Changes in minke whale distribution and abundance by season and over time in aerial surveys off Iceland 1986-2009.

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ABSTRACT

The results of aerial surveys covering most of the continental shelf waters of the Icelandic economic zone at intervals, 1987 to 2009 are summarized with respect to temporal and seasonal features given recent observed ecosystem changes. The off season component of these surveys was a part of the Icelandic Research Program of Common Minke Whales. The same observers have participated in only a few of these surveys, but it is found that although there are some observer differences the changes in minke whale sighting rates between years are fairly consistent for the two primary observers (on the left and right side of the plane) and consistent in repeated coverage of the same blocks within survey. The observers differ more in their detection functions and therefore the estimates derived from the fit of these to the data, also when including corrections for animals missed by the observers based on limited independent observer data. Sighting rates of the smallest whales (harbour porpoises) differ greatly by observers and the sighting rates of large whales are inflated if the observer has more effort at greater distances from the track line. Sighting rates of minke whales are a more robust index of relative presence in the areas in particular when comparing the off-season surveys during times of low density and therefore few sightings. Sighting rates are lowest in the spring (late April – early May). In September sighting rates are 1/3 of the midsummer rates, but variation between years is even greater and there has been a change over time in species distribution in the area.

INTRODUCTION

Aerial surveys covering most of the continental shelve waters of the Icelandic economic zone (the CIC sub area) with minke whales (*Balaenoptera acutorostrata*) as the primary target species have been conducted 6 times since 1986 (Gunnlaugsson *et al.*, 1988) during the assumed peak abundance in June and July (midsummer surveys). The aerial surveys conducted in 1987 ((Donovan and Gunnlaugsson, 1989), 1995, 2001 (Pike *et al.* 2002; Borchers *et al.*, 2009) and 2007 (Pike, Gunnlaugsson, *et al.*, 2008) were components of the large scale international NASS surveys (Pike *et al.*, 2009; Víkingsson *et al.*, 2009). The last full aerial survey was in 2009 (Pike, Gunnlaugsson, and Víkingsson, 2011).

In addition to these full scale surveys, several partial surveys have been conducted in the area in recent years. These include surveys in Faxaflói bay (block 1) in late July 1988 and September 2003 that were conducted under the control of foreign scientists for methodological experimentation (Witting, 2004; Witting and Pike, 2004a, 2004b). Surveys in the spring, midsummer (Gunnlaugsson *et al.*, 2004; Gunnlaugsson, 2005) and autumn 2004 (Víkingsson *et al.*, 2005) and spring 2005 (Víkingsson *et al.*, 2006) were a part of the Research programme on common minke whales (Marine Research Institute, 2003). In addition, a midsummer survey was conducted in block 1 in 2008 (Gunnlaugsson *et al.*, 2009)

Here earlier analysis will be considered and sighting rates of different species compared, in particular with respect to seasonal variation in distribution and abundance.

EQUIPMENT AND PROCEDURES

The airplane used in all the survey was a Partenavia Observer P-68, with one bubble window on each side of the plane. All the surveys have been flown at an altitude of 750ft (229m) except in 2007 when the altitude was 600ft (183m). The target ground speed has been 90 knots. The realized speed has been around 100 knots. The same aircraft has been used since 1995 with mostly the same pilot. Survey effort was generally abandoned if Beaufort sea state (BSS) increased above 3, or if fog, mist or heavy rain obscured visibility as estimated by the scientist (generally in the copilot seat). The same scientist was on the 1986-1988 surveys. The scientist in 1995 had been an observer in 1987 and 1988. The same scientist has been on all the full surveys since 2001 and on the spring surveys. Some scientists and observers in the Icelandic surveys have participated in surveys using similar methodology conducted off West Greenland in 1987, 1989 and 1993 (Larsen *et al.*, 1989; Donovan, 1990; Larsen, 1995) and in September 2005 (Heide-Jørgensen *et al.*, 2008) and 2007 and recently in Antarctica (Kelly *et al*., 2009) and the Faroe Islands (Gilles *et al*., 2011).

Inclinometers have been used in all the surveys for measuring the declination angle to sightings at some point, usually as they came abeam, but sometimes before. In the latter case the lateral angle was estimated using an angle board.

Sightings were sometimes investigated for species identification, but closing on uncertain minke whale and harbour porpoise sightings has generally not been productive.

MATERIAL

The surveys in 1988 and 2008 only covered block 1. Most other midsummer surveys have up to double covered this block, but have also had a relatively even coverage in other blocks. An exception is 2004 when coverage was less than half in block 1 as well as other blocks. Problems with coverage have been greatest of the east coast due to frequent fog there when there is calm. In 1986 and to a lesser extent in 2007,the north west corner of the survey area including parts of the western half of blocks 4 and 5 was ice covered, but this has not been a significant problem in other years.

The main effort in the spring and autumn surveys was in block 1, with less than half the normal survey effort in other blocks. In the autumn of 2003 there was no effort outside block 1.

Since 1987 (Donovan and Gunnlaugsson, 1989) the cue counting procedure (Hiby and Hammond, 1989) has been used for this species to facilitate absolute abundance estimation (Hiby and Ward, 1989), which is unbiased by diving animals (availability bias) when given the cue rate of the animals. For this purpose the location of each cue relative to the platform is recorded. For minke whales the cue is defined as each surfacing (the breaking of the surface) since blows are generally not visible. Only the radial distance to each cue within a chose sector is used in this procedure. The declination angle to each cue would be sufficient, but in practice this requires a time for the cue and a time at which the declination and lateral angles to the location were taken. These data were audio recorded with the timing of each cue. This also facilitates the calculation of also perpendicular (and forward) distances. Most minke sightings are of a single animal and rarely more than two. In most cases a single cue is observed in the sector up to abeam which is used in the cue counting analysis, but in some cases the animal is only seen under water there. More than one cue from the same animal before abeam is exceptional, but may be seen in very good conditions. Initial sighting locations of all other cetacean species have generally also been systematically recorded. In 1986 mostly only the perpendicular distance to sightings (declination angle abeam) was recorded (no audio recording). The observers may then have concentrated their search effort along the track line ahead as in line transect surveys, but not in the sector close to the plane, as more reasonable in cue count surveys.

In 1986 there were also some differences in the track design, but the same track design has been used since 1987 (Fig 1). In partial surveys the tracks in some blocks were modified to connect only every other vertex in the design. In 1987 some duplicate platform information was collected in block 1 by keeping the observer in the copilot seat in the front seat independent from the primary observer in the seat behind. Since 2001 such double platform information has been collected full time in the large scale surveys. This facilitates correction of abundance estimates also for the perception bias of observers (Pike, Gunnlaugsson, Elvarsson, *et al*., 2011) but the view from the copilot seat of the area close to the plane is limited, which results in low precision in these corrections. A bias that may be caused by distance estimation errors or rounding can also be assessed from the duplicate data and corrected for (Borchers *et al*., 2010) but has in later surveys, with pre-training of observers, been insignificant. In later surveys attempts have been made to get estimates of the declination angle both initially and abeam. This allows for comparison of the resulting distance estimates. The same applies when both the initial angle to the heading of the plane and the time to abeam are available.

