# Estimates of the abundance of minke whales (*Balaenoptera acutorostrata*) from the T-NASS Icelandic and Faroese ship surveys conducted in 2007.

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**ABSTRACT**

The Trans North Atlantic Sightings Survey (T-NASS) and associated surveys covered a large area of the northern North Atlantic in a synoptic fashion summer 2007. Here we provide abundance estimates for minke whales from the Icelandic and Faroese components of the T-NASS ship surveys, uncorrected for visible whales that are missed by observers (perception bias) or whales that are missed because they are diving while the vessel passes (availability bias), and compatible with earlier published estimates for the area. The basic field methodology was according to the Buckland and Turnock (BT) mode. A total of 32 sightings of high to medium certainty minke whales were sighted by the dedicated vessels, and an additional 9 were sighted by the extension vessels. Abundance was estimated as 10,782 (95% CI 4,733 to 19,262) for entire survey area covered by the dedicated vessels. Adding effort and sightings from the extension vessels reduced this estimate by 32%, probably because of a lower *g(0)* on these vessels. Post-stratification to account for areas that were covered by pack ice at the time of the survey reduced the estimate by 5%. This estimate should be considered negatively biased by uncorrected perception and availability biases, and possibly also by movement of whales in response to the vessels. Unfortunately the double platform data collected are insufficient to correct for these biases. Furthermore the survey vessels were unable to cover the area off East Greenland, and area that had high densities of minke whales in previous surveys, because of unfavourable weather and ice conditions. This estimate should therefore be considered as a minimum for the survey area.

## INTRODUCTION

The Trans North Atlantic Sightings Survey (T-NASS) was conducted in June/July 2007 under the auspices of NAMMCO and covered a large area of the northern North Atlantic. Fin (*Balaenoptera physalus*), minke (*Balaenoptera acutorostra*) and pilot (*Globicephala melas*) whales were the main target species in all areas however all species were recorded using the same methodologies. To date abundance estimates have been produced for fin (Pike *et al.* 2008b) and humpback (*Megaptera novaengliae*) (Pike *et al.* 2009a,b) whales from the Central North Atlantic area (Icelandic and Faroese components) of the survey.

Previous abundance estimates for minke whales from the Icelandic and Faroese NASS ship surveys have been summarized by Pike *et al.* (2009c). These estimates were not corrected for visible whales that are missed by observers (perception bias) or whales that are missed because they are diving while the vessel passes (availability bias). Put another way, the probability of sighting a whale that was on the trackline (termed *g(0)*) was assumed to be 1. In addition, minke whales are known to avoid vessels in some areas, introducing another potential source of negative bias (Palka and Hammond 2001). All of these biases are potentially substantial for minke whale surveys but the field methodology used before 2001 did not support their estimation. The 2007 survey used one-way independent double platforms that should enable a correction for the perception bias on the primary platform if the number of sightings is sufficient and with the "tracker" methodology that should allow for the detection of responsive movement by the animals to the vessel. This methodology should also allow for a correction for availability if sufficient spatial separation between the viewing fields of the two platforms is achieved.

Paxton *et al.* (2009) provided mark-recapture distance sampling (MRDS) estimates for minke whales from the 2007 survey under a variety of assumptions about model type, responsive movement and bias in distance estimation, as well as inclusion or exclusion of different effort types. However these estimates varied greatly and were not accepted by the IWC Scientific Committee (IWC 2009) primarily because the limited duplicate sightings data between the two platforms might not support the MRDS methodology and the information in the paper was insufficient to assess fully the methodology used. The NAMMCO Scientific Committee Working Group on Abundance Estimates in October 2009 (NAMMCO 2010 in prep.) reiterated its request for a simple conventional distance sampling (CDS) estimate consistent with earlier estimates (Pike *et al.* 2009c).

