# Density Model for Fraser's Dolphin (*Lagenodelphis hosei*) for the U.S. East Coast: Supplementary Report

Duke University Marine Geospatial Ecology Lab*

Model Version 1.2 - 2015-10-05

## Citation

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

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Roberts JJ, Best BD, Mannocci L, Fujioka E, Halpin PN, Palka DL, Garrison LP, Mullin KD, Cole TVN, Khan CB, McLellan WM, Pabst DA, Lockhart GG (2015) Density Model for Fraser's Dolphin (*Lagenodelphis hosei*) for the U.S. East Coast Version 1.2, 2015-10-05, and Supplementary Report. Marine Geospatial Ecology Lab, Duke University, Durham, North Carolina.

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## Revision History

| Version | Date | Description of changes |
|---|---|---|
| 1 | 2014-11-21 | Initial version. |
| 1.1 | 2015-05-14 | Updated calculation of CVs. Switched density rasters to logarithmic breaks. No changes to the model. |
| 1.2 | 2015-10-05 | Updated the documentation. No changes to the model. |

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*For questions, or to offer feedback about this model or report, please contact Jason Roberts ([jason.roberts@duke.edu](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 | 0 |
| NJDEP Aerial Surveys | 2008-2009 | 11 | 60 | 0 |
| NJDEP Shipboard Surveys | 2008-2009 | 14 | 836 | 0 |
| SEFSC Atlantic Shipboard Surveys | 1992-2005 | 28 | 1731 | 1 |
| SEFSC Mid Atlantic Tursiops Aerial Surveys | 1995-2005 | 35 | 196 | 0 |
| SEFSC Southeast Cetacean Aerial Surveys | 1992-1995 | 8 | 42 | 0 |
| UNCW Cape Hatteras Navy Surveys | 2011-2013 | 19 | 125 | 1 |
| UNCW Early Marine Mammal Surveys | 2002-2002 | 18 | 98 | 0 |
| UNCW Jacksonville Navy Surveys | 2009-2013 | 66 | 402 | 0 |
| UNCW Onslow Navy Surveys | 2007-2011 | 49 | 282 | 0 |
| UNCW Right Whale Surveys | 2005-2008 | 114 | 586 | 0 |
| Virginia Aquarium Aerial Surveys | 2012-2014 | 9 | 53 | 0 |
| Total | | 895 | 8332 | 2 |

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 | 2 |

Table 3: Survey effort and on-effort sightings having perpendicular sighting distances.
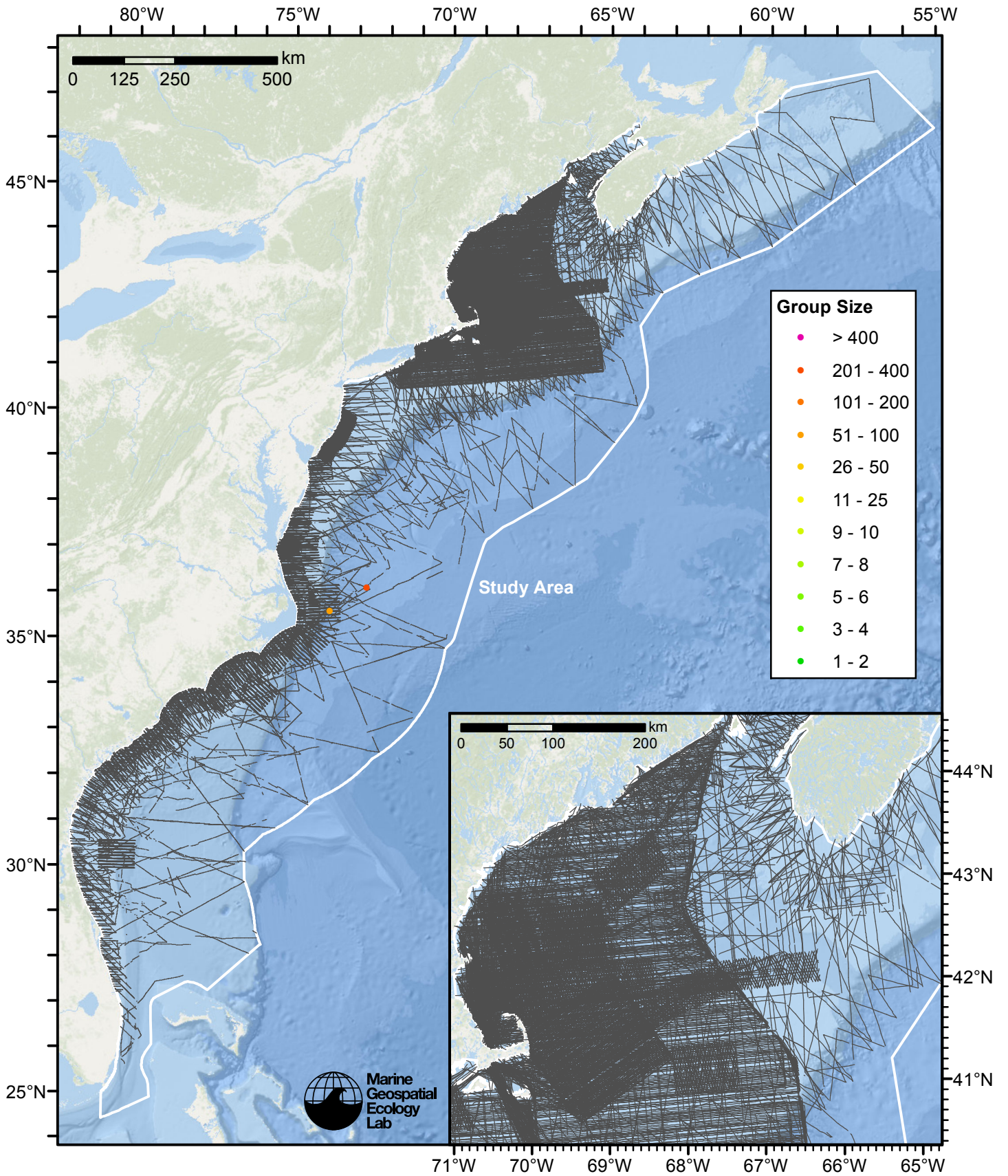
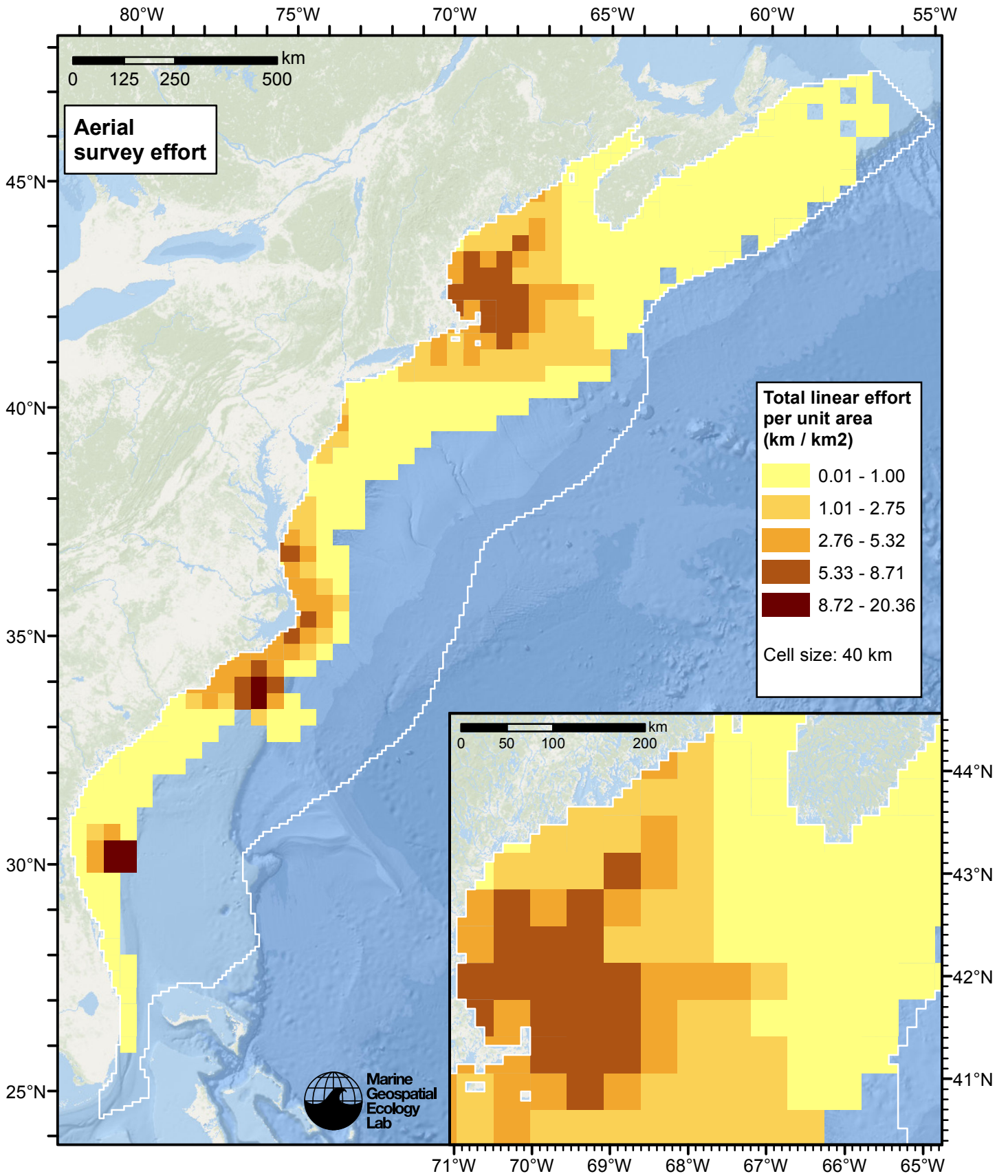Figure 1: Fraser's dolphin sightings and survey tracklines.

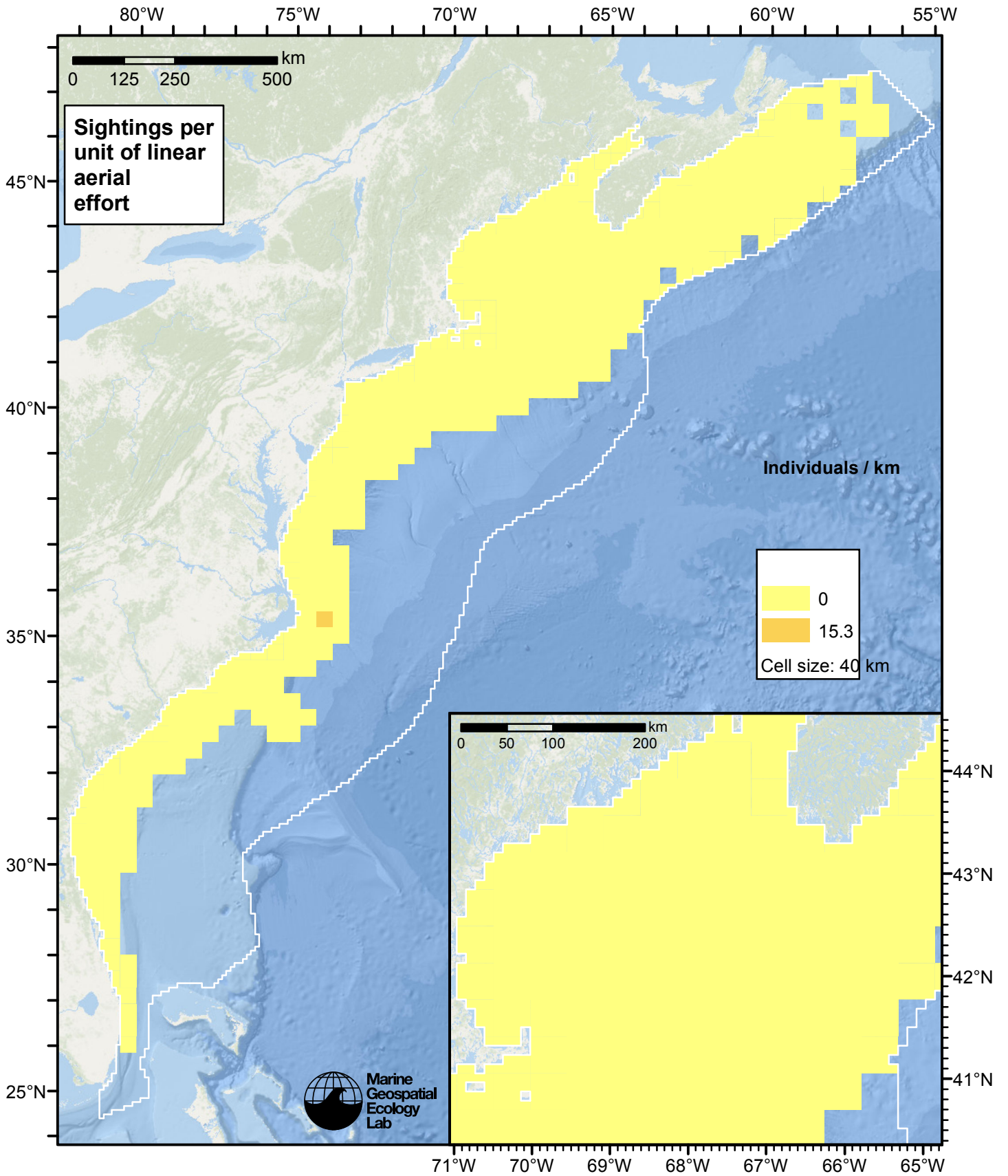Figure 2: Aerial linear survey effort per unit area.

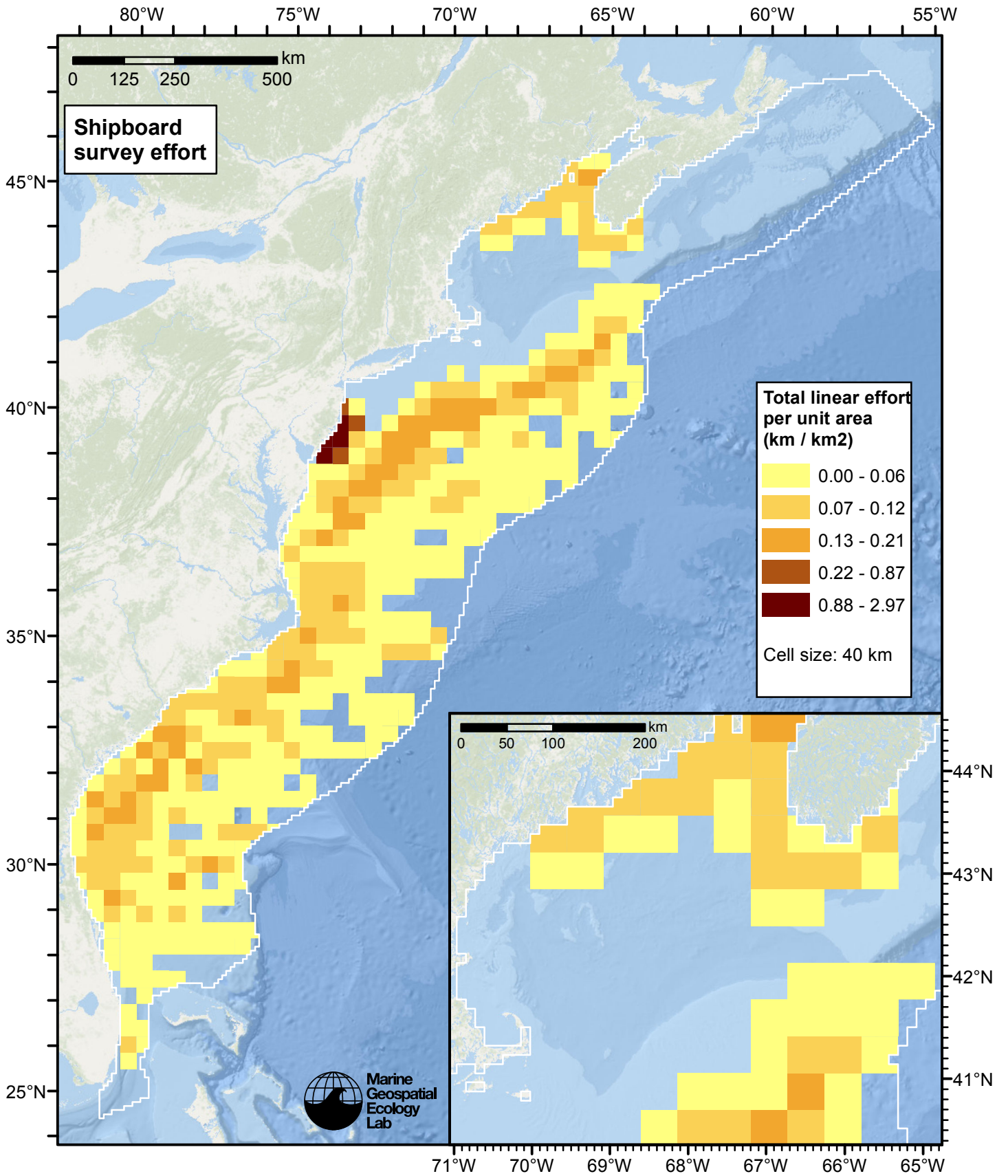Figure 3: Fraser's dolphin sightings per unit aerial linear survey effort.

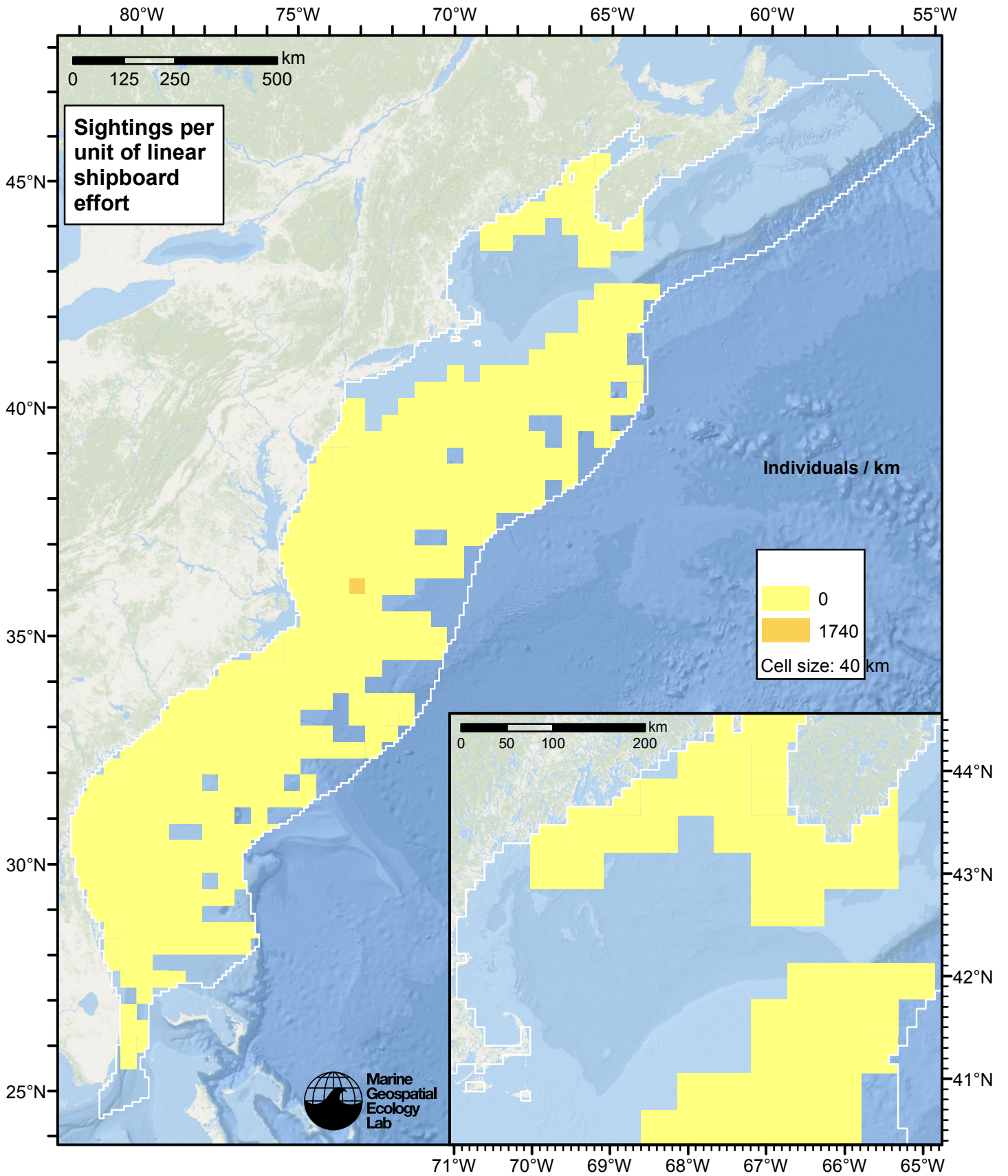Figure 4: Shipboard linear survey effort per unit area.

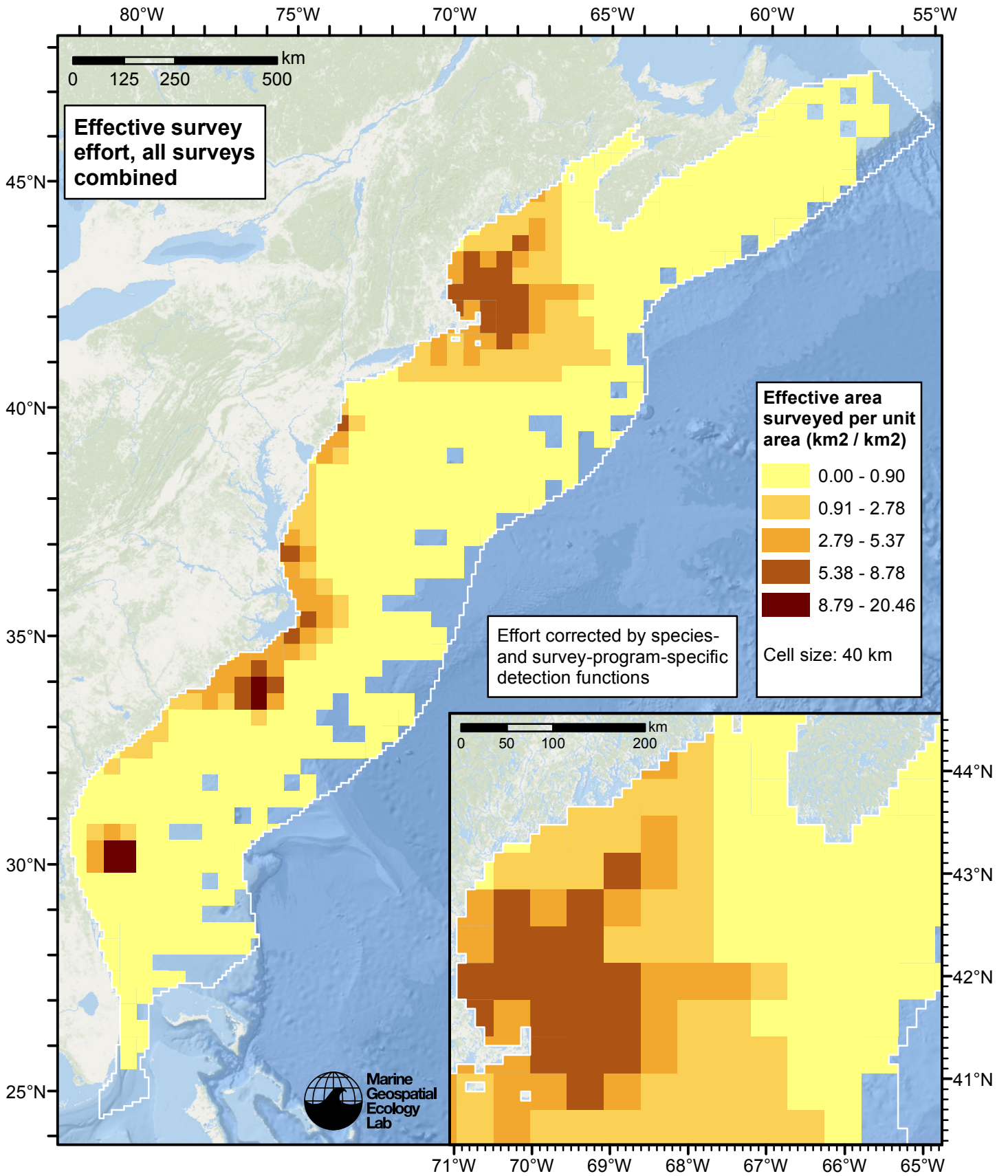Figure 5: Fraser's dolphin sightings per unit shipboard linear survey effort.

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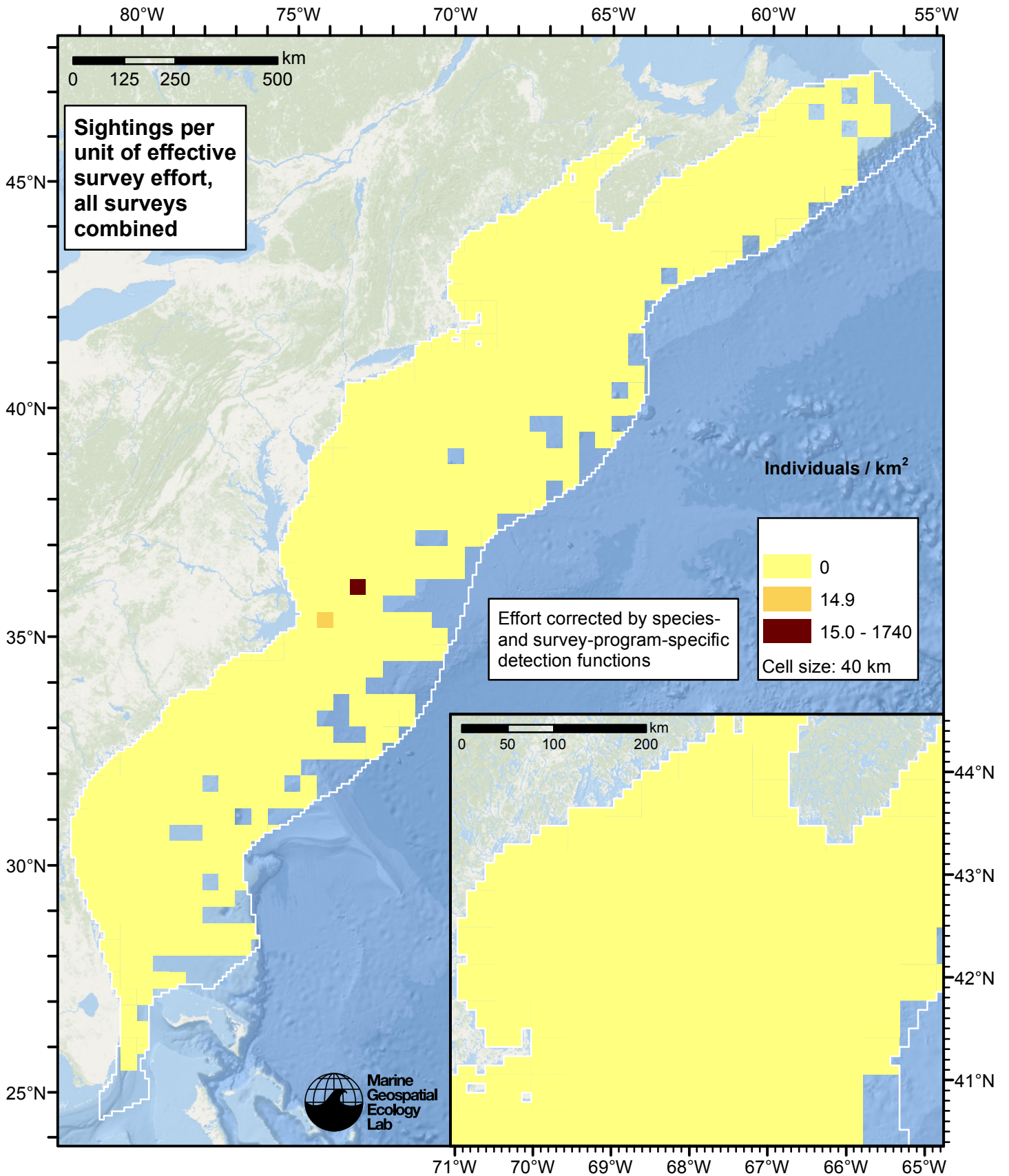
Figure 7: Fraser's dolphin sightings per unit of effective survey effort, for all surveys combined. Here, effort is corrected by the species- and survey-program-specific detection functions used in fitting the density models.

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# Detection Functions

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

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

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

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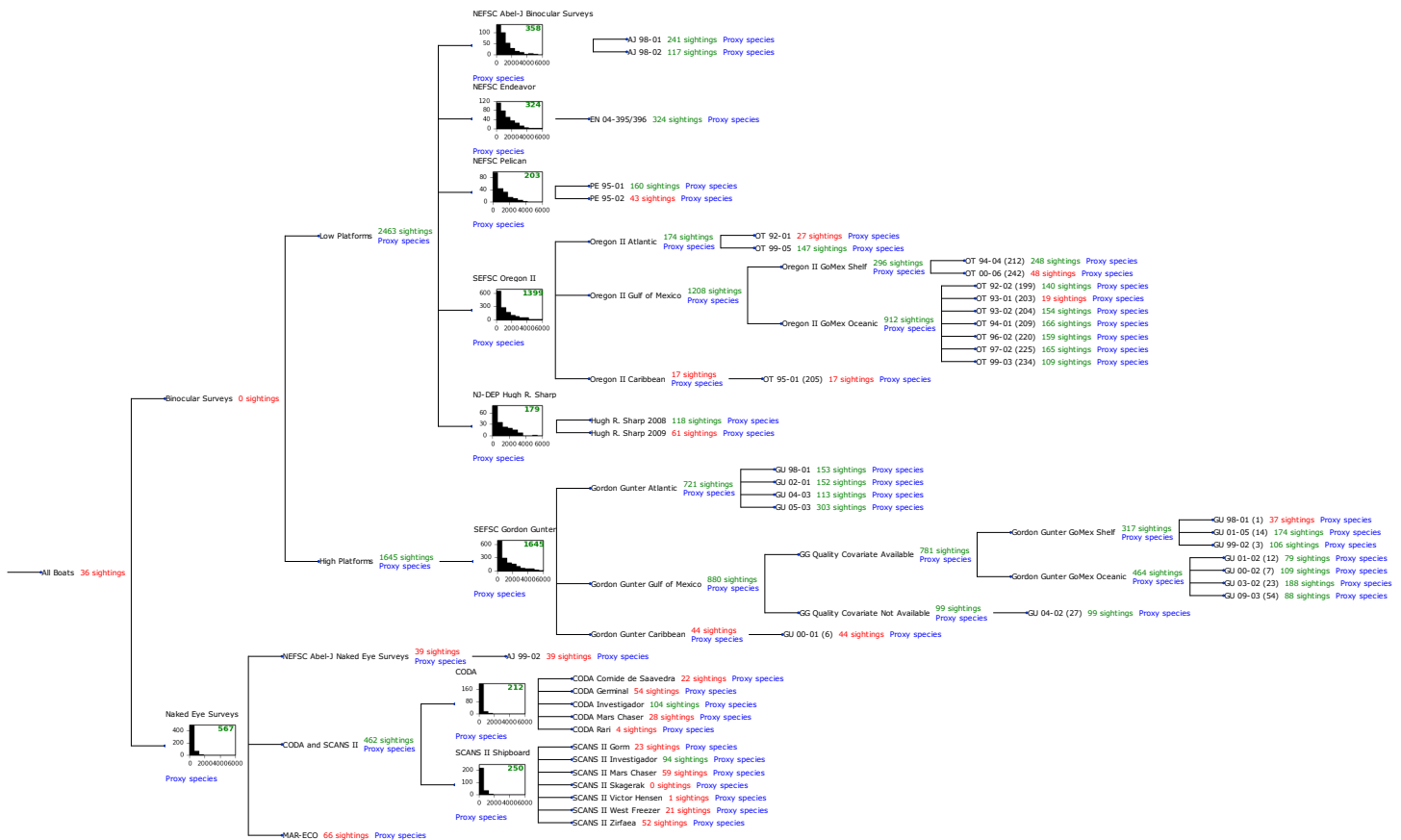
## Shipboard Surveys



Figure 8: Detection hierarchy for shipboard surveys

## NEFSC Abel-J Binocular Surveys

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

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

Table 4: Proxy species used to fit detection functions for NEFSC Abel-J Binocular Surveys. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

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

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

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

Table 6: Candidate detection functions for NEFSC Abel-J Binocular Surveys. The first one listed was selected for the density model.
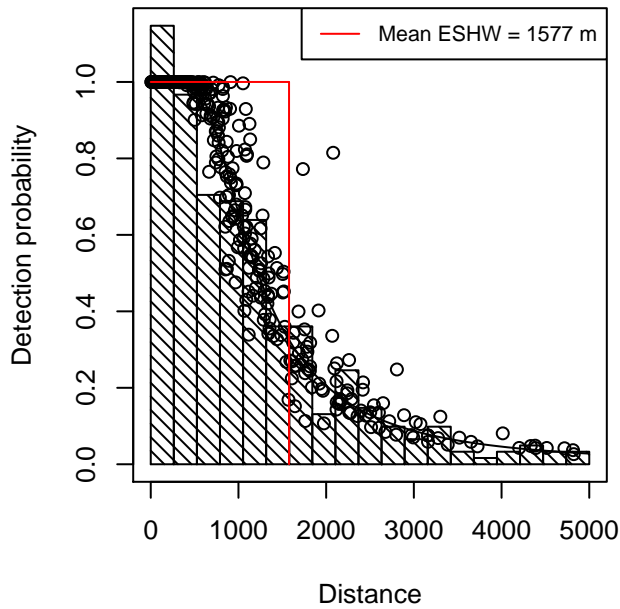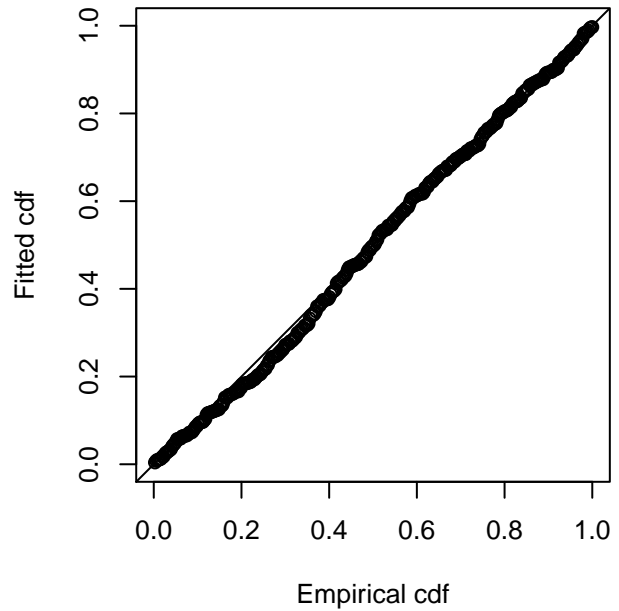
Figure 9: Detection function for NEFSC Abel-J Binocular Surveys that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

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

Shape parameters:
            estimate         se
(Intercept) 0.8389089  0.09859879

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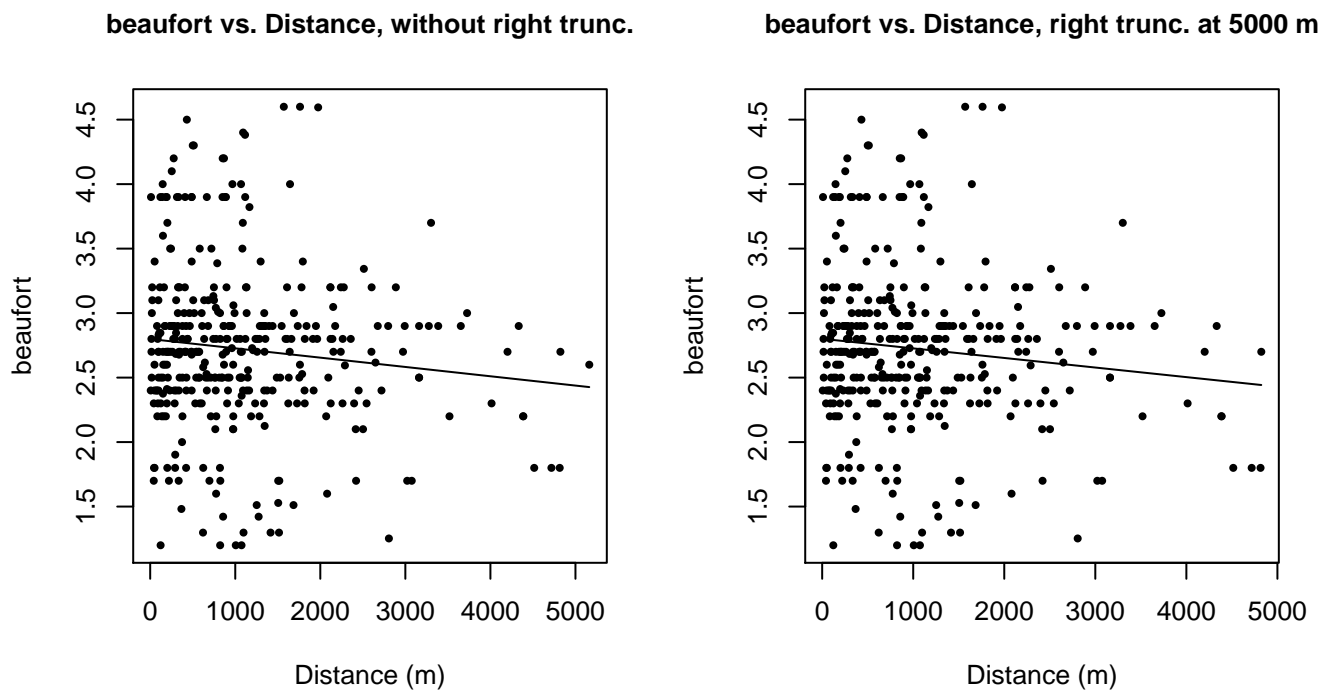
Additional diagnostic plots:

Figure 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.
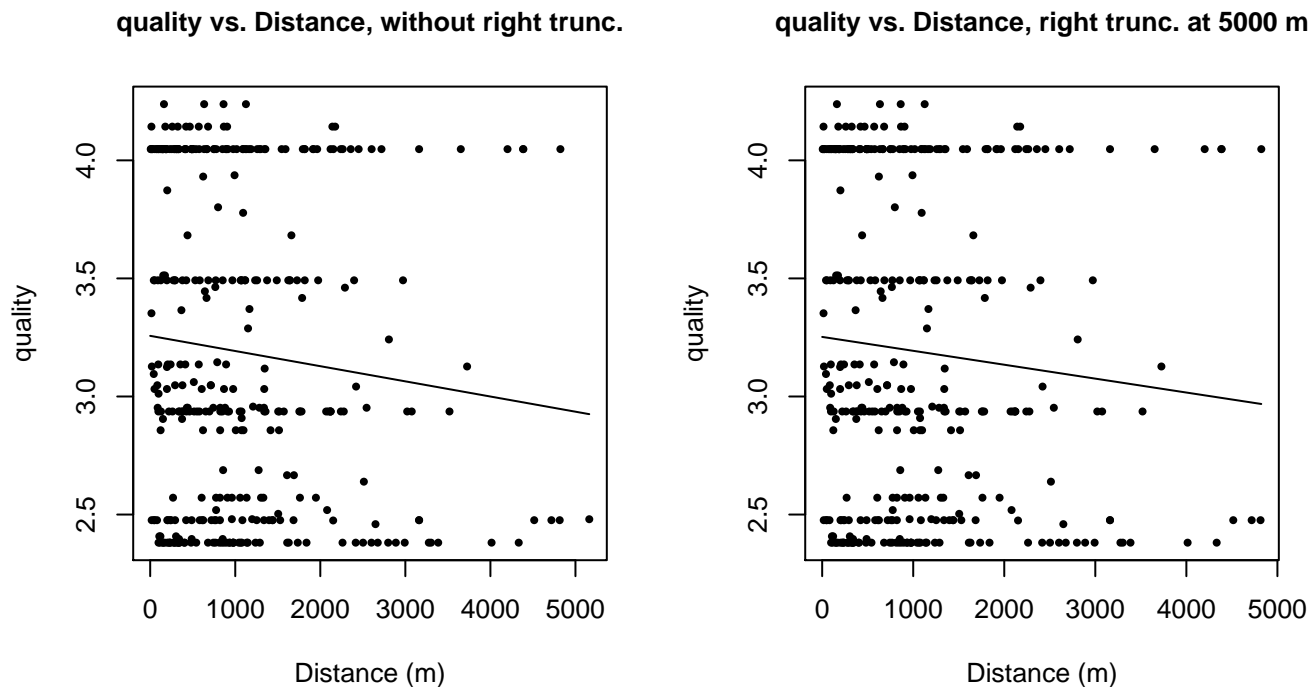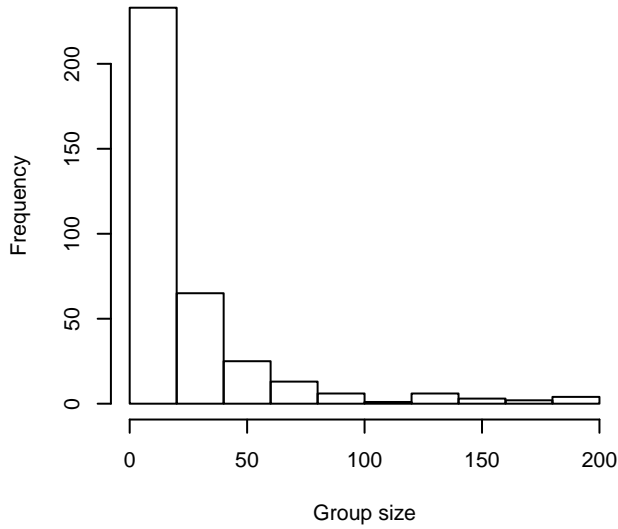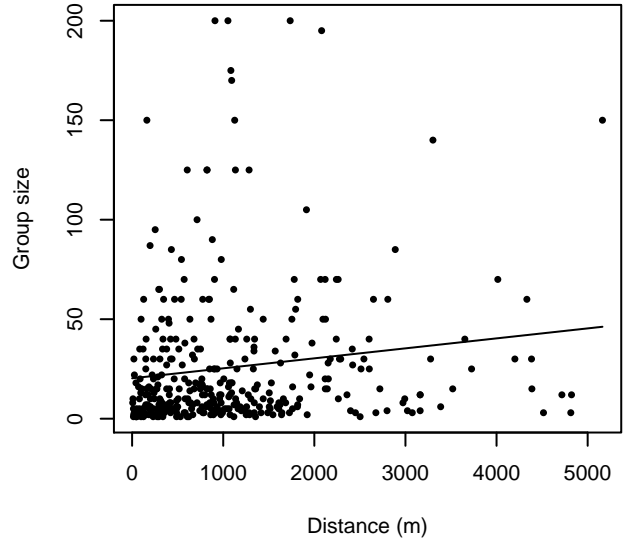


Figure 11: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
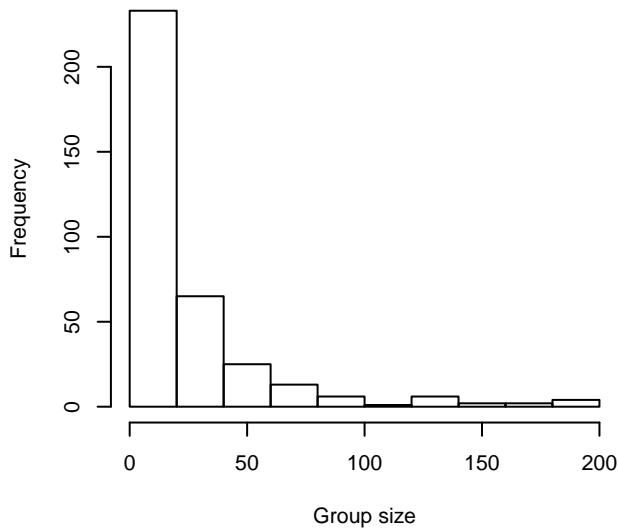
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 5000 m**

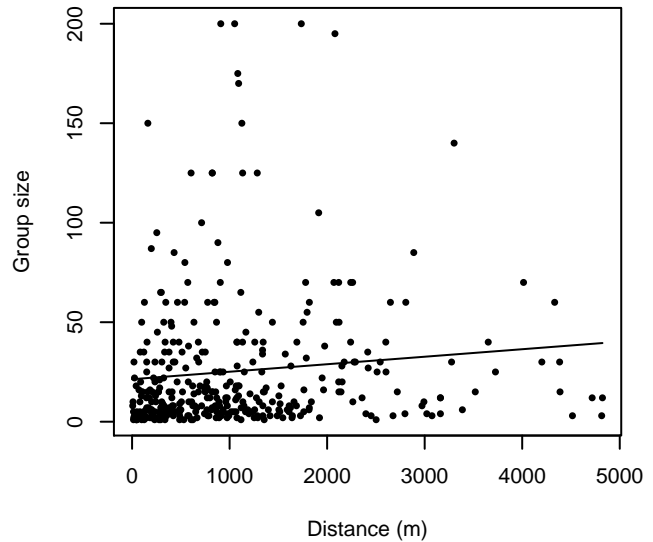**Group Size vs. Distance, right trunc. at 5000 m**

Figure 12: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**NEFSC Endeavor**

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

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

15

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

Table 7: Proxy species used to fit detection functions for NEFSC Endeavor. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

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

Table 8: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

| | | | | | | |
|---|---|---|---|---|---|---|
| hn | cos | 2 | | Yes | 5.68 | 1833 |
| hn | | | size | Yes | 6.54 | 1934 |
| hn | | | quality | Yes | 6.66 | 1934 |
| hr | | | beaufort | Yes | 7.56 | 2068 |
| hn | | | quality, size | Yes | 8.42 | 1934 |
| hr | | | beaufort, size | Yes | 8.71 | 2061 |
| hr | poly | 4 | | Yes | 10.77 | 1909 |
| hr | | | | Yes | 17.87 | 2030 |
| hr | | | size | Yes | 19.40 | 2022 |
| hr | | | quality | Yes | 19.70 | 2039 |
| hr | | | quality, size | Yes | 21.27 | 2030 |
| hr | poly | 2 | | Yes | 64.80 | 1002 |
| hn | herm | 4 | | No | | |
| hn | | | beaufort, quality | No | | |
| hr | | | beaufort, quality | No | | |
| hn | | | beaufort, quality, size | No | | |
| hr | | | beaufort, quality, size | No | | |