METHODS

Estimates of minke whale abundance have been presented for the full surveys where independent observer (IO) data is available. For 1987 and 2001 in Borchers *et al.* (2009) and 2007 and 2009 in (Pike, Gunnlaugsson, Elvarsson, *et al*., 2011). The corrections for the perception bias are based on the limited IO data that is only for one side of the plane and in 1987 collected only partly in one block. In some instances these estimates therefore had to be based on only one observer. Comparable estimates can not be obtained for the 1986 and 1995 surveys when no IO data was collected and although the partial or off season surveys have generally collected IO data the low effort, lower off season density and resultant low number of sightings in these surveys would cause corrected estimates to have large associated variances. It turned out to be impossible to recruit the same observers repeatedly for these surveys which would have opened up the possibility of obtaining a correction for perception bias across surveys.

Pike *et al.* (2009) presented a trend analysis based on the 1986 to 2001 surveys using traditional line-transect analysis for the 4 main species observed. In Pike, Gunnlaugsson, and Víkingsson, (2011) this analysis is updated for minke whales for the mid summer surveys 2007 and 2009 (excluding the 2004 partial survey). 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*., 2001). Depending on significance different covariates were incorporated in different years. The underlying assumption of the analysis was that a larger number of sightings by one observer would be reflected in proportionately larger perpendicular sighting distances.

Gunnlaugsson, (2005) reported on a GLIM analysis of all aerial surveys with block and season effects, but also including factors for sea state, cloud cover and glare estimated across all the surveys and found sighting rates of minke whales in the spring and autumn 7% (cv .32) and 36% (cv .11) of midsummer rates respectively. These results are mainly a function of the 2004 surveys (Pike *et al*., 2004; Víkingsson *et al*., 2005). The 2005 survey in April (Vikingsson *et al.* 2006) was not available in this analysis, but the low sighting rates then would strengthen these results. The basic assumption in such an analysis is that the sighting efficiency of the platform as a whole is relatively constant and that larger sighting distances in one survey would result in a compensating higher loss of sightings closer to the plane.

Here the assumptions for the mentioned analysis are reviewed and sighting rates of different species compared.

RESULTS

A full graphical presentation is given of these surveys up to 2001 in Pike *et al.* (2009). The surveys after 2001 have been presented individually before and are reproduced here in figs 1-7. The 1988 (Gunnlaugsson *et al.* 2009) and 2003 surveys were limited to block 1 and are not in these presentations, but are included in the dataset.

Generally the largest number of sightings in these surveys are minke whales in total 1452, but the largest number of animals are dolphins 6900 in 1150 sightings of genus Lagenorhychus, almost exclusively white beaked dolphins (*Lagenorhynchus albirostris*). Then humpback whales (*Megaptera novaeangliae*) 769 in 522 sightings and the harbour porpoise (*Phocoena phocoena*) mostly pairs in 356 sightings. In total 26 blue (*Balaenoptera musculus*) whale sightings have been made in these surveys and all but 3 in 1987 and 2001. These sightings were west of Iceland. Fin (*Balaenoptera physalus*) whale sightings 61 and sei (*Balaenoptera borealis*) whales 6 are mostly at the outer reaches to the south and west. Unspecified large baleen whale sightings, generally distant blows, are 43. Large whale sightings are generally of 1 to 3 animals. Sperm whales, mostly single, total 33 sighting and are generally seen in deep waters. The 63 Pilot (*Globicephala melas*) whale sightings are some of very large groups to the south of Iceland. Northern bottlenose (*Hyperoodon ampullatus*) whales totalled 12 in deep waters to the south east and a few unidentified beaked whales in deep waters south of Iceland. Sightings of killer whales (*Orcinus orca*) total 50 and their occurrence is quite variable, as also seen in ship surveys (Foote *et al*., 2007)

Minke whales appear to be the most coastal of all cetaceans around Iceland although north of Iceland densities are similar in the inner block (4) as the outer (5). This applies to dolphins and harbour porpoises as well, but these species may also be in similar densities in the outer block west of Iceland (3) as the inner blocks (1,2). Other large and medium sized whales are rare in the inner survey blocks, mostly humpback whales, seen at the outer reaches of the survey area so variation in occurrence of these species may be largely due to a shift in or out of the survey area.

Table 1a and b give sightings of minke, dolphins and large whales in the Faxaflói bay area (survey block 1) and the area north of Iceland (blocks 4+5) from all surveys in these areas. Block 1 has in general been the highest density area and together with the northern blocks constituted most of the abundance estimates of minke whales in the survey area. Humpback whales are rarely seen in block 1 so all the most likely large baleen whale sightings were combined. An additional column gives the ratio of dolphin sightings to minke sightings. The high value for 2004 in block 1 is striking, but only the second transect set was flown and sighting conditions were exceptionally good and sighting distances are greater than during the rest of this survey and in most other surveys. Sighting rates in other blocks were similar to those in 2001.

A comparison of the number of sightings of these species by observers is given in table 2a and b. Porpoises are hard to detect from an altitude of 750ft. In most years the number of porpoise sightings is too small for a meaningful comparison but in 1995 one observer (S) made a total of 46 sightings while the other primary observer made 12. The 2007 survey was flown at a lower altitude of 600ft than other surveys. This was done in an effort to obtain an estimate of porpoise abundance and with participation of a foreign observer that had such experience and this observer (A) made 78 porpoise sightings while 39 were made on the other side. In 2009 one observer (V) makes 22 sightings while 12 are made on the other side. In general the youngest observer has made the most porpoise sightings. Observers with larger number of porpoise sightings did not make noticeably larger numbers of sightings of other species nor had shorter sighting distances to these. Porpoise sightings have been found to be much more sensitive to sighting conditions than the other species (Pike *at al.* 2009). For this reason no attempt is made to compare porpoise sighting rates to other species.

Noticeable observer differences in sighting rates that are consistent between blocks are rare. There is consistent difference in 1995 and the observer making fewer sightings has shorter sighting distances. However in 2001 observer E makes fewer minke sightings, but at greater distances than the other observer. The independent observer data available then confirmed that this observer missed some cues at close range, while for the other observer this was insignificant. The observer V in 2009 makes more sightings of all species than the observers on the other side, but the sighting distances to minke whales are much greater for this observer and greater than for any observer in other years. A correction for perception bias was large for this survey. It is a surprise that this observer also makes significantly more porpoise sightings which are only made at close range. Sighting distances for this observer were not exceptional in 2004 and 2008. Overall though, the observer differences are small within surveys compared to the differences between years, when the observers are combined. Comparison by observer between surveys is limited due to changes in observers, but there is no reason to believe there were large differences in the survey teams as a whole. For instance observer N was on both the highest and lowest surveys. In general two sets of transects (differed in 1986) were flown in the bay and sighting rates from these within survey are given in able 3 and are also quite consistent. Differences seen within the same year can largely be explained by sighting conditions such as in 1988 when the later attempts could not be finished due to high sea state.

