Estimates of the abundance of humpback whales (*Megaptera novaengliae*) 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 humpback whales from the Icelandic and Faroese components of the T-NASS ship surveys. As in most previous surveys humpback whales were most commonly sighted to the north and northwest of Iceland in blocks IN and NW. Unlike in previous surveys, no humpbacks were sighted off eastern and northeastern Iceland, and few were seen close to East Greenland. Coverage in both these areas was however poor. A combined platform estimate, using conventional distance sampling analysis and non-duplicate sightings from both platforms, totalled 11,572 (95% CI 4,502 to 23,807) for humpbacks identified with high and moderate certainty in the post-stratified (to remove ice-covered areas) survey area. Effort conducted in full B-T mode was analyzed using MRDS techniques in Trial configuration and assuming point independence. This resulted in an estimated *g(0)* for the primary platform of 0.79 (cv 0.12) and an abundance of 16,633 (95% CI 6,494 to 42,601). Adding whales identified with low certainty raised this estimate by 6% for both estimates. The former estimate is uncorrected for perception and availability biases, while the latter is corrected for perception and at least partially for availability. The abundance estimated in 2007 is lower, albeit not significantly so, than those estimated for 1995 and 2001, suggesting that the rapid increase in abundance previously documented in the area may have ceased.

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.* 2008) and minke (Paxton *et al.* 2009) whales from the Central North Atlantic area (Icelandic and Faroese components) of the survey.

Previous abundance estimates for humpback whales (*Megaptera novaengliae*) from the Icelandic and Faroese NASS have been summarized by Pike *et al.* (2005), Paxton *et al.* (2009) and Smith and Pike (2009). 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. These biases were assumed to be relatively minor for humpback whales, as they are large with a visible and easily spotted blow and can be seen from a long distance, and do not frequently make long dives. However, as these biases are unlikely to be negligible, all previous estimates have been considered to be negatively biased by an unknown but probably slight degree.

Here we present abundance estimates for humpback 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 provide an estimate of *g(0)* for the primary platform using mark-recapture (or sight-resight) methods (Laake and Borchers 2004).

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.

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 (MN), Medium (coded with one question mark MN?) and Low (coded with two question marks MN??). Some proportion of "unknown large whales" (B?) could also have been humpback whales but this proportion was probably small as humpback sightings were outnumbered by fin whale sightings by nearly an order of magnitude. Two analyses were carried out to determine the sensitivity of the estimates to uncertainty in species identification: 1) High and Medium confidence humpback whales (MN + MN?) "HIGH", and; 2) High + Medium+Low confidence humpback whales (Case 1 + MN??) "LOW". The first analysis is probably most consistent with previous analyses of NASS humpback whale data (Paxton *et al.* 2009) and rather conservative, while the second analysis would have an unknown, but probably positive bias.

Data selection

The analytical procedure used required that all information about a sighting seen by both platforms (*i.e.* perpendicular distance, group size, species identification and covariates such as BSS) be the same. In some cases measurements of distance, estimates of group size and even species identification differed between platforms for the same sighting. In these cases what were considered to be the most reliable measurements (from the tracker platform if possible) were used.

Radial distance estimation

For some sightings several estimates of perpendicular distance are available from one or both platforms. As only one estimate can be used in the analysis, the "best" estimate was chosen generally as the last estimate before abeam where angle and distance was given. For duplicate sightings the distance estimate from the tracker platform was 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 5 or less were used in the analyses. This resulted in a minor loss in effort (Table 1) but no loss of humpback whale sightings.

Duplicate identification
Sightings made by the tracker platform that were duplicated by the primary platform were identified in the field by the duplicate identifier and revised in the lab by inspection of all available information from audio recordings, video, web cam, paper forms and in the database.

Analysis

Combined platform estimates
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 vessels F and Venus grouped); 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.

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.

Double platform analysis
A double platform estimate was attempted only for the high confidence species-ID case. Only effort that was conducted in full double platform mode was retained for this analysis. This resulted in a substantial reduction in survey effort (26%) (Table 1) because some vessels occasionally reverted to single platform mode due to equipment failures and/or adverse sighting conditions. As a result the total number of humpback whale sightings was about 9% fewer than for the equivalent combined platform dataset.

Density and abundance were estimated using stratified mark-recapture distance sampling (MRDS) techniques (Laake and Borchers 2005) using the DISTANCE 6.0 (Thomas *et al.* 2009) software package. Because the tracker platform was aware of sightings made by the primary platform, the platforms were not totally independent. Therefore the “trial configuration” (Laake and Borchers 2005), in which the secondary (tracker) platform serves to generate trials to determine the $g(0)$ of the primary platform, was used. We initially attempted two types of analyses: using the assumption of “full independence” (FI) wherein sightings from the platforms are considered independent at all perpendicular distances, and under the assumption of “point independence” (PI), wherein sightings from the platforms are considered independent only on the trackline (Laake and Borchers 2005). The AIC values resulting from both approaches were compared before deciding on a final model. The assumption of point independence requires the estimation of 2 detection functions: one for primary platform detections, and the other for primary platform detections conditional on detection by the tracker platform (conditional detection function), whereas the assumption of full independence requires only the latter detection function.

The detection function for the primary platform was modelled as described for the combined platform above. The conditional detection function was implemented as a logistical model with the same covariates available as for the primary platform detection function. Again the final model was chosen by minimization of AIC, after the primary platform detection function had been finalized.

