# Arrival of Beluga (*Delphinapterus leucas*) to the Mackenzie Estuary in Relation to Sea Ice: Report on spring 2011-2013 aerial surveys.

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# ARRIVAL OF BELUGA (*Delphinapterus leucas*) TO THE MACKENZIE ESTUARY IN RELATION TO SEA ICE: REPORT ON SPRING 2011-2013 AERIAL SURVEYS

by

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## ABSTRACT

To enhance our knowledge of beluga spring habitat use, aerial surveys were flown over the Mackenzie River estuary, and Tuktoyaktuk Peninsula, NT, Canada, from 2011-2013. Survey objectives were to (1) examine the arrival of beluga whales in relation to the timing and location of fast ice break-up offshore of the Mackenzie Estuary, (2) train community members in the collection and analysis of aerial survey data, and (3) provide near real-time information on the arrival and distribution of beluga in the estuary to the Inuvialuit communities. This report details the survey methodology, and plots of surfaced belugas and other marine mammals, as observed during 10 days of aerial surveys from June 2011-2013. Further analysis and interpretation of these results will enhance and update our understanding of beluga arrival patterns, and how spring distribution may be impacted by changing sea ice conditions and climate. Results will assist regulators, managers and Inuvialuit in protecting critical habitats, ensuring continued subsistence harvesting and advance our understanding of beluga habitat use.

Key words: Beluga whale; Mackenzie Estuary; aerial survey; sea ice; habitat use

## RÉSUMÉ

Afin d'améliorer nos connaissances sur l'habitat des bélugas et son utilisation en relation avec la banquise, des relevés aériens ont été effectués chaque mois de Juin pendant trois années consécutives (2011-2013) au niveau de l'estuaire Mackenzie, dans l'ouest de l'Arctique canadien. Cette étude de terrain, intégrée au sein d'un projet pluriannuel, avait pour objectifs de (1) comprendre les conditions d'entrée dans l'estuaire des bélugas en lien avec les modalités spatiales et temporelles de dislocation de la banquise, (2) former les membres des communautés locales à la collection et l'analyse des données, et (3) tenter de fournir en temps réel aux communautés un accès aux données collectées. Ce rapport décrit la méthodologie employée pour les études de terrain de 2011, 2012 et 2013, et présente les premières données obtenues. Les résultats de ce projet, ainsi que les analyses concernant l'utilisation de l'habitat en lien avec la banquise, apporteront un appui aux gestionnaires et aux communautés afin de protéger les habitats critiques et approfondir la compréhension du comportement des bélugas dans cet écosystème arctique.

Mots clés : bélugas, estuaire Mackenzie, relevés aériens, banquise, utilisation de l'habitat

# INTRODUCTION

In mid to late June, an estimated 40,000 (Hill & DeMaster, 1999) belugas (*Delphinapterus leucas*) from the Beaufort Sea population arrive to the Canadian Beaufort Sea from their Bering Sea wintering areas (Fraker, 1979). They first concentrate at the seaward edge of a narrow bridge of land-fast ice that spans the waters offshore of the Mackenzie Estuary. As spring break-up progresses, the ice bridge disintegrates and the belugas move quickly into the estuary. Throughout the month of July these whales form large aggregations in the four bays of the estuary, and it is during this time that they are subject to an annual subsistence harvest (Fraker & Fraker, 1979, McGhee, 1988).

The beluga whale is an important cultural and nutritional resource for the Inuvialuit; the aboriginal people of the Inuvialuit Settlement Region (ISR). Due to the significance of this harvest and because of past and renewed interest by the oil and gas industry in this area, the entry of beluga to the estuary, and their distribution therein, have been relatively well studied since the 1970s (Fraker *et al*. 1979; Harwood & Norton 1996; Norton & Harwood 1986). This has included reconnaissance aerial surveys to document their arrival in June (the last was flown in 1985, Norton & Harwood 1986), and systematic strip transect aerial surveys to examine their distribution in the estuary in July (the last in 1992, Harwood *et al*. 1996). Since these earlier surveys were flown, changes in climate, sea ice, river discharge, and depth of permafrost (Barber *et al*. 2008, 2012 Nghiem *et al*. 2014) have been occurring, with unknown effects on beluga arrival and distribution within the Mackenzie Estuary.

In addition, understanding of the timing and arrival of beluga into the estuary is of particular importance to the beluga harvesters of the ISR. The main rationale for this local importance is that the timing and arrival of belugas dictates when subsistence harvesters have first access to the whales. More importantly from a local perspective, how the whales assort themselves amongst the four bays of the estuary. Since harvesters from three Inuvialuit communities harvest beluga from different bays and areas of the estuary, how the whales assort themselves amongst the bays can have noticeable effects on harvest success. For example, in 1985, the sea ice bridge across Kugmallit Bay (eastern estuary) broke relatively late in the season, and in that year the whales first entered and thereafter remained in the Shallow Bay (western estuary) for most of the season. The outcome of this situation was that hunters relying on beluga whales being in Kugmallit Bay in early July did not have access to these whales, as none were able to enter the bay at the usual time. This was linked to lower harvest levels, resulting in a later harvest in Kugmallit Bay in 1985 compared with other years (Norton & Harwood, 1986).

Three consecutive seasons (2011-2013) of reconnaissance aerial surveys were flown seaward of the ice bridge offshore of the Mackenzie River estuary and Tuktoyaktuk Peninsula. The specific objectives were to (1) examine the arrival of beluga whales in relation to the timing and location of sea ice break-up offshore of the Mackenzie Estuary, (2) to foster community involvement in the surveys through data collection and analysis and (3) to the extent possible, provide the whale sighting information in near-real time to the communities and local HTCs (Hunters and Trappers Committees)[1]. Here we summarize details of the survey methods, and results from the surveys visible on maps, including surfaced marine mammals and satellite imagery of sea ice conditions. Ultimately, the sighting data will be used to critically evaluate the patterns of beluga movement and habitat use over the shelf during late spring arrival, document the time(s) and locations(s) where they first enter the estuary, and compare these to historical records dating back to 1974.

By examining spring habitat features important to beluga, in addition to correlating the arrival to the estuary with break-up, we can better assess the impacts of a changing climate on the ecology of Beaufort Sea belugas. This information will assist regulators, managers and communities in decision making required for ensuring continued subsistence harvesting opportunities, protecting important habitats and maintaining ecosystem integrity.

[1] Providing data in a timely manner was added as an objective for the 2013 field season based on feedback from local HTCs in 2011 and 2012.

