

**MARINE MAMMAL MITIGATION AND MONITORING FOR
GX TECHNOLOGY'S CANADIAN BEAUFORT
SPAN 2-D MARINE SEISMIC PROGRAM:
OCTOBER AND NOVEMBER, 2012**

by

Upun - LGL

LIMITED

for


GX TECHNOLOGY

Upun-LGL Report UA0011-01
25 April 2013

**MARINE MAMMAL MITIGATION AND MONITORING FOR
GX TECHNOLOGY'S CANADIAN BEAUFORT
SPAN 2-D MARINE SEISMIC PROGRAM:
OCTOBER AND NOVEMBER, 2012**

by

Heather R. Smith, Patrick Abgrall, and Valerie D. Moulton

Upun-LGL Limited

38 Tuma Drive

P.O. Box 1235

Inuvik, Northwest Territories

X0E 0T0

for

GX Technology Canada Ltd.

1905, 500 – 4th Avenue S.W.

Calgary, Alberta T2P 2V6

Upun-LGL Report UA0011-01

25 April 2013

Suggested format for citation:

Smith, H.R., P. Abgrall, and V.D. Moulton. 2013. Marine Mammal Mitigation and Monitoring for GX Technology's Canadian Beaufort Span 2-D Marine Seismic Program: October and November, 2012. Upun-LGL Rep. No. UA0011-01. Rep. by Upun-LGL Limited, Inuvik, NT, for GX Technology Canada Ltd., Calgary, AB. 29 p. + App.

TABLE OF CONTENTS

	Page
TABLE OF CONTENTS	iii
LIST OF FIGURES.....	v
LIST OF TABLES	vi
EXECUTIVE SUMMARY	vii
1. INTRODUCTION	1
1.1 Overview	1
1.2 Regulatory Requirements	2
2. SEISMIC OPERATIONS	2
2.1 Program Overview	2
2.2 Seismic Source Vessel	3
2.3 Ice-breaker Support Vessel	3
2.4 Airgun Array Characteristics and Operations.....	5
2.5 Seismic Data Recording	6
2.6 Additional Equipment	6
2.7 Vessel Movements and Operations.....	6
2.8 Ice Conditions.....	8
3. MARINE MAMMAL MONITORING AND MITIGATION PROGRAM	9
3.1 Introduction and Background	9
3.1.1 Marine Mammals and Seismic Surveys	9
3.1.2 Marine Mammal Mitigation and Monitoring Program.....	9
3.1.3 Marine Mammals of the Canadian Beaufort Sea	9
3.2 Field Operations	10
3.2.1 Monitoring	10
3.2.2 Mitigation Measures.....	15
3.2.3 Field Reports.....	18
3.3 Data Analysis	18
3.4 Results.....	18
3.4.1 Monitoring Effort.....	18
3.4.2 Marine Mammal Sightings	20
3.4.3 Ramp Up Delays and Airgun Array Shutdowns	23

4. SEABIRD OBSERVATIONS 24

 4.1 Introduction 24

 4.2 Field Operations 24

 4.3 Data Analysis 24

 4.4 Results 24

5. ACKNOWLEDGEMENTS 28

6. REFERENCES 28

APPENDIX A: SUMMARY OF VESSEL ACTIVITIES DURING GXT’S 2012 CANADIAN BEAUFORT SEA SEISMIC SURVEY. A-1

LIST OF FIGURES

	Page
FIGURE 1. Location of the 2012 GXT Beaufort Span 2-D seismic program in the Canadian Beaufort Sea	1
FIGURE 2. The seismic source vessel M/V <i>Geo Arctic</i>	3
FIGURE 3. The support vessel M/V <i>Polar Prince</i>	4
FIGURE 4. M/V <i>Geo Arctic</i> following in the path of open water created in the ice by the M/V <i>Polar Prince</i>	4
FIGURE 5. Spacing and configuration of the 4380 in ³ airgun array. Tow direction is to the right; tow depth is 8.5 m.	5
FIGURE 6. Trackline of the M/V <i>Geo Arctic</i> while in the Canadian Beaufort Sea during GXT’s seismic program from 16 October to 9 November 2012.	7
FIGURE 7. Trackline of the M/V <i>Polar Prince</i> while in the Canadian Beaufort Sea during GXT’s seismic program from 15 October to 9 November 2012.	8
FIGURE 8. View of the <i>Geo Arctic</i> bridge. MMOs are visible in the windows at left.	12
FIGURE 9. Inside view of the <i>Geo Arctic</i> bridge. JoeRoy Kimiksana is at the far end of the bridge, and Meike Holst is in the foreground.	12
FIGURE 10. Location of the “Big-Eye” binoculars on the <i>Polar Prince</i> flying bridge. Note MMO wearing an orange hard hat using the binoculars at top left.	13
FIGURE 11. MMO using “Big-Eye” binoculars on the <i>Polar Prince</i> monkey bridge.....	13
FIGURE 12. Photograph taken through one eyepiece of the Fujinon reticle binoculars, illustrating how the reticles are used to measure depression angles, and thus estimate distances from the location of the MMO.	14
FIGURE 13. Safety Zones (km) for whales (180 dB rms; 4380 in ³ airgun array) in different “geoacoustic” regions of the Canadian Beaufort Sea.	17
FIGURE 14. Safety Zones (km) for swimming polar bears (190 dB rms; 4380 in ³ airgun array) in different “geoacoustic” regions of the Canadian Beaufort Sea.	17
FIGURE 15. Locations of marine mammal sightings recorded by MMOs onboard the M/V <i>Geo Arctic</i> during the 2012 GXT seismic program.	21
FIGURE 16. Locations of marine mammal sightings recorded by MMOs onboard the M/V <i>Polar Prince</i> during the 2012 GXT seismic program.	22
FIGURE 17. Locations of seabird sightings recorded by MMOs on the M/V <i>Geo Arctic</i> during GXT’s 2012 seismic program.	26
FIGURE 18. Locations of seabird sightings recorded by MMOs on the M/V <i>Polar Prince</i> during GXT’s 2012 seismic program.	27

LIST OF TABLES

	Page
TABLE 1. Distances (km) and durations (h) of separation (minimum and maximum values) between the M/V <i>Geo Arctic</i> and M/V <i>Polar Prince</i> during periods with Seismic and No Seismic activity.....	8
TABLE 2. Status of marine mammals that regularly occur in the Canadian Beaufort Sea.	10
TABLE 3. Marine mammal observers for GXT’s 2012 Canadian Beaufort Sea seismic survey.	11
TABLE 4. Summary of MMO survey effort on the M/V <i>Geo Arctic</i> by time period and seismic activity.....	19
TABLE 5. Summary of MMO survey effort on the M/V <i>Polar Prince</i> by time period, anchor status and light level.	19
TABLE 6. Summary of marine mammal effort aboard the M/V <i>Polar Prince</i> by number of observers, seismic activity, and distance to the M/V <i>Geo Arctic</i>	19
TABLE 7. Marine mammal sightings during GXT’s 2012 Canadian Beaufort Span 2-D marine seismic program.	20
TABLE 8. Summary of opportunistic bird sightings during GXT’s Canadian Beaufort Sea 2D marine seismic program: October–November 2012.	25

EXECUTIVE SUMMARY

Overview

GX Technology (GXT) conducted a 2-D marine seismic survey offshore in the Canadian Beaufort Sea during October–November 2012. The survey area was within the Inuvialuit Settlement Region (ISR), with most of the Canadian lines occurring within the “disputed zone” (DZ) claimed by both Canada and the United States. Survey lines extended several kilometres eastward from the DZ as well, and into US waters to the west

The 2012 Beaufort Span 2-D program was unlike other marine seismic programs conducted previously in Canada. The primary objective of the program was to explore ice covered areas where it had previously been impossible to collect long offset, high resolution seismic data at this time of year (October – November). GXT overcame the limitations of using a conventional towed streamer array in sea ice by using an ice-strengthened seismic vessel with a modified hull (proprietary designed skeg), along with in-ice equipment, strategies and ice expertise utilized specifically for this purpose.

Seismic Operations

The seismic source vessel was the M/V *Geo Arctic*, a Russian-flagged 2-D seismic survey vessel, ice strengthened to the KM UL (1) A2 (Russian) Ice Class, equivalent to the Canadian Ice Class CASPPR Type A. The *Geo Arctic* was escorted by the Canadian-registered ice breaker support ship M/V *Polar Prince* during the project.

The *Geo Arctic* towed an airgun array composed of 28 Sercel G-gun airguns, of which 26 were active. Total discharge volume was 4380 in³. The 28 airguns were distributed in two sub-arrays with 14 airguns per sub-array. The airguns were towed at a depth of ~8.5 m below the water surface. The *Geo Arctic* also towed a single 9km-long streamer to receive the reflected acoustic signals from the sea bottom. It was towed at ~9.5 m below the water surface.

Vessel Movements and Operations

The *Polar Prince* and *Geo Arctic* departed Nome, Alaska on 11 October 2012, and transited to the Canadian Beaufort Sea, arriving on the 15th and 16th of October respectively. After receiving fuel near Herschel Island, the Sound Source Verification (SSV) test of the airgun array was completed on 23 October. The *Geo Arctic* then began collecting seismic data, then moving west into the U.S. Beaufort Sea, where it surveyed seismic lines that extended far to the west. The *Polar Prince* remained in Canada until 31 October, and then transited west, meeting up with the *Geo Arctic* on 3 November (in the U.S.). During the time that the *Polar Prince* remained in Canada, the *Geo Arctic* surveyed mostly in the U.S., returning briefly to Canada on 31 October. It then left Canada on 1 November. The *Geo Arctic* and *Polar Prince* returned to Canada on 7 November, and then departed on 9 November. This concluded the survey activities in the Canadian Beaufort Sea.

The *Geo Arctic* was in Canada for a total of 232.3 h, and travelled 1659.0 km. Airguns were active along 756.3 km of the ship’s track. Of this 756.3 km, seismic data acquisition occurred along 404.6 km. Seismic testing, mitigation airgun use, or ramping up to full array occurred along 351.7 km of the ship’s track. The *Polar Prince* was in Canada for 476.4 h, and travelled 2567.2 km.

The *Geo Arctic* and *Polar Prince* were separated by >5 km for much of the 2012 seismic program. The *Polar Prince* was at anchor 184.7 h (38.8%) of the total time spent in Canada.

Ice Conditions

The majority of the survey took place in open water. Ice was only encountered at the end of the survey on 8 and 9 November 2012. The majority of the ice was categorized as “pancake” ice, and coverage ranged from 50–90%. There were few observations of “new” ice, and coverage ranged from 1–20%. When ice coverage was $\geq 20\%$, the *Polar Prince* typically travelled ≤ 3 km in front of the *Geo Arctic*. The ice did not cause either vessel to deviate from survey lines or to reduce speed while surveying in the Canadian Beaufort Sea.

Marine Mammals in the Canadian Beaufort Sea

During summer and early fall, when most seismic surveys are conducted in the Canadian Beaufort Sea, five species of marine mammals regularly occur—two species of cetaceans (beluga and bowhead whale), two species of pinnipeds (ringed and bearded seals), and polar bears.

- The ***ringed seal*** has no status under the *Species at Risk Act* (SARA), and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has listed it as Not at Risk. It was recently designated a high-priority candidate wildlife species for assessment by COSEWIC. The ringed seal is listed as Secure by the Working Group on General Status of Northwest Territories Species.
- The ***bearded seal*** has no status under SARA, and COSEWIC has listed it as Not at Risk. It was recently designated a mid-priority candidate wildlife species for assessment by COSEWIC. The bearded seal is listed as Secure by the Working Group on General Status of Northwest Territories Species.
- The Eastern Beaufort Sea population of ***beluga*** has no status under SARA, and is listed as Not at Risk by COSEWIC. The beluga is listed as Secure by the Working Group on General Status of Northwest Territories Species.
- The Bering-Chukchi-Beaufort Sea population of ***bowhead whale*** is listed on Schedule 1 of SARA as Special Concern, and is also considered of Special Concern by COSEWIC. The bowhead is listed as Sensitive by the Working Group on General Status of Northwest Territories Species.
- The ***polar bear*** is listed on Schedule 1 of SARA as Special Concern, and is also considered of Special Concern by COSEWIC. The polar bear is listed as Sensitive by the Working Group on General Status of Northwest Territories Species, and Special Concern by the Northwest Territories Species at Risk Committee.