Here we present abundance estimates for minke whales from the Icelandic and Faroese survey areas (Fig. 1). Combined platform estimates are provided using 2 degrees of certainty in species identification and for the designed and post-stratified blocks. In addition we examine the effect of including and excluding data from non-dedicated (extension) vessels within the primary survey area and discuss sighting rates of these vessels in the Norwegian Sea compared to Norwegian dedicated surveys there

## MATERIALS AND METHODS

### Survey design and field methodology

The survey design and field methods used in T-NASS are described elsewhere (Desportes and Halldórsson 2008, Mikkelsen 2008, Gunnlaugsson 2008, Víkingsson *et. al.*2008). The basic methodology was according to the Buckland and Turnock (BT) mode (Buckland and Turnock 1992). On all vessels, observers on the primary platform operated independently of the tracker platform, but made all sightings known to the duplicate identifier on the tracker platform where they were entered on special computer/digitalised forms. On the primary platform, the general practice was to spot animals with the naked eye, but binoculars were used for identifying animals at long ranges. Trackers in the upper platform scanned the trackline ahead to the horizon with binoculars for distant sightings and tracked them until they were observed (duplicated) by the primary platform or until they passed abeam. The purpose of the tracking procedure was to detect the proportion of sightings missed by the primary platform and to account for potential responsive movements. Special emphasis was put on tracking minke whales and dolphins, but sightings of all species were registered on both platforms.

The BT mode could not be maintained at all times due to equipment problems and poor weather, which precluded binocular use. Under such circumstances the vessels switched to “Combined” mode, during which 2-way communication was allowed between platforms, or single platform mode, in which only the primary platform was operational.

In addition to the primary survey vessels, 3 other vessels conducting fishery research in the area were utilized as platforms of opportunity during the survey. These vessels were each staffed with 2 whale observers who made and recorded sightings using methods identical to those used on the primary platforms of the dedicated survey vessels. Abundance was estimated both with and without the effort and sightings of these vessels within the primary survey area.

*Post-stratification*

Parts of the survey area off northwest Iceland and near East Greenland were covered in pack ice at the time of the survey and the survey vessels could not enter the ice. Post stratification was performed to account for this. In all strata, sighting effort was to continue up to the edge of pack ice, at which point an ice-edge protocol was followed. However, in block RN weather and sighting conditions were in most cases so poor when Greenland was approached that sighting effort was useless. The vessel VE surveyed north of Iceland and hit the ice edge or drift ice in several places but from ice maps it is clear that the vessel missed an ice bay (which it would have entered if it had traversed the track in reverse). The post stratified blocks can therefore not be taken simply by connecting the points where the ice edge was hit but are based on available ice maps through the survey period.

Abundance estimation was repeated using the revised stratum areas.

### Data treatment

*Species identity*

For many sightings there was uncertainty in species identification. Sightings were categorized according to the degree of certainty as High (BA), Medium (coded with one question mark BA?) and Low (coded with two question marks BA??). Two analyses were carried out to determine the sensitivity of the estimates to uncertainty in species identification: 1) High and Medium confidence minke whales (BA + BA?) “HIGH”, and; 2) High +

Medium+Low confidence minke whales (Case 1 + BA??) "LOW". The first analysis is probably most consistent with previous analyses of NASS minke whale data (Pike *et al.* 2009c) and rather conservative, while the second analysis would have an unknown, but probably positive bias.

*Data selection*

In cases of duplicate sightings between the tracker and primary platforms, distance measurements from the tracker platform were considered more reliable and therefore preferred.

*Beaufort sea state*

Beaufort sea state (BSS) was recorded on a modified scale including additional values for 0.5 and 2.5. Only data recorded in a BSS of less than 4 (*i.e.* up to 3.5) were used in the analyses. This resulted in 36% loss of dedicated survey effort but only 1 fewer minke whale sighting.

**Analysis**

Density and abundance were estimated using stratified line transect methods (Buckland *et al.* 2001) using the DISTANCE 6.0 (Thomas *et al.* 2009) software package. The perpendicular distance data were truncated such that about 10% of the greatest distances were discarded.

The Hazard Rate and Half Normal models for the detection function *f(x)* were initially considered, and the final model was chosen by minimisation of Akaike's information criterion (AIC) (Buckland *et al.* 2001). Covariates were considered for inclusion in the model to improve precision and reduce bias. Covariates were assumed to affect the scale rather than the shape of the detection function, and were incorporated into the detection function through the scale parameter in the key function (Thomas *et al.* 2009). Covariates were retained only if the resultant AIC value was lower than that for the model without the covariate. The following covariates were considered: BSS (as recorded, integers and in 2 and 3 level classifications); vessel identity (actual and with some vessels combined); weather code, and visibility (as recorded and as a 2 level classification). Bootstrap variance estimates were used with the detection function estimated at the stratum level when appropriate.