# MATERIALS AND METHODS

## DESCRIPTION OF STUDY AREA

The reconnaissance aerial surveys were conducted over the nearshore waters of the southeastern Beaufort Sea, seaward of the land-fast ice edge of the Mackenzie Estuary and the Tuktoyaktuk Peninsula. The western extent of the surveys was from Herschel Island (69° N and 140° W) and eastward to Baillie Islands (71° N and 128° W; Figure 1).

## AERIAL SURVEY METHODS

All surveys were flown from de Havilland Twin Otter aircraft, each equipped with bubble windows at primary search positions, on-board intercoms to ensure communication among observers and pilots, GPS for navigation, pilot, co-pilot, two observers, two recorders and a survey coordinator. Charter flights were booked through Aklak (Kenn Borek[2]), Inuvik. All surveys were flown at 1000 ft (305 m), with a target groundspeed of 200 km/hr to maximize consistency with past surveys (e.g. Harwood *et al.* 1996; Norton & Harwood, 1986). A line transect method was used on both the reconnaissance and zigzag surveys (Strindberg & Buckland, 2004), with sightings recorded for a 1 km swath, on either side of the airplane. In order to determine the lateral sighting distance of marine mammals from the aircraft track line, the 1 km strip was sub-divided into four "bins", each 250 m wide (Figure 2A) and each sighting assigned to the appropriate bin. Due to the inability of observers to see directly below the airplane, the innermost bin was started at a distance of 50 m from the flight path, while the outermost bin extended to 1050 m from the flight path (Figure 2A).

As there were no distance markings on the wing of the airplane, bubble windows (one on the left and another on the right, located at front of the aircraft) were marked using a Sunnto PM-5 inclinometer to measure the angle of depression, of the bin inner and outer edges, from the horizon (Figure 2B). Two primary observers then used these bubble window marks to assign all sightings to the appropriate bin. All other non-bubble

[2] http://www.borekair.com/

windows were left unmarked and were used for observations noted by the recorders or survey coordinator (secondary observers), video cameras (2013) and GPS equipment.

Observers on the right and left sides of the airplane recorded whale sightings into a digital voice recorder, lateral sighting distance (bin number), an estimate of ice cover (%), ceiling height, presence of glare, fog and/or precipitation. Sea state was recorded according to the Beaufort Scale of Wind Force[3] and surveys were terminated if sea state exceeded Beaufort Scale 4 (whitecaps) or when low cloud or fog blocked visibility. All observers wore polarized sunglasses to minimize glare, and did not take their eyes off the search area while surveying on transect and reconnaissance flights. The pilots notified observers and recorders of the beginning and endpoints for each transect.

The survey aircraft was reserved for use in each year for a period of seven days, timed to best coincide with the time when belugas would be migrating to and entering the estuary. We flew every day in the reserved period that visibility, sea state and aircraft availability would allow. Interruptions due to these factors in some cases precluded our flying on the ideal day to observe beluga entry to the estuary.

On each survey, we attempted both a reconnaissance survey, approximately 1 km seaward of the ice edge (Figure 3), and also a ‘zigzag’ survey design (Strindberg & Buckland, 2004), which followed 40 km transects positioned away from or toward ice edge (Figure 4). Pre-determine waypoints were given to the pilots as a reference for the start of each transect. The zigzag survey was used to determine the presence of whales offshore of the ice edge. Ice images presented in this report were all obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS) website (http://modis.gsfc.nasa.gov/).

The survey plan for 2013 was to carry out both reconnaissance surveys and zigzag surveys within the same day on two separate occasions. This would allow for not only full survey area coverage in one day, but also determining how belugas are using the different habitat areas (ice edge vs. open water; Figure 5). Field preparations included caching fuel at the Tuktoyaktuk airport to allow for refuelling closer to the survey area.

[3] http://www.metoffice.gov.uk/weather/marine/guide/beaufortscale.html

The aircraft used in 2013 was equipped with wing tip tanks for extra fuel storage, which permitted longer trips between refuellings.

In 2011 and 2012, a total of three GPS were running at all times to record the flight track. Most importantly, coordinates of the start and end time of transects were documented so that they could later be used to re-create flight track lines, with corresponding sightings data, onto satellite images with Geographic Information Systems (GIS). In 2013, through a partnership with Environment Canada, observations were entered directly onto data collection forms located on a Toughbook laptop computer equipped with a GPS signal. Thus, all observations were georeferenced and recorded by a spatial program on the laptop in real time (i.e., all data points have associated GPS coordinates; Figure 6).

In addition to point observations, video cameras were provided equipped with GPS to record a constant stream of video during all surveys. This video stream was also linked with the audio files so that the georeferenced videos will have the observer's voice and recordings imbedded. Due to the modified data capture methods used in 2013, there was a greater need for survey participants to assist and manage technical gear (e.g., computers, GPS, video cameras), as such we had one observer on each side of the plane with an associated recorder sitting behind them to capture real time data, as well as one person manning both video cameras in the back windows.

This newer technology in 2013 allowed preliminary data to be processed upon completing the surveys each day. Given the interests of partners, communities and funders, one of our goals was to make data readily available to the communities of Aklavik, Inuvik, Paulatuk and Tuktoyaktuk. Data compiling from all observers took place shortly after flights and the maps were created indicating the locations and general numbers of belugas observed[4] (as shown in Figures 15-17). These maps were made widely available to the communities via their HTC online websites and Facebook sites.

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[4] The data is considered preliminary at this stage, as some whales may have been counted more than once. The data will need to be verified before final numbers are given.

## DATA PRESENTATION

The data is presented for each field season by providing an overview of all surveys completed for each year before focusing on each survey individually. All sightings from surveys listed in table 1 and plotted with transect lines on Figures 7-17. Detailed notes on survey design, extent and, ice and weather conditions are presented in table 2. Two surveys in this series, one in 2012 and one in 2013, were flown coincidentally with the time/location where belugas entered the estuary and are discussed separately.

### 2011 FIELD SEASON

The 2011 field season was the pilot year of the project and yielded few beluga sightings. Due to weather conditions (strong winds and fog), only two days of surveys were completed (Table 2). Surveys were intended to cover both the ice edge and zigzag transects in one flight. However, the fuel capacity of the plane was not enough to allow for this coverage to be completed in one survey. The ice bridge broke near Shallow Bay on June 22$^{nd}$ in 2011. In total only 30 beluga whales were observed over two days in 2011 (Table 1): June 14 (Figure 7) and June 16 (Figure 8). These low numbers are likely due to poor weather conditions, and less effort (flying days), compared to other years.