Table 9: Candidate detection functions for NEFSC Endeavor. The first one listed was selected for the density model.
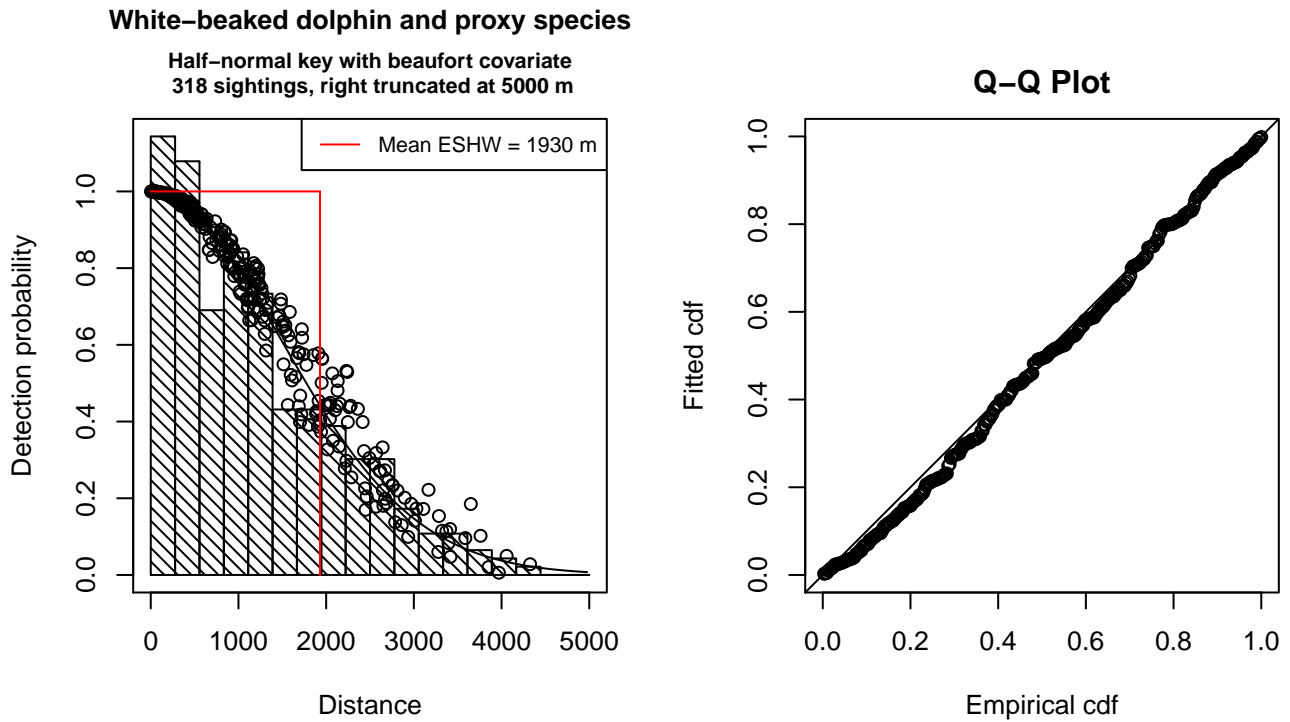


Figure 13: Detection function for NEFSC Endeavor that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Half-normal key function

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

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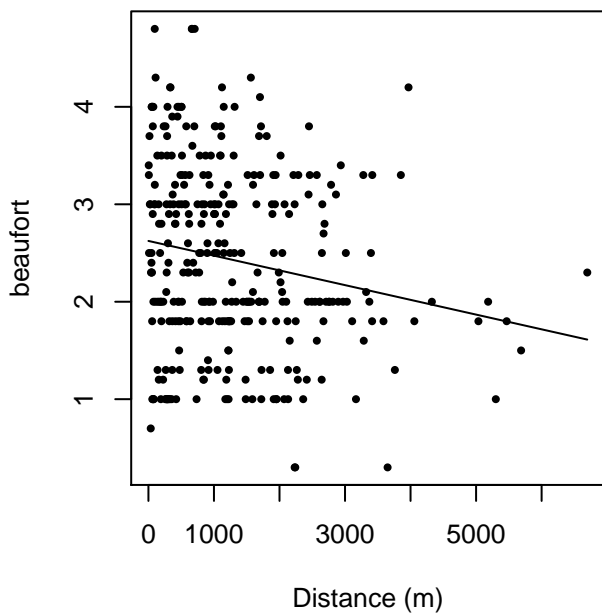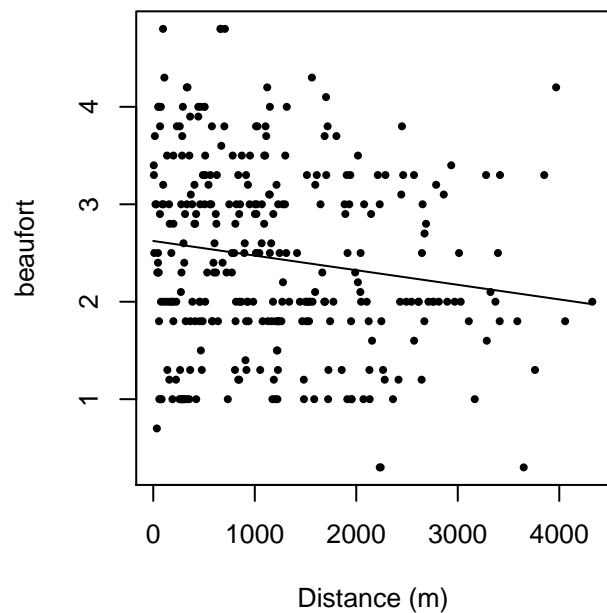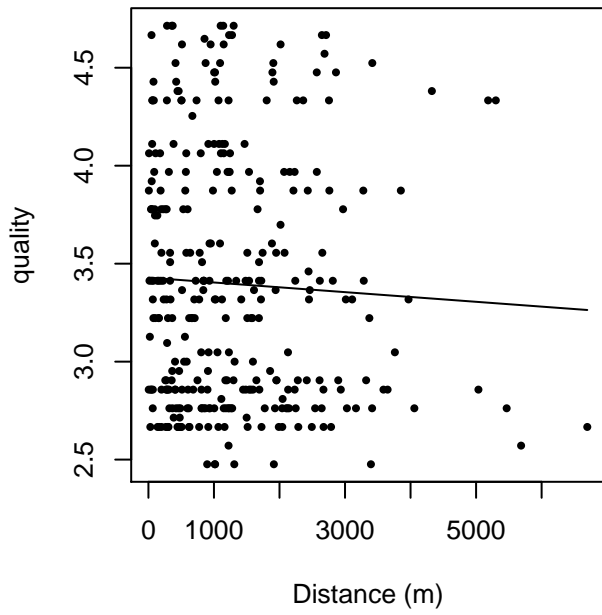
Additional diagnostic plots:



Figure 14: 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.**

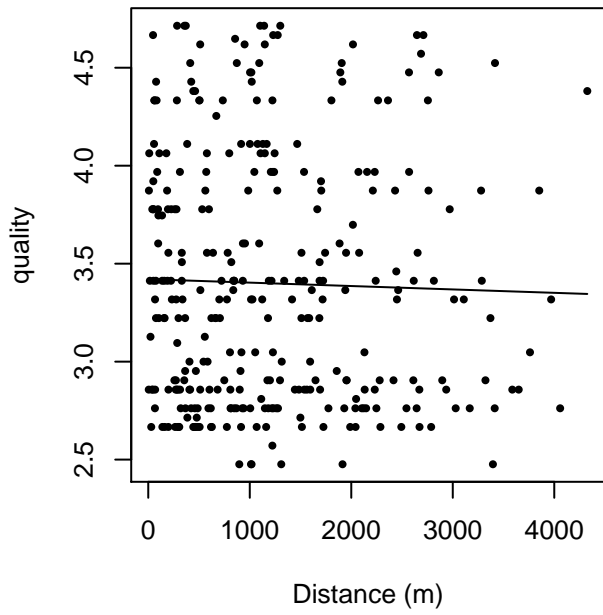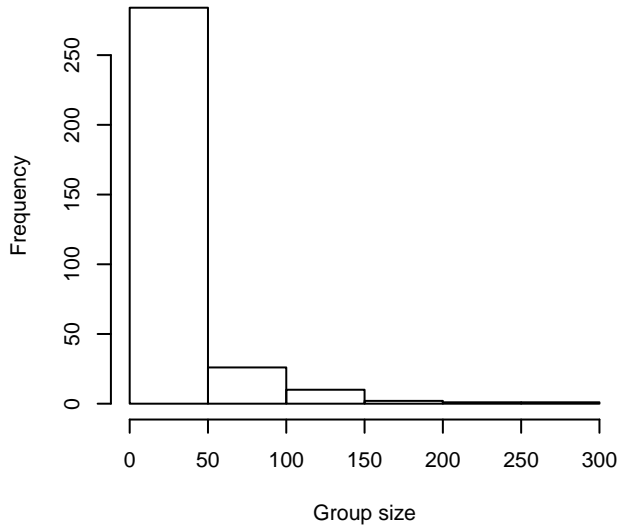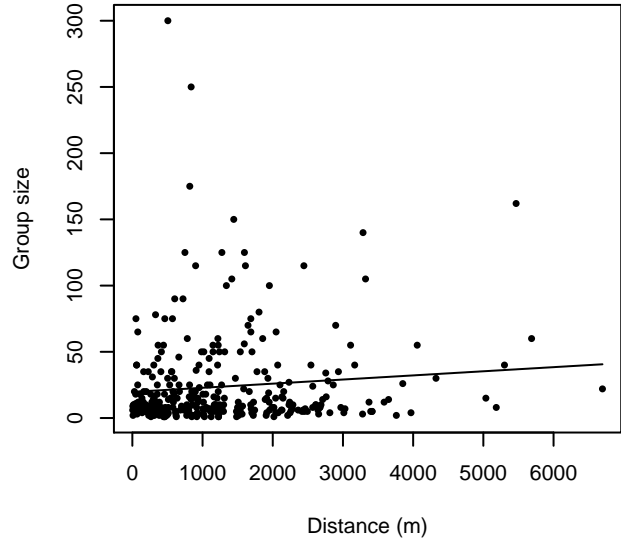**quality vs. Distance, right trunc. at 5000 m**

Figure 15: 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.
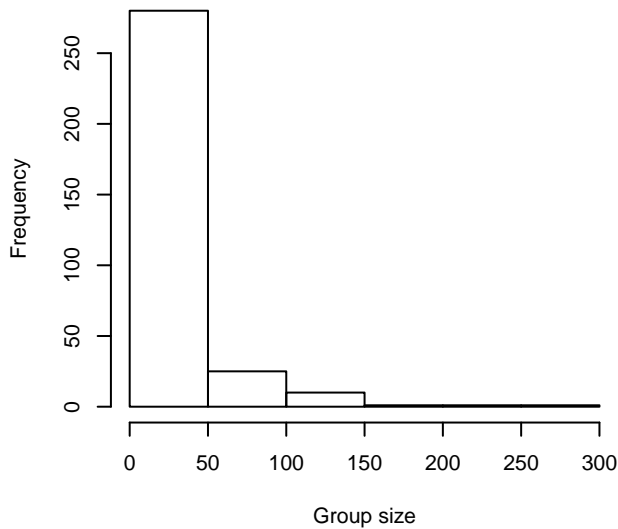
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 5000 m**

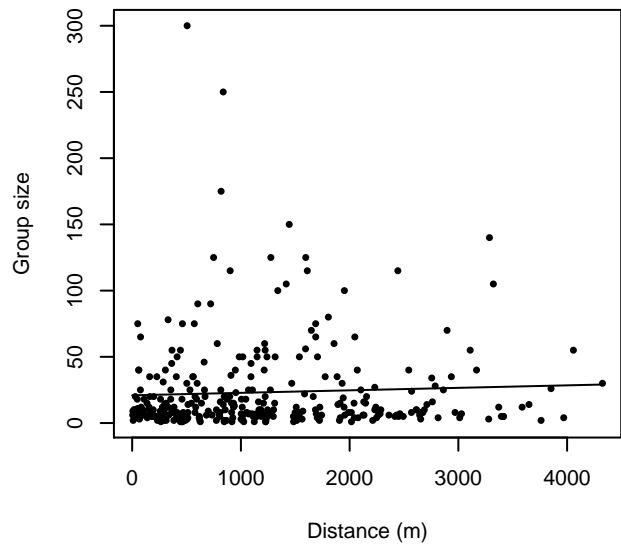**Group Size vs. Distance, right trunc. at 5000 m**

Figure 16: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**NEFSC Pelican**

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

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

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

Table 10: Proxy species used to fit detection functions for NEFSC Pelican. The number of sightings, n, is before truncation.

The sightings were right truncated at 4000m.

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

Table 11: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 12: Candidate detection functions for NEFSC Pelican. The first one listed was selected for the density model.
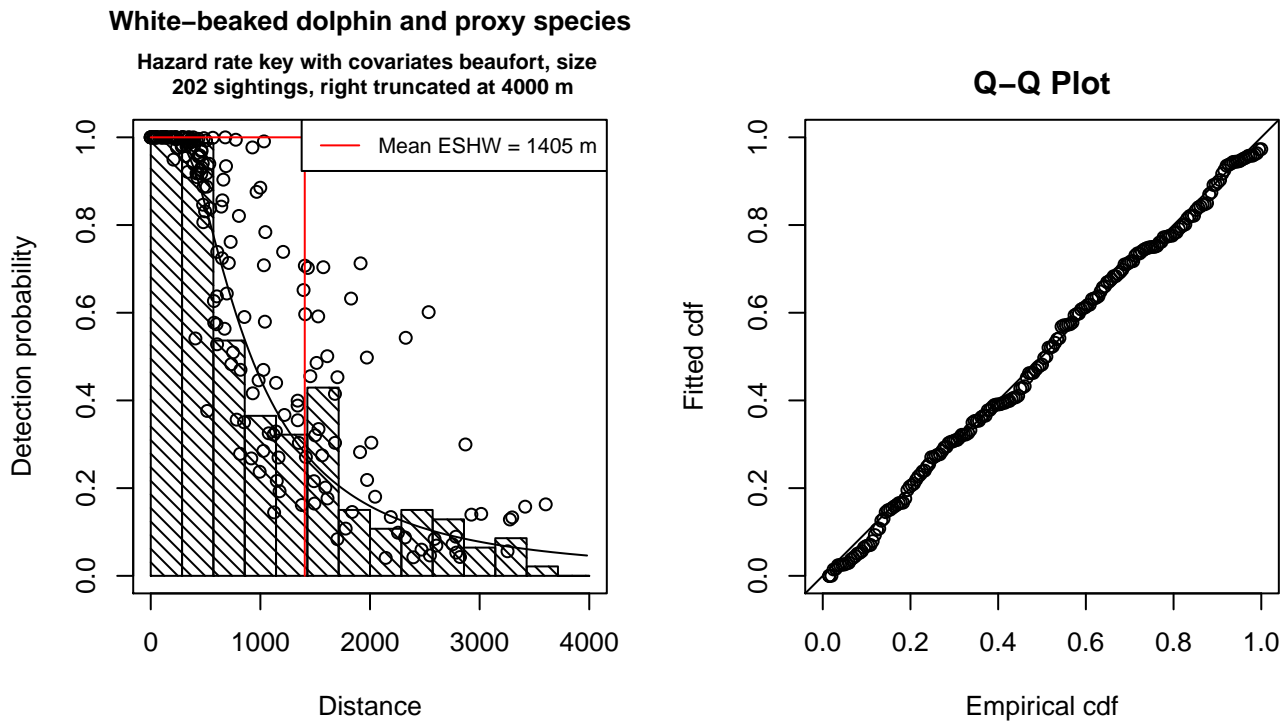


Figure 17: Detection function for NEFSC Pelican that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept)  7.5661728 0.3373193
beaufort    -0.4174589 0.1318753
```

```
size           0.4251734 0.1773940


Shape parameters:
             estimate        se
(Intercept) 0.7201716 0.1414403


                       Estimate          SE          CV
Average p             0.3096997  0.03001707 0.09692314
N in covered region 652.2447463 74.41565270 0.11409161
```
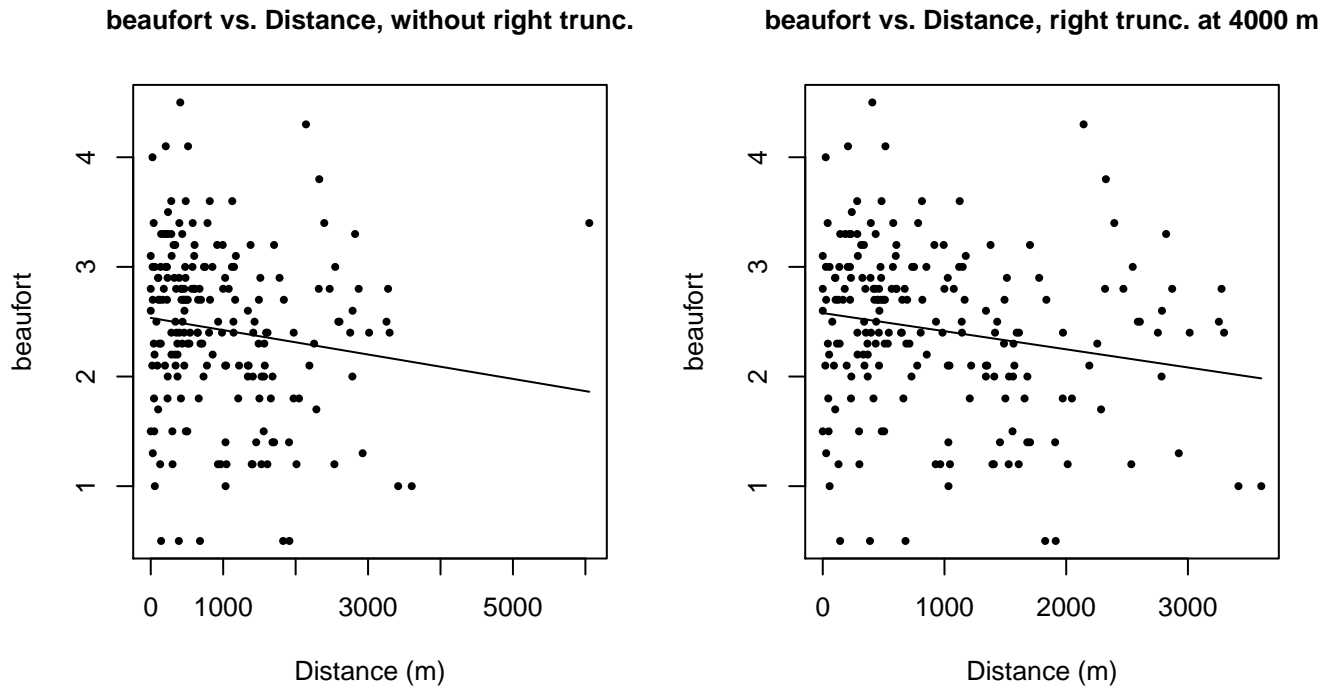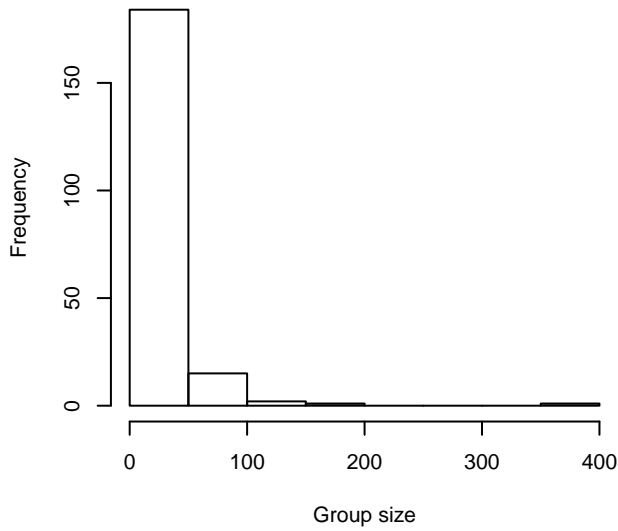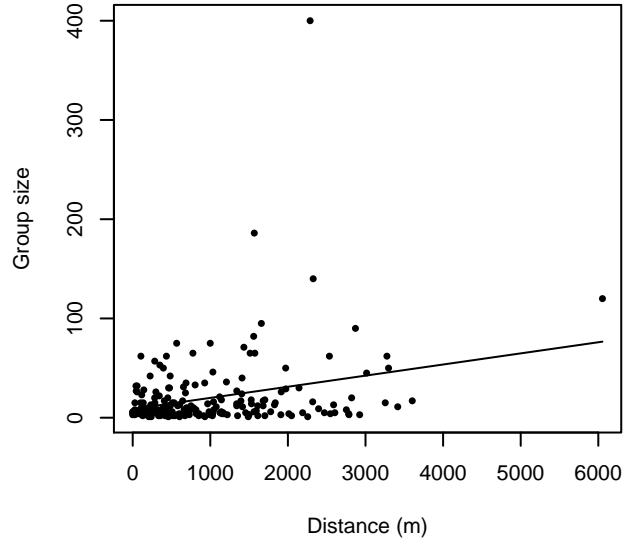
Additional diagnostic plots:



Figure 18: 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.
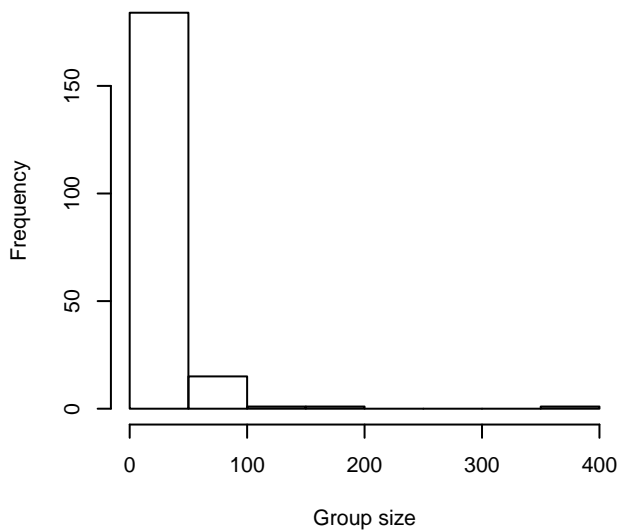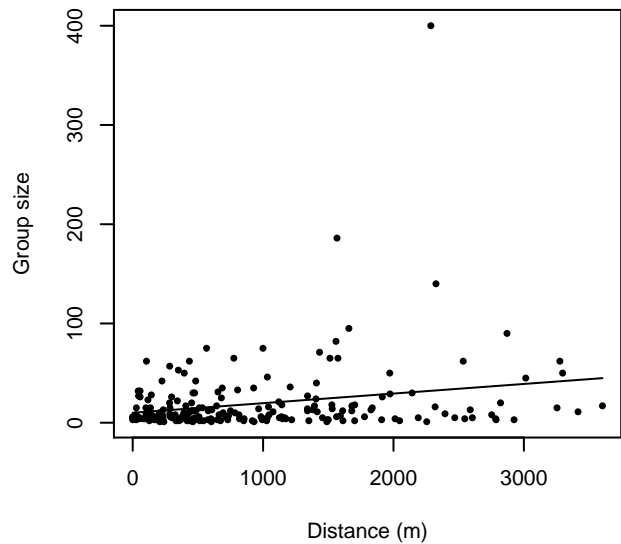
Figure 19: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

## SEFSC Oregon II

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

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

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

Table 13: Proxy species used to fit detection functions for SEFSC Oregon II. The number of sightings, n, is before truncation.

The sightings were right truncated at 5000m.

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

Table 14: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

| Key | Adjustment | Order | Covariates | Succeeded | Δ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---|
| hr | | | beaufort, size | Yes | 0.00 | 807 |
| hr | | | quality, size | Yes | 4.77 | 771 |
| hr | | | size | Yes | 40.78 | 712 |
| hr | | | beaufort, quality | Yes | 52.03 | 579 |

| | | | | | | |
|----|------|---|-----------------------|-----|--------|------|
| hr | | | quality | Yes | 77.42 | 536 |
| hr | | | beaufort | Yes | 89.47 | 513 |
| hr | poly | 4 | | Yes | 96.59 | 501 |
| hr | poly | 2 | | Yes | 103.38 | 525 |
| hr | | | | Yes | 121.28 | 461 |
| hn | cos | 3 | | Yes | 341.53 | 1351 |
| hn | cos | 2 | | Yes | 345.64 | 1510 |
| hn | | | beaufort, quality, size | Yes | 393.07 | 1951 |
| hn | | | quality, size | Yes | 417.71 | 1946 |
| hn | | | beaufort, size | Yes | 440.00 | 1977 |
| hn | | | beaufort, quality | Yes | 454.31 | 1929 |
| hn | | | size | Yes | 465.37 | 1968 |
| hn | | | quality | Yes | 465.95 | 1932 |
| hn | | | beaufort | Yes | 518.70 | 1941 |
| hn | | | | Yes | 529.51 | 1944 |
| hn | herm | 4 | | No | | |
| hr | | | beaufort, quality, size | No | | |

Table 15: Candidate detection functions for SEFSC Oregon II. The first one listed was selected for the density model.
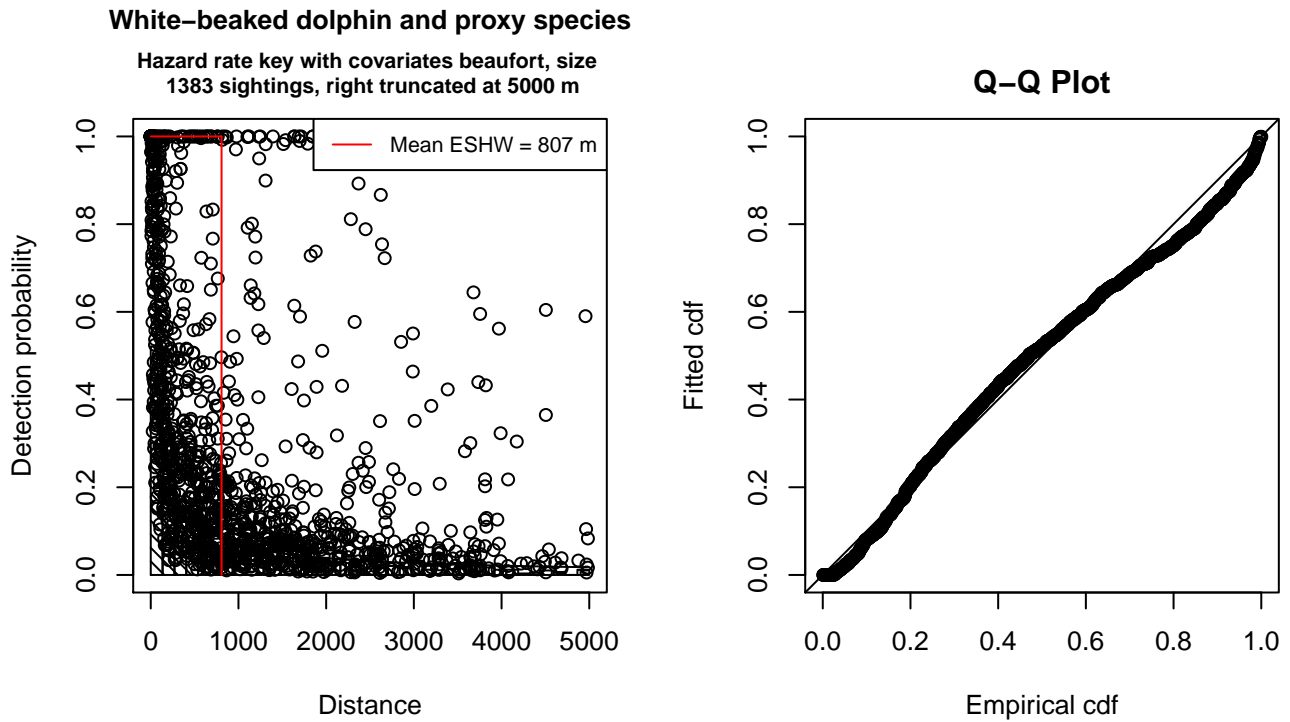


Figure 20: Detection function for SEFSC Oregon II that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

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

Shape parameters:
           estimate          se
(Intercept)       0 0.03476077


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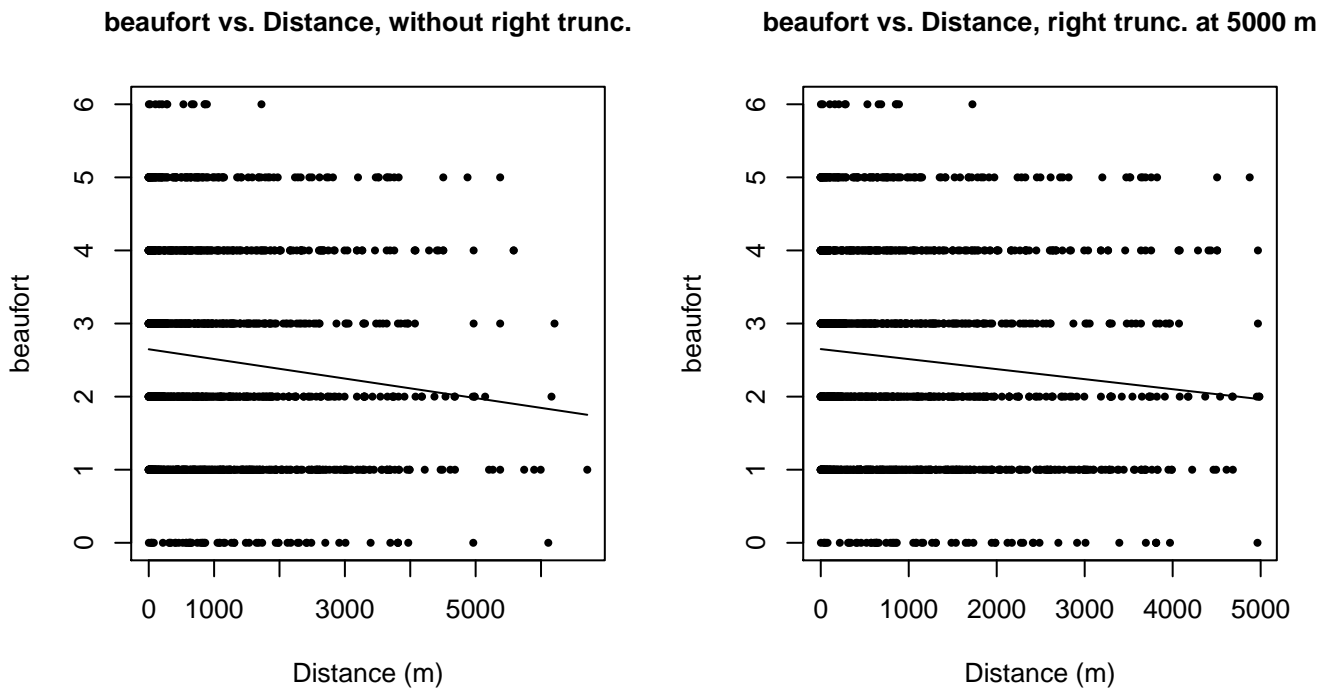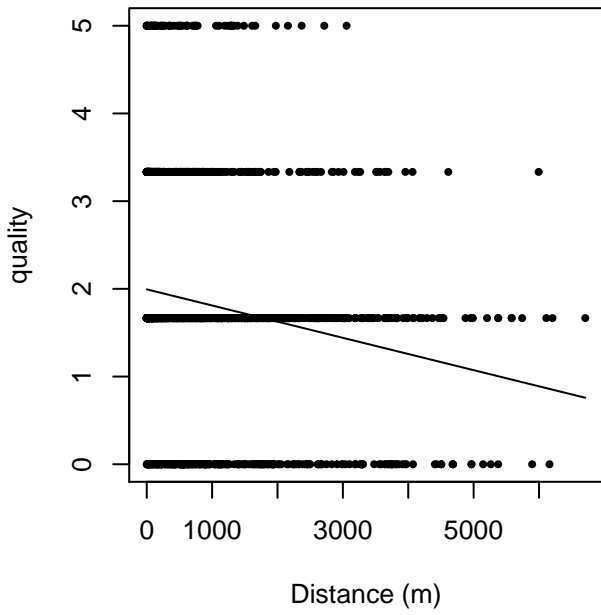
Additional diagnostic plots:



Figure 21: 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.
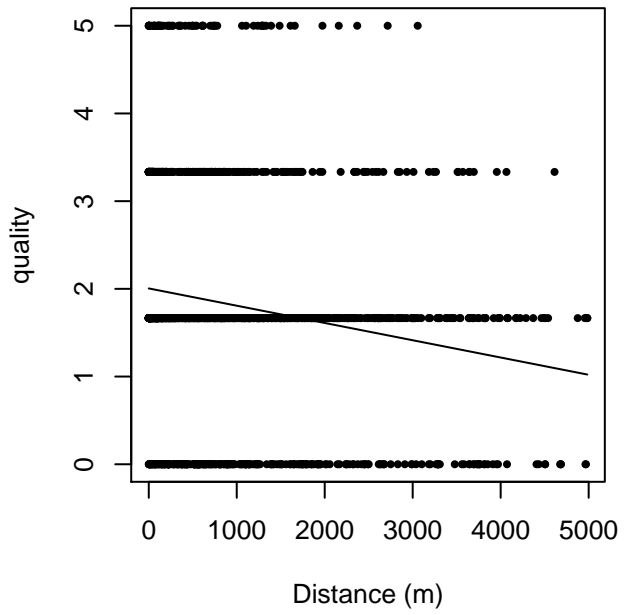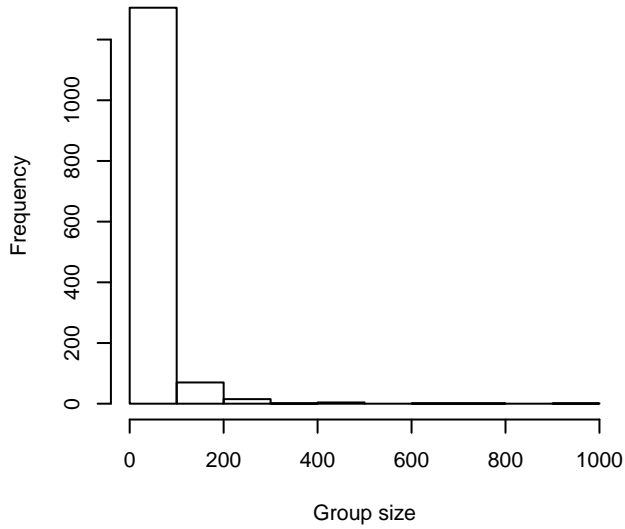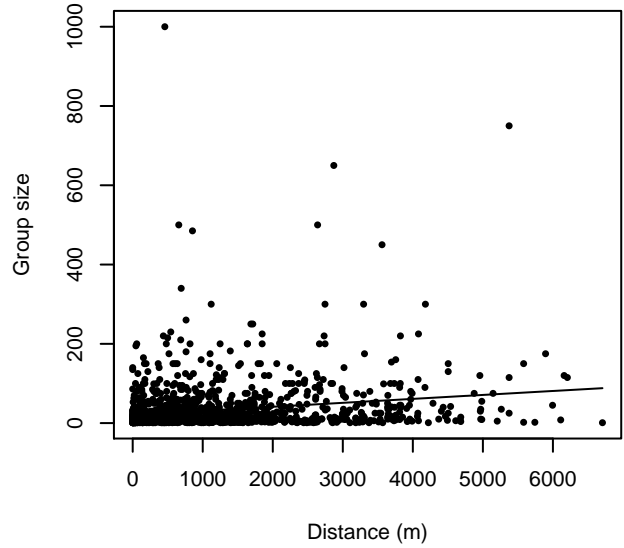
Figure 22: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
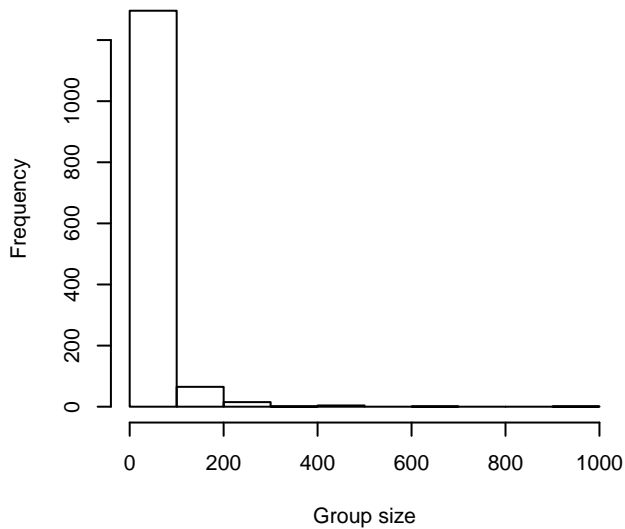
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 5000 m**

**Group Size vs. Distance, right trunc. at 5000 m**
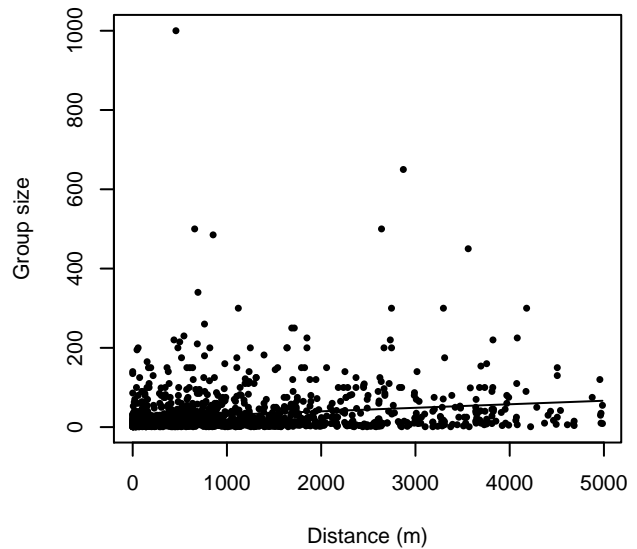
Figure 23: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

### NJ-DEP Hugh R. Sharp

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

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

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

Table 16: Proxy species used to fit detection functions for NJ-DEP Hugh R. Sharp. The number of sightings, n, is before truncation.

The sightings were right truncated at 4000m.

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

Table 17: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 18: Candidate detection functions for NJ-DEP Hugh R. Sharp. The first one listed was selected for the density model.

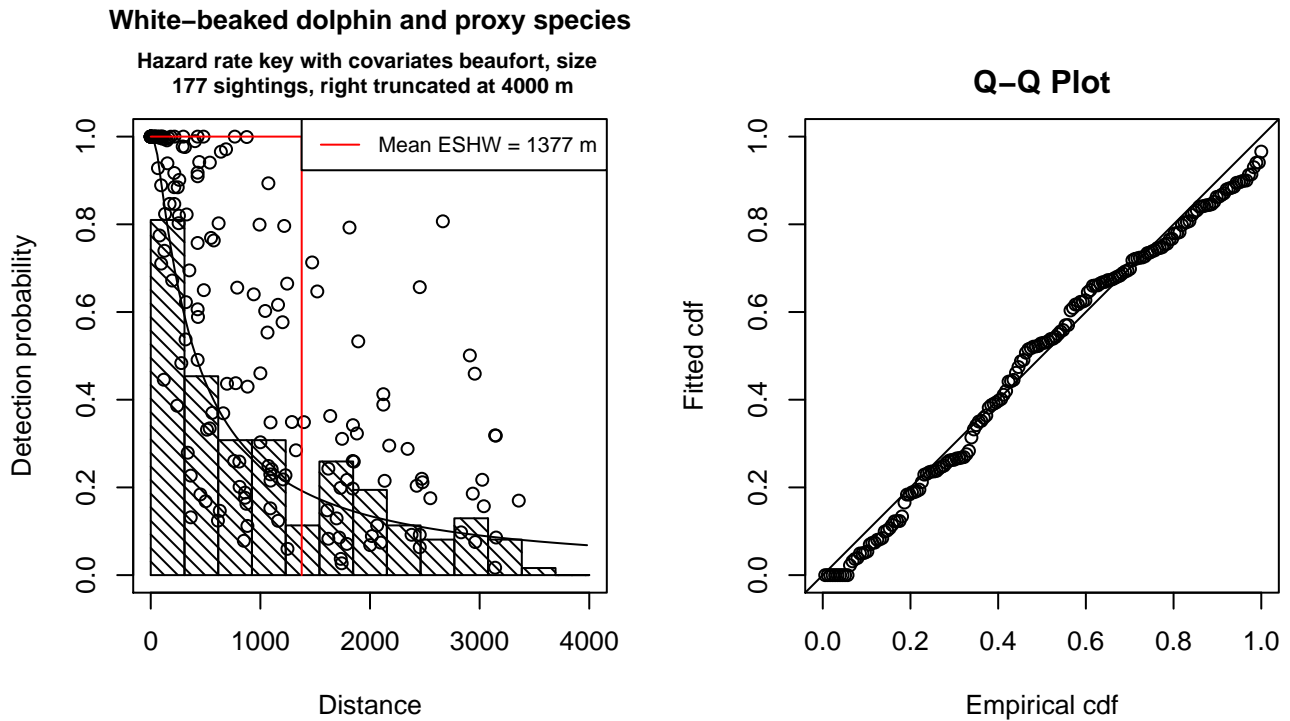

Figure 24: Detection function for NJ-DEP Hugh R. Sharp that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

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

Shape parameters:
             estimate         se
(Intercept) 0.2435139 0.154517


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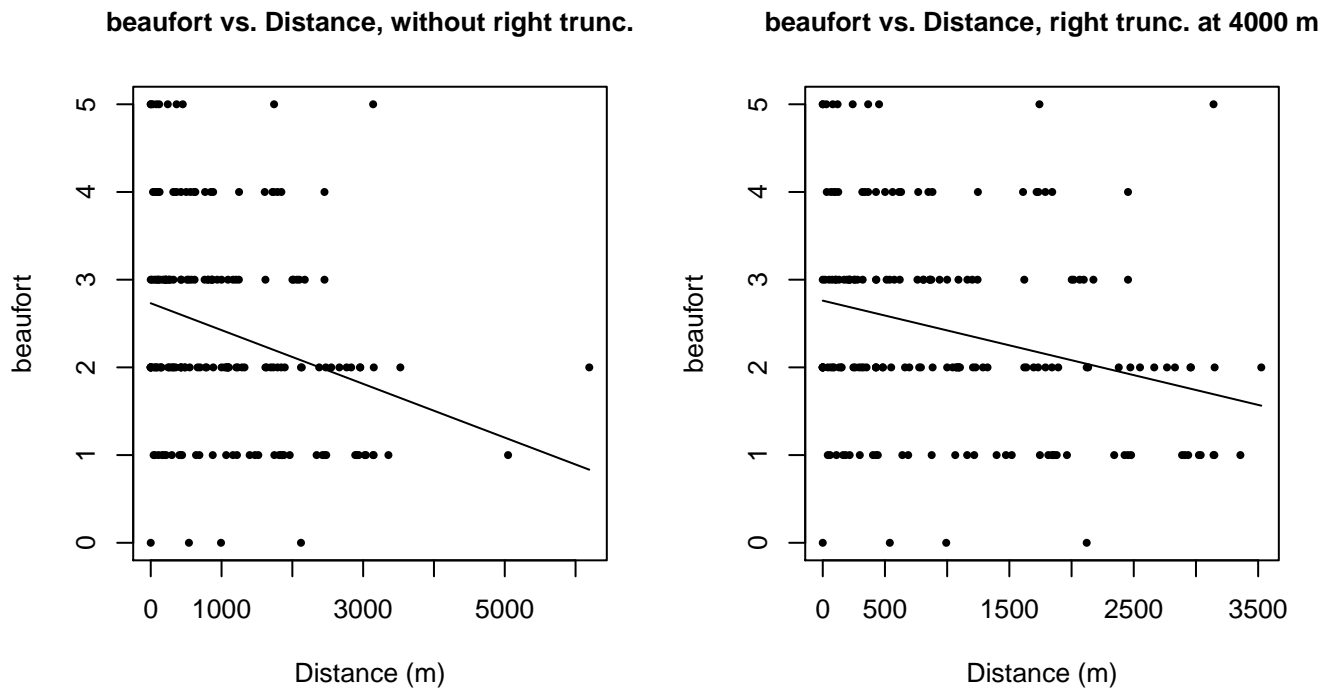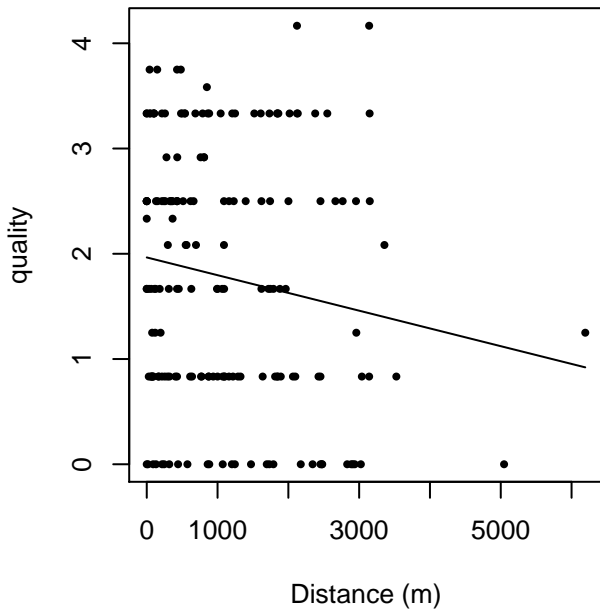
Additional diagnostic plots:



Figure 25: 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.
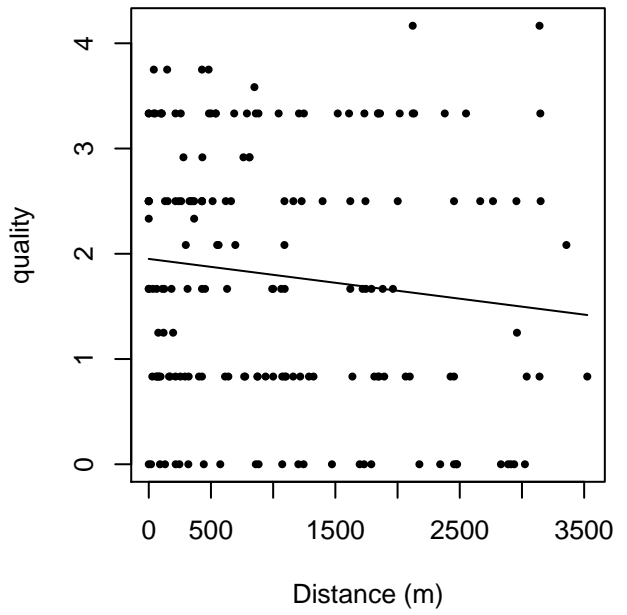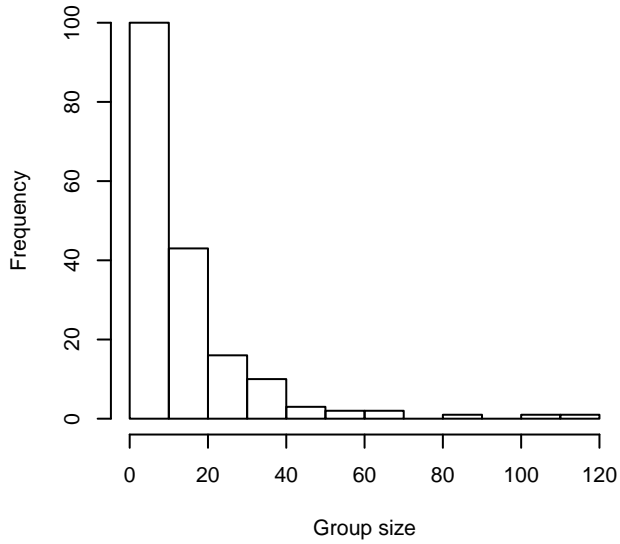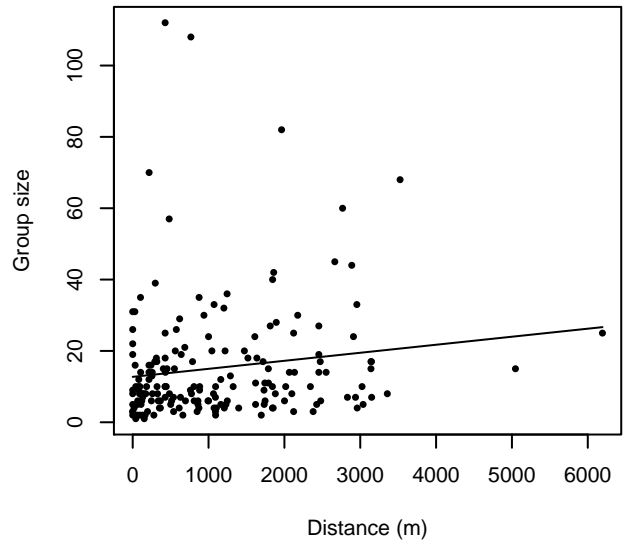
Figure 26: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
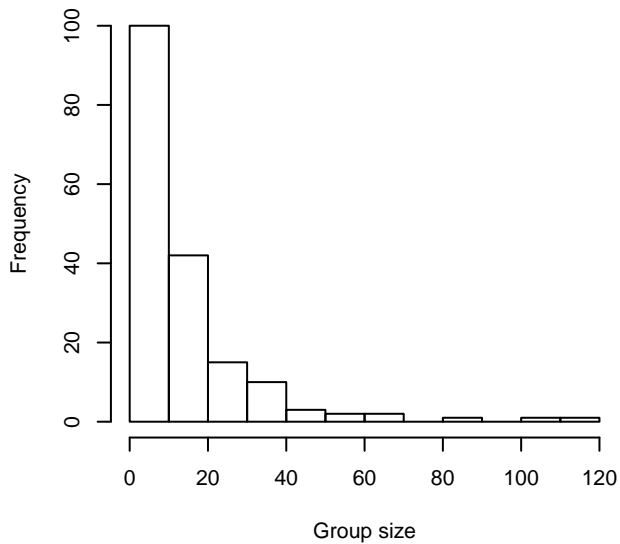
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 4000 m**

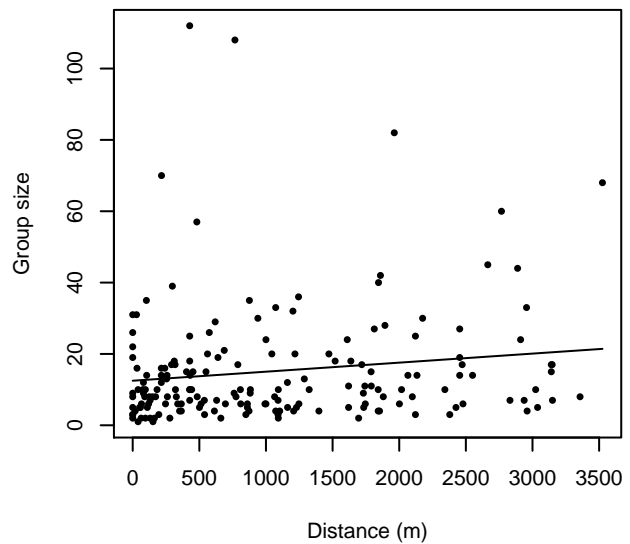**Group Size vs. Distance, right trunc. at 4000 m**

Figure 27: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**SEFSC Gordon Gunter**

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

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

34

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

Table 19: Proxy species used to fit detection functions for SEFSC Gordon Gunter. The number of sightings, n, is before truncation.

The sightings were right truncated at 6000m.

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

Table 20: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

| Key | Adjustment | Order | Covariates | Succeeded | $\Delta$ AIC | Mean ESHW (m) |
|---|---|---|---|---|---:|---:|
| hr | | | beaufort | Yes | 0.00 | 845 |
| hr | | | size | Yes | 56.50 | 827 |
| hr | poly | 4 | | Yes | 109.59 | 672 |
| hr | poly | 2 | | Yes | 120.70 | 708 |
| hr | | | | Yes | 146.78 | 605 |
| hn | | | beaufort, size | Yes | 363.66 | 2358 |

| hn | cos | 3 | | Yes | 368.33 | 1658 |
|---|---|---|---|---|---|---|
| hn | cos | 2 | | Yes | 369.53 | 1845 |
| hn | | | beaufort | Yes | 445.88 | 2329 |
| hn | | | size | Yes | 494.38 | 2392 |
| hn | | | | Yes | 562.91 | 2351 |
| hn | herm | 4 | | No | | |
| hr | | | beaufort, size | No | | |

Table 21: Candidate detection functions for SEFSC Gordon Gunter. The first one listed was selected for the density model.
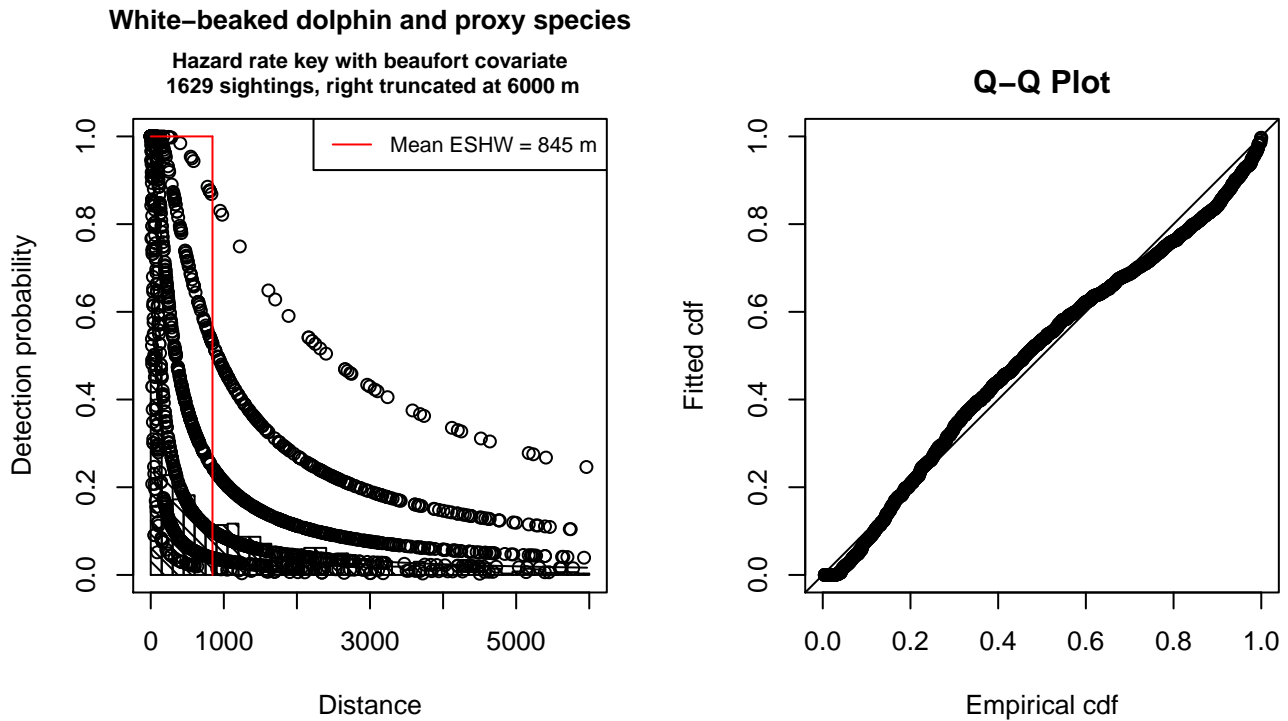


Figure 28: Detection function for SEFSC Gordon Gunter that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1629
Distance range         :  0  -  6000
AIC                    :  26333.8

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept)  7.4292786 0.19090384
beaufort    -0.9782277 0.07236275
```

```
Shape parameters:
            estimate         se
(Intercept)        0 0.03349464


                        Estimate           SE         CV
Average p           6.437877e-02 6.755469e-03 0.1049332
N in covered region 2.530337e+04 2.729041e+03 0.1078529
```
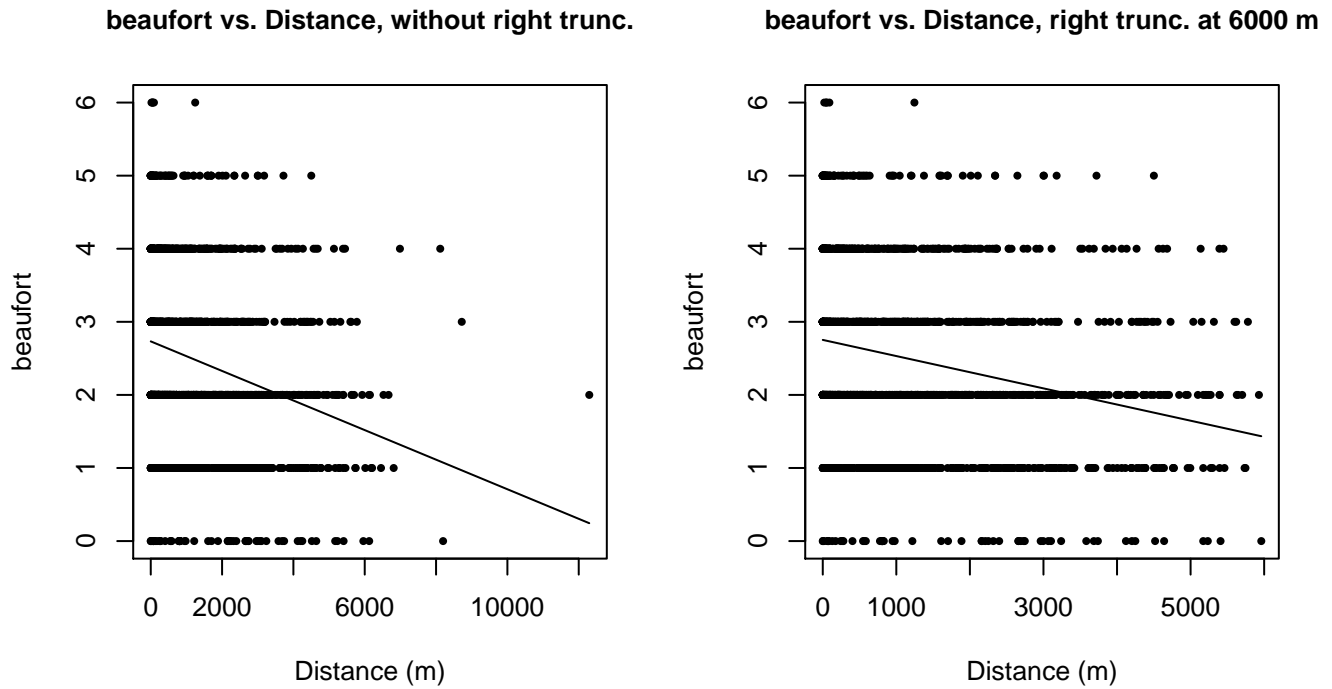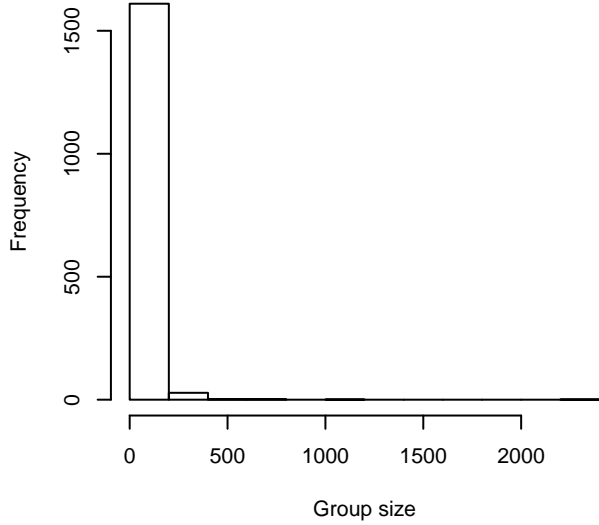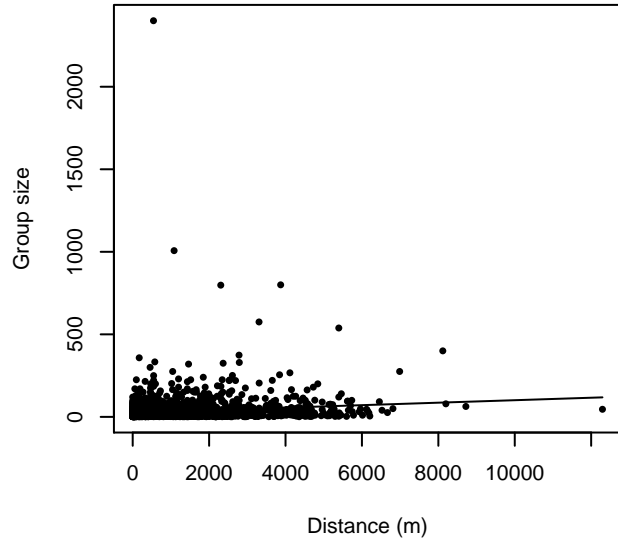
Additional diagnostic plots:



