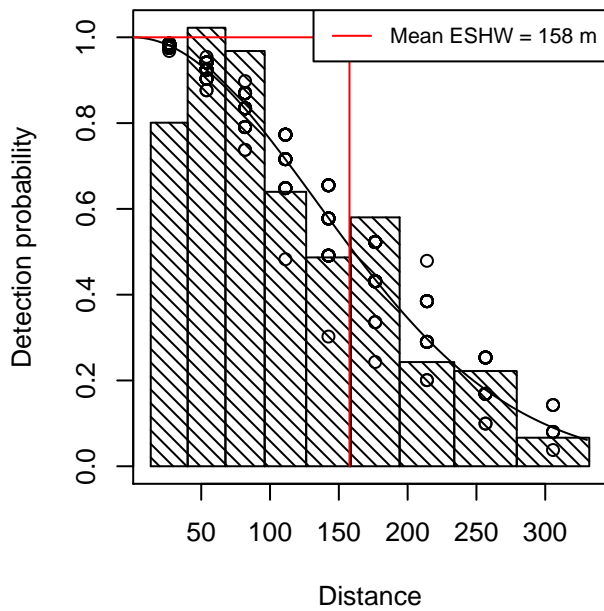
Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
hn			beaufort	Yes	0.00	158

hn			Yes	2.97	157	
hn	herm	4	Yes	4.54	163	
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	5.55	187
hr				Yes	8.05	173
hr			quality	Yes	9.36	173
hr			size	No		
hn			size	No		
hr			beaufort, quality	No		
hn			beaufort, quality	No		
hr			beaufort, size	No		
hn			beaufort, size	No		
hr			quality, size	No		
hn			quality, size	No		
hr			beaufort, quality, size	No		
hn			beaufort, quality, size	No		

Table 36: Candidate detection functions for UNCW Early Surveys. The first one listed was selected for the density model.

Pantropical spotted dolphin and proxy species

Half-normal key with beaufort covariate
 356 sightings, left trunc. 13 m, right trunc. 332 m



Q-Q Plot

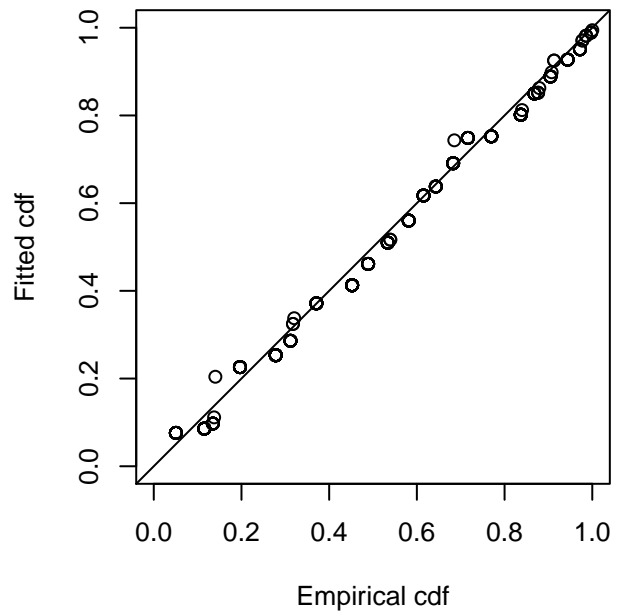


Figure 50: Detection function for UNCW Early Surveys that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 356
 Distance range : 13.30786 - 332
 AIC : 1491.716

Detection function:

Half-normal key function

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	5.1727566	0.13719725
beaufort	-0.1299466	0.06481337

	Estimate	SE	CV
Average p	0.4700761	0.0223748	0.04759826
N in covered region	757.3242104	46.4895531	0.06138659

Additional diagnostic plots:

Left truncated sightings (in black)

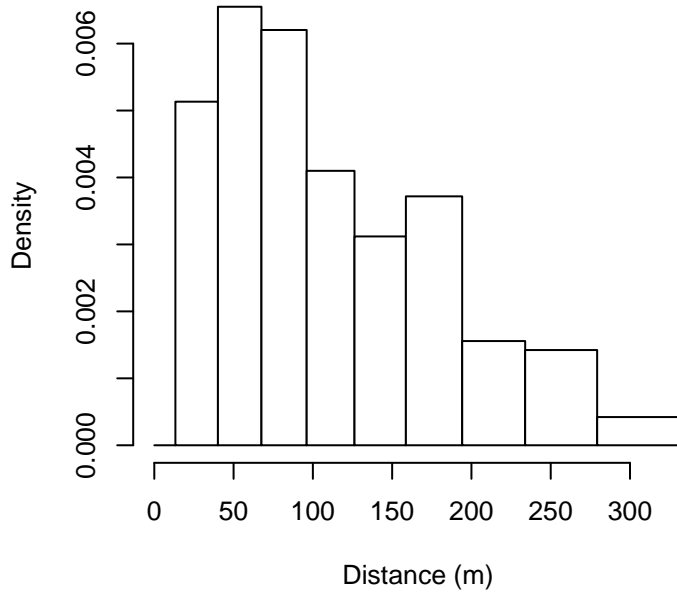


Figure 51: Density of sightings by perpendicular distance for UNCW Early Surveys. Black bars on the left show sightings that were left truncated.

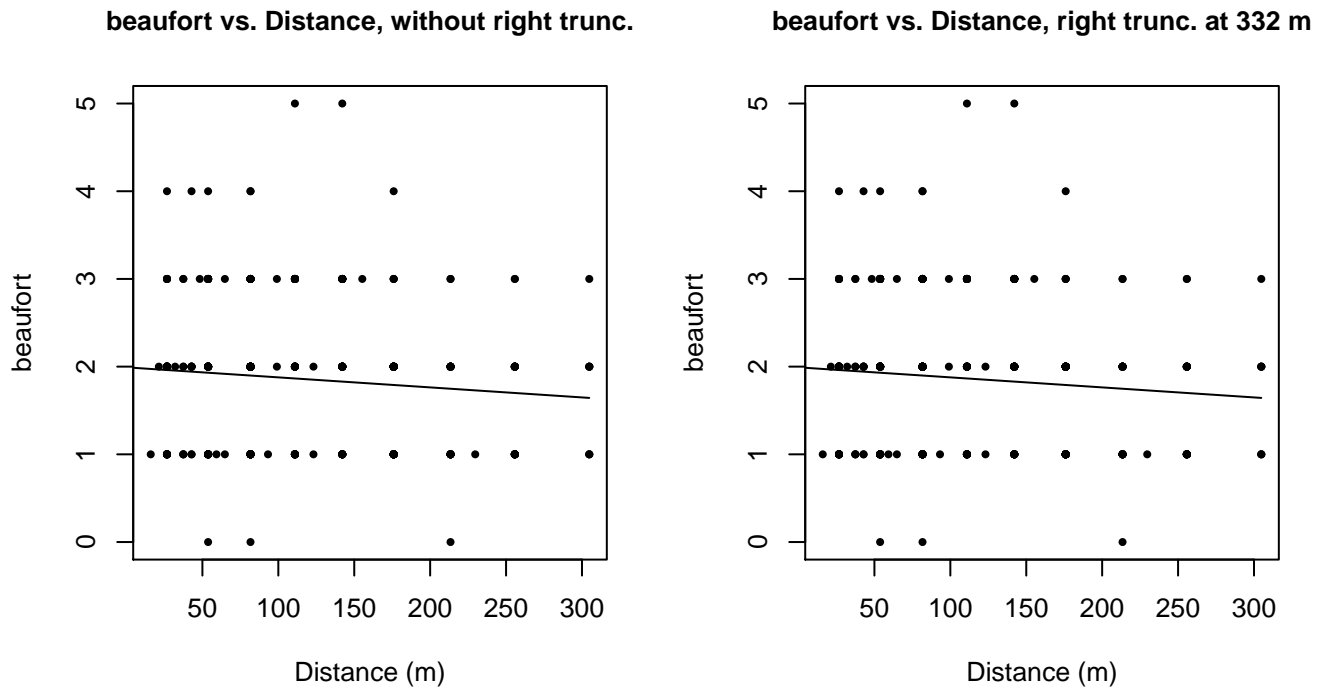
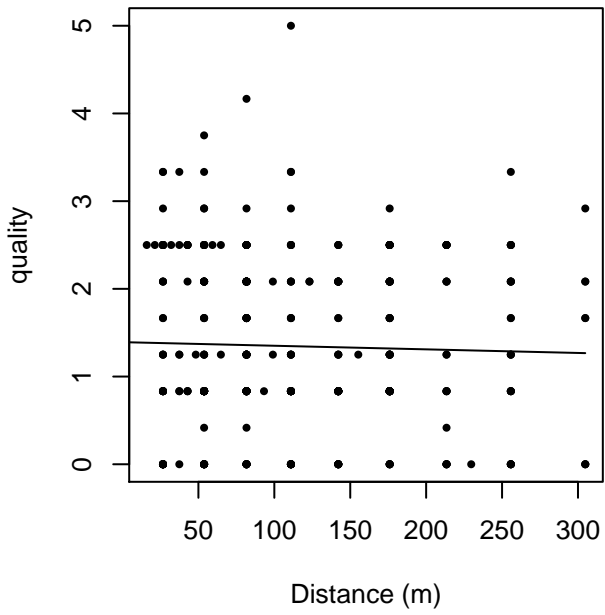


