Aerial survey in Faxaflói, Southwest Iceland in 2008, report and comparison to earlier surveys.

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ABSTRACT

An aerial survey was conducted in Faxaflói area South West Iceland in late June – July 2008. This is the 12th time that this area is surveyed in a similar manner. Density of common minke whales (*Balaenoptera acutorostrata*), the target species in these surveys, was similar to most earlier surveys and higher than in 2007 when densities were extremely low. Distribution of minke whales within the area is apparently more concentrated in shallow waters inside the Faxaflói bay in 2008 than in any earlier survey. The relative cue distribution, duplicates and measurement errors in the 2008 survey are presented.

INTRODUCTION

Aerial surveys in coastal Icelandic waters have all primarily targeted the common minke whale (*Balaenoptera acutorostrata*) and since 1987 the cue counting procedure (Hiby and Hammond 1989) has been used to facilitate absolute abundance estimation for this species (Hiby and Ward, 1989; Borchers *et al.* 2008). However, sightings of all cetacean species have been systematically recorded. Some scientists and observers in the Icelandic surveys have participated in surveys using similar methodology conducted off West Greenland in 1987, 1989 and 1993 (Donovan 1990, Larsen *et al.* 1989, Larsen 1995) and most recently in September 2005 and 2007 (Heide-Jørgensen *et al.* 2006).

Aerial surveys that covered most of the coastal area around Iceland were conducted during late June to mid July in 1986 and as a component of the international NASS surveys in 1987, 1995, 2001 (Pike *et al.* 2002). Pike *et al.* (in press) present a trend analysis based on these surveys. In 2007 a full survey (Pike *et al.* 2008) was conducted as a part of the T-NASS survey (Desportes and Halldórsson, 2008, Gunnlaugsson, 2008, Víkingsson, 2008). The 2007 survey in Iceland was flown at a lower altitude in an attempt to capture also harbour porpoises (*Phocoena phocoena*) and had one primary observer with experience from harbour porpoise surveys in the Baltic. Experiments and partial surveys 2003 to 2005 were twice conducted in the spring, April 2004 (Pike *et al.* 2004) and May 2005 and twice in the autumn, September 2003 and 2004, to investigate seasonal trends in minke whale occurrence in this region (Gunnlaugsson 2005) under the Icelandic Research Program (Marine Research Institute 2003). A survey in midsummer 2008 only covered the Faxaflói area which is the area considered here. Results are given in detail here of sightings and measurements from this survey, which has not been reported on before. Results are compared to earlier surveys in this area to elucidate variation in sighting rates in midsummer and seasonal changes.

MATERIAL AND METHODS

Survey design and effort

The survey design was identical to that used in earlier surveys except for 1986 when effort was more concentrated coastally where the highest minke whale densities were expected. Since 1987 the same two sets of track lines over the whole Faxaflói bay area (area 1) Southwest Iceland have been used (Figure 1). In some surveys both sets could not be fully completed due to weather and time constraints. Survey legs that could not be completed due to poor conditions were occasionally repeated in better conditions in the following days. Here all such effort has been included. A survey in 2004 was about half the normal effort in several areas and only set II was covered (half effort) in Faxaflói. Experiments in late July 1988 in Faxaflói covered some legs repeatedly, but excluding the southern most lines of both sets resulting in total in a 1.5 fold effort of normal surveys there. Both sets were covered in 2008 (Fig. 1).

Aircraft and equipment

The airplane used in all the survey was a Partenavia Observer P-68, with one bubble window on each side of the plane. The same aircraft and pilot have been used since 1995. The plane was equipped with a GPS and the start and end coordinates of all tracklines were entered into the GPS prior to the survey. All the surveys were flown at an altitude of 750 ft (229 m) except in 2007 when a lower altitude of 600 ft (183 m) was chosen to improve the survey for harbour porpoises and when conditions have necessitated minor deviations from this altitude. The target ground speed was 90 kts (167 kmph), however this varies somewhat with wind direction and speed. The aircraft has an endurance of about 10 hours.

The data collection system was similar to that used in previous surveys. Data was entered by voice and recorded on separate laptop computers using the HVAL software for each of the 3 observers. When the microphone was opened, a time and position signal from the GPS was also recorded so that the time and position of every observation was known. Time and position data were also transferred via modem to a laptop computer every minute while on effort.

Declination angles were measured with a hand-held declinometer (Suunto PM5), and lateral angle from the nose of the airplane was estimated using an angle board mounted on the window frame.

Data collection

The survey crew consisted of the pilot and cruise leader in the left and right front seats and two primary observers sit behind one on each side of the plane observing through bubble windows. Primary observers do not share any view and may be differently affected by conditions such as glare. The primaries changed sides at least every day. In 1987 and 1988 one primary observer was replaced by the scientist during one set (Table 2). Some primary observers have been on more than one survey as indicated by the observer codes. Observer K in 1987 was also a primary observer in 1986 although not in Faxaflói. Observer H in 1986 to 1988 acted as scientist in 1995. Search hours are here counted for each side of the plane separately and are thus double the flight hours if all equipment was working. There have been some periods when recording equipment failed for one primary observer and then only the other side of the plane is included.