### 2012 FIELD SEASON

The 2012 field season involved five survey flights between June 13$^{th}$ and June 22$^{nd}$ (Figures 10-14). Due to low numbers of belugas sighted in 2011, which was likely the factor of poor flying weather conditions, the 2012 project allocated more flight time to allow for greater coverage of the survey area over more days (Table 2). Some flights originated as zigzag surveys, but were changed to follow the sea ice if the weather conditions were poor further from the ice edge (Figure 11).  In total 755 belugas were sighted over the five days of surveys (Table 1). In additional to beluga whales, seals and bowheads were observed (Table 1).

**2013 FIELD SEASON**

In 2013, the final year of aerial surveys, three survey days were scheduled (June 16$^{th}$, 18$^{th}$ and 20$^{th}$). Contingency dates of June 21$^{st}$ and 23$^{rd}$ were held in case we were unable to fly during the scheduled dates due to weather. Due to weather and mechanical issues with the plane, the surveys were rescheduled to June 18$^{th}$, 22$^{nd}$ and 23$^{rd}$ (Table 2). Two longer surveys were planned (double the flight time) with refuelling at Tuktoyaktuk. Our survey pilots had sighted six belugas and two bowheads on June 13$^{th}$ near Sachs Harbor, indicating there were belugas just outside of the study area. Belugas were sighted all three days, with the most sighted (305) on June 22$^{nd}$ (Table 1).

## BELUGA ENTERING THE ESTUARY

On June 22$^{nd}$, 2012 the weather permitted us to fly in the area/on the same day where the ice bridge broke offshore of the Mackenzie Estuary. An ice edge survey was designed to begin at Baillie Island and head west toward the opening at Shallow Bay (Figure 14). The transects followed the ice edge starting near Baillie Island and heading west. At the end of the survey, transects were taken into the Mackenzie Estuary, slightly east of the Shallow Bay area, where the ice had broken up. Belugas were spotted both as individuals as well as in groups. Due to the impact of the broken land fast ice, more turbid brown estuary water was observed along the survey area and visible as far as the eastern most point of the survey, near Baillie Island.

In 2013, the ice bridge at Shallow Bay broke on June 21$^{st}$. However, based on cloudy satellite images obtained the night before, it was unclear when the ice bridge had fractured. In order to capture beluga moving towards the Mackenzie Estuary, zigzag surveys were flown from Herschel Island to central Mackenzie Delta on June 22$^{nd}$, 2013 (Figure 16). Once we reached the Shallow Bay area, it was clear that the land-fast ice had indeed broken. Some low fog was still in the area, but overall visibility was good. Here, the survey towards Shallow Bay was extended to include more transects in order to identify how many belugas were in this area. There were numerous whale sightings documented on the west side of the Shallow Bay area.

## SUMMARY

The number of beluga whales observed in all years is presented in Table 1. Observations in 2011 were low relative to other surveys completed in the past (late 1970s to 1985). For example, the number of whales observed in an ice survey in 1985 totaled 502 (Norton & Harwood 1986). That survey took place on June 24th, two days prior to the ice barrier breaking (Norton & Harwood 1986). The majority of whales sighted were in the Shallow Bay area and were moving toward the narrowest point of the ice bridge, an area not covered by our survey in 2011. The 2011 survey did cover much of the Tuktoyaktuk Peninsula area and less than ten belugas were sighted compared to over 100 whales observed during the 1985 survey. The ice broke on June 22nd in Shallow Bay. Why so few belugas were observed in the 2011 survey remains unclear, however, it is possibly due to the challenging weather conditions, which limited the extent and area covered by the aerial survey.

The 2012 surveys yielded better flying conditions, more survey hours and an increased number of whale sightings (Table 1). Belugas observed during the 2012 survey more closely reflected the numbers of those observed in the 1970s and 1980s, at almost 300 whales sighted on the day the ice broke (June 22nd). This supports the notion that the poor weather conditions in 2011 limited observations of belugas along the land fast ice.

In 2013, the ability to cache fuel at Tuktoyaktuk airport allowed for more flying time but only three survey days in total. Although belugas were sighted all three days, observations were generally lower than 2012, with over 300 sighted on June 22nd (Table 1). Through investigation of satellite images after the surveys, it was determined that the ice bridge had indeed broke on June 21st, 2013.

In 2011-2013 (Table 1), ice break-up dates appeared to occur a few days earlier than the date observed from 1979-1984, which averaged June 24-25 (Table 3, Norton & Harwood 1986). From 2002-2010, ice break dates have been earlier in June, with an average break-up dates of June 19th (S. Solomon Pers. Com., 2011). A full assessment of the historical surveys is required for an adequate comparison.

## FUTURE WORK

The summer of 2013 was the third and final year of the beluga sea ice surveys. Future work will focus on more data interpretation and beluga habitat use analysis. The 2011 and 2012 survey data have been digitized and transferred into GIS for final analysis. The 2013 data is already in this format due to our partnership with Environment Canada and ability to collect geotagged data while flying. The 2013 data will need to be verified before any final analyses can be performed. However, once this is complete, this data will be used for beluga habitat use analyses (present and historical), to assess temporal changes and implications of changes in sea ice and ice break-up dates. Historic surveys were digitized and transferred into GIS format during late 2012 and early 2013. While there is still some work to be finished on these older surveys, it is intended this will be completed by 2014, so that they can be compared with the 2011-2013 survey data.

For further cross validation of the aerial survey observations and continued research of the project objectives, additional methods could be tested such as remote sensing and the use of UAVs (unmanned aerial vehicles). Recognizing the high costs of running visual surveys, it may also be useful to attempt on-land data collection methods such as observational and survey information collected from local beluga hunt camps. This may increase knowledge related to changes in harvest activities as well as beluga distribution, abundance and use of the area over time. Land-based approaches to distance sampling will be addressed in 2014 as a means of continuing this type of data collection while maintaining existing ties and consultation with the local communities of the ISR.