RESULTS

Sightings and distribution

Humpback whale sightings by stratum are summarized in Table 1 and Fig. 1. As in most previous surveys (Pike *et al.* 2005) humpback whales were most commonly sighted to the north and northwest of Iceland in blocks IN and NW. Unlike in previous surveys, no humpbacks were sighted off eastern and northeastern Iceland, however this is not surprising as little effort was realized there.

Because most humpback sightings were made in blocks IN and NW, most (84%) were made by the one vessel *Venus*, which surveyed those blocks.

Combined platform estimates

A truncation distance of 2,500 m was found to be suitable for the HIGH datasets, while this was increased to 2,700 m for the LOW datasets. However other truncation distances were tried and results were not sensitive to truncation.

Mean school size varied significantly between strata so stratum specific estimates were used. Expected school size ($E(s)$), in some cases corrected for size bias in detectability from regression, was marginally higher in the more northerly strata (IN and NW) than in others, but data are sparse outside these 2 strata (Tables 2 to 4).

Tables 2 to 5 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 for the HIGH confidence case, and addition of covariates did not improve the fit (Fig. 2). The hazard rate model provided the best fit for the LOW confidence case, and again covariates did not improve the fit. Addition of the low confidence sightings increased abundance by 11%. Post stratification reduced the estimates by 12%.

The total estimate for the original survey area for the HIGH estimate was 13,205 (95% CI 5,106 to 25,986). Humpback whale density was much higher in the NW stratum than in any other area, followed by the IN stratum which had a density 1/6 that of NW. These two strata comprised 89% of the total abundance estimate. The other strata had far lower or null densities.

Double platform estimates

The proportion of humpback whales seen by the tracker platform that were missed by the primary platform increased slightly with perpendicular distance from the trackline (Fig. 3, for the HIGH confidence identification). About 25% of humpback whales within 500 m of the trackline that were seen by the tracker platform were missed by the primary platform.

Comparisons of FI and PI models revealed that PI models always had lower AIC's when the same covariates were included in the conditional detection function. In addition FI analyses always resulted in abundance estimates less than that from a conventional analysis of the primary platform data. Therefore PI was retained as the preferred approach.

The detection function for the primary platform for the HIGH confidence case is shown in Fig. 4. As for the combined platform dataset, no covariates improved the fit for the conditional detection function. The mean value for $g(0)$ was 0.79 (cv 0.12). Tables 5 and 6 provide the abundance estimates by stratum for the $g(0)$ corrected estimator. The total abundance in the original survey area was 18,722 (cv 0.45), compared to 13,205 (cv 0.42) from the equivalent combined platform analysis using all effort and non-duplicate detections (Table 2) and 14,650 (cv 0.47) for the equivalent primary platform estimate using effort conducted in double platform mode only and without $g(0)$ correction (not shown).

DISCUSSION AND CONCLUSIONS

Potential biases

Coverage

Poor weather and other factors conspired to reduce coverage of some areas that have had high densities of humpback whales in previous surveys. Particularly the areas off eastern and northeastern Iceland received little coverage by the ship survey, and these areas have had very high densities of humpbacks, especially in the 1995 and 2001 surveys (Pike *et al.* 2005, Paxton *et al.* 2009). However these areas were partially covered by the concurrent aerial survey and few humpbacks were seen (Pike *et al.* 2008). A westward shift in summer distribution of capelin (toward the coast of East Greenland) (Pálsson *et al.* 2009) might be a contributory factor in this respect. Considerable numbers of humpbacks were seen near the East Greenland ice edge in 2001; again this area was poorly covered in 2007. The NW block also received little coverage but this area had the highest density of humpback whales in the survey area. We cannot say if higher coverage here would have altered the density estimate but it would certainly have improved precision. The net effect of poor coverage in these areas would most likely be to negatively bias the estimate of abundance.

Post stratification based on ice cover in the strata bordering East Greenland reduced estimated abundance by 12%. While it is possible that there may have been whales in the pack ice these areas could not be surveyed by ship. A concurrent aerial survey over a portion of the pack ice area northwest of Iceland produced no sightings of humpback or any other whales, even though humpback whale sightings were frequent close to the ice edge (Pike *et al.* 2009). This suggests that humpback whales do not frequently enter the ice in this area. For this reason we consider the post-stratified estimates to be most accurate because they exclude pack ice areas that were not surveyed and were unlikely to hold any whales.

A substantial proportion of the realized effort (26%) was carried out without 2 platforms operating, and thus in a single platform mode (Table 1, Fig. 2). This resulted from equipment failures and other factors. This problem was particularly acute in the IN, RN and RS blocks, where from 44% to 56% of the effort was done in single platform mode. Only effort conducted in double platform mode was used to estimate $g(0)$ in the double platform estimate. The number of humpback whale sightings in double and combined platform modes does not reflect this reduction in effort however. For example, in stratum IN, only 1 fewer sighting was made in double platform mode even though only 65% of the effort was completed in that mode. In total, 76 HIGH confidence humpback sightings were made in the combined mode while 69 were made in double platform mode, a reduction of 9% in sightings with a 26% reduction in effort. As a result, the estimates from the double platform data tend to be substantially higher than those from the combined platform data because encounter rates were higher in double platform mode. The reasons for this are not clear, and it may merely be a coincidence resulting from the rather contagious nature of the spatial distribution of humpback sightings. For example the fin whale sightings do not show this feature (Pike *et al.* 2008).