Figure 29: 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.
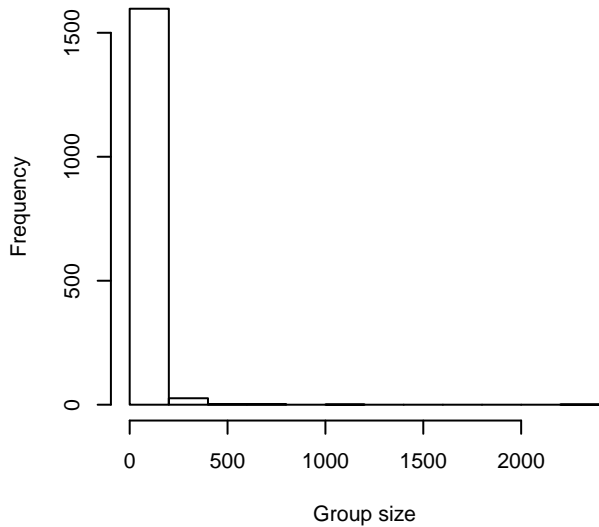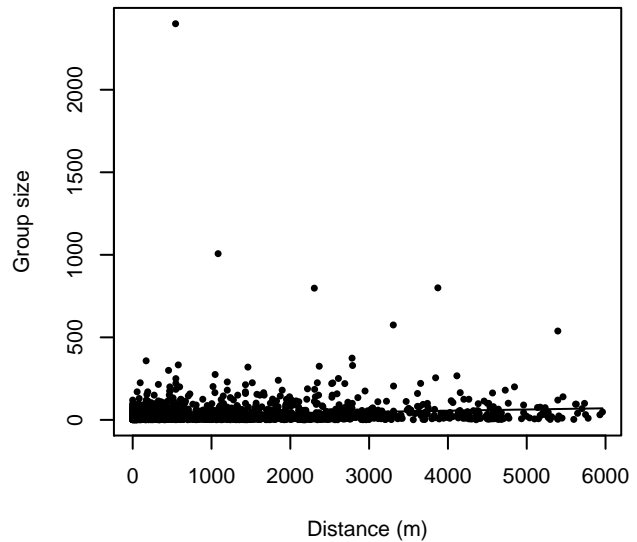
Figure 30: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**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 |
|---|---|---|
| Delphinus capensis | Long-beaked common dolphin | 0 |
| Delphinus delphis | 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 22: 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 1300m.

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

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

| Key | Adjustment | Order | Covariates | Succeeded | $\Delta$ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---|
| hr | | | beaufort, size | Yes | 0.00 | 350 |
| hr | | | size | Yes | 5.76 | 352 |
| hr | | | beaufort | Yes | 8.03 | 326 |
| hr | poly | 2 | | Yes | 9.77 | 281 |
| hr | poly | 4 | | Yes | 12.40 | 307 |
| hr | | | | Yes | 15.22 | 330 |

| | | | | | | |
|---|---|---|---|---|---|---|
| hn | cos | 2 | | Yes | 24.51 | 385 |
| hn | cos | 3 | | Yes | 33.35 | 352 |
| hn | | | size | Yes | 58.26 | 486 |
| hn | | | beaufort, size | Yes | 58.62 | 487 |
| hn | | | | Yes | 78.39 | 479 |
| hn | | | beaufort | Yes | 78.83 | 478 |
| hn | herm | 4 | | No | | |

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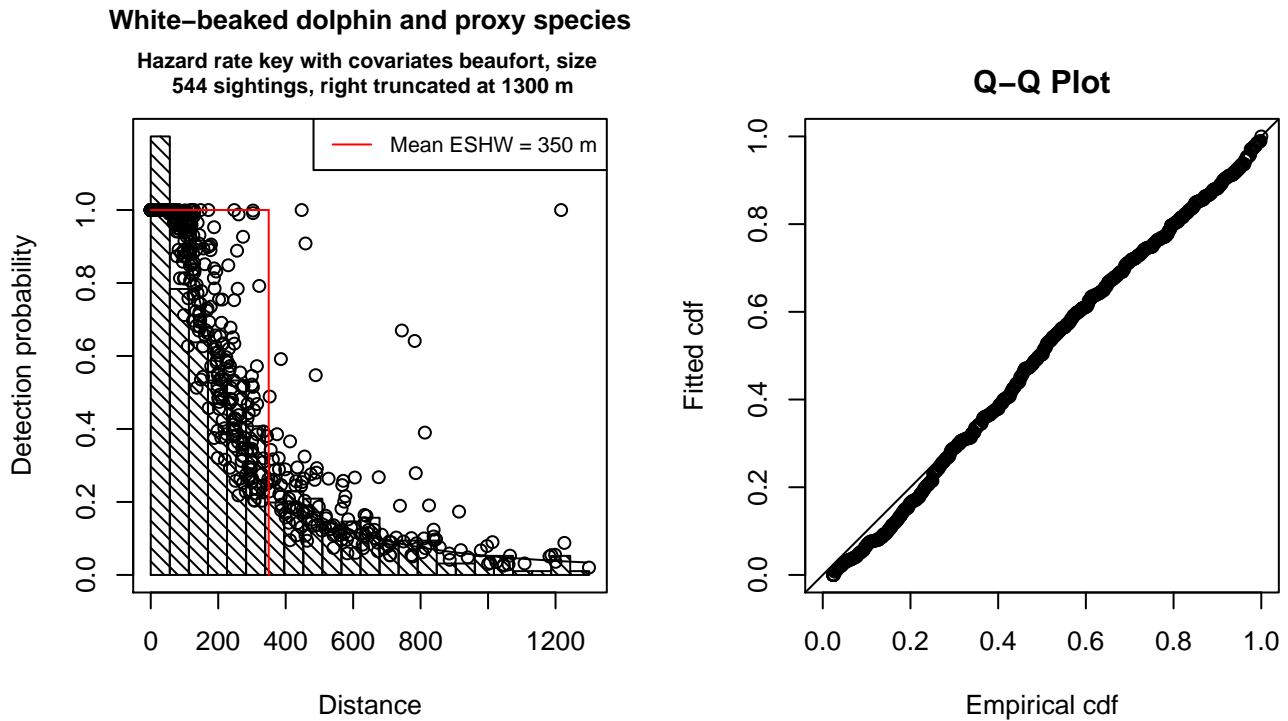


Figure 31: Detection function for Naked Eye Surveys that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  544
Distance range         :  0  -  1300
AIC                    :  7176.773

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate          se
(Intercept) 5.4832964 0.18390295
beaufort    -0.1613519 0.05731217
```

```
size          0.4285522 0.13370410


Shape parameters:
             estimate          se
(Intercept) 0.5903231 0.07541553


                          Estimate          SE          CV
Average p                 0.247145   0.01545852 0.06254840
N in covered region 2201.137384 160.79366256 0.07305026
```
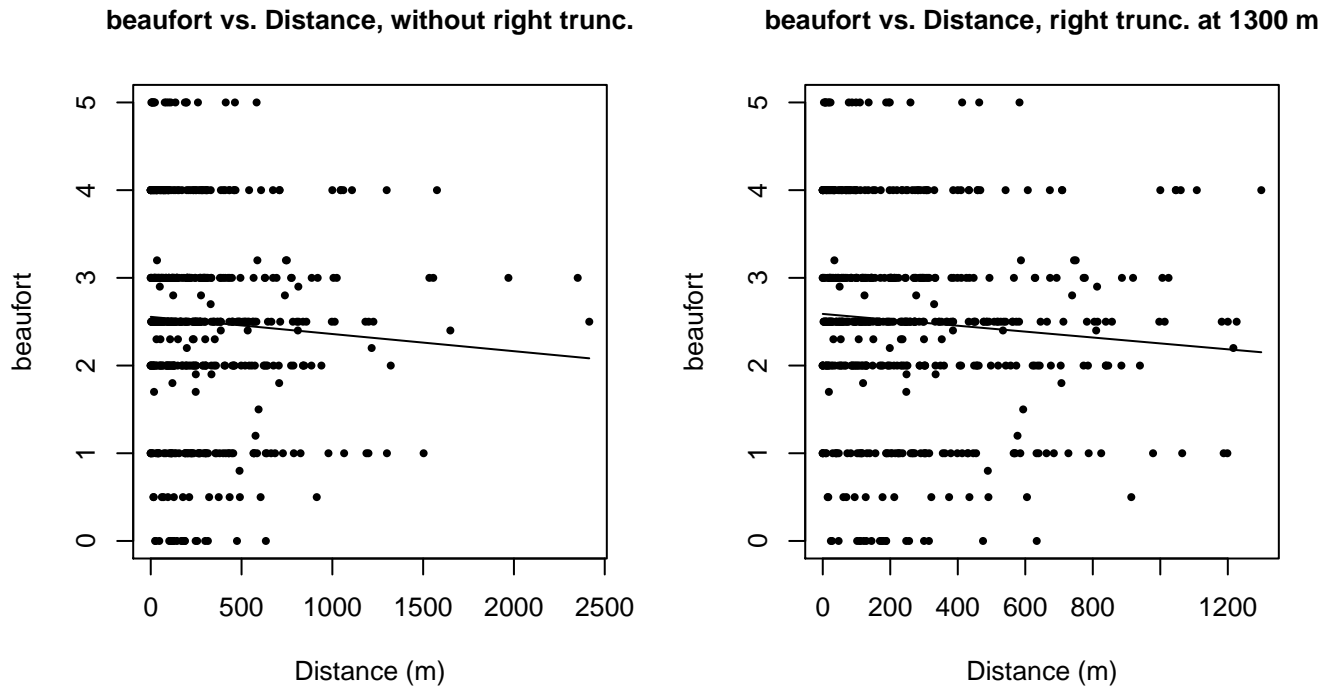
Additional diagnostic plots:



Figure 32: 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 1300 m**
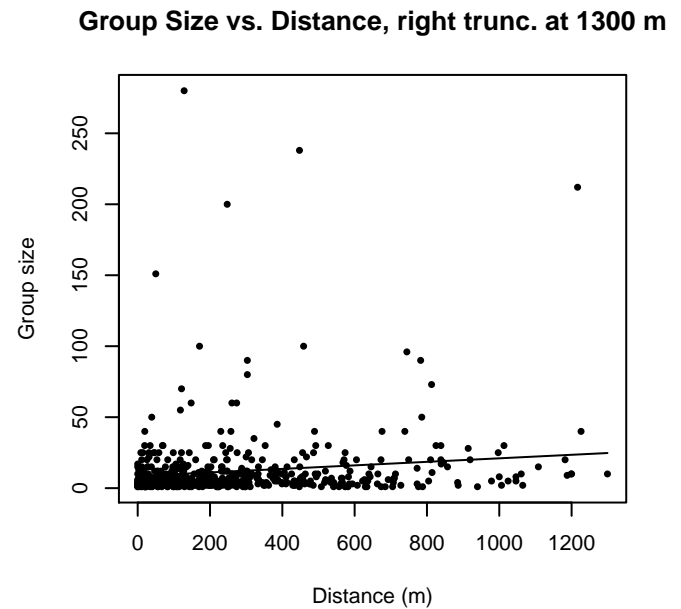
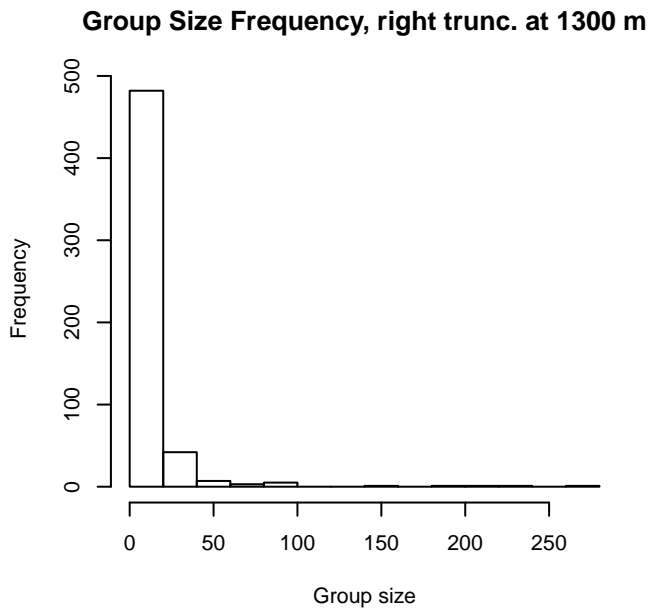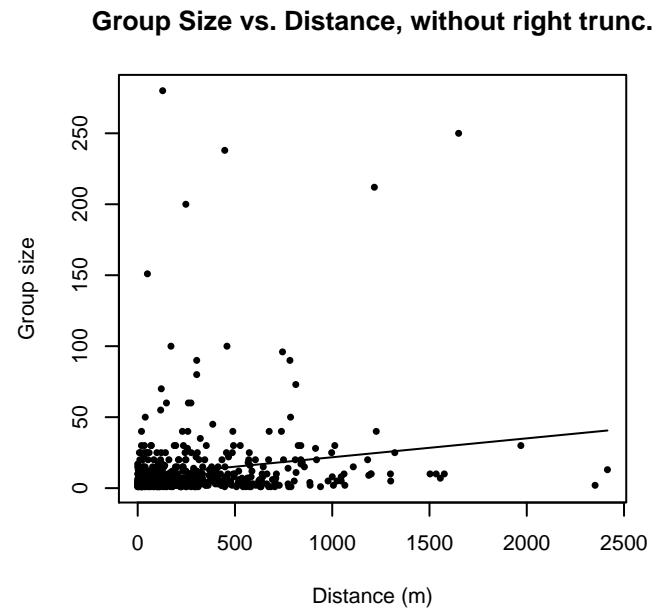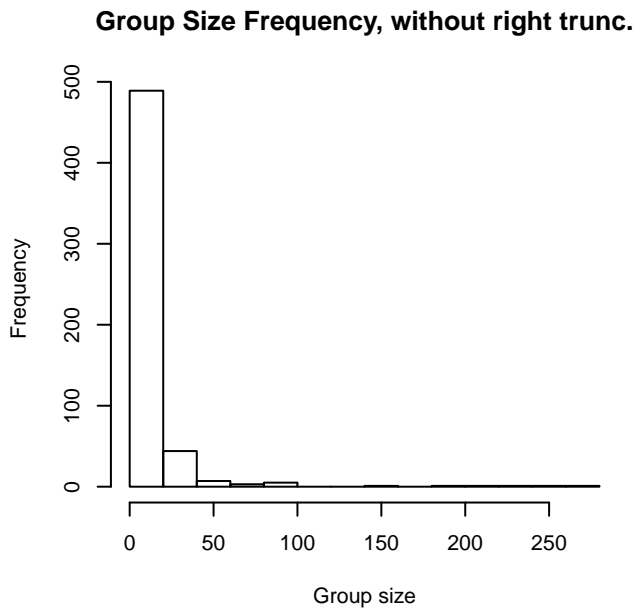**Group Size vs. Distance, right trunc. at 1300 m**

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.

## CODA

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 | 113 |

| | | |
|---|---|---:|
| 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 | 29 |
| Grampus griseus | Risso's dolphin | 2 |
| Grampus griseus/Tursiops truncatus | Risso's or Bottlenose dolphin | 0 |
| Lagenodelphis hosei | Fraser's dolphin | 0 |
| Lagenorhynchus acutus | Atlantic white-sided dolphin | 14 |
| 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 | 32 |
| 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 | 22 |
| Total | | 212 |

Table 25: Proxy species used to fit detection functions for CODA. The number of sightings, n, is before truncation.

The sightings were right truncated at 1300m.

| 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 | $\Delta$ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---:|
| hr | | | quality, size | Yes | 0.00 | 261 |
| hr | | | quality | Yes | 3.19 | 269 |
| hr | | | beaufort, size | Yes | 4.09 | 247 |
| hr | | | size | Yes | 4.85 | 238 |

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | | | beaufort | Yes | 7.89 | 249 |
| hr | poly | 2 | | Yes | 8.54 | 199 |
| hr | | | | Yes | 9.85 | 238 |
| hr | poly | 4 | | Yes | 10.46 | 214 |
| hn | cos | 2 | | Yes | 19.33 | 346 |
| hn | cos | 3 | | Yes | 34.78 | 326 |
| hn | | | quality | Yes | 47.65 | 438 |
| hn | | | quality, size | Yes | 47.93 | 438 |
| hn | | | size | Yes | 51.89 | 440 |
| hn | | | | Yes | 52.41 | 441 |
| hn | | | beaufort, size | Yes | 52.81 | 440 |
| hn | | | beaufort | Yes | 53.20 | 440 |
| hn | herm | 4 | | No | | |
| hn | | | beaufort, quality | No | | |
| hr | | | beaufort, quality | No | | |
| hn | | | beaufort, quality, size | No | | |
| hr | | | beaufort, quality, size | No | | |

Table 27: Candidate detection functions for CODA. The first one listed was selected for the density model.
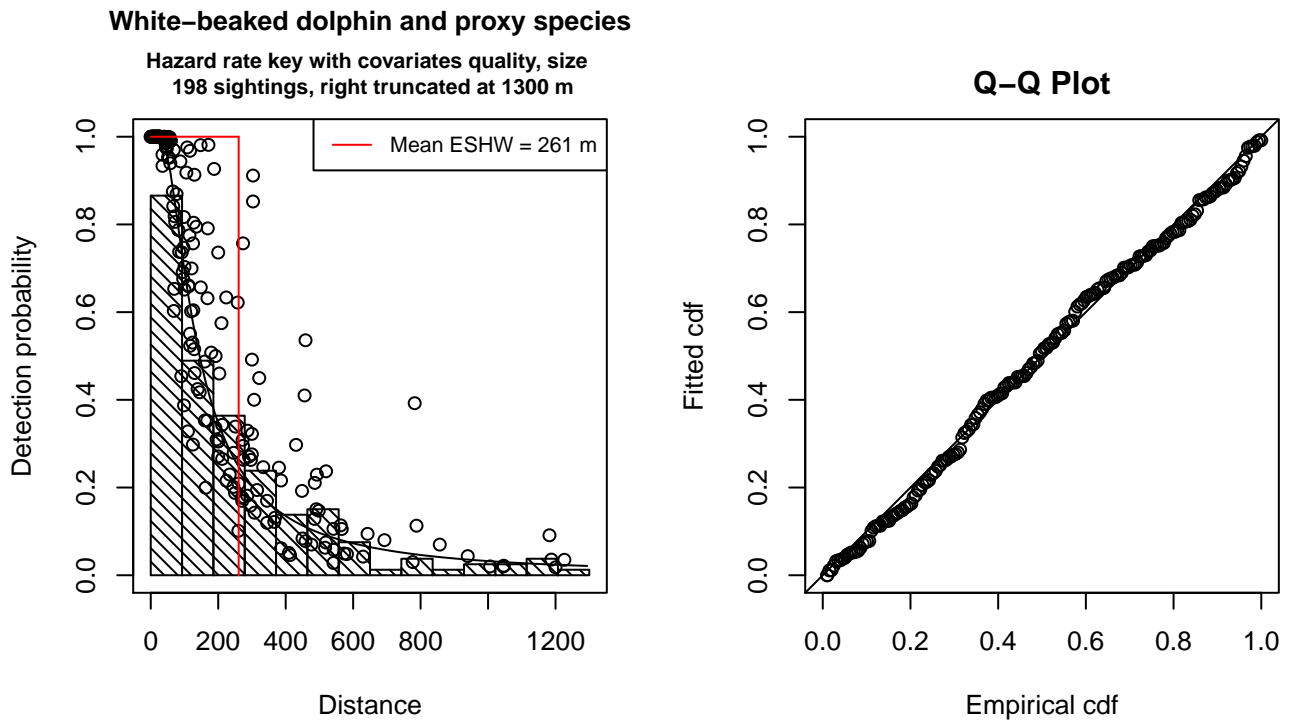


Figure 34: Detection function for CODA that was selected for the density model

Statistical output for this detection function:

44

```
Summary for ds object
Number of observations :  198
Distance range         :  0  -  1300
AIC                    :  2557.925

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate          se
(Intercept)  5.3846705 0.32986699
quality     -0.2499530 0.09909297
size         0.2319583 0.13885126

Shape parameters:
            estimate         se
(Intercept) 0.5121523 0.1063675


                       Estimate           SE         CV
Average p             0.1774326   0.02046823 0.1153578
N in covered region 1115.9169012 147.95242555 0.1325837
```

Additional diagnostic plots:

**beaufort vs. Distance, without right trunc.**  **beaufort vs. Distance, right trunc. at 1300 m**
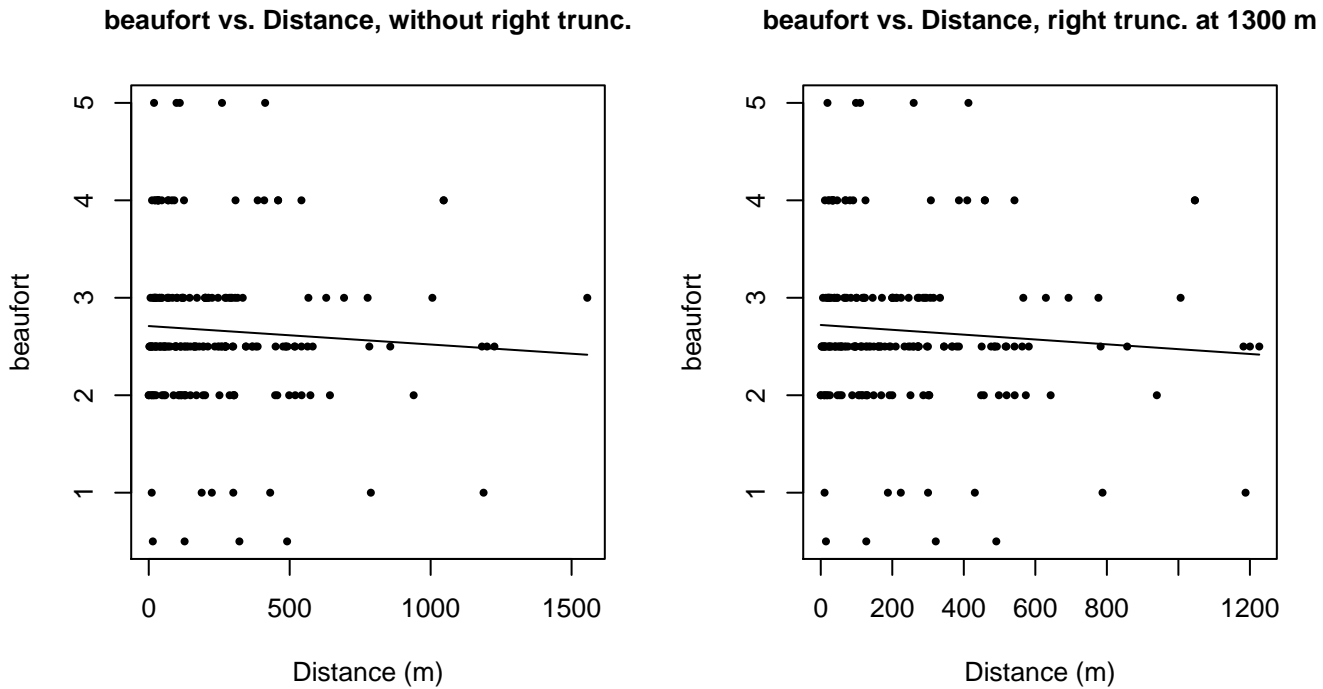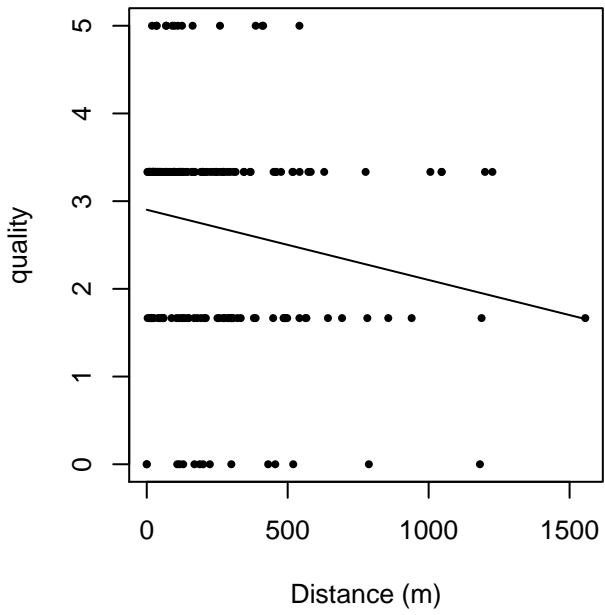


Figure 35: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

**quality vs. Distance, without right trunc.**

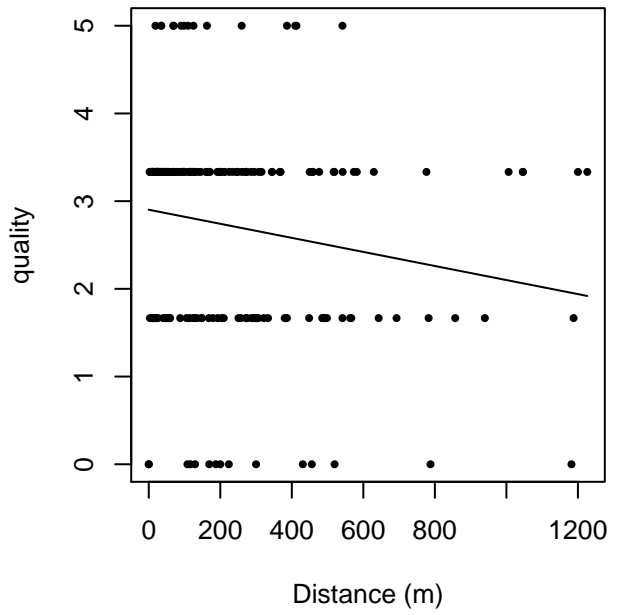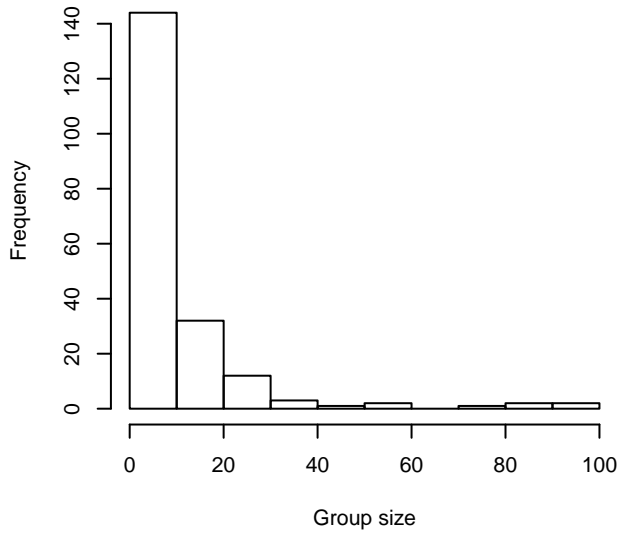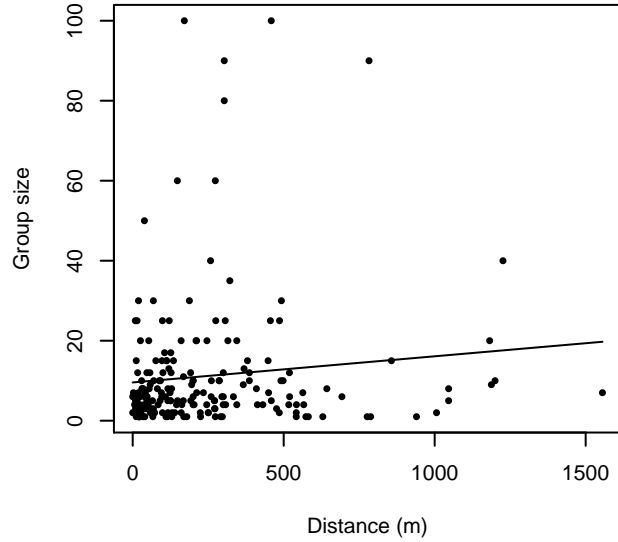**quality vs. Distance, right trunc. at 1300 m**

Figure 36: 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.
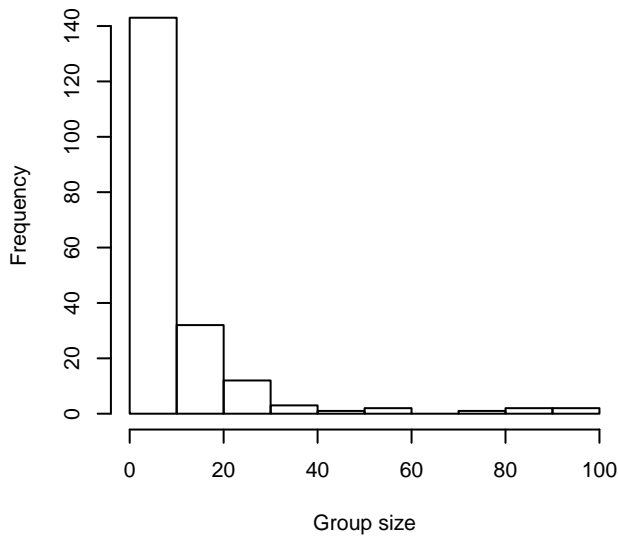
**Group Size Frequency, without right trunc.**                     **Group Size vs. Distance, without right trunc.**



**Group Size Frequency, right trunc. at 1300 m**                   **Group Size vs. Distance, right trunc. at 1300 m**
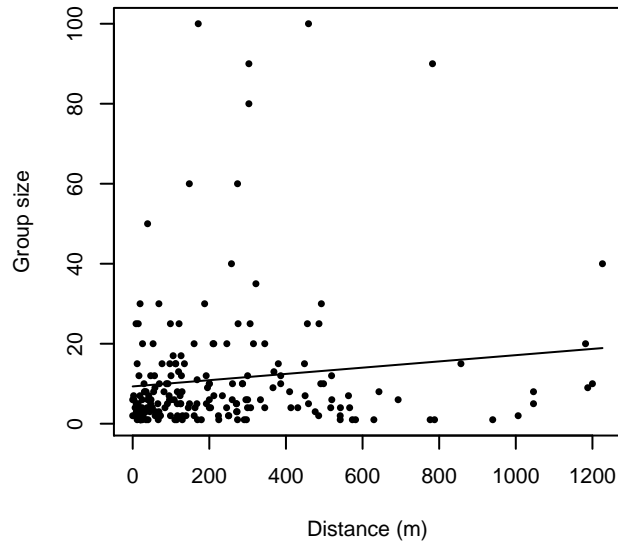
Figure 37: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

### SCANS II Shipboard

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 | 114 |

47

| | | |
|---|---|---:|
| 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 | 28 |
| Grampus griseus | Risso's dolphin | 7 |
| Grampus griseus/Tursiops truncatus | Risso's or Bottlenose dolphin | 0 |
| Lagenodelphis hosei | Fraser's dolphin | 0 |
| Lagenorhynchus acutus | Atlantic white-sided dolphin | 42 |
| 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 | 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 | 19 |
| Total | | 250 |

Table 28: Proxy species used to fit detection functions for SCANS II Shipboard. 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 29: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

| Key | Adjustment | Order | Covariates | Succeeded | $\Delta$ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---:|
| hn | | | size | Yes | 0.00 | 462 |
| hn | cos | 2 | | Yes | 0.73 | 361 |
| hn | | | beaufort, size | Yes | 1.47 | 463 |
| hn | | | quality, size | Yes | 1.78 | 462 |

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | | | | Yes | 2.50 | 379 |
| hr | | | quality | Yes | 4.03 | 380 |
| hr | poly | 4 | | Yes | 4.10 | 372 |
| hr | poly | 2 | | Yes | 4.20 | 370 |
| hr | | | beaufort | Yes | 4.22 | 378 |
| hr | | | quality, size | Yes | 6.03 | 380 |
| hn | cos | 3 | | Yes | 10.41 | 376 |
| hn | | | | Yes | 14.12 | 455 |
| hn | | | beaufort | Yes | 15.37 | 456 |
| hn | | | quality | Yes | 15.43 | 455 |
| hn | herm | 4 | | Yes | 15.69 | 454 |
| hn | | | beaufort, quality | Yes | 17.33 | 456 |
| hr | | | size | No | | |
| hr | | | beaufort, quality | No | | |
| hr | | | beaufort, size | No | | |
| hn | | | beaufort, quality, size | No | | |
| hr | | | beaufort, quality, size | No | | |

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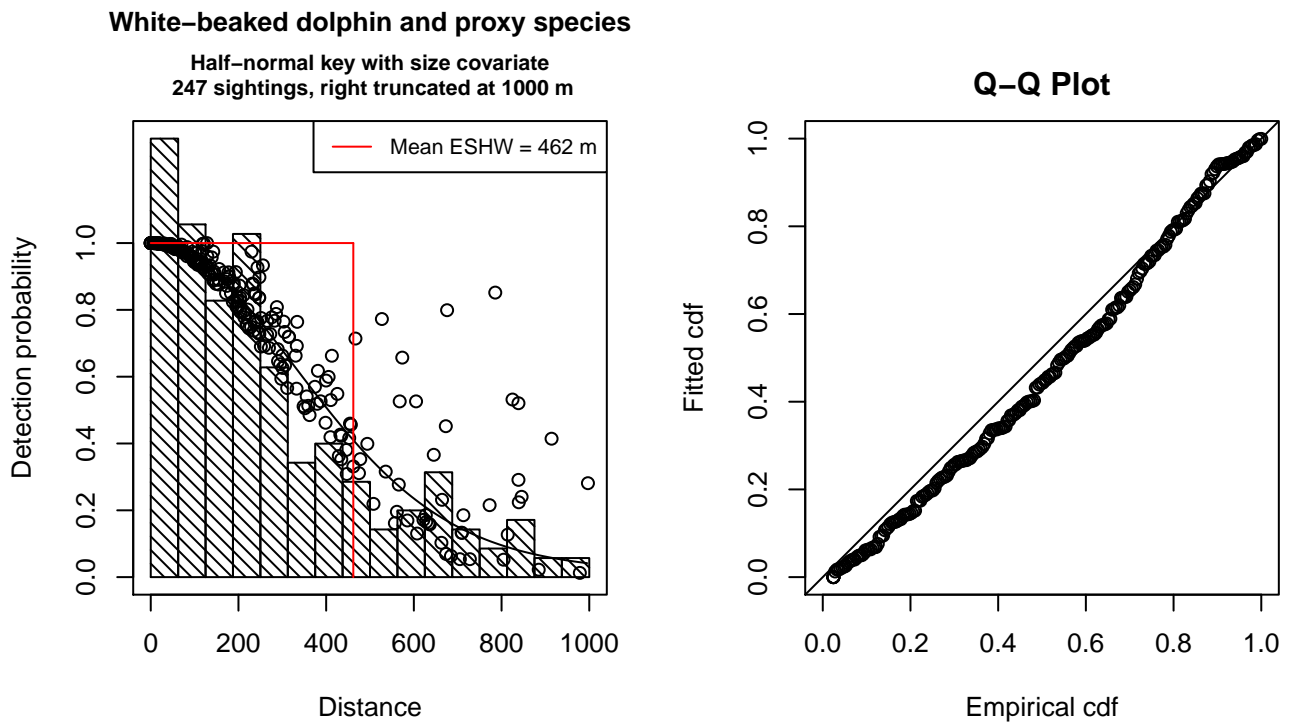


Figure 38: Detection function for SCANS II Shipboard that was selected for the density model

49

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  247
Distance range         :  0  -  1000
AIC                    :  3245.813

Detection function:
 Half-normal key function

Detection function parameters
Scale Coefficients:
            estimate          se
(Intercept) 5.6435356 0.06781568
size        0.6259412 0.18560451

                    Estimate         SE         CV
Average p           0.4405241  0.01935102 0.04392728
N in covered region 560.6958131 36.68734001 0.06543181
```
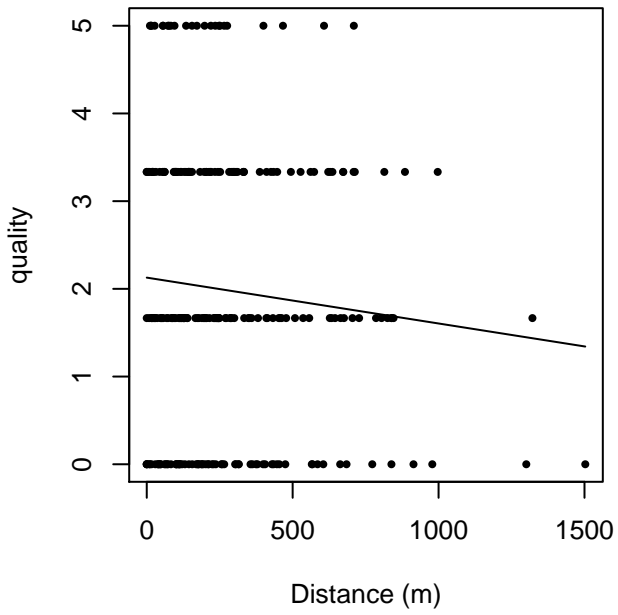
Additional diagnostic plots:



