Estimates of the abundance of fin whales (*Balaenoptera physalus*) 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) was conducted in June/July 2007 and covered a large area of the northern North Atlantic. The fin whale (*Balaenoptera physalus*) was a target species in all areas and a main target species of the Icelandic ship surveys. The survey was conducted in Buckland-Turnock mode using a primary platform and a higher tracker platform, with duplicate sightings identified in the field. As in most previous surveys fin whales were most commonly sighted to the west of Iceland in Denmark Strait. Abundance was estimated for 3 classes based on uncertainty in species identification. The combined platform estimate using unique sightings from both platforms and the species identification certainty classification most consistent with previous estimates was 21,628 (cv 0.15). Inclusion of less certain species identification sightings increased this estimate by up to 22%. This estimate is slightly lower than the estimate for a similar area from 2001. The high rate of increase of fin whales observed in the western part of this area between 1987 and 2001 may therefore have ceased. *g(0)* was estimated as 0.77 (cv 0.10) using the "trial configuration" under the assumption of point independence. The total corrected estimate was 27,493 (cv 0.20) for the identification certainty classification most consistent with earlier surveys. Potential sources of bias in these estimates are discussed.

INTRODUCTION

The Trans North Atlantic Sightings Survey (T-NASS) was conducted in June/July 2007 and covered a large area of the northern North Atlantic. The fin whale (*Balaenoptera physalus*) was a target species in all areas and a main target species of the Icelandic ship surveys.

Previous abundance estimates for fin whales from the Icelandic and Faroese NASS have been summarized by Víkingsson *et al.* (in press). 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 fin 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 fin whales from the Icelandic and Faroese survey areas (Fig. 1). Combined platform estimates are provided using 3 degrees of certainty in species identification. In addition we provide an estimated 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 *et. al.* 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 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.

Data treatment

Species identity

Species codes used here are BP for fin whales, BM for blue and BB for sei whales. For many sightings there was uncertainty in species identification. In earlier surveys in this area sightings were classified as either fin whales (BP) or like fin whales (BP?) or like fin possibly blue (BP?BM) *etc.* This is the first survey in this area where sightings were categorized according to the degree of certainty as High (BP), Medium (coded with one question mark BP?, BP?BM ...) and Low (coded with two question marks BP??, BP?BM? *etc.*). Sighting categories that were more likely fin whales than any other species were considered for the analyses (Table 1). However this does not include all categories that could have been fin whales, for example sightings of B? (unknown large whale) which were included for sensitivity testing. Other categories that might have been fin whales such as BB?BP (likely sei but possibly fin) were more likely of other species and not considered. At the same time, a portion of the uncertain fin whale sightings were likely not fin whales. For this reason, 3 analyses were carried out to determine the sensitivity of the estimates to uncertainty in species identification: 1) High and Medium confidence fin whales (BP + BP? + BP?BM + BP?BB); 2) High + Medium+Low confidence fin whales (all most likely fin whales) (Case 1 + BP?? + BP?BM? + BP?BB?) ; 3) All most likely fin whales and unidentified large whales (Case 2 + B?). The first analysis is probably most consistent with previous analyses of NASS fin whale data (Víkingsson *et al.* in press) and rather conservative, the second analysis would have an unknown bias while the third would be definitely positively biased in this respect.

Data selection

The analytical procedure used required that all information about a sighting seen by both platforms (*i.e*. angle, radial distance, group size, species identification and covariates such as BSS) be the same. In some cases measurements of angle and 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 were used.

Radial distance estimation

For some sightings several estimates of radial distance and angle 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 sometimes recorded as a range (*e.g.* 1 – 2). In these cases a decimal value was used (*e.g.* 1 – 2 becomes 1.5). 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) and a loss of 2 fin 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 5.0 (Thomas *et al.* 2005) 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.* 2005). 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 first two confidence cases. Only effort that was conducted in full double platform mode was retained for this analysis. This resulted in a substantial reduction in survey effort (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 fin whale sightings was about 30% 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 5.0 (Thomas *et al.* 2005) 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

Fin whale sightings by stratum are summarized in Table 1 and Fig. 2. As in most previous surveys fin whales were most commonly sighted to the west of Iceland in block RN. However substantial numbers were also sighted south of Iceland in block SC. The proportion of realized *vs* planned effort was low in blocks NW and FX.

Combined platform estimates

A truncation distance of 2,500 m was found to be suitable, 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 higher in the more northerly strata (IN, RN, NW) (Tables 2 to 4).

The half-normal model provided the best fit to the data in all cases. Addition of a covariate for vessel identity with vessels V, F and J combined (Confidence cases 1 and 3) or vessels V and F combined (Confidence case 2) improved the fit substantially. A single example of the fit is provided in Fig. 3 for confidence case 1. Vessel A generally had longer sighting distances than the other vessels. There is some depression in sighting frequency near the trackline, primarily due to sightings by vessels F, V and J. However the combined detection function, which is dominated by vessel A, shows little evidence of this.

Estimates for the 3 species ID confidence cases are provided in Tables 2 to 4. In all cases, effective search width (*esw*) was greatest for vessel A, followed by vessel J then the combined F and Venus. The difference is substantial, with the *esw* for vessel A nearly double that for F and V combined.

The estimates for the two less certain species ID confidence cases were 18% and 22% higher respectively than that for the High+Medium classification. These differences are proportionally similar to the increases in the number of sightings (14% and 25% respectively), by including the less confidently identified sightings and the effective search widths are not much higher than for the higher confidence. This indicates that the less confidently identified sightings were not necessarily farther from the trackline than those of higher confidence.