Species identification

The identification of sightings as humpback whales has been recorded with various levels of certainty in all previous surveys, but was a lesser problem while direct closing mode was used. The magnitude of the difference in abundance estimates between the HIGH and LOW confidence estimates was about 11%, suggesting that species identification is not a serious problem for humpback whales. This is in contrast to the case for fin whales, for which species identification certainty resulted in changes in the estimates by up to 22% (Pike *et al.* 2008). This is likely because humpback whales are easier to identify at sea with certainty, as there are more "lookalike" species for fin than for humpback whales, although there were several cases of aggregations of fin and humpback whales. We consider the HIGH confidence identification estimates most comparable to the estimates previously reported by Pike *et al.*(2005) and Paxton *et al.* (2009) for previous NASS.

Bias in distance estimation and group size

Post-hoc comparisons of distance estimates made by the tracker and primary platforms to the same fin whale sighting revealed that the resultant perpendicular distances for the primary platform were 74.6% those made by the tracker platform (Pike *et al.* 2009). While this could be a result of responsive movement, in this case attraction, such reactions are not suspected for large baleen whales. Moreover measurements made close together in time by the two platforms revealed a similar pattern. A possible explanation is systematic underestimation of distances by the primary platform. This seems more likely than the converse, as the tracker platform used reticule binoculars and sometimes video to estimate distances, while the primary did not.

Most of the fin whale sightings were made by the redfish survey vessel which made few humpback whale sightings and only 4 duplicates, all at large perpendicular distances. The north going vessel made most of the humpback whale sightings and had 20 duplicates, most at small (<1Km) perpendicular distances. Of these the primary platform underestimated distances in 15 cases and overestimated just 5 (assuming trackers were correct). Calculating an average bias is not reasonable as some of the numbers (denumerators) are small resulting in large ratios. A sensitivity test showed that a 13% negative bias in distance estimation by primary observers would result in a 5% positively biased estimate of total abundance. The bias in the abundance might therefore well exceed 10% due to this problem. Most humpback whale sightings are of more than 1 animal and they frequently occur in large dispersed groups and it is therefore in several cases not obvious that the primary platform recorded the distance to the same animals, nor did they see the same number of animals. In fact, of the 56 animals in the sightings that were duplicated the primary platform detected only 36. In addition three of the duplicates were identified with low confidence by the primary platform, one as unidentified and 3 with wrong species or the humpbacks not detected in a duplicated mixed group. These errors are not incorporated in the *g(0)* correction for missed sightings and would likely more than compensate for the distance estimation bias in the primary platform sightings.

Compared to earlier surveys the effective search widths realized here are considerably narrower. The reasons for this are probably related to the implementation of the B-T protocols, which were not used in earlier surveys.

g(0) Correction

The estimated value of *g(0)* of 0.79 for the HIGH confidence identification sightings is similar to those estimated for fin whales in 2001 and 2007 of 0.81 and 0.77 respectively (Pike *et al.* 2006, Pike *et al.* 2008). This should account for bias due to visible whales being missed by observers (perception bias) assuming that the tracker sightings (trials set up for primary observers) are an unbiased sample with respect to detection probability. It also accounts for an unknown proportion of the bias due to whales that are diving while within visible range of the primary platform (availability bias). The observers on the tracker platform used binoculars and were instructed to scan farther ahead of the vessel than those on the primary platform and were expected to sight whales that dove before they came in range of the primary platform. However we would expect this difference to be small in moderate sighting conditions, as humpback whales are visible from a long distance and do not frequently make long dives.

We suspect that *g(0)* might be somewhat conservative because no covariates (other than distance) improved the fit of the conditional detection function. Other covariates, particularly those relating to sighting cue type, might improve the fit and would likely decrease the estimate of *g(0)*, resulting in a higher abundance estimate. However such covariates were not available in the dataset, but should be included in future analyses if they are available.

As mentioned above a substantial portion of the effort in this survey was conducted in a combined (single) platform mode. It would not however be appropriate to apply this estimate of *g*(0) to the combined single platform estimate, as much of this effort was conducted with both platforms communicating and operating as a single platform. The realized *g*(0) can be applied to the single platform only, as we would expect the *g*(0) to be higher for the combined platforms because more observers are searching and the tracker platforms were higher than the primary platforms.

Comparison to previous estimates

Pike *et al.* (2005) provide regional abundance estimates for humpback whales from surveys conducted in roughly the same area as this in 1987, 1989, 1995 and 2001, and Paxton *et al.* (2009) provide spatial model-based estimates from the 1995 and 2001 surveys. The methodology used by Pike *et al.* (2005) was similar to that used here except that *g*(0) corrected estimates were not calculated. Abundance increased dramatically from 1987 to 1995, with most of this increase attributable to growth in the population summering around Iceland. Abundance in a roughly equivalent area was 11,060 (cv 0.33) in 1995 and 13,965 (cv 0.27) in 2001. The 2007 estimate for the HIGH confidence case and the post-stratified survey area was 11,572 (cv 0.44), which suggests that abundance has not changed much since 2001 However as previously mentioned the ship survey had very poor coverage off eastern Iceland and no coverage at all in most areas within 100 nm of the Icelandic coast, the latter of which were covered in the concurrent aerial survey. We therefore consider the ship survey estimate for 2007 to be negatively biased with regard to the total summer population size around Iceland. Further comparisons await the integration of the aerial and ship estimates into a single combined estimate, which will require adjustments to take into account areas of overlap, particularly off NW Iceland.