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**Table 1:** Sighting data for each survey day for 2011-2013.

| Year | Survey Date | Belugas | Beluga /km$^2$ | Bowhead | Seals | Other |
|---|---|---|---|---|---|---|
| 2011 | June 14 | 7 | 0.013 | 1 | 4 | |
| | June 16 | 23 | 0.157 | | 1 | |
| | June 22 | Observed date of break up | | | | |
| 2012 | June 13 | 32 | 0.084 | 3 | 4 | 2 |
| | June 14 | 156 | 0.376 | 12 | | |
| | June 16 | 185 | 0.394 | 3 | 1 | |
| | June 21 | 112 | 0.238 | 2 | | |
| | June 22 | 270 | 0.509 | 13 | 1 | |
| | June 22 | Observed date of break up | | | | |
| 2013 | June 18 | 54 | 0.060 | 3 | | |
| | June 21 | Observed date of break up | | | | |
| | June 22 | 305 | 0.324 | | | |
| | June 23 | 54 | 0.193 | | 2 | Polar bear |

**Table 2.** Extent of aerial surveys, type of survey flown and flight plans by date, June 2011-2013.

| Year | Survey Date | Area covered | Type of transect | # | Detailed flight notes |
|---|---|---|---|---|---|
| 2011 | June 14 | E. of Shallow Bay to Tuk Peninsula (550 km) | R/ ZZ | 8 | Due to low cloud cover in the area further west towards Herschel Island, ZZ started (13:00- 14:52 MT) at SB and continued east along ice edge. Land fast ice bridge was still fully intact, with the narrowest sections approximately 15 km wide; R survey (ended at 16:12), heading west 1 km from ice edge. |
| | June 16 | W. of Baillie Island (165 km) | ZZ | 5 | Due to strong winds and white caps the first transect starting from Baillie Island was terminated within a few km and the planned trip to Sachs Harbour aborted. Ice bridge still intact ~ 11 km wide. The survey near Baillie was not possible due to low cloud cover. |
| 2012 | June 13 | W. of Baillie to mid- Delta (380 km) | ZZ | 12 | A ZZ approach was used to identify whales further from the ice edge. Started just off of Baillie Island and headed westward (13:30-16:00). Due to white caps observed north of the Tuk Peninsula area, a portion of the survey was unable to be completed. Ice bridge was still persistent, with the narrowest section at SB (just over 50 km wide). |
| | June 14 | W. of Baillie to NE of Kugmallit (415 km) | R/ZZ | 11 | Heavy white caps prevented initial transects from Baillie Island to be terminated. Remainder of transects followed west toward ME (14:14-16:43). The ice bridge at Shallow Bay was still intact, with the narrowest section ~25-30 km wide |
| | June 16 | W of SB to Tuk Peninsula (470 km) | R/ ZZ | 14 | Start at west side of Shallow Bay with a ZZ survey, then heading east to cover Shallow Bay and mouth of ME (13:00-16:00), Weather was mostly ideal, with low clouds and fog at times. To avoid glare, a few ice edge transects were conducted. Ice bridge at SB was ~20 km wide. |
| | June 21 | SB to east of Kugmallit Bay (470 km) | R/ZZ | 12 | Ice bridge started to break on this day in SB. Transects started in SB moving north of the bay to see how far belugas were from ice edge and estuary area (9:20-11:40). The survey was again challenged by high glare and fog that resulted in many short transects and combining ice edge with zigzag. |
| | June 22 | Baillie Island to SB (530 km) | R | 13 | Ice bridge broke in SB on this day. Ice edge survey from Baillie to SB opening, transects were also taken in the ME, slightly east of SB. |

Table 2 continued on next page

**Table 2.** Continued

| | | | | | |
|---|---|---|---|---|---|
| 2013 | June 18 | Baillie Island to Herschel Island (900 km) | R/ZZ | 30 | Weather was sunny, with clear skies and high cloud. Due to unclear ice images and high southerly winds, survey efforts were focused towards the western area, which contained more open water between Herschel Island and the central ME, 22 ZZ transects completed (11:00-16:00). The ice bridge at SB was still intact (~30-40 km wide).Thick ice in the eastern portion prevented ZZ survey from Baillie Island to central ME, eight ice edge transects completed (~18:30-19:30). |
| | June 22 | Herschel Isl. To Baillie Isl. (940 km) | R/ZZ | 23 | Survey covered larger openings in the ice from Herschel Island to the central Mackenzie Delta area (11:00-15:30). Some low cloud and fog required transects to be altered early on. Ice bridge at SB had broken since last survey (June 21st), surveyed SB area in order to identify how many belugas were present. Ice edge from Tuk. Peninsula to Baillie Island (17:45-18:45). Due to fog and thick ice coverage near the end of the survey, the remainder of survey was canceled. |
| | June 23 | Baillie Island to mid-Delta (280 km) | R | 9 | Thick fog delayed the departure out of Inuvik, but cleared during ZZ transects across Kugmallit Bay. Three zigzag transects were completed in the inner delta and no whales were spotted. Due to more thick fog in the western portion of the survey area surveys redirected east toward Baillie Island (11:00-13:00). Thick ice and fog prevented transects from reaching all the way to Baillie Island. Ice edge surveys from Tuk. to Hershel Island were canceled due to limited visibility. |

SB= Shallow Bay, ME= Mackenzie Estuary, Tuk= Tuktoyaktuk
R= Reconnaissance survey, ZZ= Zigzag survey

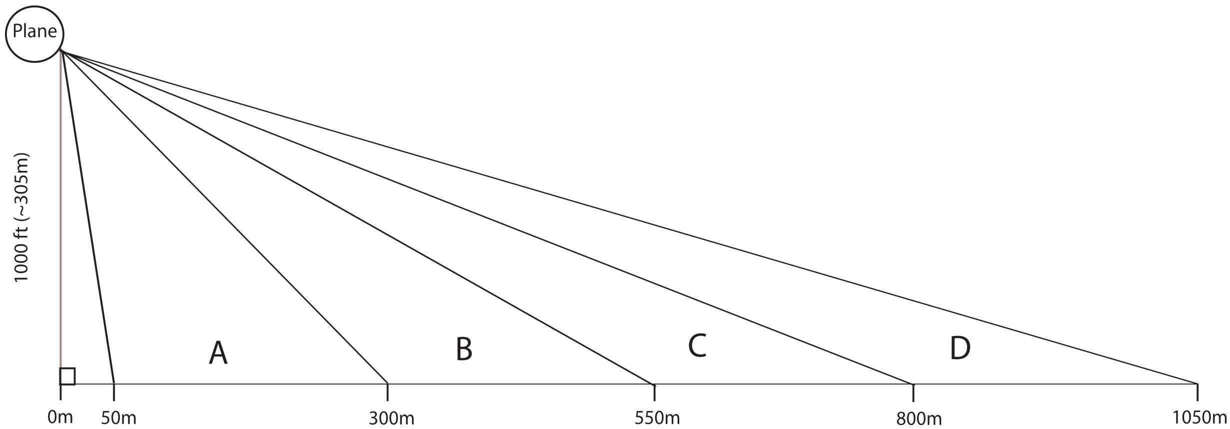
**Table 3.** Historical break-up dates (approximate) of the land fast ice bridge across Mackenzie Bay and Kugmallit Bay (Norton and Harwood, 1986).

