Paper 3

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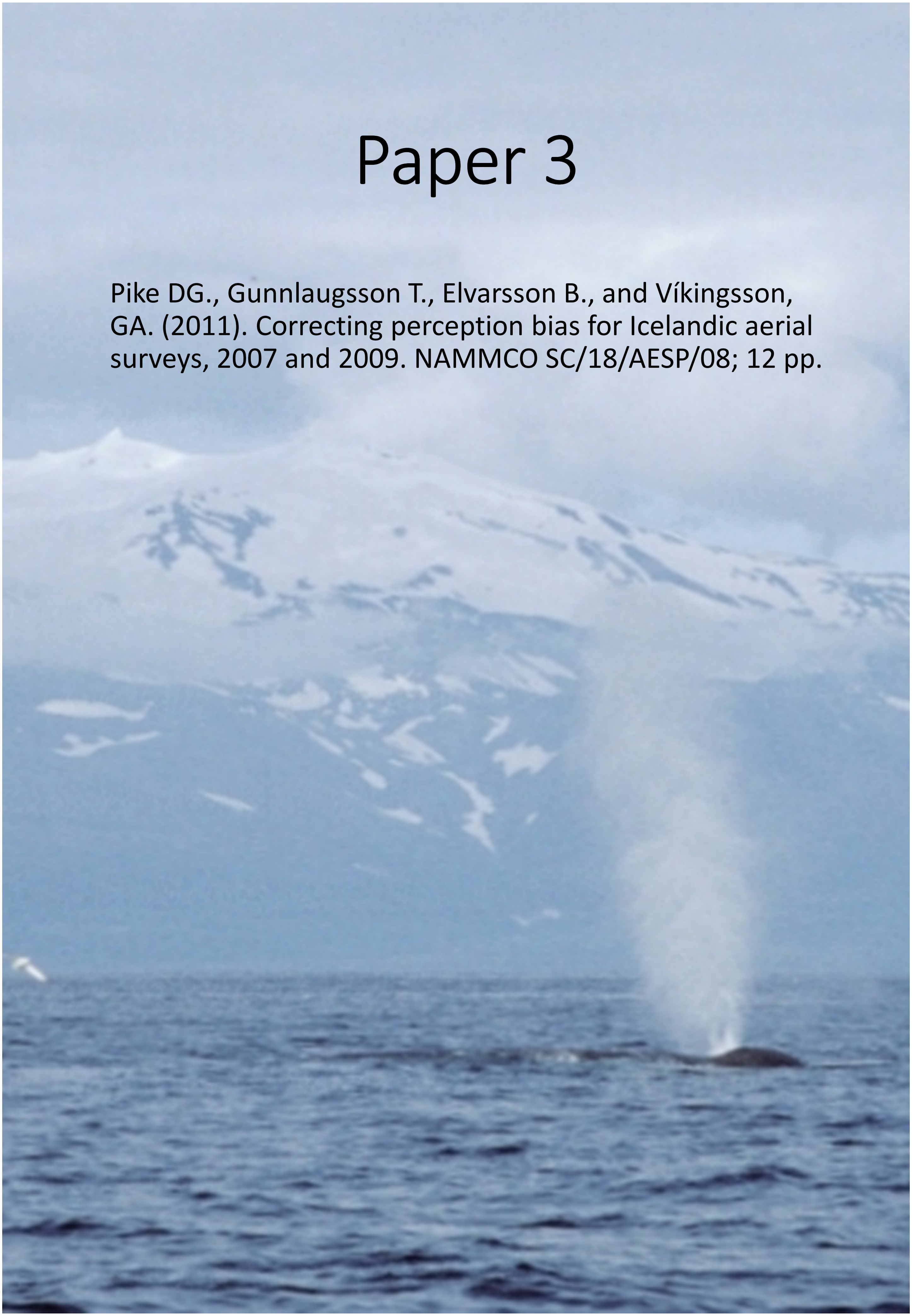

Correcting perception bias for Icelandic aerial surveys, 2007 and 2009.

Daniel G. Pike[1], Thorvaldur Gunnlaugsson[2] , Bjarki Þór Elvarsson and Gísli A. Víkingsson[2]

[1]*Esox Associates, 1210 Ski Club Road, North Bay, Ontario, Canada, P1B 8E5.* kinguq@gmail.com
[2]*Marine Research Institute, P.O. Box 1390, IS-121 Reykjavík, Iceland*

INTRODUCTION

The Icelandic aerial survey carried out in summer 2009 is a continuation of a series of surveys, using nearly identical design and methodology, conducted in 1987, 1995, 2001 and most recently in 2007 (Pike *et al.* 2008, 2009, 2011). The main target species of these surveys has been the common minke whale (*Balaenoptera acutorostrata*), however sightings of all species are registered. The cue counting procedure (Hiby and Hammond 1989) has generally been used only for minke and fin whales: for other species standard line transect methods are used. The cue-counting data collection procedure produces data suitable for either analytical method.

The 2009 survey was carried out primarily because the abundance of minke whales estimated from the 2007 survey was not consistent with earlier surveys. Pike *et al.* (2008) estimated that the abundance of minke whales in 2007 was just 24% of that estimated for 2001 by Borchers *et al.* (2009). Results from a partial survey carried out in 2008 suggested that the 2007 results might be anomalous (Gunnlaugsson 2009), which led to the decision to carry out another full survey in 2009.