Figure 52: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 332 m

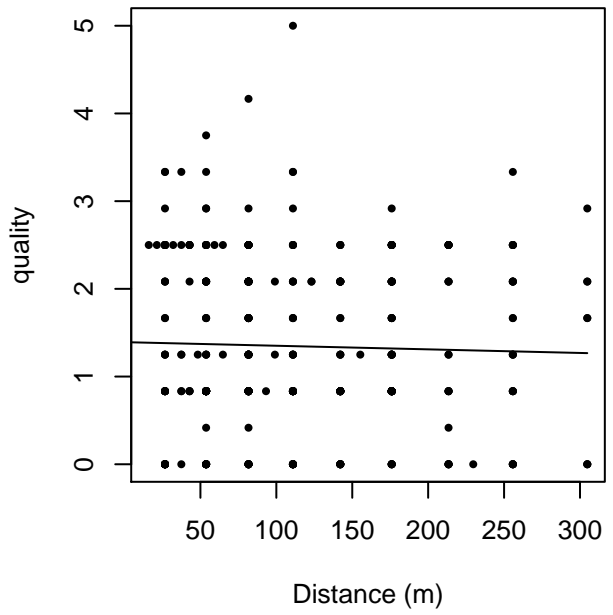


Figure 53: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

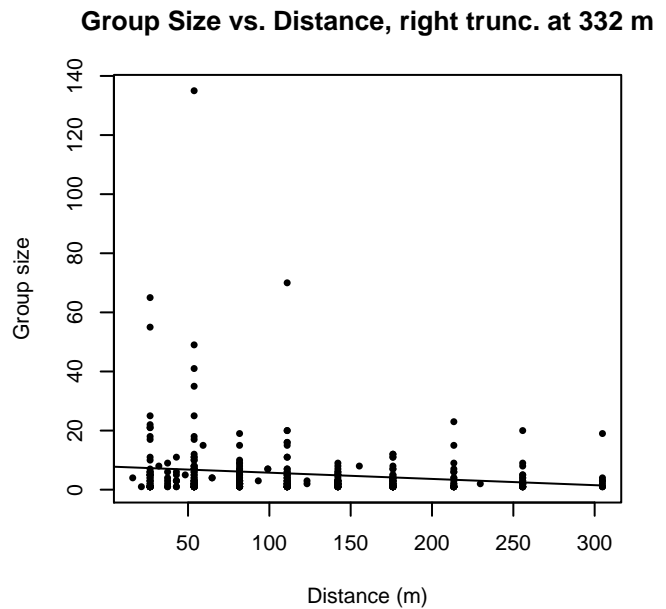
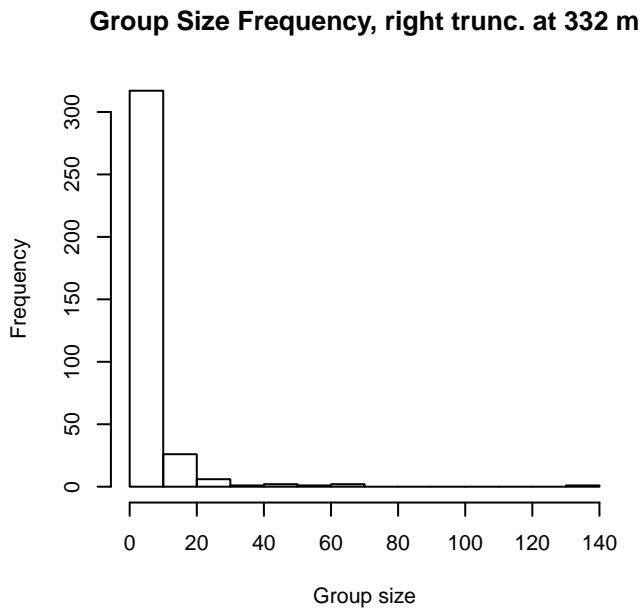
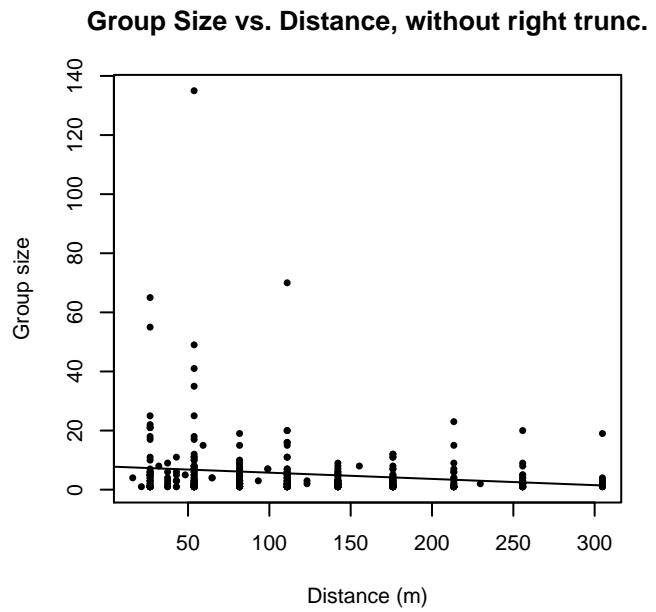
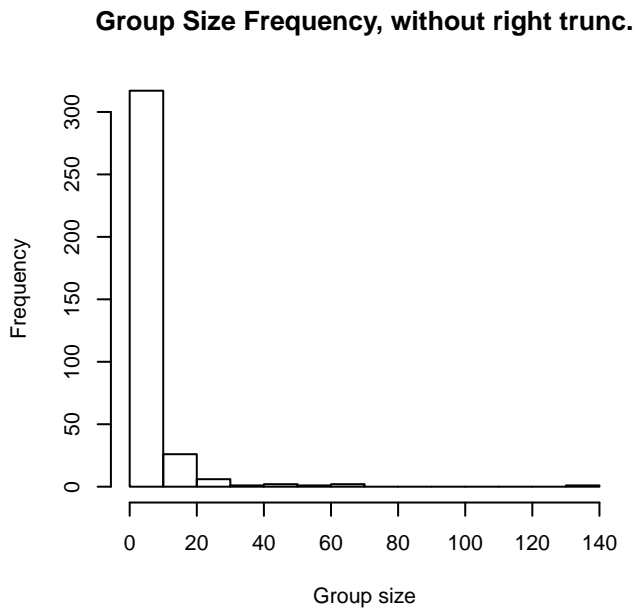


Figure 54: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

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 37: 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 38: 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	17.68	567
hn			beaufort	Yes	18.02	563
hn				Yes	18.13	562
hn			size	Yes	18.73	562
hn	herm	4		Yes	19.94	561
hr			beaufort	No		
hr			beaufort, quality	No		
hr			beaufort, size	No		
hr			beaufort, quality, size	No		

Table 39: Candidate detection functions for Virginia Aquarium Surveys. The first one listed was selected for the density model.