Figure 39: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
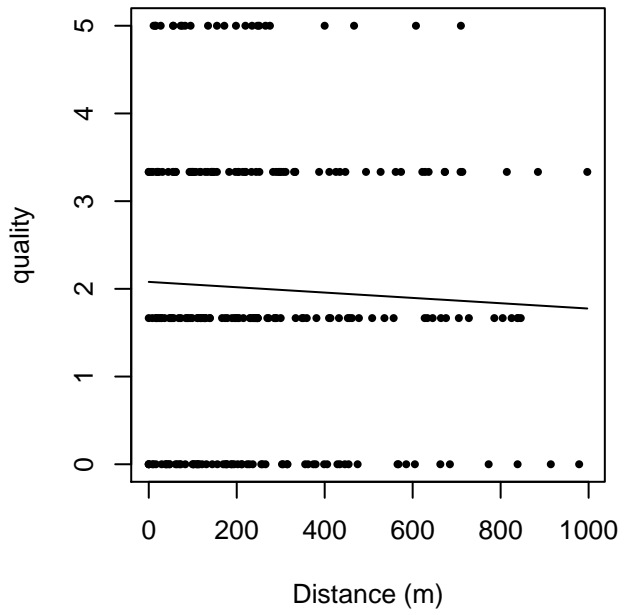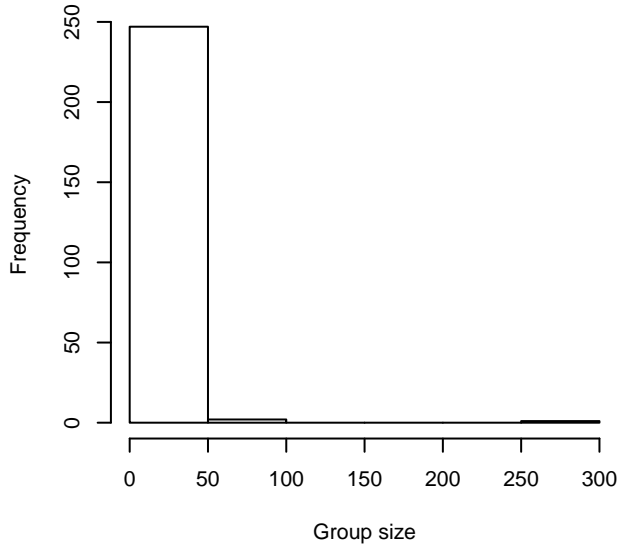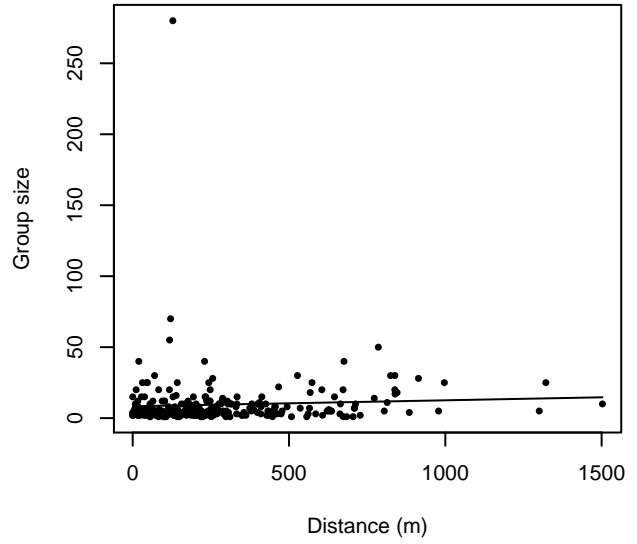
Figure 40: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
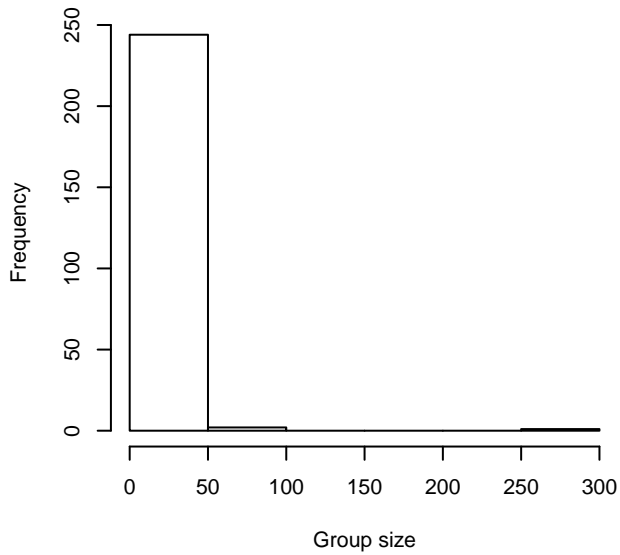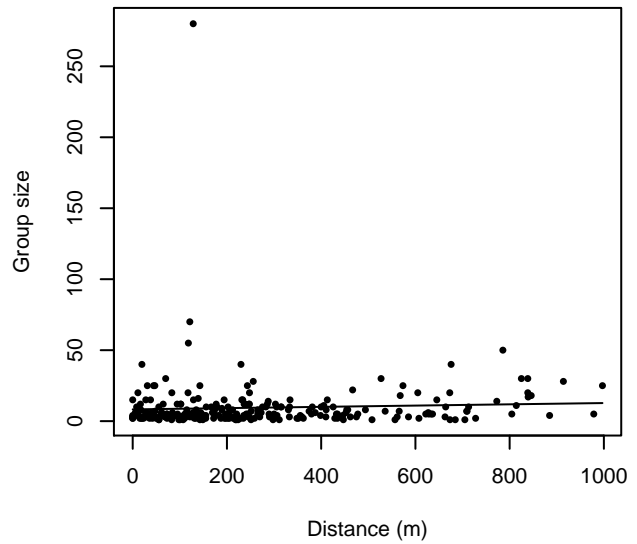
Figure 41: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.
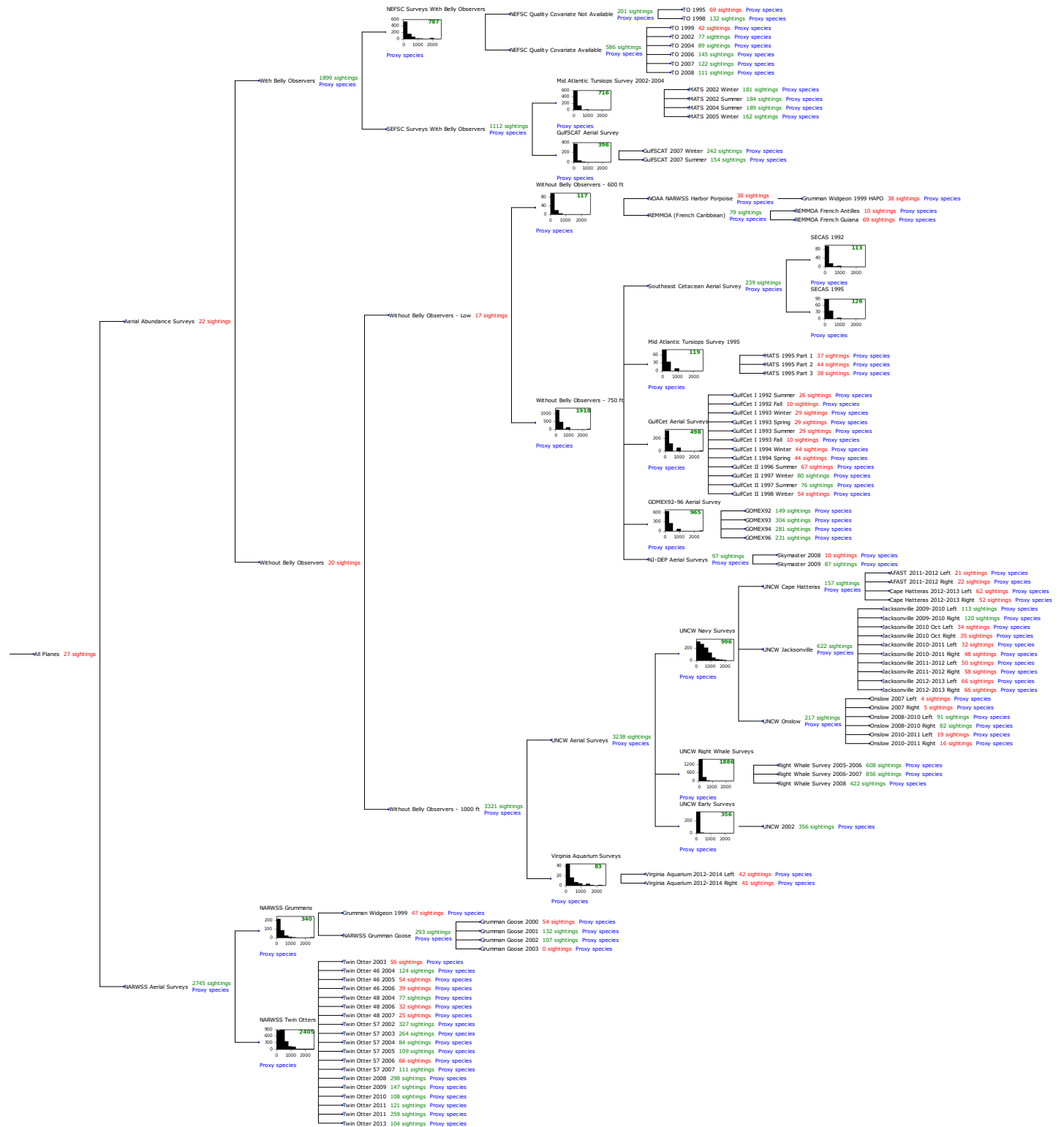
# Aerial Surveys



Figure 42: 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 31: 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 32: 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 | | No | | |
| hn | | | beaufort | No | | |
| hr | | | beaufort | No | | |
| hn | | | beaufort, size | No | | |
| hr | | | beaufort, size | No | | |

Table 33: Candidate detection functions for NEFSC Surveys With Belly Observers. The first one listed was selected for the density model.
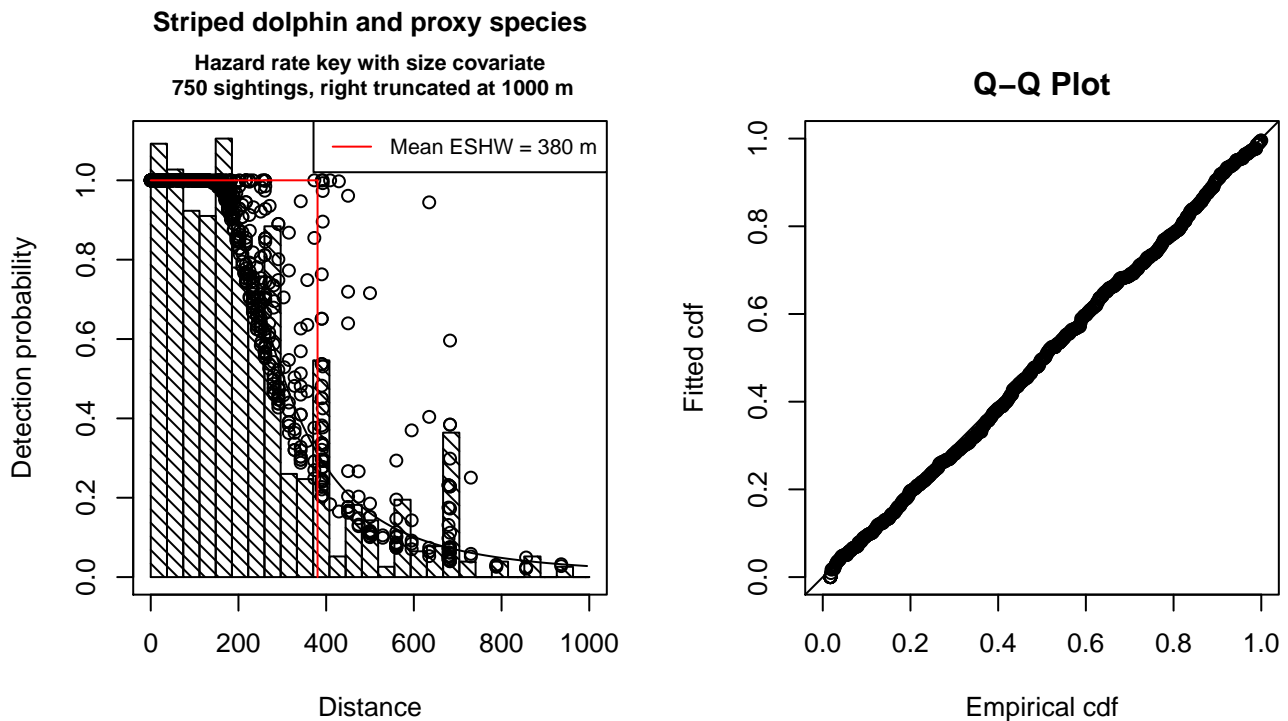


Figure 43: Detection function for NEFSC Surveys With Belly Observers that was selected for the density model

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) 5.4723434 0.05875063
size        0.4897148 0.09093801


Shape parameters:
            estimate         se
(Intercept) 1.119312 0.06987572


                      Estimate          SE          CV
Average p            0.3611765  0.01276499 0.03534280
N in covered region 2076.5469236 95.75679628 0.04611348
```
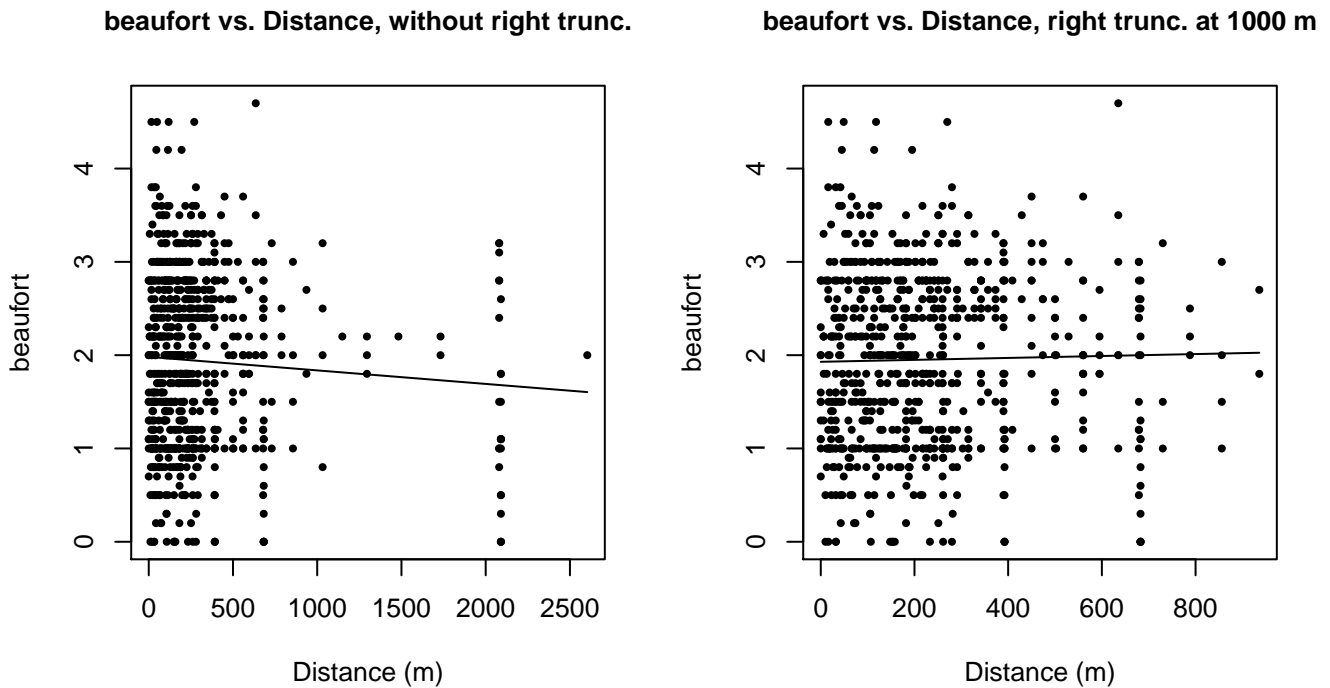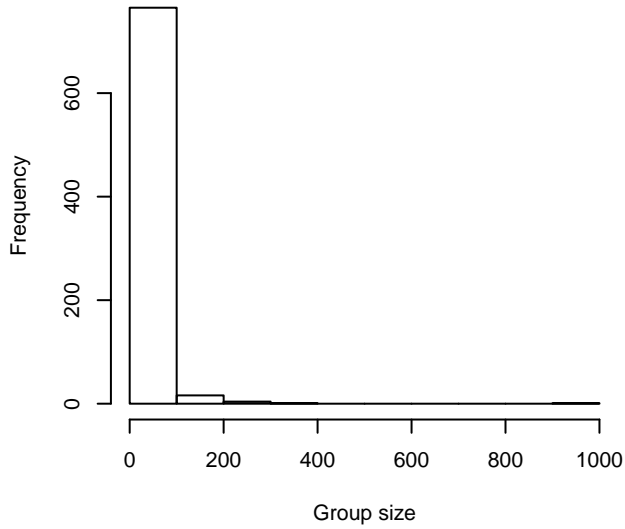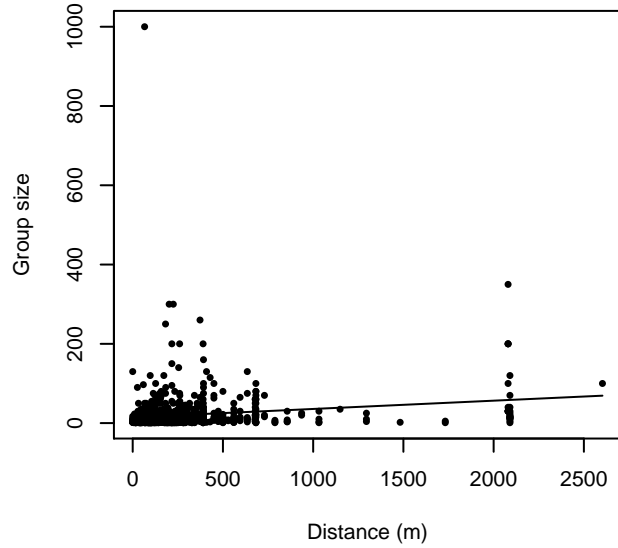
Additional diagnostic plots:



Figure 44: 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.
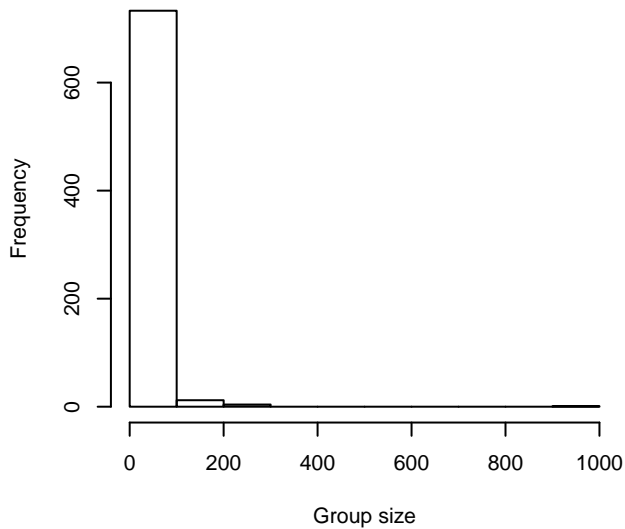
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 1000 m**

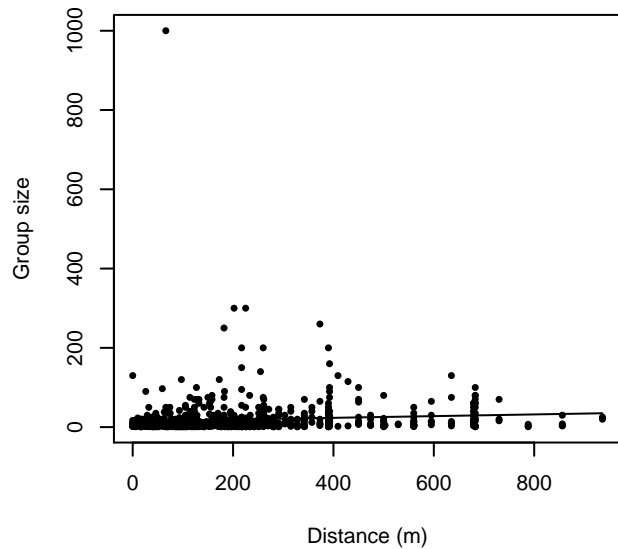**Group Size vs. Distance, right trunc. at 1000 m**

Figure 45: 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 |

57

| | | |
|---|---|---:|
| 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 34: 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 35: 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 | 325 |
| hr | | | beaufort | Yes | 7.24 | 320 |
| hr | | | size | Yes | 15.12 | 325 |

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | | | | Yes | 19.50 | 320 |
| hr | poly | 4 | | Yes | 21.50 | 320 |
| hr | poly | 2 | | Yes | 21.50 | 320 |
| hn | | | beaufort, size | Yes | 24.60 | 291 |
| hn | | | beaufort, quality, size | Yes | 26.60 | 291 |
| hn | cos | 2 | | Yes | 30.33 | 279 |
| hn | | | beaufort | Yes | 31.06 | 289 |
| hn | | | beaufort, quality | Yes | 33.06 | 289 |
| hn | | | size | Yes | 40.68 | 292 |
| hn | cos | 3 | | Yes | 41.28 | 267 |
| hn | | | quality, size | Yes | 42.58 | 292 |
| hn | | | | Yes | 44.72 | 289 |
| hn | | | quality | Yes | 46.63 | 289 |
| hn | herm | 4 | | Yes | 46.67 | 289 |
| hr | | | quality | No | | |
| hr | | | beaufort, quality | No | | |
| hr | | | quality, size | No | | |
| hr | | | beaufort, quality, size | No | | |

Table 36: Candidate detection functions for Mid Atlantic Tursiops Survey 2002-2004. The first one listed was selected for the density model.
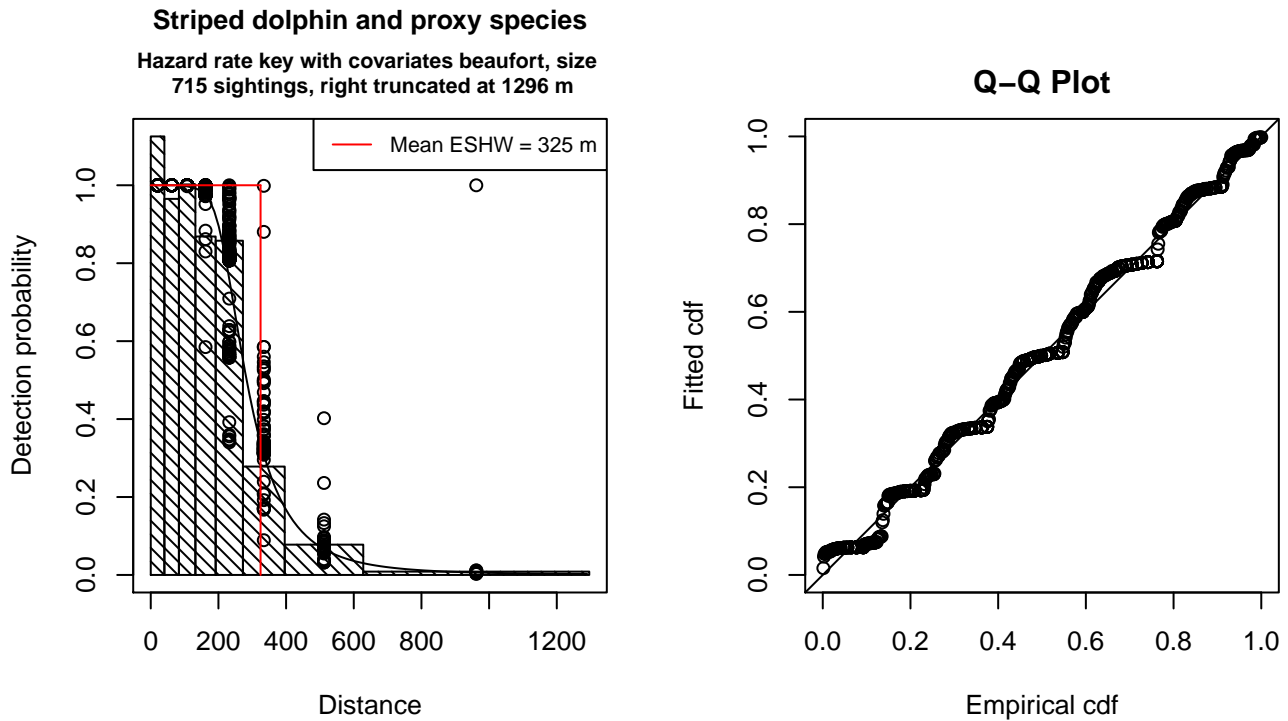


Figure 46: Detection function for Mid Atlantic Tursiops Survey 2002-2004 that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  715
Distance range         :  0  -  1296
AIC                    :  2772.625

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
              estimate         se
(Intercept)  5.7367970 0.06707586
beaufort    -0.1711625 0.03979058
size         0.3020980 0.11348684

Shape parameters:
            estimate         se
(Intercept) 1.410835 0.06851877


                        Estimate          SE         CV
Average p              0.2429646 7.460291e-03 0.03070526
N in covered region 2942.8157278 1.320027e+02 0.04485592
```
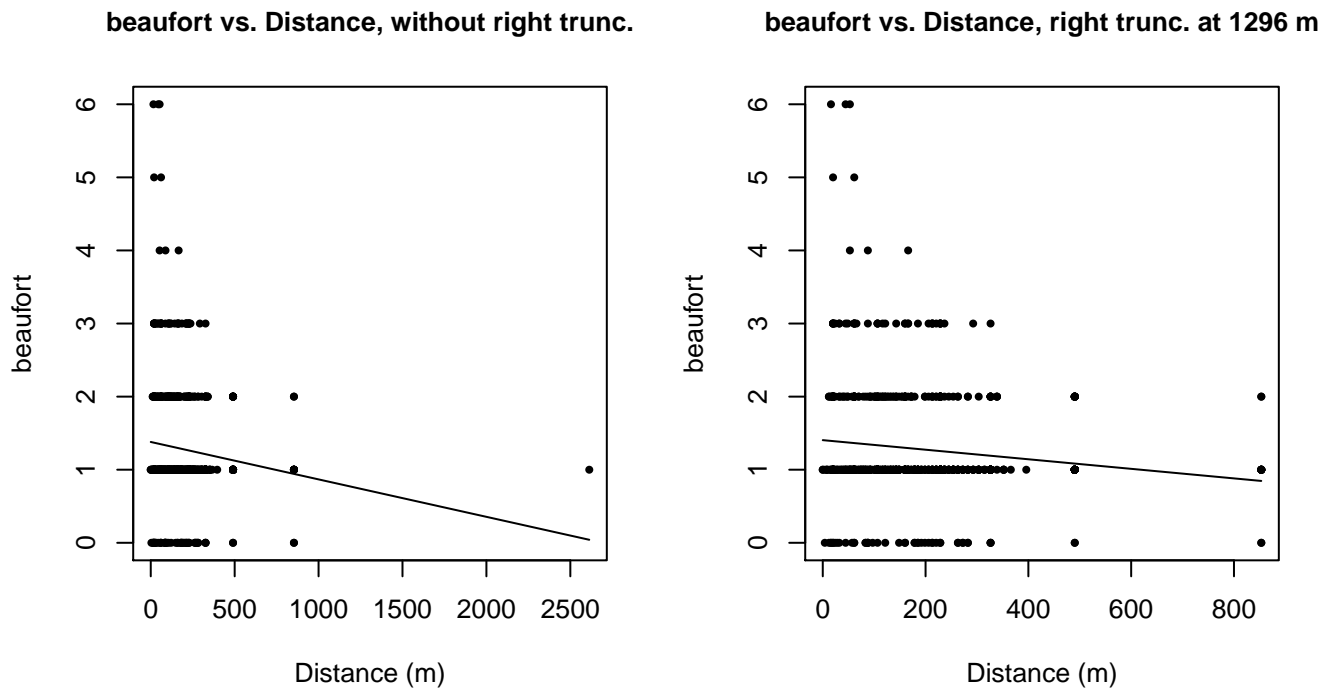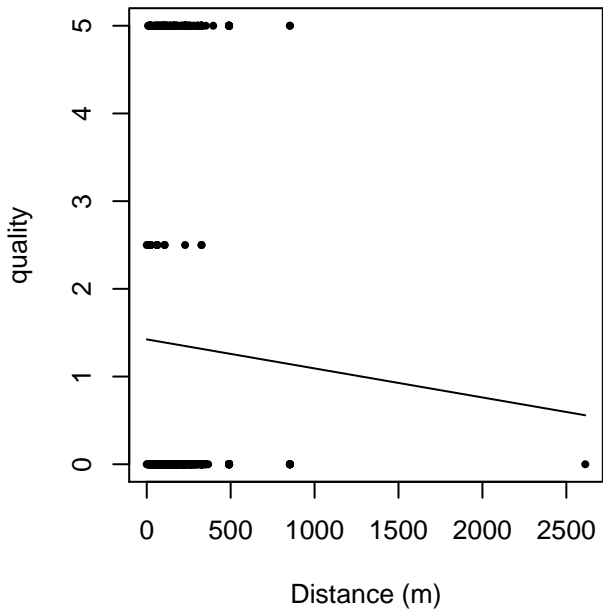
Additional diagnostic plots:



Figure 47: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
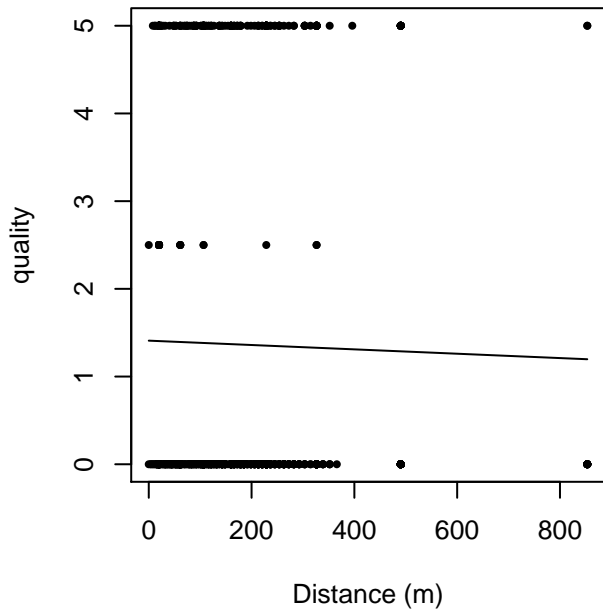
Figure 48: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.

## Group Size Frequency, without right trunc.



## Group Size vs. Distance, without right trunc.



## Group Size Frequency, right trunc. at 1296 m
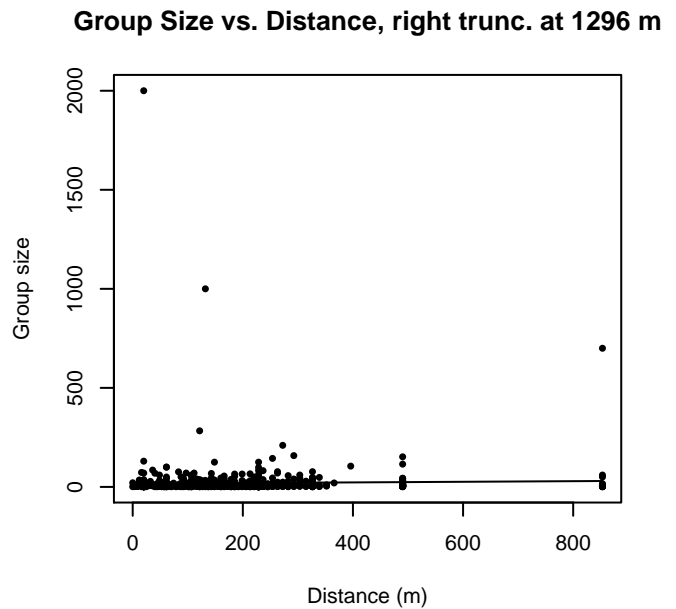


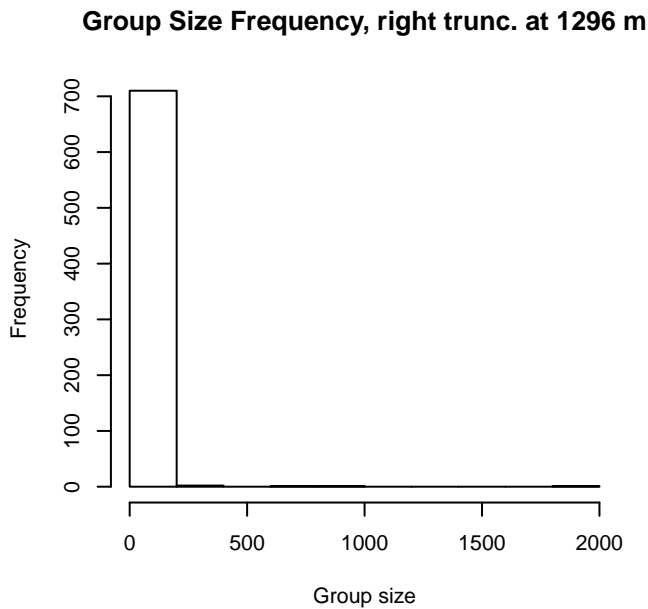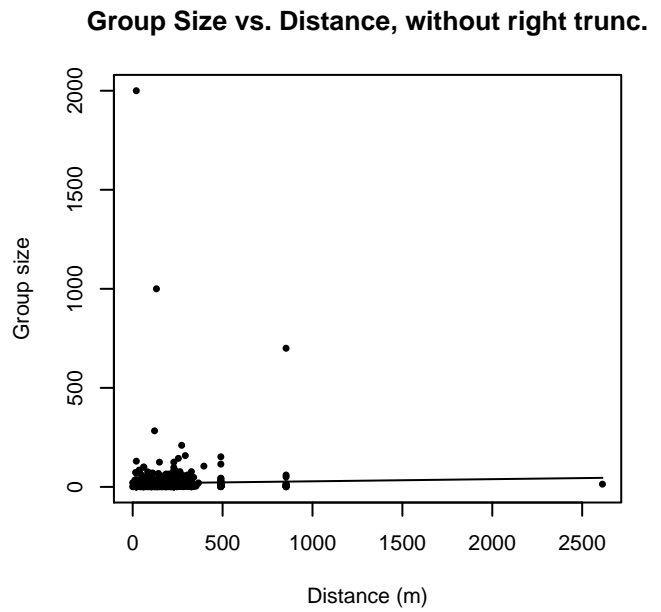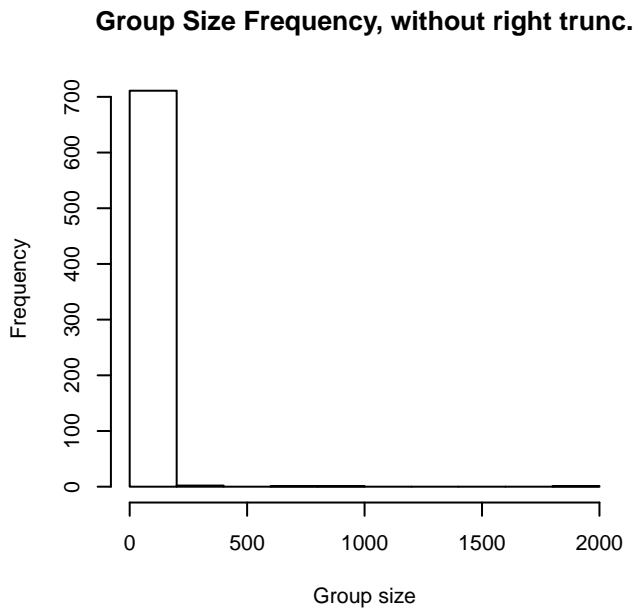## Group Size vs. Distance, right trunc. at 1296 m



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.