In block 1 sightings rate per hour of dolphins is from 1/2 to 1/4 of the sightings rate of minke whales with the exception in 1986 of a higher ratio, but transects, searching and recording procedures were different then. There is a rather downward trend in this ratio in block 1, with some exception in 2004 that had the highest sighting rates, but survey effort was then low in block 1, while in the North (blocks 4+5) dolphins have clearly increased relative to minke whales and peak in 2009.

The lowest sighting rate of minke whales in block 1 is in 2007 and is also lowest in dolphins. The lower altitude flown in 2007 could arguably have led to a reduction in effective search area in 2007, in the extreme, down to 64% of that in earlier surveys (the change in area is the square of the change in the distance). (Pike, Paxton, *et al.*, 2008) however found that the observers had to some extent compensated for this change in altitude by adopting a wider search angle. It is apparent that mid season fluctuations in minke presence in the bay are in synchrony with even greater fluctuations in the dolphin presence there. In the North the synchrony is less clear because of the increase in dolphins.

The spring surveys (2004 and 2005) have the lowest sighting rates in general but not as low for dolphins (higher than in block 1 mid summer 2007).

In both autumn surveys (both only in block 1) minke whale numbers are higher than in mid summer 2007 and 2009 and for dolphins even more so. The ratio of minke to dolphins is similar in the autumn to the mid summer ratio.

In the first surveys dolphins were more concentrated in the eastern part of the northern survey blocks (4 and 5), but in recent surveys have been more evenly distributed in these blocks. The minke whale distribution is continuous and relatively even out to the northern area boundary. In 2004 two flights went farther north up to the ice edge, but only one minke whale was sighted then. In 2004 however minke whale sightings peaked in the Faxaflói bay (block 1) and were also still numerous in the south eastern coastal block (8), although not as dense there as in earlier surveys in particular in the first two in 1986 and 1987. In April 2003 there are some minke whales in this block, but after 2004 block 8 has been void of minke whales during surveys. This extra 2004 effort to the north may therefore not be particularly informative on where the minke whales are when they vanish from the aerial survey area.

DISCUSSION AND CONCLUSION

In the dedicated shipboard surveys around Iceland (NASS and T-NASS) there has been some overlap with the aerial survey block, mainly during ship transits to or from port. These surveys show a continuous distribution of minke whales north of Iceland to Jan-Mayen and along the ice edge and coast of Greenland. The last survey in 2007 however had relatively poor coverage and unfavourable conditions in these areas and sighted few minke whales, so it is unclear if the minke whales then had shifted farther north or over to Greenland. Observers were placed on board research vessels during ocean condition surveys in the spring (latter half of May) 1991 to 1994 and 0-group autumn surveys in the periods 1983 to 1986 and again 1990 to 1995 in mid August to early September. This effort is largely within the aerial survey area, though with low effort to the South and South-East. Gunnlaugsson *et al*. (2004) compared sighting rates in these surveys and found that sighting rates were 2.37 times higher in autumn ship surveys than spring surveys in the period 1990 to 1995. These results are similar to the aerial survey results and imply that minke whale densities are in general low in coastal Icelandic waters in the spring up to and including late May. The few minke whale sightings in the spring are rather coastal. This is also supported by data from a whale watching operation in Faxaflói bay (block 1), which is quite coastal and has managed to find minke whales in the spring. There are more minke sightings in these areas in the dedicated shipboard sightings surveys in mid summer than in the autumn, but effort in the dedicated surveys was considerably higher.

It is evident in particular from the 2001, 2007 and 2009 surveys that observers can have very different spatial distribution of sightings (detection functions) and the same observer may even differ significantly between surveys. Comparing line transect estimates rather than raw sighting rates should be more accurate, give sufficient data, if the observers that make more sightings have a proportionately wider search width. However, a wider search width may imply a larger perception bias at close range, which is then not accounted for. In surveys with few sightings the fitting of a detection function will be problematic and comparison therefore limited. When detection functions are fitted covariates are not assumed to affect the sightability close to the plane, but only to narrow the effective search width. Sea state affects sighting rate most drastically and at Beaufort 3 it is reduced by half and the median perpendicular sighting distance is then (350m, n=218) larger than at Beaufort 0-1 (330m, n=660) and Beaufort 2 (317m, n=496). At Beaufort 4 distances are shortest (228m, n=50), but these few sightings/effort has not been included in these analysis. The incorporation of covariates has also varied between surveys. Cloud cover and glare also affect sighting rates, but to a lesser extent so these covariates have generally not been found significant in these surveys. When comparing raw sighting rates the covariates can be made consistent over all the surveys and the assumption that the whole team performs similarly in all surveys is supported by the relatively small differences in total sighting rates of individual observers within surveys.

The off season surveys were meant to provide information on relative abundance and were considered successful in that, but the great changes observed in the mid summer surveys since have cast some shadow on this. A north ward shift has been observed in several fish stocks in coastal Icelandic waters over this period (Astthorsson *et al*., 2007).

Haddock (*Melanogrammus aeglefinus*) that was largely confined to the south and western coastal waters has in recent years had a wider and more northward distribution. The largest haddock spawning that has been observed was in 2003 when haddock exceeded cod (*Gadus morhua*) in numbers. Cod has not recovered well during this period in spite of reduced fishing effort. The distribution of anglerfish (*Lophius piscatorius*) has extended northwards in to the east and north west coastal waters since 2001. Mackerel (*Scomber scombus*) has moved in from the south east in the most recent years while Pearlside (*Maurolicus muelleri*) has recently been exploited south west at the shelve edge.

The capelin (*Mallotus villosus*) north east of Iceland has retracted west to the ice edge and Irminger Sea, which probably explains the changes in the humpback distribution seen in both the aerial and shipboard surveys.

The aerial surveys show a clear mid summer northward shift in the case of dolphins. Minke whales have also disappeared in mid summer from the south east, but a general northward trend is less clear. The exceptionally low sighting rates in 2007 may be linked to the collapse in the sandeel stock (*Ammodytes tobianus*) (Sigurjónsson *et al*., 2000; Vikingsson and Elvarsson, 2011).. The minke whales then may well have moved out of the aerial survey area and possibly even north of the shipboard survey area, but may also have been missed by the shipboard survey due to the low coverage in conditions acceptable for sighting minke whales and low probability of sighting them in these shipboard surveys.

Since a clear fall in the presence of minke whales was not observed in the September surveys there was interest in surveying even later in the year, but this turned out to be quite impractical due to short daylight and poor weather. It was at that time anticipated that satellite marking could provide such information, but has in spite of considerable effort resulted in quite limited data. The autumn and spring surveys managed poor coverage east of the country and in the outer blocks so improving on this would be most valuable, in particular if done in the same year as the next midsummer survey.