The scientist (cruise leader) has acted as a control observer in the co-pilot seat. In later surveys and during some experiments in earlier surveys the cruise leader (or observer in the co-pilot seat) was visually isolated from the primary behind him by a curtain. Acoustic isolation was maintained while on effort by moving the intercom microphones away from the mouth. This allows comparison of sightings and the measurements for distance estimation, but the cruise leader has poor view of the area closest to the plane. Measurements for each cue are the cue time, declination angle and lateral angle from the nose of the airplane to the initial cue or shortly there after (at mark time) and the abeam time and declination abeam when feasible. The drift of the plane was recorded to get the true angle to track from the angle to heading and abeam estimates. In some cases when a cue was close to the trackline or close to abeam only abeam measurements were taken. For non target species animals were counted and initial or general behaviour recorded rather than specific individual cues and then measurements were made to enable calculation of perpendicular distance. The cruise leader decides where and when to search and when to stop searching. He is also responsible for recording environmental conditions and other control information. In the earlier surveys the cruise leader had to spend more time recording on paper. The survey was conducted mainly in passing mode, as closing on uncertain minke whale and harbour porpoise sightings has generally not been productive. Sightings of other species were sometimes investigated for species identification. Survey effort was generally abandoned if Beaufort sea state (BSS) increased above 3, or if fog, mist or heavy rain obscured visibility.

As in all surveys of this kind, the estimation of some environmental parameters such as the BSS may not be quite comparable between scientists. However the same scientist was on duty during most of the time in the 1986 to 1988 surveys while another scientist was on in both 2001 and 2007 and in a spring survey in 2004. The scientist in 2008 trained partly as an observer in 2007 and had experience from surveys elsewhere.

RESULTS

Fig. 1 shows the effort and sightings of minke whales from all midsummer surveys in the Faxaflói area. There have been only 6 sightings of killer whales (*Orcinus orca*) in this area in all the surveys and sightings of sperm whales (*Physeter catodon*) and fin whales (*Balaenoptera physalus*) are also rare, in total four of each species and all close to the area's outer limit. Fig. 2 shows the distribution of other than the aforementioned species in the area.

Table 1 gives the sightings per flight hour by year for all observers combined (including the pilot and control observer in co-pilot seat). This and other tables also give sighting rates for dolphins (D?) and for all likely large whales combined (B?). Here all likely dolphin sightings combined are included, identified dolphins in Faxaflói are almost exclusively white beaked dolphins (*Lagenorhynchus albirostris*). Large whales are predominantly blue whales (*Balaenoptera musculus*) in 1987 but mostly humpback whales (*Megaptera novaeangliae*) in later years which were absent in 1986. In 1986 effort was more concentrated coastal where minke whales might be expected so sightings of minke whales (BA) and dolphins (D?) are likely too many and too few for large whales (B?) compared to the other years

Table 2 gives sightings per flight hour by primary observers only. In general sighting rates for different observers in the same year are very similar.

The slight difference of observers in 1986 where H sees fewer minke whales but more dolphins is for instance reversed in other blocks and similarly for observers H and K in 1987, which could also be compared in other blocks in 1986.

The 1995 primary observers did not take part in other surveys. The difference between these two observers was consistent across blocks. The results from some blocks where the cruise leader acted as primary observer and can be compared to the primary observer S, indicate that this observer was rather efficient. Some difference between primary observers is also persistent in 2007 where judging by other surveys and other areas observer N seems to be rather efficient.

Table 3 gives sighting rates between sets, or repeats of sets in the same survey. Sighting conditions were very good in 2004 with 95% of the effort in BSS 1 or less. In other years about 5% of the effort was in BSS 4 or higher except for 1988 when it was 15% and then mostly during the repeats of the sets that also could not be completed due to high BSS, while during the first repeat conditions were good. In September 2003 25% of the effort in set II is in BSS 4 or higher and 20% in Beaufort 3 and in particular in the inner part of the bay. More than half the effort in 1986 was conducted in BSS 3 or higher and in 2001 during set I, but less than half (generally less than a third) in other instances.

Fig 3 gives the distribution of relative cue positions for both primary observers in 2008. Fig 4 shows for the control observer the cue positions relative to the plane and whether they were duplicated or missed by the primary observer behind on the same side of the plane. The discrepancies in distance estimation in the few duplicated sightings between control and the primary observer are not plotted here but can be read from table 4 which gives the duplicate information in detail. Table 5 gives control observer sightings with duplicate information for those species where cues were not recorded. All these sightings were duplicated and most by one primary observer that happened to be on the co-pilot side of the plane when these sightings were made.

In Fig. 5 radial distance estimates to cues obtained from the initial declination angle and angle to heading are plotted against estimates obtained from the time lapse from cue time to abeam time and the abeam declination, where both measurements were available by the same observer. All observers were combined due to the limited data. When the cue is close, or close to abeam, there is only time for one measurement as seen from the plot. The control observer rarely got more than one measurement as the view from the co-pilot seat is limited and most of the control observer sightings in 2008 were close to the plane.