Pike *et al.* (2008, 2011) presented abundance estimates for minke whales from the 2007 and 2009 surveys respectively. However these estimates were not corrected for bias due to visible whale cues that were missed by the observers, usually referred to as perception bias. Both surveys were run in a partial double-platform mode, and therefore provide data with which this bias can be estimated and corrected. There was evidence that animals were being missed at close distances in both surveys. Here we provide fully corrected abundance estimates for both surveys, using mark-recapture distance sampling techniques (Laake and Borchers 2004).

MATERIALS AND METHODS

A complete description of the methodology used and the results of the 2007 and 2009 surveys are provided by Pike *et al.* (2008, 2011) and will not be repeated here.

Abundance estimates using standard cue counting techniques are provided by Pike *et al.* (2008, 2011) for both surveys. For the 2007 survey, the authors provided estimates for the combined platforms, the primary platform and the primary platform excluding one of the observers. For 2009 estimates were provided for the combined platforms and for the combined platforms excluding one of the primary observers. At this point we are able to provide corrected estimates for the primary platform only, not for the combined platforms. Therefore a conventional cue counting analysis was carried out for the 2009 survey using the primary platform data only, to provide a baseline uncorrected estimate, using methodology identical to that of Pike *et al.* (2011), except that unique sightings by the cruise leader (CL) were excluded.

Double platform data were produced on the right side of the plane only. Data from the right side of the plane were therefore analyzed separately using mark-recapture distance sampling (MRDS) techniques (Laake and Borchers 2004) using DISTANCE 6.0 (Thomas *et al.* 2009). The present version of DISTANCE does not offer MRDS abundance estimation for point transects, of which cue-counting is a type. We therefore set up the analyses using radial rather than perpendicular distances and used the mark recapture module to estimate the proportion of available whales seen at distance 0 ($p(0)$).

For this analysis the independent observer (IO) configuration was used (Laake and Borchers 2004), which assumes the platforms are symmetrical. We assumed "full independence" (FI), wherein sightings from the platforms are considered independent at all distances, in the MR model. The following covariates were available for inclusion in the MR model: radial distance, platform, Beaufort sea state, glare (intensity, 0-3), sightability (subjective, 3 levels) and primary observer identity. Because one of the primary observers in the 2009 survey served only a short period and made only 4 sightings, additional models were tried with that observer's sightings combined with those of one of the other primary observers (*i.e.* 2 levels rather than 3). The final model was chosen by minimisation of Akaike's information criterion (AIC) (Buckland *et al.* 2001).

The estimated probability of detection at radial distance 0 ($p(0)$) for the primary platform, and its associated variance, was then applied as a multiplier to the standard estimate for that platform, under the assumption that $p(0)$ was the same for the right and left sides. For the 2007 data an additional estimate was performed utilizing the sightings of just one of the primary observers. Bootstrap variance estimates were used and 95% confidence intervals were taken as the 2.5 and 97.5 percentiles of the bootstrap distributions.

RESULTS

2007 survey

Detailed results for the primary platform uncorrected estimate were not provided by Pike *et al.* (2008) so they are provided here. A truncation distance of 1,200 m was chosen, and a half-normal model with one cosine adjustment term and no covariates best fit the detection function (Fig. 1). The total uncorrected estimate was 10,634 (95% CI 5,459, 18,262) (Table 1). This is very close to the uncorrected combined platform estimate of 10,680 (95% CI 5,873, 17,121) detailed by Pike *et al.* (2008).

The best MR model for the right side duplicate data included radial distance, platform and their interaction term as covariates, and resulted in an estimated $p(0)$ of 0.71 (cv 0.25) for the primary platform, 0.13 (cv 0.57) for the secondary platform and 0.75 (cv 0.20) for the combined right side platforms. The proportion of secondary platform sightings seen also by the primary platform decreased with distance, while the converse was true for the proportion of sightings seen by the primary platform seen also by the secondary platform (Fig. 2). The corrected total estimate was 18,262 (95% CI 7,381, 24,919) (Table 1). Post-stratification reduced both the uncorrected and corrected estimates by 11%.

The total uncorrected estimate for the single observer referred to as P2 by Pike *et al.* (2008) was 15,055 (95% CI 6,357, 27,278) (Table 2, details given by Pike *et al.* (2008)). The best MR model again included radial distance, platform and their interaction term, and resulted in an estimated $p(0)$ of 0.72 (cv 0.24) for the primary platform, 0.14 (cv 0.56) for the secondary platform and 0.76 (cv 0.18) for the combined right side platforms. The behaviour of the model with regard to duplicate sighting proportions was identical to that described above (Fig. 3). The corrected total estimate was 20,834 (95% CI 9,808, 37,042), with post stratification reducing the estimates by 15% (Table 2).