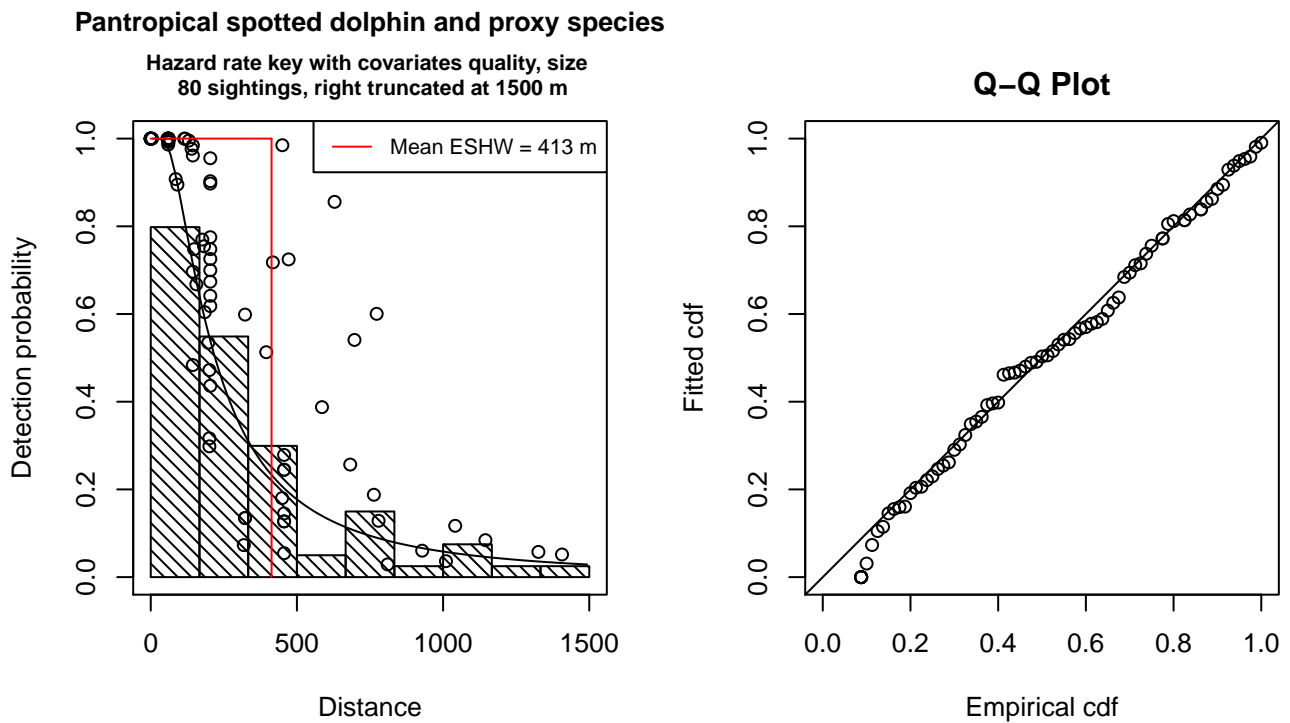


Figure 55: Detection function for Virginia Aquarium Surveys that was selected for the density model

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)	5.6518169	0.3734549
quality	-0.3758848	0.1494905
size	0.3255912	0.2331152

Shape parameters:

	estimate	se
(Intercept)	0.6332165	0.1826108

	Estimate	SE	CV
Average p	0.2217086	0.0381433	0.1720425
N in covered region	360.8339921	72.1664321	0.1999990

Additional diagnostic plots:

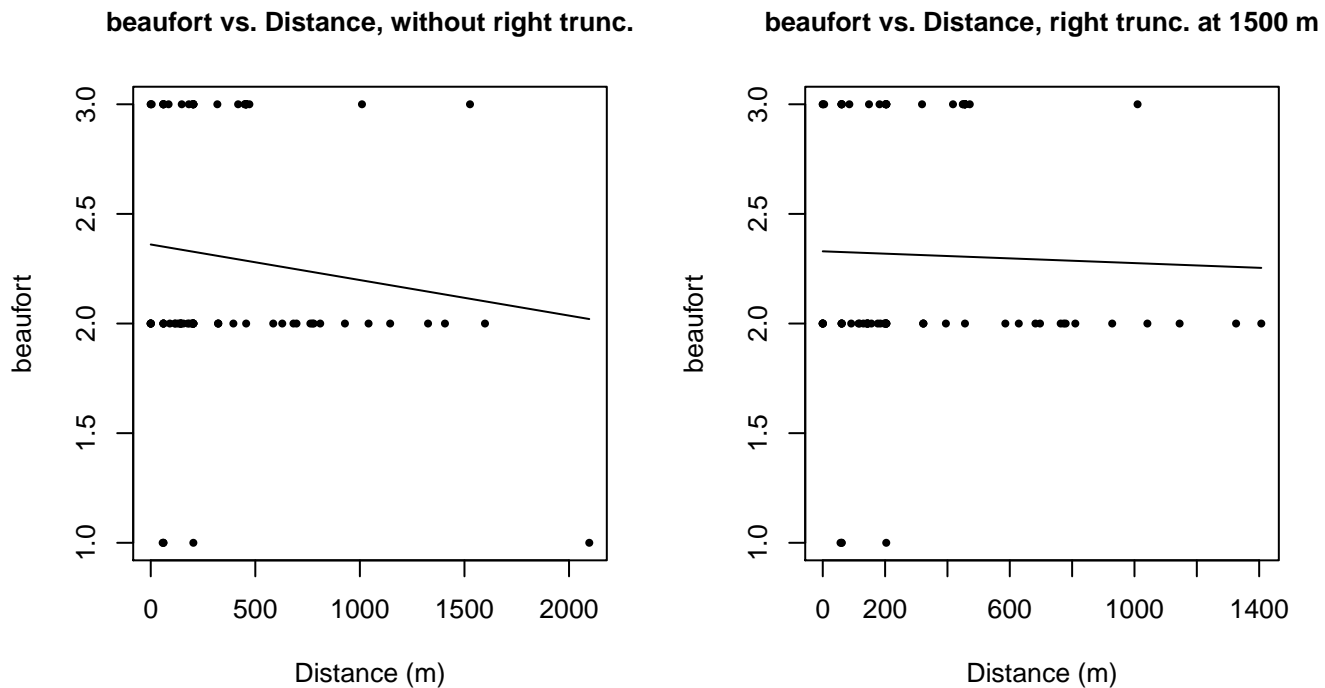
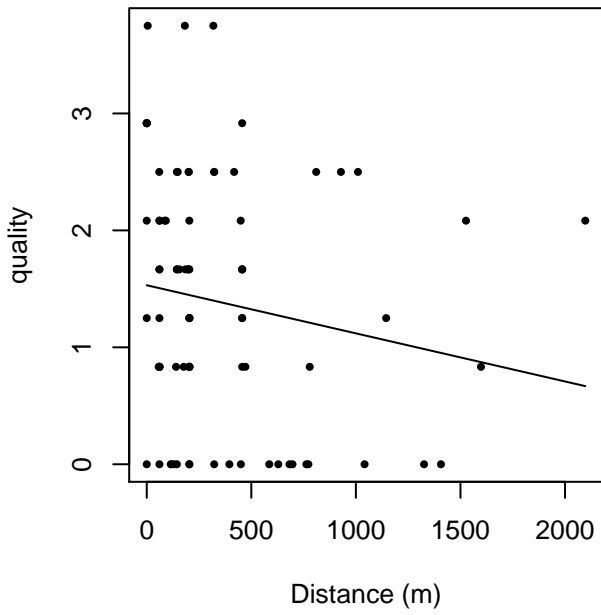


Figure 56: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 1500 m

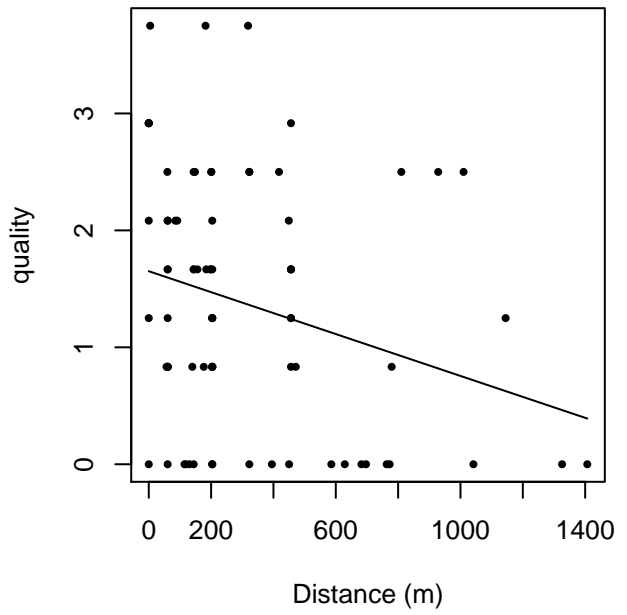
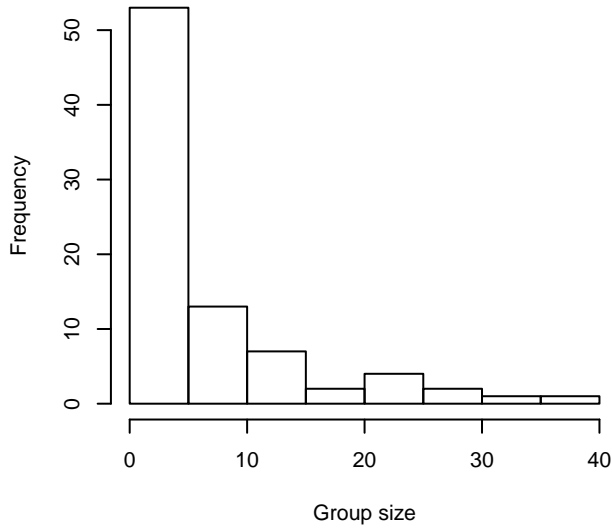
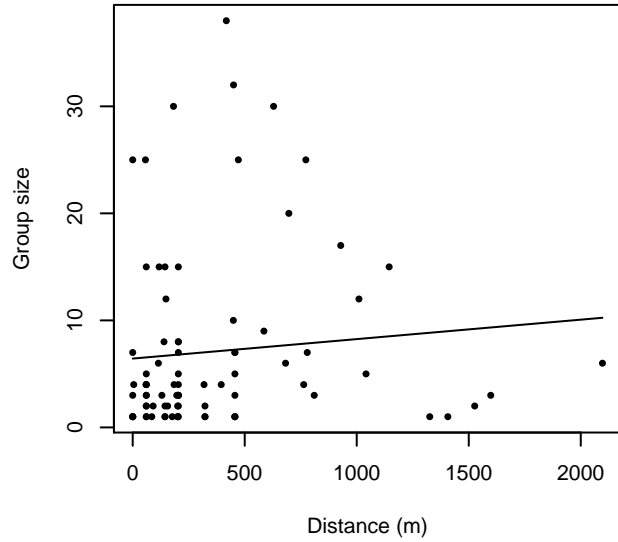