Marine Mammal Monitoring and Mitigation Program

The primary objectives of the monitoring and mitigation program were to document and minimize effects of airgun array sounds on marine mammals, and to collect data on the occurrence and distribution of marine mammals in the Canadian Beaufort Sea. These objectives were achieved through:

- Mitigation: airgun array ramp-ups, mitigation airgun use, and delay of ramp up and shut down of airgun(s) for cetaceans or swimming polar bears observed within the safety zone
- Monitoring: documenting the locations and abundance of marine mammals, as well as their responses to seismic operations

Mitigation Measures

Mitigation measures developed for GXT's previous seismic programs (as well as other seismic programs) in the Canadian Beaufort Sea included avoidance of Beluga Management Zone 1A and the application of additional measures within areas identified as Bowhead Aggregation Areas (BAAs). GXT's 2012 seismic survey was planned for October–November to avoid potential effects on beluga harvesting and bowhead whales, including BAAs that occurred earlier in the season.

Mitigation was also accomplished via the following:

- ***Shutdown (safety) zones (SZ)*** were used to minimize the potential for whales and polar bears being exposed to sound levels that may cause a temporary threshold shift in hearing (180 dB re 1 μ Pa root mean square (rms) for whales and 190 dB rms for swimming polar bears). The sizes of these zones were modelled by JASCO Applied Sciences prior to the seismic program and later verified via field measurements Sound Source Verification (SSV). An immediate shutdown of the airgun(s) would have been implemented if a whale or swimming polar bear was observed in, or about to enter, the respective SZ.
- ***Pre-start watches*** occurred for at least 30 min prior to the start of any airgun. Airguns were not activated if a whale or swimming polar bear was seen within or about to enter the SZ during the pre-start watch.
- ***Ramp-ups/Soft starts*** involved the gradual and sequential activation of airguns, beginning with the lowest volume airgun (70 in³), and taking 30 min before the array reached full volume. During the ramp-up, the SZ requirements for the full array were in effect.
- ***Airgun operations between lines*** - Airguns were usually shut down when transiting after the completion of one seismic line to reach the start of the next line (a line change). However, when the resumption of seismic activity was expected to occur during a period of poor visibility (including darkness), the smallest airgun in the array (the 70 in³ mitigation airgun) was kept operating between lines rather than shutting down the entire array. During periods of mitigation airgun use, the SZ requirements for the full array were in effect for whales and swimming polar bears.
- ***Shutdown criteria*** - All airguns would have been immediately shut down if a whale or swimming polar bear had been observed in, or about to enter, the 180 dB or 190 dB SZ, respectively.

There were no mitigation events requiring delay of ramp up or shut down of airgun(s) during the 2012 GXT seismic program in the Canadian Beaufort Sea.

Monitoring Program

Trained MMOs were stationed aboard both the *Geo Arctic* and the *Polar Prince* for the duration of the seismic program. There were two biologist MMOs aboard each vessel, two Inuvialuit MMOs (IMMOs) aboard the *Geo Arctic*, and one IMMO aboard the *Polar Prince*. All MMOs were responsible for collecting data on the occurrence and behaviour of marine mammals. The *Geo Arctic* MMO crew was also responsible for ensuring that mitigation measures were implemented when required.

Marine mammal monitoring aboard the *Geo Arctic* was conducted during all daylight periods that airgun operations were underway, regardless of sighting conditions. MMOs were also on watch during most daylight periods when the airgun array was not operating; exceptions to this generally occurred when the *Geo Arctic* was at anchor and/or bunkering for fuel near Herschel Island. Monitoring aboard the *Polar Prince* was conducted during most daylight hours, as well as during periods of darkness. There

were 1–3 MMOs on watch at a given time on each vessel; the *Geo Arctic* typically had more MMOs on watch than the *Polar Prince* because of the larger MMO team aboard the *Geo Arctic*.

Monitoring Effort

During the survey period, there were ~7-11 hours of daylight. The *Geo Arctic* had 2-3 MMOs on duty on almost every watch. Of the 29.0 watch hours during seismic activity, three MMOs were on watch for 23.2 h (80.0%), two MMOs were on watch for 5.2 h (17.9%), and one MMO was on watch for 0.6 h (2.1%). Of the 44.1 watch hours during non-seismic periods, three MMOs were on watch for 35.5 h (80.5%), two MMOs were on watch for 8.1 h (18.4%), and one MMO was on watch for 0.5 h (1.1%).

The *Polar Prince* spent a greater amount of time than the *Geo Arctic* in the Canadian Beaufort during the seismic program and conducted observations during periods of darkness using night-vision goggles (NVDs) and a forward looking thermal imaging (FLIR®), thus the total number of MMO watch hours for the *Polar Prince* exceeded those of the *Geo Arctic*.

The *Polar Prince* had two MMOs on duty for the majority of the watches (Table 6). Of the 260.7 watch hours, three MMOs were on watch for 2.1 h (0.8%), two MMOs were on watch for 181.2 h (69.5%), and one MMO was on watch for 77.4 h (29.7%).

Marine Mammal Sightings

There were a total of six marine mammal sightings during the entire seismic program in the Canadian Beaufort Sea. MMOs on the *Geo Arctic* made two observations of ringed seals. MMOs on the *Polar Prince* made one observation of belugas, two observations of ringed seals, and one observation of a bearded seal. All sightings occurred when the array was inactive.

Seabird Observations

Opportunistic seabird observations were recorded by MMOs during the course of the MMO watches. All observations were made while MMOs were stationed on the bridges of the *Geo Arctic* and the *Polar Prince*.

There were a total of 131 sightings of 331 individual birds recorded during GXT's 2012 seismic program in the Canadian Beaufort Sea. Glaucous Gulls and eiders were the most commonly observed birds. Other species observed included: Black Guillemot, Long-tailed Duck, Northern Fulmar, and Snowy Owl.

1. INTRODUCTION

1.1 Overview

GX Technology (GXT) conducted a 2-D marine geophysical (seismic reflection/refraction) survey offshore in the Canadian Beaufort Sea during October–November 2012. The survey area was within the Inuvialuit Settlement Region (ISR), with the primary survey area in the “disputed zone” (DZ) claimed by both Canada and the United States (U.S.). The survey lines were geophysically part of the same SPAN survey, so that several lines began to the east of the disputed zone (indicated in green, Figure 1), transited through that area, and continued on the US side (i.e. west of 141°W longitude). The Canadian Project (and related permitting) was considered to include all lines and work to the east of 141°W.

Because marine seismic projects emit strong sounds into the water, projects such as GXT’s have the potential to affect marine mammals (Richardson et al. 1995). Upun-LGL Limited was retained by GXT to implement a marine mammal monitoring and mitigation program. This report describes the 2012 seismic program, the marine mammal monitoring and mitigation program, and presents the results of the programs. This report also describes and presents the results of seabird observations.

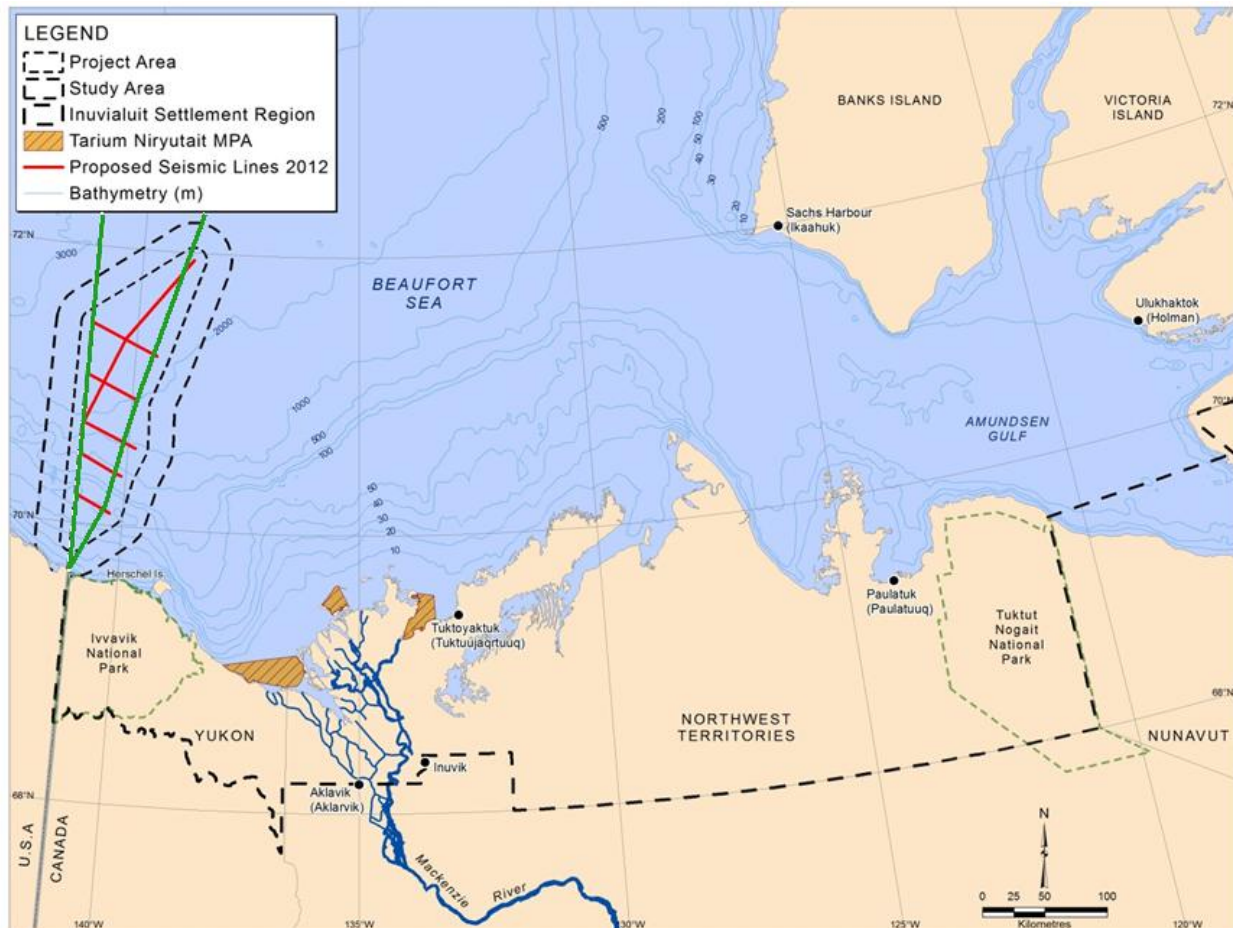


FIGURE 1. Location of the 2012 GXT Beaufort Span 2-D seismic program in the Canadian Beaufort Sea (Inuvialuit Settlement Region). Seismic lines are those proposed and approved for 2012, but all were not surveyed during the 2012 program. Also shown are the Project and Study Areas used in the environmental assessment for the program.

1.2 Regulatory Requirements

GXT's seismic program was approved by the Inuvialuit Environmental Impact Screening Committee (EISC) and the National Energy Board (NEB), which, for the purposes of this 2012 project, work together as screening/approval agencies. Other agencies with regulatory interest and/or involvement in the approval process included:

- Fisheries and Oceans Canada (DFO) with reference to potential effects on marine mammals, fish, fish habitat, and invertebrates;
- Environment Canada with reference to potential effects on birds and polar bears (Canadian Wildlife Service (CWS)), and pollution prevention; and
- Transport Canada and the Canadian Coast Guard with reference to vessel specifications, inspections, and safety.

Due to the survey area in the DZ also being claimed by the U.S., authorization for the potential effects of the proposed activities on marine mammals was required under the U.S. *Endangered Species Act* (ESA) and the U.S. *Marine Mammal Protection Act* (MMPA). The U.S. permit requirements are summarized in Bisson et al. (2013).