2009 survey

An uncorrected estimate for the primary platform only was not provided by Pike *et al.* (2011) so it is detailed here. A truncation distance of 1,600 m was chosen for these data. A half-normal function with no adjustment terms and including a covariate for observer identity resulted in the lowest AIC, however the resultant Effective Detection Radius (*EDR*) was greatly affected by only 4 sightings by observer CL, leading us to regard this model as being overfitted. We therefore chose a more conservative model using a half-normal function with no adjustment terms and including a covariate for 2-level observer identity (combining observers CL and P1), which resulted in an *EDR* of 849 m as opposed to 775 m for the former model (Fig. 4). The total uncorrected estimate was 5,284 (95% CI 2,915, 7,822) (Table 3), which is close to the estimate for the combined platforms of 5,900 (95% CI 3,423, 8,803) provided by Pike *et al.* (2011).

The best MR model for the right side duplicate data included only radial distance as a covariate and resulted in an estimated $p(0)$ of 0.55 (cv 0.10) for both the primary and secondary platforms and 0.79 (cv 0.06) for the combined right-side platforms. The model estimated that the proportion of duplicates seen by each platform decreased with distance although the actual distributions appear rather flat (Fig. 5). The corrected total estimate was 9,588 (95% CI 5,274, 14,420), with post-stratification reducing both the corrected and uncorrected estimates by 5%.

DISCUSSION AND CONCLUSIONS

Potential biases

This analysis eliminates the most important source of bias in these estimates: so-called perception bias, or visible cues being missed by observers. It was clear that observers did miss cues close to the plane in both surveys, and the available evidence indicates that this proportion for the primary platform was about 29% in 2007 and 45% in 2009.

The 2007 uncorrected estimate for the single primary observer is 42% greater than that for the full primary platform. We therefore expected $p(0)$ to be lower for the full primary platform than for the single observer primary platform. However they are nearly the same, so the corrected estimates differ by a similar proportion. Observer P1 made only 9 minke whale sightings while on the right side of the plane and duplicated none of the sightings made by the Cruise Leader (secondary platform). Therefore there is virtually no data with which to estimate $p(0)$ for this observer, which must be lower than that for observer P2. This explains why the $p(0)$ values for the single and dual observer primary platform are so similar. For this reason we think the corrected dual observer primary platform estimate is still negatively biased, and regard the single observer corrected estimate as the more accurate of the 2 provided.

The magnitude of $p(0)$ for the primary platform was lower in 2009 than 2007, and also lower than that for the full primary platform in the 2001 survey, estimated as 0.78 (cv 0.27) by Borchers *et al.* (2009). However, as noted above, we believe that the $p(0)$ for the full primary platform in 2007 is overestimated. The *EDR* estimated for the 2009 survey is greater than that for any other year. It appears that the observers in 2009 were scanning a wider area than in other years, which led to them missing a higher proportion of nearby cues. In future surveys a greater emphasis should be placed on instructing observers to concentrate their efforts closer to the plane.

The second source of bias to be addressed results from the geometry of the area searched during cue counting. Because the area is semi-circular, the surface area of the search area increases as a squared function of the radial distance from the search platform. Because of this, random error in the measurement of radial distance results in a net transfer of sightings towards distance 0. Borchers *et al.* (2009) developed maximum-likelihood estimators for distance sampling surveys in the presence of measurement. Conventional distance sampling estimators were found to be substantially biased by measurement errors when the cv of measurement error is not small (greater than about 10%). The cv for measurement error was 11% for the 2007 survey and 10% for the 2009 survey. Therefore the positive bias due to measurement error is likely not significant for these data.

Comparison to earlier surveys

When comparing abundance estimates from these aerial surveys it is important to bear in mind that the survey area constitutes only a small part of the Central North Atlantic stock area. The remaining areas were covered by vessel effort in 1987, 1995, 2001 and 2007. Unfortunately the aerial effort in 1995 and shipboard effort in 2007 were of insufficient quality to produce a reliable total population abundance estimates for these years.

Pike *et al.* (2011) summarized the trend in what were then the best available abundance estimates for minke whales in the survey area, from surveys conducted in 1987, 2001, 2007, 2008 (block 1 only) and 2009. The estimate for 1995 was not included as it is not considered reliable. Abundance was stable or slightly increasing in most strata and in the total survey area between 1987 and 2001. It decreased sharply by 2007 in all areas, such that total abundance in 2007 was 24 – 35% (depending which of the two estimates from 2007 is used) that from the 2001 survey. Abundance in block 1 in 2008 (the only block surveyed that year) rebounded to a level similar to that seen in 2001. However by 2009 abundance was the lowest yet seen in all areas, just 40 – 55% that observed in 2007 and 14% that estimated in 2001. Of particular note is the continued near total absence of minke whales from block 8 in recent surveys. This was an area of high density before 2007. There also appears to have been a shift in abundance to the northern part of the survey area. Whereas blocks 4 and 5 held 25% of the total estimated number of minke whales in 2001, they held 38% in 2009.

The corrected abundance estimates for 2007 and 2009 presented here change these conclusions only by degree. All estimates except that for block 1 in 2008 are now fully corrected for known biases. The best available estimate of abundance for 2007 was 48% that for 2001. Abundance in 2009 remains the lowest yet seen in all areas, just 46% that observed in 2007 and 22% that estimated in 2001. The latter difference is significant ($P<0.05$).