The total estimate for the survey area for the High+Medium confidence sightings was 21,628 (95% CI 15,731 to 27,739). Fin whale density was highest in block RN, followed by NW then SC. Density was very low in the Faroese blocks. Abundance was highest in RN, followed by SC..

Double platform estimates

The proportion of fin whales seen by the tracker platform that were missed by the primary platform increased slightly with perpendicular distance from the trackline (Fig. 4, for the High+Medium confidence identification). About 25% of fin 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+Medium identification is shown in Fig. 5. As for the combined platform dataset, inclusion of a covariate for vessel identity resulted in lowest AIC for the detection function. However it was later found that conditional models with this covariate included in the primary detection function would not converge. Therefore the next best model, which included BSS (as integers) as a covariate, was chosen. Estimates using this model were nearly identical to that using the model including vessel identity as a covariate. The *esw* was narrower at higher BSS.

The conditional detection function is also shown in Fig. 5 for the High+Medium confidence identification. No covariates other than perpendicular distance improved the fit of the conditional model. The mean value for *g(0)* was 0.77 (cv 0.10) for the primary platform for the High+Medium confidence identification and 0.76 (cv 0.10) for the High to Low confidence classification.

Tables 5 and 6 provide the abundance estimates by stratum for the *g(0)* corrected estimator for the High+Medium and High to Low classifications. The total abundance in the survey area for the High+Medium confidence identification was 27,493 (cv 0.20), compared to 21,628 (cv 0.15) from the equivalent combined platform analysis using all effort and non-duplicate detections (Table 2) and 23,382 (cv 0.15) 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 fin whales in previous surveys. Particularly the western part of block RN, near the East Greenland ice edge and in the NW block received very little coverage. These areas have had very high densities of fin whales in previous surveys (Víkingsson *et al.* in press). The RS, FX and the northern part of the FE block were also poorly covered, but these blocks have not had high fin whale densities in previous surveys. The net effect of poor coverage in these areas would most likely be to negatively bias the estimate of abundance.

Species identification

The identification of sightings as fin whales has been recorded with various levels of certainty in all previous surveys, but was a lesser problem while direct closing mode was used. On the vessel J, which frequently slowed down or turned on sightings once they came abeam, cases of failure to identify to species and undercounting of group size were detected, but the sample size is small. This is the first time we have assessed the sensitivity of the abundance estimate to uncertainty in species identification. The magnitude of the difference in abundance estimates was greatest between the High+Medium and the other two less certain identification cases. Interestingly the differences were roughly proportional to the increase in the number of sightings with lower identification confidence. For this survey it appears that confidence in species identification was not closely associated with the distance of the sighting from the trackline. We had expected that addition of the less certain sightings would add proportionally little to the estimate of abundance, as has been the case for blue whales in previous NASS (Pike *et al.* in press).

Some of the sightings included in the least certain identification category were likely not fin whales, so estimates based on these should be considered positively biased. We consider the High+Medium confidence identification estimates most comparable to the estimates reported by Víkingsson *et al.*.(in press) for previous NASS.

Bias in distance estimation

The primary platforms were found to be negatively biased in the estimation of radial distances by about 10% in distance estimation experiments conducted at the beginning of the survey. A negative bias in distance estimation would result in a positively biased estimate of abundance However the bias estimate from the experiments cannot necessarily be applied to the survey, as the behaviour of the observers is unlikely to be the same during the experiment as during the survey itself. In addition the observers would be expected to learn from the experiments and adjust their distance estimation procedures accordingly. We have therefore carried out preliminary analyses of the duplicate sightings data to determine if there was bias in distance estimation.

In the data from vessel AF, duplicate sightings of 47 fin whales were identified and one record picked out for each of the primary and tracker platforms. To avoid zero division and very small numbers in the calculations of the average bias, 9 sightings calculated to be within 400 m based on both platforms were excluded. Also 3 sightings calculated to be within 400 m by trackers but from primary data one at 741m and 2 at 400-500m. Also 5 sightings calculated to be within 400m from primary data but at 637, 666, 788, 913 and 1588m by trackers. The net effect is that the primary platform estimates 14 sightings to be within 400 m while the trackers have only 12 and estimate the mismatched sightings to be farther from the track.

The perpendicular distances for the remaining 30 sightings by the primary platform were on average 74.6% of the distances to the same sightings as estimated by the trackers. Distances by primary platform would hence need to be multiplied up by 1.34, or an abundance estimate would be expected to be 34% too large if based only on primary rather than only tracker data. The effect of the sightings within 400 m is of the same order.

A problem with the implementation of the BT method in the TNASS survey was that trackers were instructed to stop tracking as soon as a sighting was duplicated by primary observers and were not instructed to check the distances, species id or pod size of sightings by primary observers. The procedure called for tracking up until. At that point where the sighting was duplicated by primary observers there may not be a resighting recorded by trackers nor any additional later resightings by trackers. This results in limited overlap in the distance estimation of the platforms. The whales moving towards the trackline would therefore be more likely to be duplicated by primary observers. Also the platforms may not always agree on number of animals and may in fact not have seen the same animals in an aggregate, where the primary observers would more likely see just those animals that were closer to the track. Therefore the bias estimated in this way is probably a maximum.