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REFERENCES

Buckland, S.T. and Turnock, B.J. 1992. A robust line transect method. *Biometrics* 48:901-909.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. 2001. *Introduction to Distance Sampling*. Oxford University Press, New York, 432 pp.

Desportes, G. and Halldórsson, S.D. 2008. Cruise report for Venus & Co (June 25 – July 23). Paper NAMMCO/SC/15/TNASS/30 submitted to NAMMCO SC working group on abundance estimates, Copenhagen April 7-8, 2008., 20 pp.

Laake, J.L. and Borchers, D.L. 2004. 2005. Methods for incomplete detection at distance zero. In: Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (eds) *Advanced Distance Sampling.* Oxford University Press, Oxford, U.K., pp. 108-189.

Mikkelsen, B. 2008. TNASS 2007. Faroe Islands. Thor Chaser. Preliminary cruise report. Paper NAMMCO/SC/15/TNASS/32 submitted to NAMMCO SC working group on abundance estimates, Copenhagen April 7-8, 2008., 12 pp.

Pálsson, Ó.K., Valdimarsson, H., Ólafsdóttir, S., Guðfinnsson, H.G., Gíslason, Á., Pétursdóttir H. and Sveinbjörnsson, S. 2009. Rannsóknir á vistkerfi íslandshafs og vistfræði loðnu að sumarlagi *(Ecosystem properties of the Iceland Sea and capelin ecology during summer). Þættir úr vistfræði sjávar 2008 (Environmental conditions in Icelandic waters 2008) Hafrannsóknir no. 145* 54-59.

Paxton, C.G.M., Gunnlaugsson, Th. and Mikkelsen, B. 2009. Mark-recapture distance sampling estimate of minke whales from the Icelandic, Faroese and Russian components of T-NASS. SC/61 RMP 12 for the IWC Scientific Committee.

Paxton, C.G.M, Burt, M.L., Hedley, S.L., Víkingsson, G.A., Gunnlaugsson, Th., and Desportes, G. 2009. Density surface fitting to estimate the abundance of humpback whales based on the NASS-95 and NASS-2001 aerial and shipboard surveys. . *NAMMCO Sci. Publ.* 7:143-159.

Pike, D.G, Gunnlaugsson, Th., Øien, N, Desportes, G., Víkingsson, G.A., Paxton, C.G.M. and Bloch, D. 2005. Distribution, abundance and trends in abundance of fin and humpback whales in the North Atlantic. ICES CM 2005/R:12

Pike, D.G., Gunnlaugsson, Th. and Víkingsson, G.A. 2006. An estimate of *g(0)* for the NASS-2001 survey for fin whales (*Balaenoptera physalus*) in Icelandic and Faroese waters. SC/14/FW/19 for the NAMMCO Scientific Committee.

Pike, D.G., Gunnlaugsson, Th. and Víkingsson, G.A. 2009. T-NASS Icelandic aerial survey: Survey report and a preliminary abundance estimate for minke whales. SC/60/PFI 12 for the IWC Scientific Committee.

Pike, D.G., Gunnlaugsson, Th., Víkingsson, G.A. and Mikkelsen, B. 2008. Estimates of the abundance of fin whales (*Balaenoptera physalus*) from the T-NASS Icelandic and Faroese ship surveys conducted in 2007. SC/60/PFI/16 for the IWC Scientific Committee.

Smith, T.D. and Pike, D.G. 2009. The enigmatic humpback whale. *NAMMCO Sci. Publ.* 7:161-178.

Thomas, L., Laake, J.L., Rexstad, E., Strindberg, S., Marques, F.F.C., Buckland, S.T., Borchers, D.L., Anderson, D.R., Burnham, K.P., Burt, M.L., Hedley, S.L., Pollard, J.H., Bishop, J.R.B. and Marques, T.A. 2009. Distance 6.0. Release 2. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. http://www.ruwpa.st-and.ac.uk/distance/

Víkingsson, G.A., Ólafsdóttir, D. and Westerberg, U. 2008. TNASS 2007 - Cruise report for R/V Árni Friðriksson,, RE 200. Paper NAMMCO/SC/15/TNASS/29 submitted to NAMMCO SC working group on abundance estimates, Copenhagen April 7-8, 2008., 15 pp.

BLOCK	AREA (nm^2)	AREAP (nm^2)	EFF (nm)	EFF5 (nm)	EFF5D (nm)	K	MN	MN?	MN??	ALL
FE	61,866	61,866	511	511	448	5	0	0	0	**0**
FS	79,996	79,996	865	865	786	4	4	0	0	**4**
FX	57,775	57,775	151	151	119	3	0	0	0	**0**
IC			106	106	21	2	0	0	0	**0**
IN	95,767	91,873	772	724	400	5	24	4	0	**28**
NW	21,700	17,237	140	140	109	4	30	6	4	**40**
RN	132,109	123,981	1,502	1,422	790	7	6	1	2	**9**
RS	92,464	91,577	656	618	271	5	1	0	0	**1**
SC	207,217	207,217	2,558	2,502	2,231	10	0	0	0	**0**
TOT-F	**199,897**	**199,637**	**1,526**	**1,526**	**1,354**	**12**	**4**	**0**	**0**	**4**
TOT-I	**548,746**	**531,885**	**5,733**	**5,511**	**3,822**	**33**	**61**	**11**	**6**	**78**
TOT	**748,643**	**731,522**	**7,258**	**7,037**	**5,175**	**45**	**65**	**11**	**6**	**82**

Table 1. Survey effort and sightings by stratum. IC is unplanned effort within the aerial survey area within 100 nm of Iceland. Totals are given for the Faroese (F), Icelandic (I) and entire areas. AREAP – stratum area, post-stratified; EFF5 – effort conducted at BSS 5 or less; EFF5D – effort conducted at BSS 5 or less and in full double platform mode; K – number of transects.