DISCUSSION AND CONCLUSION

In earlier surveys significant differences have been found in the effective search area of different observers although the total number of sightings has been similar (Tabs 2-3). It is reasonable that the number of sightings does not increase with the effective search area as the perception bias is likely to increase (more animals will be missed close to the plane) as the observer diverts more effort farther from the plane. Independent observer data should correct for this and give similar abundance estimates for different observers, but in some earlier surveys such data was not collected, or only partly, and in other surveys this data has been of little value due to few sightings and limited view by the control observer in the area close to the plane.

The scientist (control observer) in 2008 made relatively fewer sightings than the scientist in 2007 and 2001. The scientist in 2008 however apparently was more concentrated close to the plane and so made some sightings there that were not duplicated by the primary observer (Fig 3). Such data is more valuable for estimating the perception bias in g(0).

For 2008 there is no apparent difference in the performance of the two primary observers (Table 2) nor their spatial distribution of detected cues relative to the plane (Fig 4). However the observer less experienced with this method has a

few discrepancies in the duplicates (Table 4) and is responsible for the largest discrepancies in Fig 5. The plot in Fig 5 does not suggest a particular bias between the initial and abeam measurements and shows that errors can be proportionately large at short distances which is not surprising as time is only recorded in whole seconds and the plane moves about 45 meters in one second. The feeling of the observers has been that declination taken when the sighting is abeam is more precise, but if the sighting was spotted far ahead and there is nothing visible when it should be abeam, both the timing and angle there would be expected to be inaccurate. Duplicates with the control observer where the primary observer did take measurements both initially and abeam are few in 2008 (also a few in 2007) but do not suggest that either is generally better. Given two measurements one might argue that the average of the two would have a smaller variance.

Density variation

The index of sightings per flight hour (Tabs 2-3) for minke whales is very similar between observers, sets and repeats of a set in the same year. The largest fluctuations may be explained by changes in sighting conditions as detailed above. Fluctuations in the dolphin and large whale index are larger. Dolphins have diverse cues and occur in groups, where as minke whales are mostly seen single animals, surfacing shortly and only once. The larger whales may be seen at large distances and mostly not close to the plane where the observers should concentrate their effort and sighting rate of these species is therefore more a function of observer behavior. Harbour porpoises are hard to detect at the speed and altitude flown in these surveys even in good conditions. More harbour porpoises were seen in 2007 when the altitude was set at 600 feet but still mainly by the observer that had a prior training in harbour porpoise surveys.

The larger whales are mainly seen in the outer region of the bay and their incidence is not in sync with the smaller whales observed mainly in shallower waters. In 2008 the distribution of minke whales is noticeably clumped in the inner part of the Faxaflói bay and the humpback whale sightings have a very similar pattern then where as in 2001 with similar humpback whale density this is not the case.

The differences in general between observers and between repeats in the same year are small compared to the differences between years (Tab 1), for minke whales in particular. The index is by far highest for both observers in 2004 and lowest in 2007 for both minke whales and dolphins. Note that there is only half effort in 2004 so variation is expected to be larger then. Conditions were in no way exceptional in 2007. 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 et al. (2007) however found that the observers had to some extent compensated for this change in altitude by adopting a wider search angle.

Seasonal distribution

Experiments were conducted in September 2003 in Faxaflói and to the south of Iceland (Witting et al. 2004) and partial surveys were conducted in late April and September 2004 and May 2005. In general realized effort has been low outside Faxaflói in these spring and autumn surveys with no effort to the East and most of the autumn effort is in Faxaflói and to the South of Iceland. Results by primary observers for Faxaflói are given in Table 2. Gunnlaugsson (2005) compared sighting rates by season and block with BSS, cloud cover and glare as covariates using the data 2001 to 2004 and found that sighting rates of minke whales in mid summer 2001 and 2004 were similar, which implies that the high value in Faxaflói in 2004 was not observed in other blocks and/or was explained by favorable conditions there and then. Compared to mid summer the spring and autumn sighting rates were 7% and 36% respectively. Results from the 2005 May survey, which were not available to that analysis, are very similar to the 2004 April survey. A basic assumption in this comparison was that density varies by season in much the same way each year. The very low density observed in late June-July 2007 and the apparent change in distribution within Faxaflói in 2008 has cast doubt on this assumption. In 2008 36 whales were caught commercially in Faxaflói and all a short distance from Reykjavík within the dense spot observed in the aerial survey, which was observed there by the whalers from spring till late autumn. The stomach content of these animals was recorded by the whalers and was sand eel in all but one day midsummer when two animals had pure krill. In the spring the sand eel was mixed with herring and bones from larger fish. Apparently the animals in the bay are at least to some extent passing through since the sex composition of the catch changes through the season with.

