Monitoring abundance and hunting of narwhals in Melville Bay during seismic surveys in 2012

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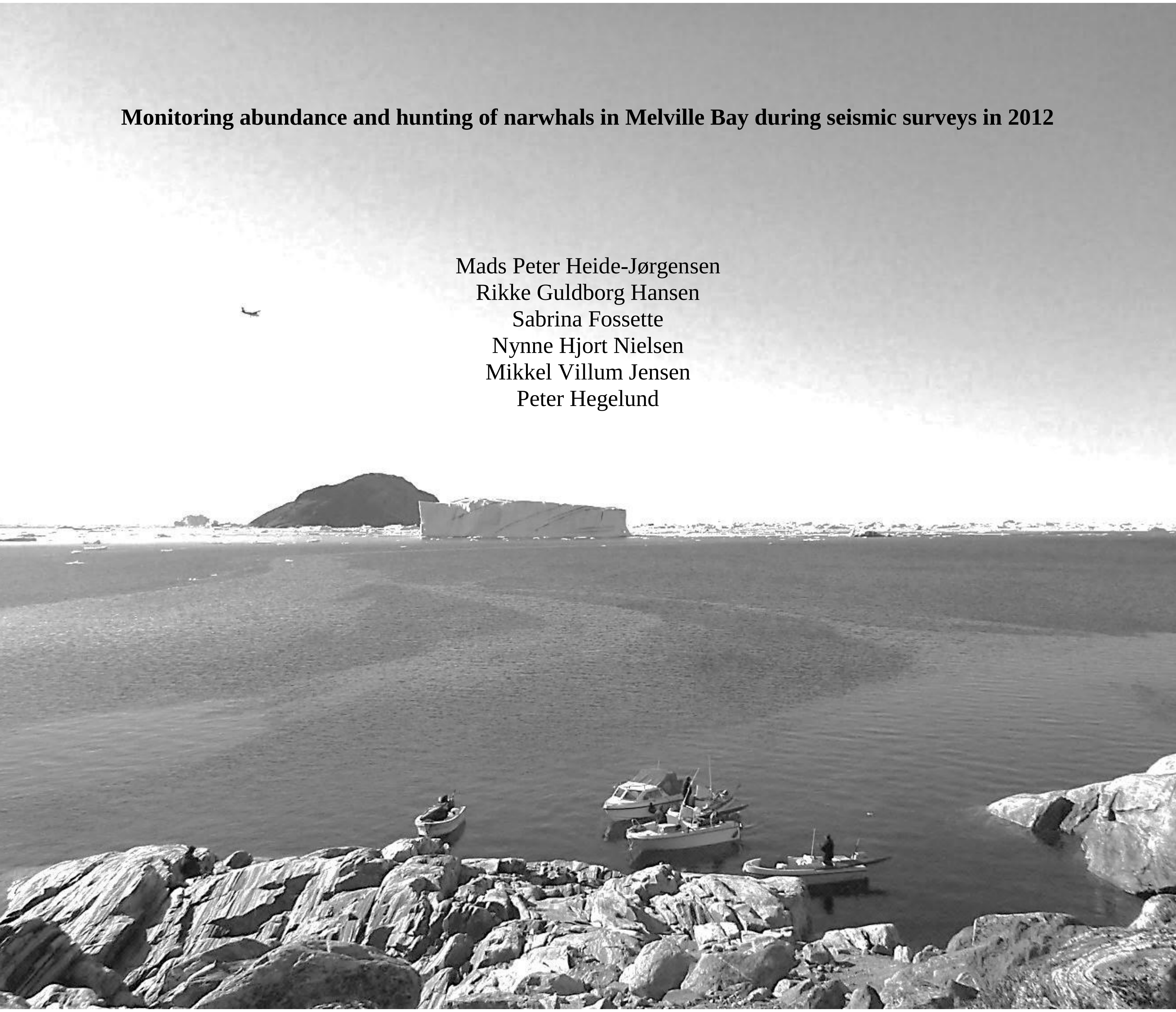

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LIST OF CONTENT

ABSTRACT

Narwhals have one of its two West Greenland summering grounds in the Melville Bay. Intense seismic survey activity was planned for August-September 2012 in northern Baffin Bay just off the coast of Melville Bay. There was concern about the potential reactions of the noise-sensitive narwhals to the seismic exploration and it was therefore decided to conduct some monitoring studies of the hunting and occurrence of narwhals in Melville Bay, including three aerial surveys, observations of the hunting activity in the Bay and a questionnaire survey among narwhal hunters. Aerial surveys conducted during the early, middle and late phases of the seismic explorations gave an indication, but no clear evidence, that there were more narwhals present inside the Melville Bay during the early part than in the late part of the period with seismic exploration. Compared to a similar survey from 2007, the abundance of narwhals in 2012 was lower but not significantly different, while the distribution in 2012 was more clumped and closer to shore. Hunters that operated inside the Melville Bay reported no changes in occurrence, availability or behavior of narwhals during the study period. No catches were reported in unusual areas and the known catch locations were all in good agreement with catch locations from previous years. In conclusion no short-term effects of seismic survey activity on narwhal abundance and narwhal hunting could be detected in Melville Bay in summer and fall 2012. More data are needed to conclude whether the clumped distribution observed in 2012 is a reaction to sound from seismic surveys. Information on sound levels in the bay and distance to seismic vessels was not available for this preliminary report; however, this information is critically important for assessing if the level of anthropogenic noise in the bay possibly could elicit a detectable response in narwhal distribution and movements.

INTRODUCTION

Seismic surveys were conducted in northern Baffin Bay off the Melville Bay during summer and fall 2012. A major concern with seismic surveys in this part of West Greenland is the interactions with narwhals that spend the summer inside the Melville Bay. Narwhal stock delineation is based on summer occurrence of narwhals in coastal areas of Canada and Greenland (Heide-Jørgensen et al. 2012). There are currently two stocks of narwhals that are recognized in West Greenland; the Melville Bay stock and the Inglefield Bredning stock. The Melville Bay that had an estimated abundance of 6.000 whales (95% CI 1.403-25.860) in 2007 is considered to be the smallest of the two stocks (estimated abundance in Inglefield Bredning in 2007 was 8.300 95%CI 5.209-13.442; Heide-Jørgensen et al. 2010).

Narwhals are primarily found in the Atlantic sector of the Arctic with the largest numbers centered in Baffin Bay and adjacent waters (Richard et al. 2010; Heide-Jørgensen et al. 2010). They are known to be skittish, highly sensitive to human activities and easily disturbed by approaching boats, even in areas without hunting. Hunting of narwhals in several areas of West Greenland, including the Melville Bay, continues to be conducted from kayaks because the whales react with long submergence times and are often lost to the observers when pursued by boats with noisy outboard engines. No direct studies have been conducted of the effects of seismic airgun noise on narwhals but they are known to react at long distances to underwater noise from vessels, with and without ice-breaking (Finley et al. 1990). The reactions of narwhals to approaching vessels include long-distance displacement, even at relatively low received sound levels (94-105 dB re 1 µPa; 20-1000 Hz). This responsiveness at such long distances is exceptional in the literature on marine mammal disturbance (see Richardson et al. 1995; it should be noted however that recent studies indicate that some other species also react to noise at long distances, e.g. Risch et al. 2012) and it is confirmed by the paucity of sightings obtained from vessels passing through areas known (from hunting returns and aerial surveys) to have high densities of narwhals (Heide-Jørgensen et al. 2010; GINR unpublished data). In particular, observers on active seismic survey vessels rarely if ever encounter narwhals, even when covering areas where narwhals are known to occur (Lang and Mactavish 2011). It is likely that the animals move away beyond detection range before the survey vessels are within the observers' range of visual detection.

The sounds produced by narwhals span a wide range of frequencies, from <300 Hz to >150 kHz (Miller et al., 1995), and the low-frequency sounds of seismic surveys are likely to overlap in frequency with at least a portion of the narwhal's vocal repertoire. It is uncertain at what distance from an operating seismic airgun array the sound pressure received by the narwhals would elicit a behavioural or physiological response. The received level would depend not only on distance but, perhaps more critically, on the size and pressure of the array, propagation conditions and distance between the array and the vessel. It is the received level (at the whale) that is likely to elicit a response.

Although narwhals dive to depths exceeding 1000 m (maximum recorded depth was 1900 m; Laidre et al. 2003), they are not considered fast swimmers. Based on contraction times, dominance of slow-twitch muscle fibers and exceptionally high myoglobin concentrations, narwhals have been characterized as slow, aerobic swimmers (Williams et al. 2010). Observations of narwhals instrumented with satellite-linked time depth recorders showed that horizontal speeds averaged 1.4 m s^{-1} (range = 0.81–2.36 m s^{-1}) and vertical speeds were within approximately 10% of this range (Dietz and Heide-Jørgensen 1995; Heide-Jørgensen and Dietz 1995). These values are among the slowest reported for any marine mammal (Williams 2009).

Narwhals make long-distance migrations in the spring and autumn (>3000 km per year), moving between coastal summering grounds (Heide-Jørgensen et al. 2003a) and winter feeding areas in the pack ice (Laidre et al. 2004). Such migrations across areas require endurance swimming (Williams et al., 2010). In summary, narwhals adhere to strict migratory schedules and routes with a high degree of site fidelity to specific localities (Heide-Jørgensen et al. 2012). They live in an environment with strong seasonal variability in habitat conditions, have few predators, and are rarely exposed to human disturbances except during the short periods when they are hunted along the edges of fast ice and in open water. The usual escape response of narwhals exposed to killer whales (*Orcinus orca*) or Inuit hunters involves prolonged submergence and entry into dense pack ice, if this is available (Williams et al. 2010; Laidre et al. 2006). In other words, they tend to hide or flee slowly and avoid detection by predators. Their observed response to an icebreaker was similar (Finley et al. 1990) and this is in contrast to the responses of other cetaceans with locomotor muscles divided equally into slow-twitch and fast-twitch fiber types, allowing for high-speed movement away from a disturbance (Ponganis and Pierce 1978).

The narwhals arrive in July in Melville Bay and preferentially seek out the front of glaciers for the summer period from August through late September. They feed little during this period but they conduct rapid and wide-ranging movements along the coast from the southern part of the bay at Kullorsuaq northwest to the Nallortoq fjord just east of Savissivik (Dietz and Heide-Jørgensen 1995, Laidre and Heide-Jørgensen 2005).

The density of narwhals in Melville Bay is low compared to other areas but the Bay is also very different from all other narwhal summering grounds that usually consist of narrow fjords or inlets bordered by coastlines at three sides. Melville Bay is essentially an open and very long coastline where the narwhals can move freely both north and south and offshore to the west.

The only other cetacean known to occur in the Melville Bay is the beluga that crosses Melville Bay, partly offshore and partly inshore, during their annual fall migration from Canada to West Greenland (Disko Bay and south) in late September through October (Heide-Jørgensen et al. 2003b). The return migration in spring occurs in May and June but further offshore due to the fast ice formation along the coast.

Both narwhals and belugas are highly sensitive to human activity and especially underwater noise generated from boat engines. It is not known how these two cetaceans will react to seismic activity in the Melville Bay, but there are reasons to believe that they will avoid the source and perhaps even abandon the area. Narwhals have strict migratory schedules and maintain isolation of summer resident populations and they will therefore have few or no alternative summer residencies to the Melville Bay (cf. Heide-Jørgensen et al. 2012). No contact between Melville Bay and those in Inglefield Bredning, the only other summering stock in West Greenland, has been documented. It is therefore not known if the narwhals will remain in the bay or move offshore during a period with seismic activity. The migrating belugas will most likely continue their migration but try to escape the sound source, very likely by choosing a route few meters from land as often seen as a danger response among belugas (Heide-Jørgensen 1994).

Narwhals are subject to a small-scale regulated hunt in Greenland. In Melville Bay the annual catch is limited to 81 narwhals. For 2012 the catch limit included a carry-over of two whales that were not taken in 2011. Northwest Greenland is a particularly important hunting area since it has two coastal summer residencies for narwhals; Inglefield Bredning and Melville Bay. In Melville Bay narwhals can only be hunted during the open-water season from August to September. In October and later, darkness protects the narwhals in the Melville Bay, although migrants from Melville Bay can still be caught in other areas.

During July hunters from the hamlets of Savissivik and Kullorsuaq at the borders of the Bay will travel extensively in Melville Bay in search for narwhals. Dinghies with medium-sized outboard engines (80-120 hk) will be used and camps will be set up at promontories where narwhals are known to pass close to land. When available the whales will be hunted from kayaks with the use of hand harpoons before they are shot. Dinghies are rarely used directly for the hunt as the whales are very skittish and will usually disappear when pursued from a boat with engine. Kayaks are either launched from shore or from the dinghies a bit off the coast but not more than a few kilometers from land. Remains of fast-ice are also occasionally also used as a platform for hunting narwhals.

The catch rate is not very high on kayak hunting (usually less than 5 whales per day) mainly because several days can pass before narwhals are observed at the camp sites and few whales can be taken each time the narwhal pods are passing the camp. Travelling to new camp sites will be avoided to the extent possible because engine noise increases the disturbance of the whales and extend the periods where hunters have no contact with the whales. Different families will have a history at each promontory and it is mainly in the central part of the Bay where an overlap by hunters from the two neighboring communities occurs. Hunters from Savissivik will use the northwestern part of the Bay around Fisher Island and hunters from Kullorsuaq will use the southern part and hunters from both areas may overlap at Nuussuaq and the Balgoni Islands. Travelling in the Bay requires a lot of fuel and a minimum of two boats travelling together. This limits the range of activities since hunting products will also have to be transferred back to the community to be sold at the fish factory.

It is unknown if and how the seismic survey activity planned for summer and fall 2012 could affect the hunting of narwhals. Possible scenarios include:

- No effect at all

- Narwhals could abandon the area and move away from the Bay and for instance turn up near communities in northern Upernavik or closer to Savissivik, where they could be hunted intensively.
- The catch rate of narwhals could drop because of changed occurrence or behavior of the whales.
- The narwhals could change from travelling constantly, to a more stationary behavior in the protected inlets where received sound levels from the seismic survey might be lower, and where they could be caught more easily.
- The narwhals could increase their travelling speed and become more difficult to hunt.
- The narwhals could remain in the Bay for a longer period to avoid offshore noise and thereby increase the risk of ice entrapment in the fall and winter.

The objective of this study was to monitor short-term changes in narwhal abundance and distribution in the Melville Bay during a season with intensive seismic surveys conducted off the Bay. Aerial surveys of narwhals in Melville Bay were conducted during the period with seismic activity with the primary purpose to detect changes in abundance and distribution of narwhals. A second objective was to collect information on the operations by the hunters useful for evaluating effects that may arise from seismic activity in the area. A third objective was to generate baseline data on narwhal occurrence in the area to be used for assessing future impacts on the population from anthropogenic activities.