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Table 1a. Sightings per search hour for all observers combined (not double counting) of minke whales (BA), dolphins (D?) and likely large baleen whales (B?) in Faxaflói bay (block 1) by year and season (June-July where unspecified). Effort summed independently for each side of the plane, (Tables 1 to 3 updated from Gunnlaugsson *et al*. 2009)

Year	Hours	BA	D?	B?	D?/BA	
1986	16.07	3.85	2.86	0.06	0.74	
1987	14.86	5.38	2.08	1.14	0.38	
1988	24.43	2.82	0.74	0.04	0.26	partial coverage
1995	16.51	5.15	2.78	0.55	0.53	
2001	17.00	6.24	1.94	1.29	0.31	
2004	5.78	17.12	8.30	0.17	0.48	transect set II only
2007*	16.45	1.64	0.36	0.18	0.21	
2008	15.39	6.91	0.97	1.10	0.14	
2009	21.94	3.60	0.73	0.18	0.20	
2004	9.75	0.62	0.41	0	0.66	late April
2005	11.50	0.87	0.43	0	0.49	May
2004	6.15	4.55	1.14	0.16	0.25	mid September
2003	24.98	2.48	0.92	0.08	0.37	late September

* altitude 600 ft in 2007, 750 ft in other years.

Table 1b. North Iceland (blocks 4+5). Full coverage in 1995.

Year	Hours	BA	D?	B?	D?/BA	
1986	39.98	1.23	1.58	0.13	1.29	
1987	34.92	0.89	1.17	0	1.32	
1995	37.19	1.18	1.69	0.54	1.43	
2001	29.20	1.82	2.57	1.20	1.42	
2004	20.34	1.18	2.75	2.21	2.33	
2007*	25.92	0.50	2.20	1.16	4.38	
2009	23.42	1.45	7.64	1.84	5.26	
2004	10.95	0.18	1.00	0	5.50	late April
2005	2.53	0.78	3.54	1.57	4.53	May
2004	10.57	0.28	1.14	0	4.00	mid September

Table 2a. Block 1. Sightings per search hour (effort for each side of the plane), of minke whales (BA), dolphins (D?) and likely large whales (B?) in Faxaflói by year in mid season, other seasons and by main primary observers.

Year	Obs.	Hours	BA	D?	B?
1986	H	8.03	2.98	3.60	0.12
	O	7.68	4.29	1.69	0
1987	D*	3.74	2.13	0.80	0.53
	H	7.74	4.65	1.55	0.90
	K	3.38	4.44	2.36	0
1988	D	2.37	2.78	0.84	0
	H	12.22	2.78	0.40	0.16
	R	9.84	1.32	0.91	0
1995	S	8.32	5.88	3.41	0.36
	Z	8.19	3.66	1.95	0.73
2001	E	8.50	4.00	1.52	0.94
	T	8.50	4.82	1.41	1.41
2003	L	12.49	1.51	0.71	0.07
	N	12.49	2.87	1.27	0.07
2004	N	4.88	0.61	0.40	0
	V	4.88	0.61	0.20	0
2004	I	3.59	9.18	7.51	0
	N	2.19	14.58	5.92	0.45
2004	N	3.07	3.89	0.96	0
	V	3.07	3.89	0.64	0.32
2005	G	5.70	0.35	0.17	0
	N	5.21	0.76	0.76	0
2007	A	8.22	1.33	0.36	0
	N	8.22	1.57	0.24	0.12
2008	N	7.70	5.72	1.17	0.64
	V	7.70	5.06	0.64	1.29
2009	V	10.96	3.54	0.84	0.18
	K	8.30	2.77	0.24	0

* Scientist keeping records in primary observer seat during IO experiment.

Table 2b. Block 4+5.

Year	Obs.	Hours	BA	D?	B?
1986	H	8.49	0.59	0.71	0.12
	O	4.38	0.68	2.05	0
	K	15.65	1.41	1.15	0.13
1987	H	17.46	0.69	1.32	0
	K	17.46	1.03	0.97	0
1995	S	18.60	1.24	1.61	0.65
	Z	9.33	1.39	3.22	0.64
2001	E	14.60	1.37	2.26	1.3
	T	14.60	1.64	1.71	1.23
2004	N	5.47	0.18	0.73	0
	V	5.47	0.18	1.28	0
2004	B	8.04	0.62	1.99	0.75
	N	10.17	1.67	3.05	2.36
2004 mid	N	5.28	0.38	0.95	0
	O	5.28	0.19	0.76	0
2007	A	12.97	0.46	2.24	0.62
	N	9.53	0.42	2.10	1.15

2009	V	8.83	0.68	5.78	3.4
	K	8.33	0.72	3.84	0.48

Table 3 Cetacean sightings for observers combined per search hour (effort for each side of the plane separately), of minke whales (BA), dolphins (D?) and likely large whales (B?) in Faxaflói by year and track set, and by track set repeat in 1988 (partial) and September 2003.

Year	Set	Hours	BA	D?	B?
1987	I	7.39	5.14	2.71	0.81
	II	7.48	5.61	1.47	1.47
1988	I-1	9.51	2.94	0.84	0
	II-1	6.86	4.22	0.59	0.15
	I-2	3.37	1.78	0.73	0
	II-2	4.68	1.28	0.64	0
1995	I	8.57	4.78	2.80	0.82
	II	7.81	5.63	2.82	0.26
2001	I	9.44	5.08	0.64	2.01
	II	7.56	7.67	3.57	0.56
2003	I-1	7.63	2.88	1.66	0.13
	II	9.23	1.52	0.43	0
	I-2	8.03	4.68	1.23	0.12
2007	I	8.77	1.48	0.57	0.11
	II	7.69	1.95	0.13	0.26
2008	I	7.51	6.13	2.26	1.20
	II	7.90	6.08	0.51	1.14
2009	I	11.78	3.82	1.37	0.34
	II	10.16	3.35	0.79	0

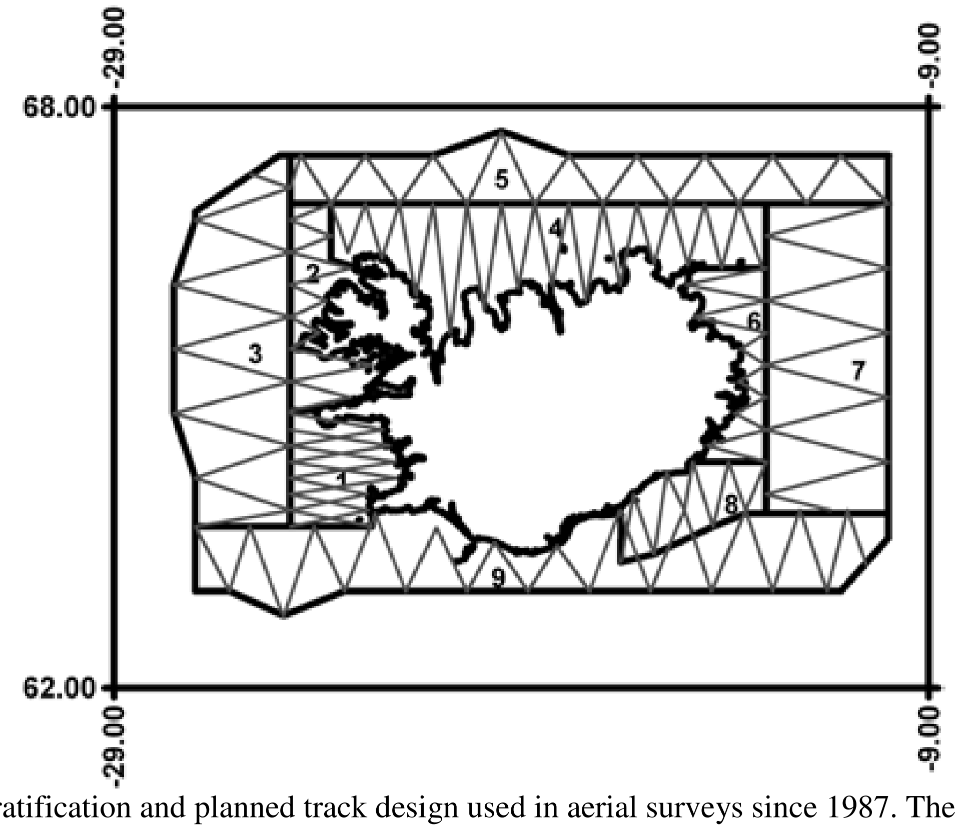


Fig 1. Stratification and planned track design used in aerial surveys since 1987. The survey

blocks are outlined with thick lines and numbered.