2. SEISMIC OPERATIONS

2.1 Program Overview

GXT's 2012 Beaufort Span 2-D seismic survey in the Canadian Beaufort Sea was a continuation of the basin-wide 2-D seismic programs successfully conducted in 2006, 2007, 2008, and 2010 (LGL et al. 2006; LGL 2007, 2008; Upun-LGL 2010). The purpose of the basin-wide programs was to collect seismic data that revealed the sub-bottom geological profile for assessments of petroleum reserves in the area. The program was not designed to identify specific potential drilling locations.

The Beaufort Span 2-D program is unlike any marine seismic program conducted before in Canada. The primary objective of the 2012 program was to explore ice covered areas where it had previously been impossible to collect long offset, high resolution seismic data. GXT overcame the limitations of using a conventional towed streamer array in sea ice by using an ice strengthened seismic vessel with a modified hull (proprietary designed skeg), along with in-ice equipment and strategies designed specifically for this purpose.

During offshore 2-D seismic surveys such as GXT's 2012 program, a vessel tows an airgun array that produces short pulses of acoustic energy. Most of the acoustic energy generated by the airguns is directed downward and radiates into the ocean floor as a hemispherical wave front. A portion of that energy is reflected back toward the water surface from the rock layers under the ocean floor. The reflected sound energy is collected by hydrophones housed in a streamer towed behind the seismic vessel. The acoustic data are then transferred to and recorded in a data processing centre housed aboard the ship. The depths of the reflecting rock layers are calculated from the times it takes for the reflected sound to reach the hydrophones. The data from a single hydrophone streamer provide 2-D "slices" of the substrate underlying the ocean bottom. Because the airgun array produces energy that can be perceived by marine organisms, the emitted sound is a primary focus of environmental management, mitigation and monitoring efforts. The following sections describe the equipment and operating details for GXT's 2012 seismic program, insofar as they are relevant to marine mammal monitoring and mitigation.

2.2 Seismic Source Vessel

Vessel	Owner/Operator	Length (m)	Beam (m)	Draft (m)
M/V <i>Geo Arctic</i>	Sevmorneftegeofizika (SMNG)	81.8	14.8	5.4

The *Geo Arctic* (Figure 2) is a Russian-flagged 2-D seismic survey vessel. It is equipped with standard navigation, radar, communication, and depth-sounding equipment. The *Geo Arctic* is ice strengthened to the KM UL (1) A2 (Russian) Ice Class, equivalent to the Canadian Ice Class CASPPR Type A. This vessel was built in Poland in 1988, and then rebuilt in Norway in 1997. The main engine is a 3090 kW Zgoda-Zulcer 6ZL 40/48. Fuel capacity is 710 m³ and endurance is 67 days. Cruising speed is 12 knots; however, the *Geo Arctic* travelled at a speed of ~4 knots while surveying. The *Geo Arctic* was escorted by the ice-breaker support vessel *Polar Prince* during the project.



FIGURE 2. The seismic source vessel M/V *Geo Arctic* (photo by S. Yin).

2.3 Ice-breaker Support Vessel

Vessel	Owner/Operator	Length (m)	Beam (m)	Draft (m)
M/V <i>Polar Prince</i>	GX Technology Canada Ltd.	67.1	15.0	6.0

The *Polar Prince* (Figure 3) is a Canadian-flagged Lloyds 100A (Arctic Class 1+) ice-breaker ship. Built in Quebec for the Canadian Coast Guard in 1959, it was totally rebuilt and modernized by the Coast Guard in 1986. It was refit in 2010, and is certified by Transport Canada Marine Safety & DNV 1A1. It has an ice-class hull and a full bubbler system (low pressure air) for icebreaking. The *Polar Prince* is propelled by 4x Morse-Fairbanks 38 D 8 1/8 diesels engines (main engines) and 2x fixed blade Superston 70 propellers. Fuel capacity is 701 m³, maximum speed is 14.5 knots and cruising speed is 11 knots. In addition to scouting for ice and facilitating crew transfers, the *Polar Prince* travelled ~500 m in front of the *Geo Arctic* to clear a path when in ice-covered waters (see Figure 4 for an example).



FIGURE 3. The support vessel M/V *Polar Prince* (photo by Upun-LGL Limited).



FIGURE 4. M/V *Geo Arctic* following in the path of open water created in the ice by the M/V *Polar Prince* (photo by Upun-LGL Limited).

2.4 Airgun Array Characteristics and Operations

The *Geo Arctic* towed an airgun array comprised of 28 Sercel G-gun airguns, of which 26 were active. Total discharge volume was 4380 in³. The 28 airguns were distributed in two sub-arrays with 14 airguns per sub-array (Figure 5). Individual airgun sizes ranged from 70–250 in³, and were operated at 2000 psi (pounds per square inch). The sub-arrays were deployed 23 m astern of the vessel (25.5 m from the stern to the centre of the array) at a depth of ~8.5 m. The distance between the array and the position from which the marine mammal observers (MMOs) conducted observations on the bridge was 83 m.

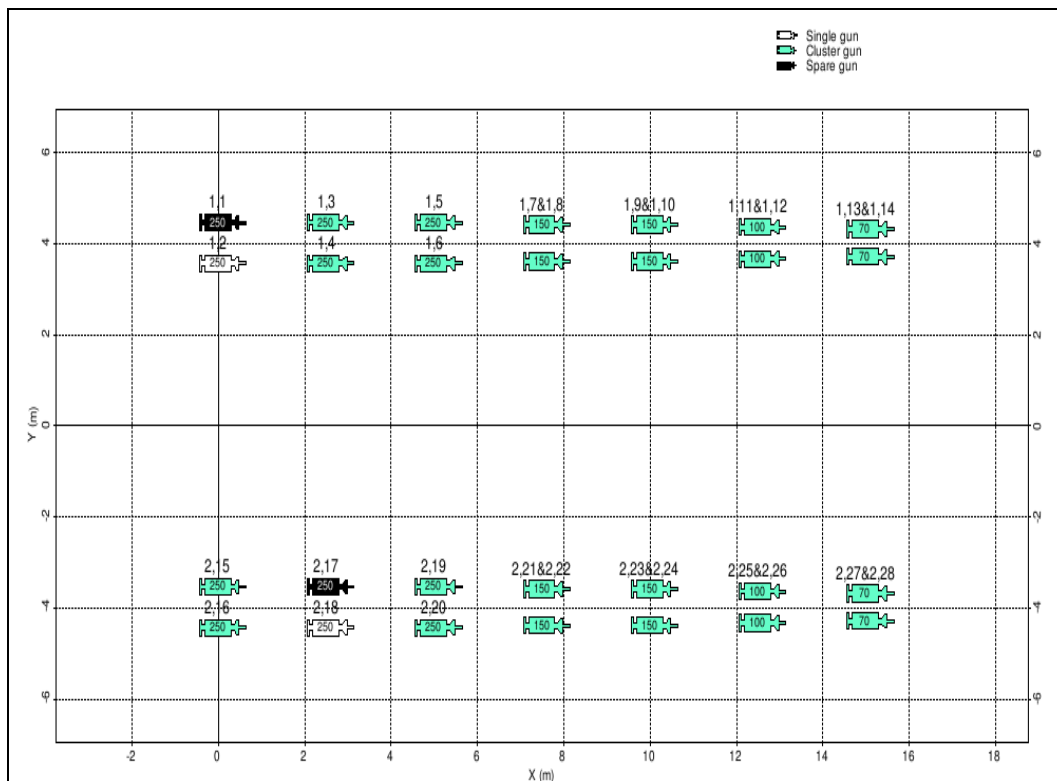


FIGURE 5. Spacing and configuration of the 4380 in³ airgun array. Tow direction is to the right; tow depth is 8.5 m (diagram provided by JASCO Applied Sciences).

The nominal zero-to-peak source pressure level @ 1 m for each pulse was estimated at 250 dB re 1 μ Pa (broadside, 10–2000 Hz). The source pressure averaged over the length of the pulse (root mean square or rms) was estimated as 220.5 dB re 1 μ Pa @ 1 m (10–2000 Hz), and the sound exposure level (SEL) at 1 m from the source was estimated as 230.5 dB re 1 μ Pa²-s (10–2000 Hz) (Matthews and MacGillivray 2012).

Airgun operations included airgun testing, ramp-up (also referred to as soft start), activating a single mitigation airgun during transits between lines, and line surveying. These operations differed in the total number of active airguns and timing.

- Testing of the airguns involved irregular volumes and timing of airgun pulses.
- The ramp-up was a mitigation measure in which the volume of the active array was gradually increased over time. The ramp-up required 30 min, with the number of active airguns starting at 1 (smallest volume, i.e., 70 in³ airgun) and doubling every 5 min until 16 airguns was

active at the 20 min mark. At 25 min, 1 airgun was added every 30 s, until the full array of 26 airguns was active.

- The mitigation airgun was a single 70 in³ airgun, and was activated during transits between lines when the resumption of seismic activity was expected to occur during a period of poor visibility (including darkness). The shotpoint interval was every 18–20 s.
- Line surveying or data acquisition occurred with the airgun array at full volume (4380 in³) as the *Geo Arctic* travelled along the pre-determined survey lines at ~4 knots. The shotpoint interval was every 37.5 m or 18–20 s.

2.5 Seismic Data Recording

The *Geo Arctic* towed a single 9 km long streamer to receive the reflected signals from the bottom. The streamer was an ION Geophysical DigiSTREAMER™ towed at ~9.5 m below the water surface. The DigiSTREAMER contained an environmentally-friendly solid fill to reduce self-noise properties while providing consistent buoyancy. The DigiSTREAMER technology is designed to perform well in cold weather, unlike solid streamers, which may become stiff and difficult to handle. The survey vessel had limited maneuverability while towing the streamer and required a ~10 km run-in for the start of a seismic line, and a 4–5 km run-out at the end of the line.

2.6 Additional Equipment

Both vessels operated industry standard echo sounders for continuous measurements of water depth while underway. These instruments are used by all large vessels to provide routine water depth information to the vessel crew. Navigation echo sounders send a single, narrowly focused, high frequency acoustic signal directly downward to the sea floor. The sound energy reflected off the sea floor returns to the vessel where it is detected by the instrument and the depth is calculated and displayed to the user. Source levels of navigational echo sounders of this type are typically in the 180–200 dB re 1 μ PA-m (Richardson et al. 1995).

The *Geo Arctic* used a downward facing single-beam Simrad EA 600 hydrographic echosounder that operates at frequencies ranging from 38 to 200 kHz with an output power of 100–2000 Watts. Pulse durations for this echosounder are between 0.064 and 4.096 milliseconds, and the pulse repetition frequency (PRF or ping rate) depends on the depth range. The highest PRF at shallow depths is about 40 pings per second.

The *Polar Prince* used an ELAC LAZ-72 echosounder. The LAZ-72 has an operating frequency of 30 kHz. The ping rate depends on the water depth. The fastest rate, which occurs in shallow depths, is about 5 pings per second.

The *Geo Arctic* was also equipped with a gravity meter and a magnetometer. Both are passive devices that do not emit sound.

2.7 Vessel Movements and Operations

MMOs joined the seismic source and support vessels in Nome, Alaska where they received technical training as well as project and vessel orientation sessions on 9 October 2012. The *Geo Arctic* and *Polar Prince* departed Nome on 11 October 2012, and transited to the Canadian Beaufort Sea, arriving on the 16th and 15th of October, respectively. After receiving fuel near Herschel Island, the Sound Source Verification (SSV) test of the airgun array was completed on 23 October (see Section 3.2.2.1 for further details). The *Geo Arctic* then began collecting seismic data, moving west into the U.S. Beaufort Sea. The *Polar Prince* remained in Canada as it awaited a break in the weather to offload four

crew members and receive replacement parts for the seismic equipment required by the *Geo Arctic*. The *Polar Prince* offloaded the crew at Sachs Harbour on 31 October, and then transited west, meeting up with the *Geo Arctic* on 3 November (in the U.S. Beaufort Sea). During the time that the *Polar Prince* remained in Canada, the *Geo Arctic* worked mostly in the U.S. Beaufort Sea, returning briefly to Canada on 31 October. It then left Canada on 1 November. The *Geo Arctic* and *Polar Prince* returned to Canada on 7 November, and then departed on 9 November. This concluded the survey activities in the Canadian Beaufort Sea (see Appendix A for further details on vessel operations).