MATERIAL AND METHODS

Aerial surveys

Survey performance

Visual aerial line transect surveys were conducted as a double-observer experiment in a fixed-winged, twin-engine aircraft (DeHavilland Twin Otter) with a target altitude and speed of 213m and 168km h^{-1}, respectively. The front observers (observer 1) acted independently of those in the rear (observer 2) and *vice versa*. Declination angles to sightings, species and group size were recorded when the animals came abeam. Beaufort sea state was recorded at the start of the day and then again when it changed. Decisions about duplicate detections (animals seen by both observer 1 and 2) were based on coincidence in timing and location of sightings. The same observers were used for all three surveys except for the 3rd survey where one observer had to be replaced, however, all observers were experienced with both the animals and the data collection schemes from >100 hrs participation in other aerial surveys. Instrumentation of the plane and the procedures for data collection were identical to those previously reported by Heide-Jørgensen et al. (2010, 2013).

The surveys of the Melville Bay were conducted during 30 July-5 August (Survey 1), 28 August-1 September (Survey 2) and 20-26 September 2012 (Survey 3) and covered the area between 74.30^{o}N and 76^{o}N (~14.821 km^2, Fig. 1). Four strata were identified and the two southern strata were surveyed by transects aligned east-west and the two northern were surveyed by north-south transects, systematically placed from the coast to offshore areas crossing bathymetric gradients, covering ~1777km (Table 1).

Collection of data on the availability correction

Data from narwhals instrumented with satellite linked time-depth recorders (Mk10a SLTDRs Wildlife Computers, cf. Dietz and Heide-Jørgensen 1995) were used to developing a correction factor for whales that were submerged below the detection depth (Richard et al. 1994, Heide-Jørgensen 2004). Measurements of the time spent above 2m depth were collected in six-hour bins and relayed through the Argos Data Collection and Location System and decoded using Argos Message Decoder (Wildlife Computers). Daily averages were calculated for daylight hours and used for deriving monthly averages that, to the extent possible, matched the survey area and dates (Table 2).

Development of abundance estimates

The declination angles to sightings when animals were abeam were converted to radial distances using the equation from Lerczak and Hobbs (1998a and 1998b). Although the observers were acting independently, dependence of detection probabilities on unrecorded variables can induce correlation in detection probabilities. Since it may not be possible to record all variables affecting detection probability, unmodelled heterogeneity may persist even when the effects of all recorded variables are modelled. Laake and Borchers (2004) and Borchers et al. (2006) developed an estimator based on the assumption that there is no unmodelled heterogeneity except at zero perpendicular distance (i.e. on the trackline) – called a point independence estimator. The alternative – a full independence estimator -

assumes no unmodelled heterogeneity at any distance. The point independence model is more robust to the violation of the assumption of no unmodelled heterogeneity than the full independence model and is therefore used in the following analyses.

Incorporating the point independence assumption involves estimating two models: a multiple covariate distance sampling (DS) detection function for combined platform detections, assuming certain detection on the trackline (Marques and Buckland 2004); and a mark-recapture (MR) detection function to estimate detection probability at distance zero for an observer. The MR detection function is the probability that an animal at a given perpendicular distance *x* with covariates *z*, was detected by an observer *q* (*q*=1 or 2), given that it was seen by the other observer, which is denoted by $p_{q|3-q}(x,z)$. It is modelled using a logistic form:

$$p_{1|2}(x,z) = p_{2|1}(x,z) = \frac{\exp\left\{\beta_0 + \beta_1 x + \sum_{k=1}^{K} \beta_{k+1} z_k\right\}}{1+\exp\left\{\beta_0 + \beta_1 x + \sum_{k=1}^{K} \beta_{k+1} z_k\right\}} \qquad (1)$$

where $\beta_0, \beta_1, \ldots, \beta_{K+1}$ represent the parameters to be estimated and *K* is the number of covariates other than distance. Note that if observer is included as an explanatory variable, then $p_{1|2}(0,z)$ will not be equal to $p_{2|1}(0,z)$. The intercepts (i.e. at x=0) of $p_{1|2}(0,z)$ and $p_{2|1}(0,z)$ are combined to estimate their detection probability on the trackline by at least one observer.

For the DS model, both half-normal and hazard rate functions were fitted, initially with no covariates (apart from perpendicular distance) and then covariates were included via the scale parameter (Marques and Buckland 2004). The available covariates were group size, side of plane (left and right), Beaufort sea state (0, 1,or2) and time to next sighting ($\leq$10 or >10s). Group size was also included as a factor variable with three levels to represent groups of size one, two to five whales and more than 5 whales. The same covariates were included in the MR model, in addition to a variable indicating observer (1 and 2). Akaike's Information Criterion (AIC) and goodness of fit tests were used for model selection.

Density (*D*) and abundance (*N*) of individual animals in a stratum were obtained using

$$\hat{D}_i = \frac{1}{2wL_i}\sum_{j=1}^{n_i}\frac{s_{ij}}{\hat{p}_{ij}} \qquad \text{and} \qquad \hat{N}_i = A_i\hat{D}_i \qquad (2)$$

where s_j is the recorded size of group j, A is the size in km^2 of the stratum, w is the truncation distance, L is the total effort in km, n is the number of unique detections and $\hat{p}_j$ is the estimated probability of detecting group j (perception bias), obtained from fitted Mark Recapture Distance Sampling (MRDS) models as described in Heide-Jørgensen et al. (2010).

In order to account for availability bias, corrected abundance (denoted by the subscript ‘c’) was estimated by

$$\hat{N}_c = \frac{\hat{N}}{\hat{a}} \tag{3}$$

where the parameter $\hat{a}$ is the estimated proportion of time animals are available for detection. The coefficient of variation (CV) of $\hat{N}_c$ was given by

$$cv\left(\hat{N}_c\right) = \sqrt{cv^2\left(\hat{N}\right) + cv^2\left(\hat{a}\right)} \tag{4}$$

Confidence intervals were estimated using the log-based method given in Buckland *et al* (2001).

Spatial analysis of sightings

A geographic information system (GIS: ArcMap 10) was used to spatially locate the observations of narwhals. The geographic coordinate system and coastline data for Greenland from the World Vector Shoreline (WSG1984) was projected as standard UTM Zone 21N (in meters). Spatial bathymetric data were extracted as a raster file from a terrain model from The General Bathymetric Chart of the Oceans which had a 30 arc-second spatial resolution (*GEBCO.net*).

Four relations were tested using nonparametric Kruskal-Wallis tests with a significance level of 5% and then compared pairwise by using the Steel-Dwass-Critchlow-Fligner procedure (two-tailed test).

1) Distance between narwhal groups and the shoreline (the mainland, islands excluded).
2) Distance between neighboring groups.
3) Group size and distance to shoreline (the mainland).
4) Group size and distance to closest group.

Data from a similar survey in 2007 in the Melville Bay were included for comparisons (Heide-Jørgensen et al. 2010).

Hunt monitoring and questionnaire survey

Between August 16 and September 12, two observers from the Greenland Institute of Natural Resources (GINR) visited local hunters from the two settlements Savissivik and Kullorsuaq, North Greenland. The purpose of the visits was to interview the hunters on current and previous hunts, as well as participate in the hunts to collect information on the hunting methods and to collect samples from caught animals.

In each settlement all active hunters were invited to a meeting where it was emphasized that the observers from GINR were not there for law enforcement and would only be acting as observers. Questionnaires were distributed to the hunters with a small reward for each questionnaire completed and returned. A local "chairman" was hired to distribute and collect the questionnaires from the hunters no later than October 1 and return them to GINR. The questionnaires were kept anonymous to improve the reliability of the replies. The date was chosen in order to get information on the entire hunting season.

The GINR observers spent some time in Savissivik and Kullorsuaq, respectively, in order to collect as much information as possible about the hunt and occurrence of narwhals, as well as samples from harvested animals. Both tasks proved difficult since most hunters were out hunting and whenever he would return, samples were hard to get because the animals were usually butchered immediately after they were caught. Only meat and *mattak* (skin) were brought back to the settlement. Some hunters from Kullorsuaq even sailed directly south to Upernavik to sell the catch after a quick stop in Kullorsuaq for fuelling.

Positions of catch localities for narwhals in the Melville Bay from 2007-2009 were extracted from supplementary data sheets (*særmeldeskemaer*) collected from the hunters by the Greenland Government, Department of Wildlife Management.

Collection of samples

Samples were collected from freshly killed animals at the hunting sites in Melville Bay, including information on date, time and position of hunt, sex, length of whale, width of tail fluke and length of tusk. The following samples were collected from each narwhal: sex organs, eyes, *mattak*, liver, kidney and the whole stomachs.

All samples were stored in a well-insulated cooler filled with ice, renewed on a regular basis. At arrival in Savissivik and Kullorsuaq the samples were moved to the freezing facility and later shipped to the laboratory at GINR in Nuuk.

Tagging of narwhals

In order to monitor the movements of narwhals in Melville Bay during the period with aerial surveys satellite transmitters were deployed on narwhals. The Kullorsuaq crew was equipped with two satellite tags which could be deployed on narwhals opportunistically when not disturbing the actual hunt. Both tags were of the type AM-A266 B-A (internally named mini-swing) manufactured by Wildlife Computers in Seattle, WA, USA. The tags were mounted on a flexible base plate of a fibre glass reinforced neoprene rubber pivoting around a 75 mm stainless steel anchor (Photo 1). An adapter was manufactured to mount the tags on a standard hunters harpoon so that it could be deployed from kayak. Harpoons with the tags were thrown into whales from a distance of 2-3 meters and if possible placed close to the dorsal ridge. Average daily positions were calculated from good quality ARGOS locations (NQ=1, 2 or 3) available from one tagged individual. In addition to positions the satellite transmitters also provided data on the diving activity of the whales including summarized frequency counts to different depth bins.

Photo 1. Satellite transmitter system for tagging narwhals in Melville Bay with harpoon mounting and approach in kayak.

Historical tracks of narwhals

A limited sample of historical track lines of narwhals from Melville Bay is available from two tagging studies in 1993-94 and 2006-07. Data from these studies have previously been published (Dietz et al. 1996, Laidre et al. 2010, Heide-Jørgensen et al. 2012) and were made available for this study under the *agreement on exchange of unfiltered Argos data from narwhals tracked in Baffin Bay*.

Good quality positions (LC=1, 2 or 3) from 1993-94 to 2006-07 were used to calculate one daily average position of the whales, except for 2007 where there were some days with only poor quality positions (LC=A, B or 0) and they were used for calculating a daily average.

RESULTS

Aerial surveys

The aerial surveys were designed to cover the entire Melville Bay within one day with an intensified effort in the central stratum, however, not all transect lines were covered during one day (Fig. 1). The realized survey effort nevertheless ensured that all transect line were covered at least once (Table 1). The sightings were concentrated in the central stratum and the two neighboring strata in all three surveys (Figs 2-4).

MRDS models do not require $g(0)$ to be one but they do rely on the probability of detection on the trackline being at a maximum. For some duplicate sightings, the observers had recorded different declination angles and thus the sightings had different perpendicular distances. There seem to be a systematic bias where angles from observer 2 were on average greater than observer 1 (t-test; p= 0.003) with an average difference of 1.4 degrees. It was decided to use the mean angle and hence perpendicular distance for all duplicate sightings. Systematic bias between observers for recorded group size was not found and the average group size for the duplicate sightings was used.

A combined detection function and perception bias estimation was established for all three surveys based on the common sampling of sightings by the two observation platforms (Table 3).

In the MRDS model a half-normal key functional form and a hazard rate form were tested and the half-normal was chosen based on its lower AIC (3189, Table 4) with a distance detection range fixed at 0-1200 m. The final DS model had distance and group size (as a factor with three levels) as an explanatory variable. The MR model had distance, group size (as a factor with three levels) and ‘time to next sighting’ as an explanatory factor. The g(0) for observer 1 was 0.76 (cv=0.067) and 0.76 (cv= 0.067) for observer 2 with a combined g(0)= 0.93 (cv= 0.03) (Model 15, Table 4).

The abundance estimates were stratified by geographic strata (Table 1). The largest abundance was found in the second survey and the largest abundance was detected in the central stratum in all three surveys and no sightings were obtained from the northwest stratum (Table 1).

Spatial analysis of sightings

Narwhals were found closer to the shoreline in both survey 2 and 3 compared to survey 1 (p= 0.0001, Table 5, Fig. 9a). There was no significant difference in the distance from narwhal groups to shoreline between survey 2 and 3 (Fig. 9a). There was no significant difference between distance to shorelines of sightings between the survey conducted in 2007 and the three surveys in 2012. The sightings obtained from the survey in 2007 were collected in the period between survey 1 and 2 in 2012, thus it represents and intermediate situation.

Narwhals were more aggregated in survey 1 and 2 compared to survey 3 (p= 0.002, Table 5, Fig. 9b). There was no significant difference in the distance between neighbouring groups between survey 1 and 2. Narwhal sightings were significantly further apart in the survey conducted in 2007 than in either of the surveys in 2012 (Fig. 10).

There were no significant relationships between neither *group size* and the distance to shoreline nor *group size* and the distance between sightings.

Questionnaire survey

Fifteen questionnaires have been returned, 3 from Savissivik and 12 from Kullorsuaq, covering 36 catches in total. In general the hunters never travel or hunt alone, they are always in pairs or in larger groups which both increases safety and facilitate the hunt as well as the subsequent flensing.

The average age of the hunters was 42.8 years of age, the youngest being 30 and the oldest 69 years old (n=14). One hunter did not provide information on his age.

Seven hunters informed that they have occasionally experienced difficulties with recovering the hunted whales in 2012, whereas 8 did not have problems landing the whale they were hunting.

All hunters reply that they caught one animal at a time and several hunters only reported one animal, whereas other reported several catches during the season. Two hunters each reported 6 caught animals over several dates.

About a quarter of the whales (22%) were shot and killed from the ice edge from March to June and 78% were shot from open boat in July-August. All animals were harpooned from kayaks prior to being killed by a rifle shot from a boat or the ice edge. Even if the blubber layer is described as thick in most occasions, the whales will sink when dead, which the *avataq* (buoy made of seal hide) connected to the harpoon head prevents. In addition to the 36 reports about catches of narwhals; three whales sampled during the GINR staff participation were not included in the questionnaire survey.

The weather for the reported hunts was generally described as “calm”, “good” or “pleasant”, only three times out of 39 was the weather described as “bad” or “rainy”. Normally hunters never go out in bad weather, both for safety reasons and due to difficulties in detecting the whales in rough waters.

Camp sites for narwhal hunting and locations for catching whales

Except for one narwhal taken north of Savissivik on March 2 all reported narwhal catches (n=39) were spread out between late May and early September 2012 (Fig. 11) and all narwhals were taken inside the Melville Bay (Fig. 12). Thirteen catches were made by hunters from Savissivik and 23 by hunters from Kullorsuaq. The preferred hunting camp sites for narwhal hunting in Melville Bay were concentrated around Nuussuaq and Fisher Islands (Fig. 13). Apparently three camp sites further south are no longer used for hunting narwhals (Table 6).