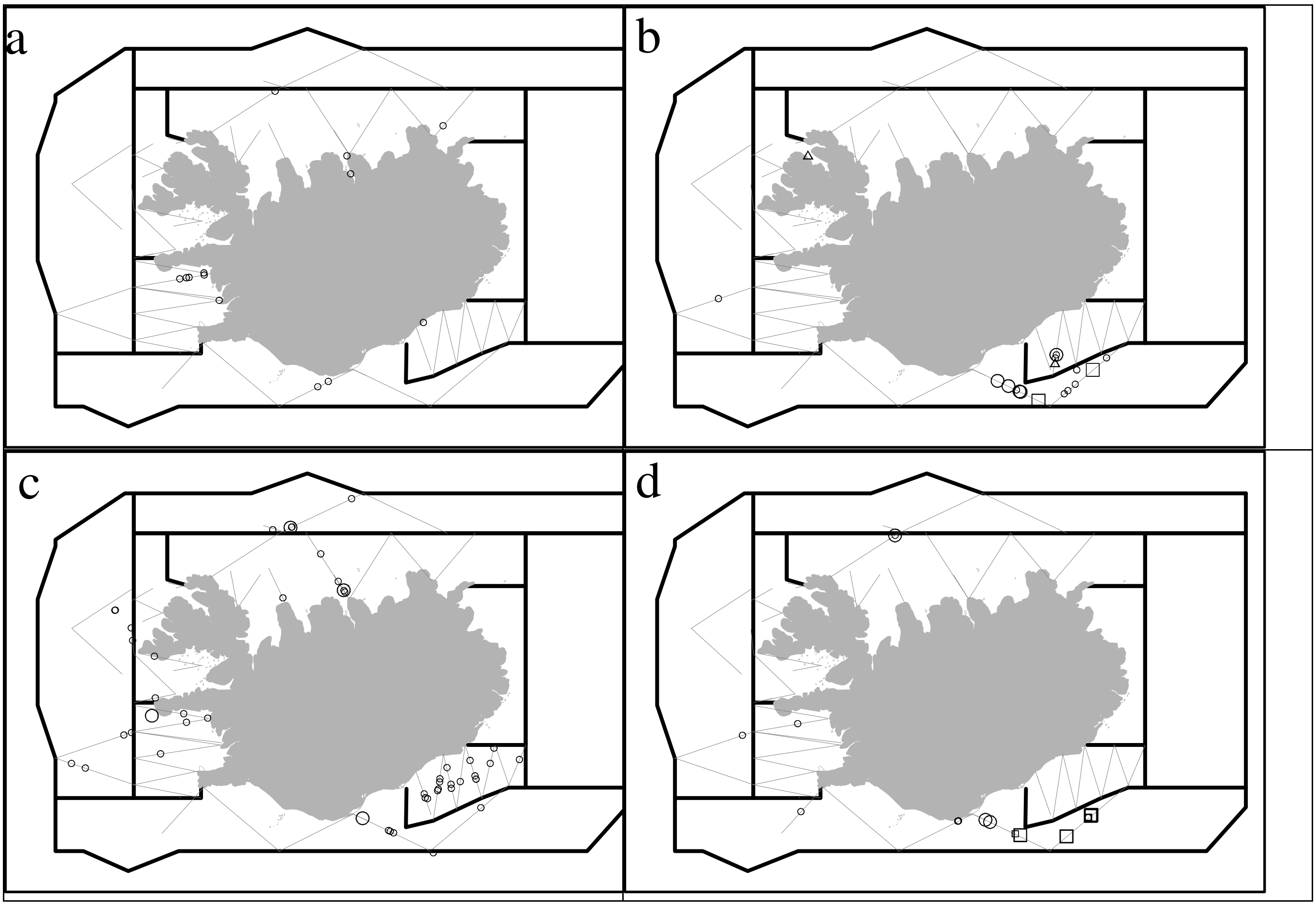


Fig. 2. Sightings of cetaceans around Iceland, April 2004. Both on and off effort sightings are shown. a) minke whales; b) fin whales (circles), group sizes 1 and 2-3, sei whales (squares) and humpback whales (triangles); c) dolphins, mainly white beaked, group sizes 1-10 and 11-16; d) killer whales (circles), group sizes 1-4 and 5-18, long finned pilot whales (squares), group sizes 1-5 and 6-23.