Pike *et al.* (2011) also examined trends in line transect density, as an indicator of relative abundance, which revealed a pattern quite similar to that explained above. They considered several possible reasons for the observed decline, including changes in temporal and/or spatial distribution and a real decline of the population. They concluded that the decline in numbers of minke whales in coastal Icelandic waters during late June-mid July, first detected in 2007, was confirmed by the 2009 survey. We concur with that conclusion.

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REFERENCES

Borchers, D.L., Pike, D.G., Gunnlaugsson, Th. and Vikingsson, G.A. 2009. Minke whale abundance estimation from the NASS 1987 and 2001 aerial surveys using cue counting with distance estimation errors. *NAMMCO Sci. Publ.* 7:95-110.

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.

Gunnlaugsson, Th., Víkingsson, G.A. and Rasmussen, M.H. 2008. Aerial survey in Faxaflói, Southwest Iceland in 2008, Report and comparison to earlier surveys. SC/61/RMP 11 for the IWC Scientific Committee.

Hiby, A.R. and Hammond, P.S. 1989. Survey techniques for estimating current abundance and monitoring trends in abundance of cetaceans. *Rep. Int. Whal. Commn* (Special issue 11):47-80.

Laake, J.L. and Borchers, D.L. 2004. 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.

Pike, D.G., Gunnlaugsson, Th. and Víkingsson, G.A. 2008. 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., Paxton, C.G.M., Gunnlaugsson, Th. and Víkingsson, G.A. 2009. Trends in the distribution and abundance of cetaceans from aerial surveys in Icelandic coastal waters, 1986-2001. *NAMMCO Sci. Publ.* 7:117-142.

Pike, D.G., Paxton, C.G.M., Gunnlaugsson, Th. and Víkingsson, G.A. 2011. Icelandic aerial survey 2009: Survey report and a preliminary abundance estimate for minke whales (Revised). SC/17/AS/07 for the NAMMCO Scientific Committee Working Group on Assessment, revised after the meeting for the NAMMCO Working Group on Abundance Estimates, 2011.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, Bishop, J.R.B. S.L., Marques, T.A., and Burnham, K.P. 2009. Distance software: design and analysis of distance sampling surveys for estimating population size. *J. Appl. Ecol.* DOI 10.1111/j.1365-2664.2009.01737.x

BLOCK	*edr* (m)		*h(0)*		*n*	*n/T*		*D*	*N*		CI L	CI U	*p*(0)		N_C		CI L	CI U
1					21	1.9624	0.25	0.4588	2,027	0.39	756	3,749			2,870	0.39	1,059	5,430
2A					1	0.3227	0.97	0.0741	132	1.05	0	476			178	1.03	0	623
2B					2	0.9050	0.62	0.2049	452	0.69	0	1,163			616	0.69	0	1,590
2					3		0.00	0.1458	582	0.60	0	1,318			804	0.61	0	1,975
3					0													
4					9	0.9883	0.44	0.2289	2,837	0.43	778	5,485			3,729	0.45	1,064	7,300
5	421	0.09	1.15E-05	0.29	1	0.2511	0.98	0.0604	651	1.10	0	2,338	0.71	0.25	880	1.05	0	3,104
5P					1	0.2564	0.98	0.0585	352	1.00	0	1,153			495	1.03	0	1,707
6					7	1.7603	0.45	0.4001	1,441	0.52	260	3,116			2,007	0.53	378	4,346
7					3	0.8569	0.35	0.2000	2,876	0.48	646	5,795			4,051	0.48	941	8,661
7P					6	0.8460	0.36	0.1974	1,986	0.46	476	4,002			2,817	0.47	690	5,905
8					1	0.2494	0.96	0.0585	218	1.11	0	898			307	1.22	0	1,210
9					0													
9P					0													
TOTALP					**45**			**0.1269**	**9,200**	**0.28**	**4,568**	**14,781**			**13,089**	**0.28**	**6,910**	**21,229**
TOTAL					**45**			**0.1243**	**10,634**	**0.30**	**5,459**	**18,262**			**14,638**	**0.30**	**7,381**	**24,919**

Table 1. Abundance of minke whales from the 2007 Icelandic aerial survey, primary platform estimate. using the original and post-stratified (P) blocks *edr* - effective detection radius (m), *h(0)* – slope of the detection function at radial distance 0; *n/T* - encounter rate, cues per hr; *D* - density, whales/nm^2, *N* - abundance estimate, CI - bootstrap 95% confidence interval; *p*(0) – proportion of visible cues seen at radial distance 0; N_c – corrected abundance estimate. Coefficients of variation are in parentheses.*esw* – effective strip width (m), *n/T* - encounter rate, sightings per nm; *D* - density, whales/nm^2, *N* - abundance estimate, CI - bootstrap 95% confidence interval. Coefficients of variation are follow the point estimates.