On the question of how far from land the whales were caught, a lot of answers were “Aap”, Greenlandic for “Yes”, some “Naamik” - “No”. The question must have been translated to: “Were the whales close to shore?” instead of “How far from land were the whales caught?” Some questionnaires provided precise estimates of the distance to shore, ranging from 100 to 5000 meters. All the hunters reported that the whales were located in the same areas where they are usually found.

Compared to the positions of the reported catches in 2007-2009, catches in 2012 were more concentrated in the central part of Melville Bay with more than half the catches at Nuussuaq (n=21) and a few catches at Savissivik and none south of 75’30^{o}N.

Sex, group size and body condition of hunted whales

The sex distribution among the hunted animals was 75 % males 25 % females and the average group size was 5.5 animals ranging from one single animal to groups of up to 20 animals. In general all hunters reported a thick blubber layer of the hunted animals, except for one whale caught March 2nd, much earlier than all the other animals, which had an exceptionally thin blubber layer.

Feeding habits

Questionnaire data on stomach contents were available from 36 catches of narwhals. The data were split into two seasons; May-June and July-August. Four types of prey were identified by hunters: Greenland halibut (*Reinhardtius hippoglossoides*), wolffish (*Anarhichas lupus)*, shrimps and squids (Gonatus sp) (Fig. 14). Greenland halibut decreased in importance from 31% to 10% between May-June and July-August. All reporting of stomach content always included only one prey item except for one report that included two items.

Observational trips into the Melville Bay

Two trips into the Melville Bay were conducted from each end, Savissivik in the north and Kullorsuaq in the south. The observers from GINR each hired a small team for the field work, in both cases the chairman handling the questionnaires and a second hunter, each with a boat were chartered. Both old and current hunting grounds were visited and pointed out on a map by the hunters. Several hunting grounds have been deserted close to Kullorsuaq and hunting is presently conducted further north in the Melville Bay (Fig. 13, Table 6).

The two teams met at the western most tip of the peninsula Nuussuaq where they camped. Upon departure from Savissivik and Kullorsuaq, the weather was quite stable and warm with open water between the icebergs and old sea ice. The days at Nuussuaq were mostly sunny without precipitation. Nuussuaq was clearly an active hunting ground with lots of fresh remains from flensing of whales scattered around the peninsula. During the period there, whales in groups of various sizes were observed every day, and several animals were harvested by other hunters sharing the site. Due to time spend with the hunters at the hunting grounds it was possible to obtain five full sample sets from hunted whales (Table 7). The majority of whales were hunted in close vicinity to the camp at Nuussuaq, and here three of the five samples were collected.

Observations in the field revealed that most hunters were either travelling with their kayaks or had the kayaks deposited on shore later use. Kayaks were used in all hunts and the impression was that the hunters always use their kayaks when hunting narwhals in Melville Bay. The fact that narwhals sink when dead is probably the reason for why hunters prefer harpooning from kayak before shooting the whale with a rifle. This procedure minimizes the risk of losing the whale compared to immediately killing it with a rifle from a dinghy.

A hunt and the following flensing

Every day hunters would take shifts on the lookout for whales. Hours after hours the lookout point, "*Qaqaliaq"*, was manned with hunters watching for narwhals while boats were moored to the shore close by and kayaks positioned to be quickly launched with all equipment carefully placed and ready to go. If no whales were seen from the lookout for an extended period, the kayaks would occasionally be loaded on the dinghies to conduct a search trip in a larger area.

When whales were sighted close to the lookout, the kayaks were launched and positioned strategically to cover the expected area where the whales would surface. The kayak is a very stealthy craft which is quite manoeuvrable. The hunter can sit and wait for his prey up to an hour almost without moving, and when a whale comes close enough, he will position himself to be behind the animal and row when it is at the surface and glide through the water when it dives. He will gradually get closer and when the animal surfaces 2 to 3 meters in front of him, he will throw his harpoon. The harpoon stick pushes the harpoon head, which acts as an anchor, under the skin of the whale while holding an approximately 20 meter long line attached to an inflated bag of sealskin, "*avataq"* which works as a buoy.

As soon as the harpoon head is securely fastened, the hunter will shout *ai-ai-ai,* and the nearest of the other kayaks will assist with a second harpoon as will a boat with hunters equipped with rifles. When the animal is dead it will be towed by the boat to the nearest flat beach or rock in order to be flensed; a job that normally lasts less than an hour.

Various organs, the meat and the skin with a thin layer of blubber "*mattak",* as well as the tusk, if present, are kept. The tusk and the "*mattak",* being the most valuable parts of the animal, are often sold. There is a well-defined key how to divide the outcome of a caught narwhal. The hunter who sets the first harpoon in the animal is entitled to the tusk and a part of the "*mattak"*. The hunter who sets the second harpoon is entitled to a fair share of the "*mattak"* evenly split with the hunter who kills the animal. Assisting hunters at the flensing site will get a share of meat and "*mattak"* for their own use.

Observations and statements from the hunters.

The hunters made a number of statements on narwhal hunt regulations but they also contributed some biological information. The statements by the hunters are provided here unedited:

"The numbers of both narwhal and beluga have gone up since the hunting rules got more rigorous..."

"I can see a difference in both size and numbers of the whales since quotas and hunting methods got adjusted in 2007, they are getting more numerous and bigger"

"The current quota of 300 animals is making living hard for the hunters"

"Killer whales are rarely observed around Kullorsuaq"

"I have seen a pod of 10 to 15 killer whales between Kullorsuaq and Nuussuaq"

"The ice cap has retracted significantly in the Melville Bay"

"A narwhal has been caught in Savissivik 2011 with a piece of a tusk from another whale embedded in the blubber around the head… the whale was in good shape" (see Photo 2)

Photo 2: Tip of tusk found embedded in narwhal melon.

"Numerous times I have seen narwhals give birth, which can take shorter or longer time. The calves are good for dog food"

"I have seen several narwhals with two foetuses in the belly and also up to three calves of various sizes swimming with a single mother"

"The hunters are going north from Kullorsuaq with the sole purpose of catching narwhals"

"It rarely happens that the harpoon kills the narwhal, and if it happens it is because the harpoon hits right behind the skull, in the rib region or in the kidneys. Both small and big animals can die like that"

"From August to October minke whales get very close to the boats in waters around Kullorsuaq"

Collection of samples

A total of five samples were collected from the Inuit hunt of narwhals in Melville Bay (Photo 3, Table 7); all adult whales (>342 cm) and two of them being males both with tusks. Samples for later age determination and examination of sexual maturity, feeding habits and burden of organochlorines were collected and are now stored at GINR, Nuuk.

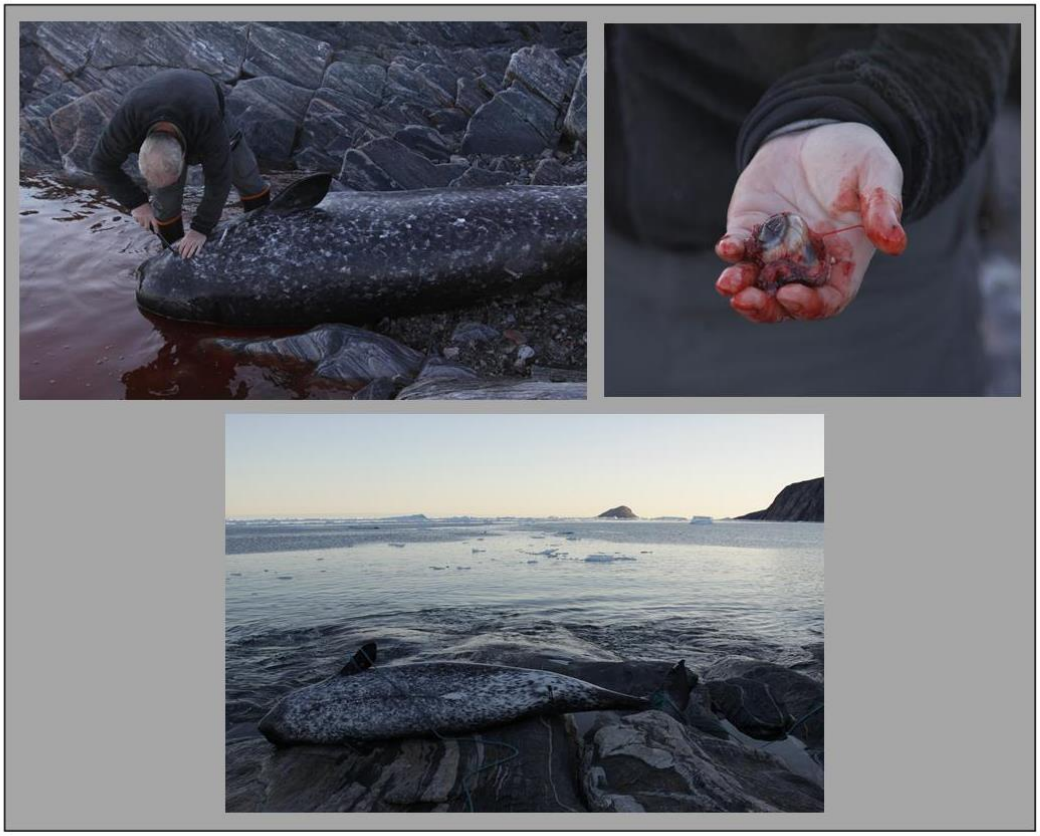

Photo 3. Sampling of narwhals at Nuussuaq, August 2012.

Based on mass of testes (including epididymides), one male was sexually mature (#895; average mass = 510g) and one was not (#897; average mass = 69g).

Based on the mass of the ovaries (in two females; average mass = 19g) and the presence of a large *Corpus luteum* (CL) in the left ovary of the third female (#896) supporting a 42.2 cm fetus (Photo 4), all three females were sexually mature. One other female had a *Corpus albicans* (CA, #899), but otherwise no CLs or CAs were found in any of the other ovaries. The last female had 15 follicles, but no CL or CA suggesting she just had reached sexual maturity but was not pregnant and has not been through a pregnancy (#898).

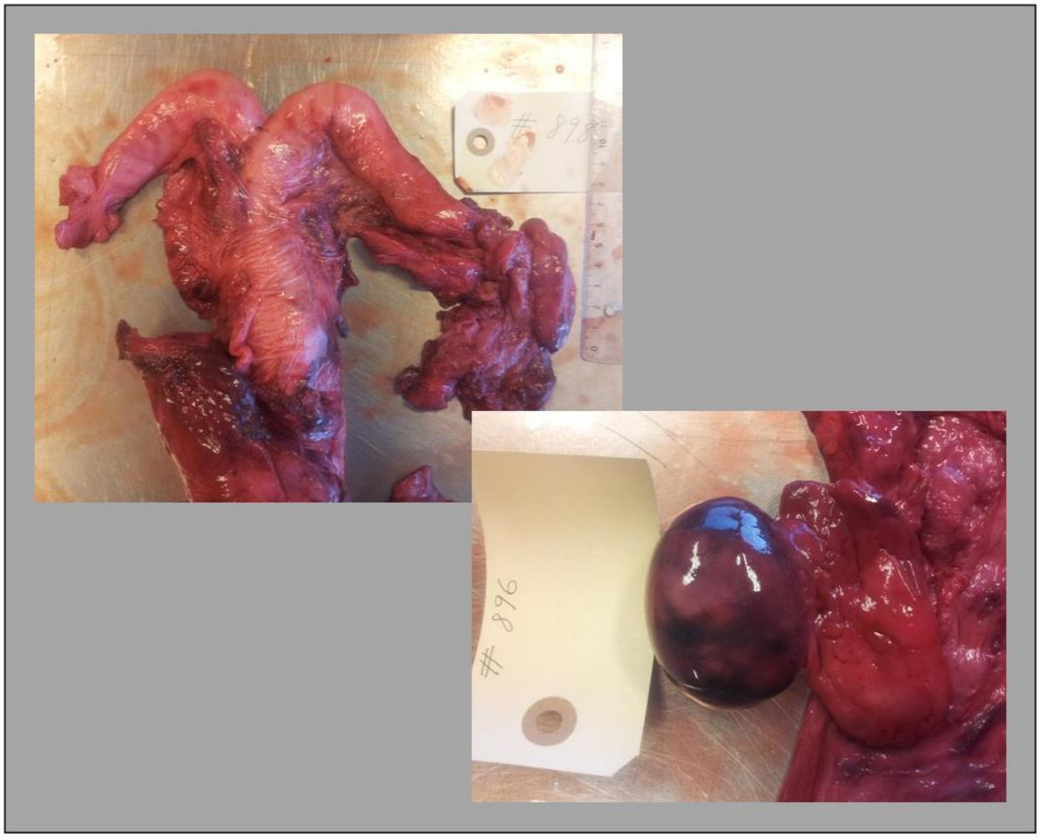

Photo 4. Uterus and ovary with corpus luteum of #898 and #896.

All five narwhals had remains of food items in their stomachs. Some only had hard parts (beaks and lenses of cephalopods and otoliths) while others had fresh food items as well (Gadus sp, Gonatus sp and shrimps) (Table 8). All five whales had fresh remains of shrimps, though it was only parts of the shell or the antenna. Two of the whales had a high proportion of unidentified dissolved matter which was assumed to be mostly shrimps due to the red coloration. Two narwhals had fresh remains of polar cod and one had fresh remains of halibut. The fish were partly dissolved, but findings of backbones matched the otoliths thus supporting the species identification. All five narwhals were infested with nematodes, but none to a major degree. Two of the narwhals had around 10 rocks (app. 2 x 1.5 cm) in their stomach and one whale had a large completely intact ray (*Rajidae*) egg (7 x 4 cm).

Narwhal tracking

The two hired guides were provided with harpoon mounted satellite transmitters to be deployed from their kayaks. Both hunters succeeded in tagging a whale on August 31 (Table 9) but one tag failed for unknown reasons to provide any positions, while the other performed well until September 20 when contact was lost. During the tracking period the animal migrated 120 kilometres northwest almost to the settlement of Savissivik in just two days, just to spend the next six days swimming to about 50 kilometres south of the tagging location (Fig. 15). During this period the animal stayed within the survey area. On September 14 the whale was located in the off-shore areas, well out of the survey area in deeper waters (>1000 m). The last position was received on September 20, back within the survey area, less than 40 kilometres from where the tag was deployed three weeks earlier. The tracking showed that the animal spends 9 days within the survey area, one day outside the survey area and for 11 days no positions were obtained.

The one whale (#7931) that provided positions also gave data on diving patterns of the whale. The mean percentage of time spent at surface (0-2m) was 25.4% (SD=0.14) for 6 observations during 6-hr intervals (12-24 UTC, Table 2). About 4% of the 148 dives went below 700 m and 79% were shallower than 150m. Diving activity ranged between 3 and 4 dives per hour for the four days with data; 31/8, 8, 12 and 14/9.