| **Year** | **Mackenzie Bay** | **Kugmallit Bay** |
|---|---|---|
| 1972 | NA[a] | NA |
| 1973 | June 22-23 | June 27 |
| 1974 | July 10-11 | July 10-11 |
| 1975 | Late June | Late June |
| 1976 | NA | NA |
| 1977 | June 17 | NA |
| 1978 | July 5 | July 5-6 |
| 1979 | June 19 | July 1 |
| 1980 | June 27 | June 30 |
| 1981 | June 15 | June 27 |
| 1982 | June 22 | July 10 |
| 1983 | June 23 | June 29 |
| 1984 | NA | NA |
| 1985 | June 26 | July 6 |
| Mean 1972-1984 | June 24-25 | July 2-3 |

[a] NA = no data available


**Figure 1**. Map of the southeast Beaufort Sea and study area.

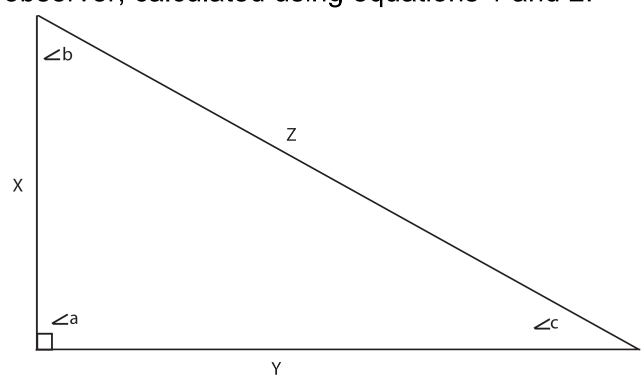
A: Bin distances for whale observations




B: Bins were marked on the window of each observer, calculated using equations 1 and 2:

(1) $X^2+Y^2=Z^2$

(2) $\sin(c)=X/Z$




Where X was set to the altitude of the airplane (305m), and Y was set to the distance from the plane for each bin (see A). Values for angles B and C and bin distances are shown in table bellow.

| Bin | Distance from aircraft (Y) in meters | Z (m) | <c (degrees) |
|---|---|---|---|
| Start Bin A | 50 | 309.1 | 80.7 |
| Start Bin B | 300 | 427.8 | 45.5 |
| Start Bin C | 550 | 628.9 | 29.0 |
| Start Bin D | 800 | 856.2 | 20.9 |
| End of Transect | 1050 | 1093.4 | 16.2 |

**Figure 2.** Methods used for calculating bin angles and animal distances from plane: A) bin distances for whale observations starting at 50m from the plane (each bin of 250m was shifted 50m further away from the plane to keep consistent), and B) angle calculations and values for bin distances.

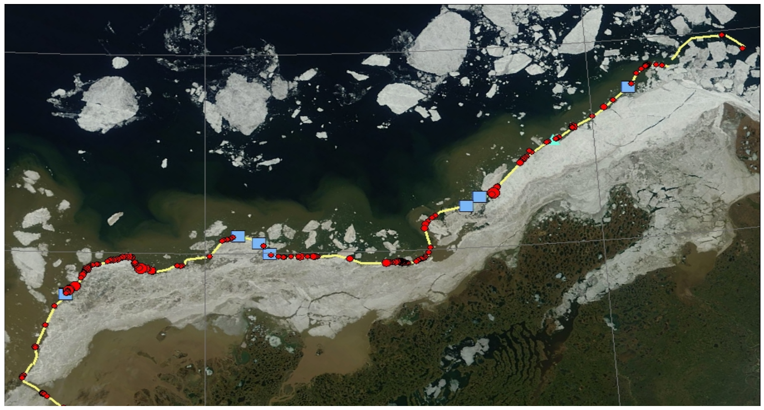


**Figure 3**. Example of Ice edge survey design (map from June 22, 2012 survey).

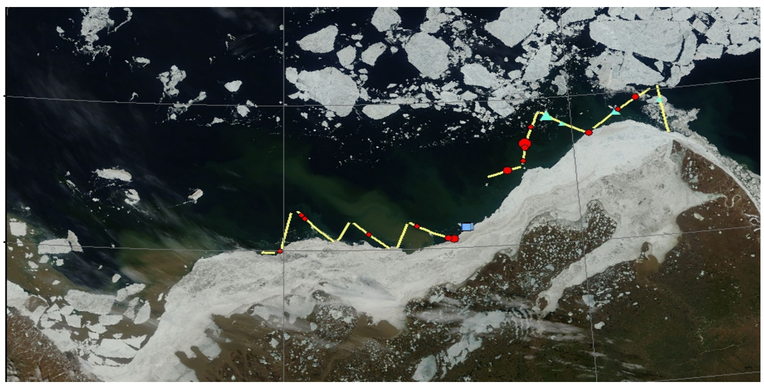


**Figure 4**. Example of transect (zigzag) survey design (map from June 13, 2012).

**Figure 5**.  Aerial view of belugas in the offshore area during the 2012 field season.

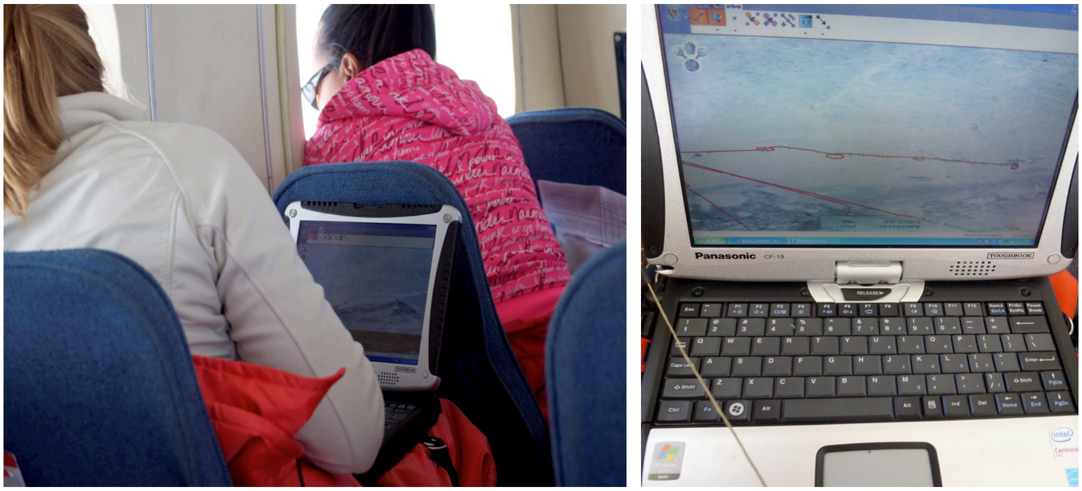



**Figure 6**. The observer looks out the window and notes beluga sightings to the recorder who uses a GPS enabled Toughbook laptops to record data in real time.