BLOCK	*edr* (m)		*h(0)*		*n*	*n/T*		*D*	*N*		CI L	CI U	***p*(0)**		N_C		CI L	CI U
1					11	1.012	0.31	0.4903	2,166	0.46	659	4,529			2,974	0.47	888	6,316
2A					1	0.296	1.02	0.1499	267	1.22	0	1,004			367	1.11	0	1,339
2B					2	0.883	0.64	0.4134	913	0.69	0	2,314			1,239	0.68	0	3,117
2					7		0.00	0.2902	1,157	0.61	0	2,838			838	0.62	0	1,930
3					0													
4					2	0.215	0.67	0.1058	1,311	0.78	0	3,917			1,834	0.81	0	5,444
5	417	0.12	1.17E-05	0.31	1	0.258	0.98	0.1186	1,278	0.99	0	4,182	0.72	0.24	1,855	1.00	0	6,331
5P					1	0.269	0.98	0.1243	747	1.05	0	2,488			1,040	0.95	0	3,459
6					7	1.650	0.46	0.7754	2,793	0.51	456	5,884			3,991	0.51	760	8,661
7					3	0.845	0.37	0.4088	5,880	0.49	1,449	12,119			7,946	0.49	1,877	16,438
7P					3	0.866	0.35	0.4189	4,215	0.47	1,096	8,487			5,578	0.49	1,020	11,126
8					1	0.235	0.99	0.1197	446	1.12	0	1,831			628	1.05	0	2,325
9					0													
9P					0													
TOTALP					**28**			**0.1807**	**13,091**	**0.33**	**5,792**	**23,035**			**17,650**	**0.34**	**7,220**	**30,695**
TOTAL					**28**			**0.1760**	**15,055**	**0.36**	**6,357**	**27,278**			**20,834**	**0.35**	**9,808**	**37,042**

Table 2. Abundance of minke whales from the 2007 Icelandic aerial survey, primary platform estimate, observer P2 only, using the original and post-stratified (P) blocks. See Table 1 for details.

BLOCK	*edr* (m)		*h(0)*		*E(s)*		*n*	*n/T*		*D*	*N*		CI L	CI U	*p*(0)		N_C		**CI L**	**CI U**
1							53	4.926	0.31	0.2925	1,292	0.41	353	2,395			2,326	0.40	780	4,372
2							4	1.451	0.25	0.0822	328	0.32	116	527			590	0.33	205	959
3							3	0.501	0.63	0.0301	423	0.56	0	959			776	0.54	0	1,726
4							19	2.312	0.45	0.1341	1,662	0.41	560	3,196			3,006	0.42	1,089	6,103
5	849	0.05	2.81E-06	0.17	1.01	0.02	3	0.914	0.58	0.0542	585	0.59	0	1386	0.55	0.10	1,074	0.54	0	2,436
6							1	1.247	0.91	0.0746	269	0.83	0	751			475	0.85	0	1,374
6P							1	1.247	0.91	0.0744	142	0.85	0	404			252	0.84	0	737
7							0													
8							0													
9							5	0.686	0.41	0.0399	725	0.52	127	1577			1,341	0.51	232	2,848
9P							5	0.686	0.41	0.0400	567	0.49	110	1216			1,060	0.50	175	2,211
TOTALP										**0.0624**	**4,978**	**0.25**	**2,691**	**7,569**			**9,129**	**0.24**	**5,084**	**13,766**
TOTAL										**0.0618**	**5,284**	**0.24**	**2,915**	**7,822**			**9,588**	**0.24**	**5,274**	**14,420**

Table 3. Abundance of minke whales from the 2009 Icelandic aerial survey, primary platform estimate, using the original and post-stratified (P) blocks. See Table 1 for details.

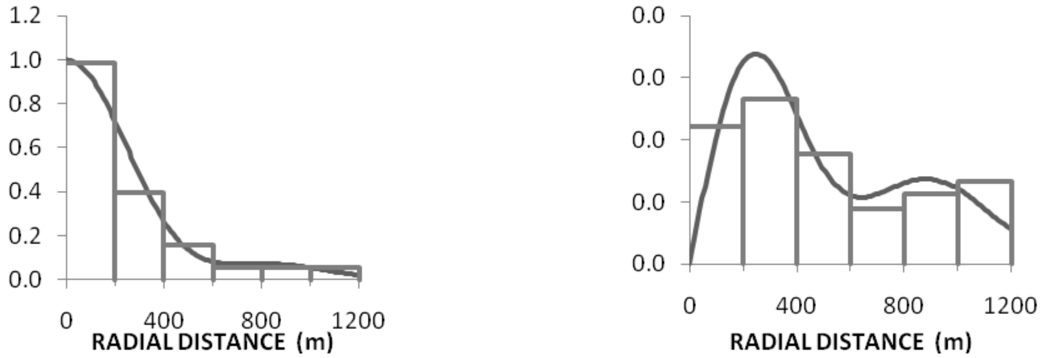

Fig. 1. Detection functions for primary observers in 2007, showing detection probability scaled in inverse proportion to radial distance squared (left panel) and observed probability density (right panel).