Old satellite tracks; presence in survey area in relation to date

Satellite tagging of narwhals has been carried out in 1993-94 and in 2006-07 at their summer residence in Melville Bay. The whales were tagged ultimo August or early September with a total of 16 whales instrumented with one or more satellite transmitters (MK10, SPLASH and SPOT), of which 15 whales provided useful positions in September and 12 whales in October (Table 10).

Movements of the whales during September showed extensive usage of the entire Melville Bay with some affinity for the central part of the Bay between Nuussuaq and Fisher Islands (Fig. 16). When contrasting the five years with data it seems like the whales were located further offshore in 1994 and that they made more coastal movements in other years, especially in 2007 (Fig. 17).

The area used for the aerial surveys covers part of the area where the positions from the narwhals have been acquired. Of the narwhal positions in September 75% were from inside the survey area with a decrease in positions towards the end of the month (Fig. 18). More than 38% of the positions from 22nd

September-30th September (period corresponding to survey 3) were acquired from outside the survey area.

Of the narwhal positions in October 77% were from outside the survey area with an increase towards the end of the month. More than 85% of the positions from 9th October-31st October were obtained from outside the survey area and by the end of the month no narwhals remained within the survey region.

Melville Bay during September-October is usually more or less ice free but previous years (1993-1994) have shown late departure of fast ice from the previous winter with fast-ice remaining along the coast. These events could have affected the distribution of narwhals by preventing the whales from entering the glacier front areas and pushing them further offshore. The positions from 1993-94 increase the proportion of narwhal positions located outside the survey area.

DISCUSSION

This report deals with some of the possible short-term responses from the narwhal population in Melville Bay to offshore seismic survey activity conducted in northern Baffin Bay in summer and fall of 2012. No seismic vessels were observed during the aerial surveys and we have no information yet on sound transmission from the airgun activity and sound levels that the narwhals were exposed to in Melville Bay. When these data become available we will examine the relationship between narwhal distribution and the received sound levels in the Bay.

Abundance and distribution of whales

This study aimed at producing abundance estimates and examining the distribution of narwhals in Melville Bay during seismic exploration. The distribution of narwhals in all three surveys was more clumped than that found in a previous survey in Melville Bay (2007). Narwhals showed an affinity to the central strata where the most glacial activity takes place and they were observed closer to the mainland during the early and late part of the seismic exploration (survey 2 and 3). In addition narwhal groups were more scattered, e.g. further apart in survey 3. The scatterings could to some degree be explained by the usual timing of departure of whales in Melville Bay where app. 40% of previously satellite tagged whales have left the Bay at the time of the third survey.

The density of narwhals in Melville Bay in 2012 varied only slightly between the two first surveys with the 2nd survey being the highest. The abundance and density, however, dropped during the 3rd survey in late September. A comparison of the timing of the departure of satellite tracked whales from 1993 through 2006 revealed that >50% of the whales have left the survey area by October 1 suggesting that the fall migration away from Melville Bay starts sometimes in mid-September. The decline in abundance of narwhals at the 3rd survey is most likely caused by emigration from the area, and cannot be attributed to unusual disturbance levels.

The selected covariates in the MRDS model suggest that sighting probability increases with group size and that the event of several small subgroups in a large "super-group" prevents the observers from detecting all small groups. Although the point estimates (survey 1, 2, 3 = 1826, 2800, 517 whales respectively) suggests that there are less whales in the Bay during the late period with seismic exploration, the confidence intervals around the point estimates overlap between surveys and the point estimates do not differ significantly from each other.

The fully corrected abundance estimate from the 2nd survey in 2012 (2,800; 95% CI 1354-5827) indicate an abundance in the same magnitude but provides a more precise estimate than the abundance estimated in Melville Bay in 2007 (6,444; 95% CI 1,403-25,860, Heide-Jørgensen et al. 2010).

Feeding habits

All previous information suggests that the Melville Bay is not an area where narwhals are feeding intensively (Laidre and Heide-Jørgensen 2005, GINR unpubl. data from sampling in 2006 and 2007). The diet usually also contains relatively few species and are dominated by polar cod/Arctic cod, squids and shrimps. The stomach samples examined in this study as well as the information collected from hunters confirm the low diversity diet and the absence of full stomachs with fresh remains.

Information on the hunting of the whales

In retrospect the questionnaire had a few wording flaws which made the translation between Danish, Greenlandic and English a bit uncertain, and which caused some questions to be answered ambiguously or unclear. These answers have not been used in the interpretation of the questionnaires. Most questions have remained clear through translations though, and have created a base of information that describes the hunter's perception of the narwhals and the narwhal hunt in Melville Bay.

Perhaps the most important piece of information from the questionnaire survey is the widespread use of kayaks in the hunt in Melville Bay. This is also in agreement with the field effort in the Bay and confirms previous experience that narwhals are very skittish and hard to approach in this area, but also that loss rates, due to the harpoon-first techniques, are low for this hunt.

Narwhals rarely exhibit only one prey item in the stomachs and the notion by the hunters of just one type of prey suggests that more detailed examination of the stomachs are needed to get a valid picture of the complete diet. The examination of the stomach contents confirm both the limited food intake during the narwhals stay in Melville Bay but also that several prey items are always involved in the diet. Apparently shrimps are important species in the diet together with polar cod/Arctic cod and squids. The single detection of a halibut otolith and backbone could be from feeding outside the Melville Bay.

The questionnaire survey and the sampling of caught whales provide basic information about 39 catches from Melville Bay and adjacent areas. The total catch from the Melville Bay in 2012 stock was 79 which imply that the questionnaire survey only captured information from about half the catches. A number of communities south of Kullorsuaq are catching narwhals *en route* to and from the Melville Bay or use Melville Bay as a summer hunting ground.

Although the circumstances and locations around 40 catches without records are unknown, no information obtained from this study suggest that narwhals have been subject to hunting activities outside the traditional hunting grounds (i.e. spring ice floe hunt and summer hunt in Melville Bay) in 2012. Inside the Melville Bay the hunting was concentrated around Nuussuaq which also in the past has been the most important locality for hunting of narwhals.

Satellite tracking

It is not clear why the longevity of tags deployed by harpoon is significantly lower than tags mounted on captured animals but it is a consistent observation from several studies. For longer term tracking of narwhals in Melville Bay it is recommended that live capturing operations with surgical instrumentation of whales is conducted following previously developed procedures (Dietz and Heide-

Jørgensen 1994). Nevertheless, the short-term tracking with a harpoon tag confirms previous observations that narwhals are stationary within the Melville Bay during the summer season.

Limitations of study

This study provides no insight to effects of long-term disturbances as we have not been able to follow the population after they depart from the Melville Bay area. Persistent disturbance of narwhals (and other acoustically sensitive Arctic species) could disrupt important behavior, causing the animals to abandon important summering areas, and change their migration patterns. As they leave the summering grounds, narwhals are generally heading towards winter feeding grounds, and disturbance could cause them either to return and risk ice entrapment or to move to wintering areas that are sub-optimal for feeding. Considering that narwhals already appear to be approaching their physiological capacity (i.e. dive limits) and may have little flexibility to adjust their swimming and diving behavior (Williams et al. 2010), it seems critical that the whales are not disturbed to such an extent that their basic annual cycle is disrupted.

CONCLUSION

1. The aerial surveys during the early and late part of the seismic exploration gave an indication but no clear evidence that there were more narwhals present inside the Melville Bay during the early part than in the late part of the seismic exploration. From other years we know that 50% of the animals have left the Melville Bay by late September and this seasonal variation in abundance is not related to seismic activity.

2. Compared with a similar survey from 2007, narwhals in 2012 had a more clumped distribution, with distance between sightings being closer and all narwhals seen within the central strata. It is not possible to conclude whether this change in distribution is a reaction to sound from seismic surveys or if other causes are involved.

2. Hunters that operated inside the Melville Bay reported no changes in occurrence, availability or behavior of narwhals during the study period.

3. No catches were reported in unusual areas and the known catch locations were all in good agreement with catch locations from previous years.

4. No changes in feeding intensity or diet, compared to previous years without seismic activity, could be detected.

In conclusion no *short-term effects* of seismic survey activity on narwhal distribution, abundance, timing of southbound migration and feeding habits could be detected in Melville Bay in summer and fall 2012. It remains unclear whether a more clumped distribution in 2012 compared to 2007 could be related to seismic activity. Information on sound levels in the bay and proximity of seismic vessels were not available for this preliminary study and this information will be important for assessing if there were noise levels in the Bay that potentially could elicit a detectable response in narwhal behavior.

If further oil exploration activities are planned for northern Baffin Bay and in Melville Bay it is recommended that the aerial survey monitoring of abundance of narwhals is continued to assess whether there are any long-term changes in abundance in the Bay. It is also recommended that narwhals are captured in nets and instrumented with satellite transmitters to allow for more permanent attachment of transmitters that will facilitate observations of changes in the migratory habits when they depart from Melville Bay and head towards their wintering grounds.

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Table 1. Summary of survey effort and number of sightings seen by each platform for each survey and in each stratum and survey. Note that the number of unique sightings is the number of sightings seen by observer 1 plus the number seen by observer 2 minus duplicates. Estimates uncorrected for availability bias of expected group size, group abundance, group density (groups/km^2), narwhal abundance, narwhal density (animals/km^2) and narwhal abundance corrected for availability bias are proivided. Coefficient of variance (*cv*) is given in parenthesis.

Survey	Strata	Area (km^2)	Number of transects	Effort (km)	Number seen by observer			Number of unique sightings	Expected cluster size	Abundance of groups	Density of groups (groups/km^2)	Abundance of whales	Density of whales (whales/km^2)	Abundance of whales corrected for availability bias
					1	2	Duplicates							
1	S	6,376	11	1,088	7	7	5	9	5.44 (*0.22*)	33 (*0.51*)	0.0051 (*0.51*)	177 (*0.62*)	0.0277 (*0.62*)	770 (*0.62*)
	C	2,076	10	1051	37	33	23	47	3.64 (*0.10*)	63 (*0.23*)	0.0305 (*0.23*)	230(*0.26*)	0.1109 (*0.26*)	1000 (*0.27*)
	NE	2,721	11	976	4	6	4	6	1.09 (*0.01*)	12 (*0.98*)	0.0044 (*0.98*)	13 (*0.98*)	0.0048 (*0.98*)	57 (*0.98*)
	NW	3,748	5	507	0	0	0	0	-	-	-	-	-	-
	TOTAL	**14,821**	**37**	**3,622**	**49**	**46**	**33**	**62**	**3.91 (*0.17*)**	**107 (*0.24*)**	**0.0072 (*0.24*)**	**420 (*0.31*)**	**0.028 (*0.31*)**	**1826 (*0.32*); 95%CI 992-3361**
2	S	6,376	12	1,206	15	17	15	17	2.87 (*0.08*)	63 (*0.83*)	0.0099 (*0.83*)	181 (*0.79*)	0.0283 (*0.79*)	787 (*0.79*)
	C	2,076	10	764	71	60	42	89	2.33 (*0.09*)	175 (*0.47*)	0.0841 (*0.47*)	390 (*0.46*)	0.11877 (*0.46*)	1696 (*0.47*)
	NE	2,721	11	863	10	9	8	11	3.05 (*0.03*)	24 (*1.01*)	0.0093 (*1.01*)	74 (*1.01*)	0.0283 (*1.01*)	322 (*1.01*)
	NW	3,748	5	396	0	0	0	0	-	-	-	-	-	-
	TOTAL	**14,821**	**38**	**3,229**	**96**	**86**	**65**	**117**	**2.46 (*0.08*)**	**262 (*0.39*)**	**0.0176 (*0.39*)**	**644 (*0.38*)**	**0.0435 (*0.38*)**	**2800 (*0.39*); 95% CI 1354-5827**
3	S	6,376	11	690	0	0	0	0	-	-	-	-	-	-
	C	2,076	10	911	15	11	7	19	3.21 (*0.15*)	30 (*0.54*)	0.0145 (*0.54*)	97 (*0.64*)	0.0465 (*0.64*)	422 (*0.64*)
	NE	2,721	11	506	2	2	2	2	3.58 (*0.07*)	6 (*0.95*)	0.0024 (*0.95*)	23 (*0.95*)	0.0086 (*0.95*)	100 (*0.95*)
	NW	3,748	3	167	0	0	0	0	-	-	-	-	-	-
	TOTAL	**14,821**	**35**	**2,274**	**17**	**13**	**9**	**21**	**3.28 (*0.12*)**	**36 (*0.47*)**	**0.0025 (*0.47*)**	**119 (*0.55*)**	**0.0080 (*0.55*)**	**517 (*0.56*); 95% CI 187-1429**
ALL	**TOTAL**	**44,463**	**110**	**9,124**	**162**	**145**	**107**	**200**	**2.92 (*0.10*)**					

Strata: South (S); Central (C); Northeast (NE); Northwest (NW)

Table 2. Data on time available for detection collected from five narwhals instrumented in Melville Bay in August-September 2007 and 2012, one female instrumented in November 2008 and one whale instrumented in Qaanaaq 2012. The monthly averages for #20162 and #10946 were calculated from the daily averages based on recordings during 24-hr of the fraction of time spent at, or above, 2m depth. For the other whales monthly averages are based on 6-hr time-at-depth readings. In this table, *n* is the daily average of surfacing events collected between 10:00 and 20:00, SD is the standard deviation of the daily averages.

		August *	September	March	April	May	June	July
	Mean	0.15	0.23	0.18	0.2	0.21	0.16	0.13
20162	*n* (days)	31	24	24	26	31	28	31
Melville Bay	SD		0.02	0.01	0.01	0.01	0.01	0.01
	Mean	0.25	0.20					
10946	*n* (days)	2	30	na	na	na	na	na
Melville Bay	SD	0.04	0.02					
	Mean			0.25	0.27	0.13	0.11	0.05
3961	*n* (6 hr)	na	na	9	11	19	13	9
Uummannaq	SD			0.05	0.16	0.15	0.09	0.02
	Mean		0.25					
7931	*n* (6 hr)	na	6	na	na	na	na	na
Melville Bay	SD		0.14					
	Mean					0.21		
20168	*n* (6 hr)					3		
Qaanaaq	SD					0.04		
	Mean	0.20	0.23			0.18		
	n	2	3			3		
	SD	0.07	0.03			0.04		

Table 3. Distribution of sightings from all three surveys combined on the two survey platforms in the detection range 0-1200 m with duplicates (resightings) indicated. Number of unique sightings is the sum of sightings seen by the primary and the secondary platform minus the number of duplicate sightings

Unique sightings	200
Sightings seen by primary	162
Sightings seen by secondary	145
Duplicate sightings	107

Table 4. AIC values after fitting explanatory variables to the DS and MR models. The final model chosen are given in bold and 'ΔAIC' indicates the difference between the chosen model and the specified model. HN indicates a half-normal form and HZ indicates a hazard rate form for the DS model. The explanatory variables are perpendicular distance (D), group size (S), group size as a factor with three classes (1, 2-5 and ≥6 narwhals) (S_3), Beaufort sea state (BF), side of plane (SP), observer (O) and time to next observation ≤10 sec (T).