### 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 |

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| | | |
|---|---|---|
| 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 37: 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 38: 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 39: Candidate detection functions for GulfSCAT Aerial Survey. The first one listed was selected for the density model.
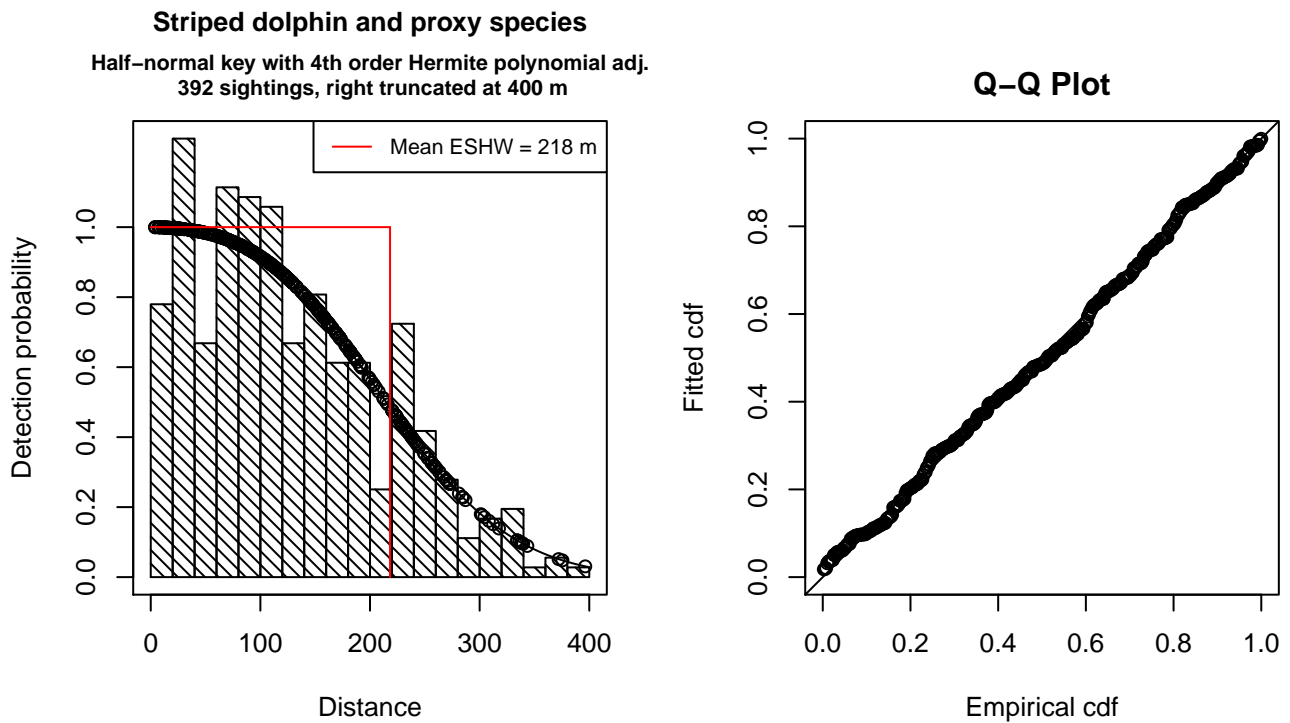


Figure 50: Detection function for GulfSCAT Aerial Survey that was selected for the density model

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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) 4.855664 0.07416788

Adjustment term parameter(s):
                 estimate          se
herm, order 4 -0.04125508 0.01270725


Monotonicity constraints were enforced.
                      Estimate        SE          CV
Average p            0.5457491  0.04201236 0.07698108
N in covered region 718.2787706 60.45880788 0.08417179

Monotonicity constraints were enforced.
```
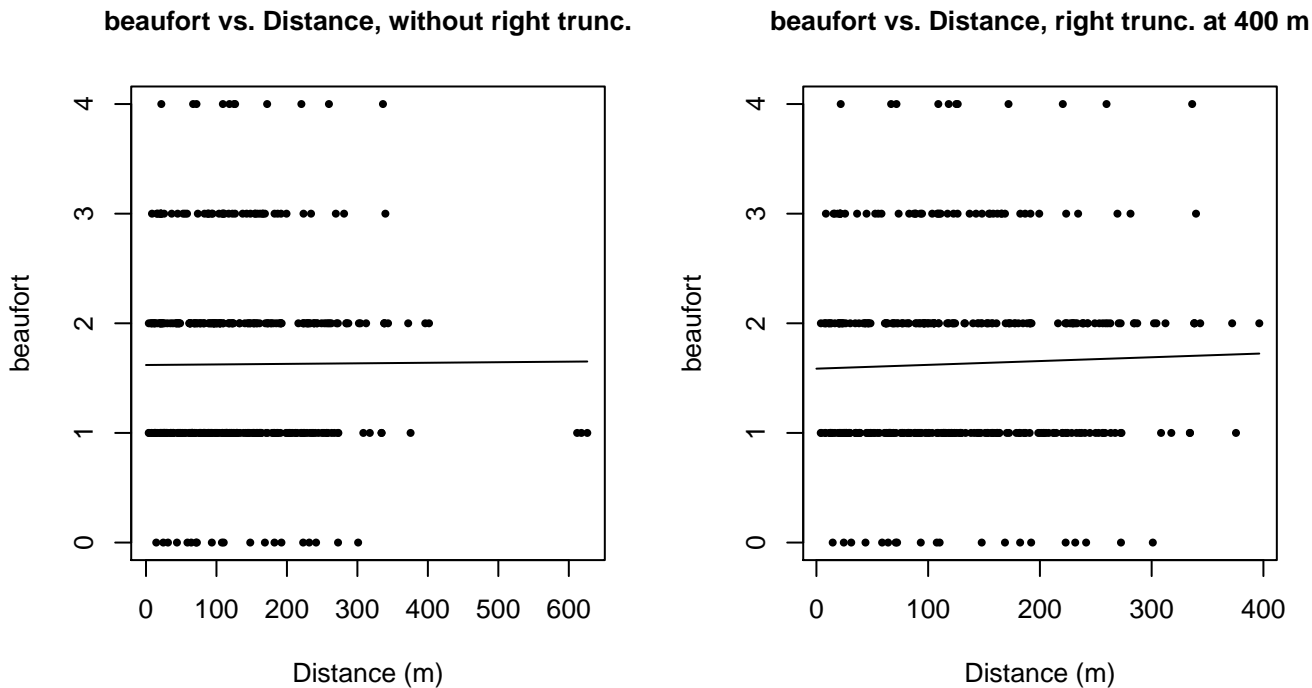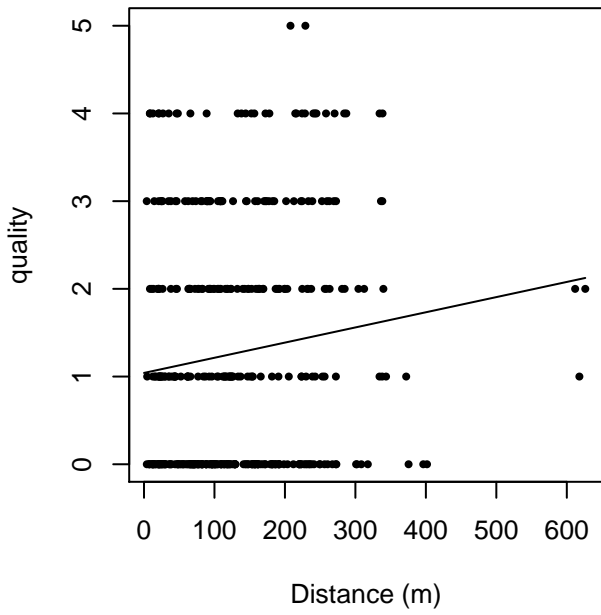
Additional diagnostic plots:



Figure 51: 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.
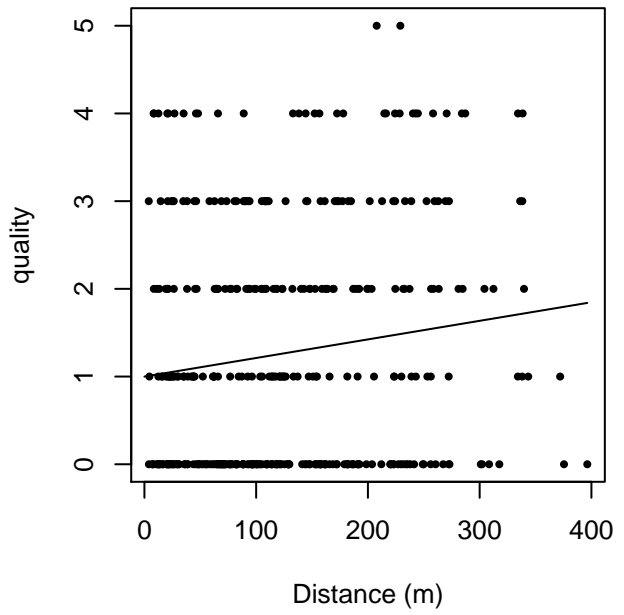
Figure 52: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
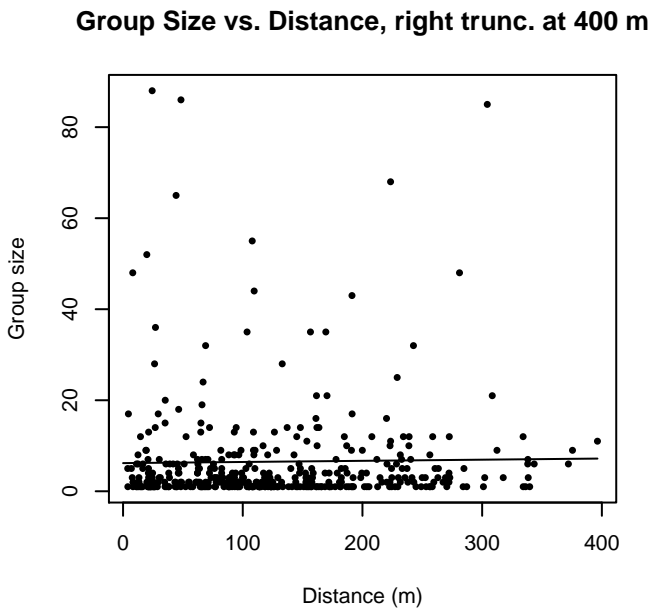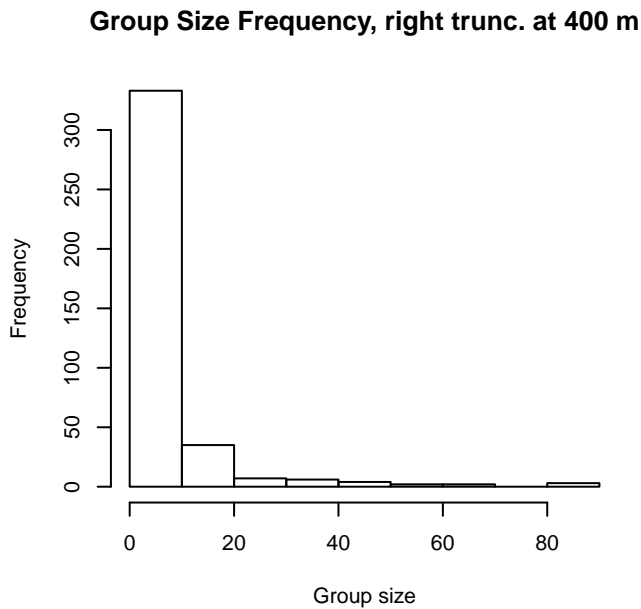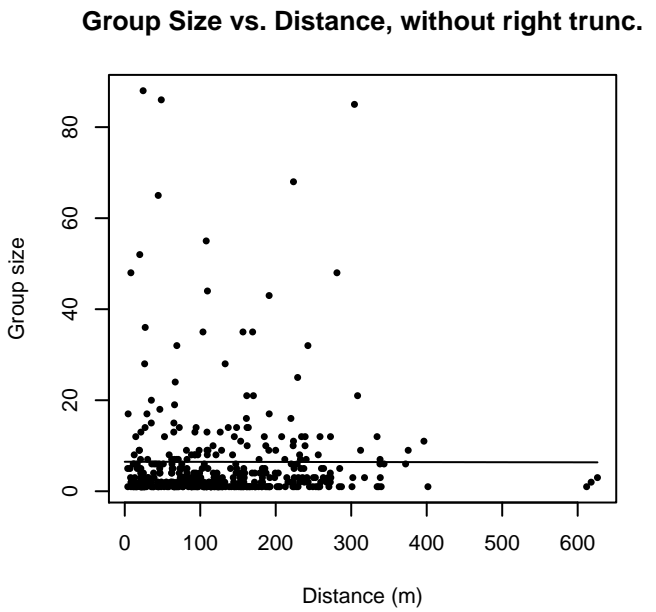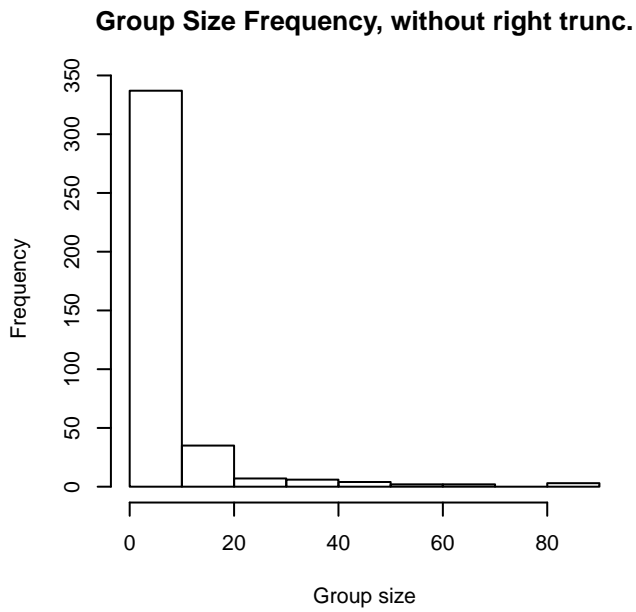
Figure 53: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

## 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 40: 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 41: 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 | | | beaufort | Yes | 1.82 | 273 |
| hn | herm | 4 | | Yes | 1.85 | 280 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 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 42: Candidate detection functions for Without Belly Observers - 600 ft. The first one listed was selected for the density model.

**Striped dolphin and proxy species**

**Half−normal key with no adjustments**
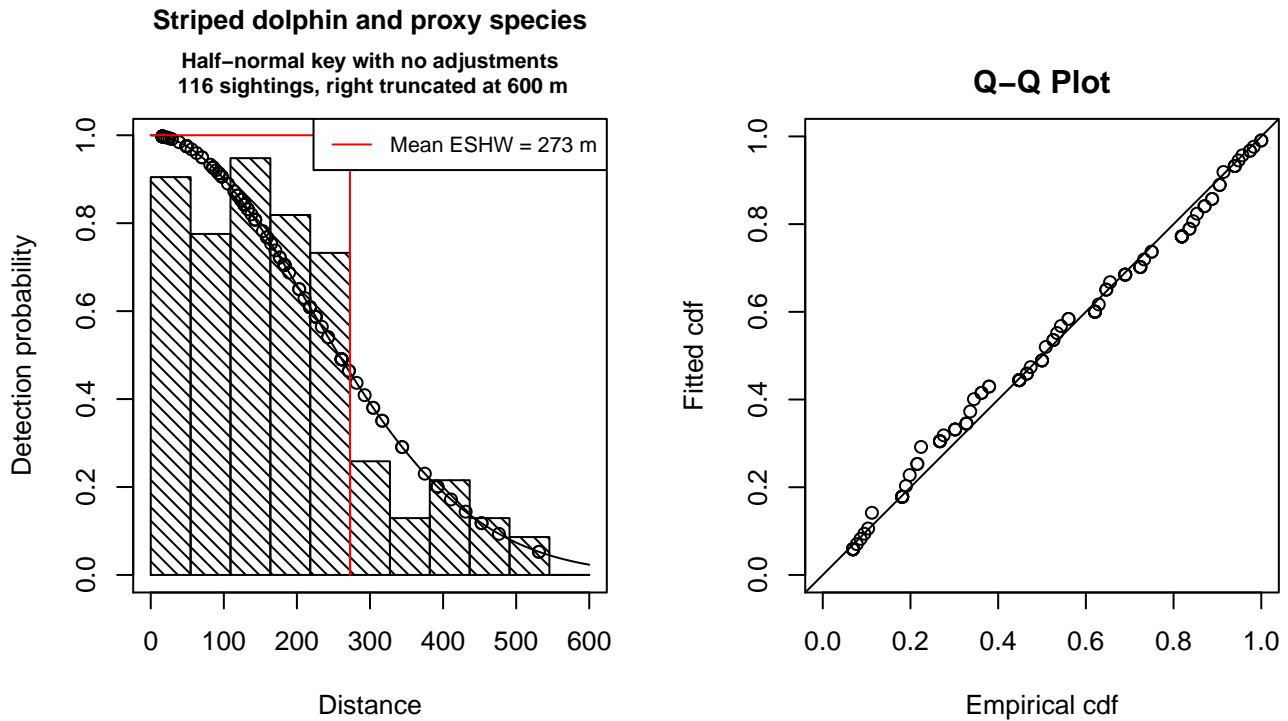**116 sightings, right truncated at 600 m**



Figure 54: 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
```

69

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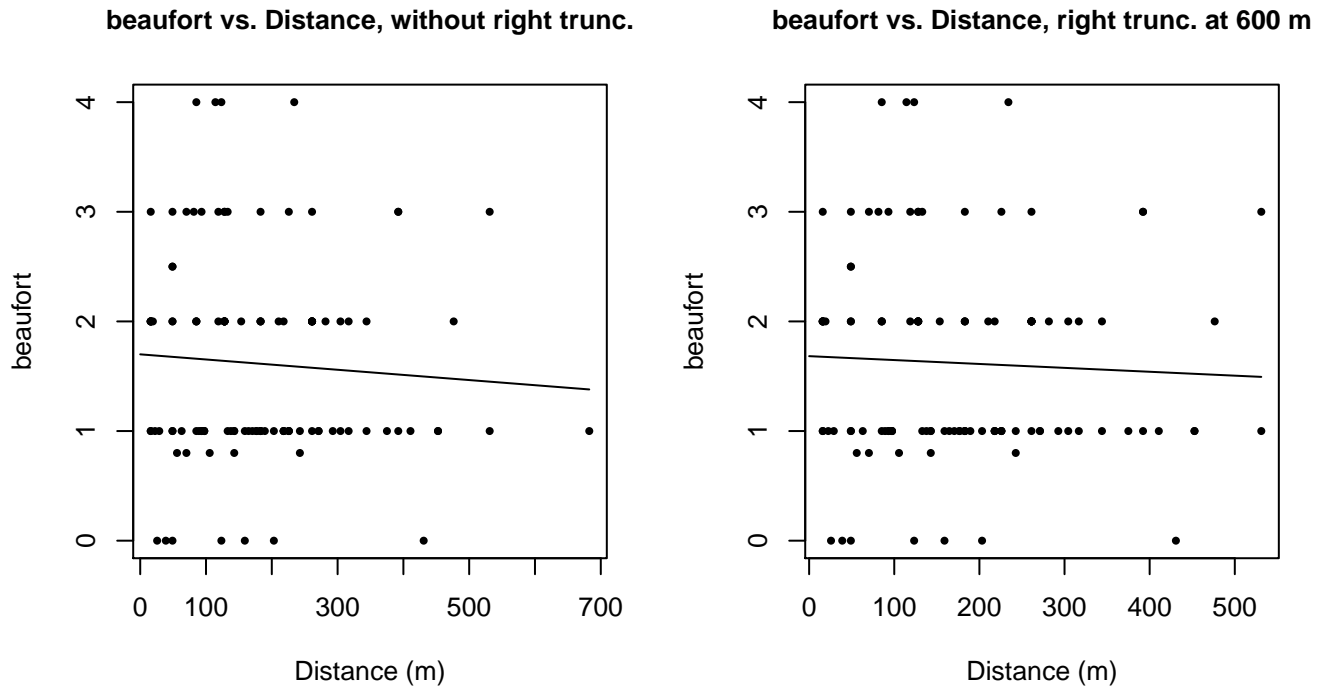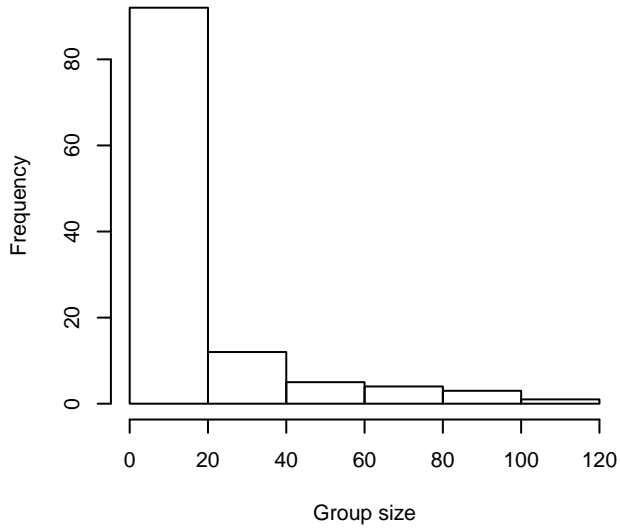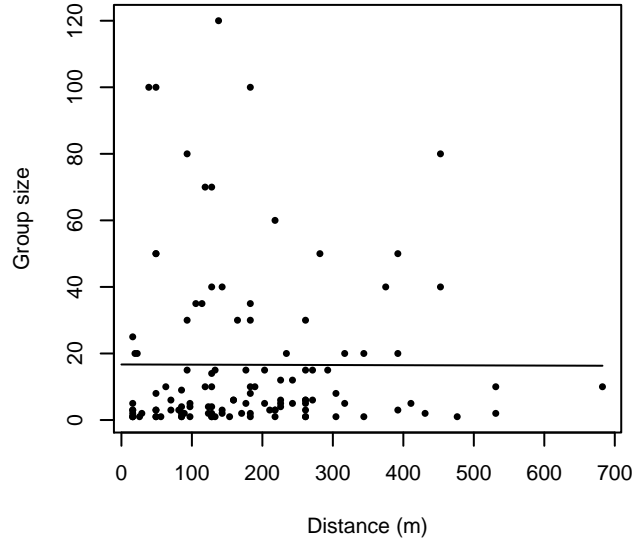
Additional diagnostic plots:



Figure 55: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
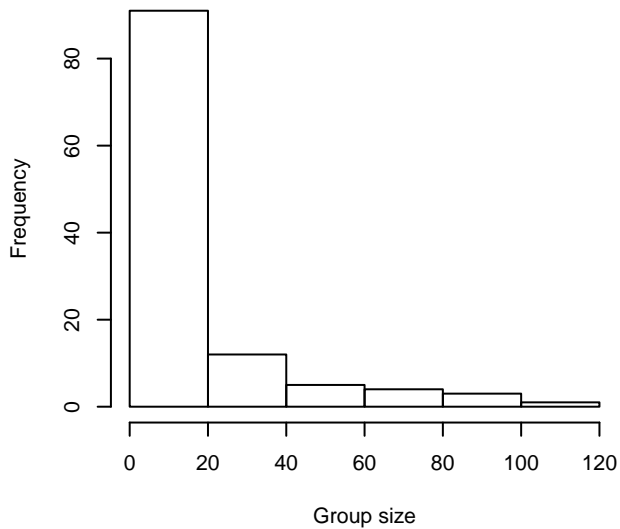
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

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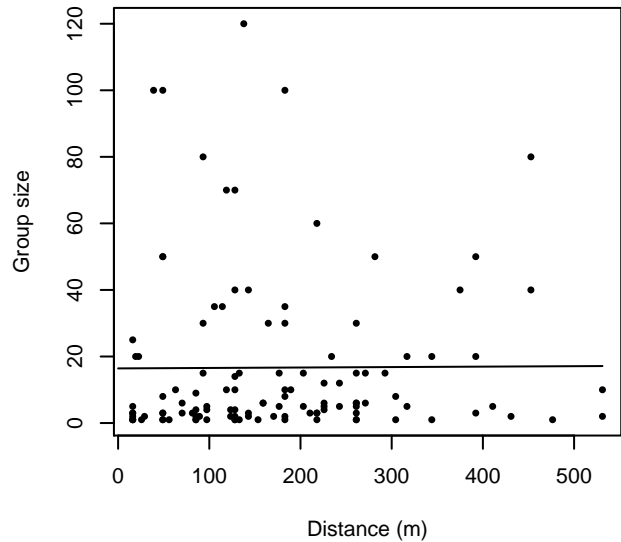
**Group Size vs. Distance, right trunc. at 600 m**

Figure 56: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**Without Belly Observers - 750 ft**

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

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

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

Table 43: Proxy species used to fit detection functions for Without Belly Observers - 750 ft. The number of sightings, n, is before truncation.

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

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

Table 44: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

| Key | Adjustment | Order | Covariates | Succeeded | Δ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---:|
| hr | | | size | Yes | 0.00 | 392 |
| hr | | | | Yes | 8.40 | 388 |
| hr | poly | 2 | | Yes | 10.38 | 388 |

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | poly | 4 | | Yes | 10.38 | 388 |
| hn | cos | 2 | | Yes | 39.35 | 354 |
| hn | cos | 3 | | Yes | 59.72 | 342 |
| hn | | | size | Yes | 81.81 | 402 |
| hn | | | | Yes | 95.30 | 401 |
| hn | herm | 4 | | Yes | 96.81 | 401 |
| hr | | | beaufort | No | | |
| hn | | | beaufort | No | | |
| hr | | | quality | No | | |
| hn | | | quality | 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 45: Candidate detection functions for Without Belly Observers - 750 ft. The first one listed was selected for the density model.
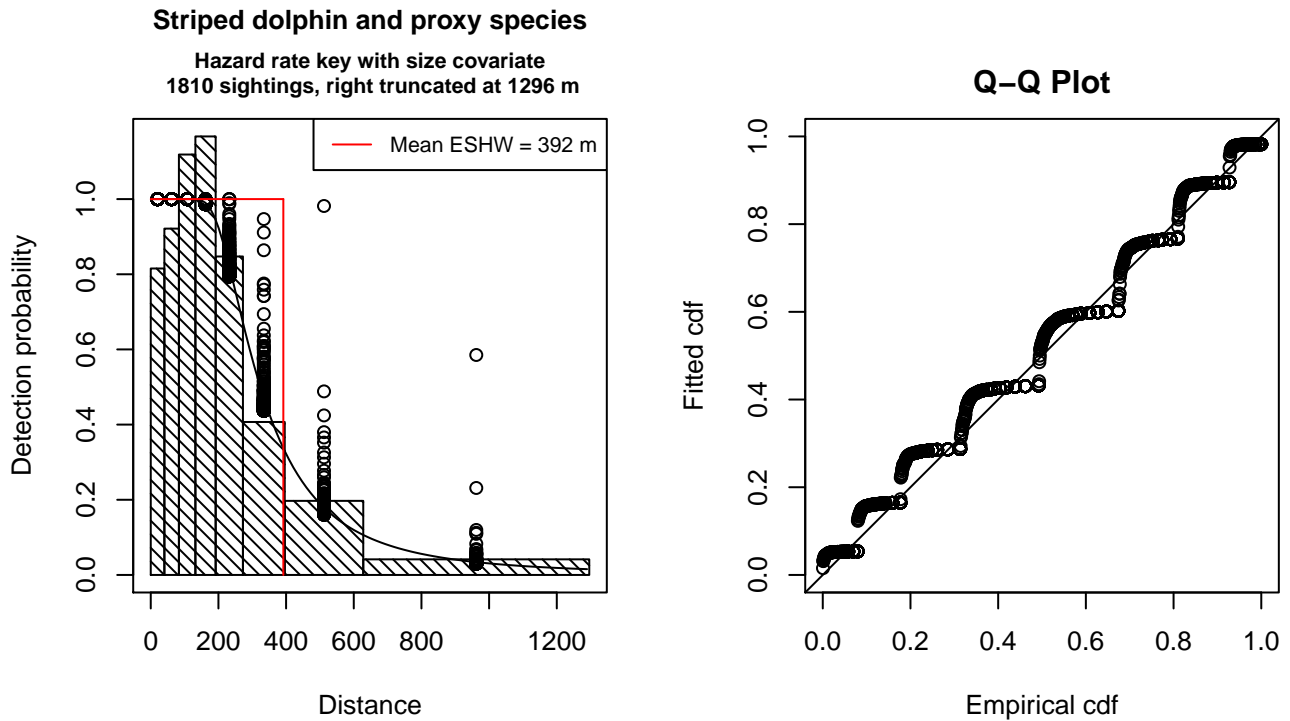


Figure 57: Detection function for Without Belly Observers - 750 ft that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  1810
Distance range         :   0  -  1296
AIC                    :  7378.672


Detection function:
 Hazard-rate key function


Detection function parameters
Scale Coefficients:
            estimate          se
(Intercept) 5.6088057 0.03890075
size        0.1034633 0.02841209


Shape parameters:
            estimate          se
(Intercept) 1.023516 0.04368421


                      Estimate           SE          CV
Average p            0.2999988 7.471092e-03 0.02490374
N in covered region 6033.3566458 1.915759e+02 0.03175279
```
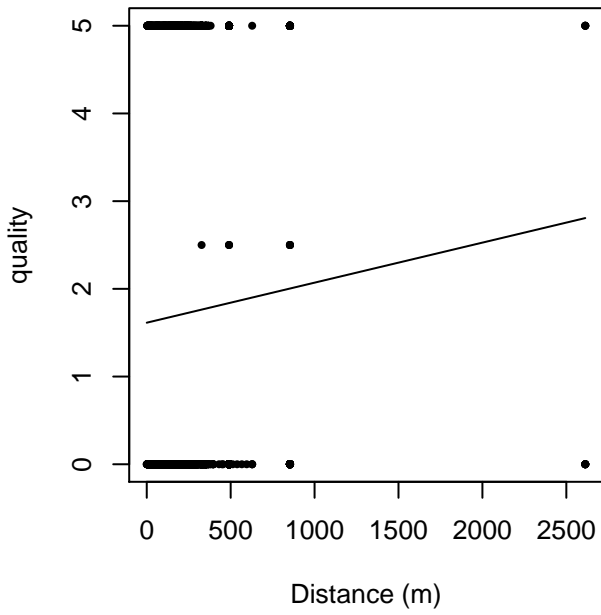
Additional diagnostic plots:



Figure 58: 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.
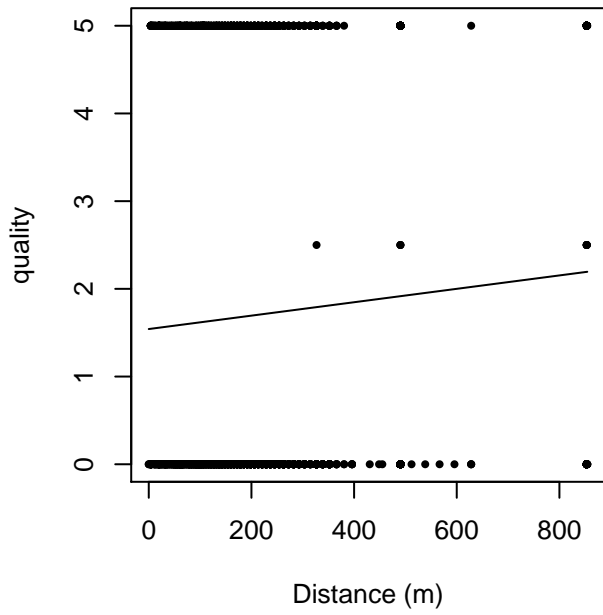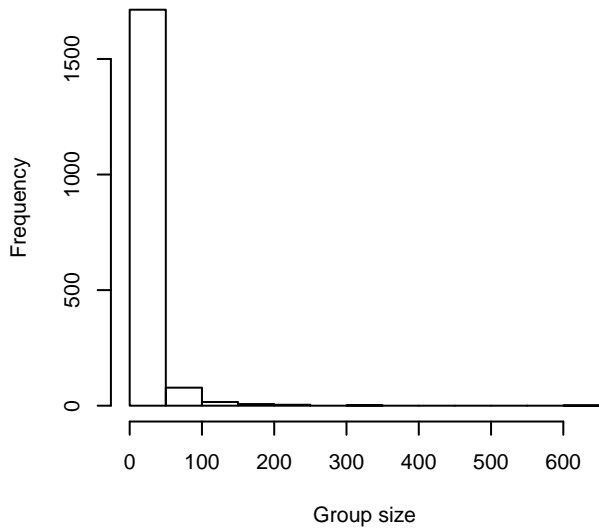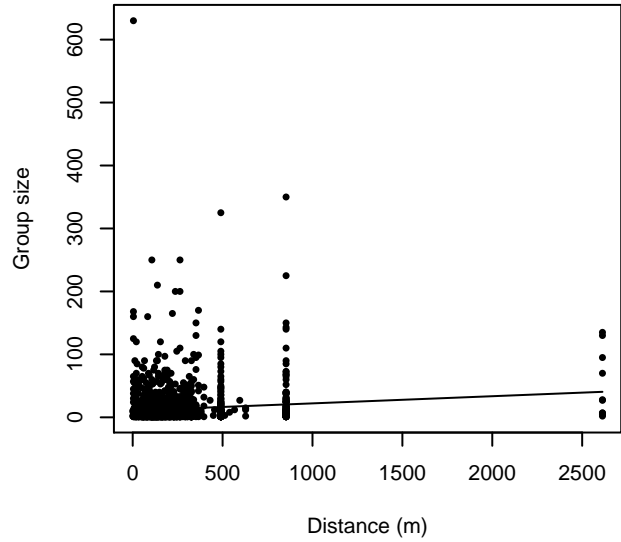
Figure 59: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
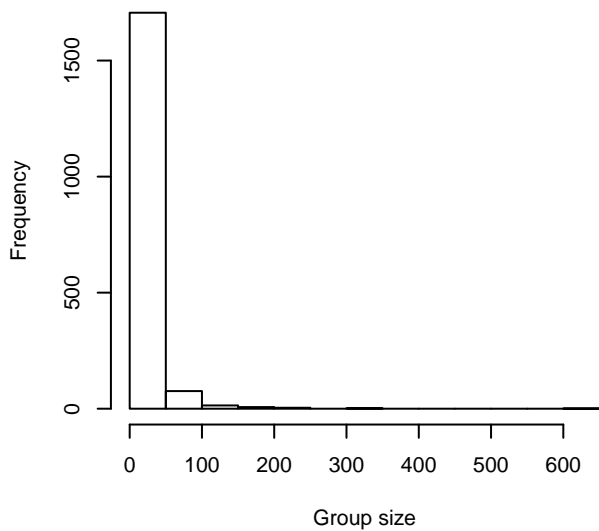
**Group Size Frequency, without right trunc.**　　**Group Size vs. Distance, without right trunc.**



**Group Size Frequency, right trunc. at 1296 m**　　**Group Size vs. Distance, right trunc. at 1296 m**
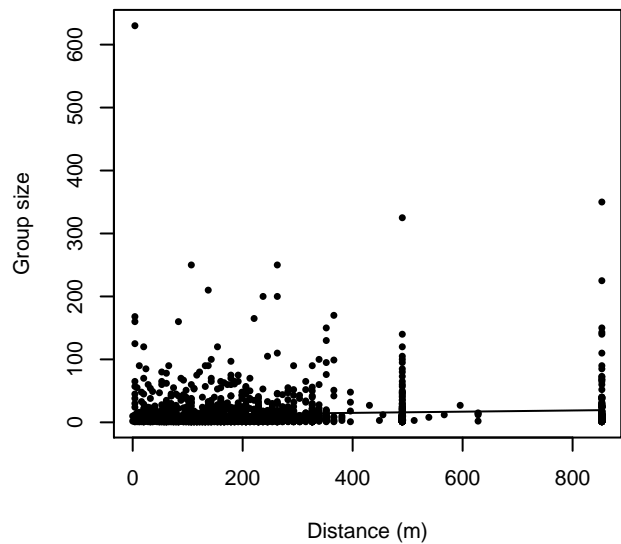


Figure 60: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

### SE_secas92

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

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

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

Table 46: Proxy species used to fit detection functions for SE_secas92. The number of sightings, n, is before truncation.

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

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

Table 47: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | | | size | Yes | 15.77 | 257 |
| hr | | | | Yes | 18.01 | 216 |
| hn | cos | 2 | | Yes | 19.23 | 189 |
| hr | poly | 2 | | Yes | 20.01 | 216 |
| hr | poly | 4 | | Yes | 22.44 | 187 |
| hn | | | beaufort | Yes | 35.20 | 260 |
| hn | | | | Yes | 41.73 | 264 |
| hn | cos | 3 | | Yes | 41.97 | 219 |
| hn | herm | 4 | | Yes | 43.30 | 264 |
| hn | | | size | No | | |
| hn | | | beaufort, size | No | | |

Table 48: Candidate detection functions for SE_secas92. The first one listed was selected for the density model.
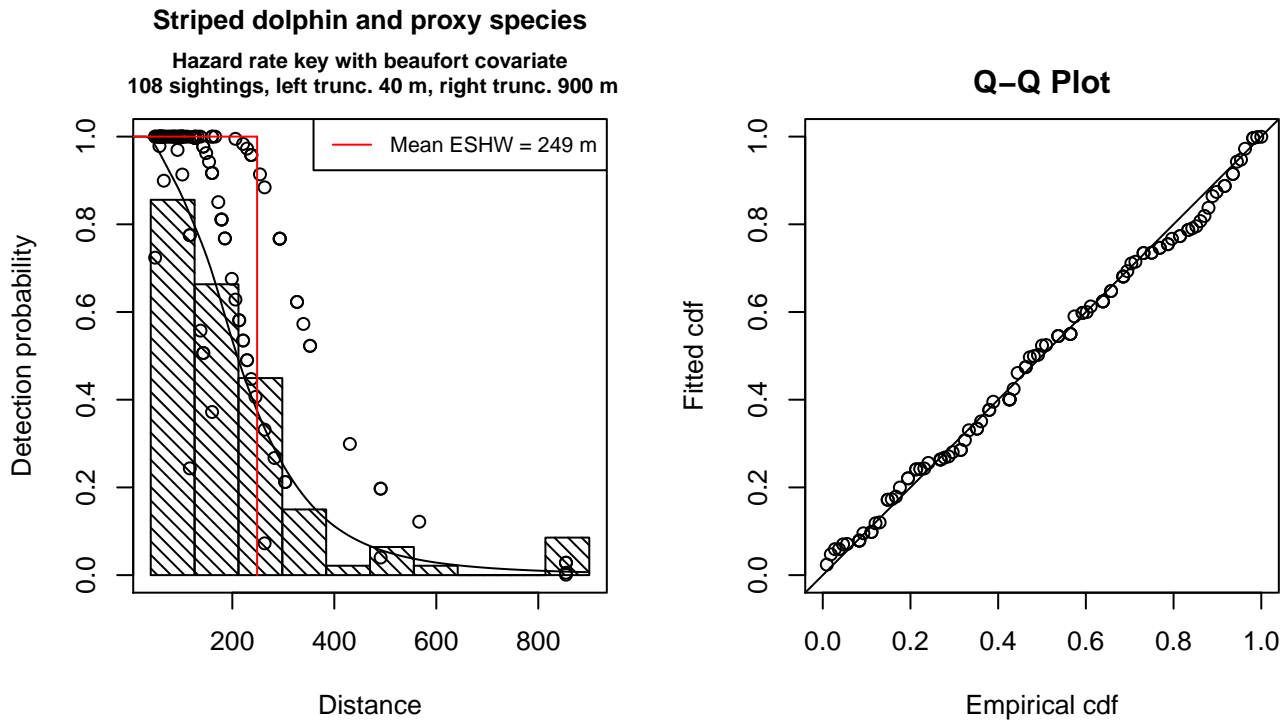


Figure 61: Detection function for SE_secas92 that was selected for the density model

Statistical output for this detection function:

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


Detection function:
 Hazard-rate key function
```

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


Shape parameters:
           estimate         se
(Intercept) 1.299333 0.1172672


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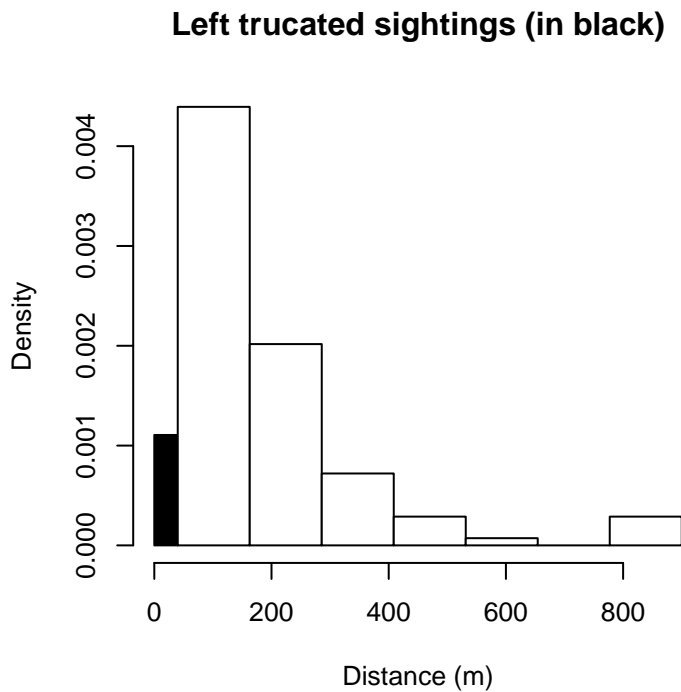
Additional diagnostic plots:



**Left trucated sightings (in black)**

Figure 62: Density of sightings by perpendicular distance for SE_secas92. Black bars on the left show sightings that were left truncated.

**beaufort vs. Distance, without right trunc.**

**beaufort vs. Distance, right trunc. at 900 m**
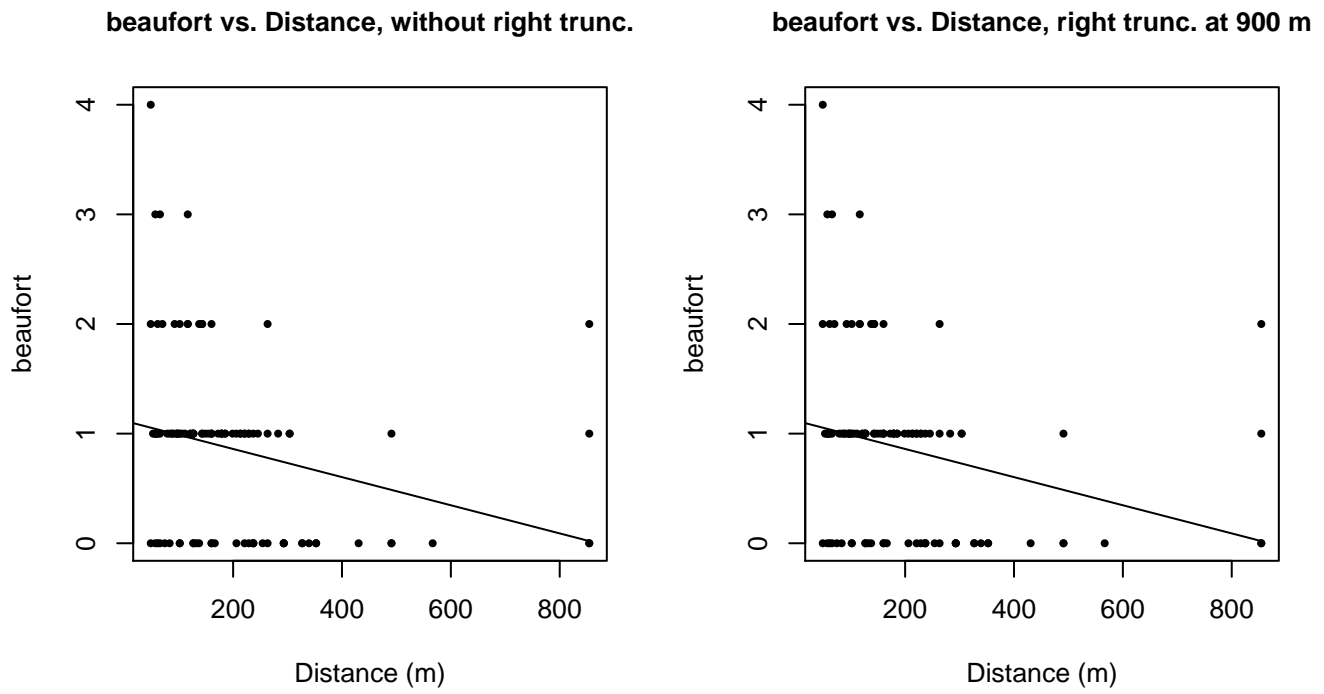
Figure 63: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
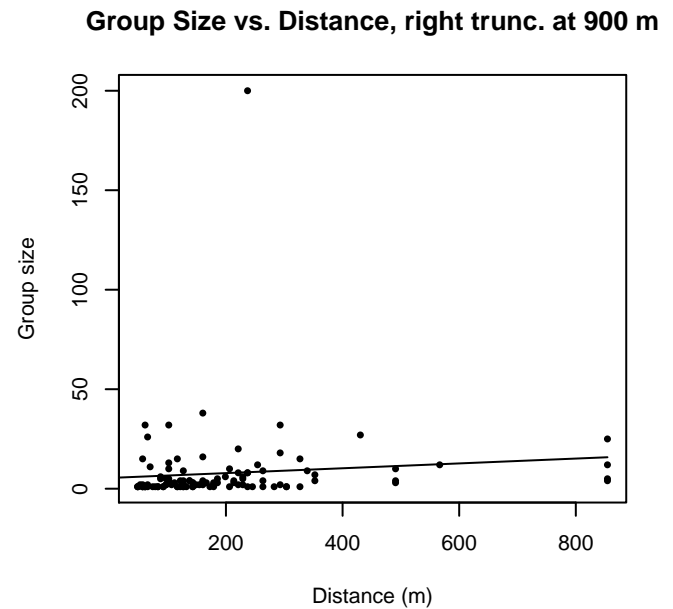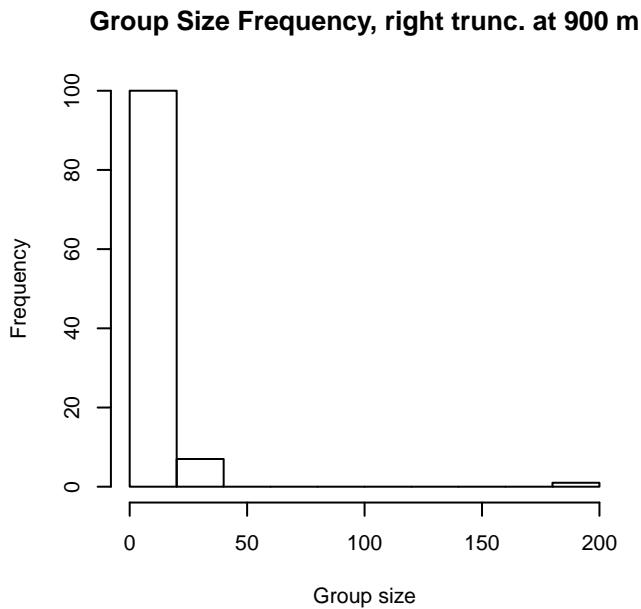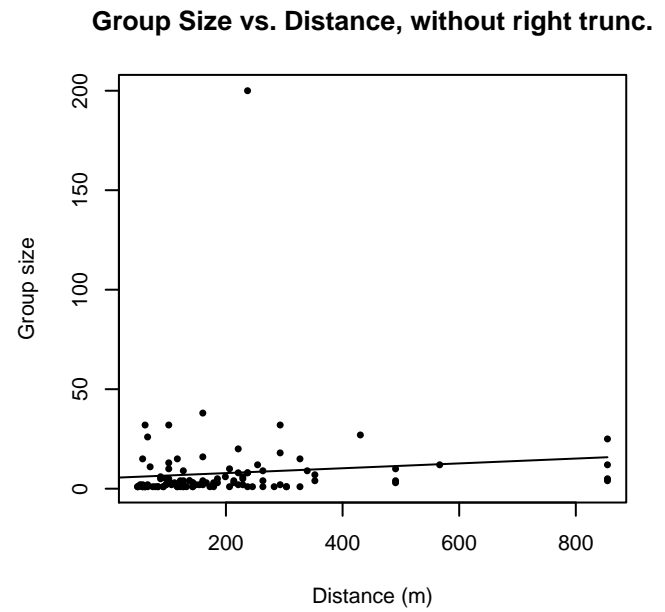
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 900 m**

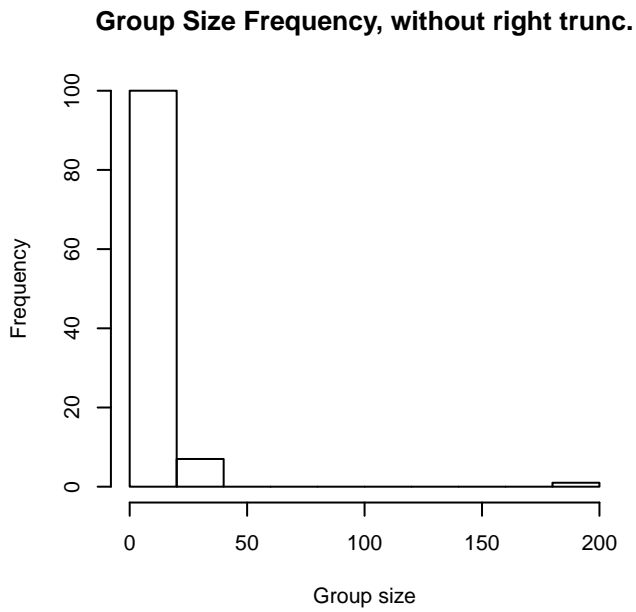**Group Size vs. Distance, right trunc. at 900 m**

Figure 64: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**SE_secas95**

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

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

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

Table 49: Proxy species used to fit detection functions for SE_secas95. The number of sightings, n, is before truncation.