Block	n	*n/L*	cv	*E(S)*	cv	*esw*	*f(0)*	cv	*D*	*N*	cv	LCI	UCI
FE	0												
FS	3	3.47E-03	0.58	1.51	0.26				0.0044	356	0.74	0	981
FX	0												
IC	0												
IN	26	3.59E-02	0.62	1.77	0.19	1,289	8.15E-01	0.1427	0.5457	5,226	0.75	0	15,702
NW	31	2.21E-01	0.36	1.71	0.08				0.3043	6,602	0.48	2,437	13,835
RN	7	4.92E-03	0.70	1.57	0.19				0.0061	805	0.76	64	2,261
RS	1	1.62E-03	0.96	1.63	0.30				0.0023	215	0.98	0	709
SC	0												
	68								**0.0176**	**13,205**	**0.42**	**5,106**	**25,986**

Table 2. Estimated density and abundance of humpback 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	0												
FS	3	3.47E-03	0.58	1.52	0.26				0.0045	359	0.75	0	1,009
FX	0												
IC	0												
IN	26	3.59E-02	0.66	1.77	0.20	1,289	8.21E-04	0.1366	0.0534	4,903	0.80	0	14,800
NW	31	2.21E-01	0.35	1.71	0.08				0.3073	5,297	0.46	1,981	10,794
RN	7	4.92E-03	0.65	1.58	0.19				0.0063	786	0.71	70	2,143
RS	1	1.62E-03	0.91	1.67	0.28				0.0025	227	0.92	0	704
SC	0												
	68								**0.0158**	**11,572**	**0.44**	**4,502**	**23,807**

Table 3. Estimated density and abundance of humpback whales identified with HIGH confidence from the combined platforms and using post-stratification. See Table 2 for variable definitions.

Block	n	*n/L*	cv	*E(S)*	cv	*esw*	*f(0)*	cv	*D*	*N*	cv	LCI	UCI
FE	0	0.00E+00											
FS	3	3.47E-03	0.58	1.51	0.26				0.0043	344	0.74	0	976
FX	0	0.00E+00											
IC	0	0.00E+00											
IN	28	3.87E-02	0.64	1.72	0.15	1,255	8.05E-04	0.12	0.0589	5,638	0.79	555	16,397
NW	37	2.64E-01	0.30	1.64	0.10				0.3382	7,338	0.43	3,065	14,918
RN	8	5.63E-03	0.59	1.55	0.19				0.0068	905	0.64	0	2,120
RS	1	1.62E-03	0.94	1.64	0.29				0.0023	214	0.95	0	666
SC	0	0.00E+00											
	77								**0.0193**	**14,439**	**0.41**	**5,923**	**28,716**

Table 4. Estimated density and abundance of humpback whales identified with LOW confidence from the combined platforms, and using the original strata. See Table 2 for variable definitions.

Block	**n**	***n/L***	**cv**	***E(S)***	**cv**	***esw***	***f(0)***	**cv**	***D***	***N***	**cv**	**LCI**	**UCI**
FE	0												
FS	3	3.47E-03	0.57	1.54	0.26				0.0045	359	0.74	0	980
FX	0												
IC	0												
IN	28	3.87E-02	0.64	1.73	0.14	1,255	8.06E-04	0.12	0.0593	5,450	0.79	592	16,103
NW	37	2.64E-01	0.30	1.65	0.09				0.3467	5,977	0.43	2,482	11,932
RN	8	5.63E-03	0.59	1.55	0.19				0.0069	859	0.63	118	2,092
RS	1	1.62E-03	0.89	1.69	0.27				0.0026	234	0.90	0	695
SC	0												
	77								**0.0176**	**12,879**	**0.44**	**5,074**	**26,455**

Table 5. Estimated density and abundance of humpback whales identified with LOW confidence from the combined platforms and using post-stratified blocks. See Table 2 for variable definitions.

Block	n_P	n_T	n_{PT}	n_P/L	**cv**	***E(S)***	***g(0)***	**Cv**	***D***	***N***	**cv**	**LCI**	**UCI**
FE	0	0	0	0.0000									
FS	1	2	0	0.0013	1.02	2.00			0.0033	265	1.03	20	3,607
FX	0	0	0	0.0000									
IC	0	0	0	0.0000									
IN	14	20	9	0.0350	0.66	1.79	0.7912	0.12	0.0812	7,779	0.63	1,468	41,219
NW	18	20	12	0.1651	0.65	1.72			0.3709	8,050	0.75	1,125	57,584
RN	5	4	3	0.0063	0.56	1.60			0.0132	1,740	0.63	385	7,853
RS	1	1	1	0.0037	1.38	2.00			0.0096	888	1.39	35	22,410
SC	0	0	0	0.0000									
	39	**47**	**25**							**18,722**	**0.45**	**7,114**	**49,266**