In the dedicated shipboard surveys around Iceland (NASS and T-NASS) there has been little overlap with the aerial survey block except for mainly transit. Observers were however 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 mostly within the aerial survey area, but little 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 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 distribution of minke whale sightings within the bay in September 2003 and 2004 is similar to the distribution in 2001 and 2004 mid summer. The few spring sightings are rather coastal. The whale watching operation, which is quite coastal and finds minke whales in the spring, supports a more coastal distribution then.

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Table 1. Sightings per search hour for observers combined on each side of the plane separately of minke whales (BA), dolphins (D?) and likely large whales (B?) in Faxaflói by year.

Year	Hours	BA	D?	B?	
1986	16.07	3.85	2.86	0.06	
1987	14.87	5.37	2.08	1.14	
1988	24.43	2.82	0.74	0.04	partial coverage
1995	16.38	5.18	2.80	0.55	
2001	17.00	6.23	1.94	1.35	
2004	5.78	17.10	8.28	0.17	
2007*	16.45	1.70	0.36	0.18	
2008	15.40	6.10	1.36	1.16	
2004	9.75	0.62	0.41	0	late April
2005	11.50	0.87	0.43	0	May
2004	6.15	4.55	1.14	0.16	mid September
2003	24.98	2.48	0.92	0.08	late September

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

Table 2 Sightings per search hour 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
	I	7.68	4.29	1.69	0
1987	D*	3.74	2.67	0.80	1.06
	H	7.74	5.55	1.54	0.90
	K	3.38	5.01	2.36	0
1988	D	2.37	3.78	0.84	0
	H	12.22	3.19	0.40	0.16
	R	9.84	1.72	0.91	0
1995	S	8.19	5.98	3.41	0.36
	Z	8.19	3.66	1.95	0.73
2001	E	8.50	3.88	1.41	0.94
	T	8.50	4.70	1.17	1.40
2003	L	12.49	1.51	0.63	0.07
late September	N	12.49	2.87	1.11	0.07
2004	N	4.88	0.61	0.40	0
late April	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	0.64	0
mid September	V	3.07	3.89	0.64	0.32
2005	G	5.70	0.35	0.17	0
May	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	5.84	1.81	0.64
	V	7.70	5.06	0.64	1.29

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

Table 3 Cetacean sightings for observers combined per search hour 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 September	I-1	7.63	2.88	1.44	0.13
	II	9.23	1.52	0.43	0
	I-2	8.03	4.68	0.99	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

Table 4. All cues in 2008 aerial survey in Faxaflói Southwest Iceland (single minke whales unless noted) by control and duplicate information from primary observer on the right (co-pilot) side of the plane within 1500m radial distance and duplicate information from primary
Radial distance (Rd), perpendicular distance (Pd) and forward distance (Fd).

Control			Primary duplicates			
Rd	Pd	Fd	Rd	Pd	Fd	
Observer more experienced with method						
131	131	0	121	121	0	
186	179	55	143	132	55	
196	196	17				- missed
225	225	12	253	250	10	
228	225	5				- missed
292	146	253				- missed
365	366	0				unclear if cued abeam
409	360	195				- missed
469	254	395				- missed
Observer less experienced with method						
137	137	42				remote duplicate
161	154	48				duplicated under water abeam
253	253	0				- missed
266	263	46	540	538	41	outlier?
282	125	253	492	272	411	Primary sees 2 minkes?
352	120	331				remote duplicate
428	127	409				remote duplicate
513	513	0	433	430	58	
703	665	229				- missed
565	565	0				Humpback - missed

Table 5. Perpendicular distance estimates to other sightings (non cue records, dolphins unless noted) by control (C) in 2008 aerial survey in Faxaflói SW Iceland, all recorded abeam and all were duplicated by primary observer. Group size is given as estimated by control and primary observer.

Perp. Dist.		Group size	
Control	Primary	Control	Primary
Observer more experienced with method			
178	228	Sperm whale	
191	252	3	7
253	253	2	6
282	250	2	3
292	NA	3	7
628	990	8	20
Observer less experienced with method			
282	265	2	3