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

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

Table 50: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 51: Candidate detection functions for SE_secas95. The first one listed was selected for the density model.
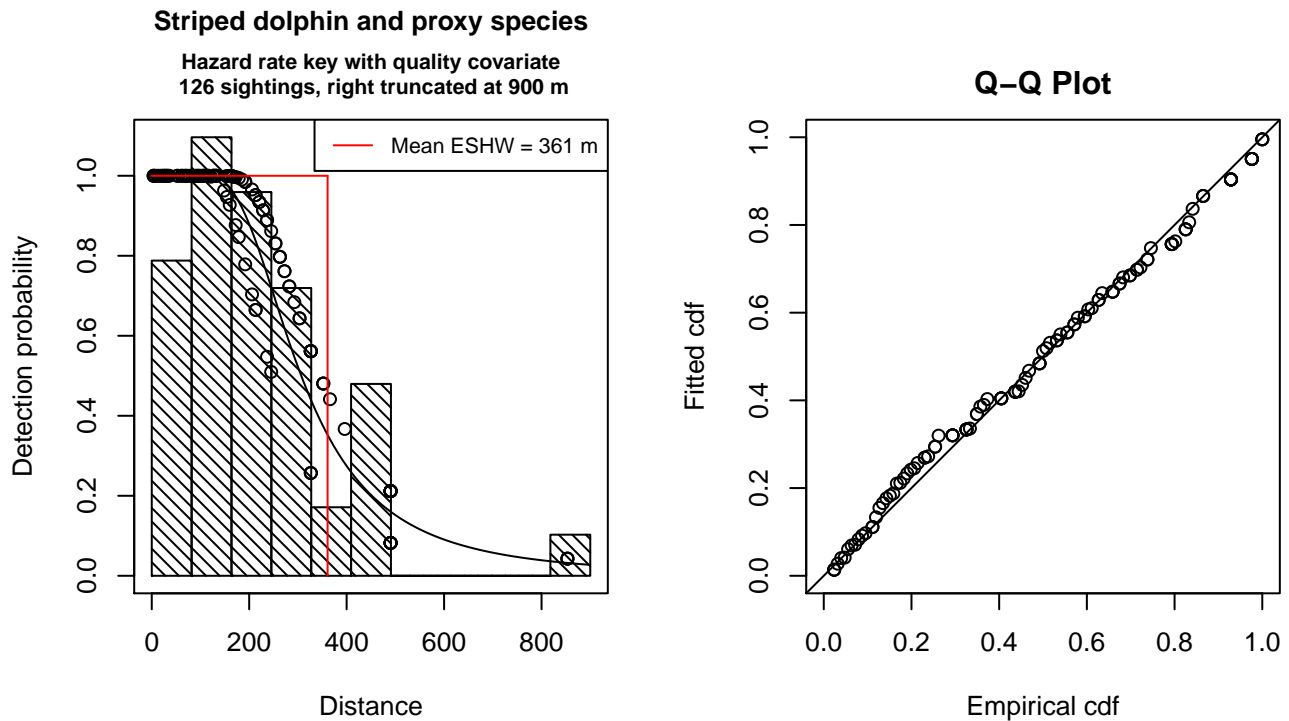


Figure 65: Detection function for SE_secas95 that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

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

Shape parameters:
            estimate        se
(Intercept) 1.116802 0.1798011


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

Additional diagnostic plots:
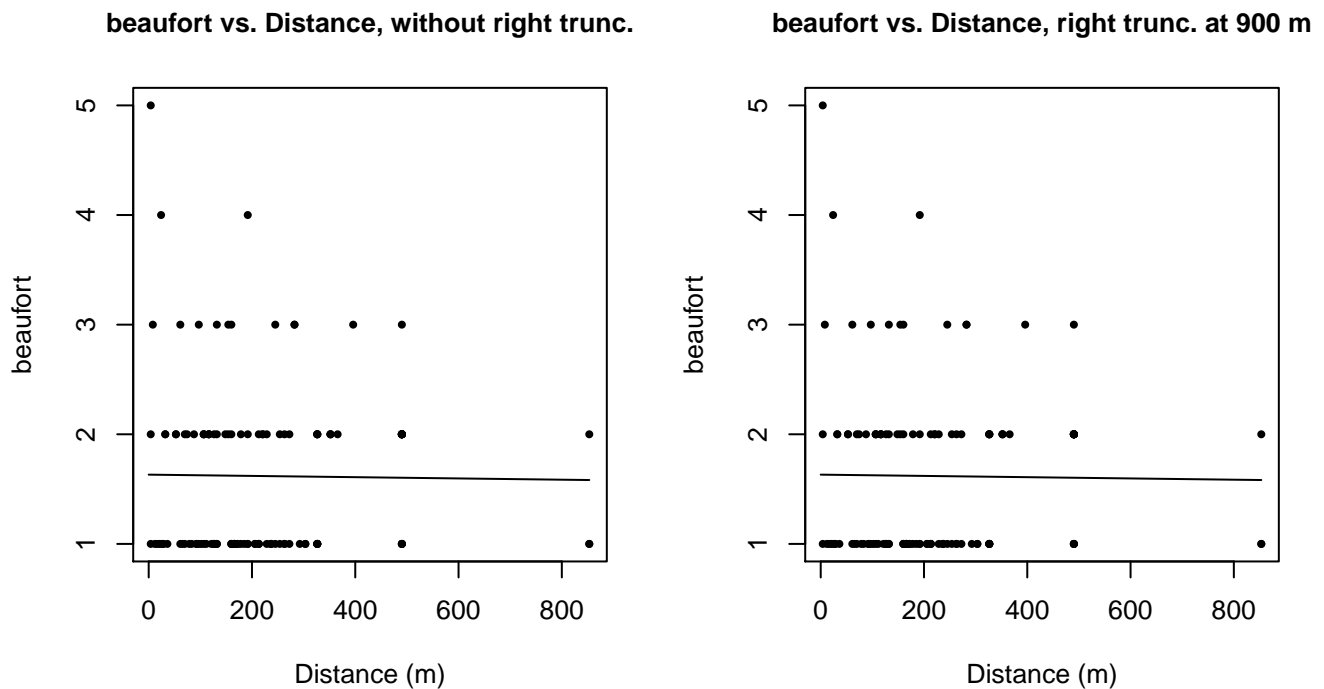


Figure 66: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
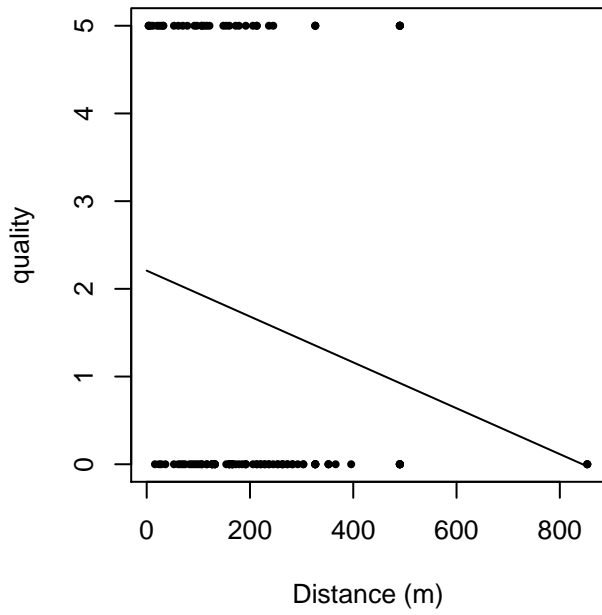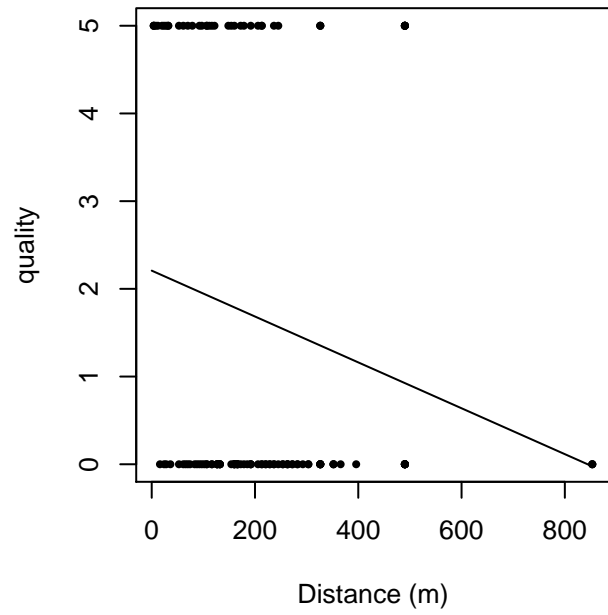
Figure 67: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
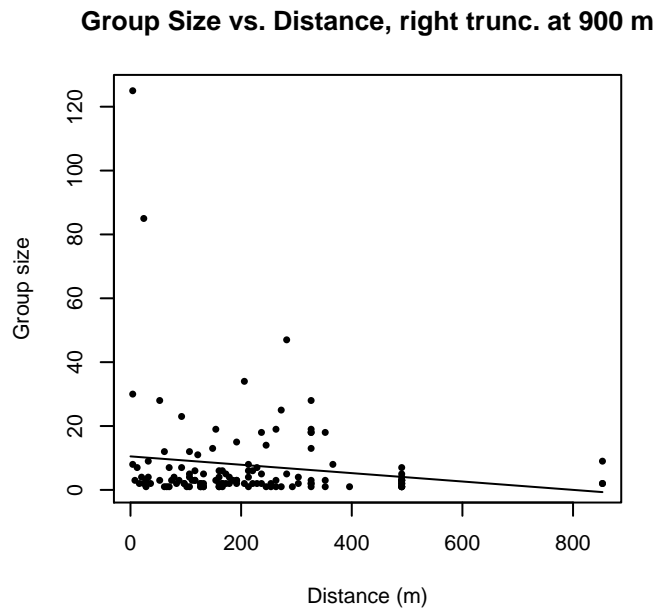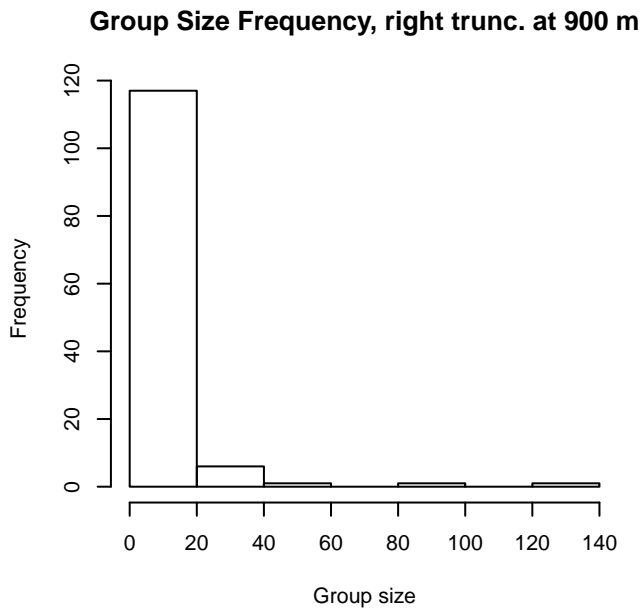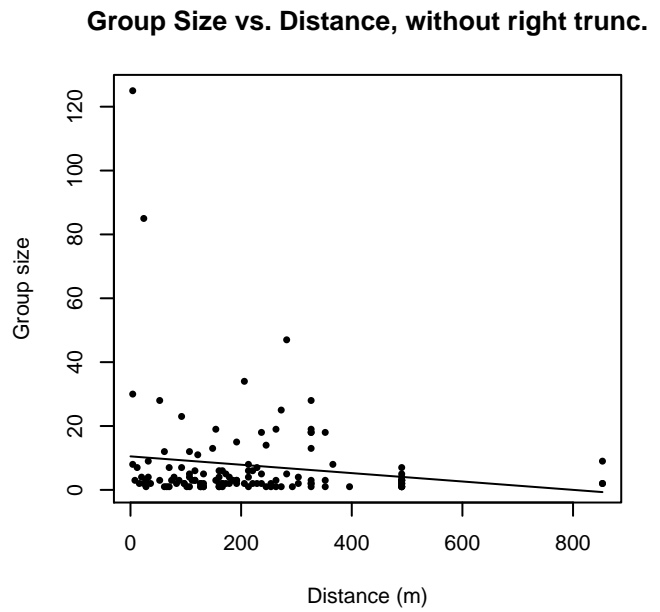
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 900 m**

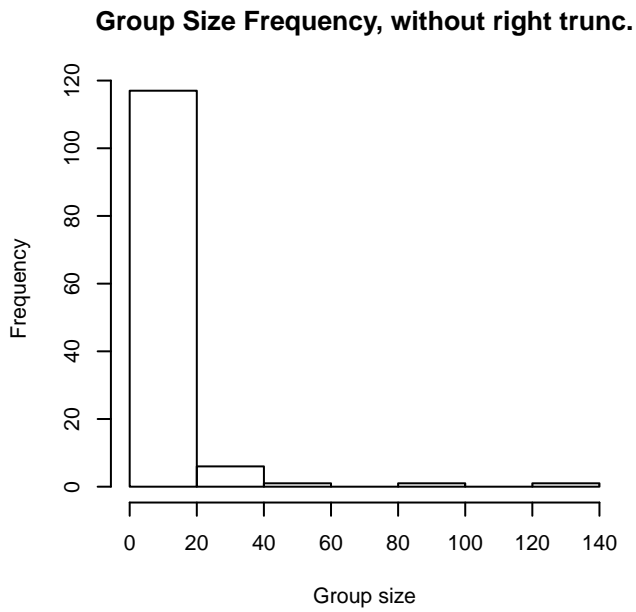**Group Size vs. Distance, right trunc. at 900 m**

Figure 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.

**Mid Atlantic Tursiops Survey 1995**

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

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

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

Table 52: Proxy species used to fit detection functions for Mid Atlantic Tursiops Survey 1995. The number of sightings, n, is before truncation.

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

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

Table 53: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

| Key | Adjustment | Order | Covariates | Succeeded | Δ AIC | Mean ESHW (m) |
|---|---|---|---|---|---|---|
| hr | | | | Yes | 0.00 | 416 |
| hr | | | quality | Yes | 1.20 | 425 |
| hr | | | size | Yes | 1.63 | 420 |

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

Table 54: Candidate detection functions for Mid Atlantic Tursiops Survey 1995. The first one listed was selected for the density model.
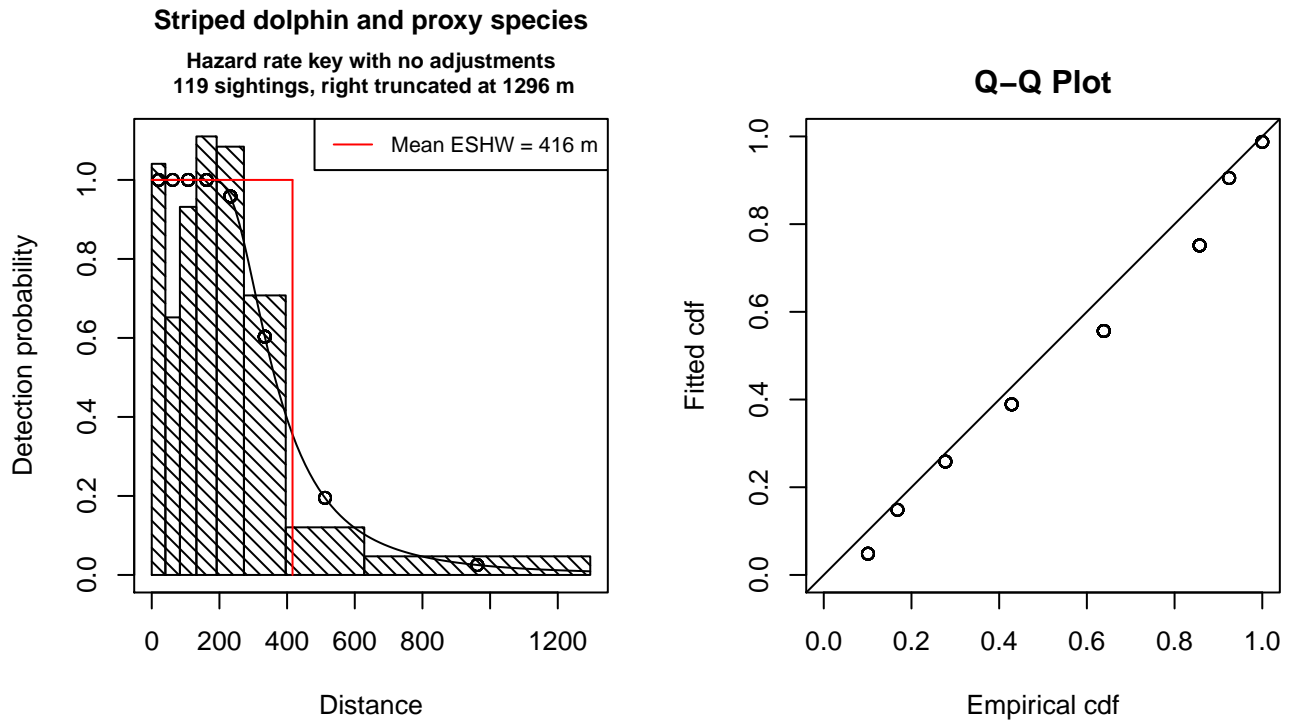


Figure 69: Detection function for Mid Atlantic Tursiops Survey 1995 that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  119
Distance range         :  0  -  1296
AIC                    :  481.8113


Detection function:
 Hazard-rate key function


Detection function parameters
Scale Coefficients:
            estimate        se
(Intercept) 5.788509 0.117856


Shape parameters:
            estimate        se
(Intercept)  1.22245 0.1594061


                     Estimate          SE          CV
Average p             0.32101  0.02785003  0.0867575
N in covered region 370.70494 42.64341671 0.1150333
```

Additional diagnostic plots:
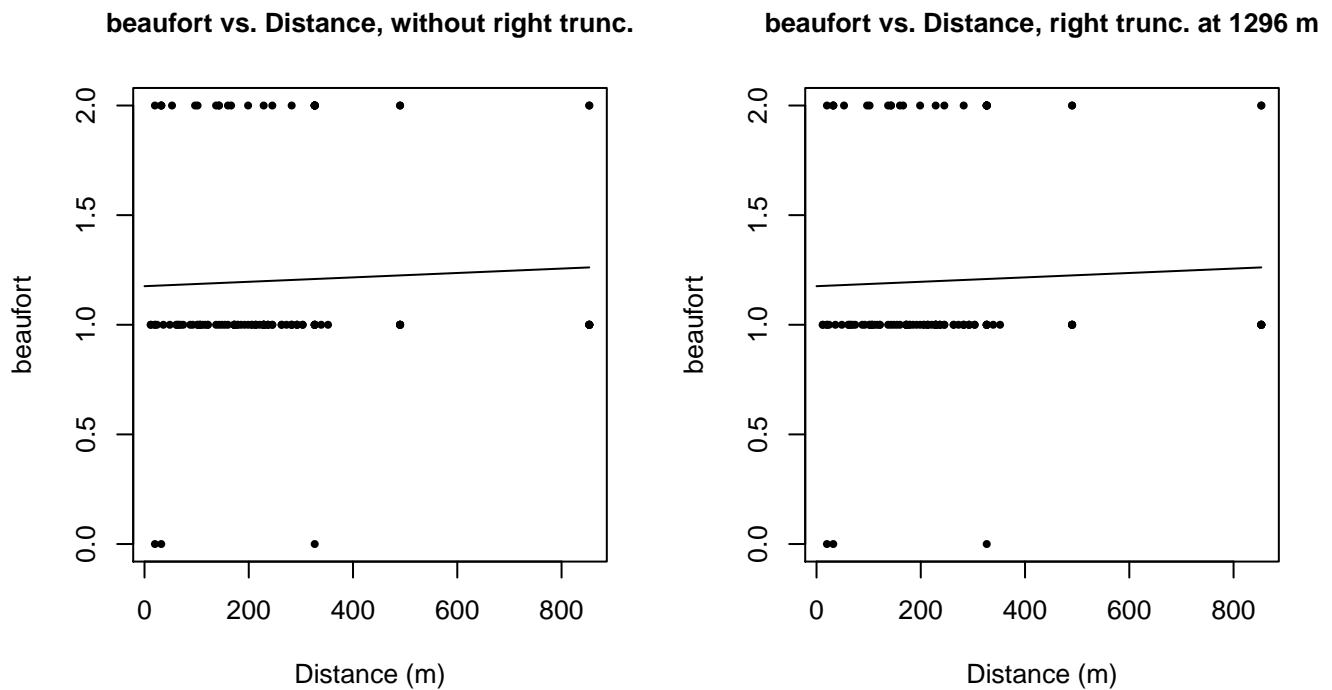


Figure 70: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
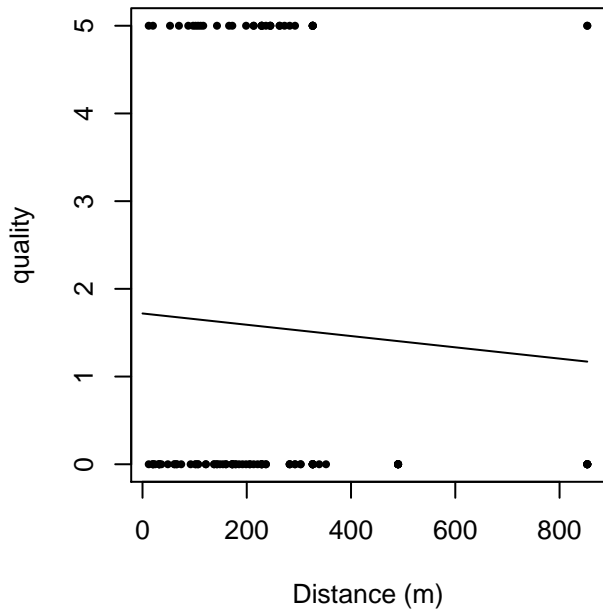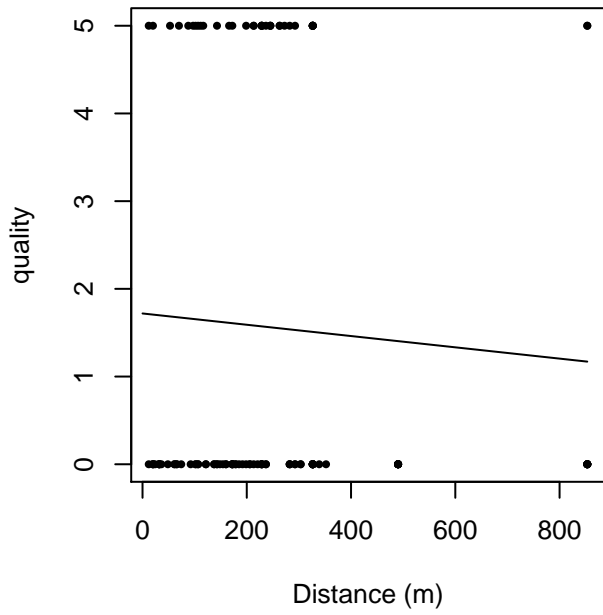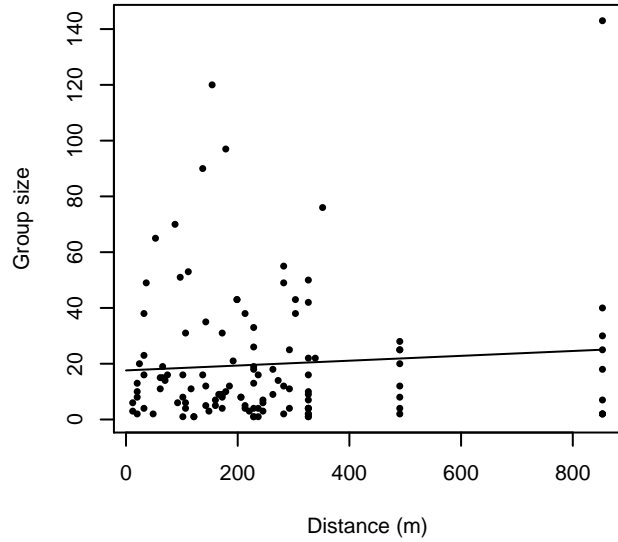
Figure 71: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
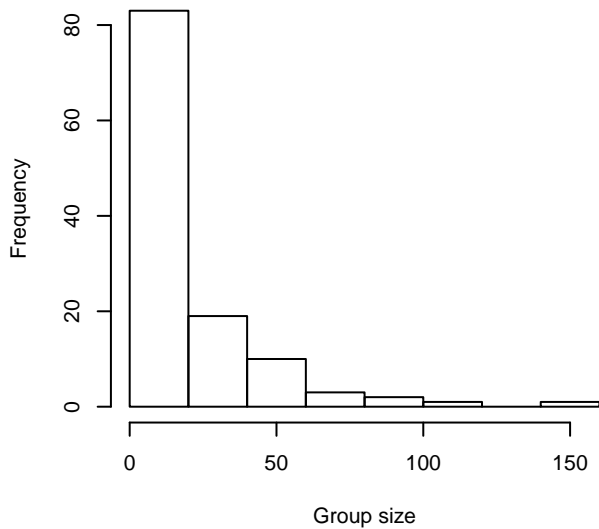
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 1296 m**

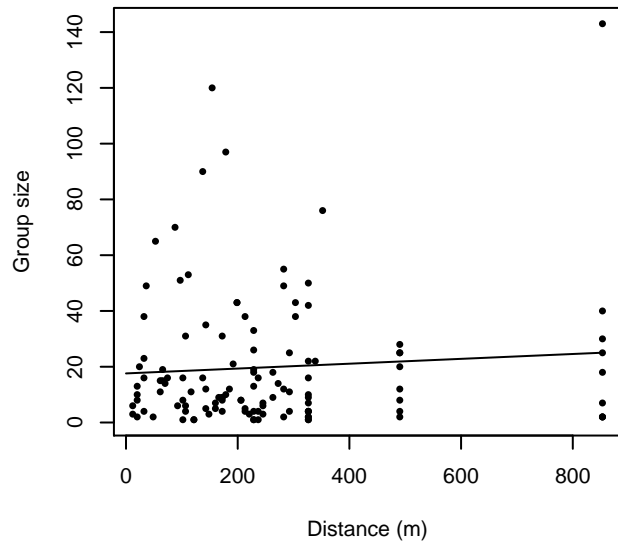**Group Size vs. Distance, right trunc. at 1296 m**

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

**GulfCet Aerial Surveys**

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

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

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

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

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

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

Table 56: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

| hr | poly | 4 | | Yes | 3.41 | 394 |
|----|------|---|--|-----|------|-----|
| hn | cos | 2 | | Yes | 4.97 | 368 |
| hn | cos | 3 | | Yes | 10.69 | 340 |
| hn | | | size | Yes | 31.42 | 441 |
| hn | | | | Yes | 34.80 | 439 |
| hn | herm | 4 | | Yes | 36.57 | 439 |
| hr | | | beaufort | No | | |
| hn | | | beaufort | No | | |
| hr | | | quality | No | | |
| hn | | | quality | 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 57: Candidate detection functions for GulfCet Aerial Surveys. The first one listed was selected for the density model.
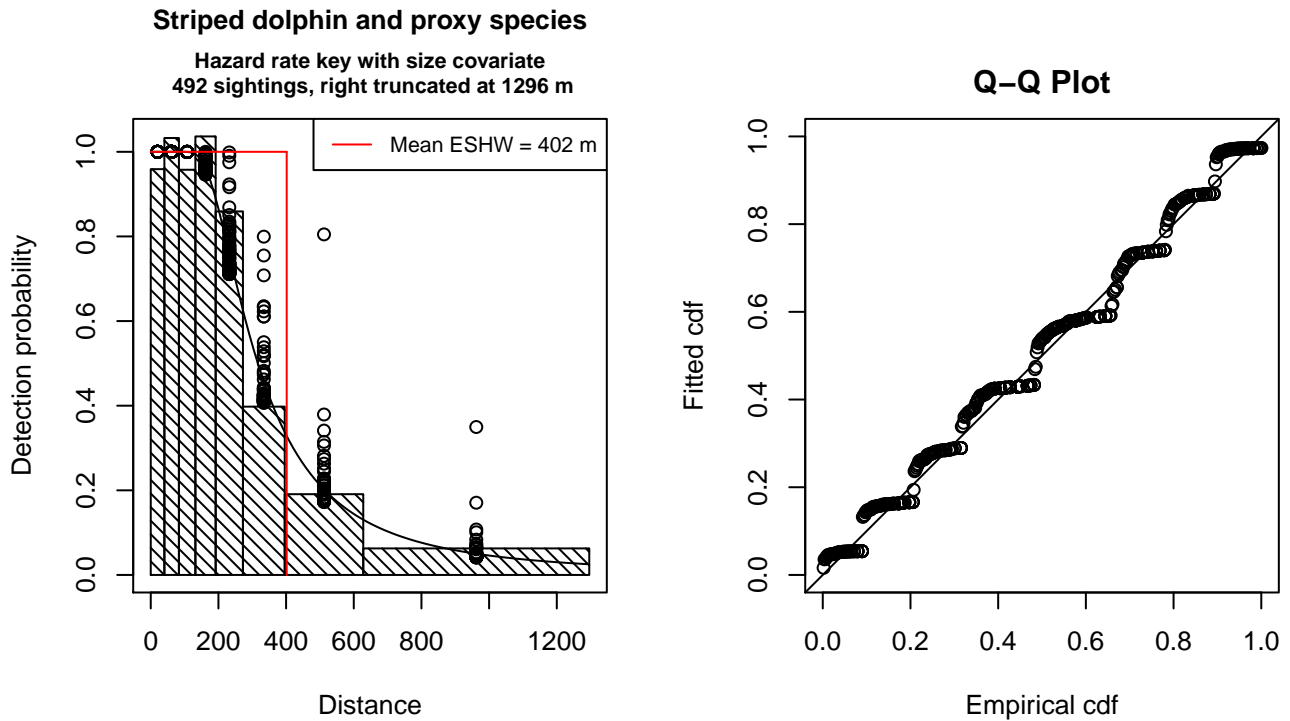


Figure 73: Detection function for GulfCet Aerial Surveys that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate         se
(Intercept) 5.5354386 0.09101914
size        0.1398343 0.06269366

Shape parameters:
            estimate         se
(Intercept) 0.8669391 0.08291978


                      Estimate          SE         CV
Average p            0.3057321  0.01666672 0.05451413
N in covered region 1609.2517747 106.64340484 0.06626894
```

Additional diagnostic plots:
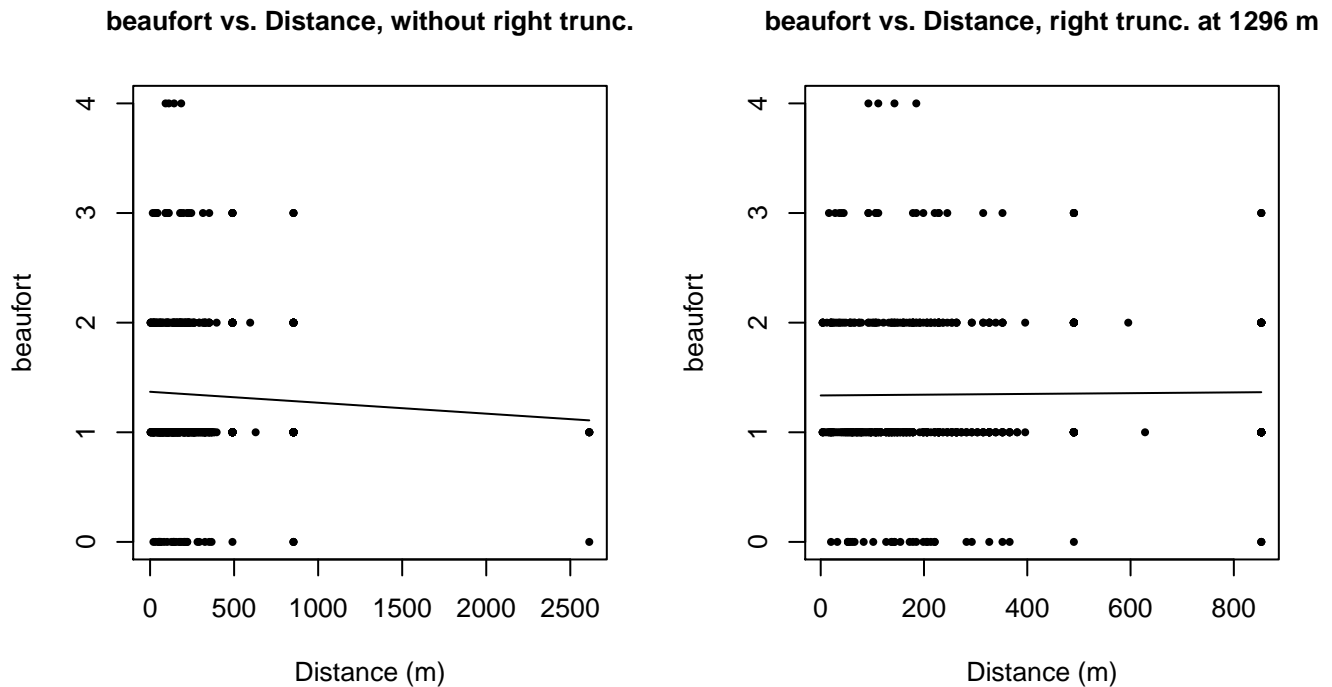


Figure 74: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
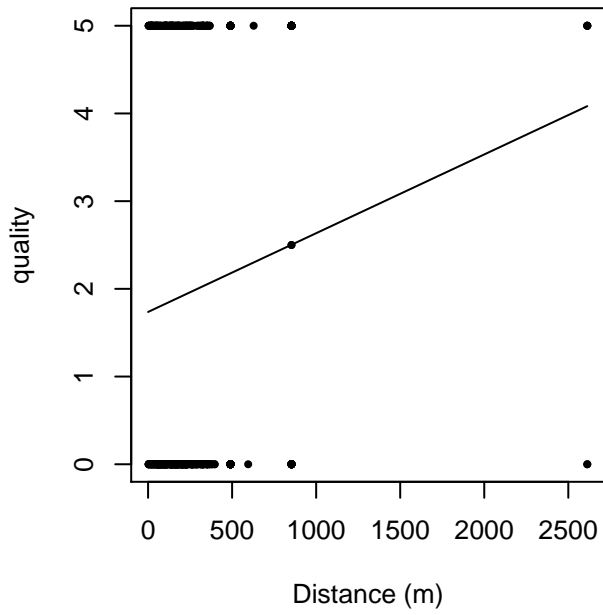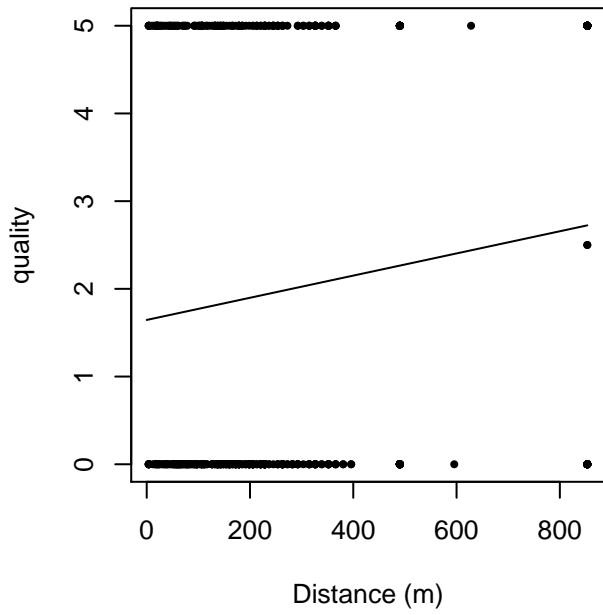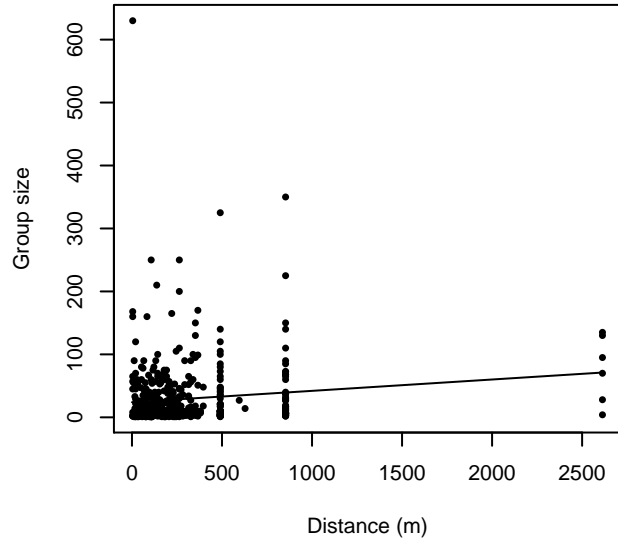
Figure 75: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
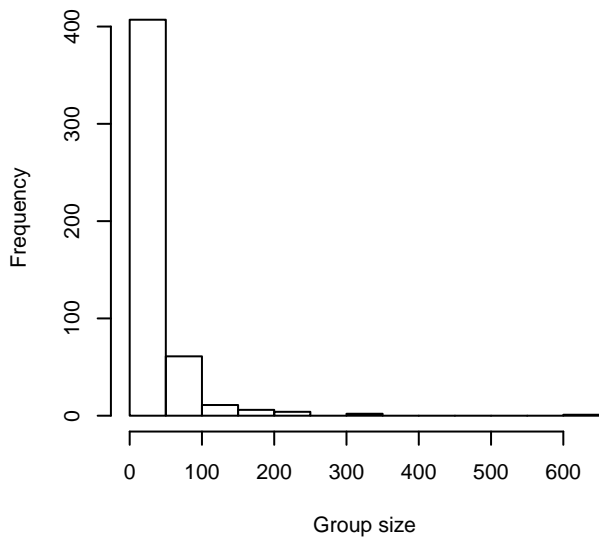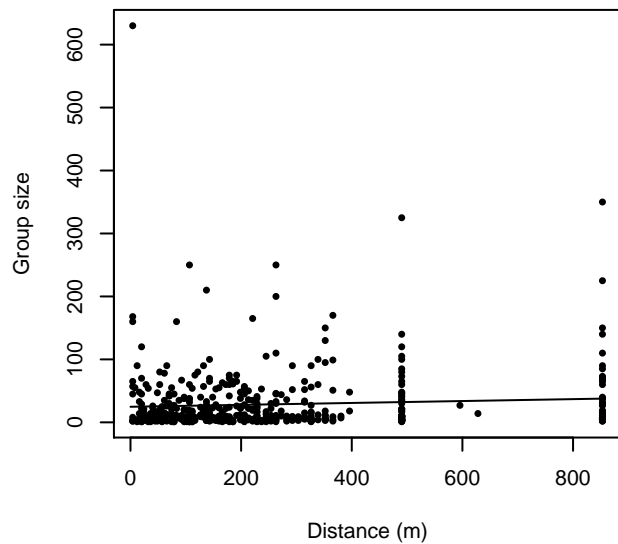
Figure 76: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

**GOMEX92-96 Aerial Survey**

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

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

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

Table 58: Proxy species used to fit detection functions for GOMEX92-96 Aerial Survey. The number of sightings, n, is before truncation.

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

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

Table 59: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

| | | | | | | |
|---|---|---|---|---|---|---|
| hr | | | size | Yes | 0.00 | 281 |
| hn | cos | 3 | | Yes | 4.86 | 220 |
| hr | | | | Yes | 4.90 | 278 |
| hr | poly | 4 | | Yes | 6.90 | 278 |
| hr | poly | 2 | | Yes | 6.90 | 278 |
| hn | cos | 2 | | Yes | 12.08 | 259 |
| hn | | | size | Yes | 39.54 | 304 |
| hn | | | | Yes | 41.95 | 304 |
| hn | herm | 4 | | Yes | 43.71 | 304 |
| hr | | | beaufort | No | | |
| hn | | | beaufort | No | | |
| hr | | | quality | No | | |
| hn | | | quality | 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 60: Candidate detection functions for GOMEX92-96 Aerial Survey. The first one listed was selected for the density model.
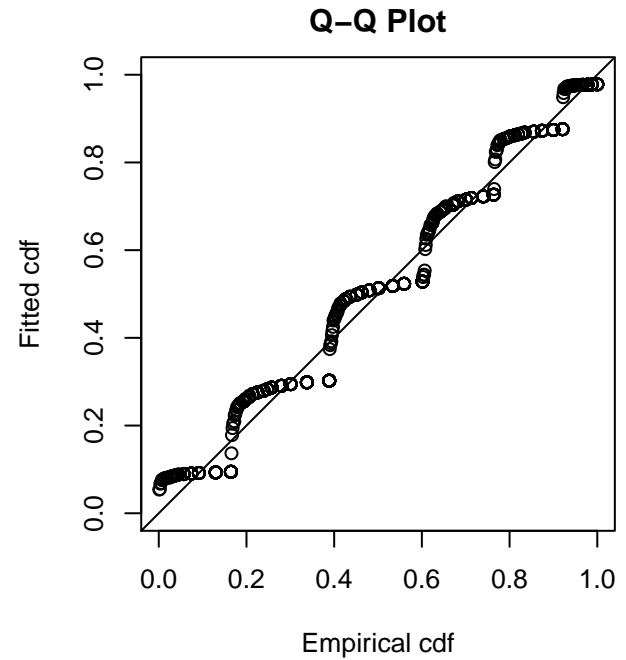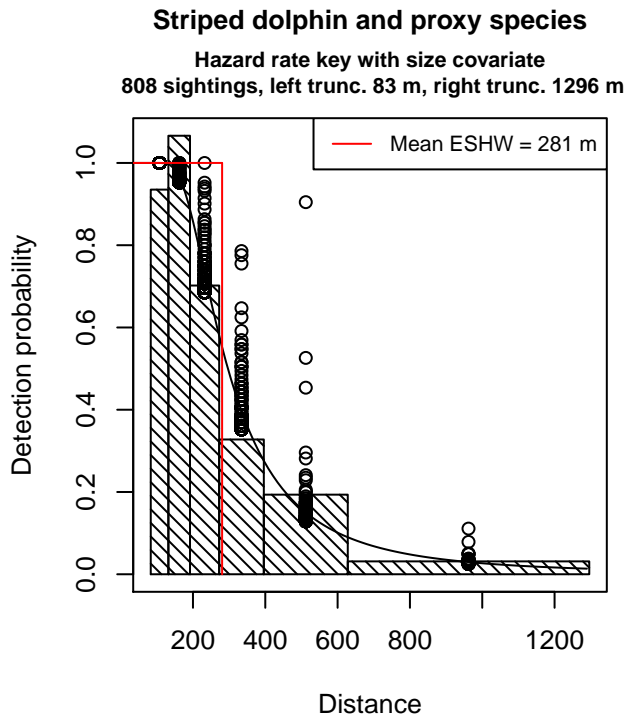
Figure 77: Detection function for GOMEX92-96 Aerial Survey that was selected for the density model

Statistical output for this detection function:

```
Summary for ds object
Number of observations :  808
Distance range         :  83.2036  -  1296
AIC                    :  2832.21

Detection function:
 Hazard-rate key function

Detection function parameters
Scale Coefficients:
            estimate          se
(Intercept) 5.48993350 0.06755593
size        0.09571101 0.04017188

Shape parameters:
           estimate          se
(Intercept) 0.9892248 0.05853657


                    Estimate          SE          CV
Average p          0.2138271   0.01146024 0.05359584
N in covered region 3778.7542797 234.43000362 0.06203896
```

Additional diagnostic plots:

## Left trucated sightings (in black)
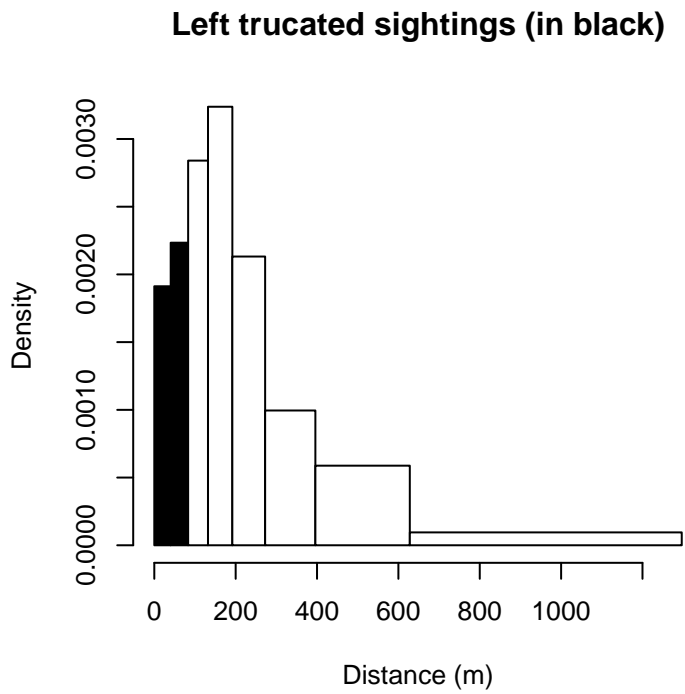


Figure 78: Density of sightings by perpendicular distance for GOMEX92-96 Aerial Survey. Black bars on the left show sightings that were left truncated.
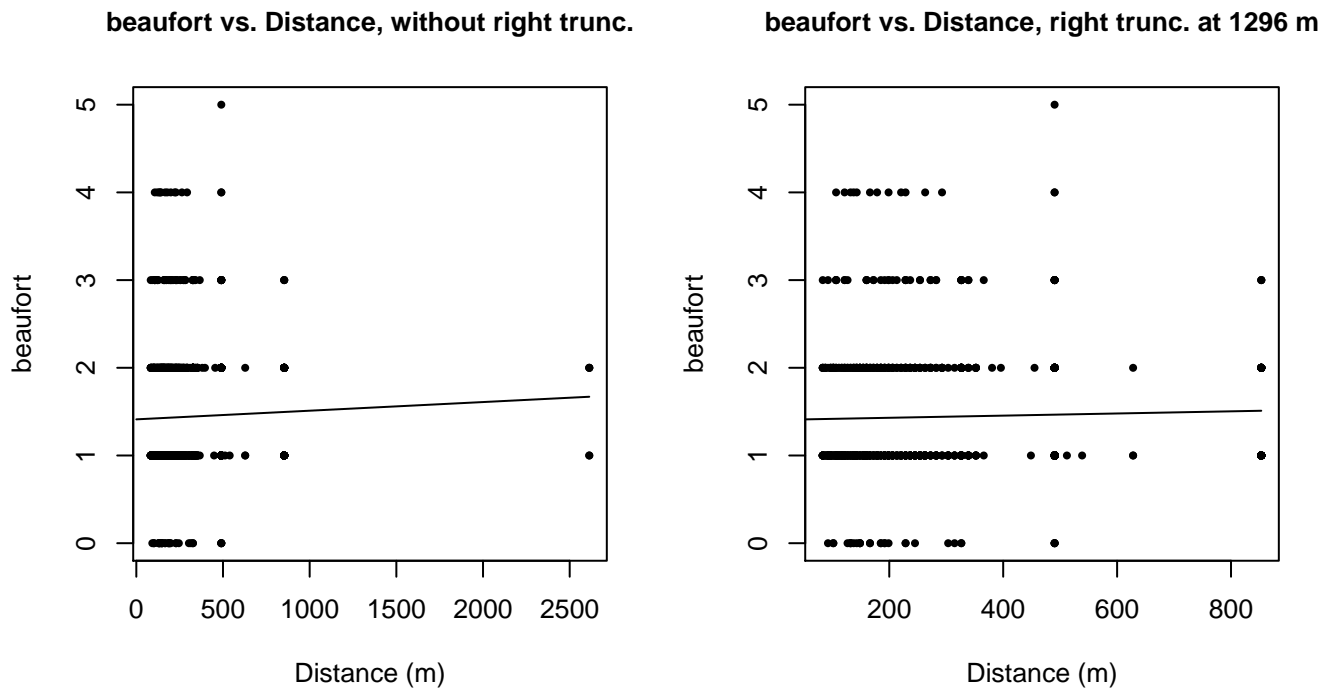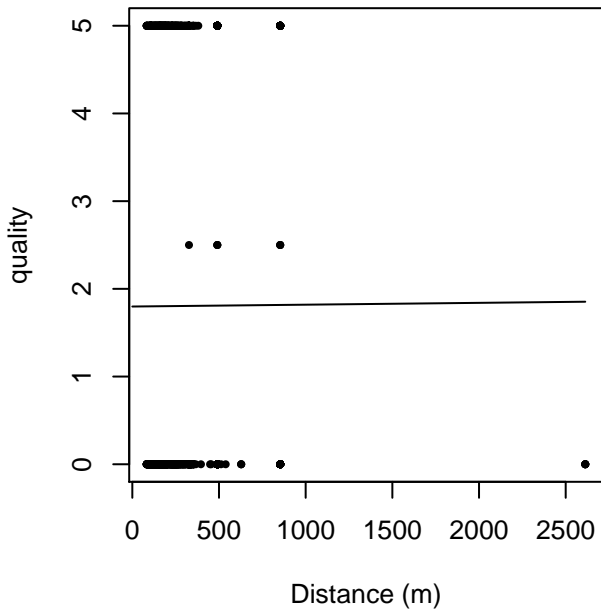