To determine if there was size bias in pod detectability, ln($s$) (pod size) was regressed against the estimated detection probability. If this regression was significant at the $P$<0.15 level, the detection of groups was considered to be size biased and the estimate of mean group size was adjusted using this regression.

## RESULTS

**Sightings and distribution**

Minke whale sightings by stratum are summarized in Table 1 and Fig. 1. As in most previous surveys (Pike *et al.* 2009c) minke whales were commonly sighted to the north of Iceland in block IN. Several were also sighted off the Faroe Islands. Few were sighted northwest of Iceland but there was little effort realized in the NW block. Unlike in previous surveys, few minke whales were sighted to the west of Iceland, especially close to East Greenland, however this is not surprising as little effort was realized there.

A total of 9 sightings of minke whales were made by the extension vessels in the planned survey area, all in block IN.

All minke whale sightings by the dedicated survey vessels were of single animals. The extension vessels sighted 4 groups of 3 whales and one group of 2 whales.

**Abundance estimates**

A truncation distance of 1,200 m was found to be suitable for both the HIGH and LOW datasets, with and without the data from the extension vessels. The distribution of perpendicular distances has a sharp peak within 200 m of the ship and declines sharply thereafter with a long tail. The half-normal model provided the best fit to all datasets (Fig. 2).

Tables 2 and 3 provide the stratified abundance estimates HIGH and LOW confidence cases for both the designed and post-stratified blocks. The half-normal model provided the best fit to the data in all cases. No covariates improved the fit of the models although some models failed to converge, probably because of the sparseness of the data.

The total estimate for the original survey area for the HIGH estimate was 10,782 (95% CI 4,733 to 19,262). The strata IN and FE together contained 81% of this estimate. Post stratification reduced this estimate slightly by

5%. Addition of the low certainty sightings (LOW estimate) increased the estimated abundance by 4%. to 11,193 (95% CI 5,007 to 18,815). Incorporation of the effort and sightings from the extension vessels reduced estimated abundance by 32%. Quantitatively similar comparisons can be made for the LOW estimate.

## DISCUSSION AND CONCLUSIONS

### Potential biases

*Coverage*

Poor weather and other factors conspired to reduce coverage of some areas that have had high densities of minke whales in previous surveys. Particularly the area off East Greenland received little coverage by the ship survey, primarily due to poor weather conditions combined with the presence of pack ice, in which the ships could not operate. This area had relatively high densities of minke whales in all 4 ship surveys up to and including 2001 (Pike *et al.* 2009c). Post-stratification to remove ice-covered areas from the survey area reduced estimated abundance by 5%, however it is likely that this did not address the main bias, as the area adjacent to the ice edge, which has had high densities of minke whales in the past, was poorly covered. It is therefore likely that the lack of coverage here results in a probably large negative bias in the estimate of abundance for the survey area.

*Species identification*

The identification of sightings as minke whales has been recorded with various levels of certainty in all previous surveys, but was less of a problem while direct closing mode was used. The magnitude of the difference in abundance estimates between the HIGH and LOW confidence estimates was only 4%, suggesting that species identification is not a serious problem with this species, at least for the dedicated survey vessels. We consider the HIGH estimates to be most comparable to previous estimates for this species (Pike *et al.* 2009c).

The extension vessels sighted 6 groups of 2 or 3 minke whales out of 9 sightings in total, while all sightings recorded by the dedicated vessels were of single animals. Similarly most sightings in previous ship and aerial surveys have been of single animals (Pike *et al.* 2008a, 2009c). While the reasons for this difference are unknown, it leads us to suspect the possibility of misidentification by the observers on the extension vessels, most probably mistaking northern bottlenose whales (*Hyperoodon ampullatus*), which do tend to occur in small groups, for minke whales. These species are similar in size and colouration and can be difficult to discriminate at sea.

*g(0) Correction*

We did not attempt to estimate and correct for the proportion of visible sightings that were missed by observers (perception bias), or the proportion of diving animals that were invisible and therefore not sighted (availability bias), as our remit was to present a CDS estimate for this species. Paxton *et al.* (2009) estimated *g(0)*, incorporating perception bias and some proportion of availability bias, as 0.95. However this was based on only 5 duplicate sightings between the tracker and primary platforms, which casts some doubt on the reliability of this estimate. Other studies (Schweder *et al.* 1997, Schweder 1999, Skaug *et al.* 2004, Pike *et al.* 2009c) have found these biases to be substantial for minke whale ship surveys. Nonetheless it does mean that our estimates are quite close to the equivalent estimates (*i.e.* those assuming point independence) by Paxton *et al*. (2009) since the *g(0)* correction was minimal. Paxton *et al.* (2009) estimated 10,900 (95% CI 6,600 to 30,000) under assumptions comparable to those used here for the HIGH estimate, but applying a small *g(0)* correction. Our estimates are somewhat more precise, however.