Figure 57: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

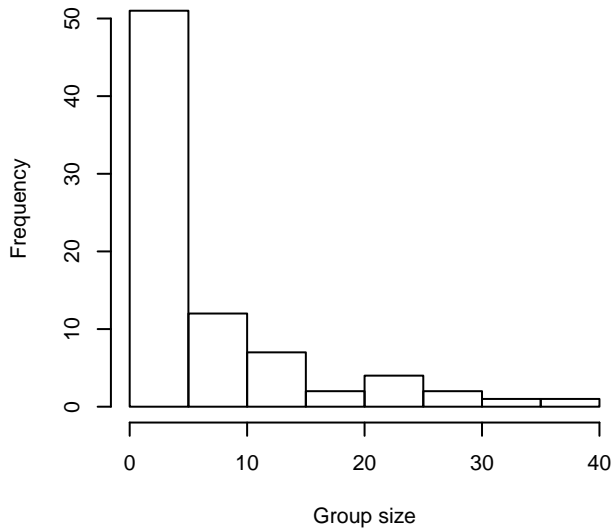
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 1500 m



Group Size vs. Distance, right trunc. at 1500 m

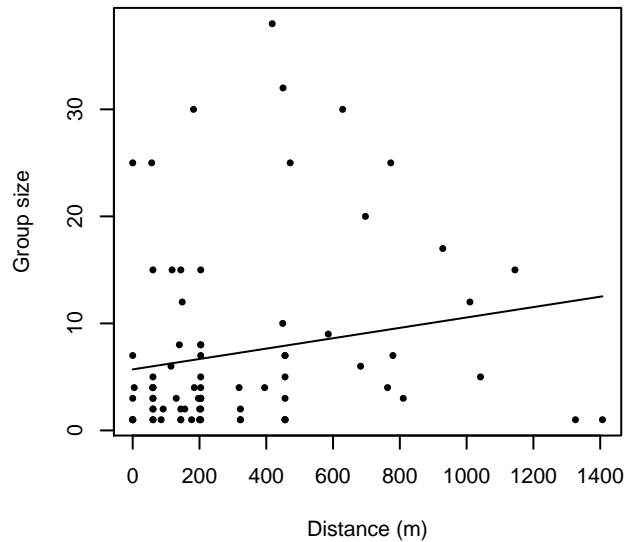


Figure 58: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NARWSS Grumman's

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 40: 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 truncated as well. Sightings closer than 107 m to the trackline were omitted from the analysis, and it was assumed that 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.

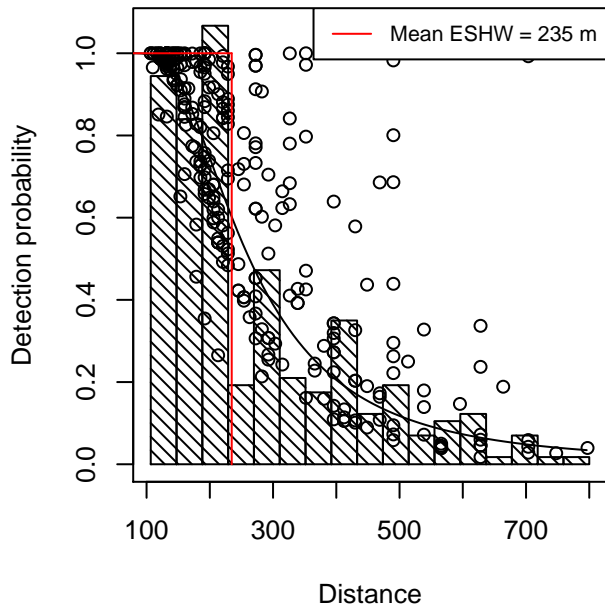
Table 41: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

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
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	2		No		
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 42: Candidate detection functions for NARWSS Grummans. The first one listed was selected for the density model.

Bottlenose dolphin and proxy species
 Hazard rate key with covariates quality, size
 285 sightings, left trunc. 107 m, right trunc. 800 m



Q-Q Plot

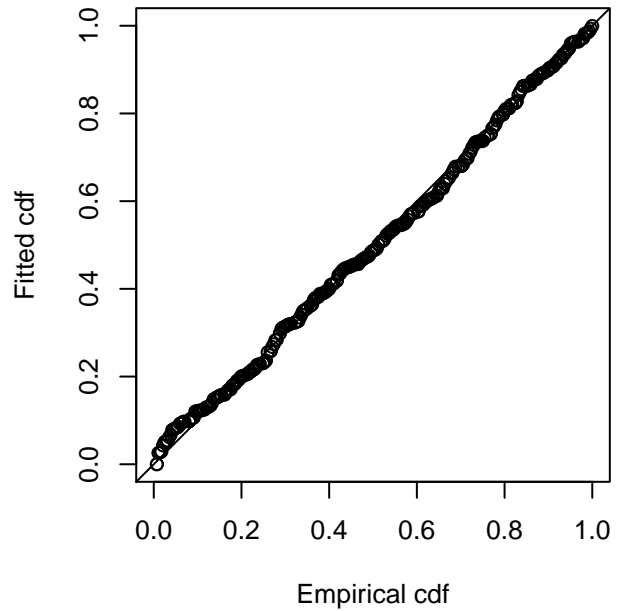


Figure 59: Detection function for NARWSS Grummans that was selected for the density model

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:

Left truncated sightings (in black)

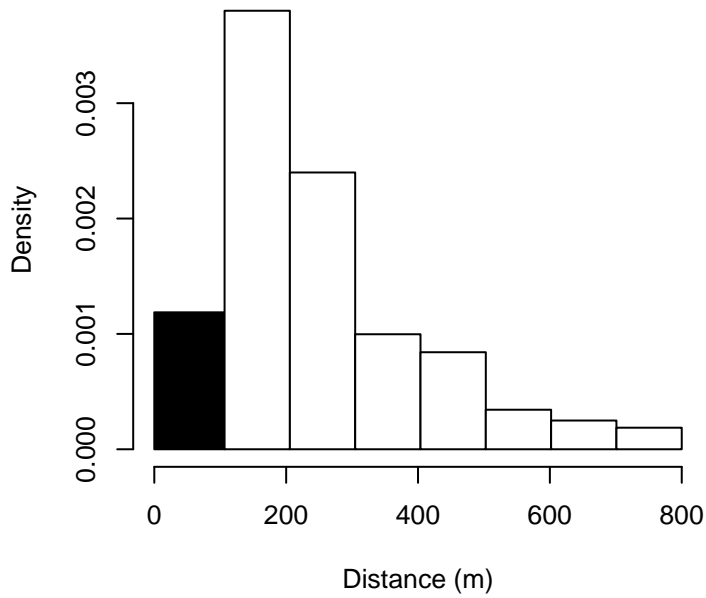


Figure 60: Density of sightings by perpendicular distance for NARWSS Grummans. Black bars on the left show sightings that were left truncated.