The apparent difference in distance measurements between the tracker and primary platforms could be interpreted as responsive movement; *i.e.* whales moving towards the vessel and thus being detected closer to the vessel by the primary platform. However this is unlikely because a comparison based only on measurements close together in time shows no less bias. Also fin whales have not been noted to react to vessels at distances of more than a few tens of meters by whalers nor observers in earlier surveys when closing mode was used. In this survey fin whales rarely surfaced this close to a vessel and had they reacted over some tens of meters this would not be detected from the tracking resightings which are generally over one km apart, when considering the precision in distance and angle estimation.

Preliminary runs incorporating a negative bias of 0.15 in radial distance measurements by the primary platforms resulted in an abundance estimate 9% lower than with the uncorrected data. Extrapolating this to a bias of 1.34 as suggested by the analysis above would give an estimate 21% less than the base case. Clearly this difference requires further investigation.

In earlier surveys scientists and observers cooperated in getting a final best estimate of distance based on resightings and when available the closing distances. Reticule binoculars were rarely available so distances in these surveys may have been biased, but comparison to the last survey is not possible.

g(0) Correction

The estimated value of *g(0)* of 0.77 for the High+Medium confidence identification sightings is close to that estimated by Pike *et al.* (2006) for the 2001 survey (0.81). 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 fin whales are visible from a long distance and do not frequently make long dives. When sighting conditions are poor, which may not always be realized by observers or realizable from recorded data, as multiple factors affect sightability, then the bias may be severe but sample size will be low for stratified analysis. Of concern in this implementation of the BT method is that trackers were hesitant to assign any species identification (except unidentified large whale) to the sightings while far ahead and may thus have left out the difficult trials where the animal did not resurface close to the vessel.

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.

Undercounting of group size is not accounted for in the *g(0)* presented here. On vessel AF in 48 duplicated sightings of 73 fin whales by trackers (or unidentified large whales later identified by primary as fin whales) there are 35 whales within 1000m (all identified as fin whales also by primary) and in two of these sightings by primary of a single animal a group size of two is recorded by tracker. Both are high confidence fin whales within 500m perpendicular where the last record from tracker is about 10 minutes prior to the record by primary, there is no record by tracker at that time, probably because the primary observer was quicker to spot the sighting then, so the tracker stopped tracking/recording. There is also one whale missed at about 1000m perpendicular and 4 at over 2000m. On vessel JakupB there are 15 sightings of 21 fin whales with estimates of school size by both platforms. One single animal was confirmed to be two animals when closed on at 500m perpendicular. There is also a group of 3 by tracker where primary has just one but both are low confidence species id, and then there is one whale missed at greater

distance. On vessel Venus there is no duplicate of fin whales but 21 duplicate sightings of 57 humpback whales by trackers where 38 whales are seen by primary. These findings suggest an additional downward bias of about 10% for fin whales.

It is of interest to compare the combined platform estimate using all non duplicate High+Medium confidence sightings (Table 2), the equivalent primary platform estimate of 23,382 (cv 0.15) using effort conducted in double platform mode only (not shown), and the equivalent *g(0)* corrected primary platform estimate (Table 5). Despite the fact that realized effort in double platform mode was only 74% of the total effort (Table 1), the abundance estimate is very similar to the combined platform estimate and the variance is nearly the same. The slightly higher point estimate for the primary platform might be due to uncorrected bias in distance estimation by the primary platform. This suggests that acceptable estimates of abundance for fin whales might be feasible using a single platform and somewhat less effort than achieved in this survey, particularly if greater accuracy (*i.e.* less bias) in distance estimation could be achieved. The increase in estimated abundance afforded by estimating *g(0)* is marginal for fin whales, however it is likely to be more substantial for other target species, particularly minke whales.

Comparison to previous estimates

Víkingsson *et al*. (in press) provide regional abundance estimates for fin whales from surveys conducted in roughly the same area as this in 1987, 1989, 1995 and 2001. Over this period, abundance in the WEST region, which corresponds approximately to blocks NW+RN, increased from 3,600 in 1987 to 14,000 in 2001, an annual rate of increase of 10% (95% CI 6 to 14%). Rates of increase for other regions were not significantly different from null. Total abundance for NW+RN for this survey (High+Medium confidence, Table 2) is 13,398 (95% CI 8,616 to 18,800), slightly lower than that observed in 2001. Total abundance was also lower than that seen in 2001, due primarily to lesser abundance in other areas. The results from this survey therefore suggest that the increase in the abundance of fin whales around Iceland and in the East Greenland – Iceland stock area may have ceased.

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Table 1. Survey effort and sightings by stratum. Totals are given for the Faroese (F), Icelandic (I) and entire areas. 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	AREA	EFF	EFF5	EFF5D	K	BP	BP?	BP?BM	BP??	BP?BM?	BP?BB?	B?	ALL
FE	61,866	511	511	448	5	1							**1**
FS	80,255	865	865	786	4	4	1					6	**11**
FX	57,776	151	151	119	3								**0**
IC		106	106	21	2								**0**
IN	95,767	772	724	400	5	5	5		2			6	**18**
NW	21,700	140	140	109	4	3	1		3			5	**12**
RN	132,109	1,502	1,422	790	7	138	53	15	18	1		19	**244**
RS	92,464	656	618	271	5	14	4	5	6		1	1	**31**
SC	206,706	2,558	2,502	2,231	10	42	16		10	2		3	**73**
TOT-F	**199,897**	**1,526**	**1,526**	**1,354**	**12**	**5**	**1**	**0**	**0**	**0**	**0**	**6**	**12**
TOT-I	**548,746**	**5,733**	**5,511**	**3,822**	**33**	**202**	**79**	**20**	**39**	**3**	**1**	**34**	**378**
TOT	**748,643**	**7,258**	**7,037**	**5,175**	**45**	**207**	**80**	**20**	**39**	**3**	**1**	**40**	**390**

Table 2. Estimated density and abundance of fin whales identified with High+Medium 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; *N*- abundance; LCI and UCI – upper and lower confidence limits.