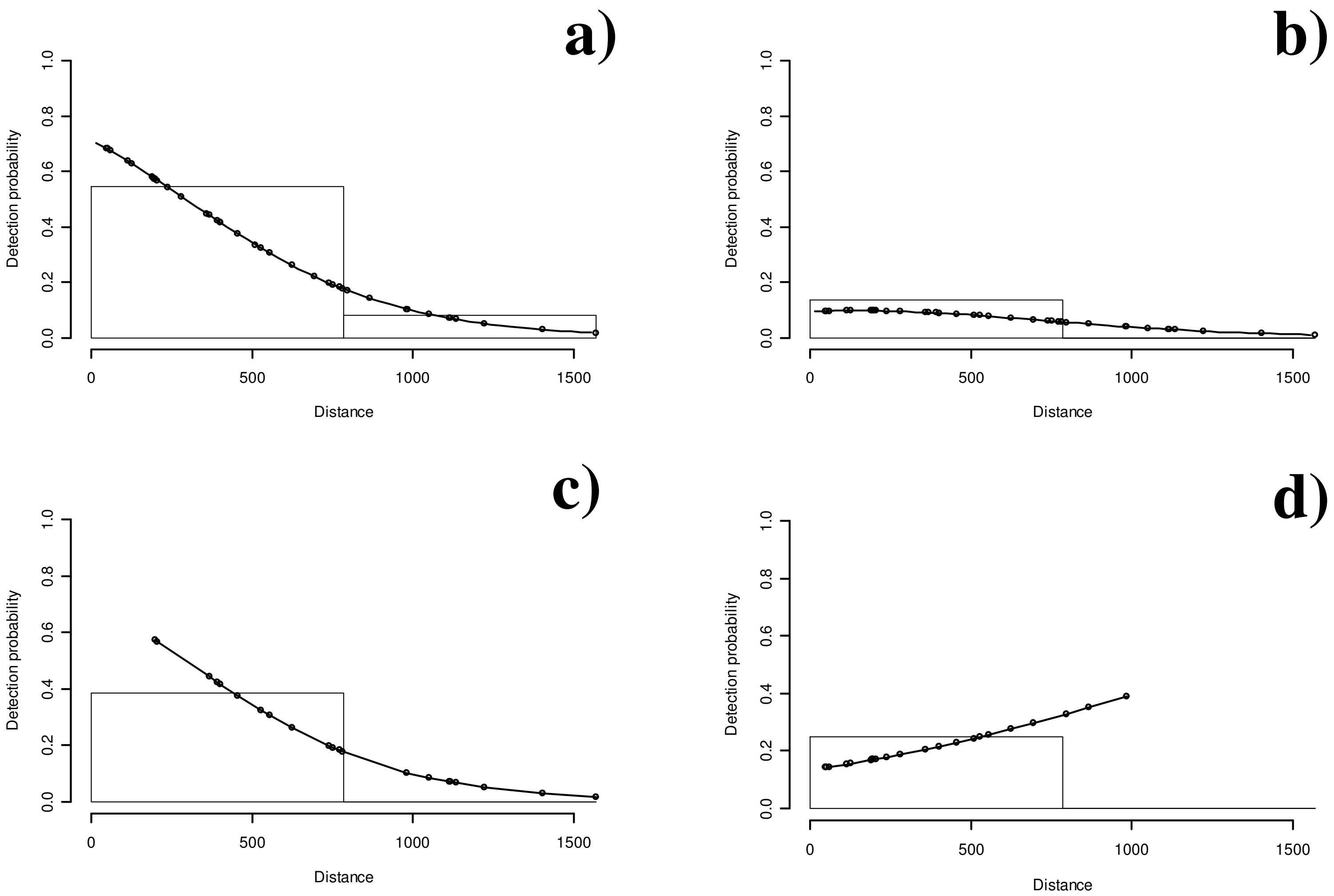

Fig. 2. Conditional (MR) detection function for the full primary platform, 2007. Plotted points are the estimated probability of detection for each sighting, and the bars show the actual data distribution. a) Primary platform, probability of detection by radial distance; b) duplicate detections by radial distance; c) Proportion of secondary platform sightings seen by primary platform; d) proportion of primary platform sightings seen by secondary platform..