*Responsive movement and distance estimation errors*

Paxton *et al.* (2009) found that there was insufficient evidence to determine whether or not minke whales moved in response to the survey vessel. Paxton *et al.* (2009) found that abundance estimated under the assumption of full independence (which should correct for bias due to responsive movement if all relevant covariates are included) was nearly 3 times higher than that estimated under the assumption of point independence, suggesting substantial aversive movement. However, this difference seems excessive and may be due to the small size of the dataset. The field methodology used should allow for the detection of responsive movement but trackings of minke whales were rare and only 3 tracked minke whales came within 1000 meters of the vessel. Of these 1 showed possible attraction, another crossed the trackline and 1 is commented as laying on its right side, which can hardly be considered a typical sighting. Therefore the evidence for responsive movement is equivocal.

However aversive movement has been observed for this species (Palka and Hammond 2001). If minke whales tended to avoid the survey vessels, estimates uncorrected for this would be negatively biased

Detection of responsive movement may also be confounded by possible underestimation of distances by the primary platform, as observed for fin whales during this survey (Pike *et al.* 2008b). The number of duplicate sightings of minke whales is too small to determine whether the primary platform underestimated distances to minke whales by comparison to the tracker platform, but Paxton *et al.* (2009) tested the sensitivity of the abundance estimation to this and found that if there was a distance underestimation bias by the primary platform of 25%, this would only result in a 12% bias in the abundance estimate, because many of the distance estimates came from the tracker platform, which is assumed to be unbiased.

In addition to frequent equipment failures, which limited the ability of observers to track sightings and generate duplicate data in this survey, a problem with the implementation of the BT methodology in this survey was that trackers were instructed to stop tracking as soon as a sighting was duplicated, and not to confirm the distance and angle measurements and associated data of the primary platform when a sighting was duplicated, or of primary sightings that were not initially detected by the tracker platform. If responsive movement is suspected to be significant then tracking should continue until the sighting passes abeam of the vessel and the trackers should confirm primary platform sightings for better distance and angle estimation and to enable detection of distance estimation bias.

*Ice cover and post-stratification*

In 2007 the pack ice edge approached quite closely to northeast Iceland, and much of the aerial survey block in this area was covered by ice (Pike *et al.* 2008a). The survey vessels could not enter the ice, and instigated an ice edge protocol in cases when the ice edge was reached before the end of a transect. Post-stratification in this case involved adjusting the western edges of strata IN, NW, RN and RS using satellite data on ice extent at the time of the survey. This resulted in a minor (2%) reduction in survey area and a consequent reduction in estimated abundance of 5%. Minke whales are known to enter the ice and are hunted annually in the coastal waters of East Greenland (Helms *et al.* 1997), but it is not known if they occur in high densities within the ice pack. The concurrent aerial survey spent several hours flying over pack ice off northwest Iceland, and saw no cetaceans of any species (Pike *et al.* 2008a). If minke whales do enter the pack ice in this area, abundance will be underestimated.

**Inclusion of extension vessel effort and sightings**

Although the extension vessels added effort and sightings to the survey area, the inclusion of this effort resulted in a substantial decrease in estimated abundance. Encounter rates were lower for the extension vessels than for the dedicated vessels in the same strata. The extension vessels had only 2 observers on effort compared to 5-6 on effort on each shift on the dedicated vessels; therefore the observing “power” of the extension vessels was considerably lower. In addition the sighting distances to minke whales seen by the extension vessels were on average greater than the distances to those seen from the dedicated vessels. As a result the additional sightings and effort reduced estimated abundance by 32%. The net effect of the addition of the extension vessel effort would seem to be a general dilution of the encounter rate for relatively few additional sightings. Given the low number of sightings made by these vessels, and the difference in mean group size between the dedicated and extension vessels, a comparison of sighting rates in overlap areas is unlikely to produce a useful estimate of *g(0)* for the extension vessels.