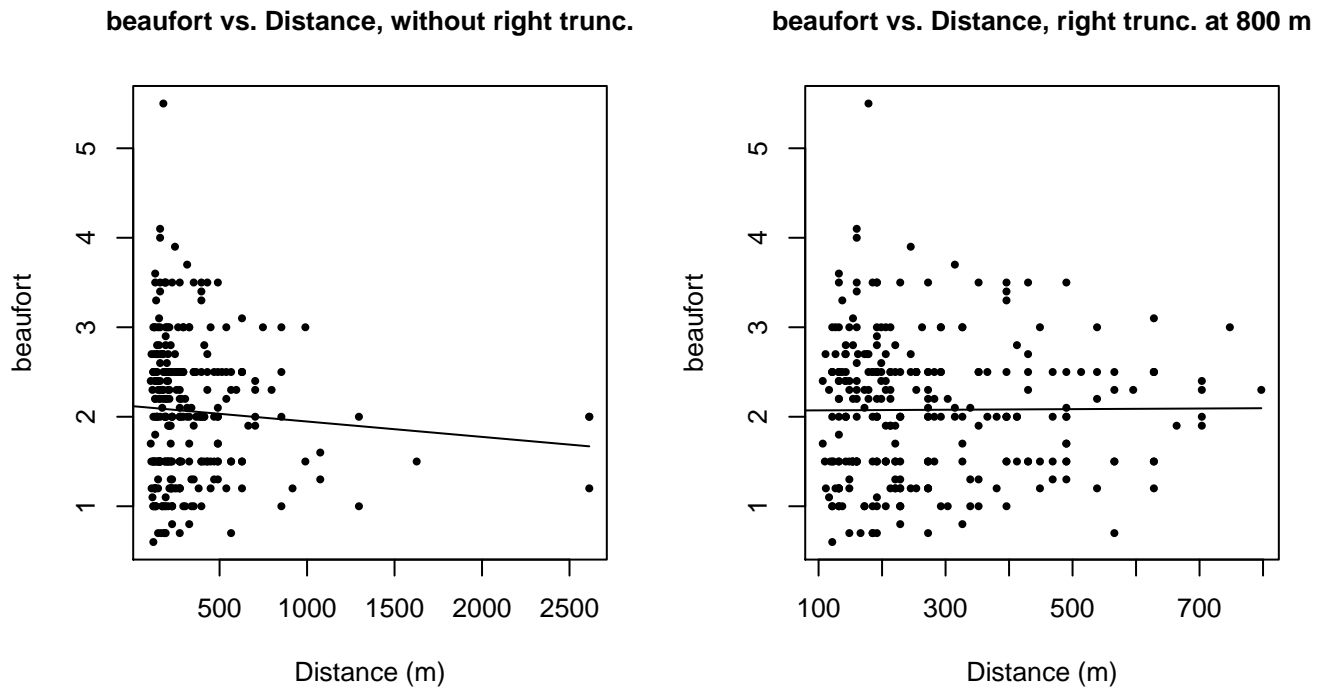


Figure 61: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

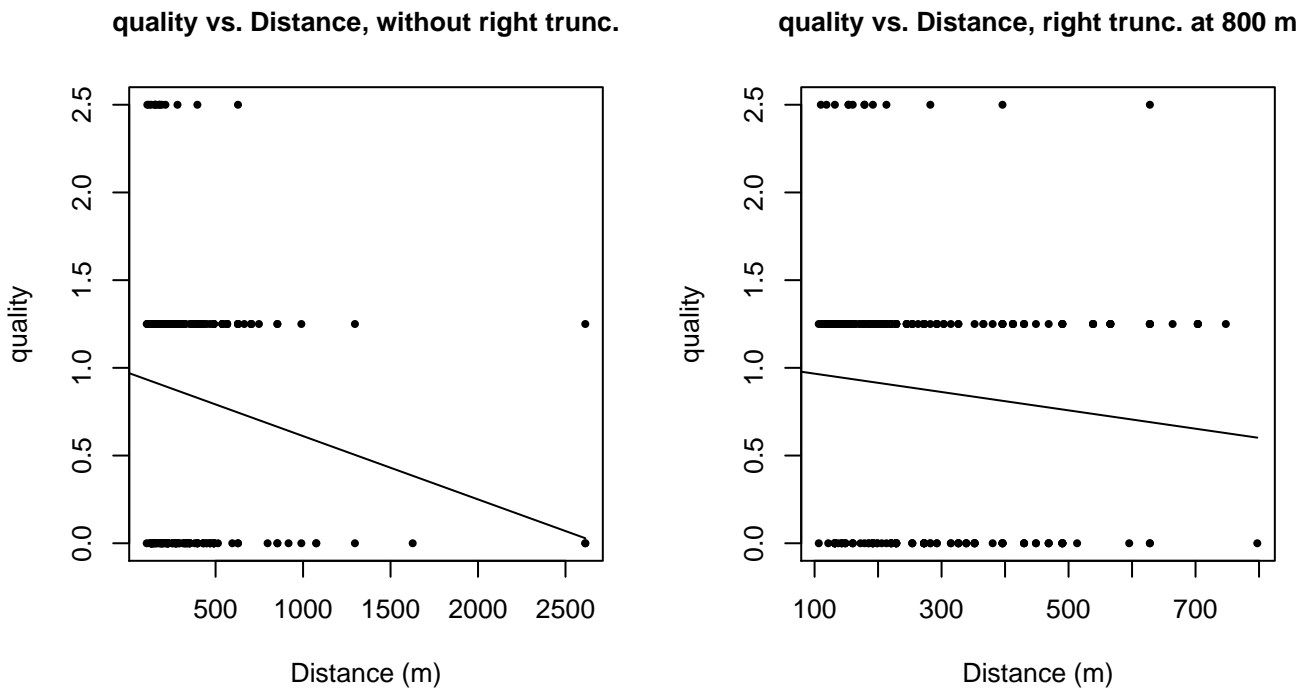
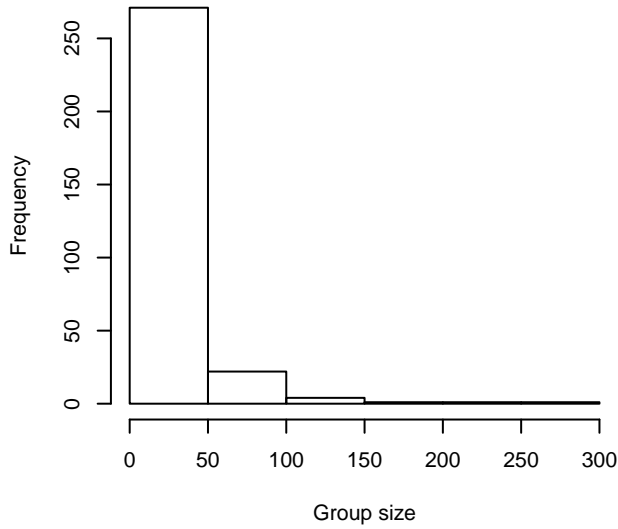
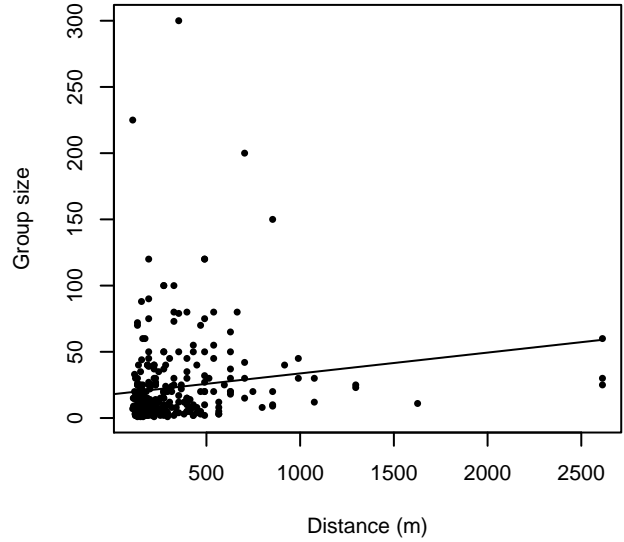


Figure 62: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

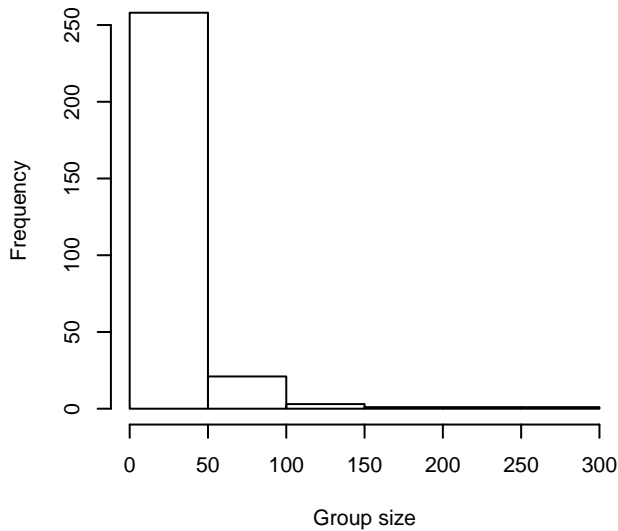
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 800 m