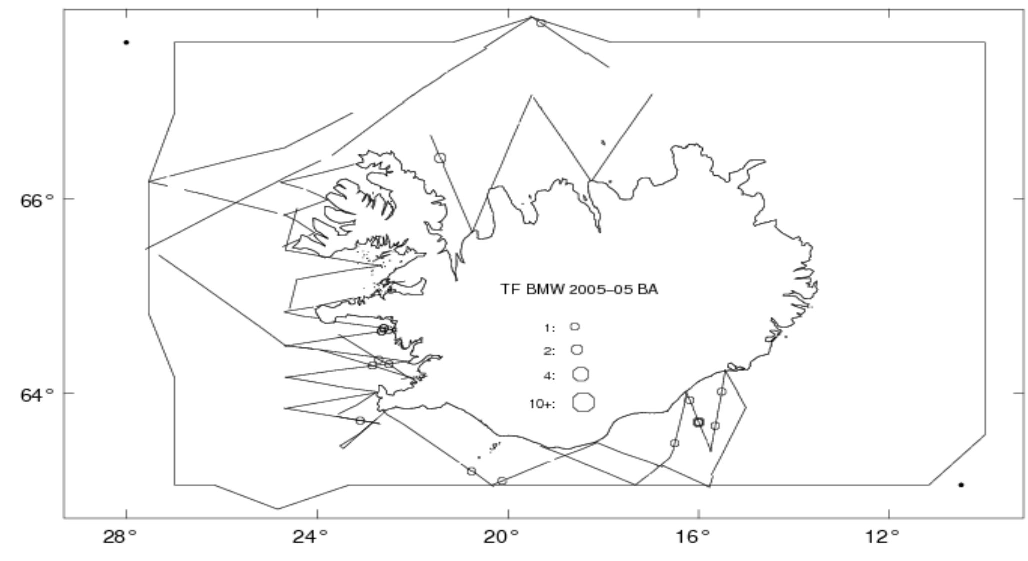
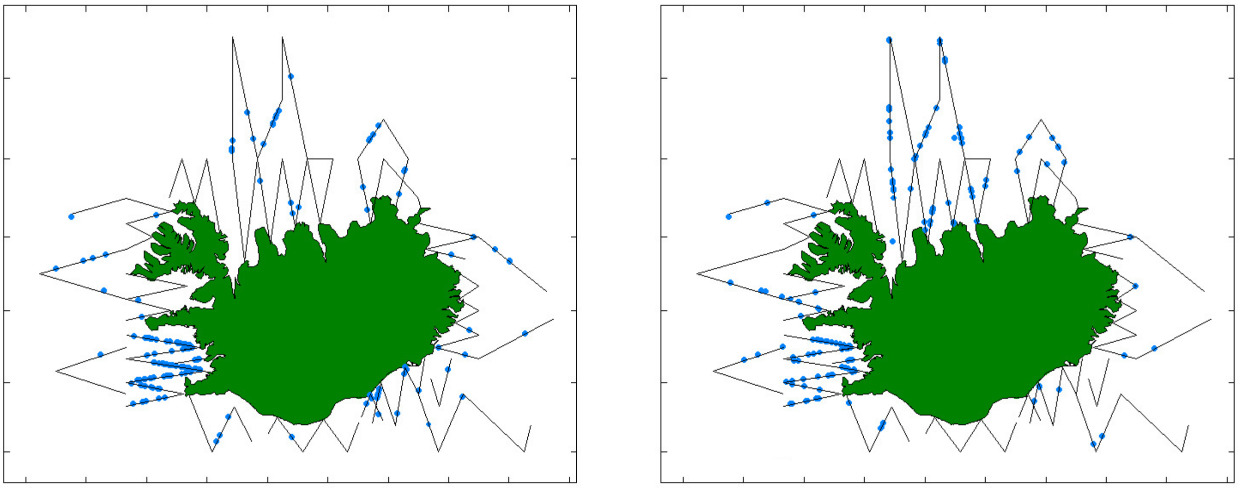


Figure 3. Effort and sightings of minke whales during an aerial survey 11.-26. May 2005.



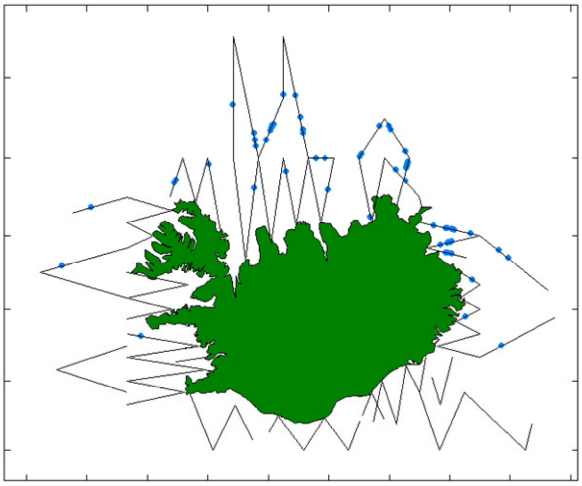


Figure 4. Aerial sighting survey in Icelandic waters June - July 2004. Tracklines and sightings of common minke whales (first), dolphins (middle) and humpback whales (last). Two trips up to the ice edge north of Iceland are outside the designed survey block.