Block	n	*n/L*	cv	*E(S)*	cv	*esw*	*f(0)*	cv	*D*	*N*	cv	LCI	UCI
FE	0	0.00E+00											
FS	5	5.78E-03	0.64	1.00		1,074	8.83E-04	0.27	0.0052	417	0.55	0	917
FX	0	0.00E+00											
IC	0	0.00E+00											
IN	10	1.38E-02	0.27	1.21	0.14	1,074	9.26E-04	0.14	0.0140	1,345	0.29	589	2,037
NW	3	2.14E-02	1.14	1.48	0.31	1,074	6.50E-04	0.68	0.0305	661	0.78	0	1,725
RN	184	1.29E-01	0.19	1.37	0.02	1,729	5.79E-04	0.05	0.0952	12,572	0.20	8,104	17,879
RS	23	3.72E-02	0.43	1.00	0.01	1,729	5.78E-04	0.07	0.0197	1,824	0.45	252	3,490
SC	57	2.28E-02	0.38	1.18	0.04	1,074	9.41E-04	0.06	0.0233	4,808	0.35	1,638	8,043
	282								**0.0344**	**21,628**	**0.15**	**15,731**	**27,739**

Table 3. Estimated density and abundance of fin whales identified with High to Low confidence from the combined platforms. 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	313
FS	5	5.78E-03	0.64	1.00		901	1.05E-03	0.28	0.0061	489	0.56	0	1,101
FX	0												
IC	0												
IN	12	1.66E-02	0.25	1.15	0.11	901	1.12E-03	0.11	0.0193	1,852	0.22	1,071	2,676
NW	6	4.28E-02	0.51	1.40	0.22	901	1.11E-02	0.12	0.0732	1,589	0.62	255	4,029
RN	202	1.42E-01	0.17	1.34	0.02	1,709	5.84E-04	0.06	0.1041	13,752	0.18	9,230	19,174
RS	30	4.86E-02	0.39	1.05	0.06	1,709	5.84E-04	0.01	0.0281	2,595	0.46	373	5,051
SC	66	2.64E-02	0.36	1.32	0.07	1,298	7.77E-04	0.06	0.0252	5,202	0.34	1,944	8,897
	321								**0.0405**	**25,479**	**0.14**	**18,964**	**32,666**

Table 4. Estimated density and abundance of fin whales and unidentified large whales (B?) from the combined platforms. 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	10	1.16E-02	0.33	1.00	0.04	1,245	8.09E-04	0.06	0.0084	671	0.28	358	1,087
FX	0	0.00E+00											
IC	0	0.00E+00											
IN	17	2.35E-02	0.20	1.17	0.10	1,245	8.09E-04	0.06	0.0198	1,892	0.21	958	2,607
NW	11	7.84E-02	0.36	1.29	0.22	1,245	8.05E-04	0.10	0.0728	1,580	0.41	323	2,974
RN	217	1.53E-01	0.18	1.33	0.01	1,740	5.76E-04	0.05	0.0815	14,294	0.18	9,716	19,718
RS	30	4.86E-02	0.39	1.05	0.06	1,740	5.76E-04	0.05	0.0270	2,497	0.46	394	4,873
SC	68	2.72E-02	0.35	1.31	0.06	1,245	8.09E-04	0.06	0.0267	5,526	0.34	2,183	9,399
TOTAL	**353**								**0.0421**	**26,458**	**0.13**	**19,830**	**33,899**

Table 5. Estimated density and abundance of fin whales sighted from the primary platform and identified with High+Medium confidence. Only effort and sightings collected in double platform mode are included. The estimate is corrected for *g(0)*. See Table 2 for variable definitions.

Block	**n**	***n/L***	**cv**	***E(S)***	**cv**	***esw***	***f(0)***	**cv**	***g(0)***	**cv**	***D***	***N***	**cv**	**LCI**	**UCI**
FE	0														
FS	4	5.09E-03	0.80	1.00	0.00						0.0052	416	0.85	44	3,939
FX	0														
IC	0														
IN	6	1.50E-02	0.74	2.00	0.00	1,467	6.82E-04	0.05	0.77	0.10	0.0129	1,235	0.78	145	10,477
NW	4	3.68E-02	1.61	4.00	0.00						0.0254	551	1.62	15	19,721
RN	153	1.94E-01	0.22	1.32	0.02						0.1485	19,620	0.22	11,918	32,299
RS	2	7.39E-03	0.43	1.00	0.00						0.0062	574	0.45	161	2,040
SC	60	2.71E-02	0.38	1.25	0.05						0.0247	5,096	0.41	2,148	12,091
	229										**0.0367**	**27,493**	**0.20**	**18,289**	**41,328**

Table 6. Estimated density and abundance of fin whales sighted from the primary platform and identified with High to Low confidence. Only effort and sightings collected in double platform mode are included. The estimate is corrected for *g(0)*. See Table 2 for variable definitions