Group Size vs. Distance, right trunc. at 800 m

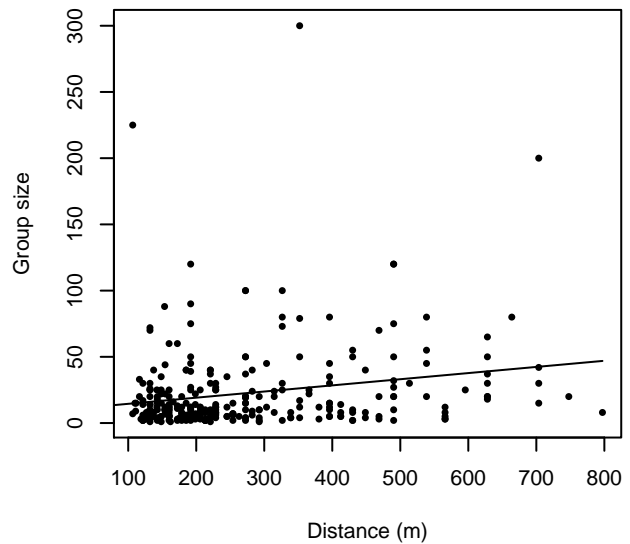


Figure 63: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

NARWSS Twin Otters

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	539

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	86
Grampus griseus/Tursiops truncatus	Risso's or Bottlenose dolphin	0
Lagenodelphis hosei	Fraser's dolphin	0
Lagenorhynchus acutus	Atlantic white-sided dolphin	1732
Lagenorhynchus albirostris	White-beaked dolphin	4
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	4
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	39
Total		2405

Table 43: Proxy species used to fit detection functions for NARWSS Twin Otters. The number of sightings, n , is before truncation.

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 truncated as well. Sightings closer than 160 m to the trackline were omitted from the analysis, and it was assumed that 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 44: Covariates tested in candidate “multi-covariate distance sampling” (MCDS) detection functions.

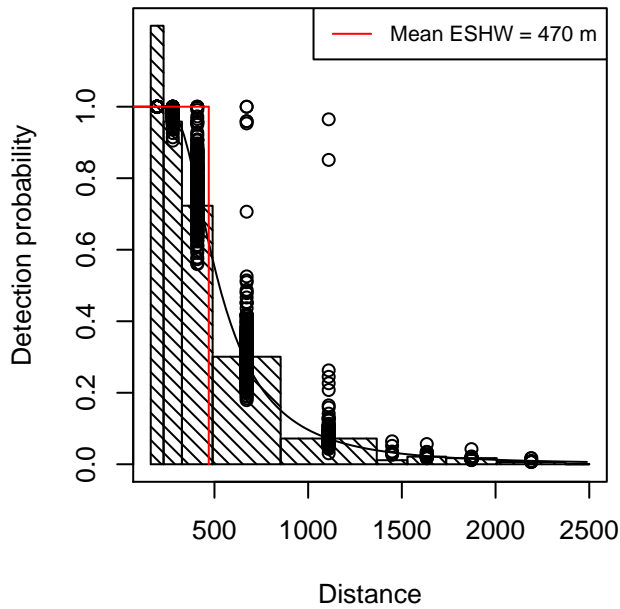
Key	Adjustment	Order	Covariates	Succeeded	Δ AIC	Mean ESHW (m)
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hr			beaufort, size	Yes	0.00	470
hr			size	Yes	5.29	463
hr			quality, size	Yes	7.11	463
hr	poly	2		Yes	9.16	430
hr	poly	4		Yes	10.71	442
hr			beaufort	Yes	17.46	464
hr				Yes	22.55	458
hr			quality	Yes	24.49	458
hn	cos	2		Yes	33.82	434
hn	cos	3		Yes	54.89	361
hn			beaufort, size	Yes	162.73	517
hn			size	Yes	162.85	518
hn			quality, size	Yes	164.00	518
hn			beaufort, quality, size	Yes	164.45	517
hn			beaufort	Yes	185.34	516
hn				Yes	186.28	516
hn	herm	4		Yes	186.91	516
hn			beaufort, quality	Yes	187.34	516
hn			quality	Yes	188.03	516
hr			beaufort, quality	No		
hr			beaufort, quality, size	No		

Table 45: Candidate detection functions for NARWSS Twin Otters. The first one listed was selected for the density model.

Bottlenose dolphin and proxy species

Hazard rate key with covariates beaufort, size
1987 sightings, left trunc. 160 m, right trunc. 2500 m



Q-Q Plot

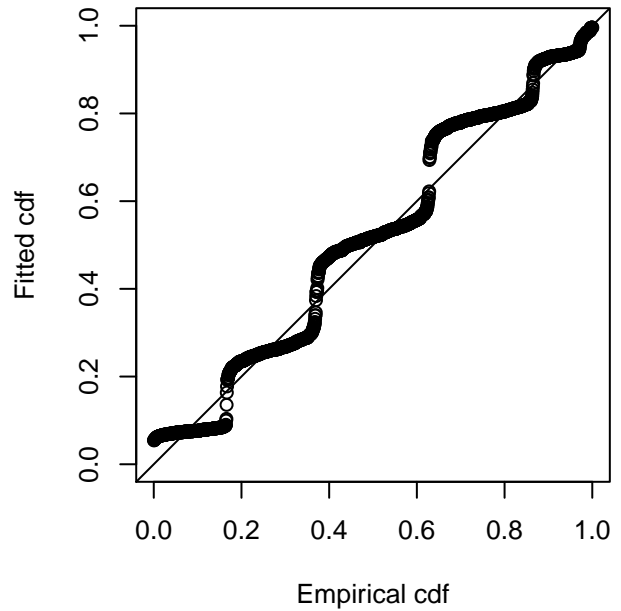


Figure 64: Detection function for NARWSS Twin Otters that was selected for the density model

Statistical output for this detection function:

Summary for ds object

Number of observations : 1987
Distance range : 160.0674 - 2500
AIC : 6745.856

Detection function:

Hazard-rate key function

Detection function parameters

Scale Coefficients:

	estimate	se
(Intercept)	6.26395198	0.06468196
beaufort	-0.07274292	0.02643651
size	0.08974254	0.02445737

Shape parameters:

	estimate	se
(Intercept)	1.110483	0.0356417

	Estimate	SE	CV
Average p	1.845364e-01	5.774489e-03	0.03129187
N in covered region	1.076752e+04	4.016208e+02	0.03729928

Additional diagnostic plots:

Left truncated sightings (in black)

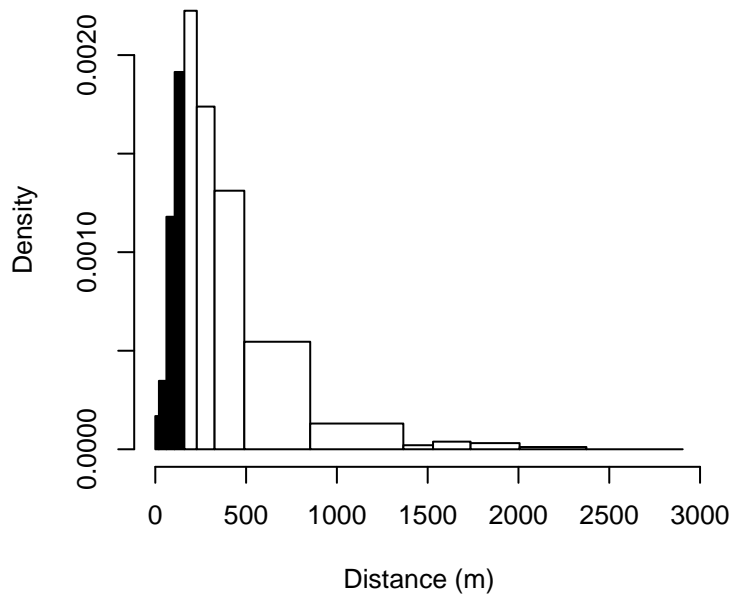
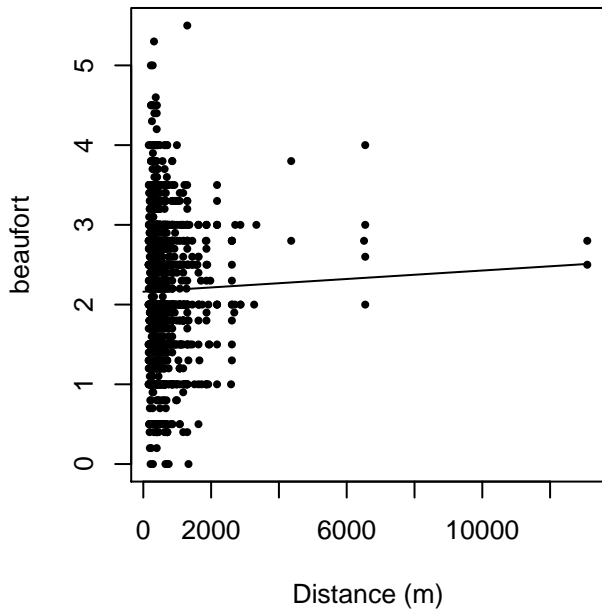