In 2008 the NAMMCO Working Group on Abundance Estimates discussed at length possible explanations for the decrease in minke whale abundance as observed in the Icelandic coastal area. This decrease did not seem to be compensated by an apparent increase in abundance in other surveyed areas, however large areas that had high minke whale densities in previous surveys were not covered in 2007. The Group recommended the analysis of the T-NASS Extension minke whale data in the Norwegian Sea, an area which was not covered by the dedicated survey, and a comparison of sighting rates to earlier surveys in that area.

The Norwegian Sea was most recently surveyed as part of the Norwegian survey program between 2002-2007 (Bøthun *et al.* 2009). In the Small Area EW, which roughly corresponds to the Norwegian Sea, a total of 314 sightings of minke whales were recorded, for an encounter rate of 0.0512 whales per nautical mile. The extension vessels made 14 sightings of minke whales (BA + BA?) in the area defined as the Norwegian Sea by the International Hydrographic Organization (http://www.iho.org/), with an encounter rate of 0.0083 whales per nautical mile. This is lower than the encounter rate of the Norwegian dedicated survey vessels by nearly an order of magnitude. While Bøthun *et al.* (2009) do not provide information to enable a statistical comparison, the magnitude of the difference suggests that it is significant. It seems likely that the extension vessels had a much lower *g(0)* than the dedicated vessels due to their lower platforms and the fact that they carried only 2 cetacean observers, as opposed to 4 per shift on the dedicated vessels. In addition, the extension vessels covered the area a few weeks later in the season than the dedicated vessels, which may have contributed to the difference.

Clearly the data from the extension vessels provide no evidence to suggest higher than usual densities in the Norwegian Sea during the period of the survey. The intent of placing cetacean observers on the extension vessels was to extend the survey to areas that otherwise would not be covered. While this may prove of value in providing information on distribution and relative abundance of the different species and for spatial modelling, in particular if this becomes a standard in these surveys, it appears that these data may be of limited use for estimating absolute abundance.

**Comparison to previous estimates**

Pike *et al*. (2009c) provide regional abundance estimates for minke whales from surveys conducted in roughly the same area as this in 1987, 1989, 1995 and 2001. Surveys up to and including that in 1995 used single platforms only while the 2001 survey used a double platform mode similar to that used in 2007. Abundance outside the aerial survey block was between 12,000 and 14,000 from 1987 to 1995, but was substantially higher at 26,000 in 2001. There was no significant trend in any region over the period however. Pike *et al.* (2009c) attributed the higher numbers seen in 2001 partly to differences in survey methodology which resulted in greater observing power (*i.e.* higher *g(0)*) in that year. Our LOW estimate using the original strata of 11,193 (95% CI 5,007 to 18,815) is the one most comparable to these earlier estimates, but the poor coverage realized in the western part of the area near the East Greenland ice edge, areas that had high density in earlier surveys, probably means that this estimate is substantially negatively biased compared with the others. However we consider all the estimates to be substantially negatively biased due to uncorrected biases due to perception, availability and responsive movement, which we believe would outweigh any possible positive bias due to distance underestimation. The HIGH estimate of 10,782 (95% CI 4,733 to 19,262) might be preferred where utmost precaution is requested, although this estimate is less precise.

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| BLOCK | AREA (nm²) | AREAP (nm²) | EFF4DED (nm) | EFF4NDED (nm) | K D | K ND | BA D | BA ND | BA? D | BA? ND | BA?? D | BA?? ND | ALL D | ALL ND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE | 61,866 | 61,866 | 280 | 211 | 5 | 4 | 7 | 0 | 0 | 0 | 0 | 0 | **7** | **0** |
| FS | 79,996 | 79,996 | 647 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | **2** | **0** |
| FX | 57,775 | 57,775 | 48 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** |
| IC | | | 106 | 44 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | **1** | **0** |
| IN | 95,767 | 91,873 | 499 | 318 | 5 | 10 | 12 | 8 | 4 | 1 | 2 | 0 | **18** | **9** |
| NW | 21,700 | 17,237 | 126 | 0 | 4 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | **3** | **0** |
| RN | 132,109 | 123,981 | 1,129 | 308 | 6 | 9 | 2 | 0 | 1 | 0 | 3 | 0 | **6** | **0** |
| RS | 92,464 | 91,577 | 380 | 178 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0** |
| SC | 207,217 | 207,217 | 1,405 | 61 | 10 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | **1** | **0** |
| **TOT-F** | **199,897** | **199,637** | **974** | **211** | **10** | **4** | **9** | **0** | **0** | **0** | **0** | **0** | **9** | **0** |
| **TOT-I** | **548,746** | **531,885** | **3,645** | **908** | **30** | **25** | **16** | **8** | **7** | **1** | **6** | **0** | **29** | **9** |
| **TOT** | **748,643** | **731,522** | **4,619** | **1,119** | **40** | **29** | **25** | **8** | **7** | **1** | **6** | **0** | **38** | **9** |