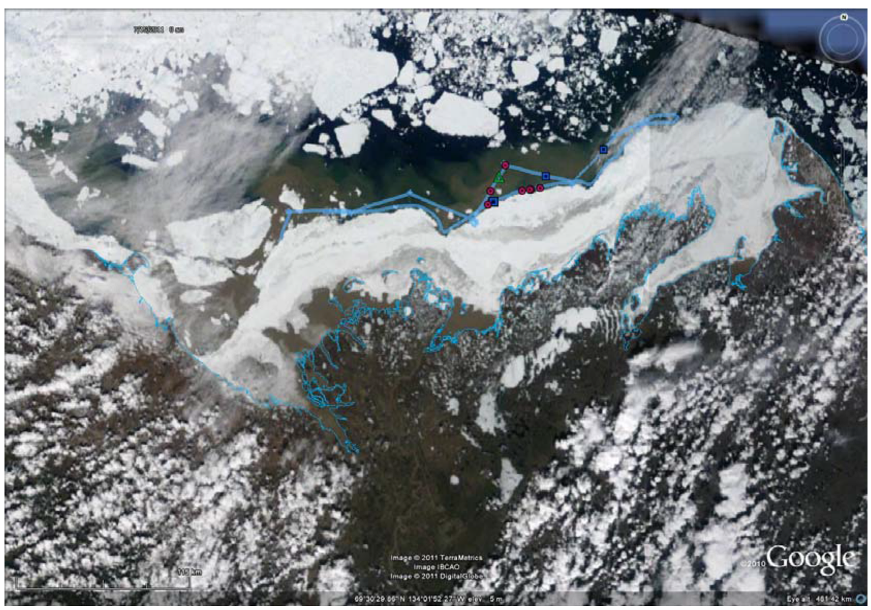



**Figure 7**. Survey transect and observations of all marine mammals observed over the June 14$^{th}$ MODIS ice image A total of seven beluga whales (red circles), four seals (blue squares) and one bowhead whale (green triangle) were observed. All beluga whale sightings were of solitary individuals.


**Figure 8**. June 14th MODIS ice image with June 16th survey transects and sightings of marine mammals. Twenty-three beluga whales (red circles), one seal (blue squares) were sighted all within the eastern side of the Tuktoyaktuk Peninsula. A final transect was attempted south of the ice edge to evaluate if any whales had entered via Shallow Bay; no whales were sighted.

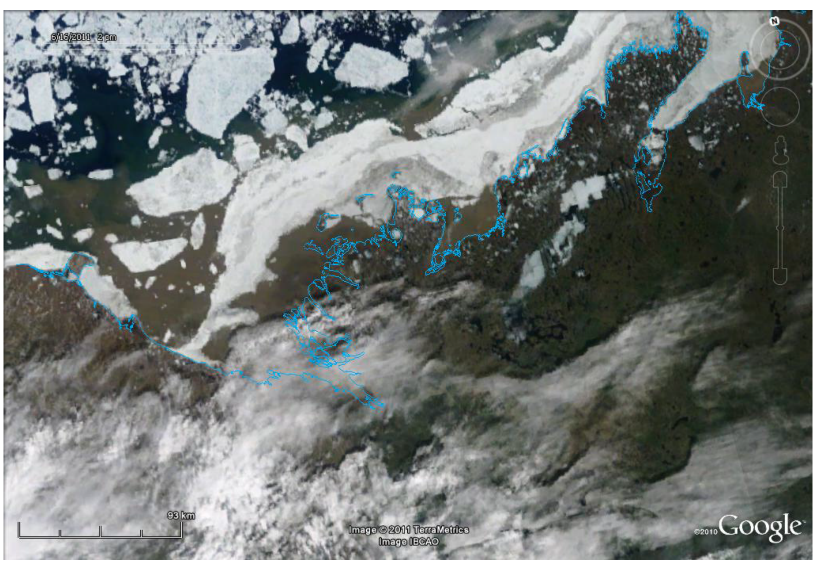



**Figure 9**. June 20th MODIS image of the ice bridge (narrowest point is about 6.5 km). Last survey scheduled for 2011, with the intention to focus on Shallow Bay. The survey was attempted but not completed due to poor weather. Based on MODIS images, it was documented that the ice bridge broke in Shallow Bay on June 22nd.

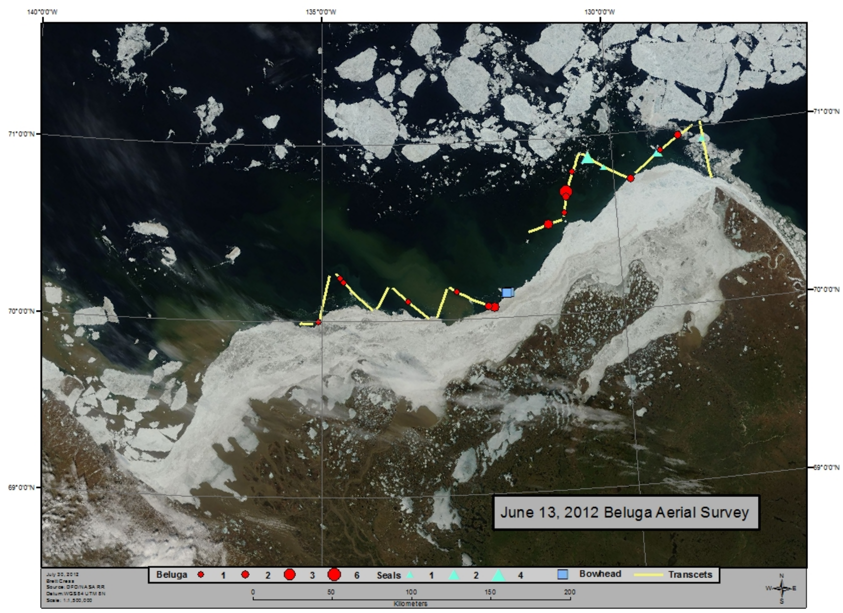



**Figure 10**. June 13th zigzag flight transects from Baillie to mid-Delta with beluga sightings (red dots), bowhead (blue square) and seals (triangle). The majority of the area surveyed off the sea ice in the east was blue water, which began to turn turbid toward the west, north of the Kugmallit Bay region.