Block	**n**	***n/L***	**cv**	***E(S)***	**cv**	***esw***	***f(0)***	**cv**	***g(0)***	**Cv**	***D***	***N***	**cv**	**LCI**	**UCI**
FE	0														
FS	4	5.09E-03	0.80	1.00	0.00						0.0054	437	0.85	46	4,190
FX	0														
IC	0														
IN	8	2.00E-02	0.66	1.59	0.13	1,464	6.83E-04	0.05	0.76	0.10	0.0178	1,707	0.70	241	12,095
NW	6	5.52E-02	1.02	1.91	0.62						0.0398	864	0.97	67	11,096
RN	162	2.05E-01	0.18	1.30	0.02						0.1592	21,028	0.19	13,845	31,937
RS	3	1.11E-02	0.43	1.00	0.00						0.0092	854	0.45	239	3,044
SC	68	3.08E-02	0.36	1.31	0.06						0.0292	6,044	0.38	2,705	13,505
	251										**0.0413**	**30,933**	**0.18**	**21,679**	**44,138**

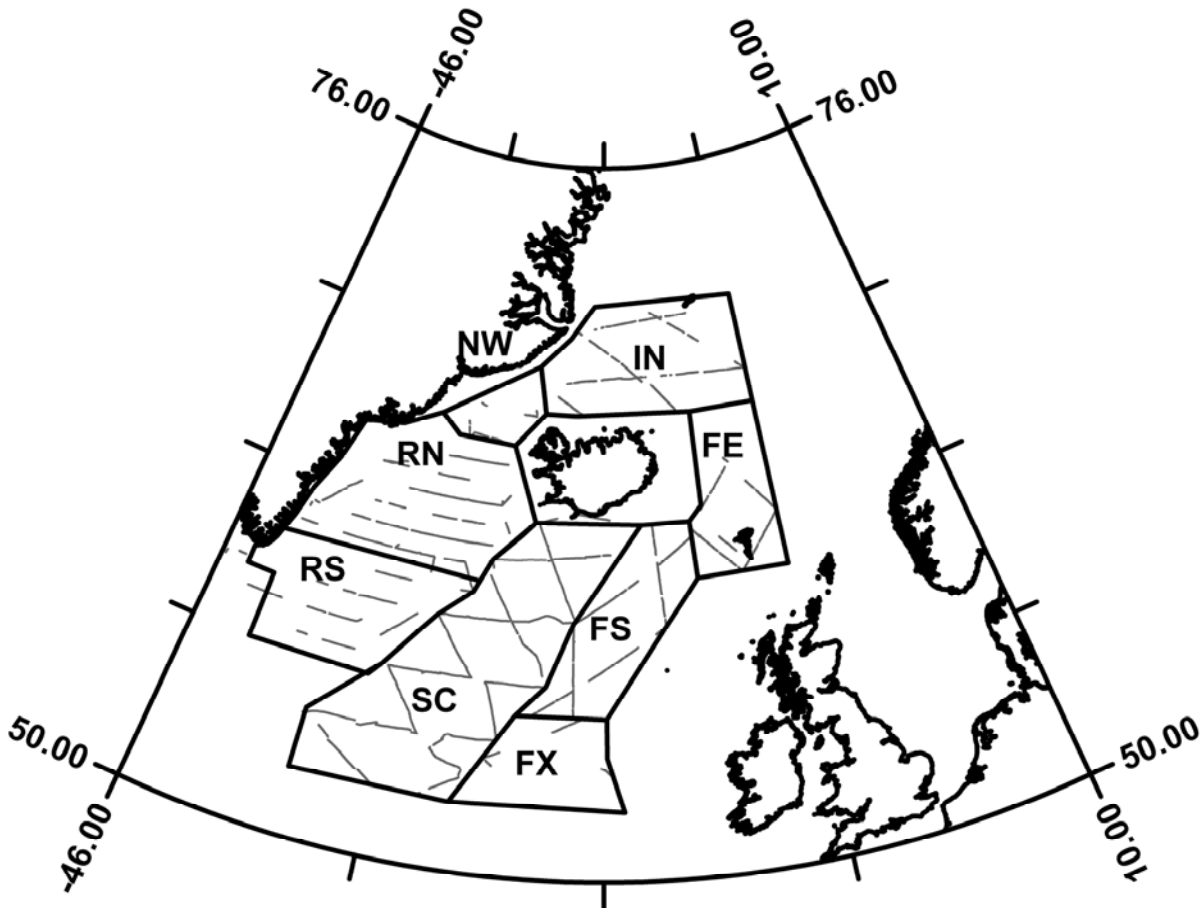


Fig. 1. Strata and realized survey effort.