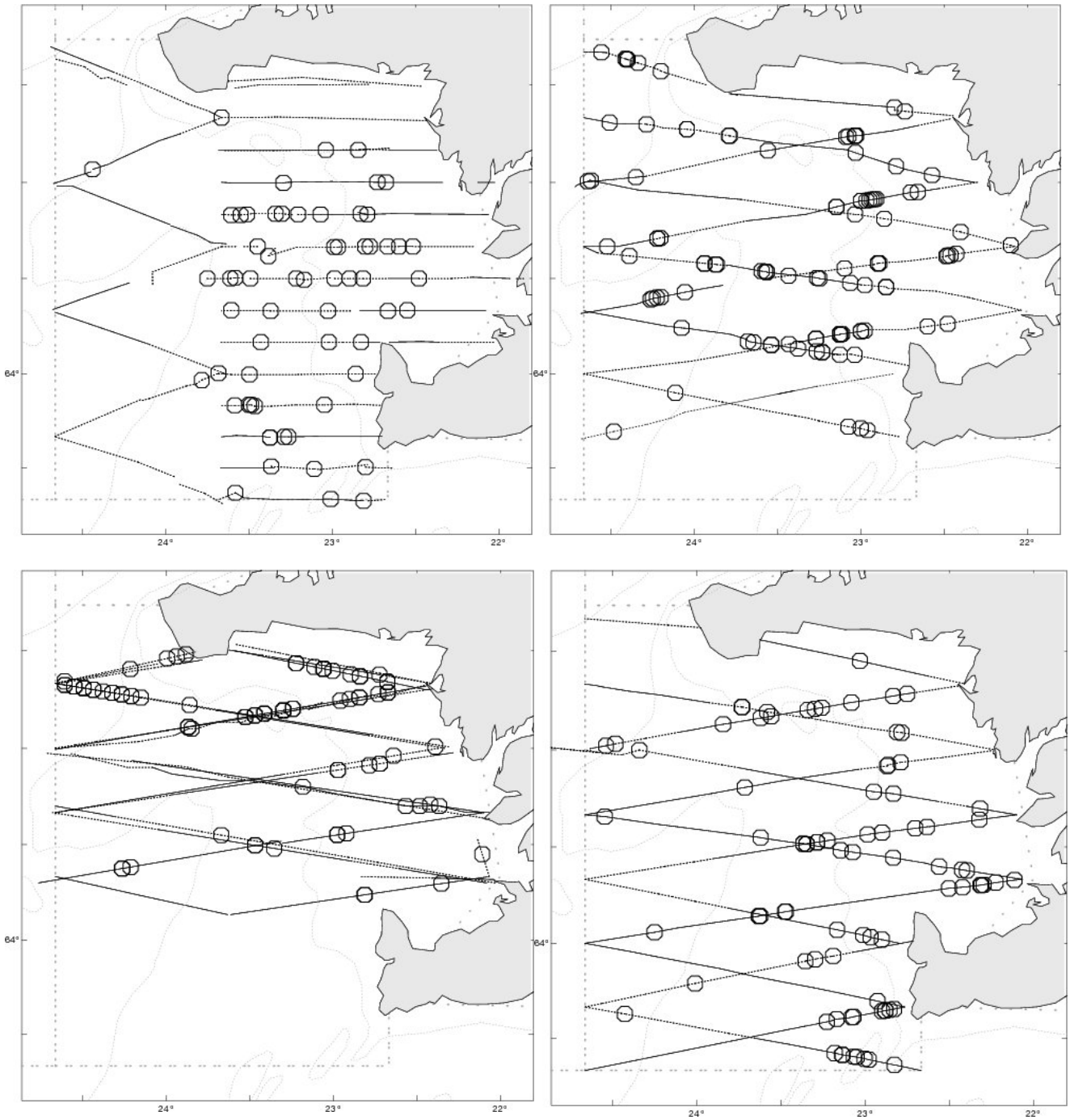


Fig. 1 (page 1 of 2). Effort (solid black lines, dotted lines in Beaufort sea state 3 or higher) and minke sightings in aerial surveys in Faxaflói in a) 1986 (top left), b) 1987 (top right), c) 1988 (bottom left), d) 1995 (bottom right)