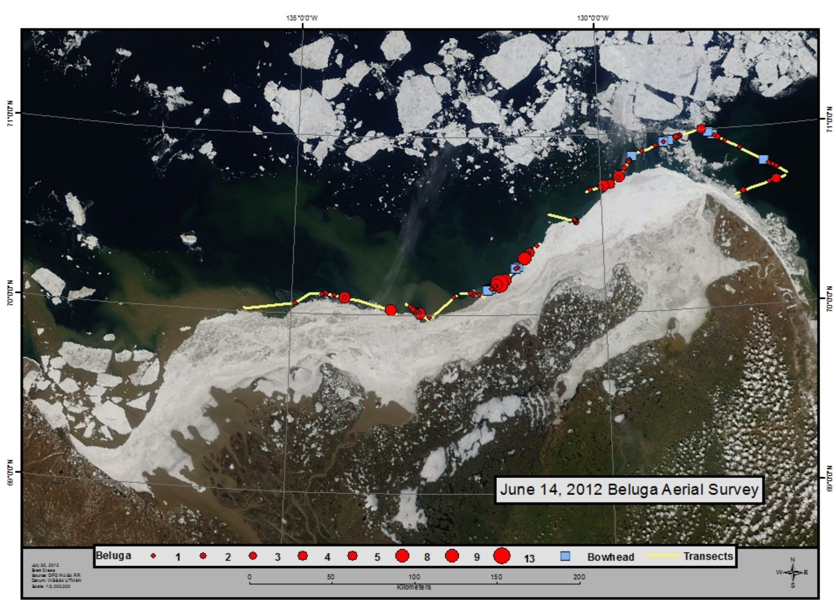



**Figure 11**. June 14th ice edge survey with all marine mammal sightings: beluga (red dots), bowhead (blue square) and seals (triangle).

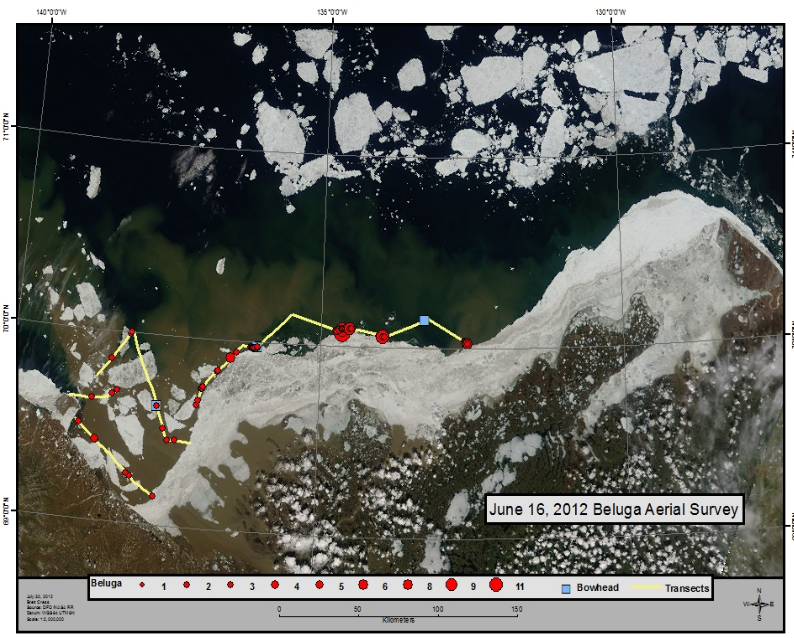



**Figure 12.** June 16th transects from Tuktoyaktuk Peninsula to Shallow Bay. Map includes all sightings of beluga (red dots), and bowhead (blue square) whales.

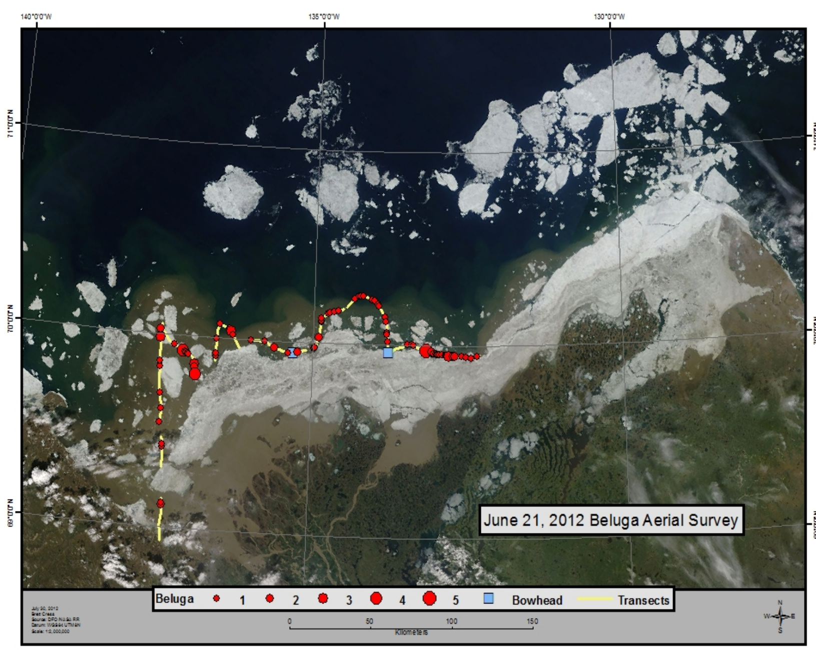



**Figure 13.** June 21st zigzag and ice edge survey. Due to poor weather conditions and large floes of ice, flight lines had to be adjusted resulting in slightly more rounded transects. Beluga (red dots) and bowhead (blue square) were both sighted.

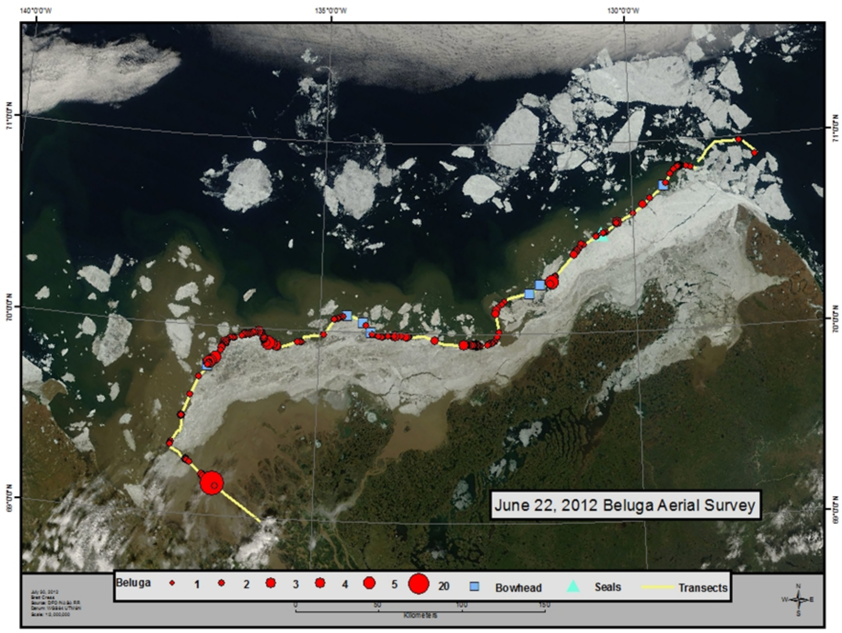



**Figure 14**. June 22$^{nd}$ ice edge survey extending from Baillie to Shallow Bay showing beluga (red dots) and bowhead (blue square) sightings. June 22$^{nd}$ was also the day the ice bridge broke.