Table 1. Survey effort and sightings by stratum. IC is unplanned effort within the aerial survey area within 100 nm of Iceland and is not included in the estimates of abundance. Totals are given for the Faroese (F), Icelandic (I) and entire areas. $AREA_P$ – stratum area, post-stratified; EFF4DED – effort conducted at BSS<4 by dedicated survey vessels; EFFNDED – effort conducted at BSS<4 by extension vessels; K – number of transects.

| Block | n | *n/L* | cv | *E(S)* | cv | *esw* | *f(0)* | cv | *D* | *N* | cv | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE | 7 | 2.235E-02 | 0.41 | | | | | | 0.0462 | 2,860 | 0.44 | 0 | 4,883 |
| FS | 2 | 3.077E-03 | 0.43 | | | | | | 0.0068 | 541 | 0.53 | 0 | 1,162 |
| FX | 0 | | | | | | | | | | | | |
| IC | 1 | 8.235E-03 | 0.65 | | | | | | | | | | |
| IN | 14 | 2.776E-02 | 0.40 | | | | | | 0.0611 | 5,847 | 0.50 | 1,879 | 12,497 |
| $IN_P$ | 14 | 2.743E-02 | 0.36 | 1 | 0 | 449 | 2.318E-03 | 0.25 | 0.0610 | 5,605 | 0.50 | 1,786 | 11,807 |
| NW | 2 | 1.538E-02 | 0.76 | | | | | | 0.0339 | 735 | 0.82 | 0 | 2,001 |
| $NW_P$ | 2 | 1.434E-02 | 0.79 | | | | | | 0.0319 | 550 | 0.86 | 0 | 1,577 |
| RN | 3 | 2.773E-03 | 0.51 | | | | | | 0.0061 | 800 | 0.62 | 164 | 2,022 |
| $RN_P$ | 3 | 2.777E-03 | 0.48 | | | | | | 0.0615 | 763 | 0.61 | 156 | 1,813 |
| RS | 0 | | | | | | | | | | | | |
| SC | 0 | | | | | | | | | | | | |
| **$TOTAL_P$** | **29** | | | | | | | | **0.0140** | **10,271** | **0.36** | **4,596** | **18,037** |
| **TOTAL** | **29** | | | | | | | | **0.0144** | **10,782** | **0.36** | **4,733** | **19,262** |

Table 2. Estimated density and abundance of minke whales identified with HIGH confidence from the combined platforms. . *n*- number of sightings; *L* – effort (nm); *E(S)*-group size; esw – effective search width (m); *f(0)* – probability density of the detection function at distance 0; *D*- density of animals (no. per $nm^2$); *N*- abundance; LCI and UCI – upper and lower 95% confidence limits.