Figure 65: Density of sightings by perpendicular distance for NARWSS Twin Otters. Black bars on the left show sightings that were left truncated.

beaufort vs. Distance, without right trunc.



beaufort vs. Distance, right trunc. at 2500 m

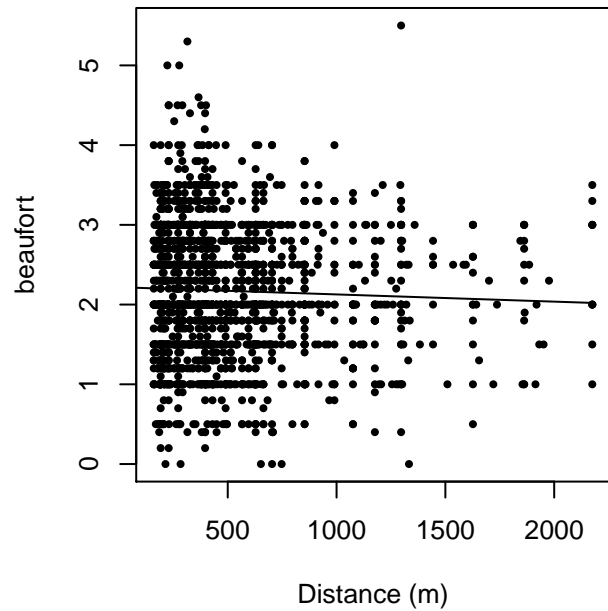
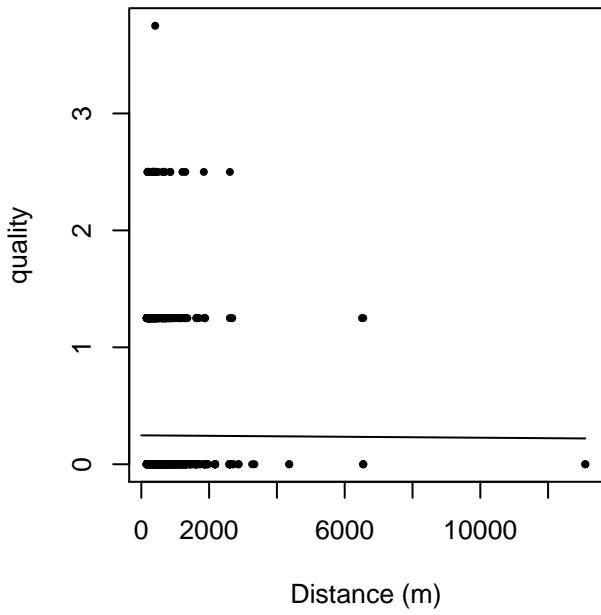


Figure 66: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

quality vs. Distance, without right trunc.



quality vs. Distance, right trunc. at 2500 m

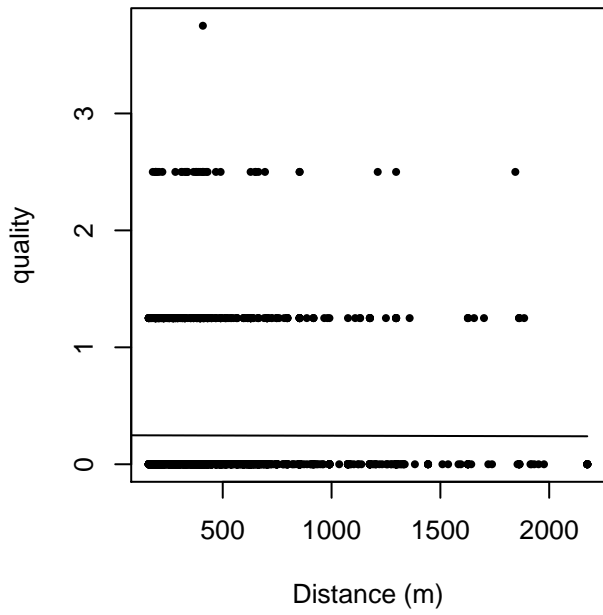
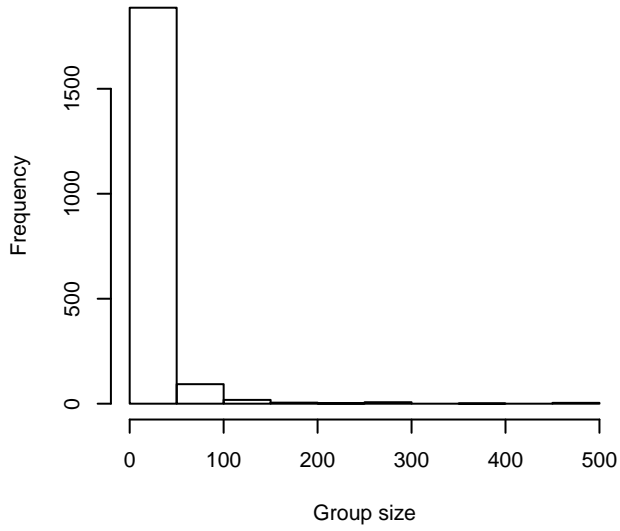
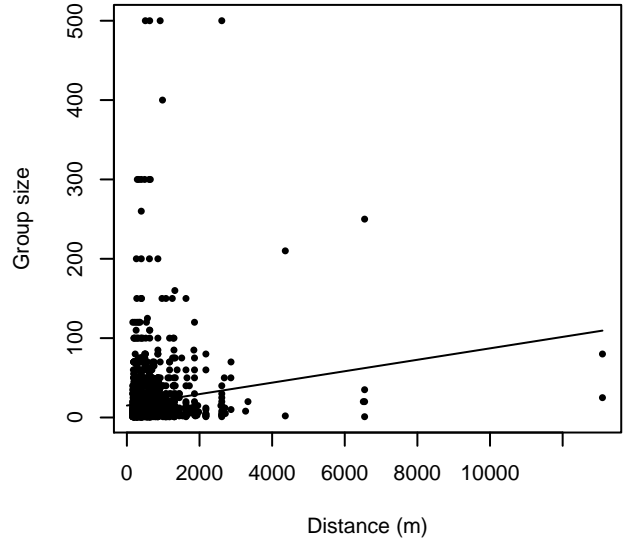


Figure 67: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions.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

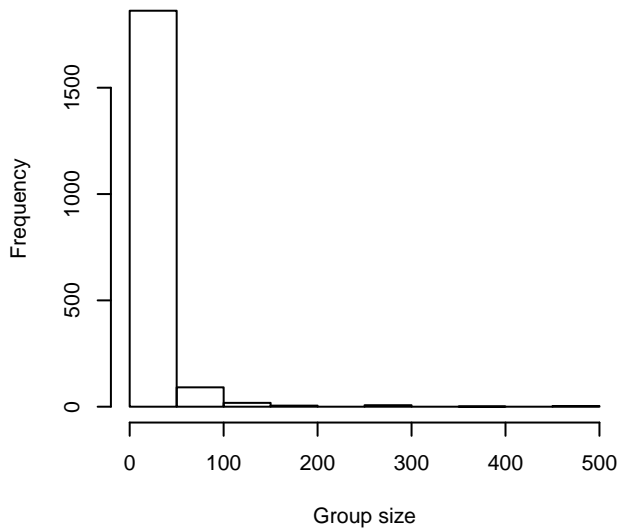
Group Size Frequency, without right trunc.



Group Size vs. Distance, without right trunc.