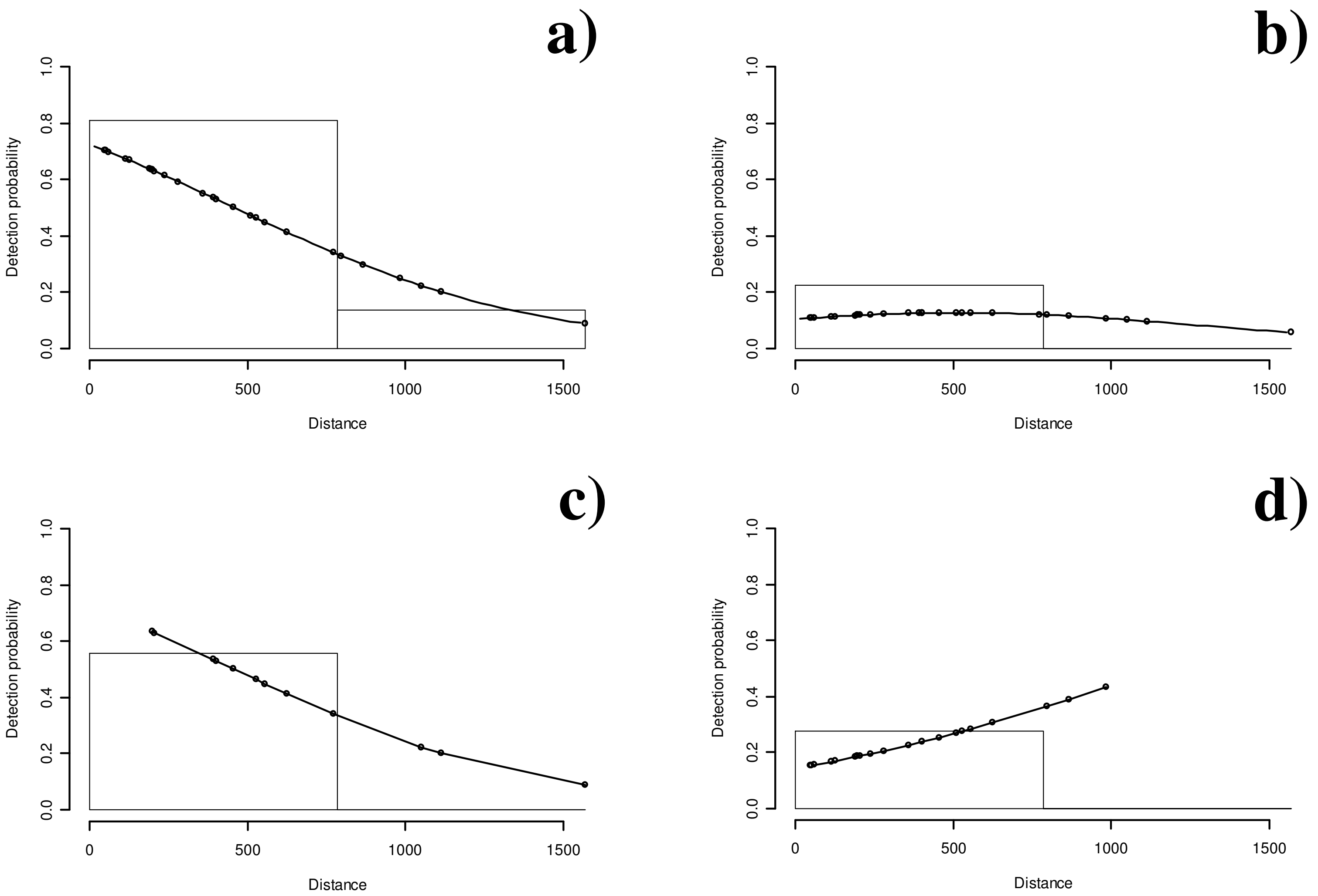

Fig. 3. Conditional (MR) detection function for the primary platform, observer P2 only, 2007. See Fig. 2 for details.