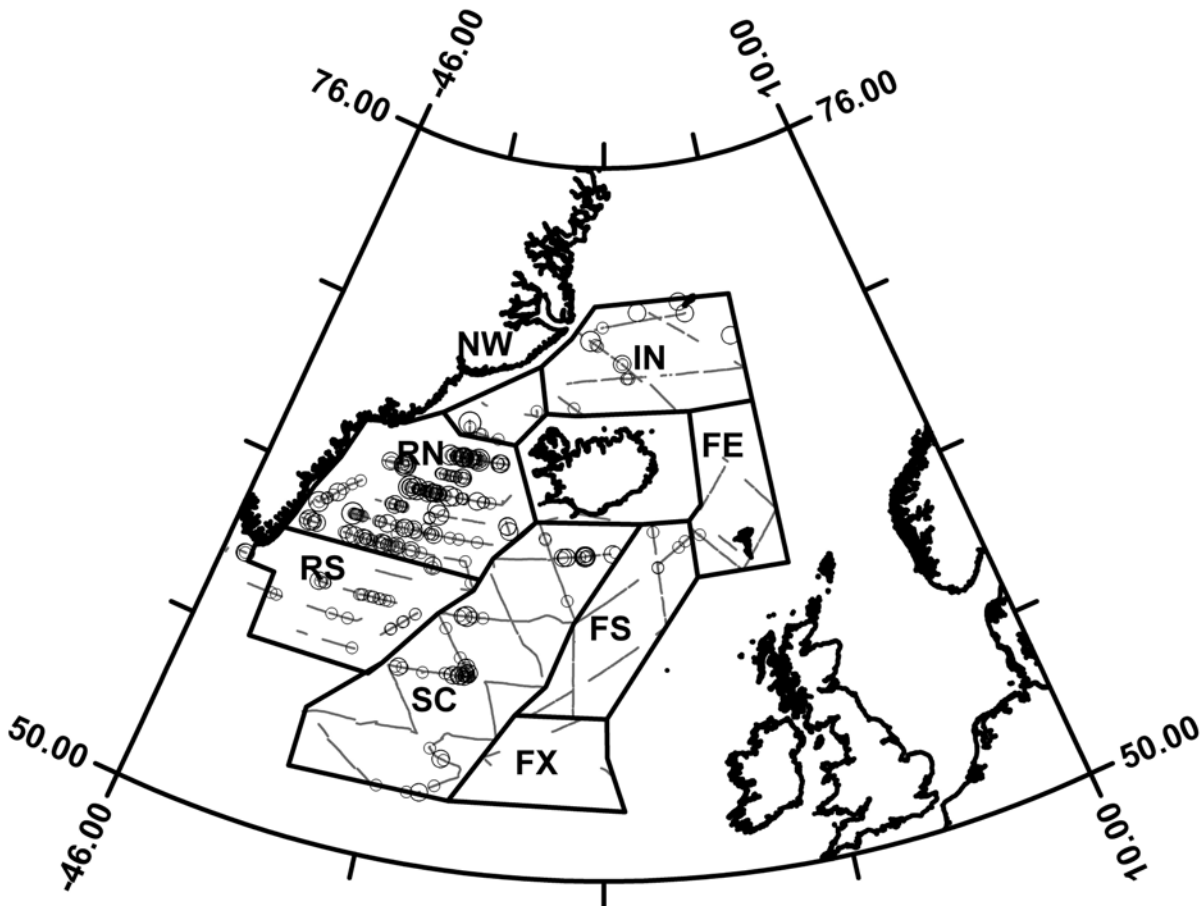
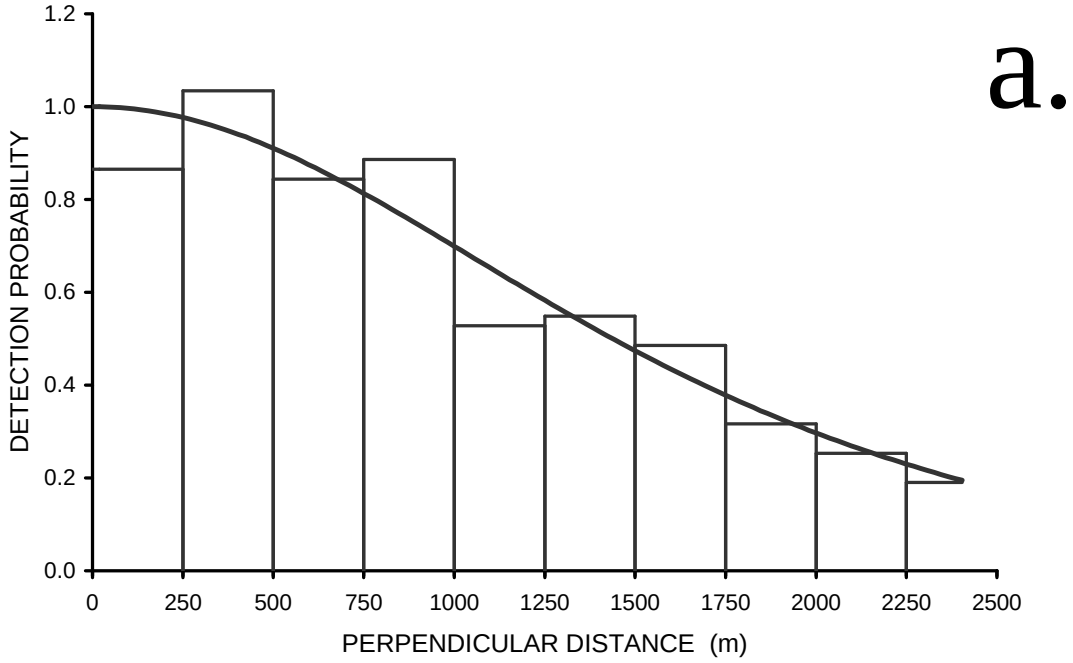
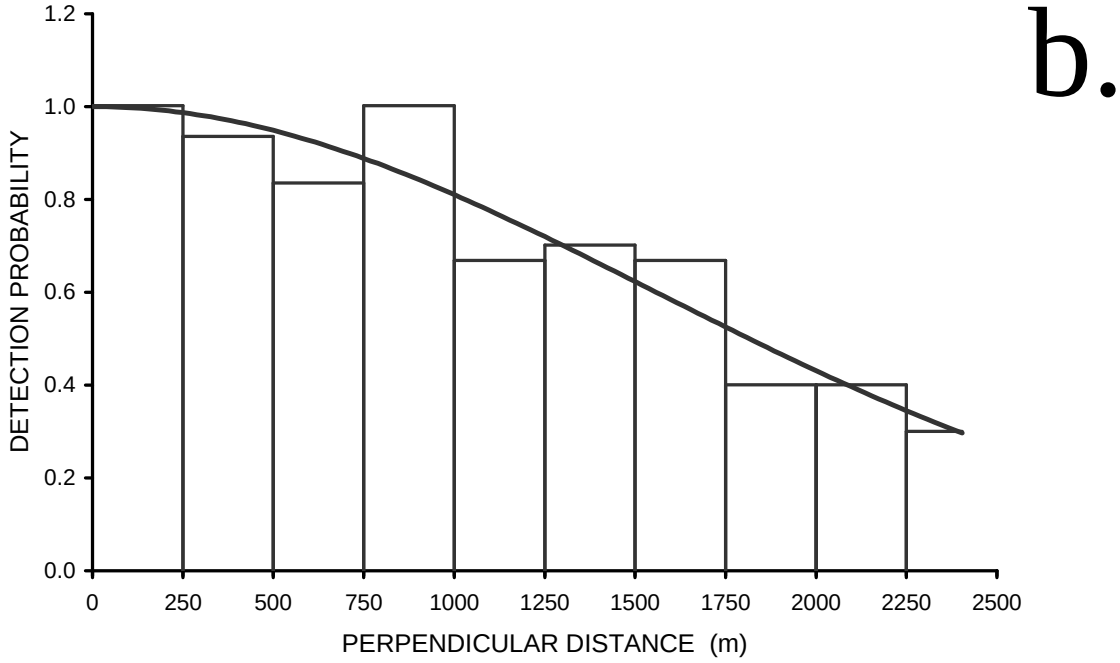