Model	DS model	MR model	AIC	ΔAIC
1	HN: D	D	3208	18.24
2	HZ: D	D	3209	19.90
3	HN: D + BF	D	3209	19.12
4	HN: D + S	D	3204	14.93
5	HN: D + S_3	D	3203	13.81
6	HN: D + SP	D	3208	18.08
7	HN: D	D + BF	3208	18.38
8	HN: D	D + S	3206	16.81
9	HN: D	D + S_3	3199	9.40
10	HN: D	D + SP	3204	14.98
11	HN: D	D + O	3207	17.11
12	HN: D	D + T	3201	11.89
13	HN: D	D + S_3 + T	3194	4.42
14	HN: D + S_3	D + T	3197	7.46
15	**HN: D + S_3**	**D + S_3 + T**	**3189**	**0.00**

Table 5. The average distance (km) and the significant relationship between a) a narwhal sighting and the shoreline and b) a narwhal sighting and the closest narwhal sighting.

	Distance to shoreline (km)		Distance between narwhal sightings (km)	
Survey 1	9599	FAR	1123	CLOSE
Survey 2	5356	CLOSE	580	CLOSE
Survey 3	4789	CLOSE	1273	CLOSE
Survey 2007	7617	BETWEEN	6782	FAR

Table 6. List of hunting camp sites in Melville Bay (see Fig. 12).

Old hunting camp sites – no longer in use			
Number	Latitude	Longitude	Locality name
1	74.0667	57.0000	Nunatarssup Itivdlia, Havgård Kystland
2	74.0917	57.0317	Tugtulikaussaq, Lille Renland
3	75.0083	58.0117	Niaqorssuaq, Red Head
Hunting camp sites currently in use and some that have also been used in the past			
4	75.0617	58.0533	Nalungiarssuaq, Astrup Kystland
5	75.0650	58.0500	Nalungiarssuaq, Astrup Kystland
6	75.0733	59.0250	Qeqertarsugssuaq, Stenersen Ø
7	75.0767	59.0217	
8	75.0983	60.0050	
9	76.0033	60.0300	
10	76.0083	60.0833	
11	76.0067	61.0200	Balgoni Øer
12	76.0417	61.0750	Leven Ø
13	76.0750	62.0017	Heilprin Ø – Kayaks in depot
14	76.1083	61.0667	Naujapaluk/Ataata Nunaat, Fisher Øer
15	76.1250	61.0467	Naujapaluk, Fisher Øer
16	76.1500	61.0117	
17	75.7980	59.0731	Nuussuaq
18	75.9534	60.0118	
19	76.0718	60.8741	
20	76.1425	61.0145	
21			Nuussuaq

Table 7. List of samples of narwhals collected in Melville Bay 2012.

IDNO #	Date	Locality	Length (cm)	Fluke width (cm)	Tusk length (cm)	Sex	Sex organs	Eyes	Skin	Liver	Kid-ney	Sto-mach	Meat
897 *)	27/8	Nussuaq	349	70	15	♂	x	x	x	x	x	x	
898 *)	31/8	75,8667N 59,3167W	342	83	-	♀	x	x	x	x	x	x	
899	23/8	75,1461N 59,7485W	345	82	-	♀	x	x	x	x	x	x	
896	25/8	75,8265N 59,3162W	364 Girth 1.95	91	-	♀	X (foetus)	x	x	x	x	x	x
Foetus from 896	25/8	75,8265N 59,3162W	42.2 Girth 30,0 1110 gr	11,2									
895 *)	5/9	76,1461N 61,1423W	447	120	160 ext 200 int+ext	♂	x	x	x	x	x	x	

*) not included in questionnaire survey

Table 8. Examination of stomach samples for prey items.

ID	Mass (g)	Fresh remains					Otoliths			Other		Nematods
		Polar cod	Halibut	Shrimp	Squid	Other	Polar cod	Cod sp	Halibut	Squid beaks	Rocks	
895	1900 (mostly water)			√		Ray egg	√	√		√		√
898	200	√		√			√	√		√		√
899	1300		√	√	√	Dissolved food	√	√	√	√	√	√
896	900 (mostly water)			√						√		√
897	900 (mostly water)			√		Dissolved food				√	√	√

Table 9. List of deployments of narwhal transmitters. Description of placement is based on the visible part of the whale in a dive out. Placement of tag on whale is described by three letters in combination: R, right or L, left – F, front, M, mid or B, back – H, high – M, middle or L, low.

Tag ID	Tag Type	Date	Time	Position	Placement	Who	Comments
7931	MiniSwing	31/08/12	17:30:00	75.9808N 59,3000W	MMH	TP	Group of 4, medium sized male, small tusk
20166	MiniSwing	31/08/12	17:45:00	75,9808N 59,3000W	MMH	OK	Group of 3, medium sized whale, sex unknown

Table 10. Number of narwhals with active transmitters in Melville Bay for each year and month.

Year	September	October
1993	5	3
1994	3	2
2006	3	3
2007	4	4
2012	1	0

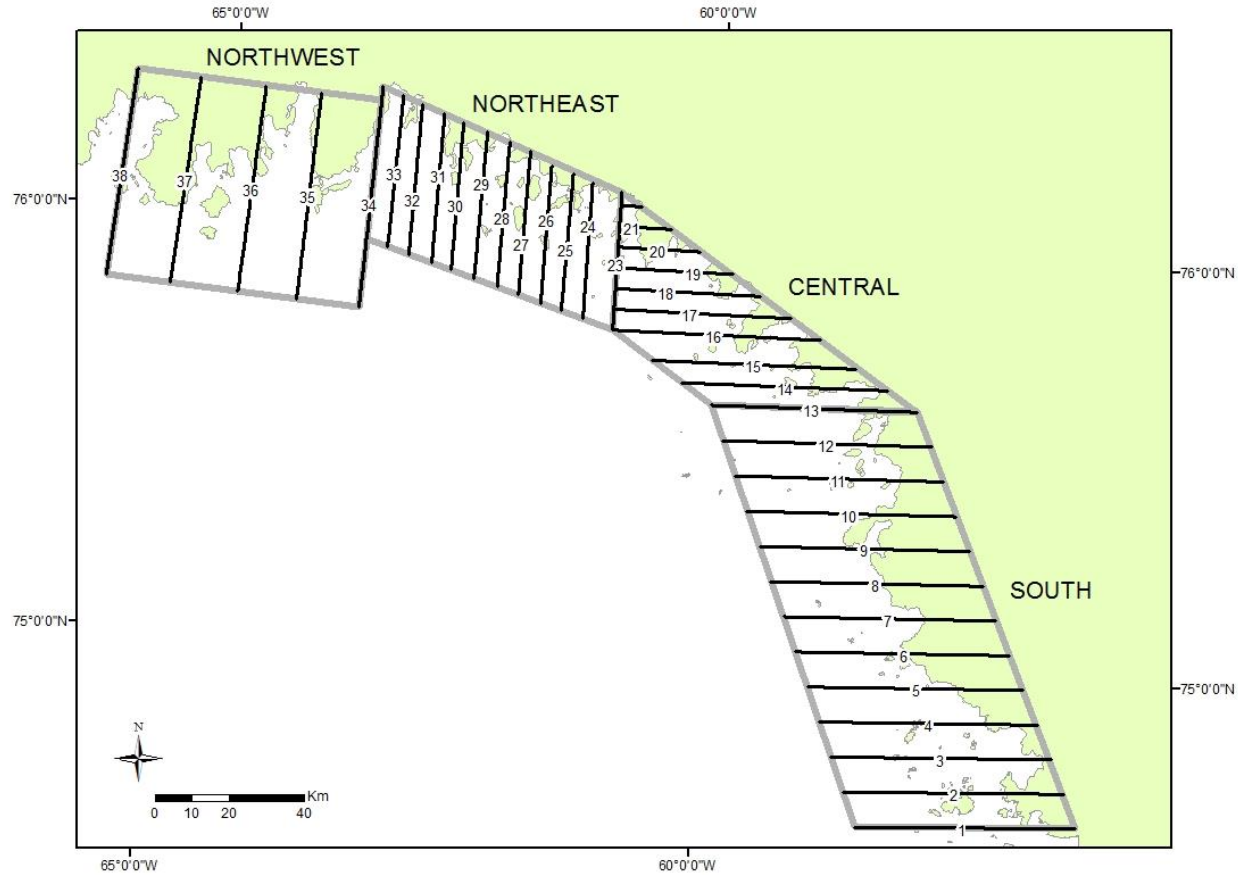


Figure 1. Design of strata and transects for surveys conducted in Melville Bay in 2012.

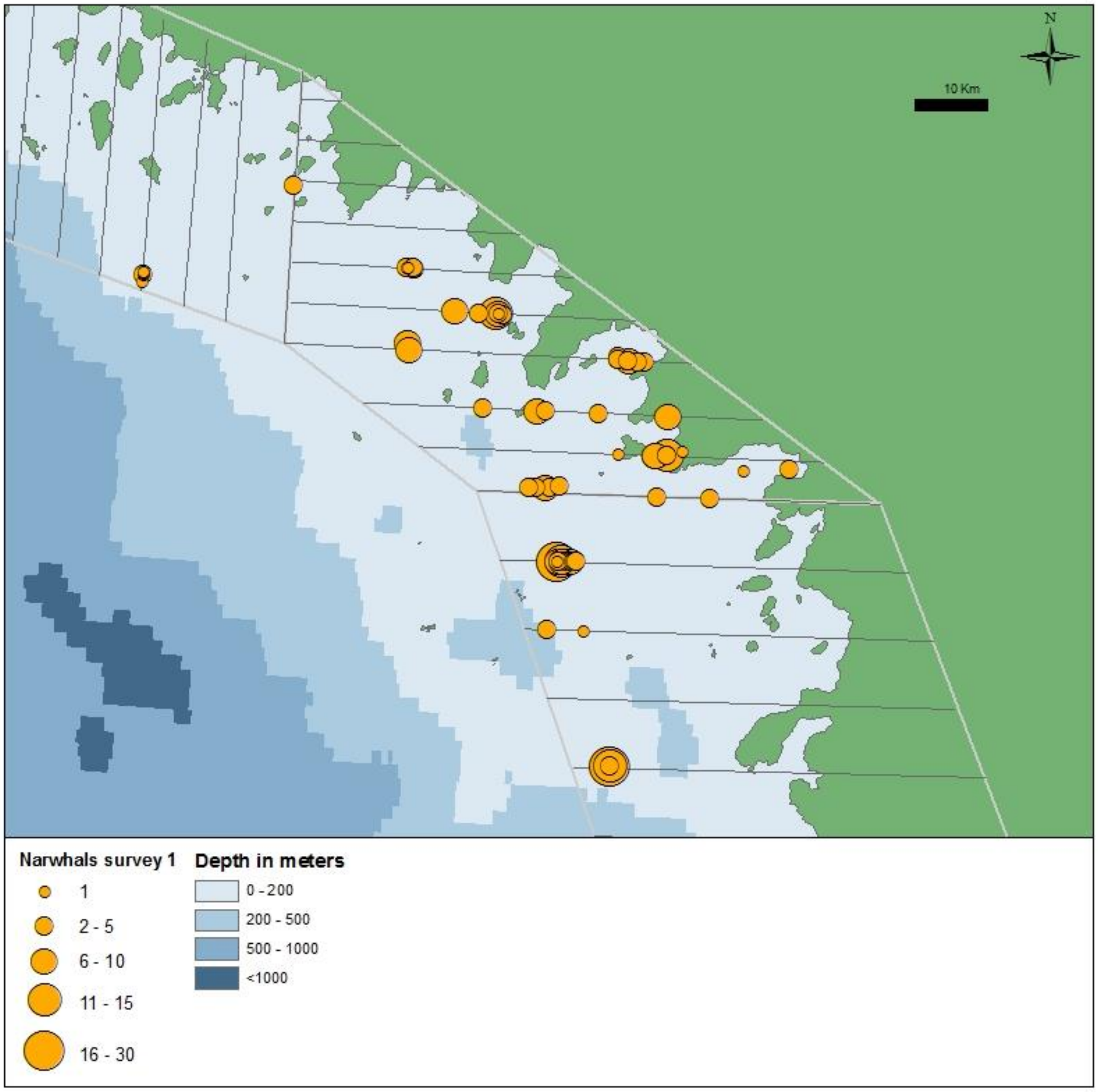


Figure 2. Sightings of narwhals during survey 1 between July 30 and August 5. Transects without sightings in the southern and western strata (see Fig. 1) are not shown.

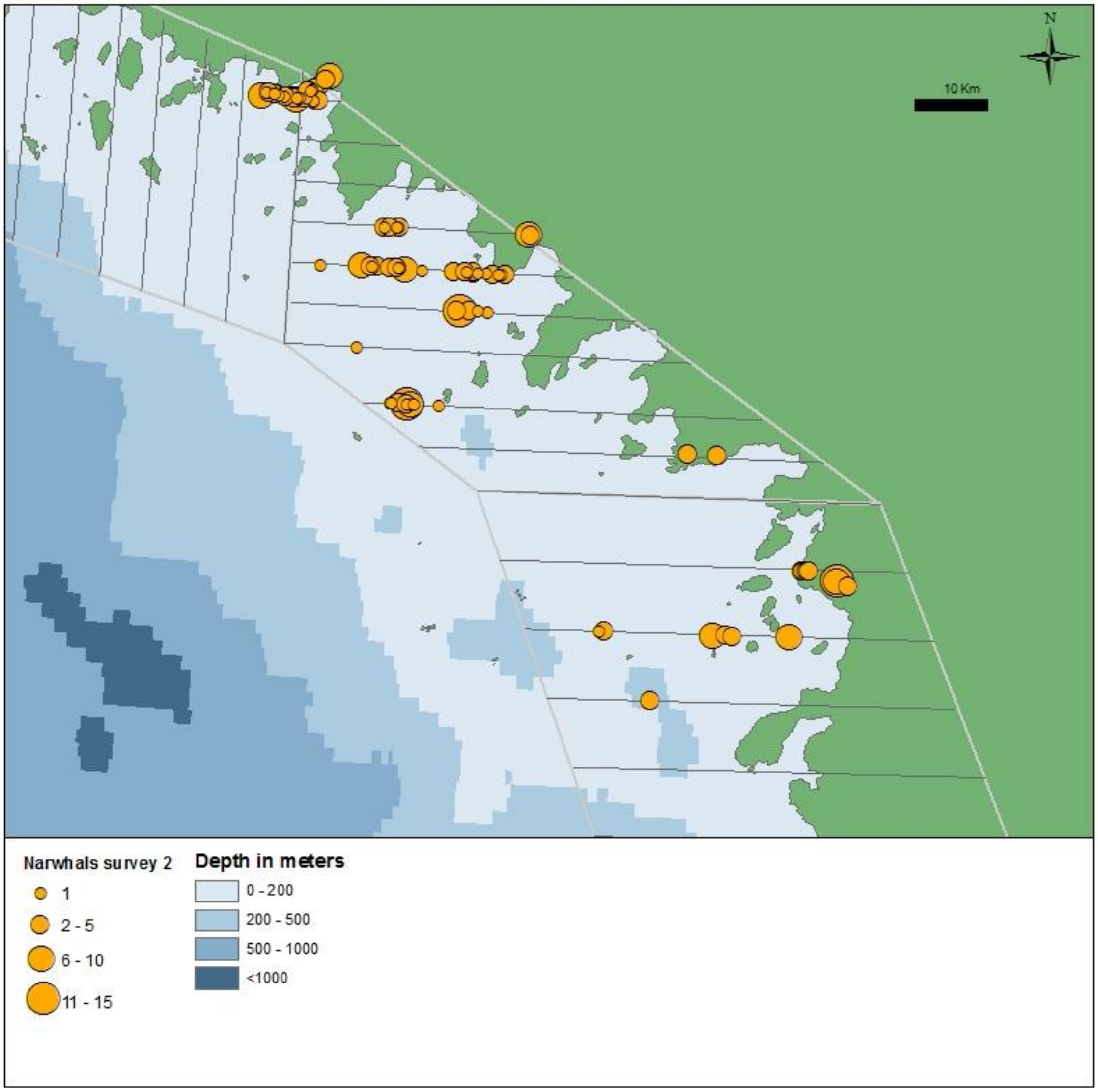


Figure 3. Sightings of narwhals during survey 2 between 28 August and 1 September. Transects without sightings in the southern and western strata (see Fig. 1) are not shown.