Table 6. Estimated density and abundance of humpback whales sighted from the primary platform and identified with HIGH confidence and using the original strata Only effort and sightings collected in double platform mode are included. The estimate is corrected for *g(0)*. nP – number of sightings from the primary platform; nT – number of sightings from the tracker platform; nPT – number of sightings seen by both platforms. See Table 2 for other variable definitions

Block	n_P	n_T	n_{PT}	n_P/L	cv	*E(S)*	*g(0)*	Cv	*D*	*N*	cv	LCI	UCI
FE	0	0	0	0.0000									
FS	1	2	0	0.0013	1.02	2.00			0.0033	265	1.03	20	3,595
FX	0	0	0	0.0000									
IC	0	0	0	0.0000									
IN	14	20	9	0.0350	0.60	1.79	0.7912	0.12	0.0812	7,462	0.63	1,408	39,542
NW	18	20	12	0.1651	0.72	1.72			0.3709	6,394	0.75	894	45,741
RN	5	4	3	0.0063	0.60	1.60			0.0132	1,633	0.63	362	7,370
RS	1	1	1	0.0037	1.38	2.00			0.0096	880	1.39	35	22,195
SC	0	0	0	0.0000									
	39	**47**	**25**							**16,633**	**0.44**	**6,494**	**42,601**

Table 7. Estimated density and abundance of humpback whales sighted from the primary platform and identified with HIGH confidence and using the post-stratified blocks. Only effort and sightings collected in double platform mode are included. The estimate is corrected for *g(0)*. See Table 6 for variable definitions

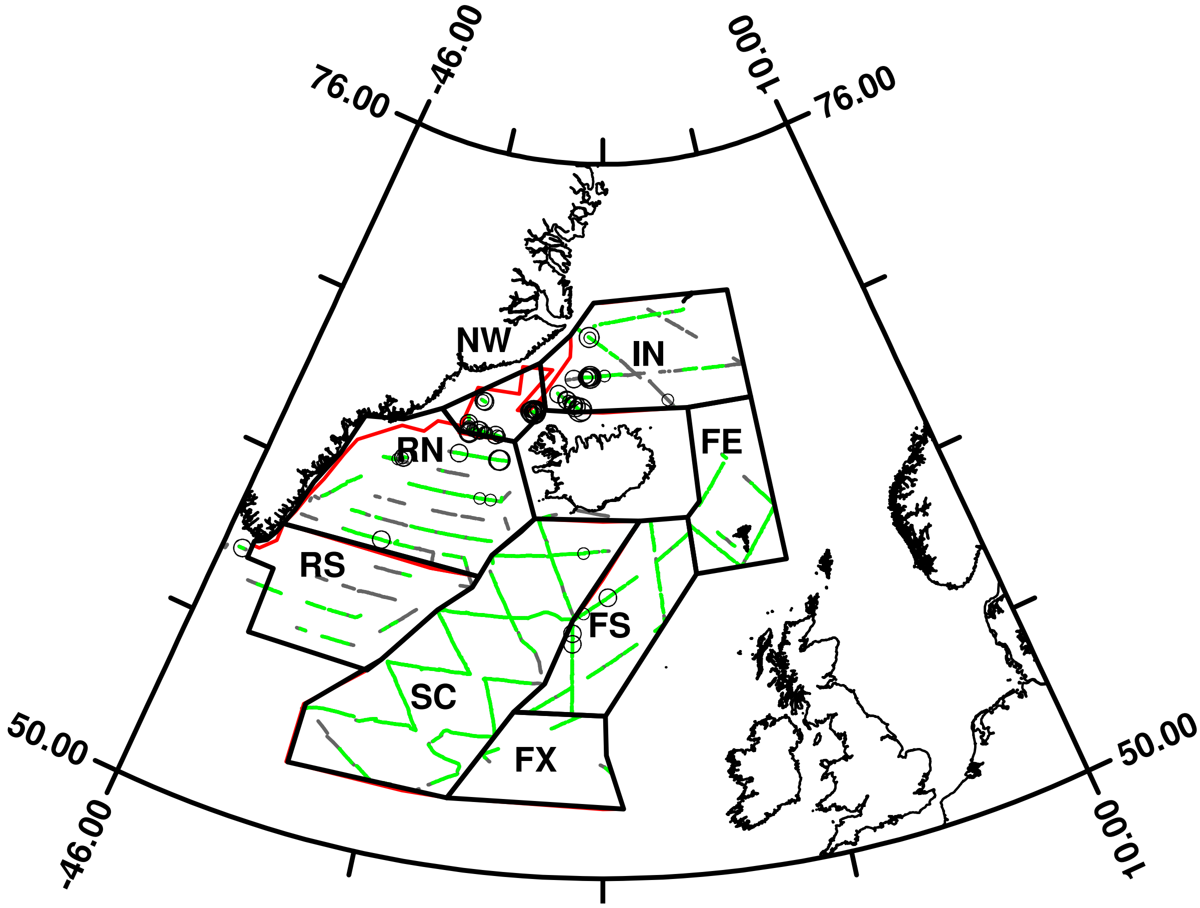
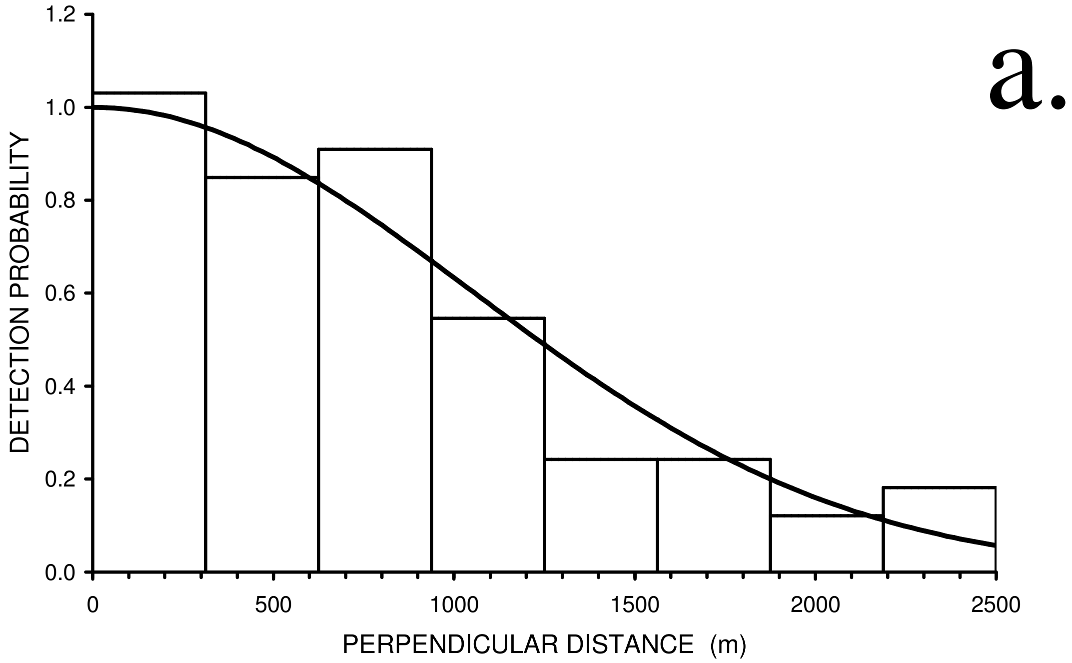