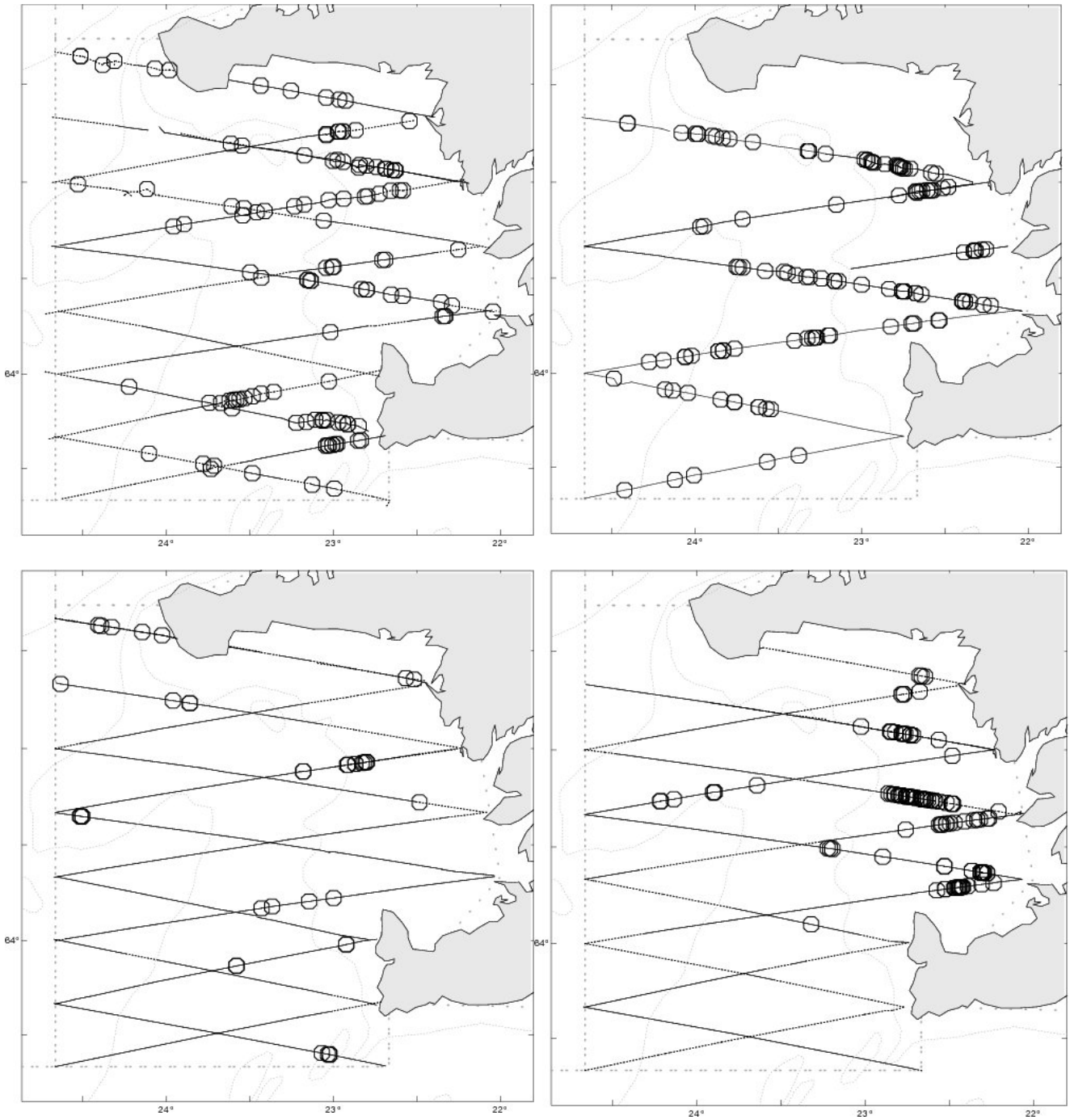


Fig. 1 (page 2 of 2). Effort (solid black lines, dotted lines in Beaufort sea state 3 or higher) and minke sightings in aerial surveys in Faxaflói in e) 2001 (top left), f) 2004 (top right), g) 2007 (bottom left), h) 2008 (bottom right). Track set II starts lower left and has one point close to Reykjavik.