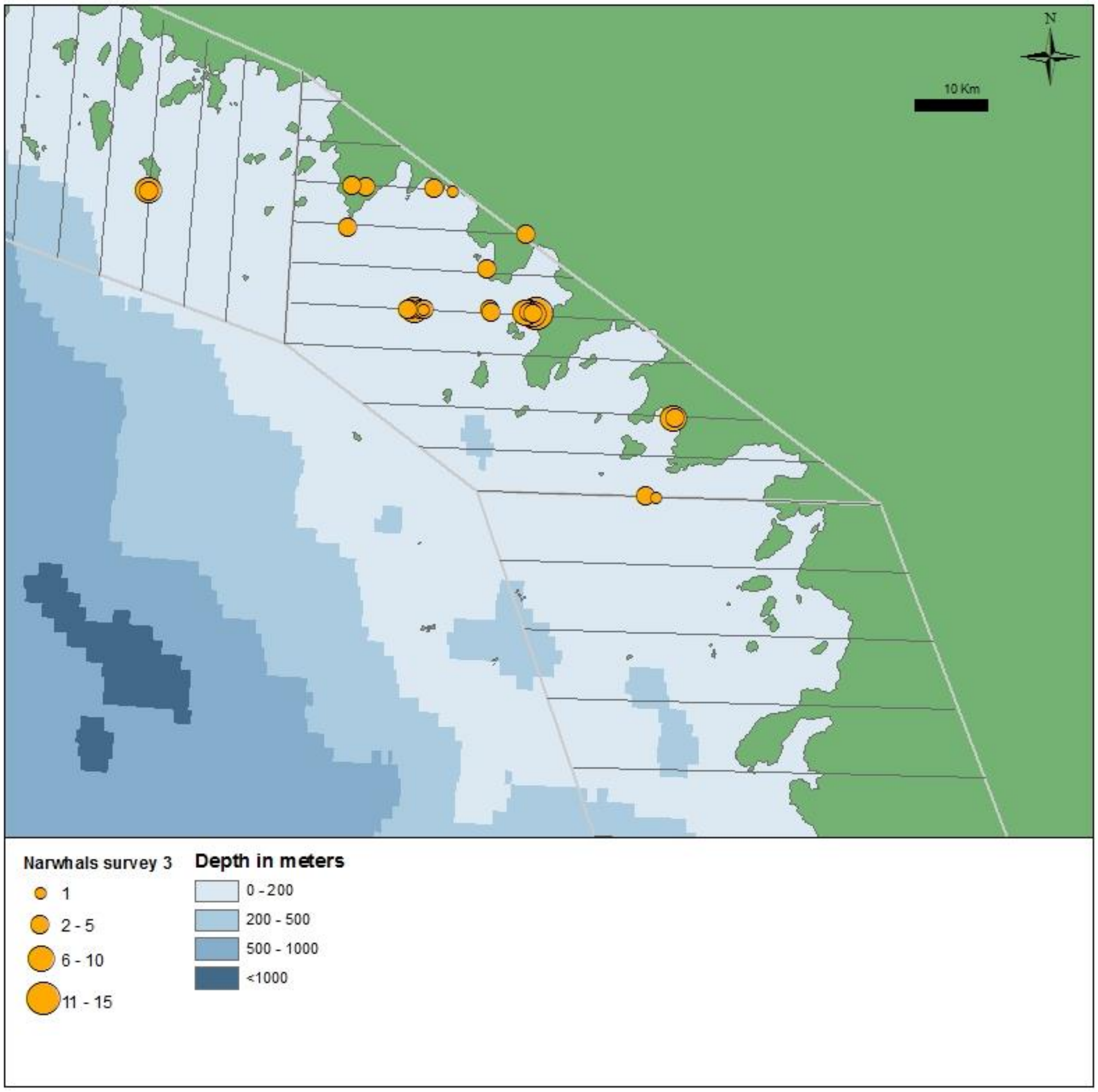


Figure 4. Sightings of narwhals during survey 3 between 20 and 26 September 2012. Transects without sightings in the southern and western strata (see Fig. 1) are not shown.

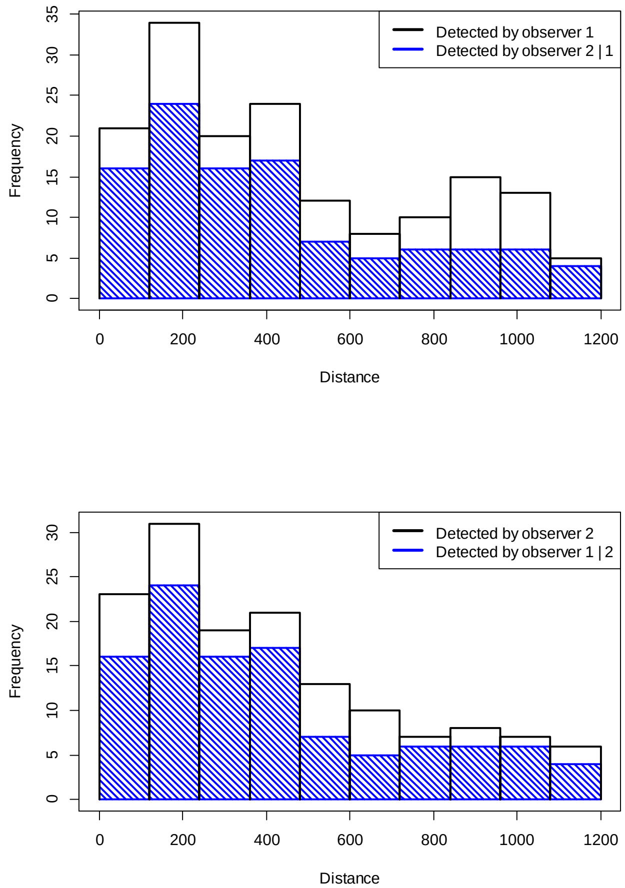


Figure 5. Detection function plots for all three surveys in Melville Bay 2012 combined. Upper panel show observer 1 detections that are duplicated by observer 2 and lower panel shows observer 2 detections duplicated by observer 1. Duplicate detections are indicated in the blue shaded areas.

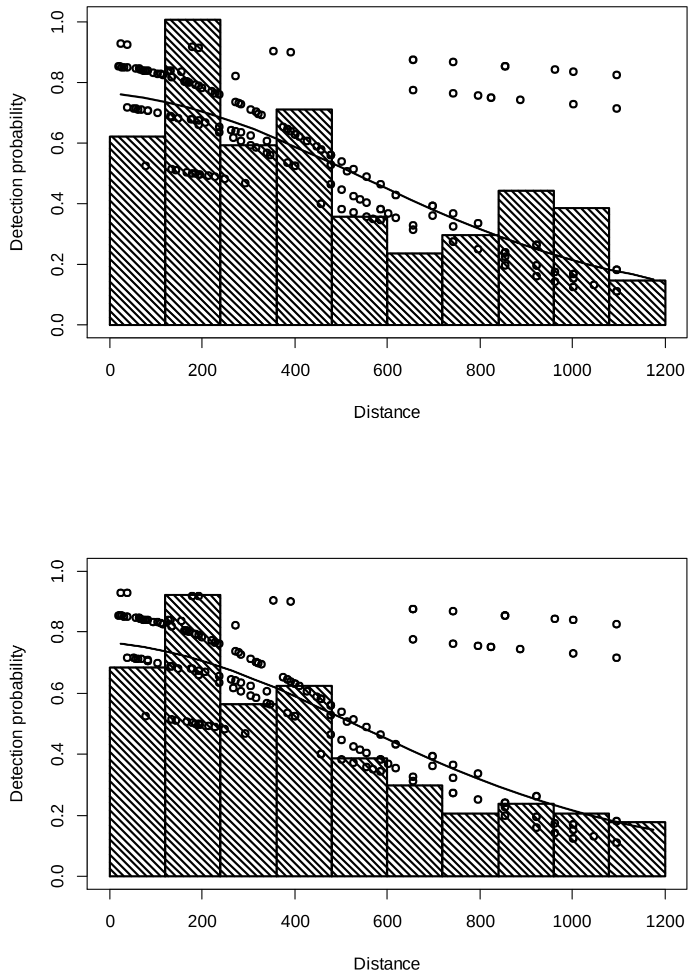
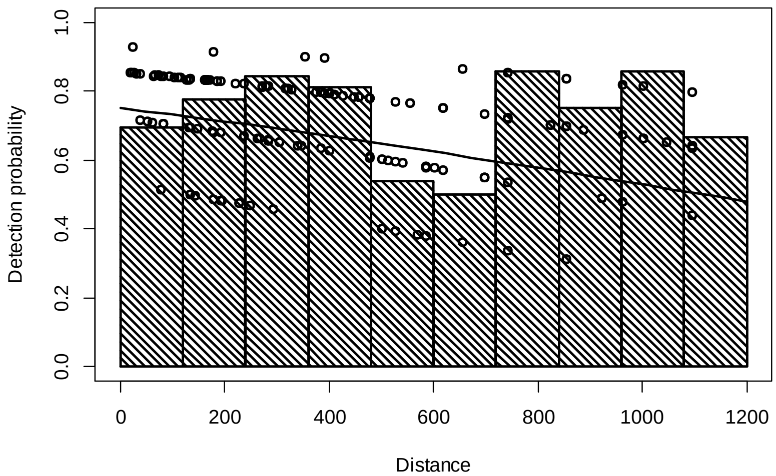


Figure 6. Detection function plots for all three surveys in Melville Bay 2012 combined. Perpendicular distance distributions for each observers with the chosen model superimposed. The dots indicate the values for each observer. Upper panel observer 1 detections lower panel observer 2 detections. Lines are fitted models.



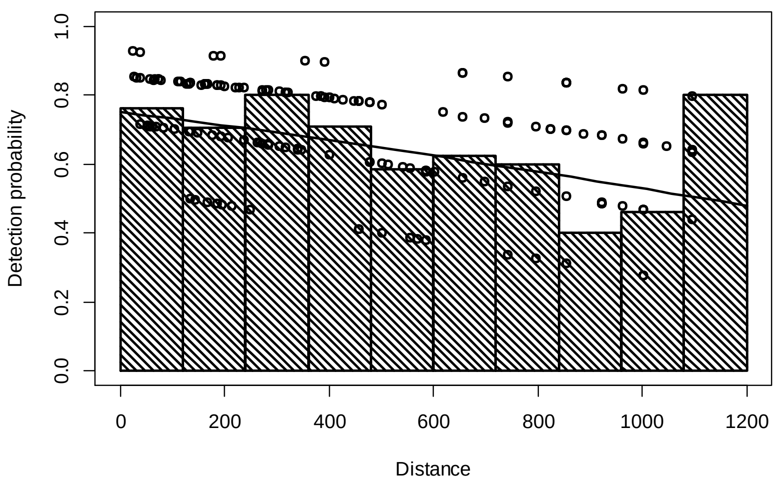


Figure 7. Detection function plots for all three surveys in Melville Bay 2012 combined. Conditional distributions for each observer with the chosen MR model superimposed. Upper panel shows detection plot of observer 1 given detection by observer 2. Lower panel shows detection plot of observer 2 given detection by observer 1.

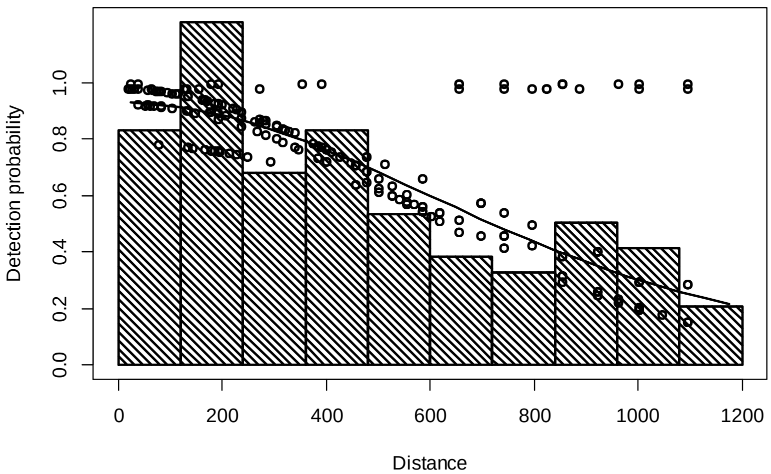


Figure. 8. Detection function plots for all three surveys in Melville Bay 2012 combined. Perpendicular distance distributions for both observers combined with the chosen DS model superimposed and intercept obtained from the MR model. The dots indicate the probability of each detection given its perpendicular distance and other covariate values.