Fig.2. Sightings of fin whales (High+Medium confidence identification) in the T-NASS Faroese and Icelandic ship surveys. Symbol size is proportional to group size in the range of 1 to 5.


a.
DETECTION PROBABILITY
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
PERPENDICULAR DISTANCE (m)


b.
DETECTION PROBABILITY
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
250
500
750
1000
1250
1500
1750
2000
2250
2500
PERPENDICULAR DISTANCE (m)

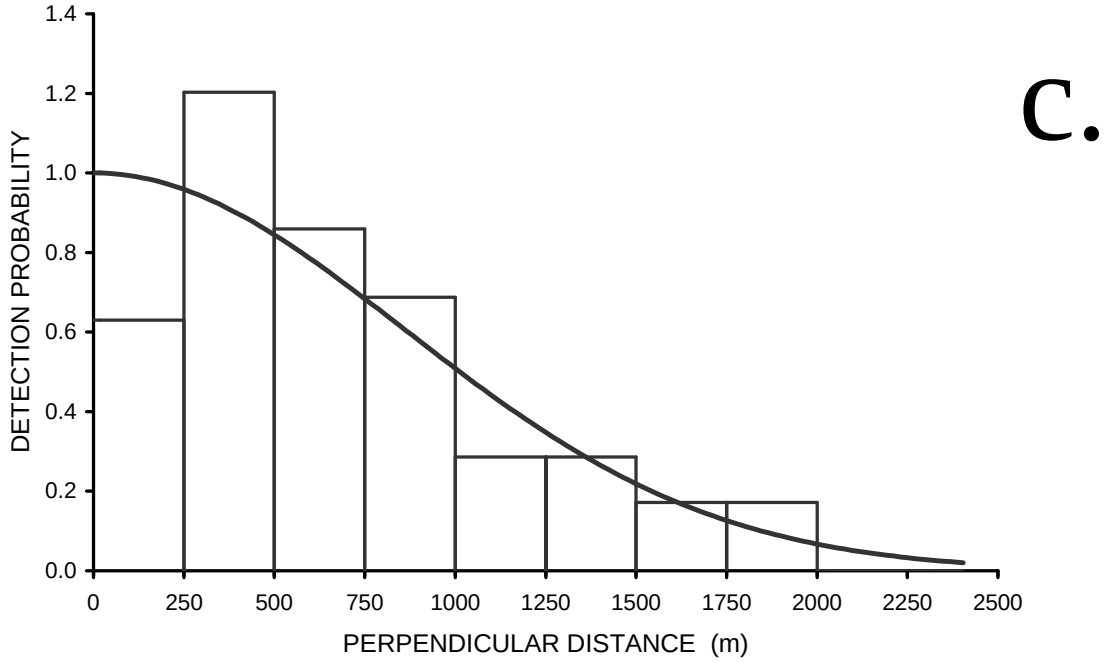


Fig. 3. Detection functions for the High+Medium confidence fin whale sightings. a. all data; b. vessel A; c. vessels F, J and V.