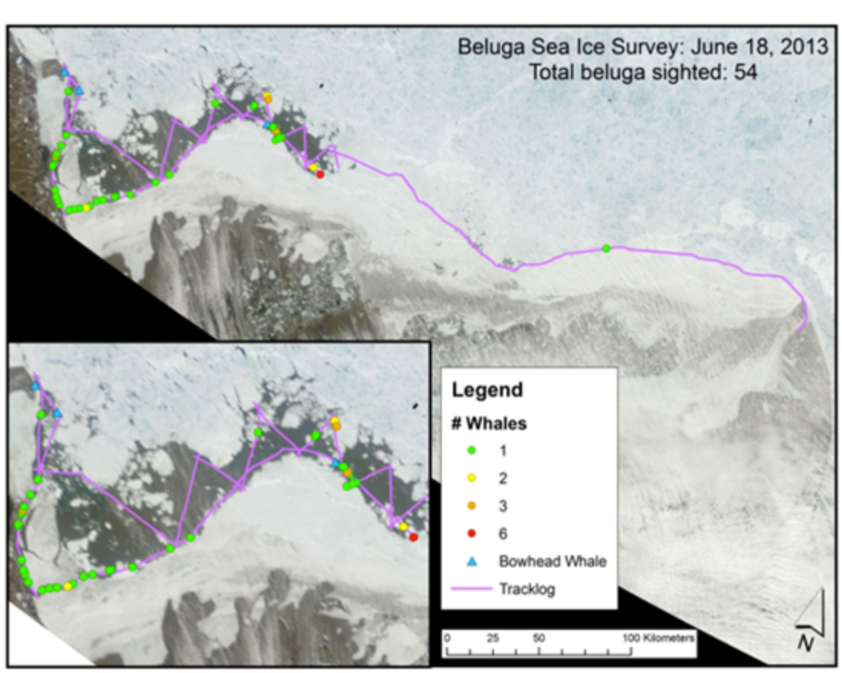



**Figure 15**. Transects from June 18$^{th}$ with preliminary data indicating location and number of beluga and bowhead whales.

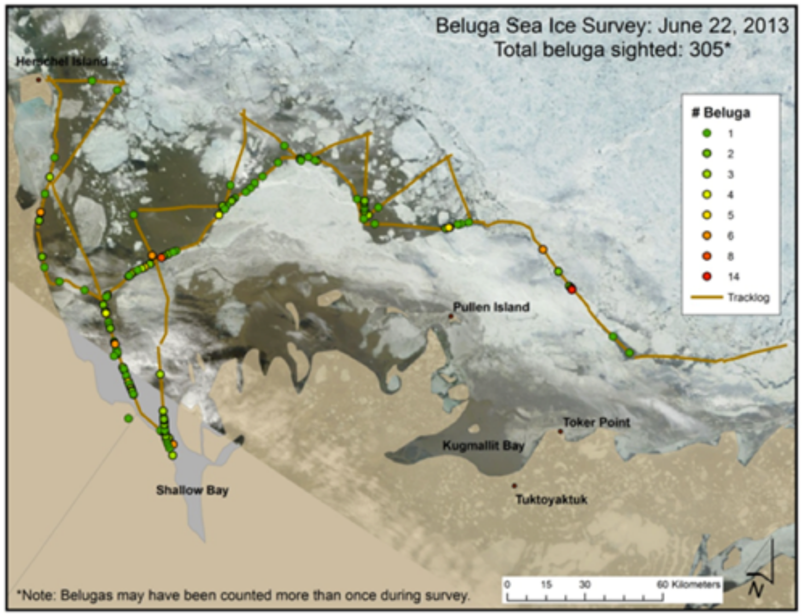



**Figure 16**: Transects from June 22nd with preliminary data indicating location and number of beluga whales. Ice bridge had broken on June 21st, zigzag transects were completed across Kugmallit Bay, including three transects in the inner delta, however, no whales were spotted.

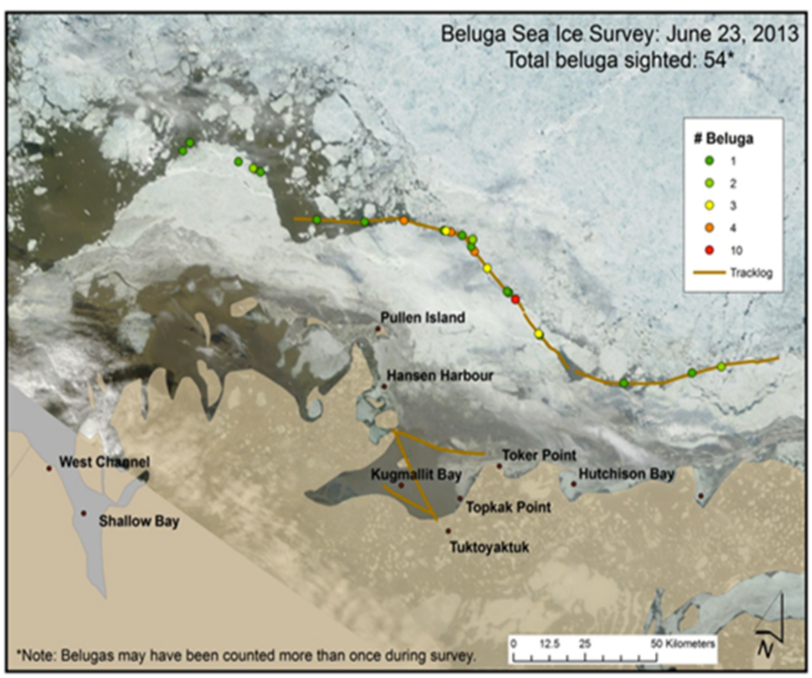



**Figure 17.** Transects from June 23rd, with preliminary data indicating location and number of beluga whales.