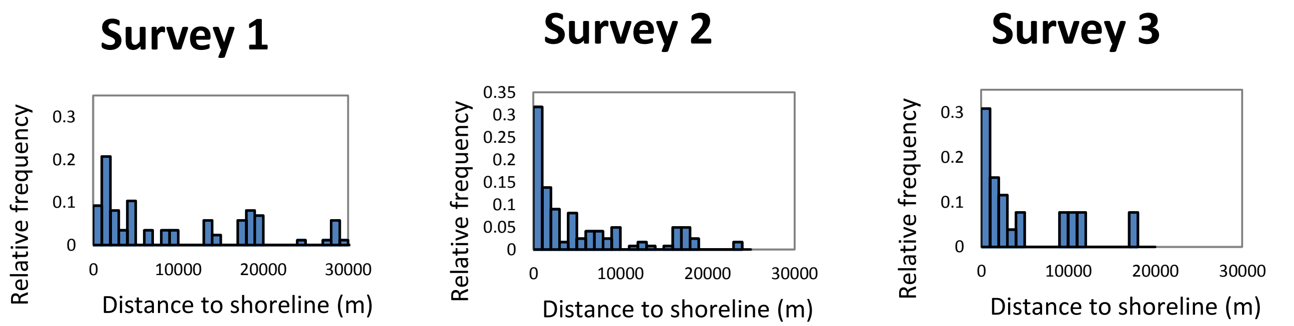


Figure 9a. The relative frequency of distance from narwhal sightings to the shoreline.

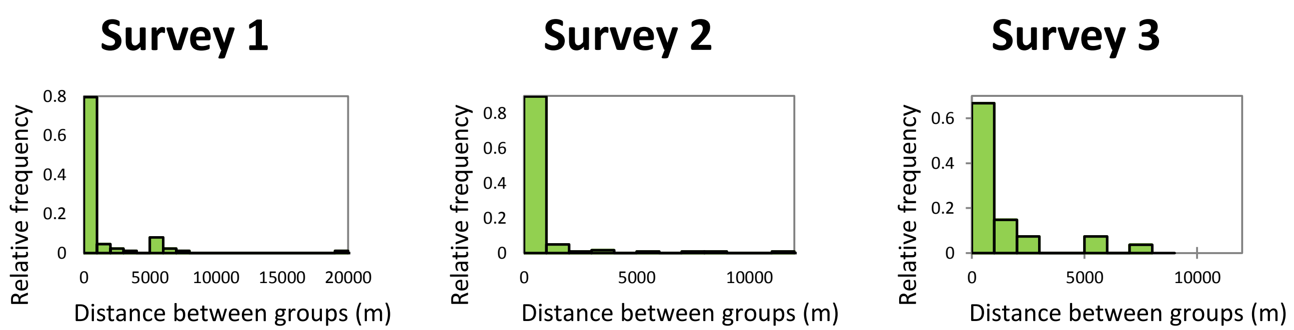


Figure 9b. The relative frequency of distance between sightings (groups) of narwhals.

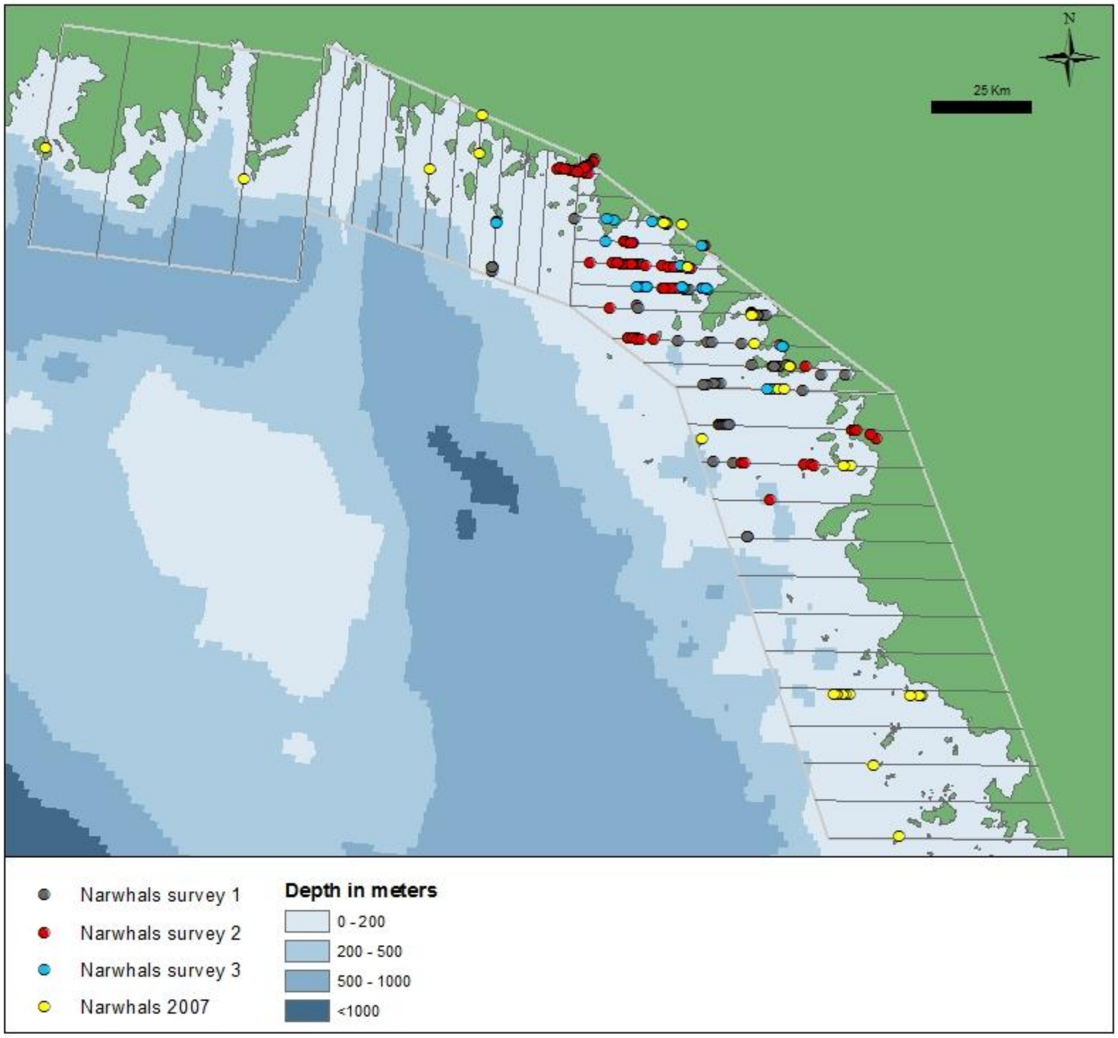


Figure 10. Positions of sightings of narwhals in Melville Bay from three aerial surveys in 2012 and one survey in 2007.

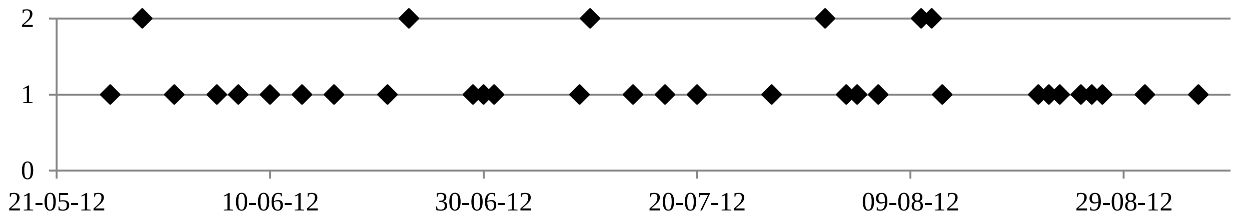


Fig. 11. Distribution of 39 catches on dates for the two communities Kullorsuaq and Savissivik 2012. One catch from Savissivik from 2 March was omitted from the graph.

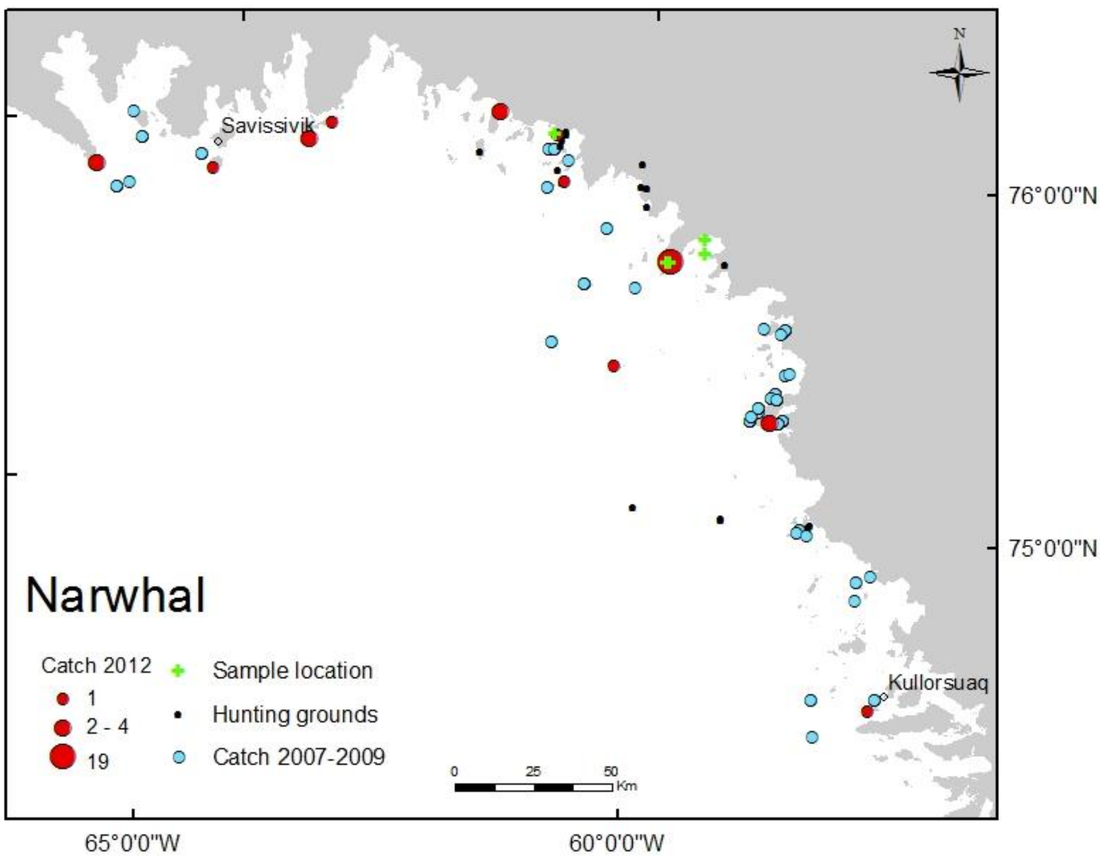


Figure 12. Positions of narwhal catches in 2012 compared to reports from 2007-2009. The hunting grounds are those also listed in Fig. 13.

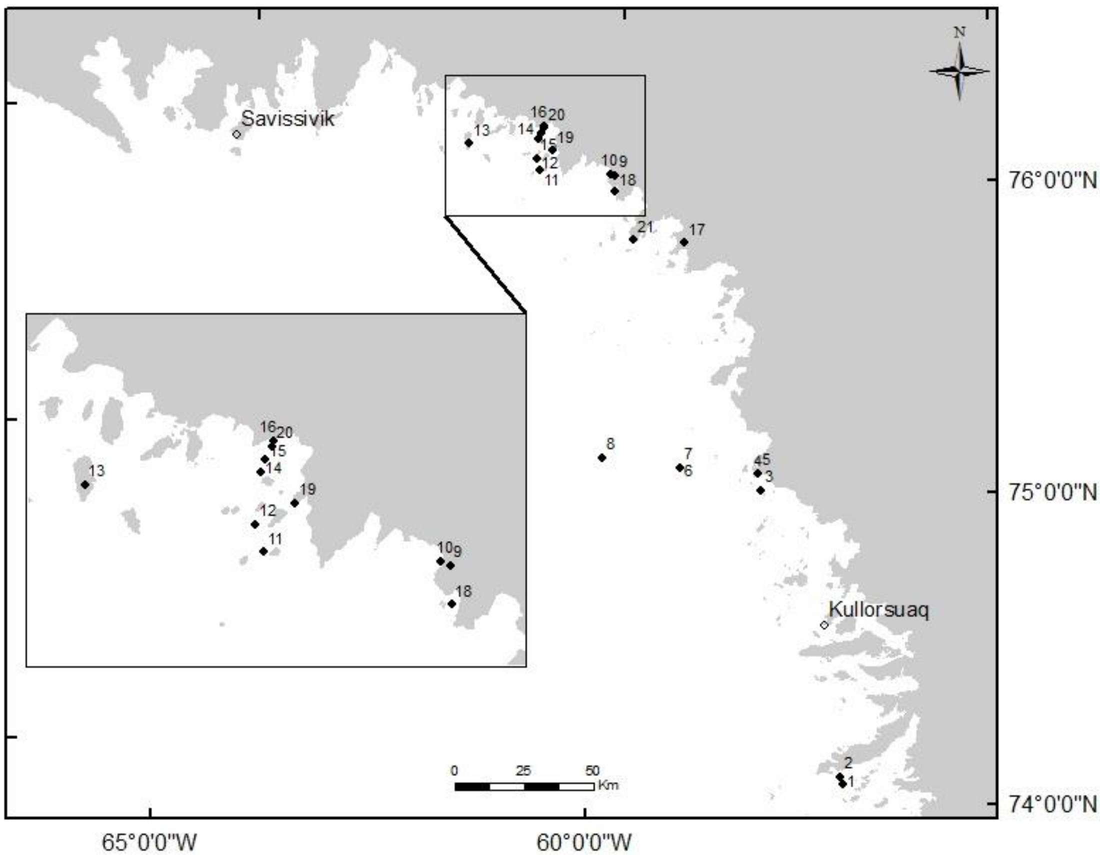


Fig. 13. Map of hunting camp sites in Melville Bay. Camp no. 1-3 are old camp sites no longer in use for narwhal hunting whereas no. 4-21 are used today and some of them also in the past (see Table 5 for details about the camp sites).

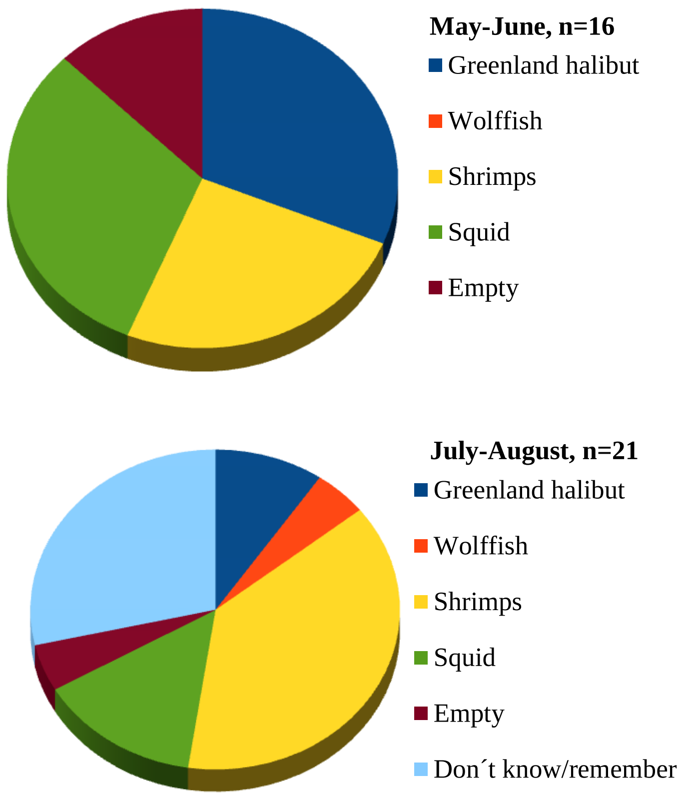


Fig. 14. Diet composition of 36 narwhals from Melville Bay and adjacent areas in 2012. The data from the questionnaire survey was used for calculating the proportions of each species in the stomachs.