Figure 79: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
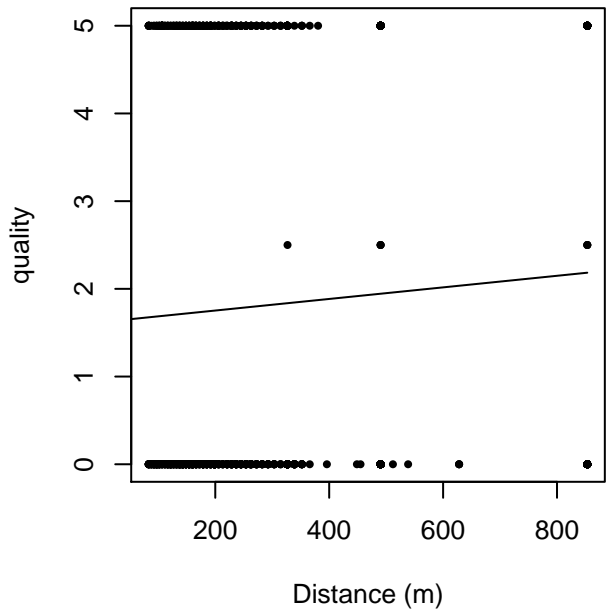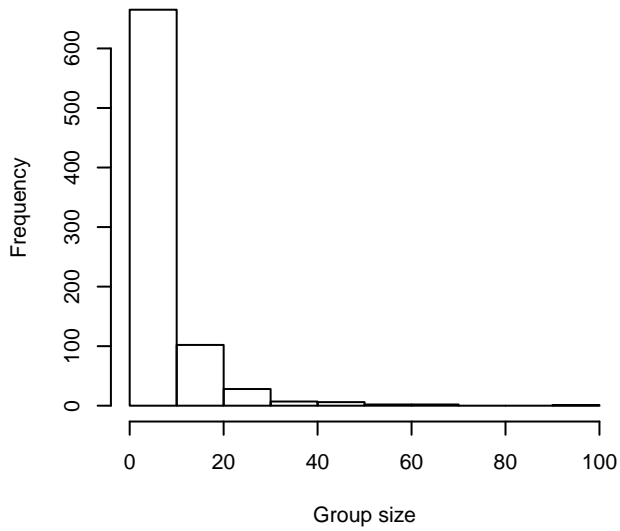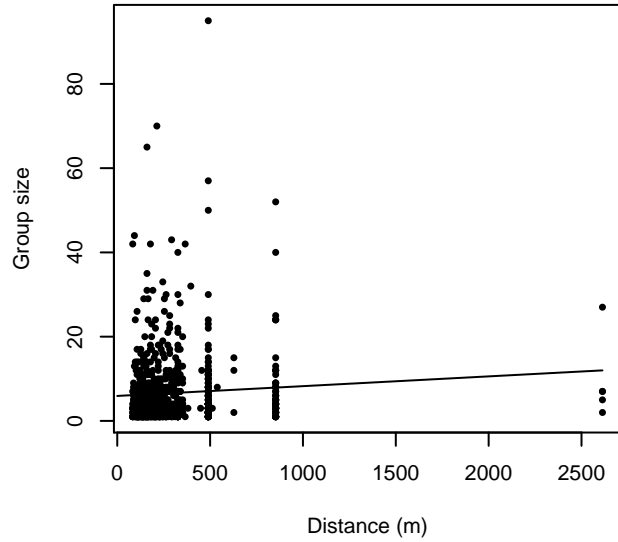
Figure 80: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
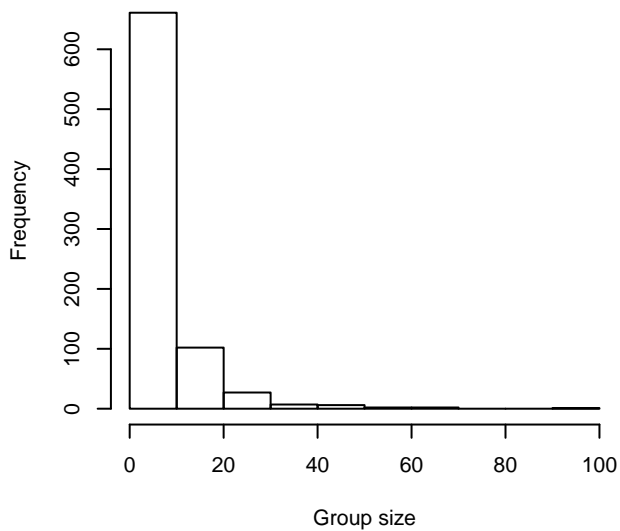
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 1296 m**

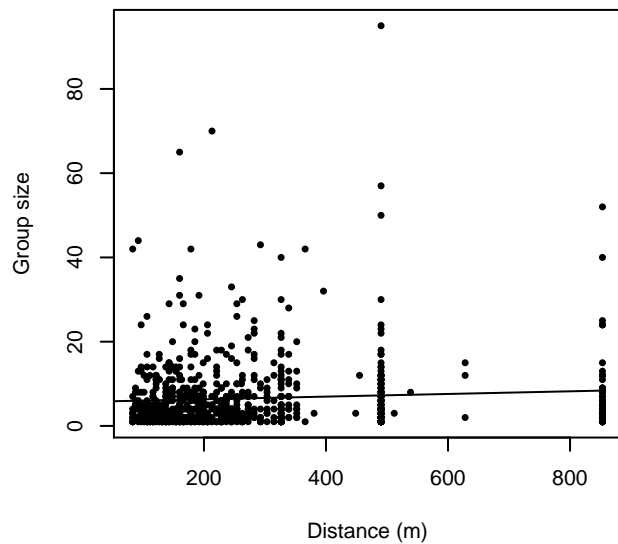**Group Size vs. Distance, right trunc. at 1296 m**

Figure 81: 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 61: 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 62: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 63: Candidate detection functions for UNCW Navy Surveys. The first one listed was selected for the density model.
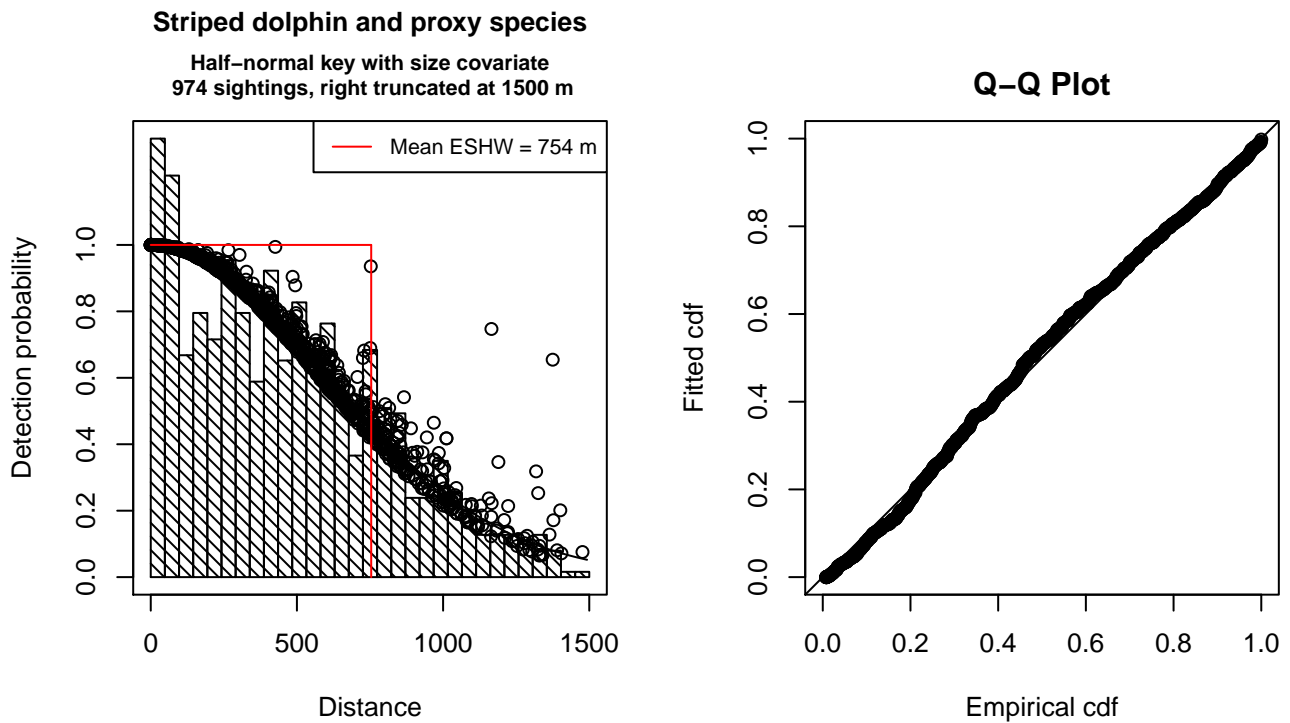


Figure 82: Detection function for UNCW Navy Surveys that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Half-normal key function

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

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

Additional diagnostic plots:
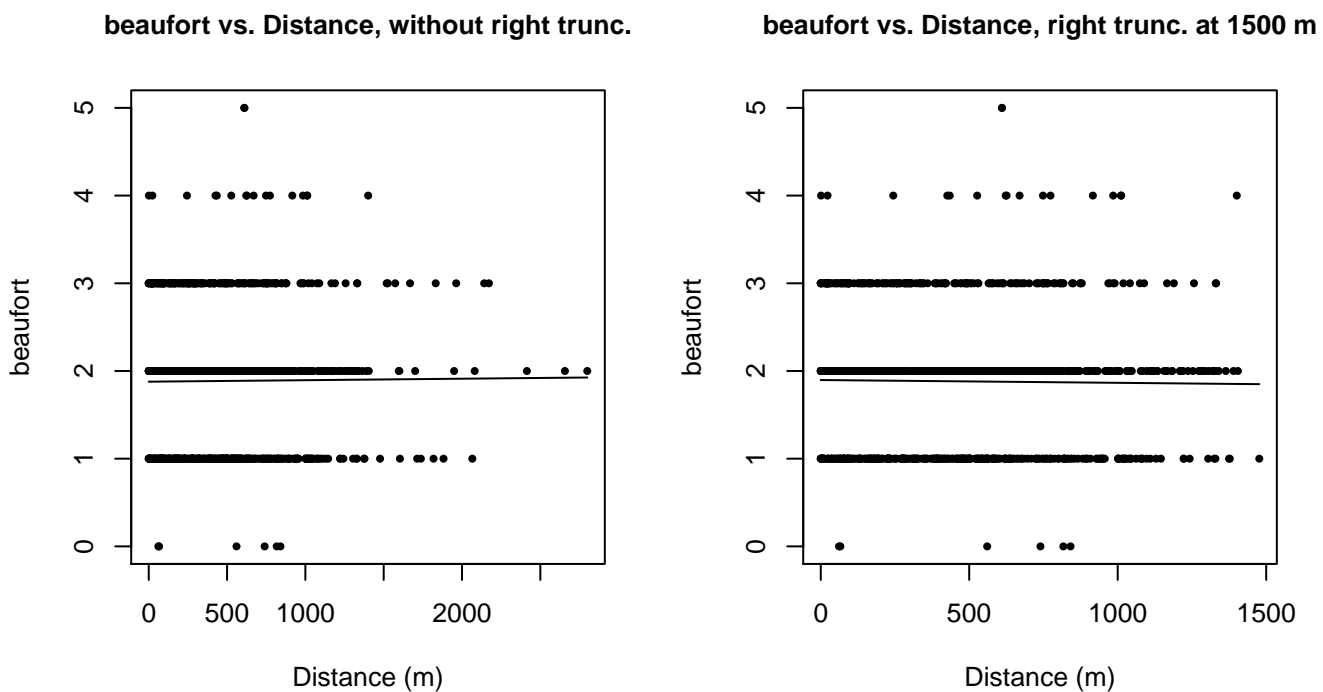


Figure 83: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
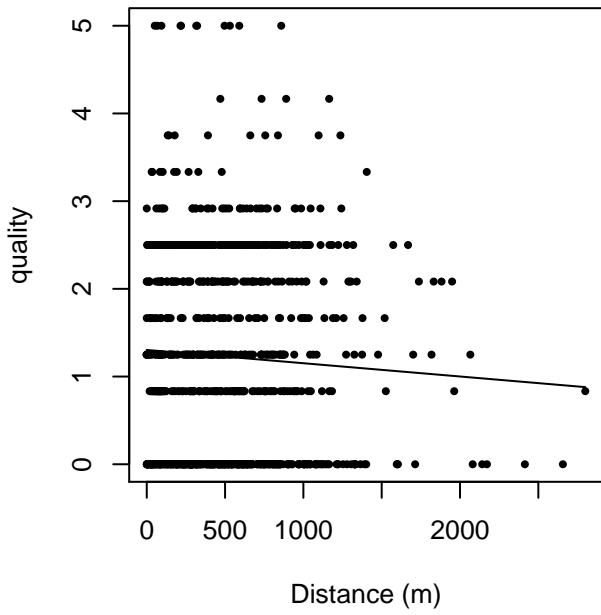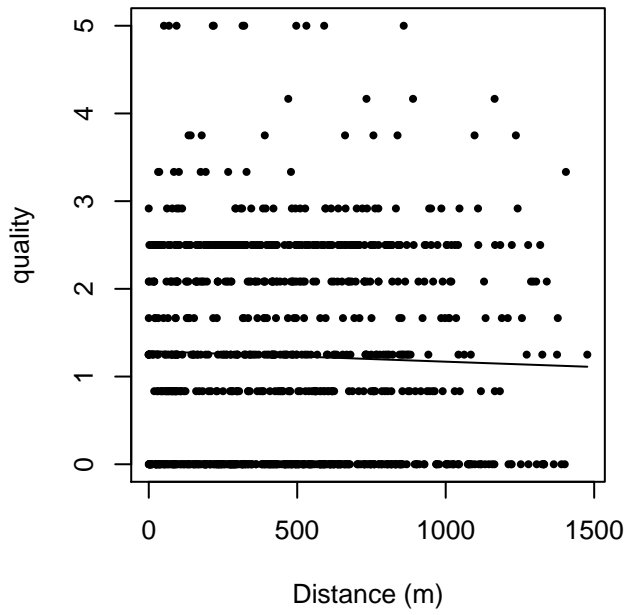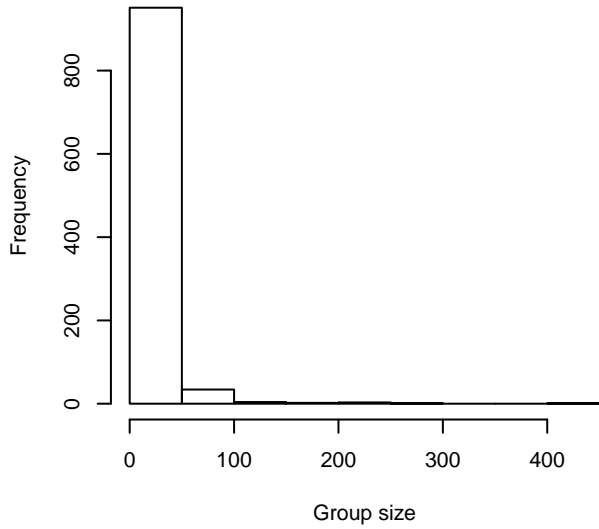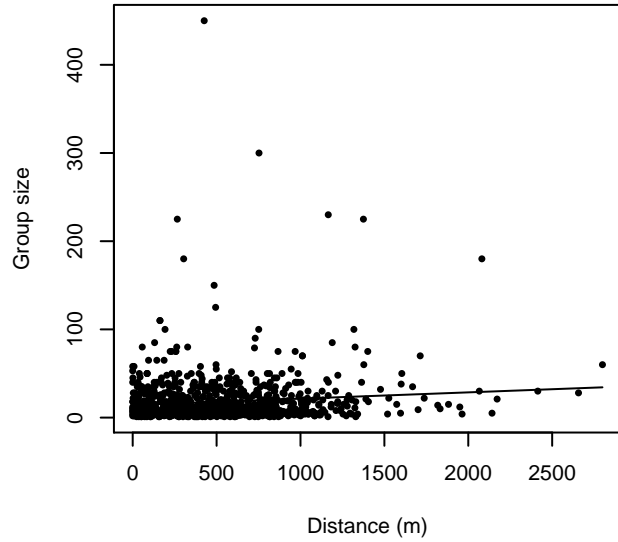
Figure 84: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
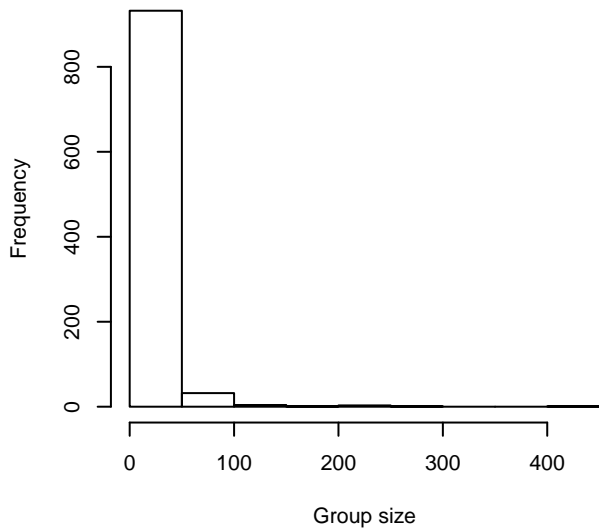
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 1500 m**

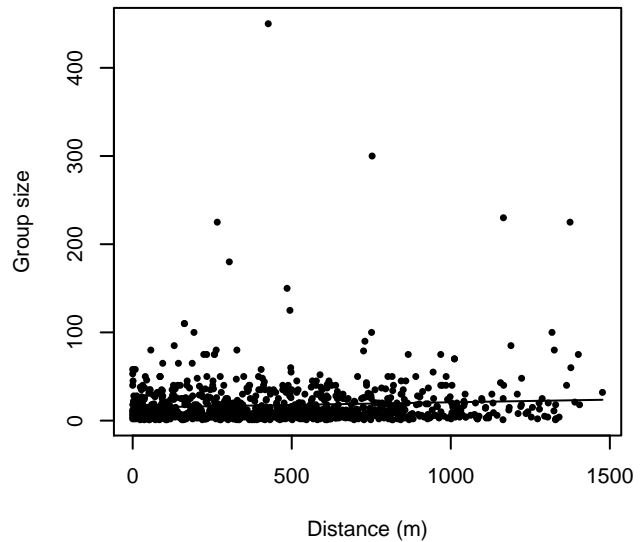**Group Size vs. Distance, right trunc. at 1500 m**

Figure 85: 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 |

107

| | | |
|---|---|---:|
| 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 64: Proxy species used to fit detection functions for UNCW Right Whale Surveys. The number of sightings, n, is before truncation.

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

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

Table 65: 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 66: Candidate detection functions for UNCW Right Whale Surveys. The first one listed was selected for the density model.
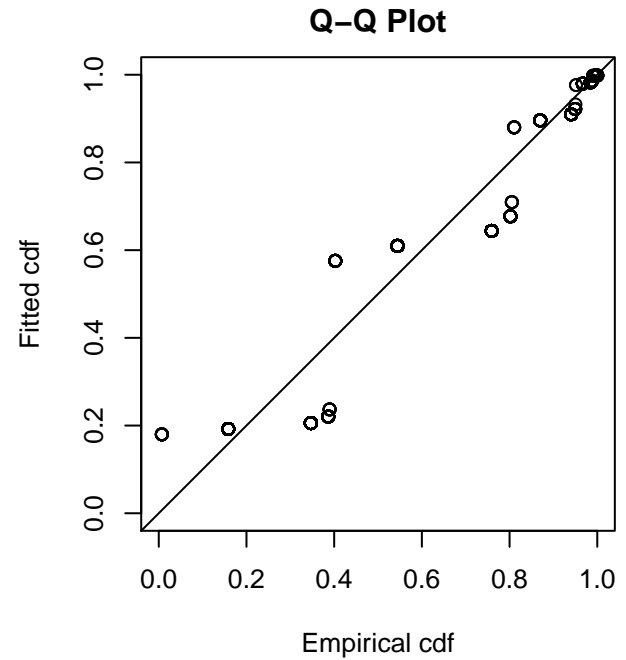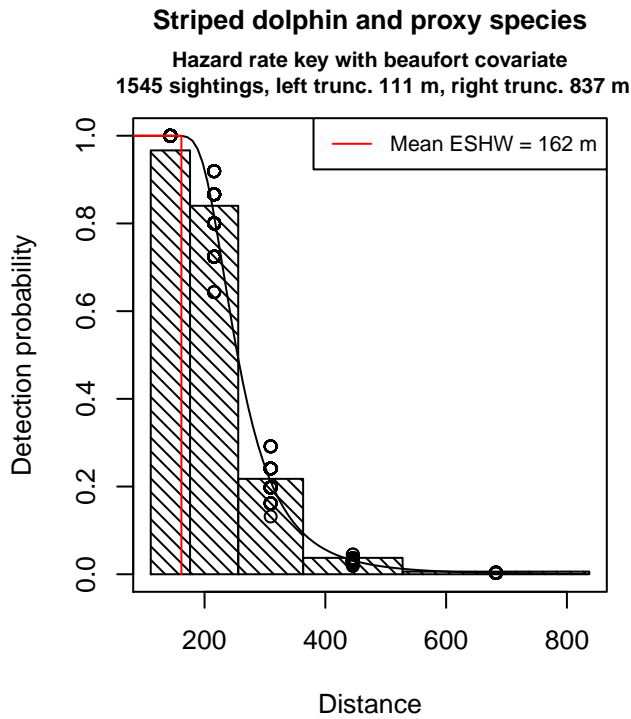
Figure 86: Detection function for UNCW Right Whale Surveys that was selected for the density model

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:
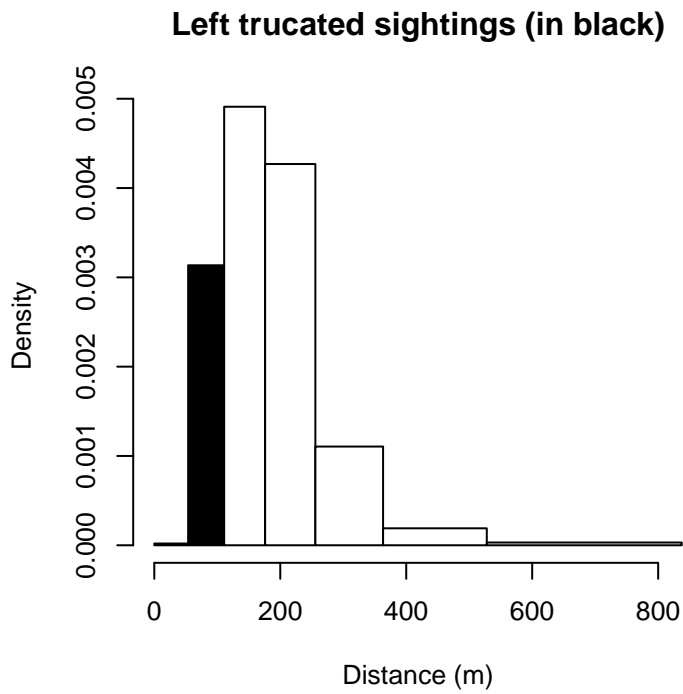
## Left trucated sightings (in black)



Figure 87: Density of sightings by perpendicular distance for UNCW Right Whale Surveys. Black bars on the left show sightings that were left truncated.
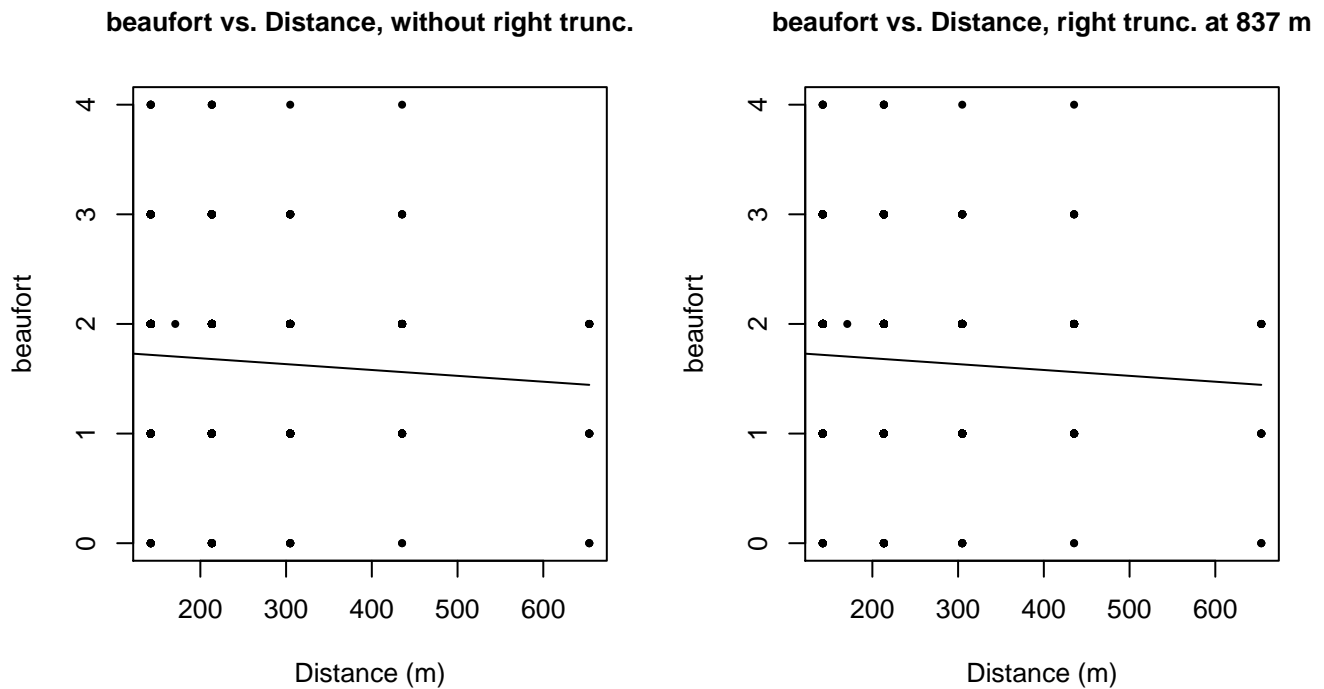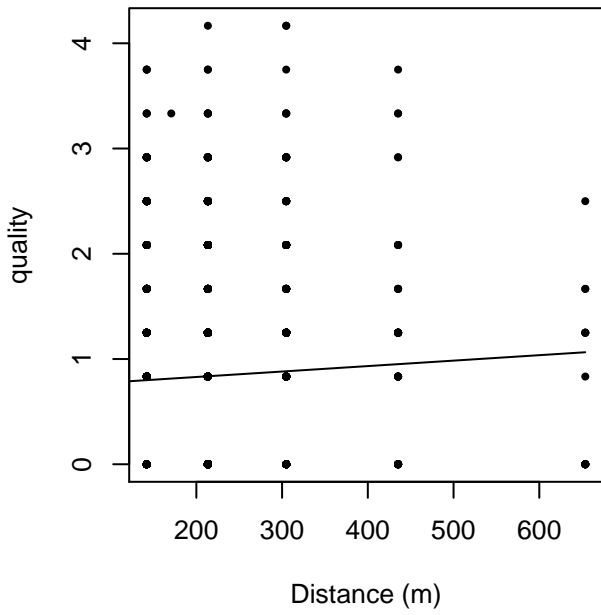


Figure 88: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
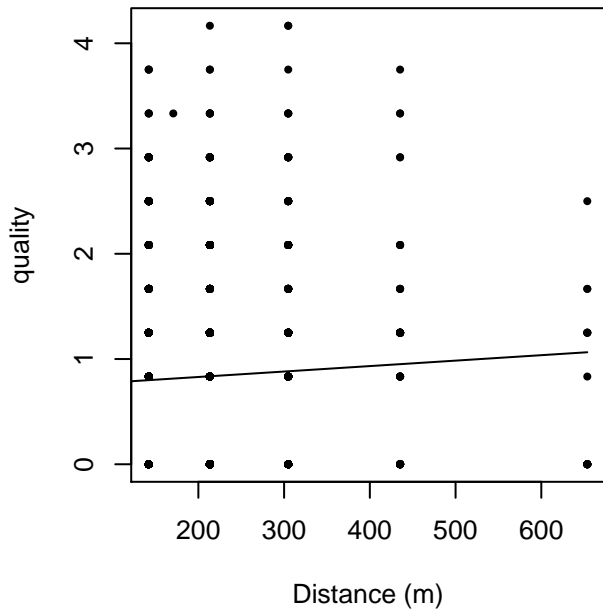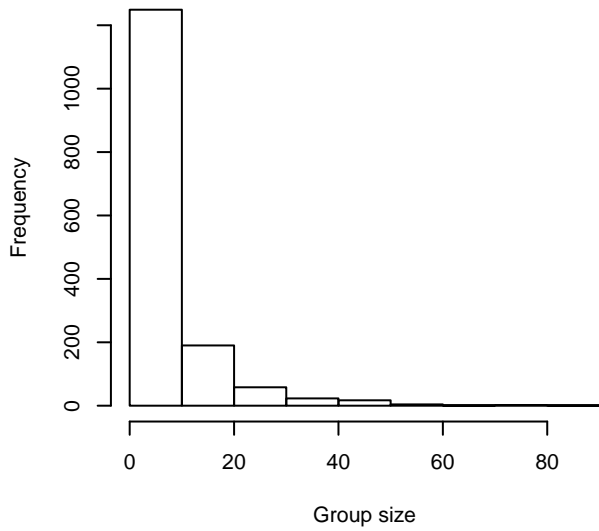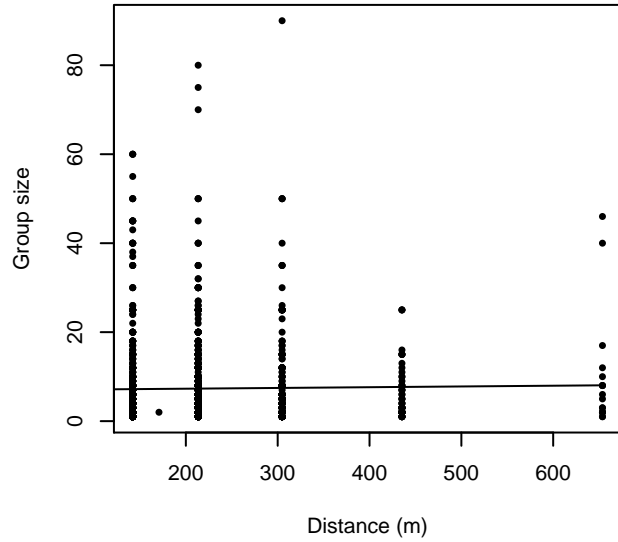
Figure 89: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
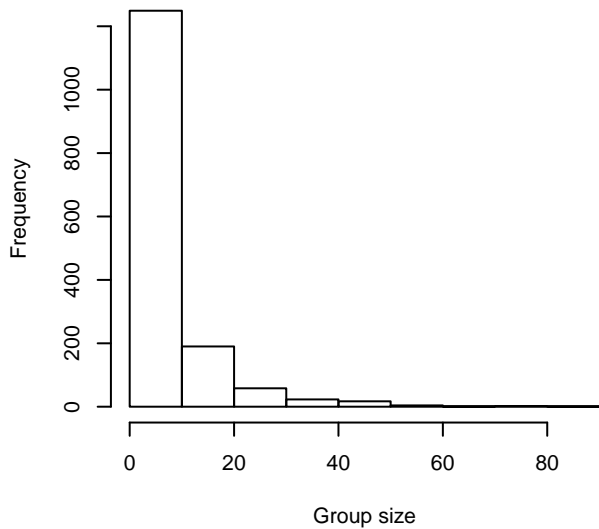
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 837 m**

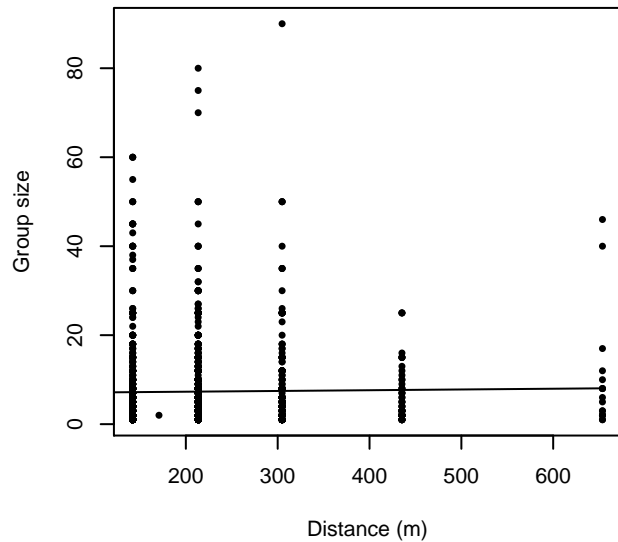**Group Size vs. Distance, right trunc. at 837 m**



Figure 90: 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 67: Proxy species used to fit detection functions for UNCW Early Surveys. The number of sightings, n, is before truncation.

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

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

Table 68: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 69: Candidate detection functions for UNCW Early Surveys. The first one listed was selected for the density model.
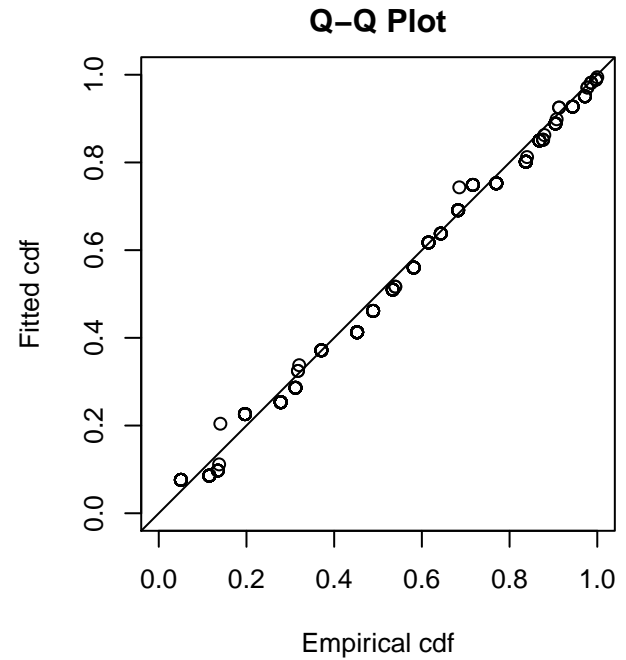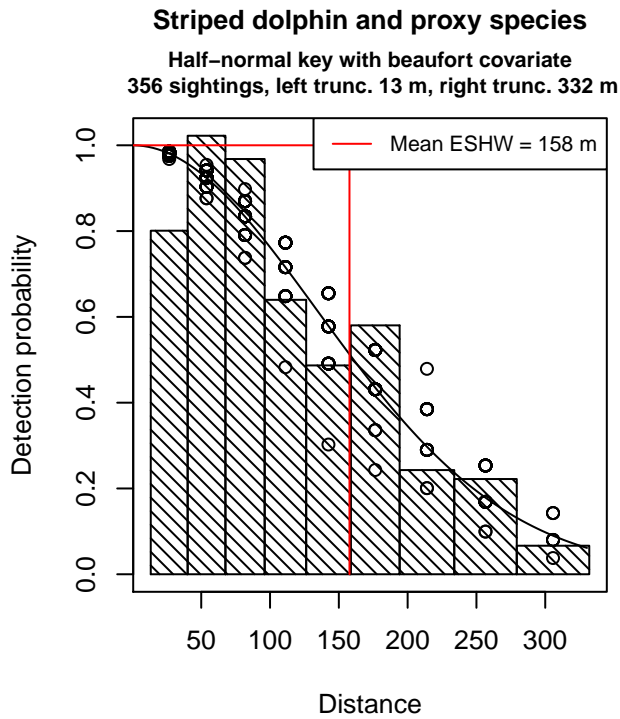
Figure 91: Detection function for UNCW Early Surveys that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Half-normal key function

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


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

Additional diagnostic plots:

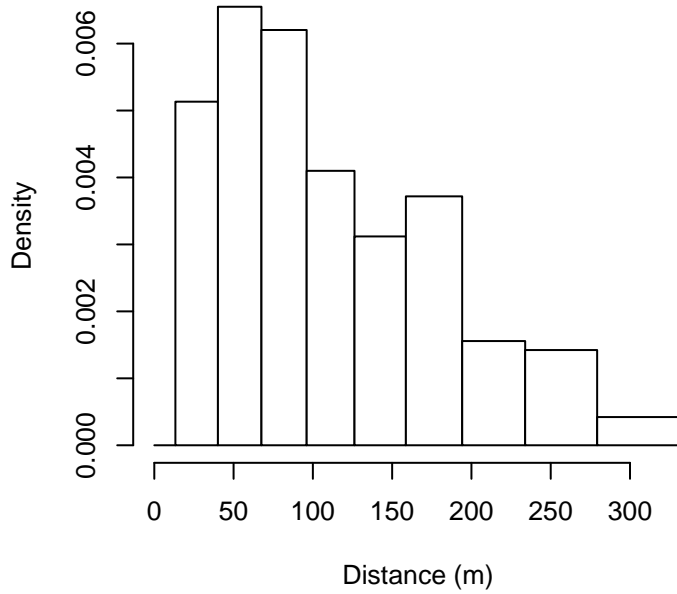**Left trucated sightings (in black)**



Figure 92: Density of sightings by perpendicular distance for UNCW Early Surveys. Black bars on the left show sightings that were left truncated.
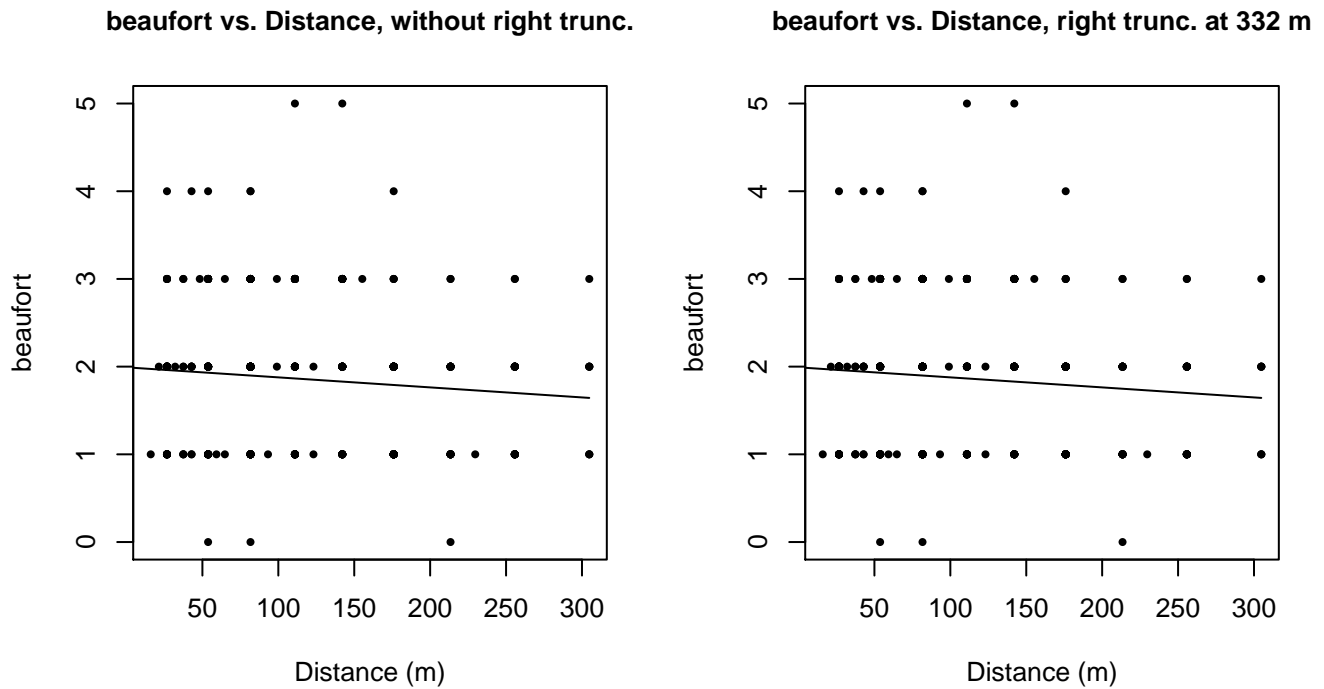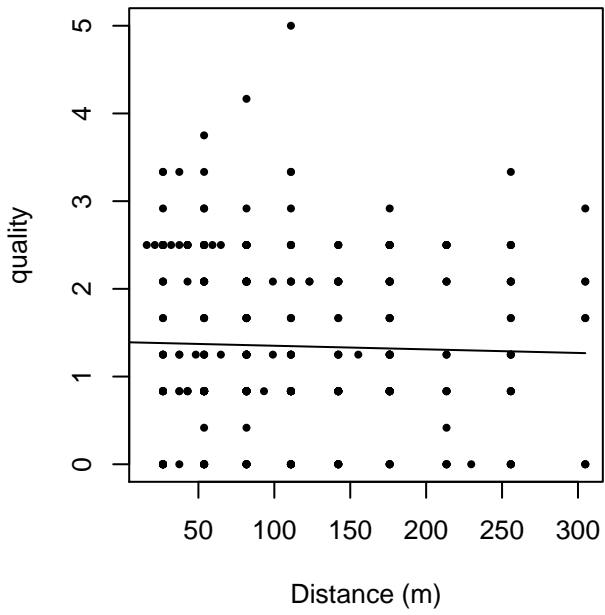


Figure 93: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.
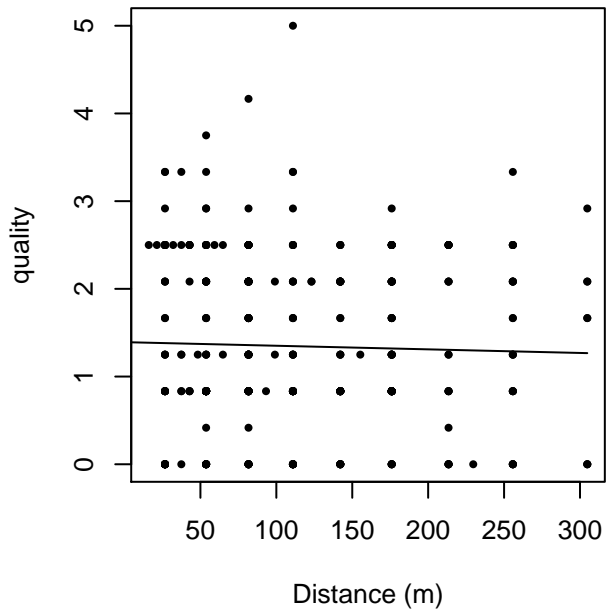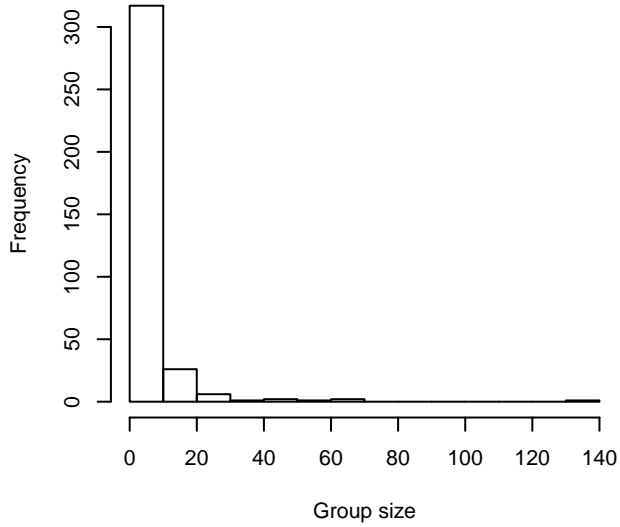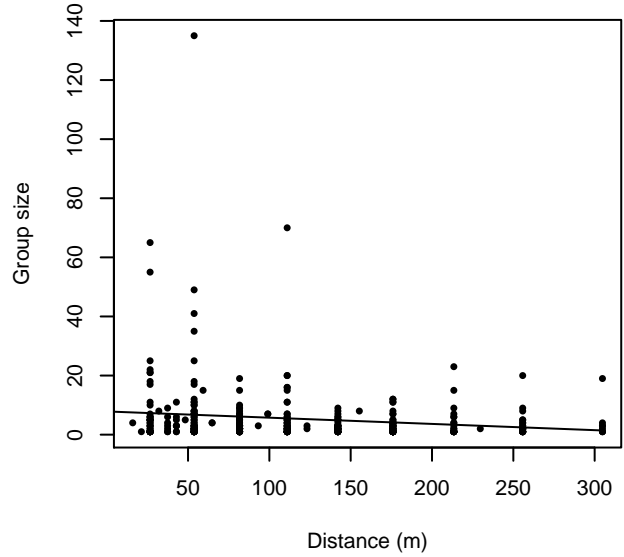
Figure 94: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
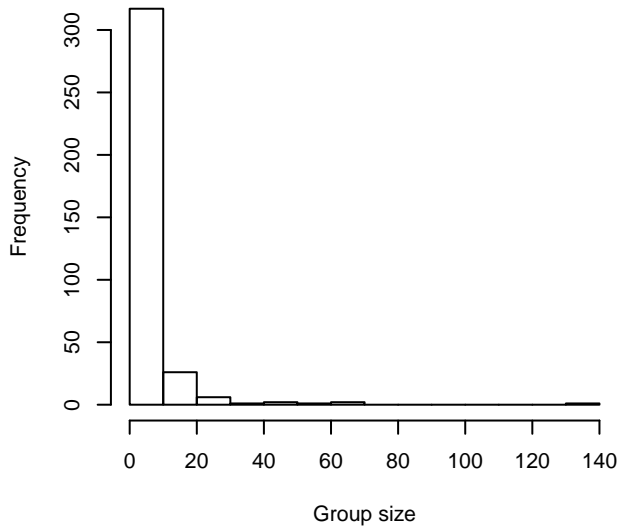
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 332 m**
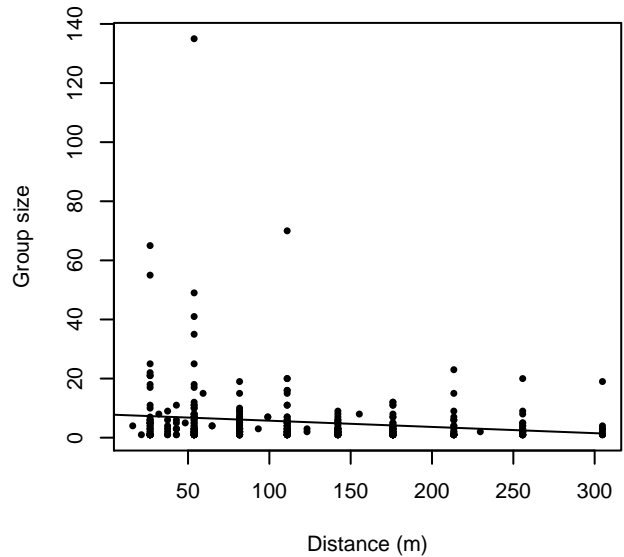
**Group Size vs. Distance, right trunc. at 332 m**

Figure 95: 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 |

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| | | |
|---|---|---|
| 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 70: 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 71: Covariates tested in candidate "multi-covariate distance sampling" (MCDS) detection functions.