The *Geo Arctic* was in Canada for a total of 232.3 h (spread over 14 days), and travelled 1659.0 km (Figure 6). Airguns were active along 756.3 km of the ship's track. Of this 756.3 km, seismic data acquisition occurred along 404.6 km. Seismic testing, mitigation airgun use, or ramping up to full array occurred along 351.7 km of the ship's track. The *Polar Prince* was in Canada for 476.4 h (spread over 23 days), and travelled 2567.2 km (Figure 7).

The *Geo Arctic* and *Polar Prince* were separated by >5 km for much of the 2012 seismic program. The *Polar Prince* was at anchor 184.7 h (38.8%) of the total time spent in Canada.

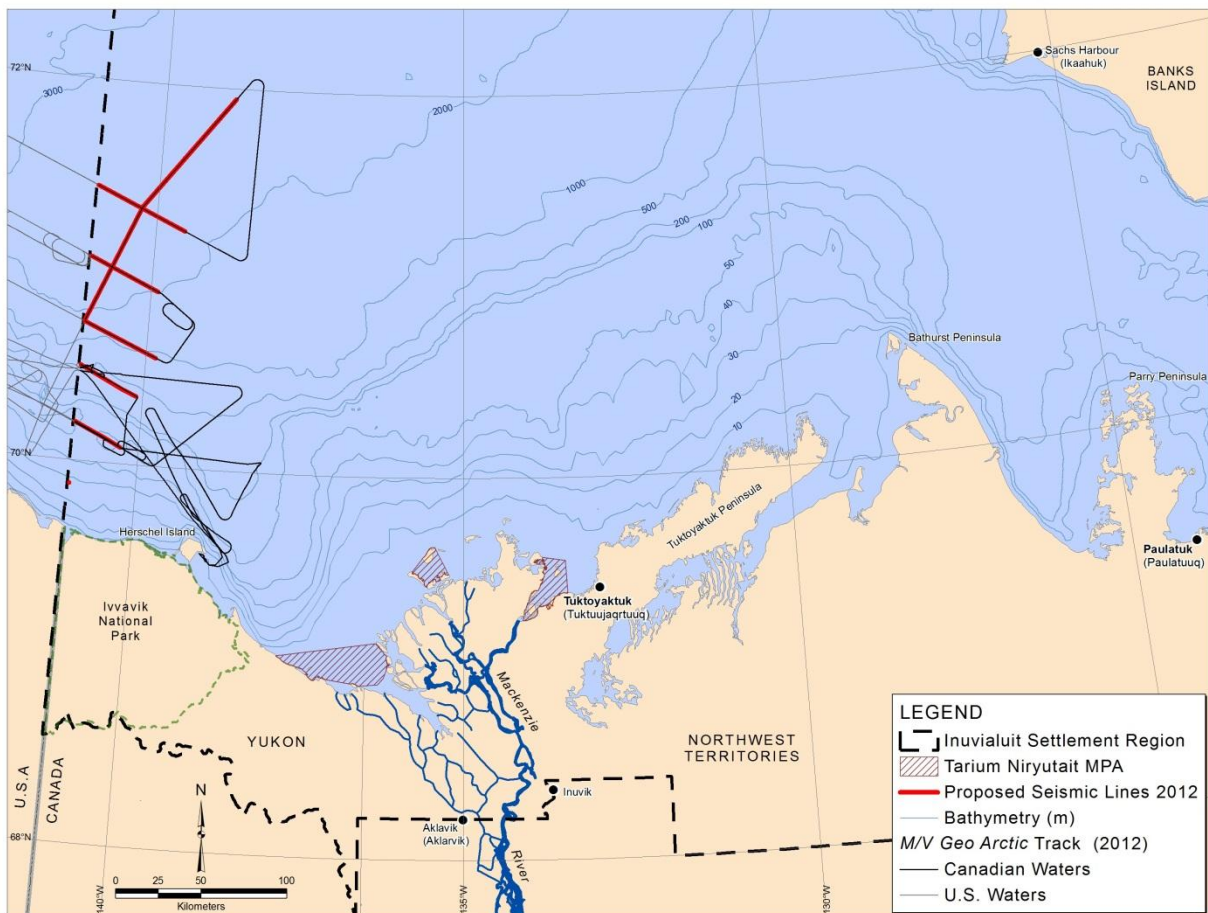


FIGURE 6. Trackline of the M/V *Geo Arctic* while in the Canadian Beaufort Sea during GXT's seismic program from 16 October to 9 November 2012.

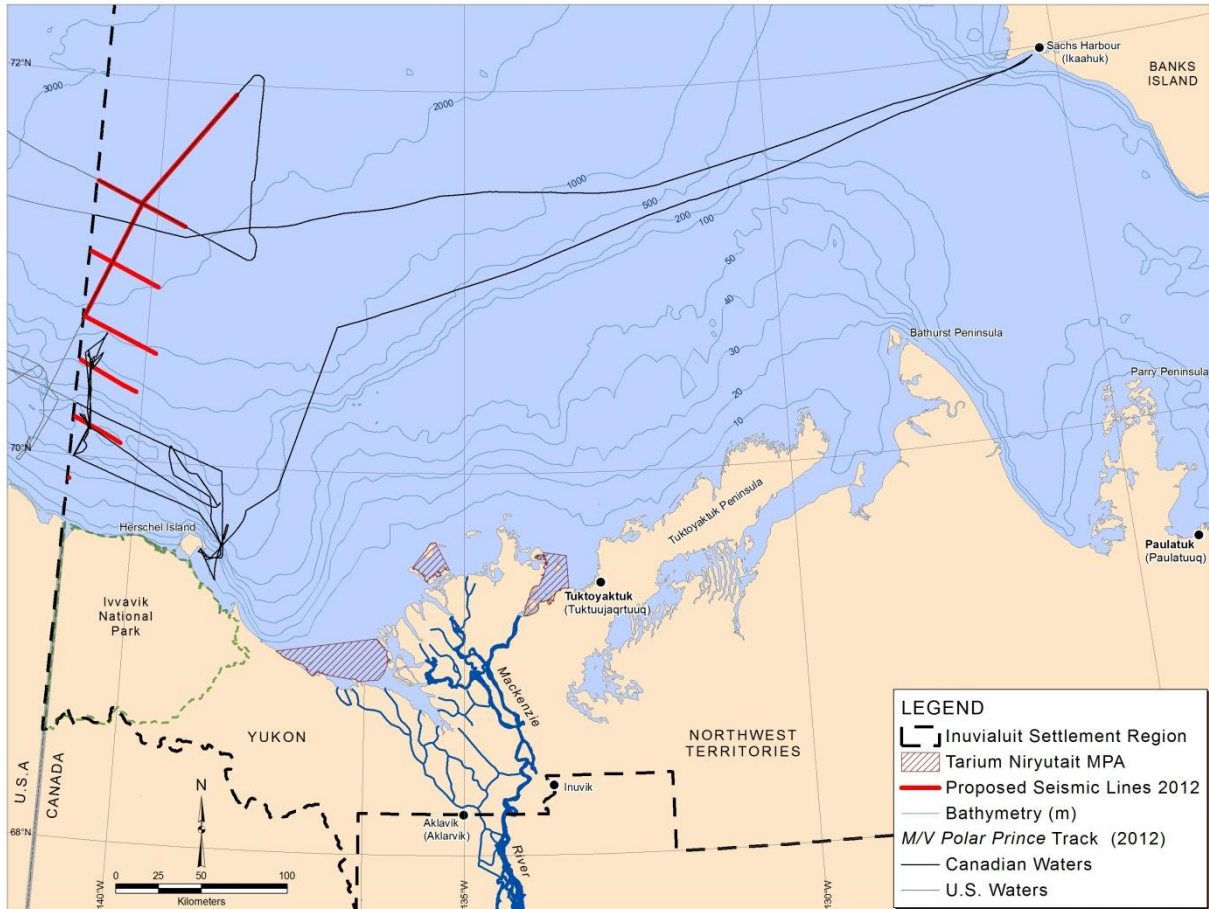


FIGURE 7. Trackline of the M/V *Polar Prince* while in the Canadian Beaufort Sea during GXT’s seismic program from 15 October to 9 November 2012.

2.8 Ice Conditions

The majority of the seismic survey took place in open water. Ice was only encountered at the end of the survey on 8 and 9 November 2012. The majority of the ice was categorized as “pancake” ice, and coverage ranged from 50–90%. There were few observations of “new” ice, and coverage ranged from 1-20%. When ice coverage was $\geq 20\%$, the *Polar Prince* typically travelled ≤ 3 km in front of the *Geo Arctic*. Ice conditions did not cause either vessel to deviate from survey lines or to reduce speed while surveying in the Canadian Beaufort Sea.

TABLE 1. Distances (km) and durations (h) of separation (minimum and maximum values) between the M/V *Geo Arctic* and M/V *Polar Prince* during periods with Seismic and No Seismic activity. Values are provided for weekly periods and overall.

Time period	Seismic				No Seismic			
	Distance (km)		Time (h)		Distance (km)		Time (h)	
	Min	Max	<5 km	≥ 5 km	Min	Max	<5 km	≥ 5 km
15–21 Oct	6.8	83.5	0.0	23.8	0.4	106.2	35.8	90.3
22–28 Oct	2.1	614.7	1.5	132.4	6.7	549.4	0.0	38.7
29 Oct–4 Nov	61.2	531.5	0.0	111.1	526.6	526.6	0.0	0.6
5–11 Nov	1.8	10.3	21.0	16.5	1.5	2.8	4.5	0.0
Overall	1.8	614.7	22.5	283.9	0.4	549.4	40.3	129.6

3. MARINE MAMMAL MONITORING AND MITIGATION PROGRAM

3.1 Introduction and Background

3.1.1 Marine Mammals and Seismic Surveys

Marine seismic surveys emit sound energy into the water (Greene and Richardson 1988; Richardson et al. 1995) and have the potential to affect marine mammals given the reported auditory and behavioural sensitivity of many such species to underwater sounds (Richardson et al. 1995; Gordon et al. 2004; Southall et al. 2007). The effects could consist of behavioural or distributional changes, and perhaps (for animals very close to the sound source) temporary or permanent reduction in hearing sensitivity (Richardson et al. 1995; Gordon et al. 2004; Southall et al. 2007). However, potential effects may be reduced by marine mammals moving away from approaching sound sources (Richardson et al. 1995; Gordon et al. 2004; Stone and Tasker 2006).

3.1.2 Marine Mammal Mitigation and Monitoring Program

The monitoring and mitigation program was developed to address concerns about the effects of the seismic survey on marine mammals and the subsistence hunting of marine mammals, notably belugas, within the ISR. The monitoring and mitigation program incorporates recommendations from discussions with the Fisheries Joint Management Committee (FJMC) and DFO.

The primary objectives of the monitoring and mitigation program were to document and minimize effects of airgun array sounds on marine mammals, and to collect data on the occurrence and distribution of marine mammals in the Canadian Beaufort Sea. These objectives were achieved through:

- Mitigation: airgun array ramp-ups, mitigation airgun use, and delay ramp up and shut down airgun(s) for cetaceans and swimming polar bears observed within the safety zone.
- Monitoring: documenting the locations and abundance of marine mammals, as well as their responses to seismic operations.

Mitigation measures developed for GXT's previous seismic programs (as well as other seismic programs) in the Canadian Beaufort Sea included avoidance of Beluga Management Zone 1A (FJMC 2001; Upun-LGL 2010) and the application of additional measures within areas identified as Bowhead Aggregation Areas (BAAs; LGL 2008). GXT's 2012 seismic survey was planned for October–November to avoid potential effects on beluga harvesting and bowhead whales, including BAAs that occurred earlier in the season.

3.1.3 Marine Mammals of the Canadian Beaufort Sea

During summer and early fall, when most seismic surveys are conducted in the Canadian Beaufort Sea, five species of marine mammals regularly occur—two species of cetaceans (beluga and bowhead whale), two species of pinnipeds (ringed and bearded seals), and polar bears. The conservation status of those species is listed in Table 2. Background information on the distribution and population status, natural history, and seasonal movements of those species in and near the survey area is provided in Upun-LGL (2010).