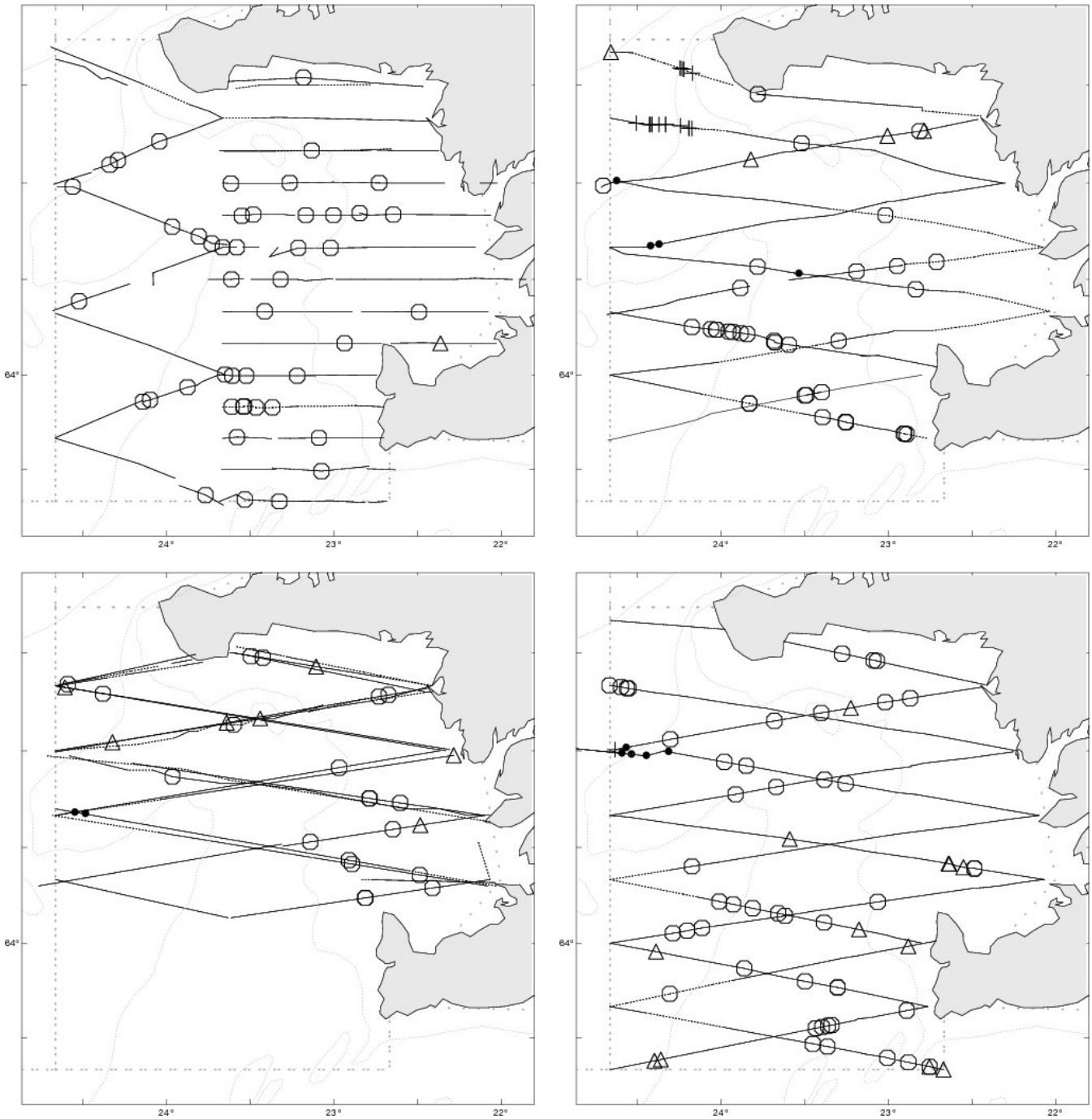


Fig 2 (page 1 of 2). Effort (solid black lines, dotted lines in Beaufort sea state 4 or higher) in aerial surveys in Faxaflói in a) 1986 (top left), b) 1987 (top right), c) 1988 (bottom left), d) 1995 (bottom right). Whale sightings of humpback (black dot), blue (plus sign), dolphins (circle), harbor porpoise (triangle). 1987

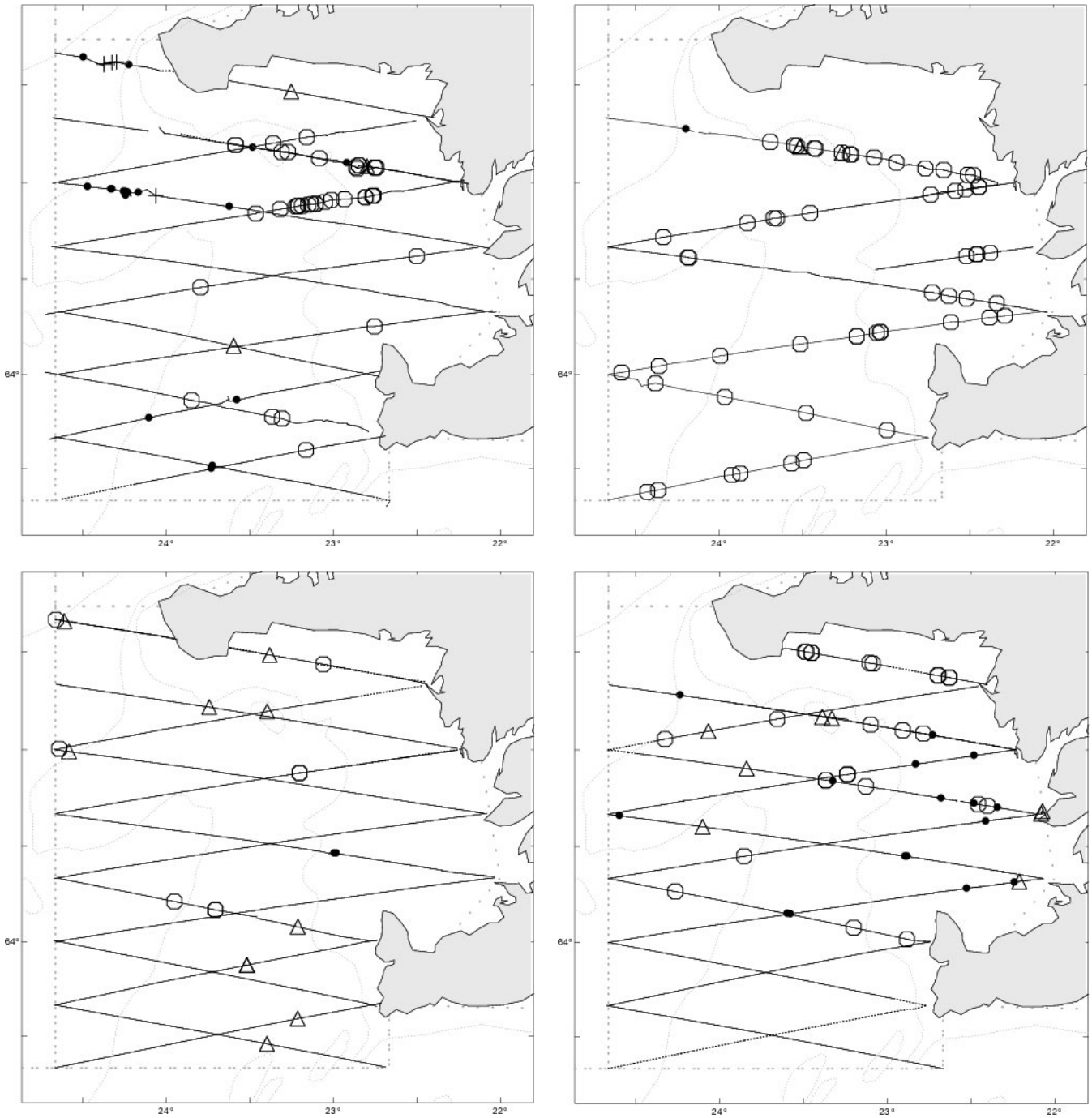
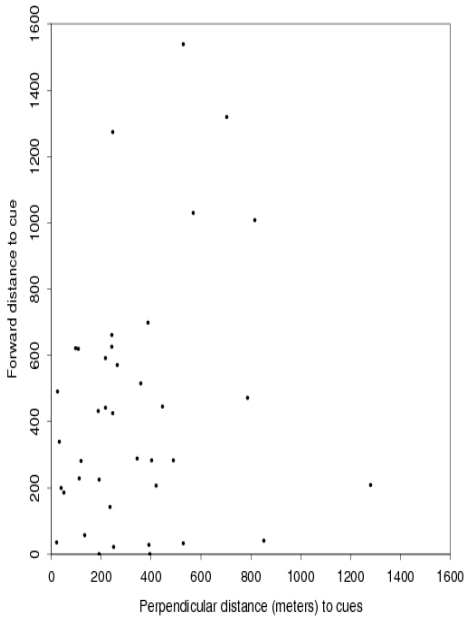