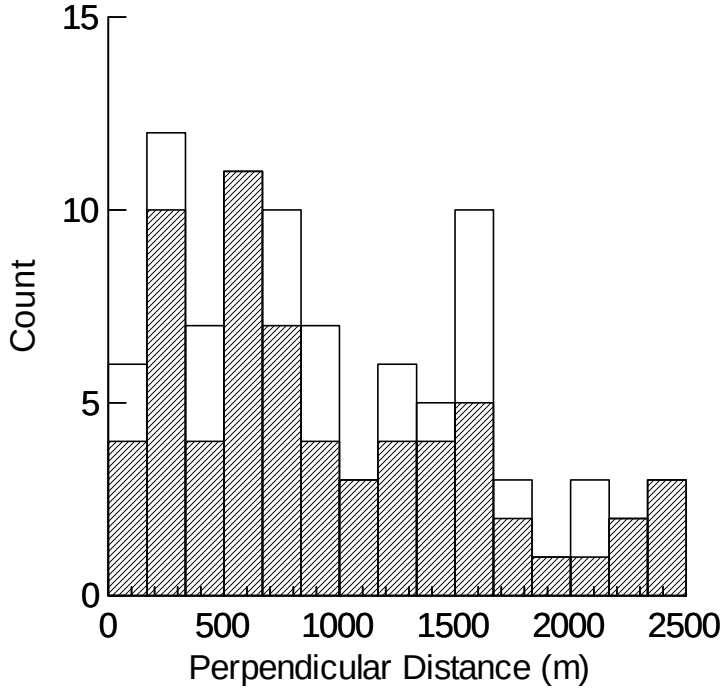


Fig. 4. Detection function for fin whales detected with High+Medium confidence from the tracker platform, and proportion of these sightings seen by the primary platform (hatched area).

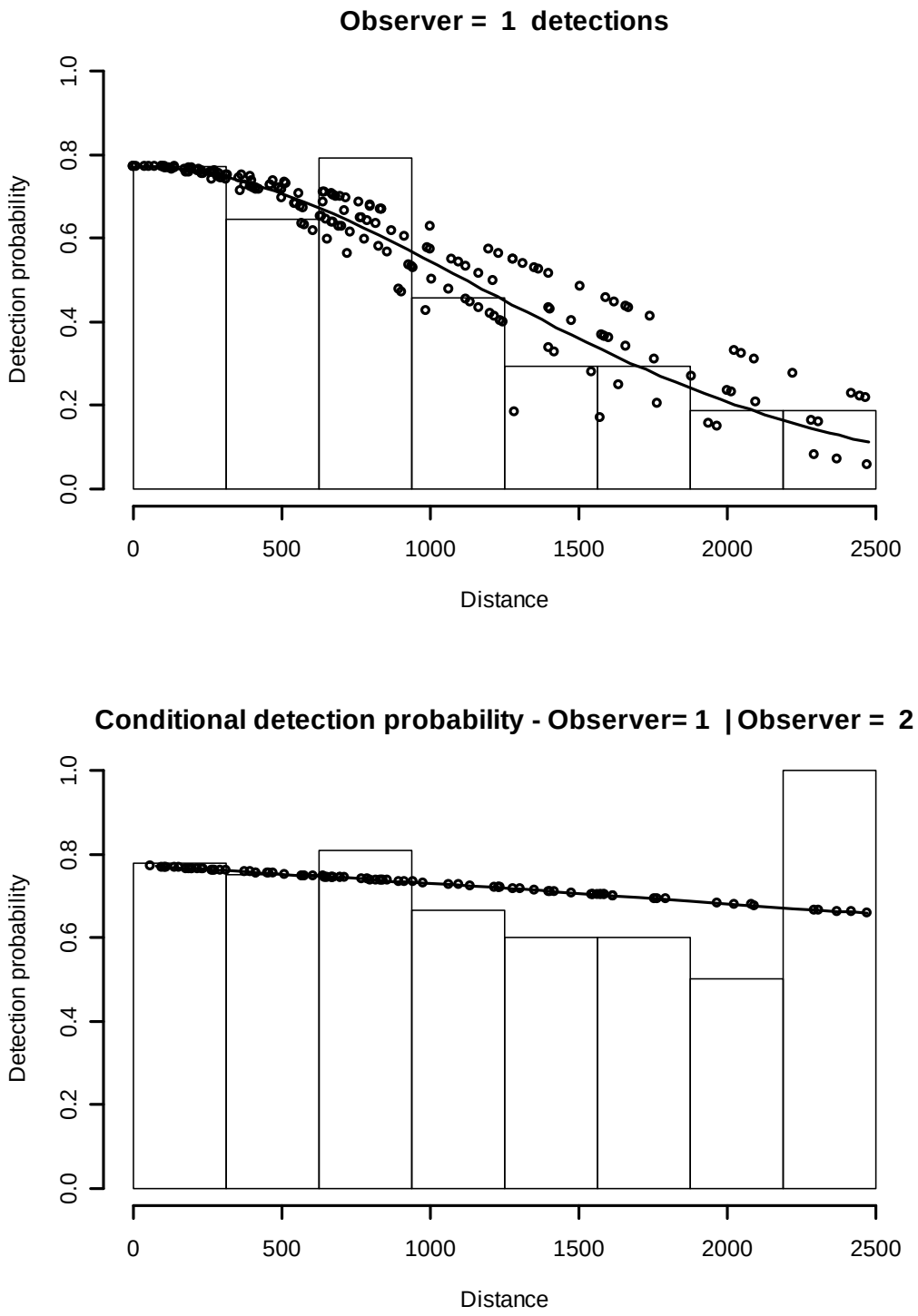


Fig. 5. Detection function for High+Medium confidence fin whales for the primary platform (top), and detection function conditional on detection by the tracker platform. The points are data points estimated from covariate values, while the line is the fitted model