During the period of GXT's 2012 seismic program, belugas and bowhead whales were expected to be migrating west out of the Canadian Beaufort to wintering areas in the Bering Sea. Bowhead whales migrate westward from late August through mid or late October and belugas begin to migrate west during August and September. Ringed seals, bearded seals, and polar bears occur year-round in the Canadian Beaufort.

TABLE 2. Status of marine mammals that regularly occur in the Canadian Beaufort Sea.

Species	Population	Status		
		SARA ¹	COSEWIC ²	NT ³
Ringed seal (<i>Pusa hispida</i>)	-	NS	NAR: CWS-1	Secure
Bearded seal (<i>Erignathus barbatus</i>)	-	NS	CWS-2	Secure
Beluga (<i>Delphinapterus leucas</i>)	Eastern Beaufort Sea	NS	NAR	Secure
Bowhead whale (<i>Balaena mysticetus</i>)	Bering-Chukchi- Beaufort	Schedule 1: SC	SC	Sensitive
Polar bear (<i>Ursus maritimus</i>)	Southern Beaufort Sea subpopulation	Schedule 1: SC	SC	Sensitive: Special Concern

1. *Species at Risk Act* (GoC 2013): NS = No Status; SC = Special Concern.
2. Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2012, 2013): NAR = Not at Risk; SC = Special Concern; CWS= Candidate Wildlife Species for assessment: 1= high-priority, 2= mid-priority.
3. Status in the NT: “Secure” and “Sensitive” are Status Ranks (Working Group on General Status of NWT Species 2011); to date, only the polar bear has been assessed by the NWT Species at Risk Committee (SARC) (2013).

3.2 Field Operations

3.2.1 Monitoring

The primary objectives of the vessel-based monitoring efforts were to document the locations and abundance of marine mammals, and any behavioural responses to the seismic operations. These objectives were implemented by a team of MMOs.

3.2.1.1 Marine Mammal Observers

Trained MMOs were stationed aboard both the *Geo Arctic* and the *Polar Prince* for the duration of the seismic program. There were two biologist MMOs aboard each vessel; two Inuvialuit MMOs (IMMOs) and one Inupiat¹ MMO aboard the *Geo Arctic*; and one IMMO and one Inupiat MMO aboard the *Polar Prince* (Table 3).

All MMOs were responsible for collecting data on the occurrence and behaviour of marine mammals. The *Geo Arctic* MMO crew was also responsible for ensuring that mitigation measures were implemented when required. The MMO teams aboard the vessels were in radio contact with one another while on watch and when the vessels were in close proximity to each other. MMO teams alerted one another when marine mammals were sighted.

¹ Inupiat MMOs were aboard the vessels as required by U.S. regulators for surveys conducted by ION Geophysical (GXT’s parent company) in U.S. waters.

TABLE 3. Marine mammal observers for GXT's 2012 Canadian Beaufort Sea seismic survey.

<i>Geo Arctic</i>	<i>Polar Prince</i>
Meike Holst (lead MMO)	Joseph Beland (lead MMO)
Heather Smith	Suzanne Yin
Colin Gordon (IMMO)	Spencer Mangelana (IMMO)
JoeRoy Kimiksana (IMMO)	Tim Burris (Inupiat MMO)
Freddie Kaleak (Inupiat MMO)	

3.2.1.2 Monitoring Effort

Marine mammal monitoring aboard the *Geo Arctic* was conducted during all daylight periods that airgun operations were underway, regardless of sighting conditions. Observers always watched for marine mammals for a period of at least 30 min preceding the planned start of airgun operations. To compare marine mammal occurrence and behaviour during periods with versus without airgun operations, MMOs were also on watch during most daylight periods when the airgun array was not operating; most exceptions to this occurred when the *Geo Arctic* was at anchor and/or bunkering for fuel near Herschel Island. Monitoring aboard the *Polar Prince* was conducted during most daylight hours, as well as a number of hours of darkness (via night-vision goggles (NVD) and a forward looking thermal imaging (FLIR®)).

There were 1–3 MMOs on watch at a given time; the *Geo Arctic* typically had more MMOs on watch than the *Polar Prince* because of the larger MMO team aboard the *Geo Arctic*. MMO shifts were always less than four consecutive hours, and usually of 2–3 hour duration. Observations usually began at first light and continued past sunset. During the survey period (October–November), there were ~7–11 hours of daylight during which MMOs were on watch.

3.2.1.3 Observation Procedures

Observers watched from the bridge of the *Geo Arctic* and from the bridge of the *Polar Prince*, scanning systematically with the naked eye and 7x50 reticle binoculars. The *Geo Arctic* MMOs on watch paid particular attention to the safety zones (see Section 3.2.2.1) ahead and to the sides of the vessel, watching for marine mammals about to enter the zone as the ship moved forward. The bridge of the *Geo Arctic* spanned the width of the vessel near the bow. From within the ship, the bridge afforded good forward and side visibility for the observers from about the 8 o'clock position on the port side, across the bow (12 o'clock), to about the 4 o'clock position on the starboard side (Figures 8 and 9). MMOs also made regular observations outside, weather permitting, from the bridge wings on either side of the bridge. Observing from the bridge wings allowed the MMOs to gain some visibility astern of the vessel (between 4 o'clock and 8 o'clock).

The bridge on the *Polar Prince* was much smaller than on the *Geo Arctic*, but also afforded good forward and side visibility from about the 8 o'clock position on the port side, across the bow (12 o'clock), to about the 4 o'clock position on the starboard side. During periods of excellent weather and visibility conditions, scans were also made using Fujinon 25 × 150 “Big-Eye” binoculars mounted on the *Polar Prince* flying bridge (Figures 10 and 11).

The Fujinon 7 × 50 binoculars were equipped with reticles to measure depression angle relative to the horizon (Figure 12). The reticle markings, together with the known height above sea level of the observers on the bridge, enabled the observers to estimate distances to the marine mammals that were sighted.



FIGURE 8. View of the *Geo Arctic* bridge. MMOs are visible in the windows at left (photo by S. Yin).



FIGURE 9. Inside view of the *Geo Arctic* bridge. JoeRoy Kimiksana is at the far end of the bridge, and Meike Holst is in the foreground (photo by H. Smith, Upun-LGL).



FIGURE 10. Location of the “Big-Eye” binoculars on the *Polar Prince* flying bridge. Note MMO wearing an orange hard hat using the binoculars at top left (photo by H. Smith, Upun-LGL).



FIGURE 11. MMO using “Big-Eye” binoculars on the *Polar Prince* monkey bridge (photo by S. Yin).

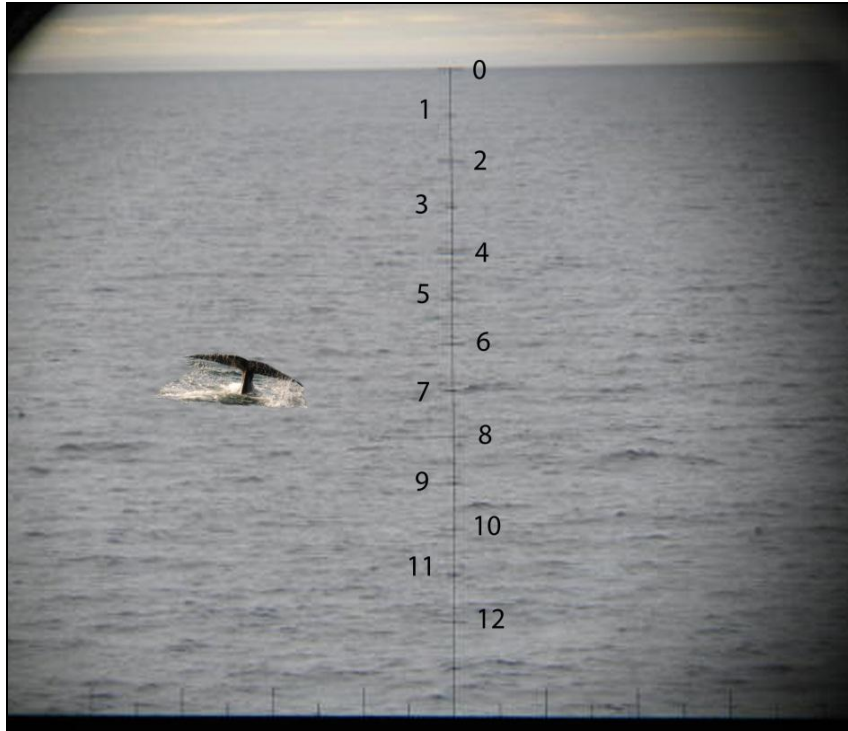


FIGURE 12. Photograph taken through one eyepiece of the Fujinon reticle binoculars, illustrating how the reticles are used to measure depression angles, and thus estimate distances from the location of the MMO (photos by R. Etagiak (reticles) and M. Milligan (whale)).

MMOs on the *Polar Prince* also maintained night-watches, typically between 2–4 h a night, to test the effectiveness of NVDs and a FLIR camera system.

While on watch, MMOs systematically recorded the vessel's position, activity, and environmental conditions every 30 min, or whenever conditions changed substantially. The number of MMOs on watch was also recorded. Additional data were recorded when marine mammals were observed. MMOs were prepared to record any off-watch marine mammal sightings.

Operational activities recorded by MMOs included the number of airguns in use, total volume of the airguns, and the type of vessel/seismic activity. The *Geo Arctic* MMOs alerted the *Polar Prince* MMOs to changes in seismic activity status via radio, satellite telephone, or email.

The following environmental data was recorded: water depth, wind force (Beaufort wind force scale), cloud cover (%), precipitation type, visibility (farthest distance MMO could see clearly), daylight category (light, dark, or twilight), light intensity (measured with a light meter), glare (amount and location), and ice conditions (type, location, amount).

The following information was recorded for each marine mammal sighting: date, time, species, total number of individuals, number of juveniles, bearing relative to vessel's heading, direction of movement relative to the vessel, distance from the vessel, behaviour when sighted, whether animal was in the water or hauled out on ice or land, behavioural pace, reaction to the vessel, vessel position, water depth, observer initials, species identification reliability, closest point of approach (CPA), time of CPA, and the time that mitigation measures were requested (if necessary). Distance to marine mammals was measured from the MMO's location on the bridge. The distance of the animal from the airgun array was calculated during data error checking and processing at the end of the season. However, for sightings near or within the safety zone in effect at the time, the distance from the marine mammal to the nearest

airgun was estimated and recorded for the purposes of implementing shutdowns. The bearing from the vessel to individual or groups of marine mammals was estimated using positions on a clock face, with the bow of the vessel considered to be 12 o'clock and the stern 6 o'clock.

3.2.1.4 Data Recording

All effort and sightings data were recorded directly into the *PSO Tracker* database using a laptop computer (a PSO is a Protected Species Observer in U.S. waters, the equivalent of a Marine Mammal Observer in Canadian waters – the *PSO Tracker* software was designed in the U.S., hence the name and terminology within the program). Paper datasheets were available to be used as backup, but were not needed. The *PSO Tracker* database was developed to prevent entry of out-of-range values and codes. Details regarding the seismic activities (start and stop times, number of airguns firing, etc.) were collected from the airgun operators log on the *Geo Arctic*, and were used to create database entries for times when MMOs were not on watch (e.g., at night).

Vessel position was logged every 60 s by a Bluetooth global positioning system (GPS) unit integrated with the *PSO Tracker* database. Vessel tracklines for the entire cruise were also recorded using Garmin GPS units as backup.

3.2.2 Mitigation Measures

Mitigation measures in place for marine mammals were detailed in GXT's Marine Mammal Mitigation and Monitoring Plan that was reviewed by DFO. GXT's Mitigation and Monitoring Plan incorporates DFO's "Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment" (www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismicsismique/statement_enonce_e.asp). The Statement of Canadian Practice outlines minimum standards for mitigation procedures. GXT's plan met those standards and, in some respects, exceeded the standards outlined in the Statement by including mitigations developed specifically for the Canadian Beaufort Sea, such as larger shutdown or safety zones and BAAs. The mitigation measures, particularly the details specific to GXT's seismic program in Canadian waters, are reviewed below.