Fig 2 (page 2 of 2). Effort (solid black lines, dotted lines in Beaufort sea state 4 or higher) in aerial surveys in Faxaflói area in e) 2001 (top left), f) 2004 (top right), g) 2007 (bottom left), h) 2008 (bottom right). Whale sightings of humpback (black dot), blue (plus sign), dolphins (circle), harbor porpoise (triangle).



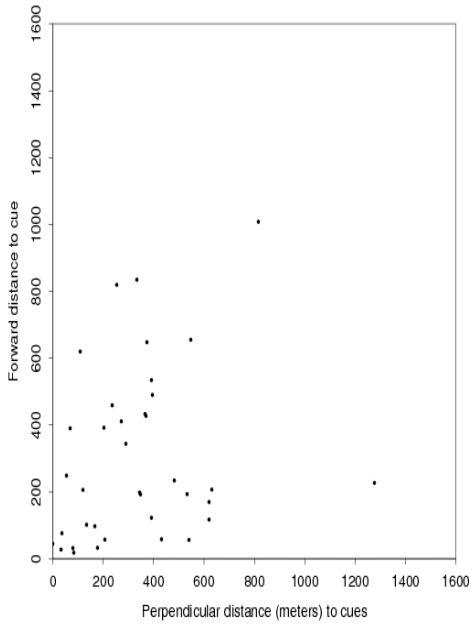


Fig 3. Relative positions of cues by primary observers: more experienced (left) and less (right).

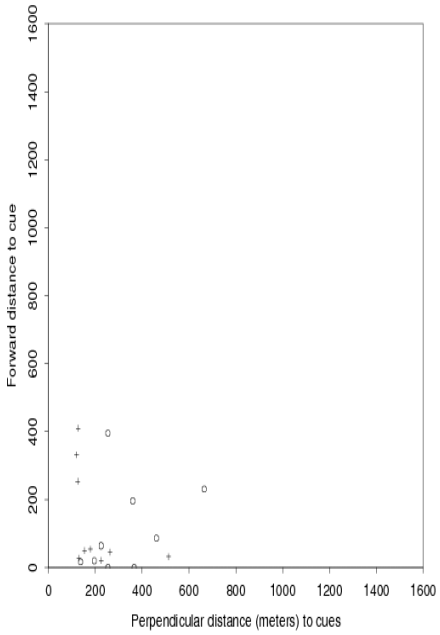


Fig 4. Relative positions of cues by control observer duplicated (+) and missed (o) by the primary observer behind on the same side.

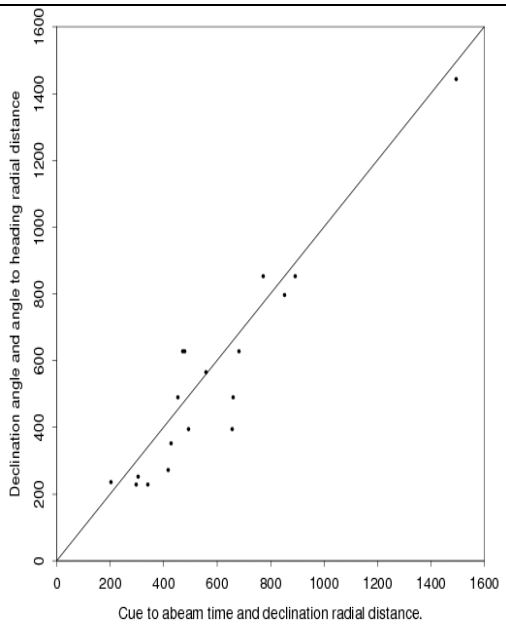


Fig 5. Radial distances to cues as measured by same observer initially and abeam.