Fig. 1. Strata, realized survey effort and sightings of humpback whales. Post stratification is indicated by red borders. Effort in green was conducted in double platform mode. Symbol size for sightings is proportional to group size from 1 to 5.



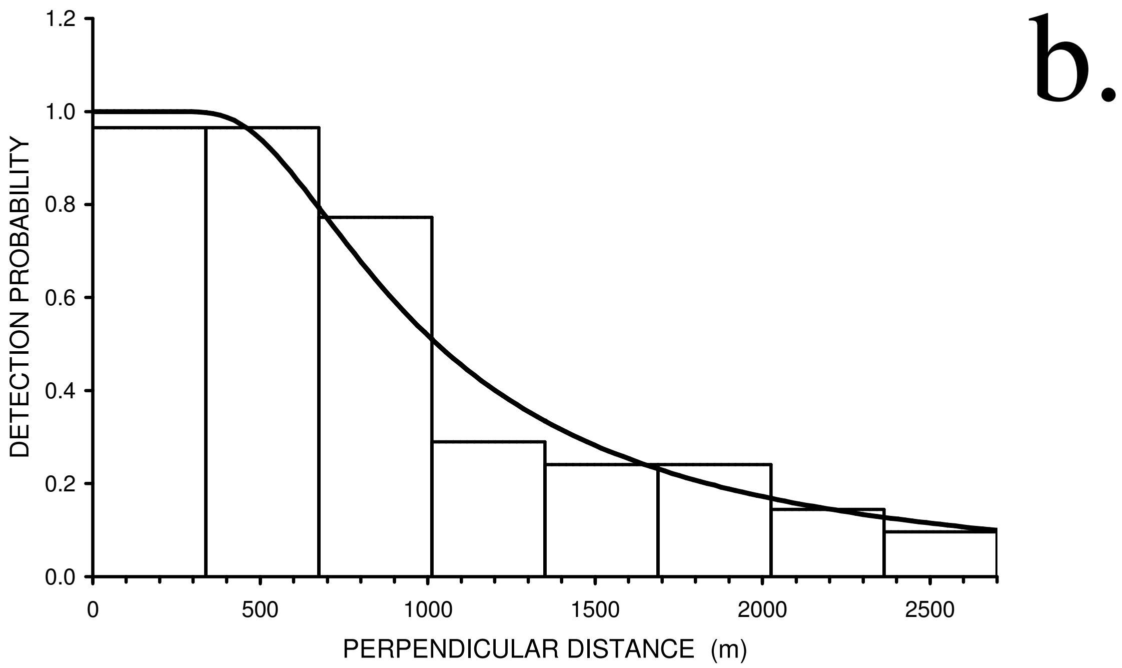


Fig. 2. Detection functions humpback whale sightings. a. HIGH confidence species ID; b. LOW.