3.2.2.1 Shutdown (safety) Zones

The shutdown or safety zones (SZ) for GXT's seismic program were based upon U.S. National Marine Fisheries Service (NMFS) policy that cetaceans should not be exposed to impulsive sounds exceeding 180 dB re 1 Pa rms (NMFS 2000). While there is limited scientific basis for this threshold level, it has been recommended as a conservative injury exposure criterion until more scientific information is available. This criterion has been used in establishing the shutdown zones for seismic surveys in some parts of Canada, including Devon's 2001 and 2002 and GXT's 2006-2010 seismic programs in the Canadian Beaufort Sea. In addition to shutdown zones for whales, Environment Canada has requested that a 190 dB shutdown zone be used when swimming polar bears are encountered.

Like previous GXT seismic programs in the Canadian Beaufort Sea, acoustic modelling was used to predict the 180 and 190 dB SZs of the airgun array (4380 in³) prior to the start of the seismic program. Modelling accounted for conditions in the arctic that are known to influence sound propagation—water temperature, salinity, sub-sea permafrost and ice cover. Because the proposed 2012 seismic survey area had regions with different acoustic transmission characteristics, the use of a single fixed-size SZ was not considered appropriate. As required by DFO, sound source verification (SSV) tests were conducted from 20–23 October to validate and revise if necessary the SZs estimated by modelling for the airgun array prior to seismic surveying. Results of the SSV and additional modelling indicated the pre-season SZ estimates were appropriate for use in the field (Matthews and MacGillivray 2012)—no changes to the SZs

were required during the monitoring and mitigation program. The 180 and 190 dB SZs used during the monitoring program are shown in Figures 13 and 14, overlaid on the proposed seismic lines. Note that these safety zones were also applied during periods of ramp up and mitigation airgun use.

MMOs on the *Geo Arctic* used a geographic information system (GIS) that overlaid the vessel position on maps of the 180 and 190 dB SZ in order to remain aware of any changes in the safety radii as the vessel moved throughout the survey area.

3.2.2.2 Pre-start Watch

Before any airgun activity was started, MMOs kept watch of the SZ to see if marine mammals were within the SZ, or approaching it and about to enter. MMOs conducted this pre-start watch for at least 30 min prior to the start of any airgun. This was required whenever the array had been silent for 20 min or more, for whatever reason.

Airguns were not activated if a whale or swimming polar bear was seen within or about to enter the appropriate SZ during the pre-start watch. If a whale or swimming polar bear was seen, the airguns would not have been started until it was observed to have left the SZ and the rest of the 30 min watch was complete, or until 30 min had passed after the animal (or any other whale/swimming polar bear) was last sighted.

The pre-start watch could not begin until the entire SZ was visible as agreed upon by all MMOs on watch.

3.2.2.3 Ramp-ups/Soft starts

Ramp up or soft start is a mitigation procedure that involves the gradual and sequential activation of airguns in the array over a specified period of time. This, in theory, provides an opportunity for marine mammals to move away from the area before the airgun array reaches its full volume (i.e., maximum sound level). Ramp-ups are included in the Statement of Canadian Practice.

During GXT's 2012 seismic program, the ramp-up began with the lowest volume airgun (70 in³). The number of active airguns doubled every 5 min until 16 airguns was active at the 20 min mark. At 25 min, one airgun was added every 30 s, until the full array of 26 airguns was active. A ramp up from a complete shutdown took 30 min before the array reached full volume. During the ramp-up, the SZ requirements for the full array were in effect (i.e., the SZ was watched, and the ramp-up would have been stopped if a whale or a swimming polar bear was sighted within (or approaching) the 180 dB and 190 dB SZ, respectively.

Ramp-ups were implemented after periods when all airguns are inactive, and after periods of single airgun use between seismic lines.

3.2.2.4 Airgun Operations Between Lines

Airguns were usually shut down when transiting after the completion of one seismic line to reach the start of the next seismic line (a line change). The airgun array could not be ramped up from a complete shutdown if the entire SZ was not visible. Therefore, when the resumption of seismic activity was expected to occur during a period of poor visibility (including darkness), the smallest airgun in the array (the 70 in³ mitigation airgun) was kept operating between lines. The rationale for the mitigation airgun procedure is that the sound from a single airgun would deter marine mammals from the area.

3.2.2.5 Shutdown Criteria

All airguns would have been immediately shut down if a whale or swimming polar bear had been observed in, or about to enter, the 180 dB or 190 dB SZ, respectively. If a shutdown had occurred, the MMOs would have maintained a watch in an effort to determine when the whale/polar bear left the SZ.

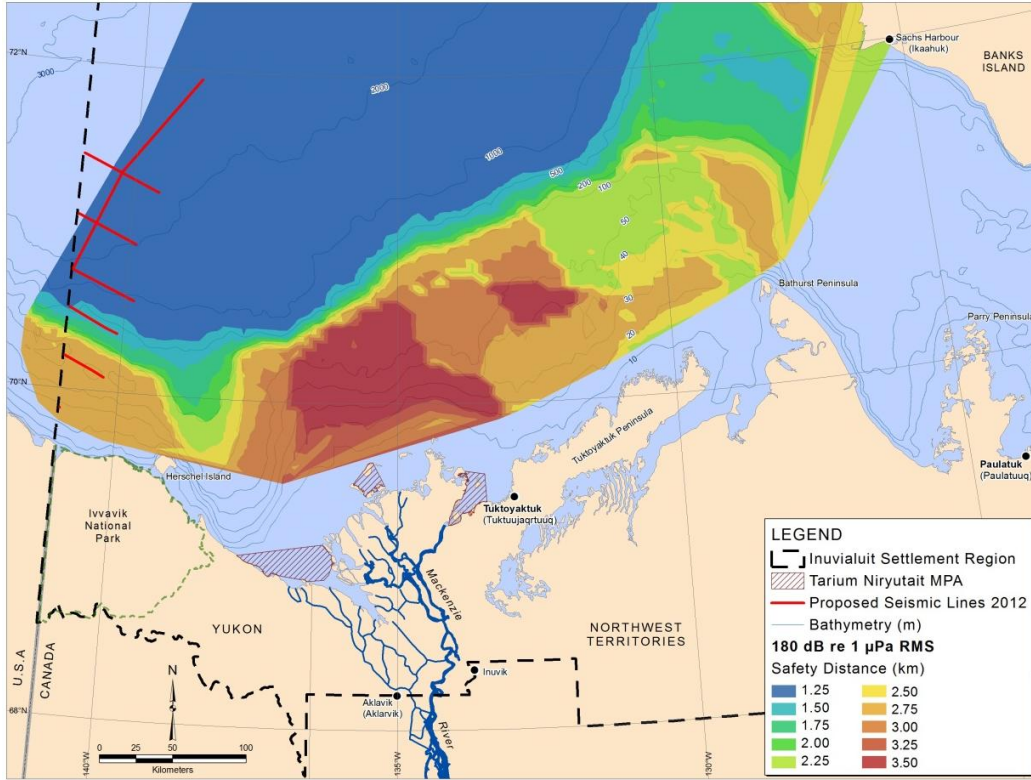


FIGURE 13. Safety Zones (km) for whales (180 dB rms; 4380 in³ airgun array) in different “geoacoustic” regions of the Canadian Beaufort Sea.

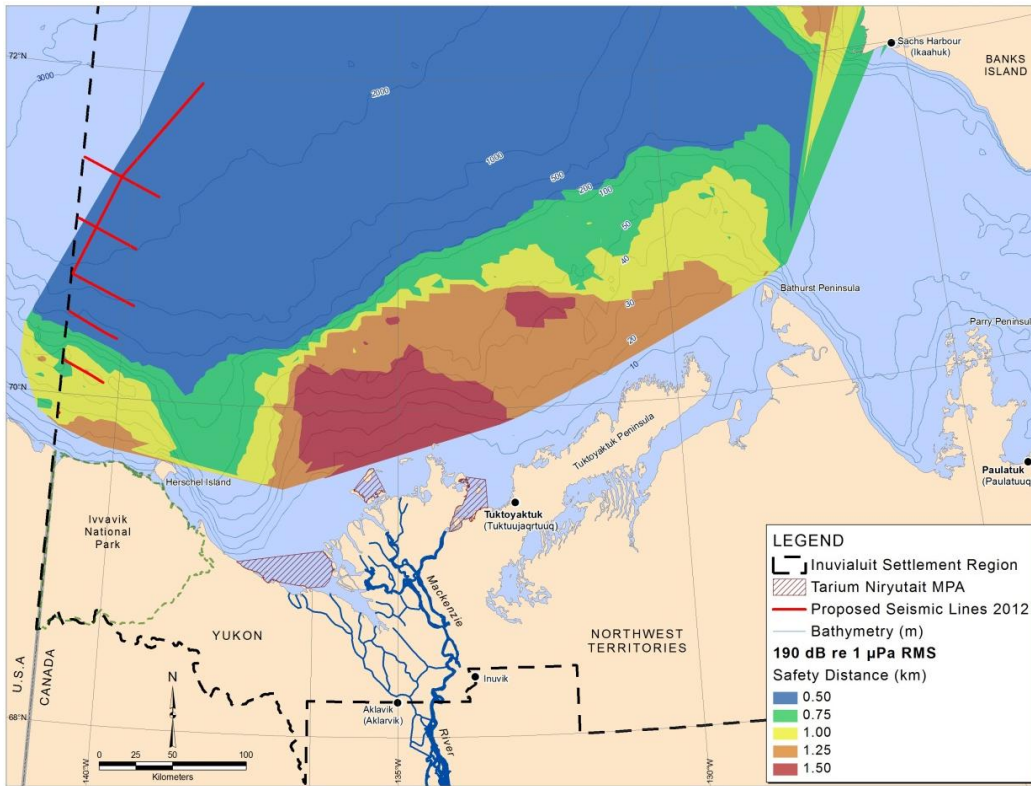


FIGURE 14. Safety Zones (km) for swimming polar bears (190 dB rms; 4380 in³ airgun array) in different “geoacoustic” regions of the Canadian Beaufort Sea.

Airgun(s) would not have been activated until the animal was confirmed to be outside the SZ, or if not re-sighted, after a period of 30 min.

3.2.3 Field Reports

Lead MMOs prepared and submitted weekly reports to GXT that summarized vessel activities (location and seismic activity) and marine mammal sightings. Reports also included summaries of MMO observation effort. The Lead MMO aboard the *Geo Arctic* also provided daily verbal reports of marine mammal sightings to the client representatives.

Independent weekly reports were prepared by the IMMOs on each vessel. These were not reviewed by the biologist MMOs or GXT, and were emailed directly to the FJMC and the six Inuvialuit Hunters and Trappers Committees (HTCs). This protocol was established at the request of HTCs during the 2007 consultations, and has been implemented since then, with modifications as advised by the HTCs and other Inuvialuit agencies.

3.3 Data Analysis

Sightings data are commonly filtered to exclude periods of effort with poor sighting conditions when the ability to detect marine mammals is reduced (e.g., Harris et al. 2009; Beland et al. 2013). If included in the analysis, these data would negatively bias the calculation of various sighting metrics (e.g., sighting rates). For the purposes of this report, “useable” data were defined as effort or sightings made when ship speed was >3.7 km/h (>2 kt) and sightability was not impaired. Sightability was considered to be impaired when any of the following conditions occurred: visibility <3.5 km, wind force greater than Beaufort Scale 5, or >60° of severe glare between 90° port (left) and 90° starboard (right) across the bow.

When the effort data were filtered according to these criteria, ~60% of the *Geo Arctic* data was considered useable and only ~28% of the *Polar Prince* data was considered useable. The majority of the *Polar Prince* effort data was classified as being not useable because it was collected when the vessel was anchored off Herschel Island. When the sightings data for both vessels were filtered according to these criteria, all but two sightings were eliminated. Because there are limited data available for the entire 2012 program, we have elected to present all effort and sightings data in this report.

3.4 Results

3.4.1 Monitoring Effort

MMOs aboard the *Geo Arctic* were on watch during all daylight periods of seismic activity, as well as many hours without seismic activity (Table 4).