Group Size Frequency, right trunc. at 2500 m



Group Size vs. Distance, right trunc. at 2500 m

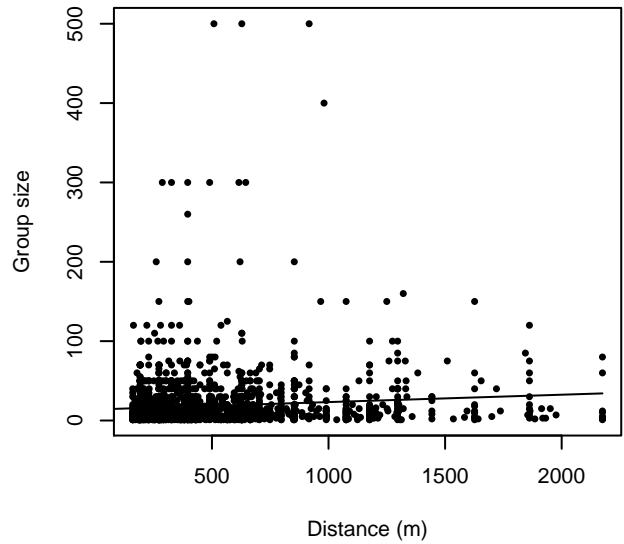


Figure 68: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

$g(0)$ 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	0.61	Perception	Palka (2006)
Shipboard	NEFSC Endeavor	Any	0.94	Perception	Palka (2006)
Aerial	All	1-5	0.43	Both	Palka (2006)
		>5	0.960	Both	Carretta et al. (2000)

Table 46: 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 Model

The pantropical spotted dolphin occurs worldwide in tropical, sub-tropical, and some warm-temperate waters between 40 N and about 40 S; outside of the Pacific Ocean, its distribution is primarily oceanic (Perrin 2001). It is the most abundant oceanic (> 200m depth) delphinid in the Gulf of Mexico (Jefferson and Schiro 1997). In our east coast study area, the surveys utilized in our analysis reported only 17 sightings over the study period, 1992-2014. Most were reported over the continental slope or abyssal waters in the southern half of the study area, consistent with the literature’s description of a warm-water, oceanic species. Four sightings were reported at 40.6 N on August 16, 1998 just off Georges Bank. At our request, E. Josephson at NOAA NEFSC reviewed the original records and confirmed that sketches and written descriptions indicate that these were pantropical spotted dolphins. Finally, two were reported on the shelf in the southern half of the study area (the original records for these were not reexamined).

With so few sightings we could not model density from environmental predictors; we fitted a stratified model instead. We first split the study area at the shelf break, defined here as the 125 m isobath, and estimated mean density for all surveys that occurred in the oceanic “Slope and Abyss” region. We allowed this region to extend to the northernmost extent of the study area on the basis that the four sightings at 40.6 N occurred beyond the species’ range reported in the literature, but acknowledge that presence in the far north is unlikely. We split the continental shelf waters at Cape Hatteras. North of here,

we assumed the species was absent, on the basis that cold, neritic waters are poor habitat for this species (and no sightings were reported in the region). South of Cape Hatteras, we estimated mean density from the two sightings that occurred there.

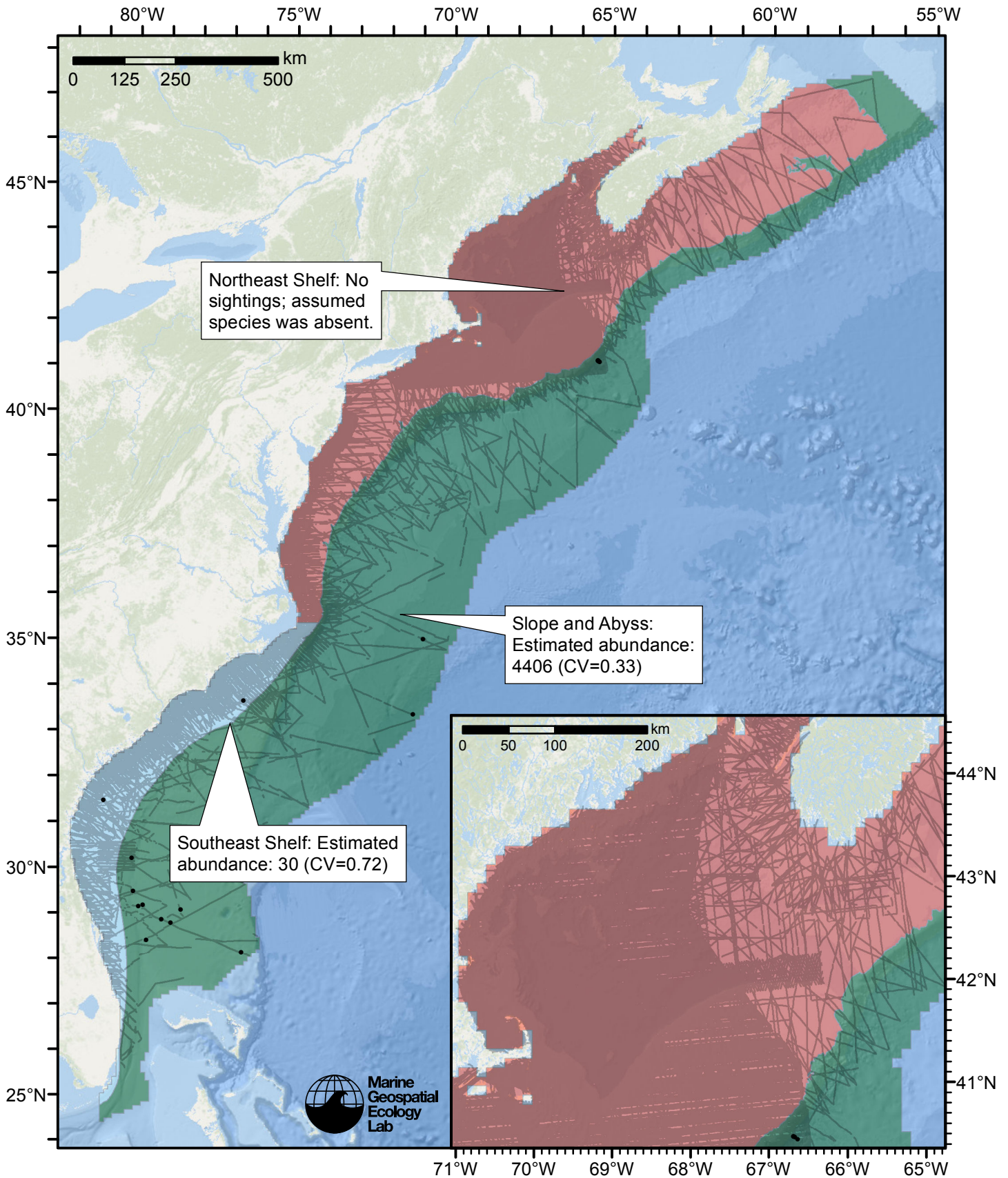


Figure 69: Pantropical spotted dolphin density model schematic. All sightings are shown, including those that were truncated when detection functions were fitted. The coefficient of variation (CV) underestimates the true uncertainty of our estimate, as it only incorporated the uncertainty of the GAM stage of our model. Other sources of uncertainty include the detection functions and $g(0)$ estimates. It was not possible to incorporate these into our CV without undertaking a computationally-prohibitive bootstrap; we hope to attempt that in a future version of our model.

Abundance Estimates

Dates	Model or study	Estimated abundance	CV	Assumed g(0)=1	In our models
1992-2013	Our model	4436	0.33	No	
Jun-Aug 2004	Maryland to Bay of Fundy (Waring et al. 2007)	0	0.00	No	Yes
Jun-Aug 2004	Florida to Maryland (Waring et al. 2007)	4439	0.49	No	Yes
Jun-Aug 2004	Florida to Bay of Fundy, combined	4439	0.49	No	Yes
Jul-Sep 1998	Maryland to to Gulf of St. Lawrence (only on-shelf in Nova Scotia) (Waring et al. 2007)	343	1.03	No	Yes
Jul-Aug 1998	Florida to Maryland (Waring et al. 2007)	12747	0.56	Yes	Yes
Jul-Sep 1998	Maryland to Gulf of St. Lawrence, combined	13090		Yes/No	Yes

Table 47: Estimated mean abundance within the study area for our model and independent estimates from NOAA and/or the scientific literature. The Dates column gives the dates to which the estimates apply. For our model, these are the years for survey data were available. Our coefficient of variation (CV) estimates are probably too low, 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. 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. Note that our abundance estimates are averaged over the whole year, while the other estimates apply to specific months or seasons. Please see the Discussion section below for our evaluation of our models compared to the other estimates.

Discussion

Our stratified model estimated 4436 pantropical spotted dolphins, with 4406 off-shelf and 30 on-shelf. This estimate was very similar to NOAA's most recent estimate of 4439, from 2004 (Waring et al. 2007).

The known ecology of this species and the pattern of sightings in the southeast suggest that it is more common in the southern part of the study area. Given additional sightings from future surveys, we could attempt a habitat-based density model. To facilitate this, we recommend additional surveying of off-shelf waters throughout the latitudinal extent of the study area.

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