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

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

Table 72: Candidate detection functions for Virginia Aquarium Surveys. The first one listed was selected for the density model.
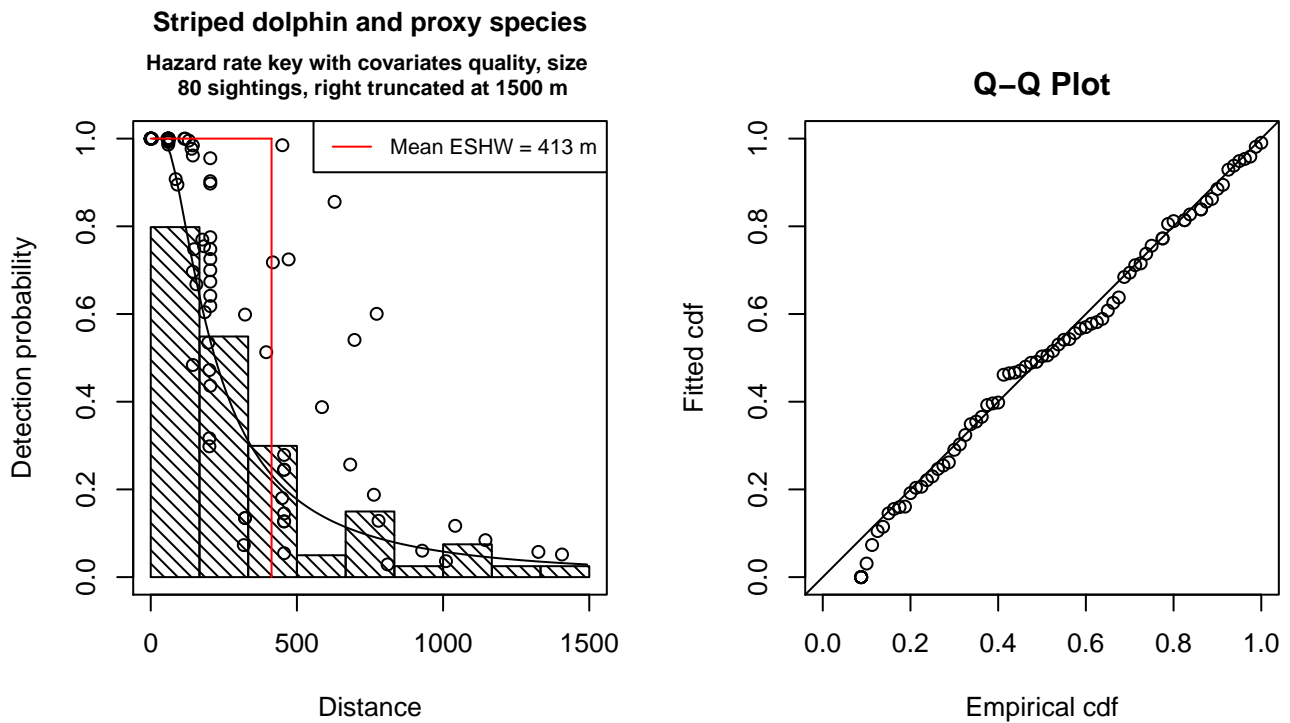


Figure 96: Detection function for Virginia Aquarium Surveys that was selected for the density model

Statistical output for this detection function:

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

Detection function:
 Hazard-rate key function

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

Shape parameters:
              estimate         se
(Intercept) 0.6332354 0.1825191


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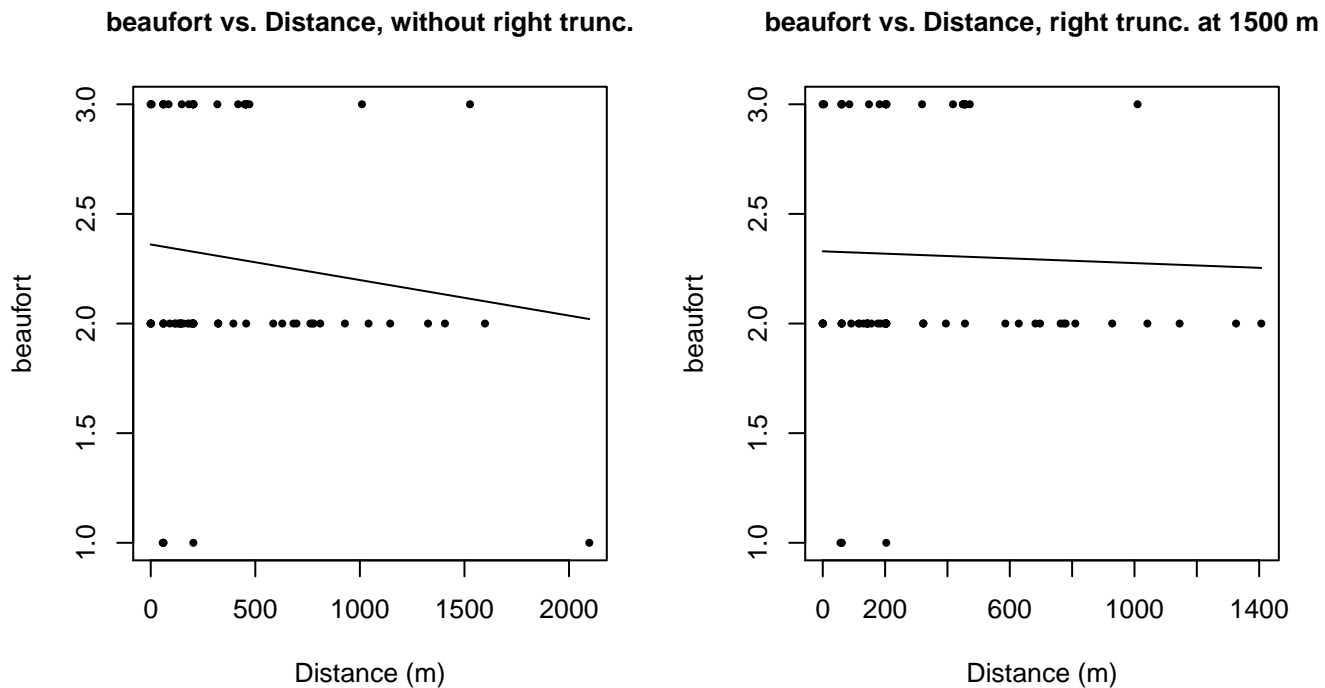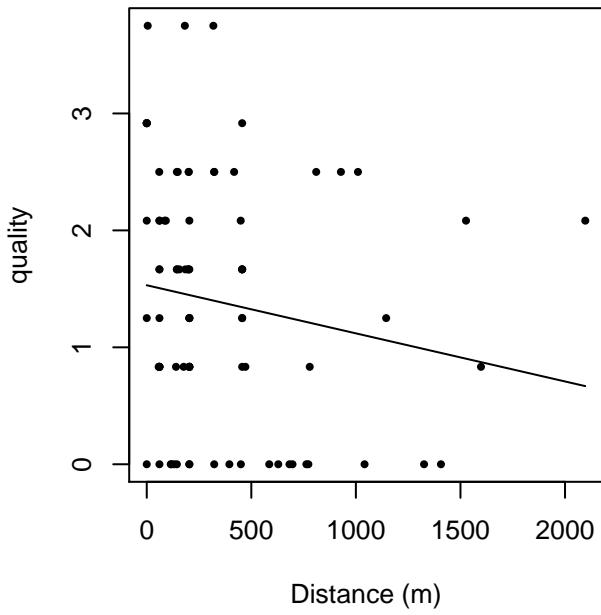
Additional diagnostic plots:



Figure 97: 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.
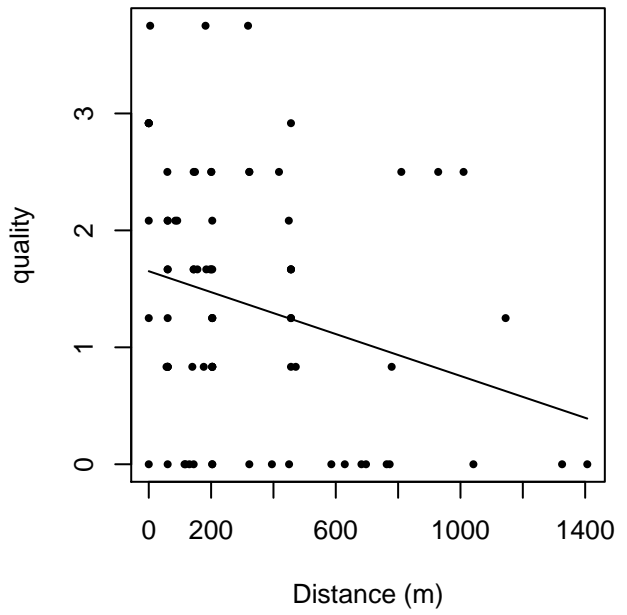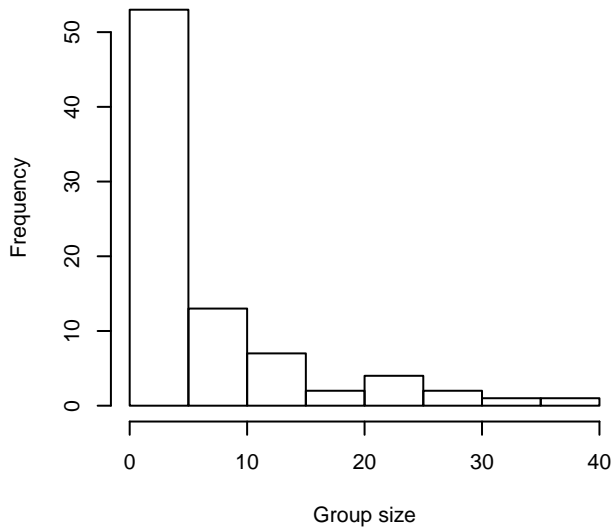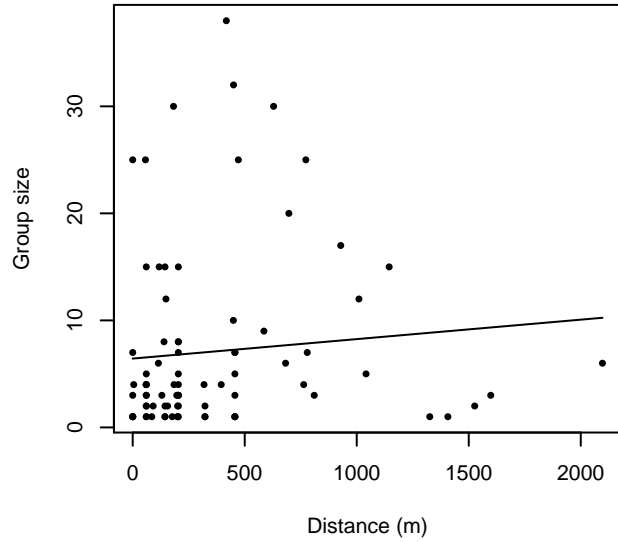
Figure 98: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
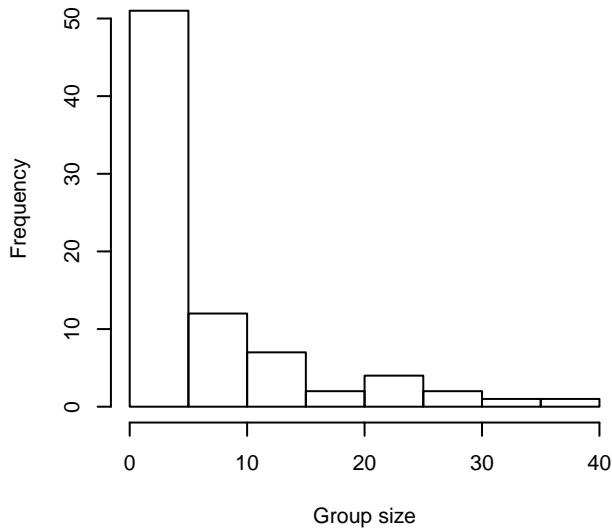
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

**Group Size Frequency, right trunc. at 1500 m**

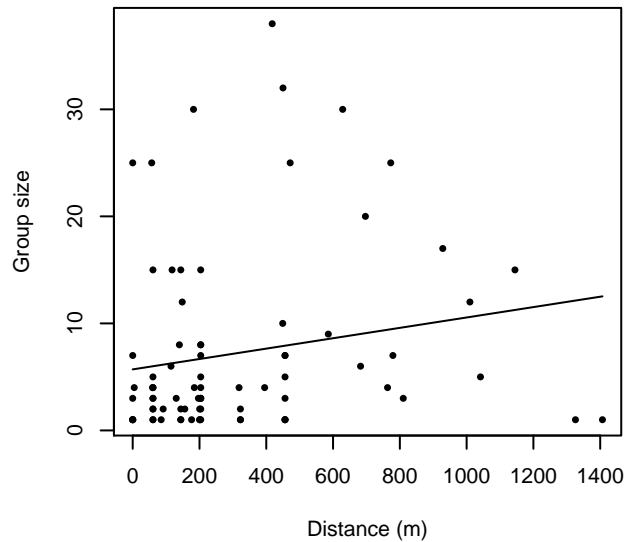**Group Size vs. Distance, right trunc. at 1500 m**

Figure 99: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

## NARWSS Grummans

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

| Reported By Observer | Common Name | n |
|---|---|---|
| Delphinus capensis | Long-beaked common dolphin | 0 |
| Delphinus delphis | Short-beaked common dolphin | 42 |

124

| | | |
|---|---|--:|
| 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 73: Proxy species used to fit detection functions for NARWSS Grummans. The number of sightings, n, is before truncation.

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

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

Table 74: 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 | cos | 3 | | Yes | 34.13 | 179 |
| hn | herm | 4 | | Yes | 35.13 | 222 |
| hn | cos | 2 | | No | | |
| hn | | | beaufort | No | | |
| hn | | | beaufort, quality | No | | |
| hr | | | beaufort, quality | No | | |
| hn | | | beaufort, quality, size | No | | |
| hr | | | beaufort, quality, size | No | | |

Table 75: Candidate detection functions for NARWSS Grummans. The first one listed was selected for the density model.
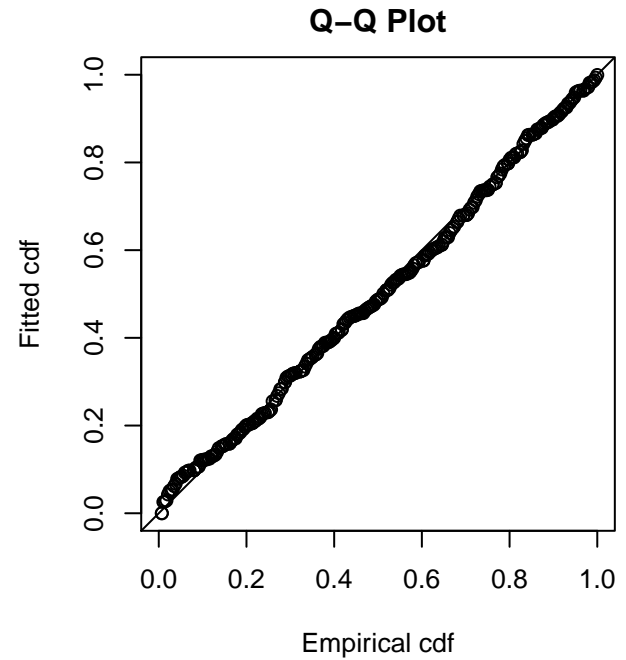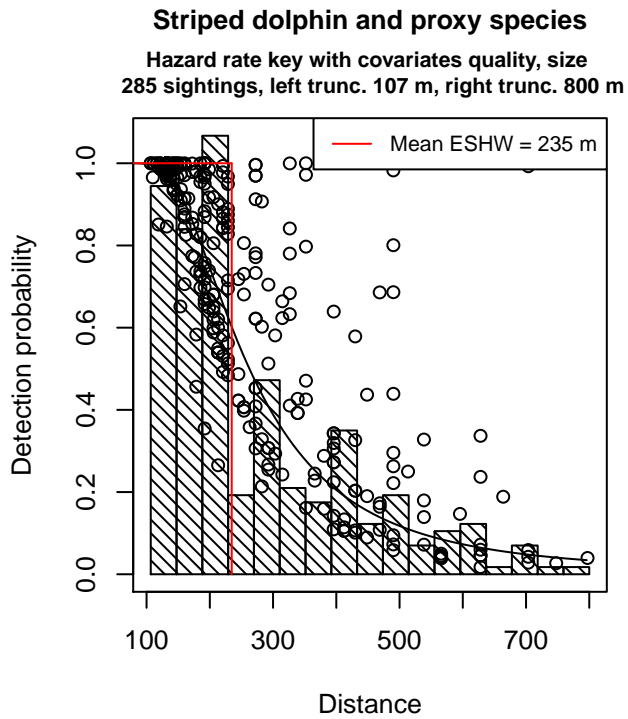
Figure 100: Detection function for NARWSS Grummans that was selected for the density model

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 trucated sightings (in black)**


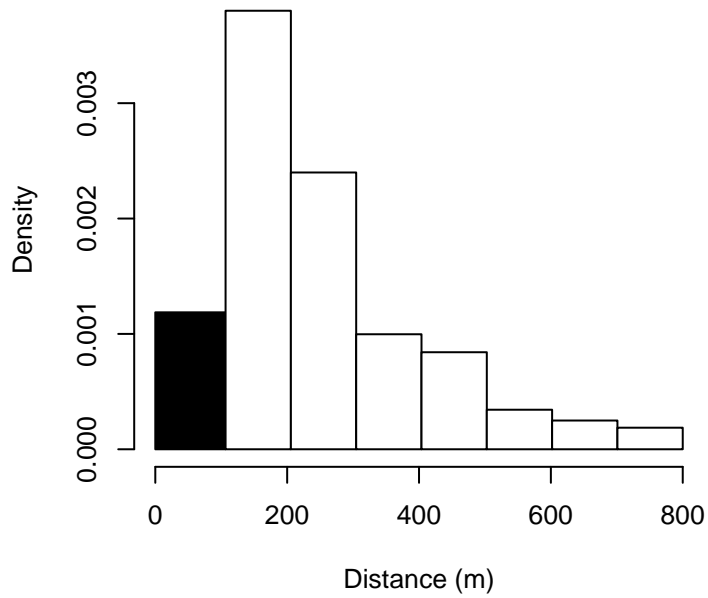
Figure 101: Density of sightings by perpendicular distance for NARWSS Grummans. Black bars on the left show sightings that were left truncated.

**beaufort vs. Distance, without right trunc.**          **beaufort vs. Distance, right trunc. at 800 m**
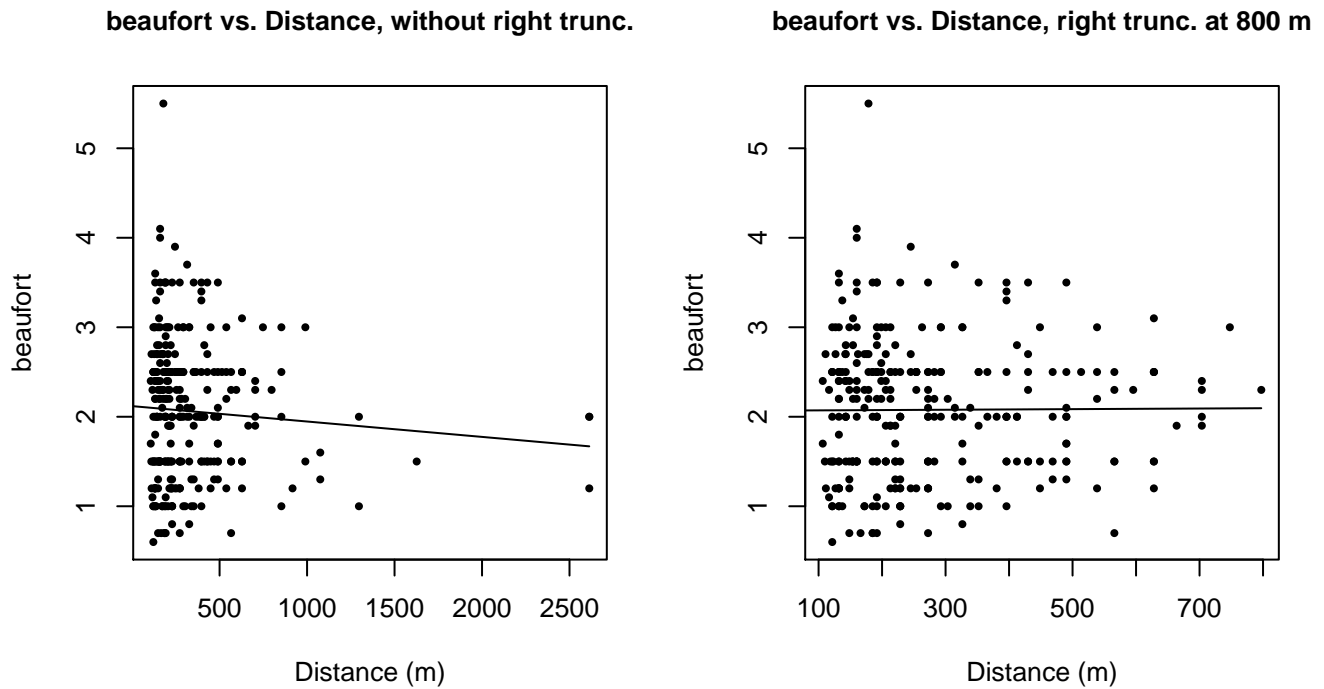


Figure 102: Scatterplots showing the relationship between Beaufort sea state and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). The line is a simple linear regression.

**quality vs. Distance, without right trunc.**
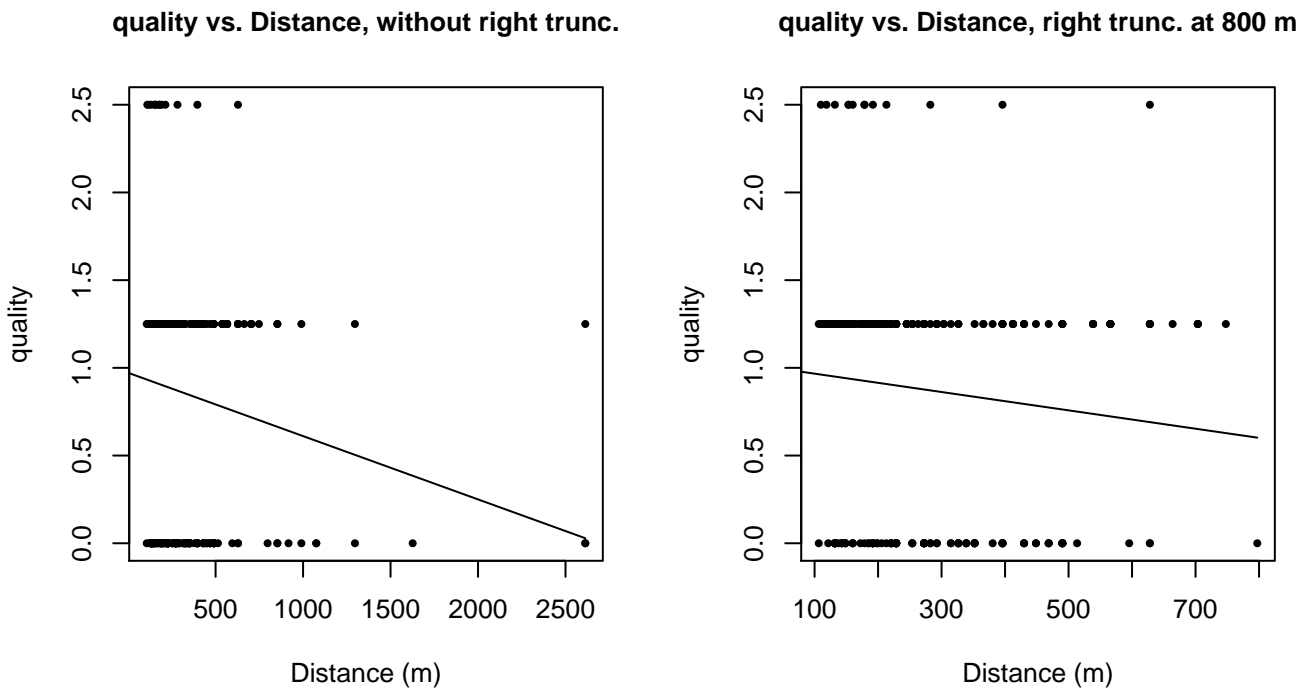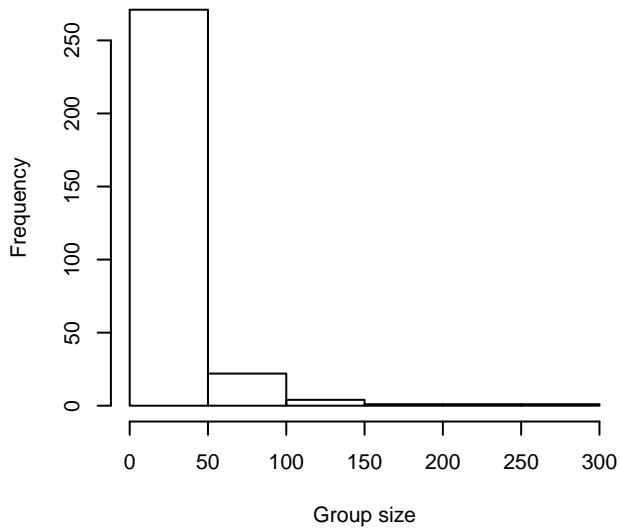
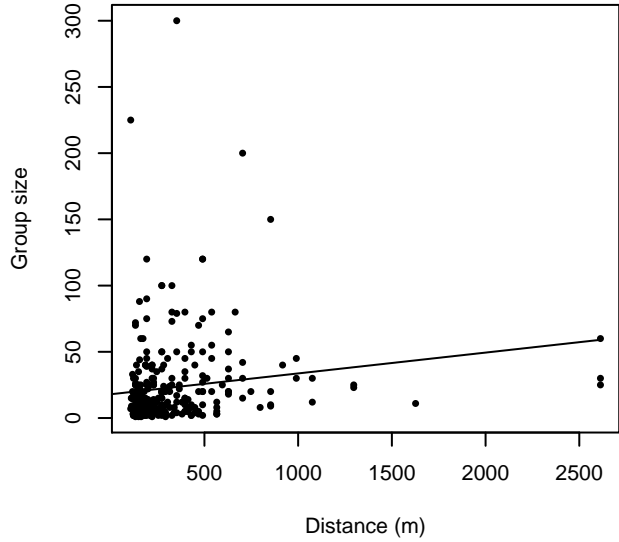**quality vs. Distance, right trunc. at 800 m**

Figure 103: 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.
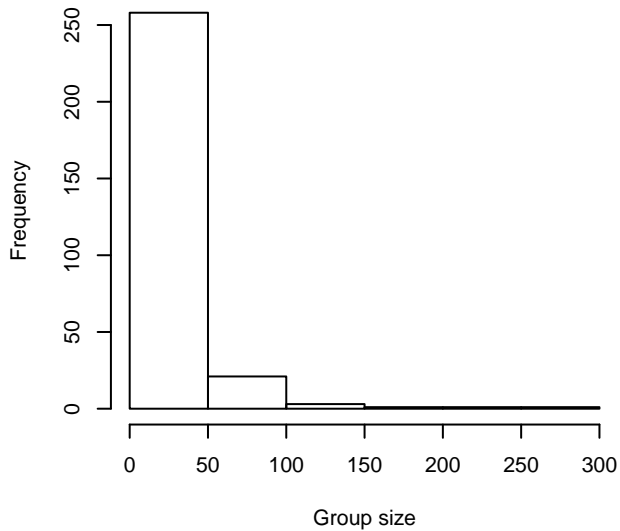
**Group Size Frequency, without right trunc.**

**Group Size vs. Distance, without right trunc.**

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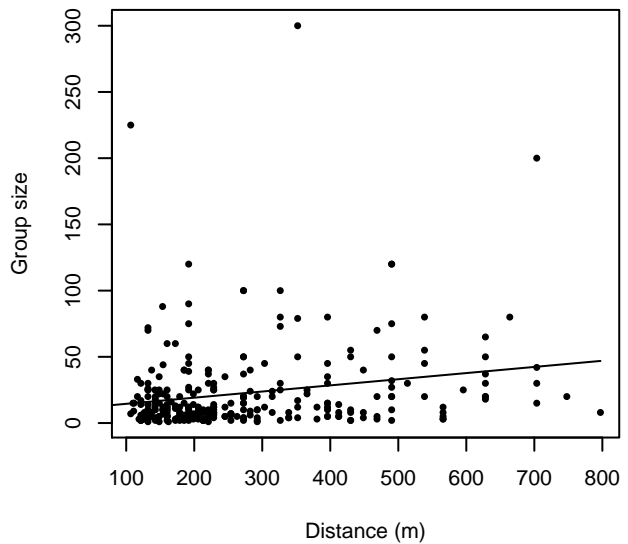
**Group Size vs. Distance, right trunc. at 800 m**

Figure 104: 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 76: 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 truncted as well. Sightings closer than 160 m to the trackline were omitted from the analysis, and it was assumed that the the area closer to the trackline than this was not surveyed. This distance was estimated by inspecting histograms of perpendicular sighting distances. The vertical sighting angles were heaped at 10 degree increments up to 80 degrees and 1 degree increments thereafter, so the candidate detection functions were fitted using linear bins scaled accordingly.

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

Table 77: 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 | 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 78: Candidate detection functions for NARWSS Twin Otters. The first one listed was selected for the density model.

**Striped dolphin and proxy species**

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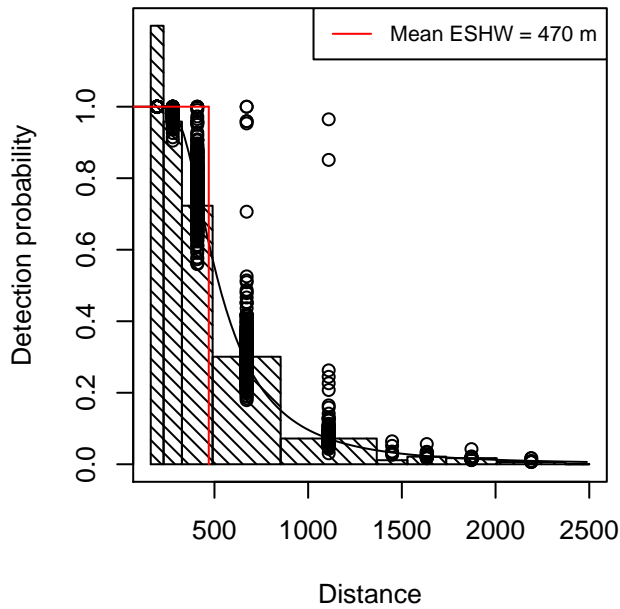
**Q–Q Plot**
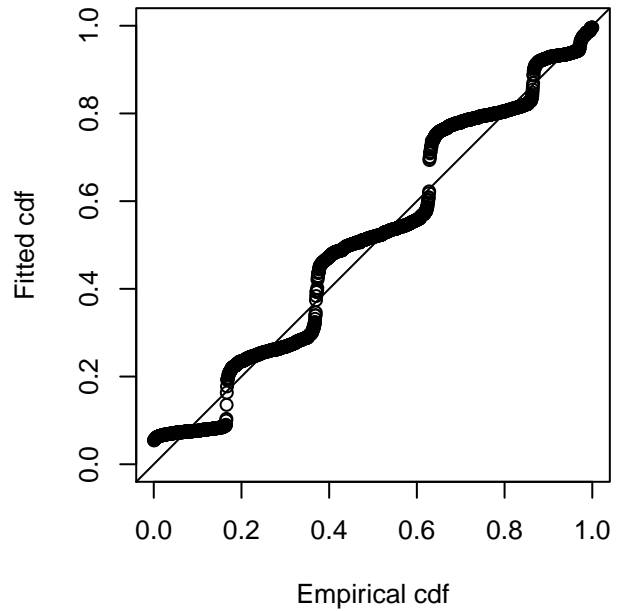


Figure 105: Detection function for NARWSS Twin Otters that was selected for the density model

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 trucated sightings (in black)**



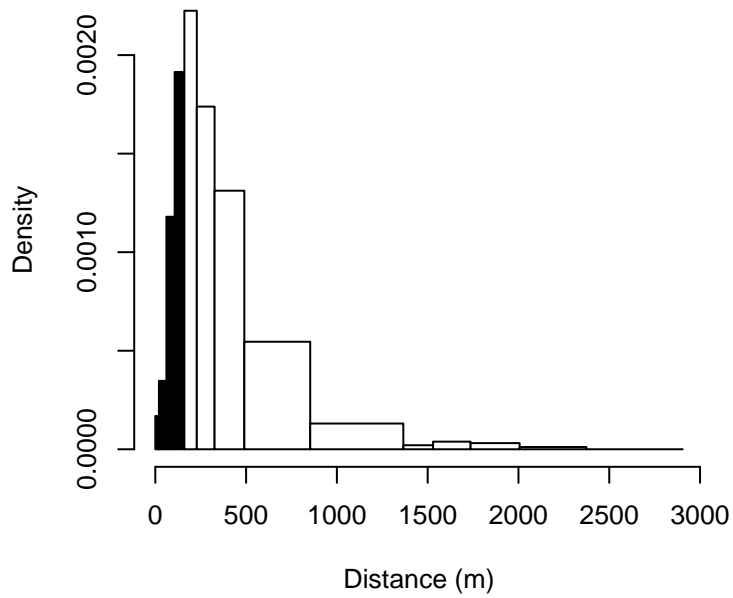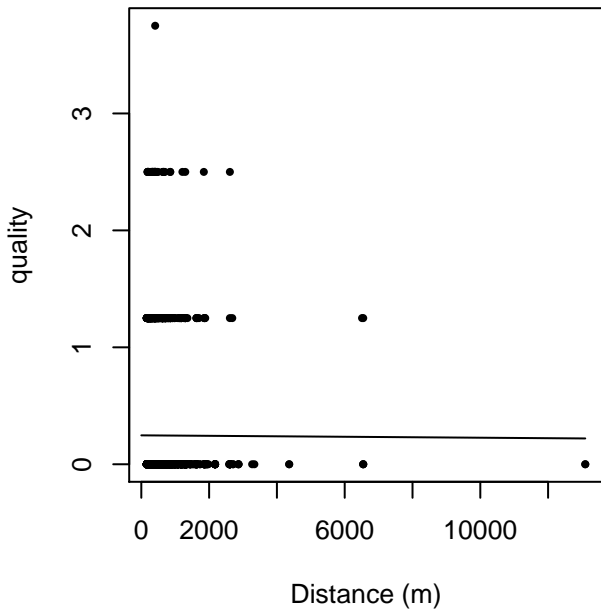Figure 106: Density of sightings by perpendicular distance for NARWSS Twin Otters. Black bars on the left show sightings that were left truncated.

**beaufort vs. Distance, without right trunc.**

**beaufort vs. Distance, right trunc. at 2500 m**



Figure 107: 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.
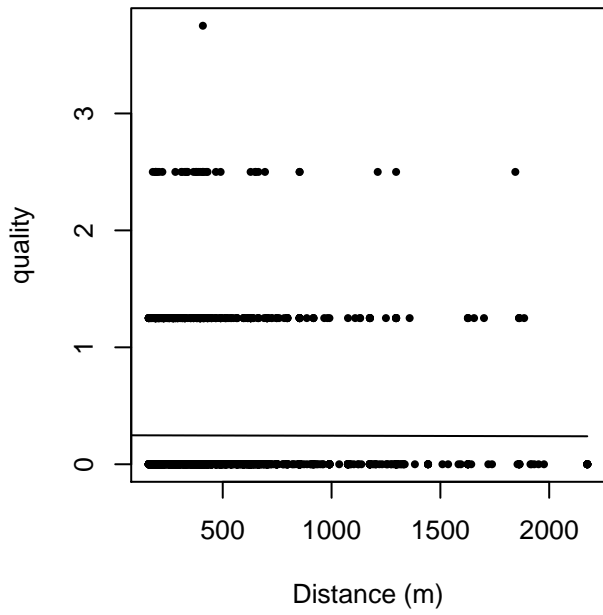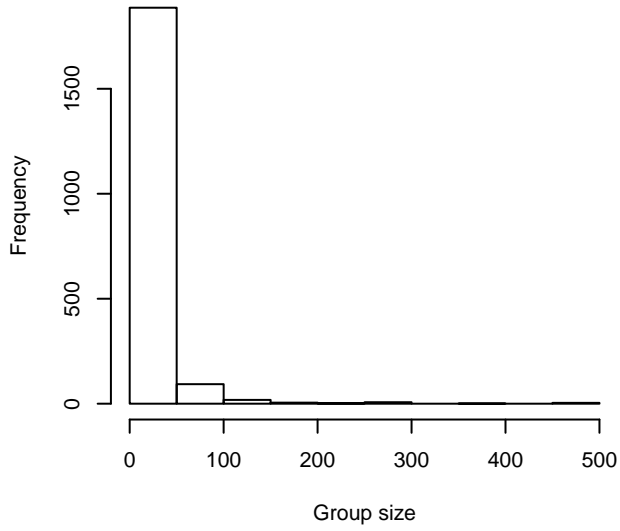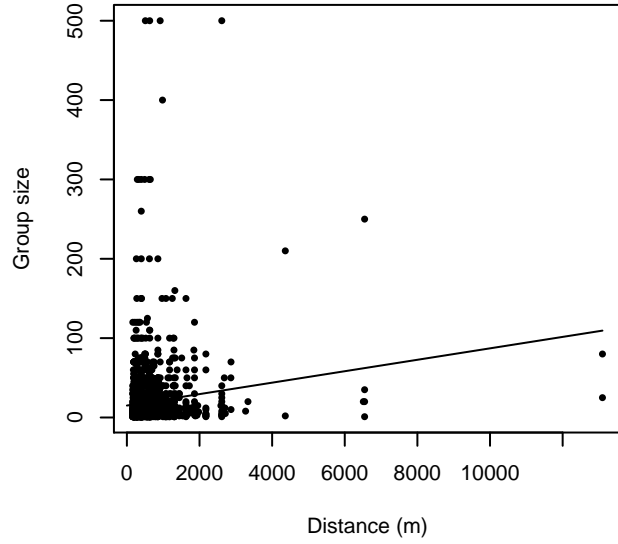
Figure 108: Scatterplots showing the relationship between the survey-specific index of the quality of observation conditions and perpendicular sighting distance, for all sightings (left) and only those not right truncated (right). Low values of the quality index correspond to better observation conditions. The line is a simple linear regression.
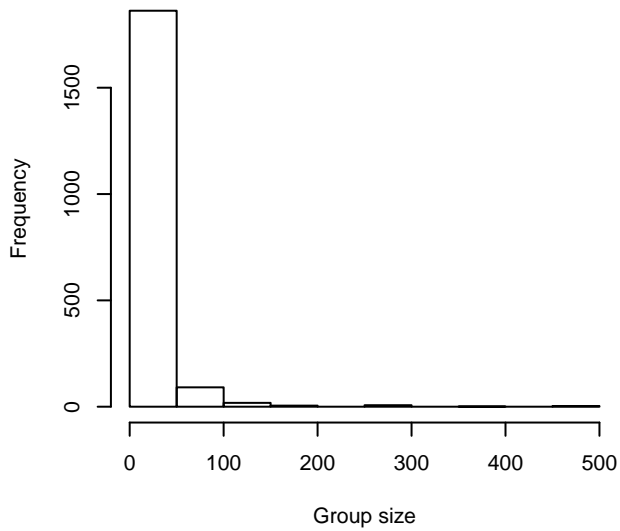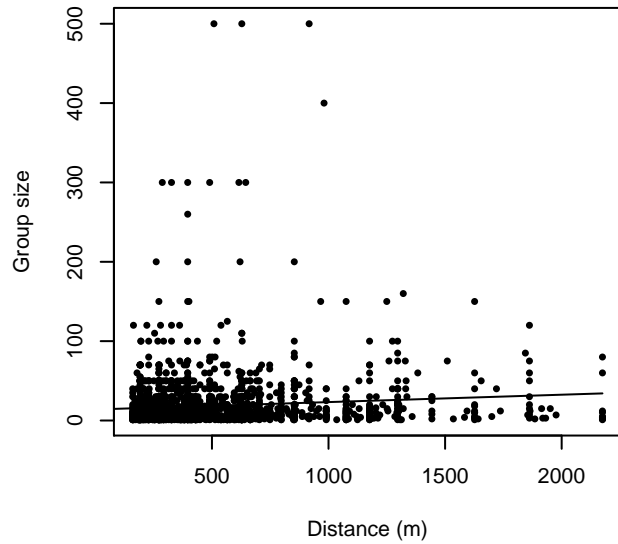
Figure 109: Histograms showing group size frequency and scatterplots showing the relationship between group size and perpendicular sighting distance, for all sightings (top row) and only those not right truncated (bottom row). In the scatterplot, the line is a simple linear regression.

## *g(0)* Estimates

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

Table 79: Estimates of *g(0)* used in this density model.

For shipboard surveys, we were unable to locate species-specific g(0) estimates in the literature. Instead, we utilized Barlow and Forney's (2007) estimates for delphinids, produced from several years of dual-team surveys that used bigeye binoculars and similar protocols to the surveys in our study. These estimates accounted for both availability and perception bias and 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. No sightings of the species modeled here were sighted by shipboard surveys, so the choice of g(0) has a negligible effect on the final abundance estimate.

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

Fraser's dolphin is a tropical species that is found world-wide on the high seas (Jefferson and Schiro 1997). In the Gulf of Mexico, where it has been argued that the species may be more common than anywhere else in the North Atlantic (Dolar 2009), NOAA only reported 5 sightings during the entire series of surveys from 1992-2009 utilized in our study. In the east coast study area, NOAA only reported 2 sightings. With insufficient sightings to model density using environmental predictors, we fitted a stratified model to off-shelf waters, defined here as those deeper than the 125m isobath, south of the Gulf Stream's north wall, identified in a long term climatology of ocean currents.
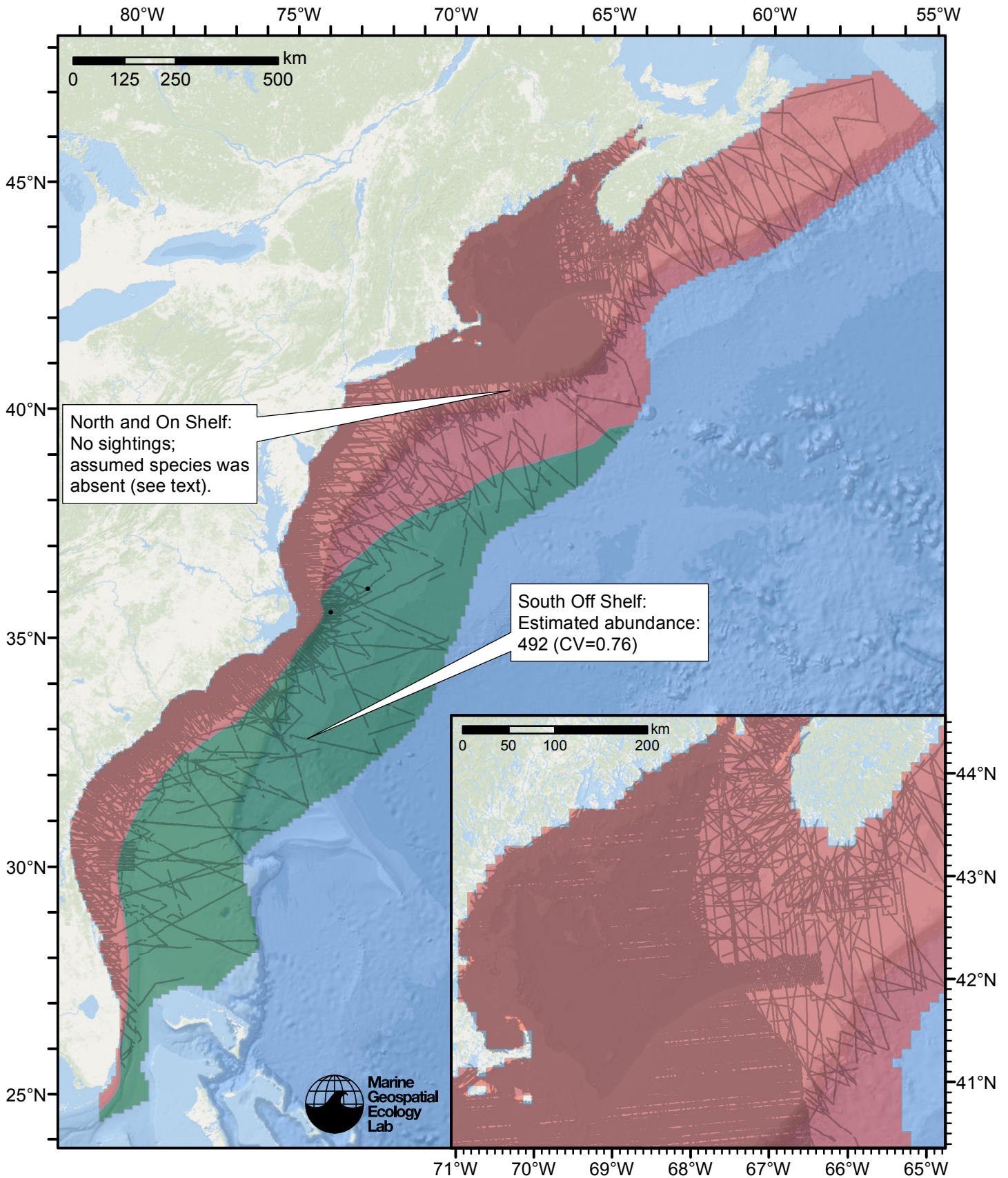
Figure 110: Fraser's dolphin density model schematic. All sightings are shown, including those that were truncated when detection functions were fitted. The coefficient of variation (CV) underestimates the true uncertainty of our estimate, as it only incorporated the uncertainty of the GAM stage of our 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.

# Discussion

At the time of this writing, NOAA had never produced an abundance estimate for Fraser's dolphin in the north Atlantic, nor could we locate one in the literature, so we have no basis with which to compare our estimate.

NOAA did produce a stock assessment report, most recently in 2007 (Waring et al. 2007). This report contains the statement "Abundance has not been estimated from the 1999 vessel survey in western North Atlantic because the sighting was not made during line-transect sampling effort". In the data that we received from NOAA, originally produced by NOAA for the Navy's NODE project (DON 2007b), this sighting was marked as "on effort", as best as we could determine, and we utilized it in our model here.

# References

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Palka DL (2006) Summer Abundance Estimates of Cetaceans in US North Atlantic Navy Operating Areas. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 06-03: 41 p.

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