The *Geo Arctic* had 2-3 MMOs on duty on almost every watch. Of the 29.0 watch hours during seismic activity, three MMOs were on watch for 23.2 h (80.0%), two MMOs were on watch for 5.2 h (17.9%), and one MMO was on watch for 0.6 h (2.1%). Of the 44.1 watch hours during non-seismic periods, three MMOs were on watch for 35.5 h (80.5%), two MMOs were on watch for 8.1 h (18.4%), and one MMO was on watch for 0.5 h (1.1%).

The *Polar Prince* spent more time than the *Geo Arctic* in the Canadian Beaufort Sea during the seismic program and conducted observations during periods of darkness testing night vision equipment as part of the US requirements. Therefore, the total number of MMO watch hours for the *Polar Prince* exceeded those of the *Geo Arctic* (Table 5).

The *Polar Prince* had two MMOs on duty for the majority of the watches (Table 6). Of the 260.7 watch hours, three MMOs were on watch for 2.1 h (0.8%), two MMOs were on watch for 181.2 h (69.5%), and one MMO was on watch for 77.4 h (29.7%).

TABLE 4. Summary of MMO survey effort on the M/V *Geo Arctic* by time period and seismic activity.

Seismic Activity	Survey Effort (h)				
	15–21 Oct	22–28 Oct	29 Oct–4 Nov	5–11 Nov	Total
No Seismic	29.6	8.7	1.3	4.5	44.1
Seismic					
Ramp Up	0.8	2.0	1.3	0	4.1
Mitigation Airgun	2.4	1.6	4.7	1.1	9.8
Testing	6.6	0	0	1.9	8.5
Full Array	0	4.1	1.0	1.5	6.6
Total Seismic ¹	9.8	7.7	7.0	4.5	29.0
Total MMO Effort	39.4	16.4	8.3	9.0	73.1

¹ Includes: ramp up, mitigation airgun, testing and full array.

TABLE 5. Summary of MMO survey effort on the M/V *Polar Prince* by time period, anchor “status” and light level.

Anchor “Status”	Survey Effort (h)				
	15–21 Oct	22–28 Oct	29 Oct–4 Nov	5–11 Nov	Total
At Anchor					
Daylight	0	37.2	10.5	0	47.7
Darkness	0	0	0	0	0
Subtotal	0	37.2	10.5	0	47.7
Not At Anchor					
Daylight	34.5	23.7	29.1	8.9	96.2
Darkness	18.4	5.9	11.6	9.1	45.0
Subtotal	52.9	29.6	40.7	18.0	141.2
Total MMO Effort	52.9	66.8	51.2	18.0	188.9

¹ Includes: ramp up, mitigation airgun, testing and full array.

TABLE 6. Summary of marine mammal effort aboard the M/V *Polar Prince* by number of observers, seismic activity, and distance to the M/V *Geo Arctic*.

Number of observers	Monitoring effort (h)			
	Seismic		No seismic activity	
	<5 km	≥5 km	<5 km	≥5 km
1	1.1	44.1	0.0	22.2
2	20.8	118.5	7.2	34.7
3	0.0	0.9	0.5	0.7

3.4.2 Marine Mammal Sightings

There were a total of six marine mammal sightings during the entire seismic program in the Canadian Beaufort Sea (Table 7); all occurred during periods when the airguns were inactive. MMOs on the *Geo Arctic* made two observations of ringed seals. MMOs on the *Polar Prince* made one observation of belugas, two observations of ringed seals, and one observation of a bearded seal. Each sighting is described below. The location of each sighting is shown in Figures 15 and 16.

TABLE 7. Marine mammal sightings during GXT's 2012 Canadian Beaufort Span 2-D marine seismic program.

Vessel	Date	Species	Sighting ID	# Individuals	CPA (m) ¹	Seismic Activity
<i>Geo Arctic</i>	18 Oct	Ringed seal	GEO20125	1	15	No Seismic
<i>Geo Arctic</i>	18 Oct	Ringed seal	GEO20126	1	10	No Seismic
<i>Polar Prince</i>	19 Oct	Beluga	POL201212	125	2725	No Seismic
<i>Polar Prince</i>	25 Oct	Ringed seal	POL201213	1	30	No Seismic
<i>Polar Prince</i>	25 Oct	Ringed seal	POL201214	45	900	No Seismic
<i>Polar Prince</i>	28 Oct	Bearded seal	POL201215	1	200	No Seismic

¹ CPA = closest point of approach

GEO20125

Date: 18 October 2012

Time (AKDT): 09:21:55

Location: 69.5804° N, 138.628° W

A single ringed seal was observed from the M/V *Geo Arctic* while the array was inactive. The vessel was underway (~3.4 knots), and was slowly transiting around Herschel Island as the streamer was being deployed. The visibility was estimated at 5 km and the wind force was Beaufort Scale 4. The seal was observed just off the starboard side of the bow; the CPA to the MMO (on the bridge) was 15 m. The seal looked at the vessel, but exhibited no overt reaction.

GEO20126

Date: 18 October 2012

Time (AKDT): 15:30:15

Location: 69.8991° N, 139.332° W

A single ringed seal was observed from the M/V *Geo Arctic* while the array was inactive. The vessel was underway (~4.8 knots), heading NW of Herschel Island to test the airgun array. The visibility was estimated at 0.5 km and the wind force was Beaufort Scale 4. The seal was observed just off the port side of the bow; the CPA to the MMO (on the bridge) was 10 m. The seal looked at the vessel, and then dove.

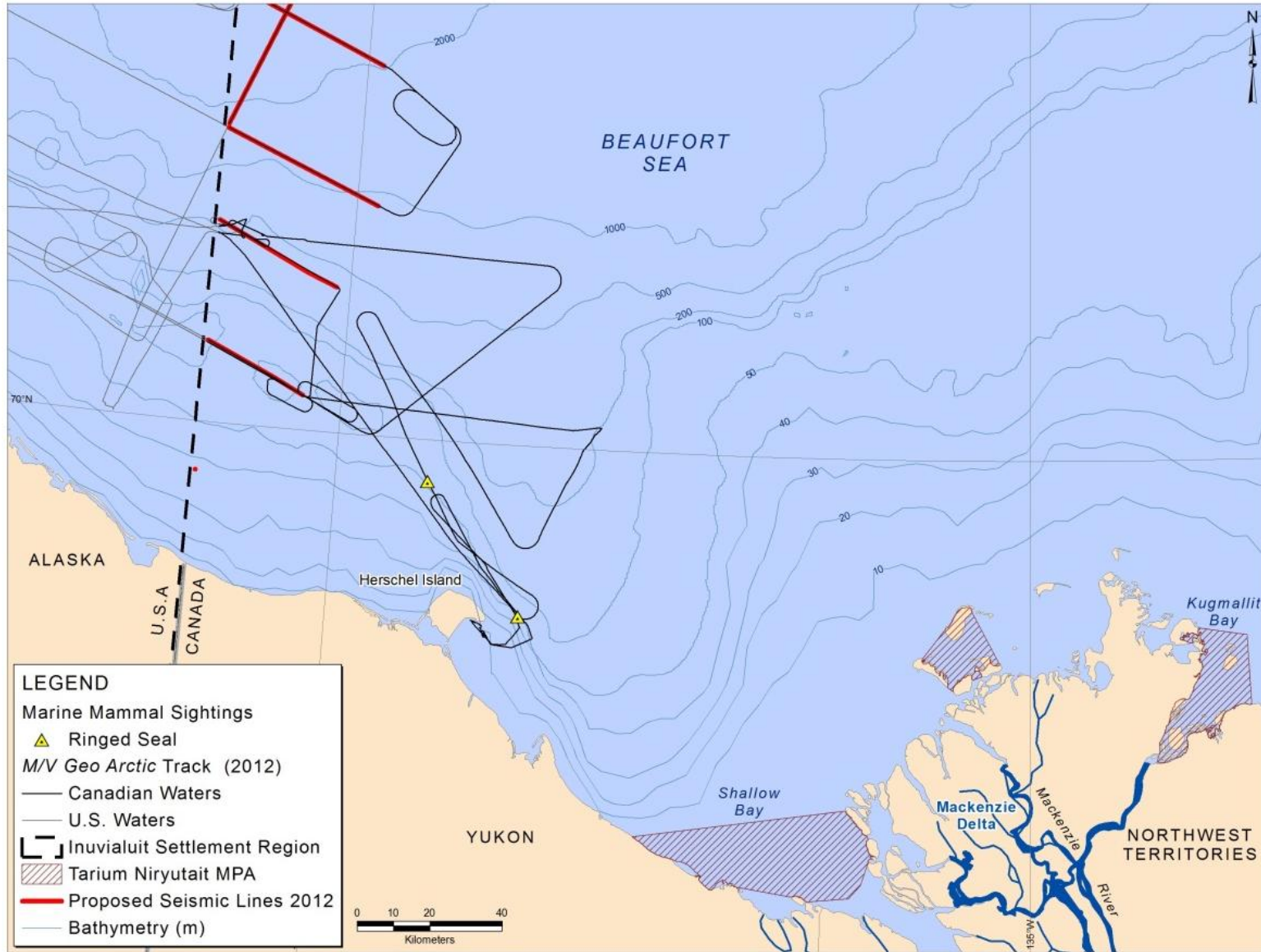


FIGURE 15. Locations of marine mammal sightings recorded by MMOs onboard the M/V *Geo Arctic* during the 2012 GXT seismic program.

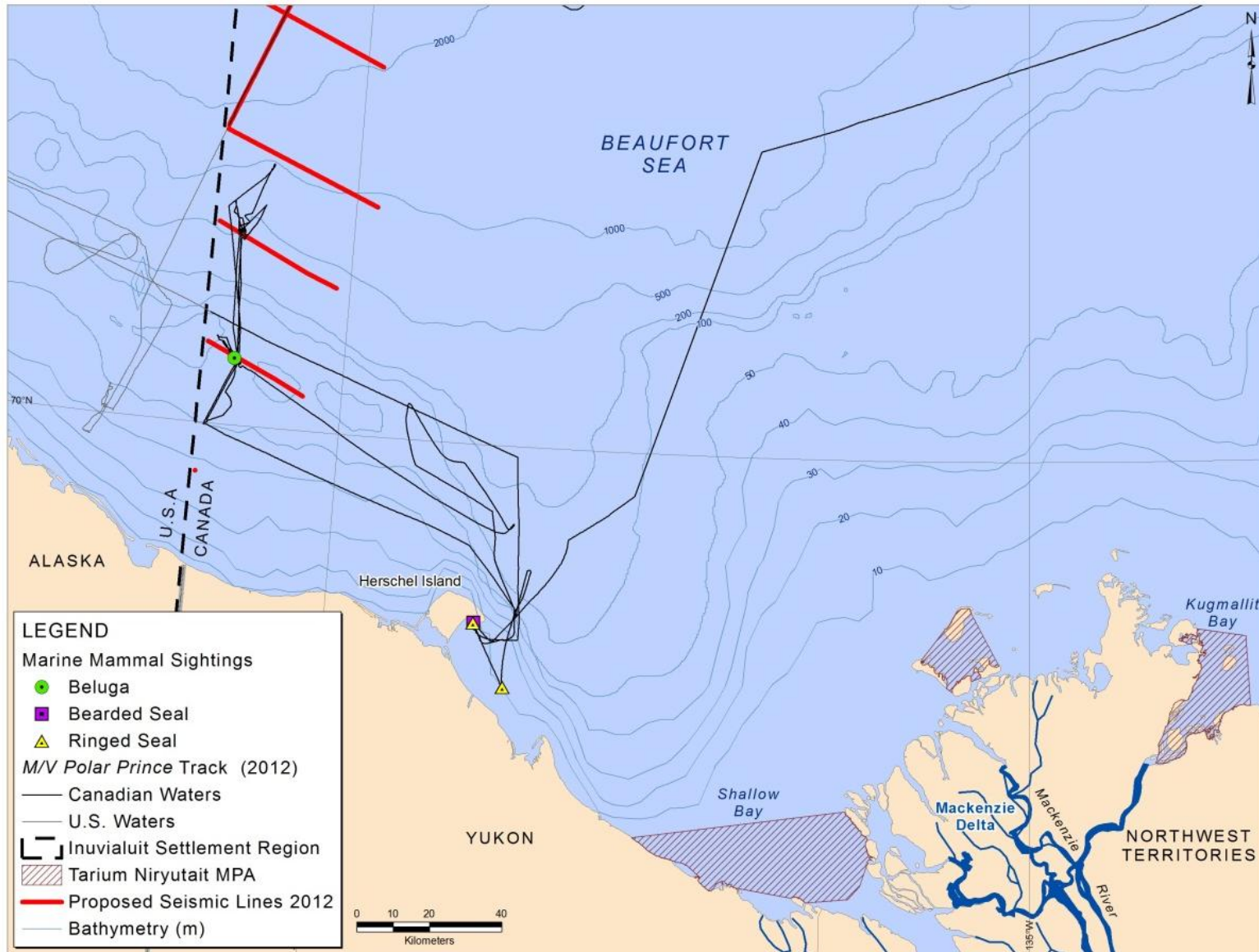


FIGURE 16. Locations of marine mammal sightings recorded by MMOs onboard the M/V *Polar Prince* during the 2012 GXT seismic program.