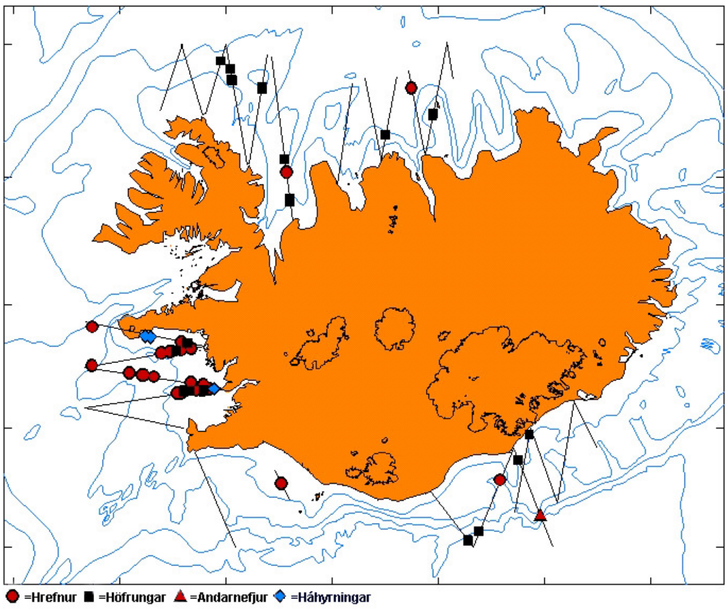
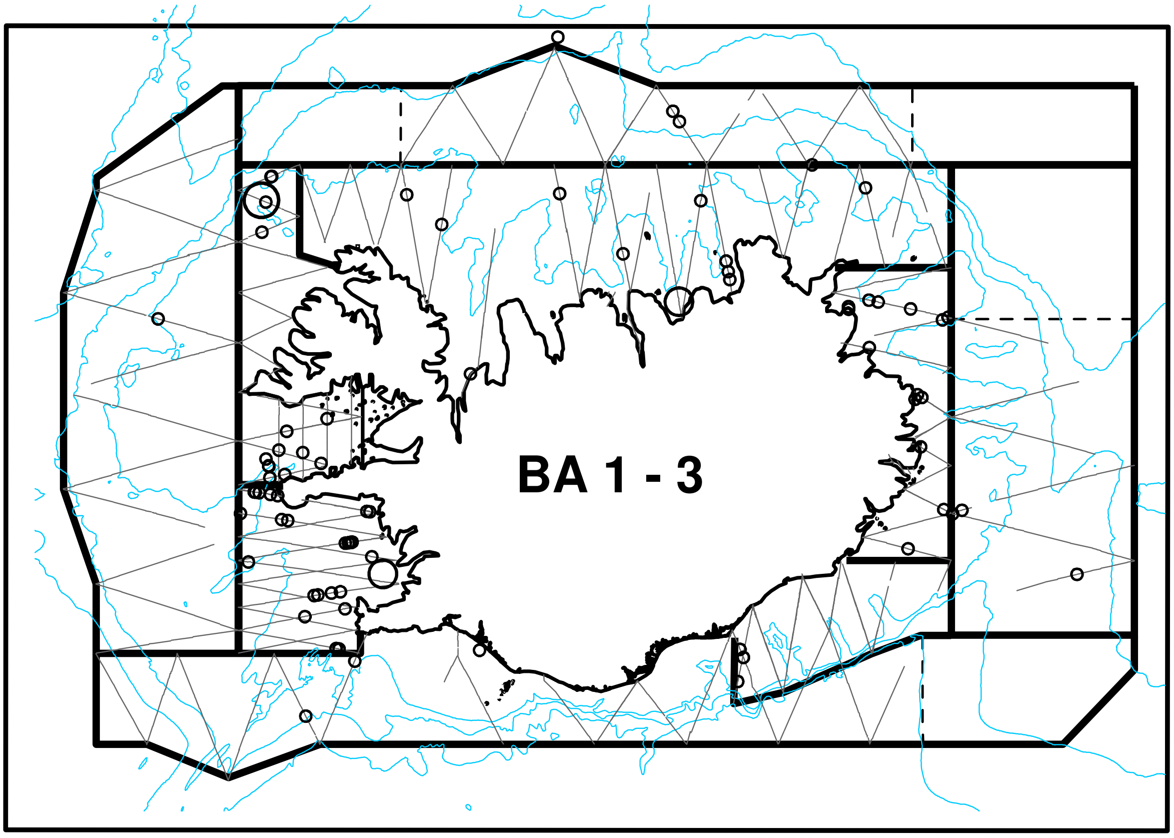
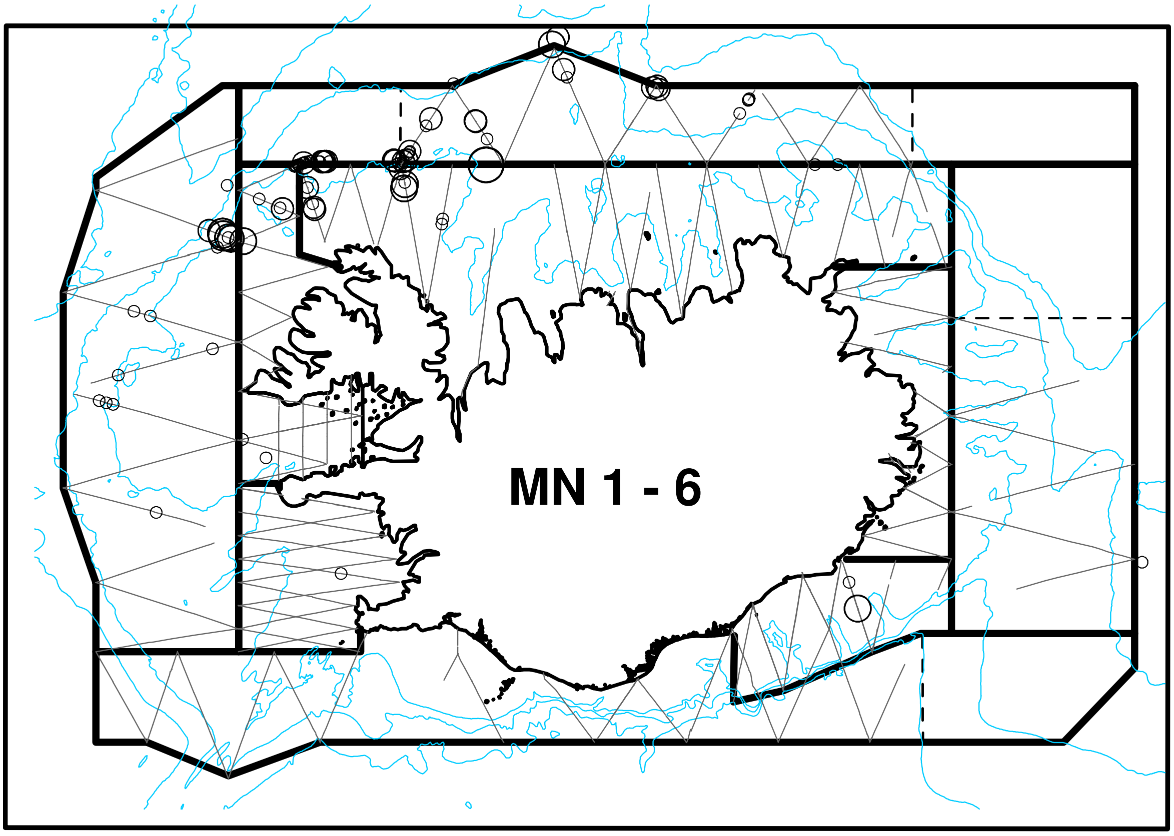


Figure 5. Aerial sighting survey in Icelandic waters in September 2004. Tracklines and sightings of common minke whales (red circles), dolphins (black squares), northern bottlenose whales (triangle) and killer whales (blue diamonds).


BA 1 - 3


MN 1 - 6

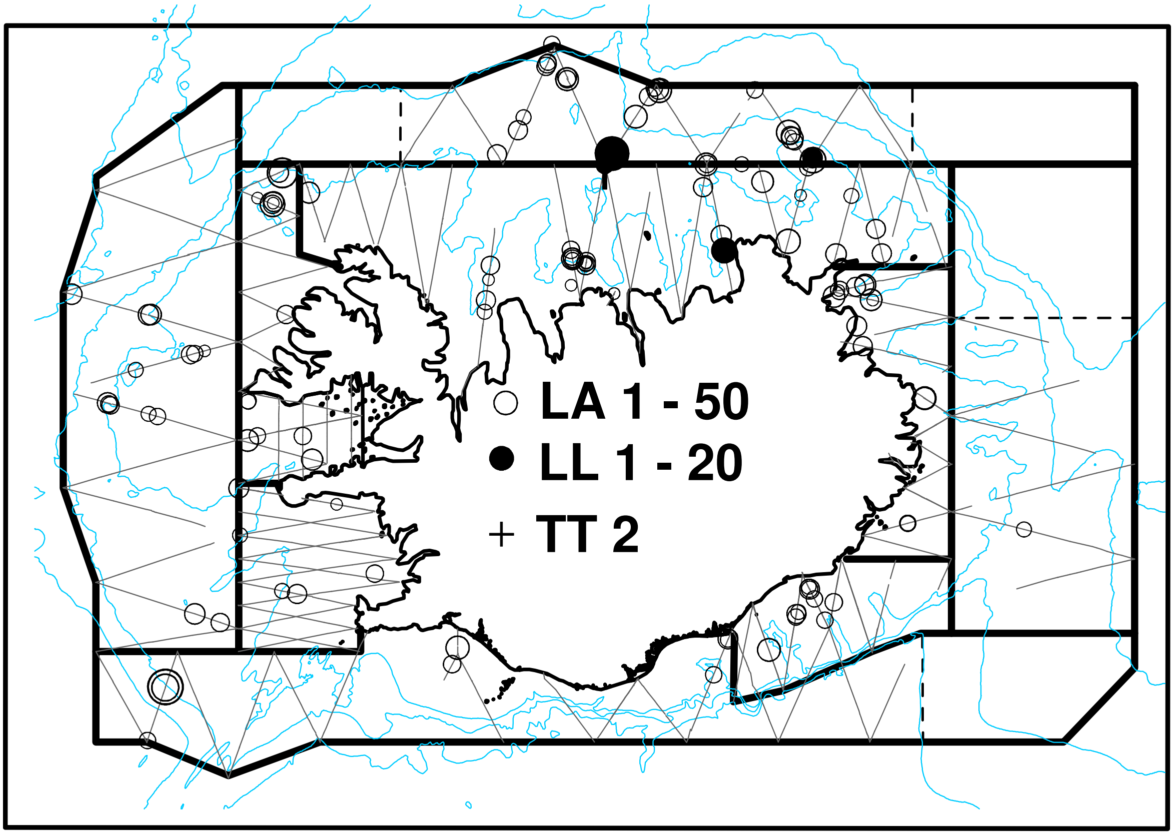
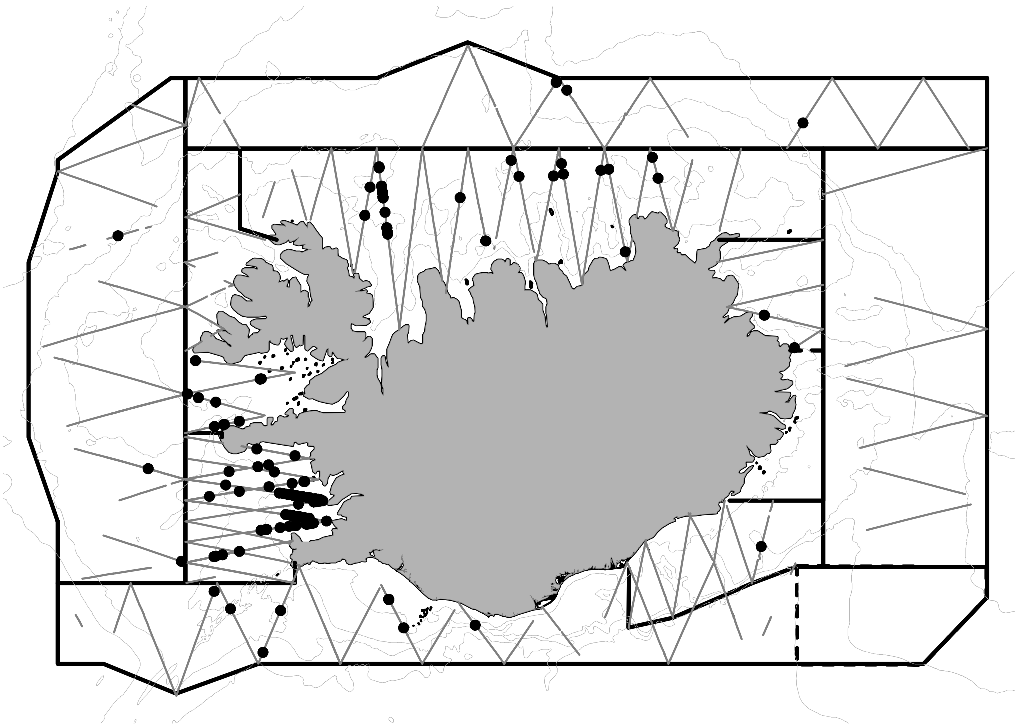