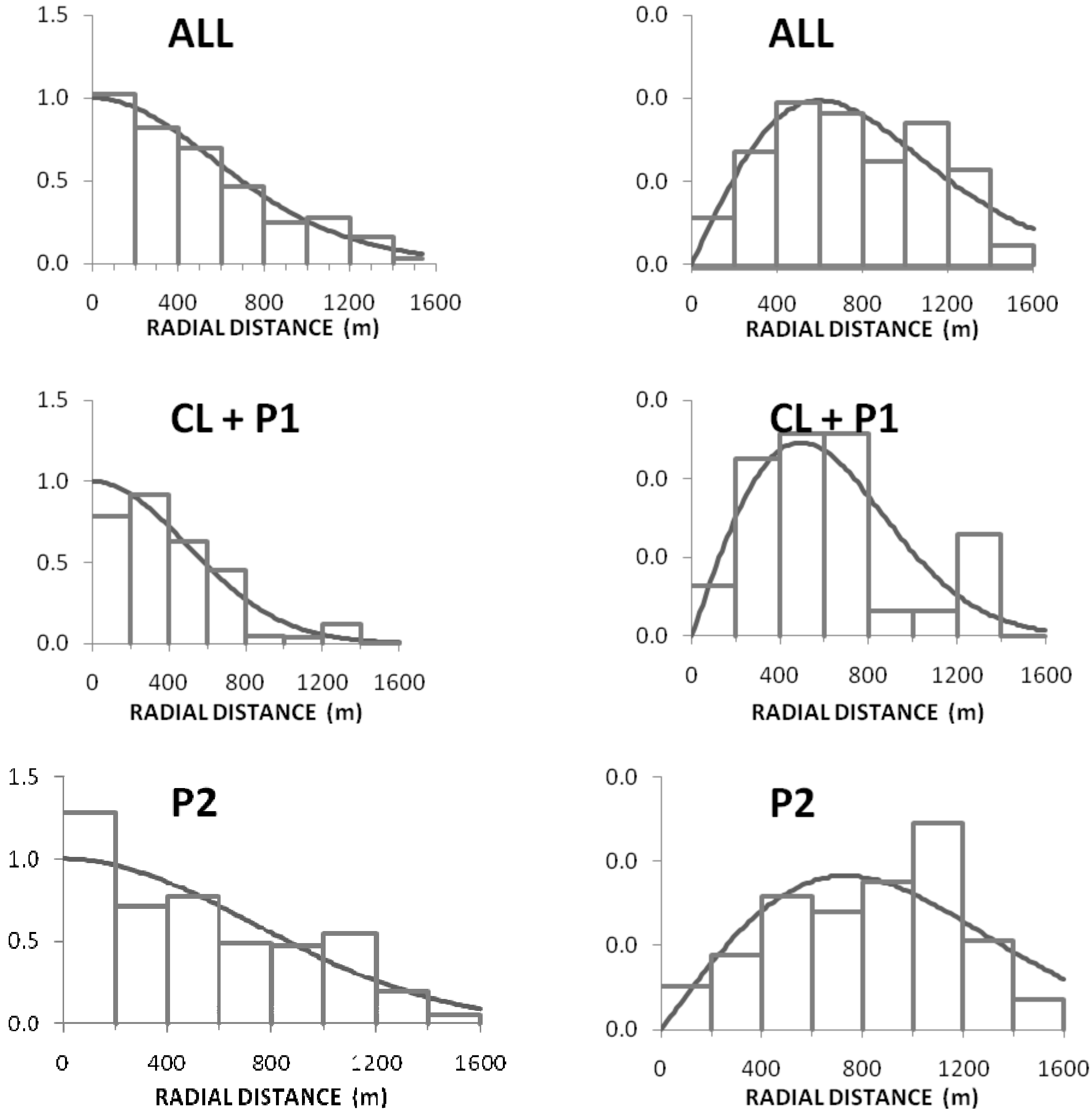

Fig. 4. Detection functions for primary observers in 2009 (top) and by observer (observers CL and P1 combined) for minke whales, showing detection probability scaled in inverse proportion to radial distance squared (left panels) and observed probability density (right panels

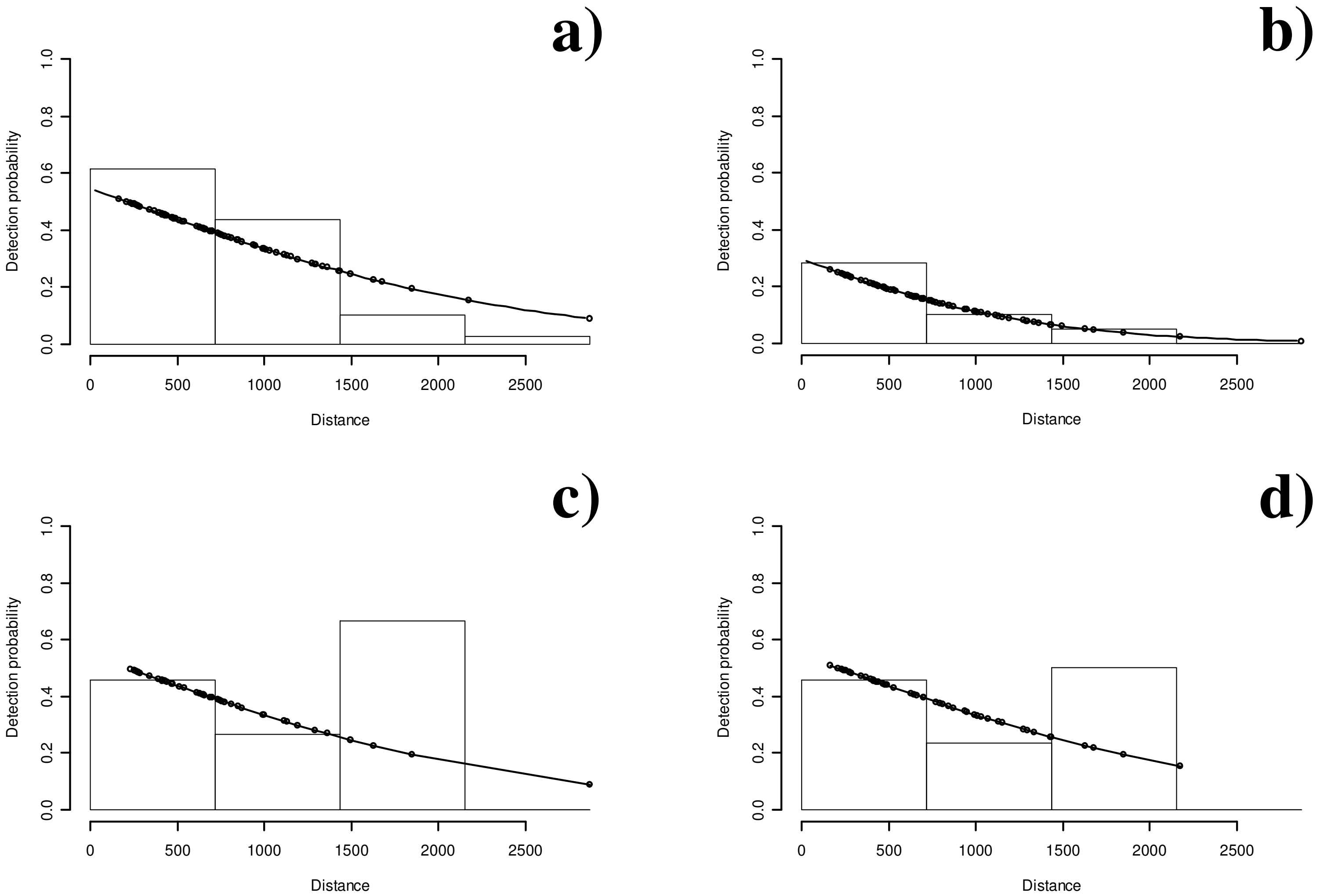

Fig. 5. Conditional (MR) detection function for the primary platform, 2009. See Fig. 2 for details