| Block | n | *n/L* | cv | *E(S)* | cv | *esw* | *f(0)* | cv | *D* | *N* | cv | LCI | UCI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FE | 7 | 2.209E-02 | 0.42 | | | | | | 0.0423 | 2,618 | 0.46 | 0 | 4,658 |
| FS | 2 | 2.990E-03 | 0.44 | | | | | | 0.0060 | 478 | 0.53 | 0 | 1,011 |
| FX | 0 | | | | | | | | | | | | |
| IC | 1 | 8.120E-03 | 0.65 | | | | | | | | | | |
| IN | 16 | 3.146E-02 | 0.28 | | | | | | 0.0634 | 6,069 | 0.43 | 2,315 | 11,812 |
| $IN_P$ | 16 | 3.117E-02 | 0.26 | 1 | 0 | 487 | 0.0021 | 0.23 | 0.0623 | 5,726 | 0.42 | 2,266 | 11,164 |
| NW | 2 | 1.416E-02 | 0.83 | | | | | | 0.0288 | 625 | 0.89 | 0 | 1,814 |
| $NW_P$ | 2 | 1.442E-02 | 0.80 | | | | | | 0.0289 | 499 | 0.85 | 0 | 1,344 |
| RN | 4 | 3.777E-03 | 0.44 | | | | | | 0.0076 | 1,005 | 0.55 | 293 | 2,289 |
| $RN_P$ | 4 | 3.755E-03 | 0.46 | | | | | | 0.0075 | 924 | 0.55 | 249 | 2,135 |
| RS | 0 | | | | | | | | | | | | |
| SC | 1 | 7.430E-04 | 1.01 | | | | | | 0.0014 | 290 | 1.01 | 0 | 1,045 |
| **$TOTAL_P$** | **33** | | | | | | | | **0.0144** | **10,536** | **0.32** | **4,946** | **17,979** |
| **TOTAL** | **33** | | | | | | | | **0.0149** | **11,193** | **0.33** | **5,007** | **18,815** |

Table 3. Estimated density and abundance of minke whales identified with LOW confidence from the combined platforms. See Table 2 for variable definitions.

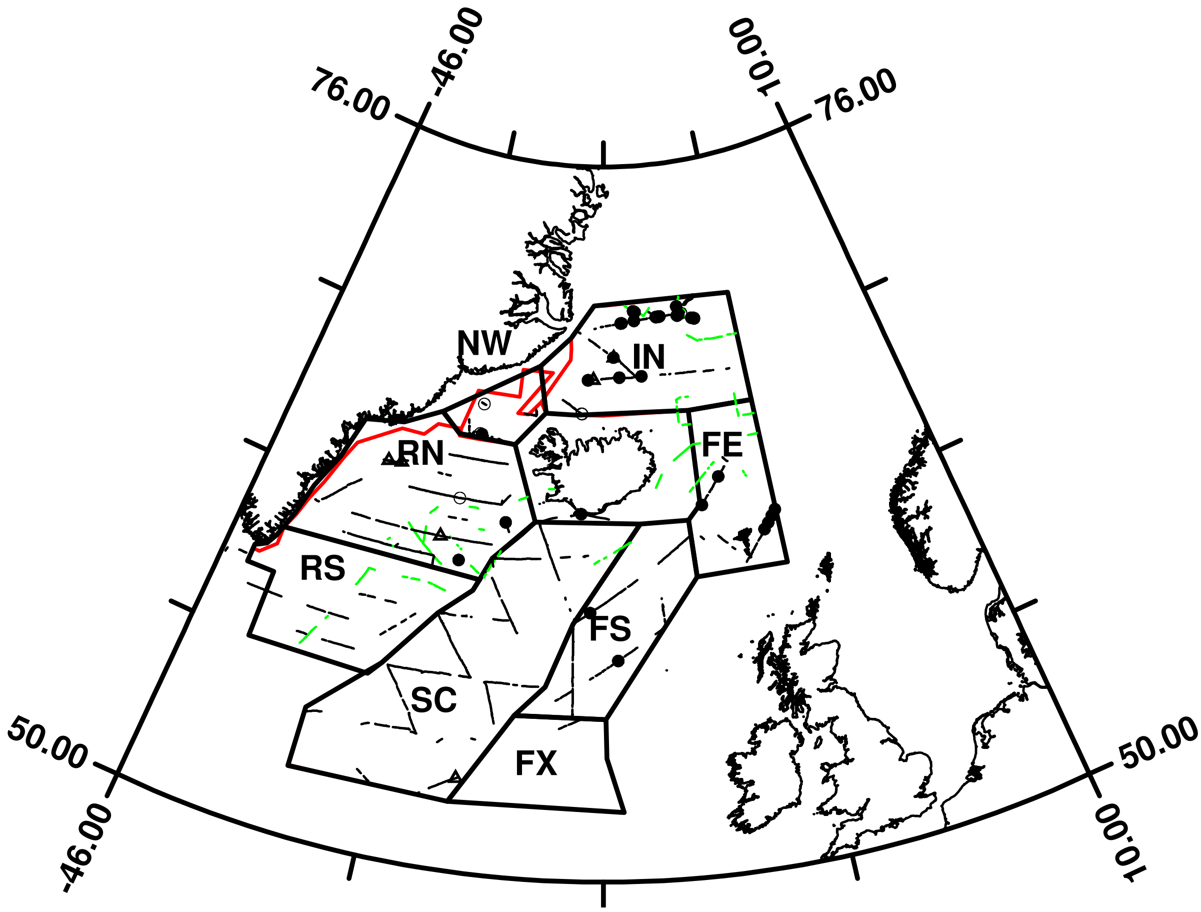
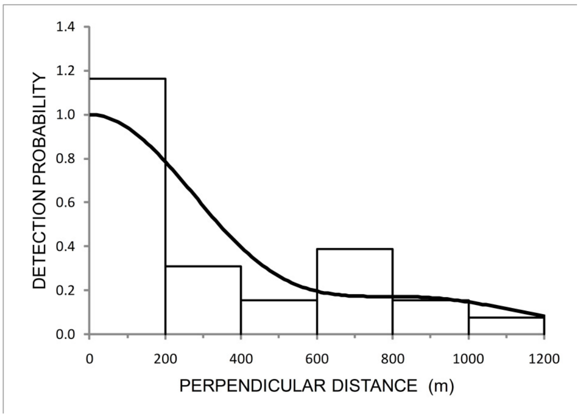
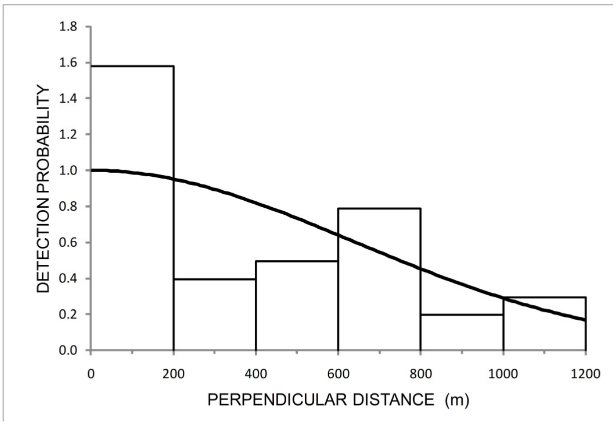