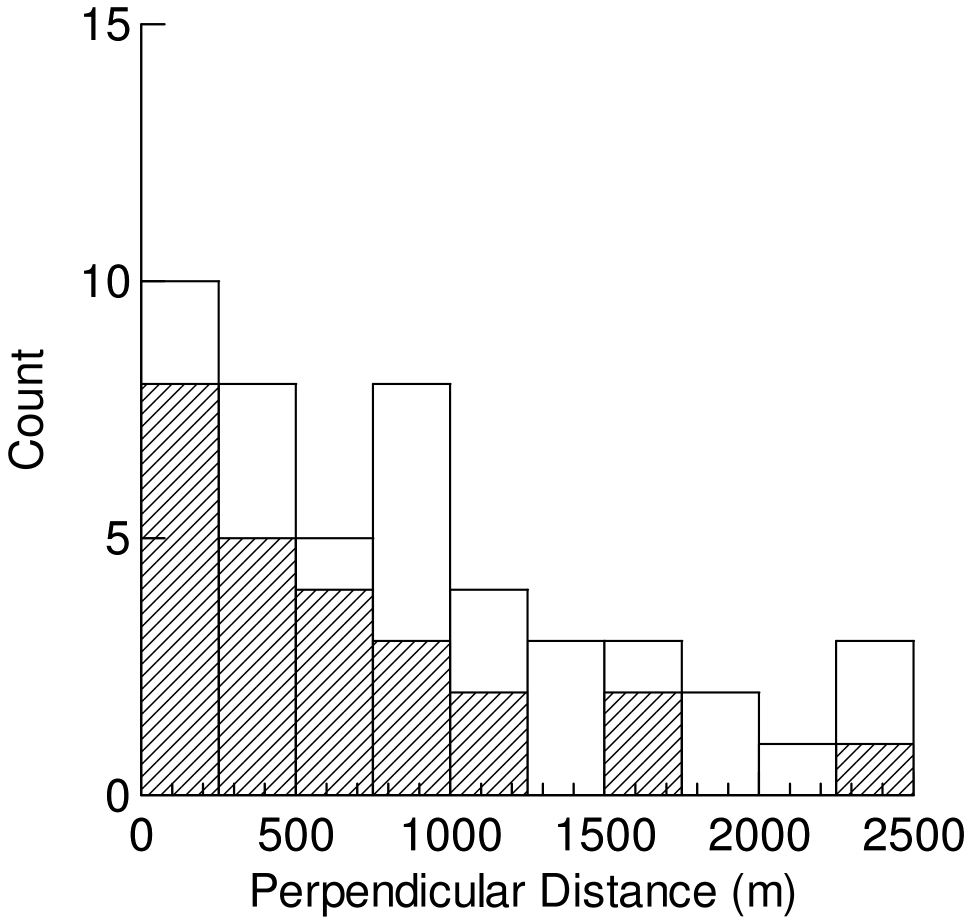


Fig. 3. Detection function for humpback whales detected with HIGH confidence from the tracker platform, and proportion of these sightings seen by the primary platform (hatched area).

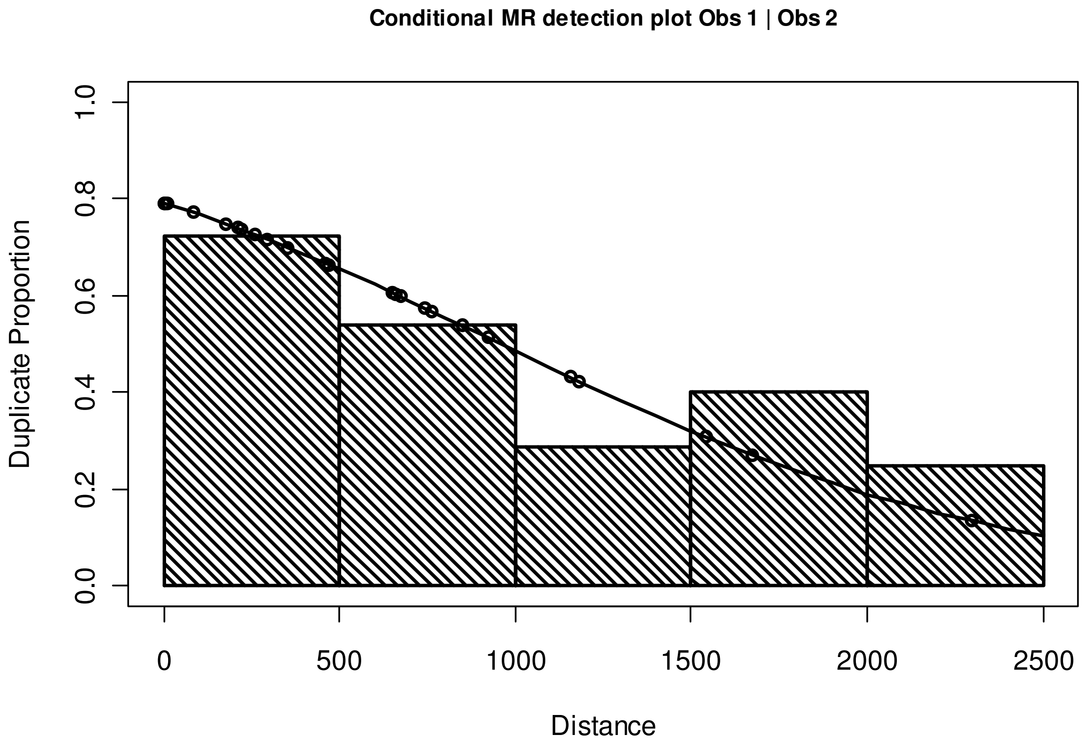


Fig. 4. Detection function for HIGH confidence humpback whales conditional on detection by the tracker platform. The points are data points estimated from covariate values, while the line is the fitted model