Fig. 6. On and off effort sightings of cetacean groups in aerial survey June – July 2007. Symbol size is proportional to the range of group sizes listed for each species. Top: BA – minke whale; Middle: MN – humpback whale; Bottom: LA – white-beaked dolphin; LL – white-sided dolphin; TT – bottlenosed dolphin.



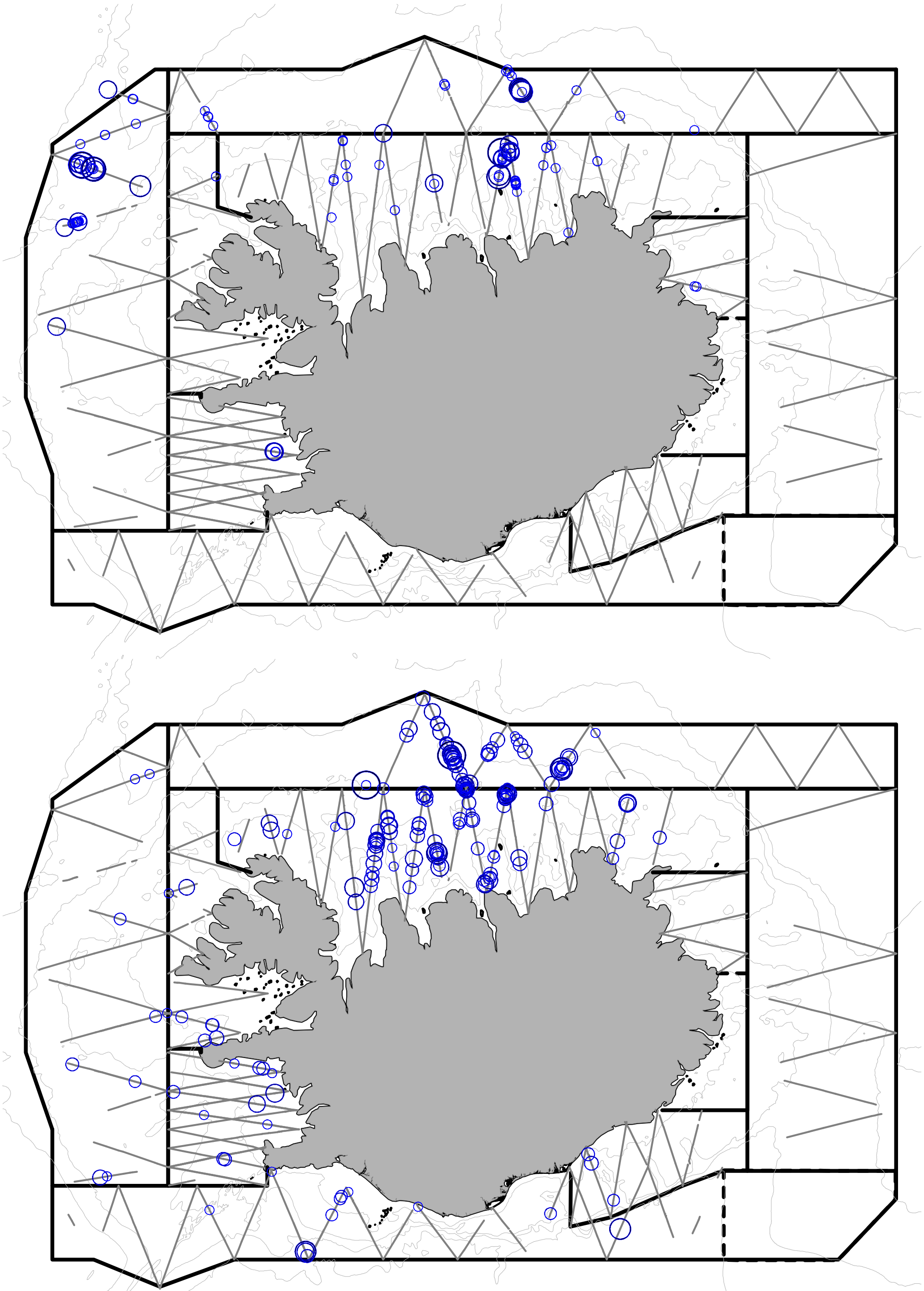


Fig. 7. Aerial survey 2009 effort and sightings around Iceland. Top: Minke whale cues at BSS<4. Middle: Humpback whale group sizes 1-6. Bottom: dolphin group sizes 1-50.