Fig. 1. Strata, realized survey effort and sightings of minke whales. Post stratification is indicated by red borders. Effort in green is from the extension vessels. Filled circles – BA; Open circles – BA?; Triangles – BA??.

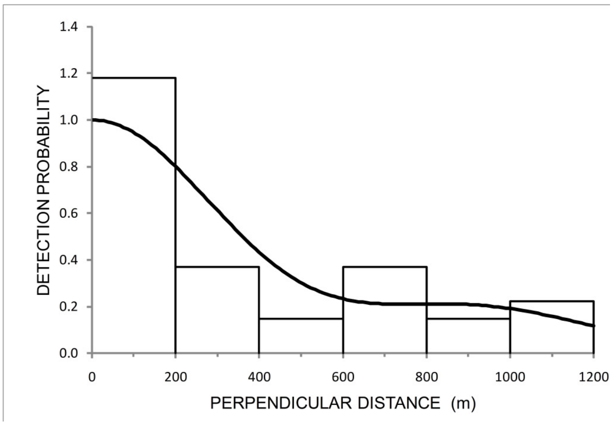
a.




b.




c.




d.

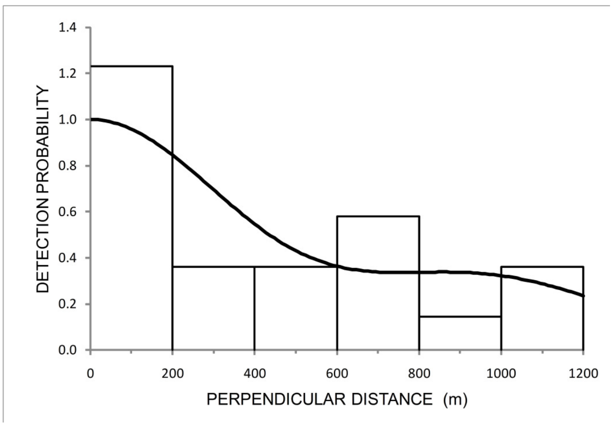



Fig. 2. Detection functions minke whale sightings. a. HIGH confidence species ID; b. HIGH, with extension vessels; c. LOW confidence species ID; d. LOW, with extension vessels.