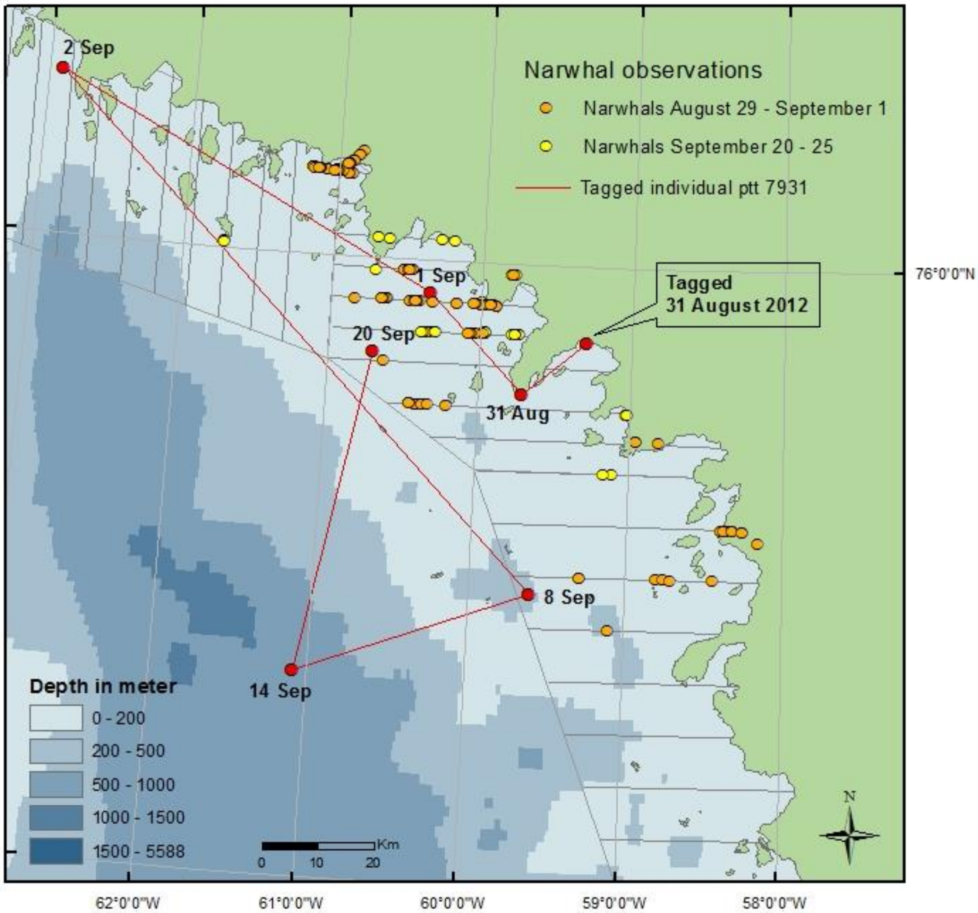


Fig. 15. Track of one narwhal (#7931) in Melville Bay between 31 August and 20 September when contact was lost. Sightings from the aerial surveys before and after the tracking period are shown together with transect lines.

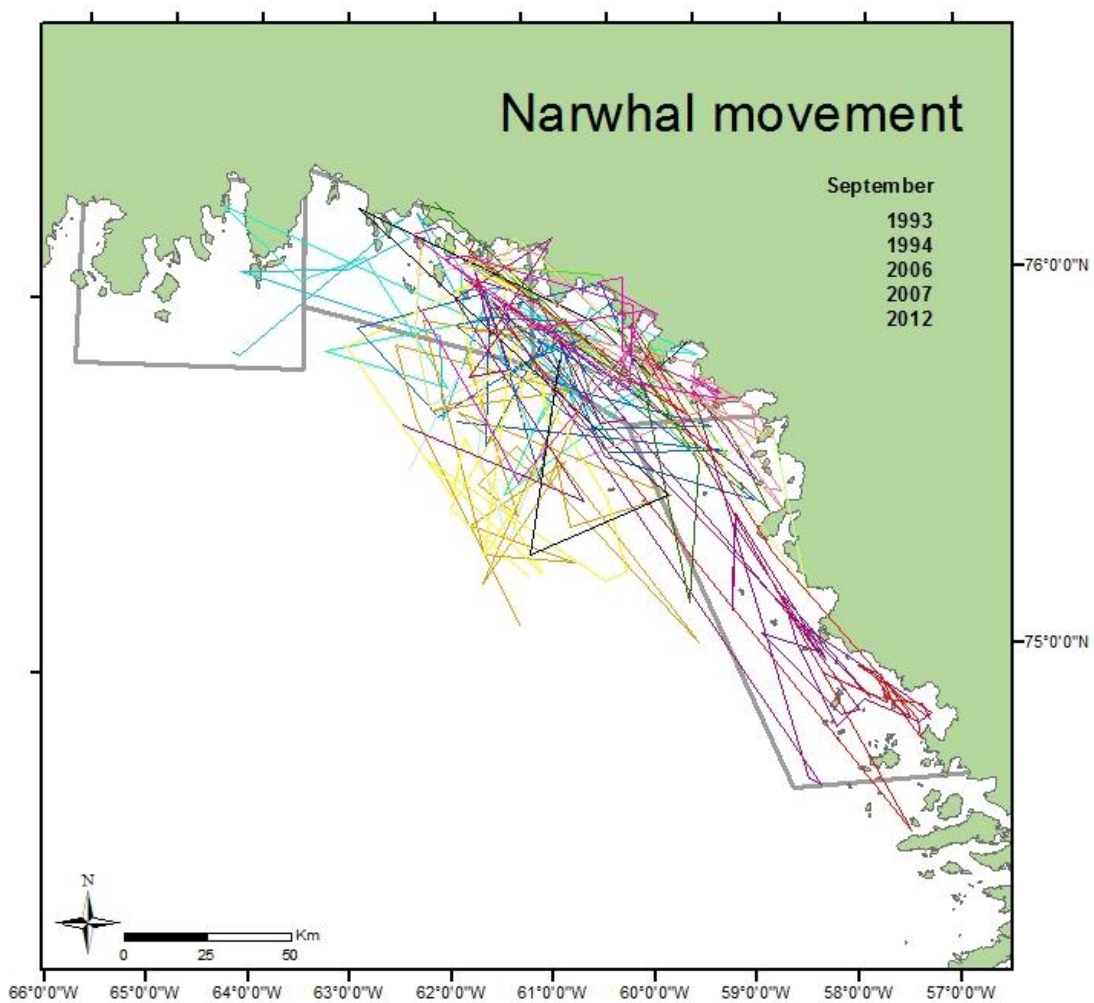


Fig. 16. Movements of individual narwhals in September. Data from Dietz et al. 1996, Laidre et al. 2010 and Heide-Jørgensen et al. 2012 and this study.

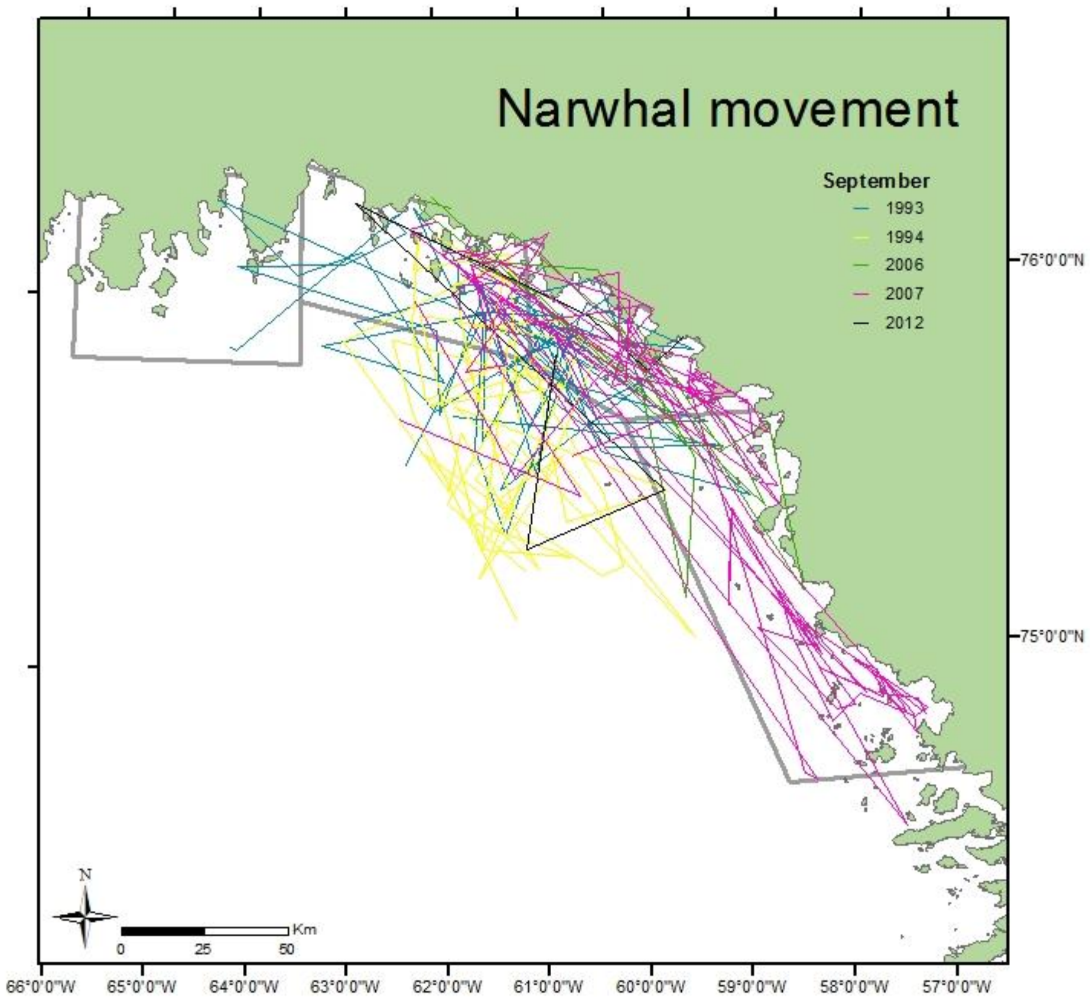


Fig. 17. Movements of narwhals in different years. Data from Dietz et al. 1996, Laidre et al. 2010 and Heide-Jørgensen et al. 2012 and this study.

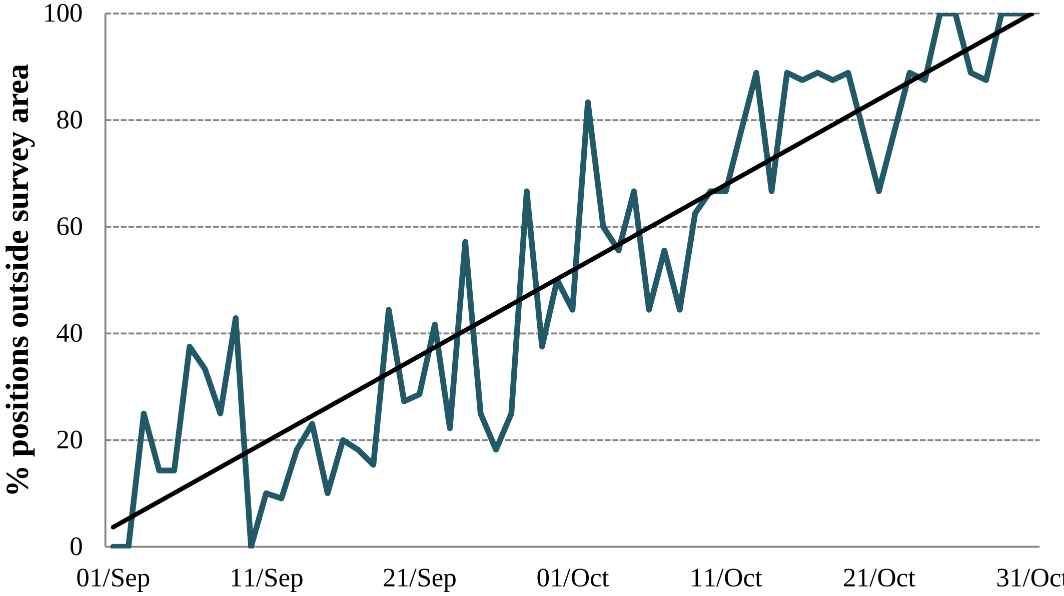


Fig. 18. Regression of the proportion of satellite tagged narwhals located outside the survey area in relation to day of the months of the September and October. Data from Dietz et al. 1996, Laidre et al. 2010,Heide-Jørgensen et al. 2012 and this study.

APPENDIX 1 **QUESTIONNAIRE TO HUNTERS**

Pinngortitaleriffik
Box 570
3900 Nuuk

Settlement:____
Your age:_____________________________________

Did you catch any narwhals in 2012?____
Were there any narwhals that could not be caught?________________________________
Why could they not be caught?____

Do the narwhals float when they get shot?____________________________________

Question	Catch 1	Catch 2	Catch 3	Catch 4	Catch 5
How many did you catch at each hunt?					
Which date?					
Where precisely were they caught?					
How far from land were they caught?					
Were they where they use to be?					
Were there other participants in the hunt - who?					
Were they caught from kayak or bigger vessel?					
Were the whales harpooned or shot?					
Were they shot from the ice edge or in open water?					
Were there any lost (ie. harpooned or shot without retrieval)?					
How many whales were there in the pods from which there were catches?					
Was it a male or female?					
How thick was the blubber layer?					
What was the stomach content?					
How was the weather?					
Did you observe killer whales in the area?					
Other comments					

The questionnaire is to be completed late September and send to Peter Hegelund (pehe@natur.gl), Grønlands Naturinstitut, Boks 570, 3900 Nuuk, or delivered to Timotheus Petersen, Kullorsuaq or Ole Kristiansen, Savissivik. The completed questionnaire is rewarded with Dkr 500,00.