POL201212

Date: 19 October 2012

Time (AKDT): 14:47:57

Location: 70.1649° N, 140.794° W

An estimated 125 belugas were observed from the M/V *Polar Prince* while the array was inactive. The vessel was slowly transiting (~2.6 knots) to the SSV area. The visibility was estimated at 9 km and the wind force was Beaufort Scale 5. The belugas were observed at a distance of 4 km from the *Polar Prince*. The herd of belugas was initially very spread out, and stretched from approximately 350° to 30°, relative to the bow of the vessel. The belugas were travelling at a moderate pace in a direction perpendicular to the vessel trackline, and were estimated to have a CPA of 2725 m to the MMOs aboard the *Polar Prince*. None of the belugas approached the *Polar Prince* or exhibited any noticeable reaction.

POL201213

Date: 25 October 2012

Time (AKDT): 08:54:45

Location: 69.4058° N, 138.704° W

A single ringed seal was observed from the M/V *Polar Prince* while the array was inactive. The vessel was slowly transiting (~0.6 knots) between anchor sites just off Herschel Island. The visibility was estimated at 9 km and the wind force was Beaufort Scale 1. The seal was observed off the starboard side of the bow; the CPA to the observer was 30 m. The seal milled at the surface before diving. It traveled at a sedate pace, and showed no overt reaction to the vessel.

POL201214

Date: 25 October 2012

Time (AKDT): 11:56:09 to 15:09:45

Location: 69.5603° N, 138.939° W

Forty-five ringed seals, 10 of which were juveniles, were observed from the M/V *Polar Prince* while the array was inactive. The seals were observed hauled out and resting on ice at Simpson Point, Herschel Island. The *Polar Prince* was at anchor, ~900 m from the seals. The visibility was estimated at 10 km and the wind force was Beaufort Scale 2. The seals showed no reaction to the vessel.

POL201215

Date: 28 October 2012

Time (AKDT): 10:08:12

Location: 69.5607° N, 138.936° W

A single bearded seal was observed from the M/V *Polar Prince* while the array was inactive. The *Polar Prince* was at anchor at Simpson Point, Herschel Island. The visibility was estimated at 1 km and the wind force was Beaufort Scale 7. The bearded seal was initially observed logging (resting) on the water's surface, but then slowly dove underwater. The CPA to the observer was 200 m. The seal did not show an overt reaction to the vessel.

3.4.3 Ramp Up Delays and Airgun Array Shutdowns

Ramp up delays and shutdowns of the airgun(s) were not required during the 2012 seismic program in the Canadian Beaufort Sea.

4. SEABIRD OBSERVATIONS

4.1 Introduction

The distribution and abundance of seabirds offshore in the Canadian Beaufort Sea have received little study (BREA 2013). MMOs aboard the *Geo Arctic* and *Polar Prince* recorded opportunistic observations of sea-associated birds during GXT's 2012 seismic program in the Canadian Beaufort Sea. As requested by the CWS, these data will be submitted for inclusion in a Canadian Beaufort Sea seabird database.

4.2 Field Operations

Opportunistic seabird observations were recorded by MMOs during the course of the MMO watches. All observations were made while MMOs were stationed on the bridges of the *Geo Arctic* and the *Polar Prince*. Birds were observed using the naked eye, as well as Fujinon 7×50 reticle binoculars or Canon 18×50 image stabilized binoculars. MMOs used field guides to verify bird identifications. When birds were observed following the ship, MMOs attempted to avoid re-recording individual birds.

Observations were recorded using paper datasheets. At the end of each day, data were entered into a Microsoft Excel spreadsheet with fields compatible with the CWS Eastern Canada Seabirds at Sea (ECSAS) database. The following data were recorded for each sighting: date, time, location, observer name, species (or highest taxonomic level of which the observer was certain), number of individuals, age and sex (when possible), flight direction, closest approach distance to the vessel, visibility, wind force, ice conditions, and water depth. Observations of bird behaviour were also recorded.

4.3 Data Analysis

Data were error-checked prior to tabulating summaries for the 2012 field season. The taxonomic level to which some observations were assigned was “generalized” when comments were included on datasheets that indicated a lack of confidence in the identification (e.g., “unidentified duck, ID uncertain” was reclassified as “duck sp.”). Observations of unidentified species were excluded from the summaries. Observations were also excluded when comments indicated that the bird had previously been recorded (i.e., ship followers).

4.4 Results

There were a total of 131 sightings of 331 individual birds recorded during GXT's 2012 seismic program in the Canadian Beaufort Sea (Table 8, Figures 17 and 18). Glaucous Gulls and eiders were the most commonly observed birds. Glaucous Gulls were observed as singletons or in small groups (group size 1–6), and were frequently noted as either following or being attracted to the vessels. Eiders were observed in larger groups (group size: *Geo Arctic* = 1-30, *Polar Prince* = 2-25), and were usually observed much farther away from the vessels (Table 8).

TABLE 8. Summary of opportunistic bird sightings during GXT's Canadian Beaufort Sea 2D marine seismic program: October–November 2012.

Vessel/ Species	Scientific Name	Number of sightings	Number of individuals	Mean CPA ¹ (m)	Notes
Geo Arctic					
Black Guillemot	<i>Cephus grylle</i>	1	1	300	- In winter plumage
Alcid sp.	Alcidae	1	2	200	
Long-tailed Duck	<i>Clangula hyemalis</i>	1	1	200	
Eider sp.	<i>Somateria</i> sp.	8	70	303	- Group size ranged from 1–30 - Mean group size = 8.75 - 7 of the 8 observations specified that eiders were brown - Most were flying in a westerly direction (SW, W, NW) - There was only 1 observation of eiders circling the vessel - Some eiders were tentatively identified as either common or king
Duck sp.	Anatidae	3	45	500	- Group size ranged from 8–25 - Mean group size = 15 - Ducks were brown
Loon sp.	<i>Gavia</i> sp.	1	1	580	
Northern Fulmar	<i>Fulmarus glacialis</i>	1	2	500	
Black-legged Kittiwake	<i>Rissa tridactyla</i>	1	2	100	
Glaucous Gull	<i>Larus hyperboreus</i>	69	109	189	- Group size ranged from 1–6 - 51 of the 69 sightings were of single gulls - 20 of the 69 sightings were of gulls circling the vessel - More than half of the gulls were identified as adults
Gull sp.	Laridae	10	10	545	- All sightings were of single gulls - 3 gulls were noted to be circling the vessel
Geo Arctic Totals		96	243		
Polar Prince					
Common Eider	<i>Somateria mollissima</i>	1	2	25	- brown or female birds
Eider sp.	<i>Somateria</i> sp.	4	47	438	- Group size ranged from 3–25 - Mean group size = 11.75 - 3 of the 4 observations were identified as brown or female eiders
Glaucous Gull	<i>Larus hyperboreus</i>	27	35	509	- Group size ranged from 1–3 - 20 of the 27 sightings were of single gulls - Most identified as adults - 2 gulls landed on vessel
Northern Fulmar	<i>Fulmarus glacialis</i>	1	2	200	
Snowy Owl	<i>Bubo scandiacus</i>	2	2	40	- One owl landed on the A-frame on the bow
Polar Prince Totals		35	88		

Note: The data presented here are not comprehensive (every bird observed was not recorded), and should not be used to calculate seabird densities (as survey effort was not recorded). Bird sightings were recorded opportunistically.

¹ CPA = closest point of approach

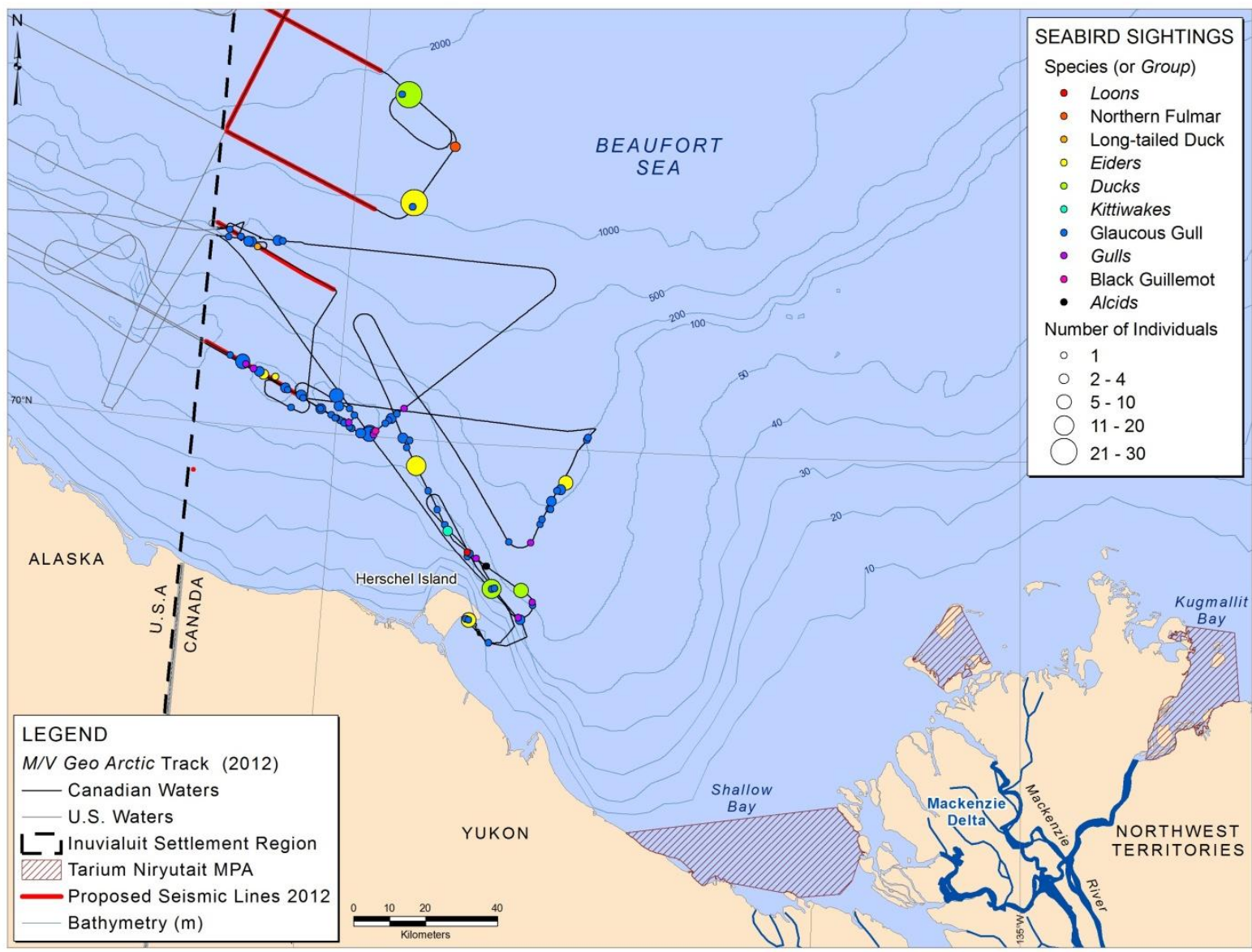


FIGURE 17. Locations of seabird sightings recorded by MMOs on the M/V *Geo Arctic* during GXT's 2012 seismic program.

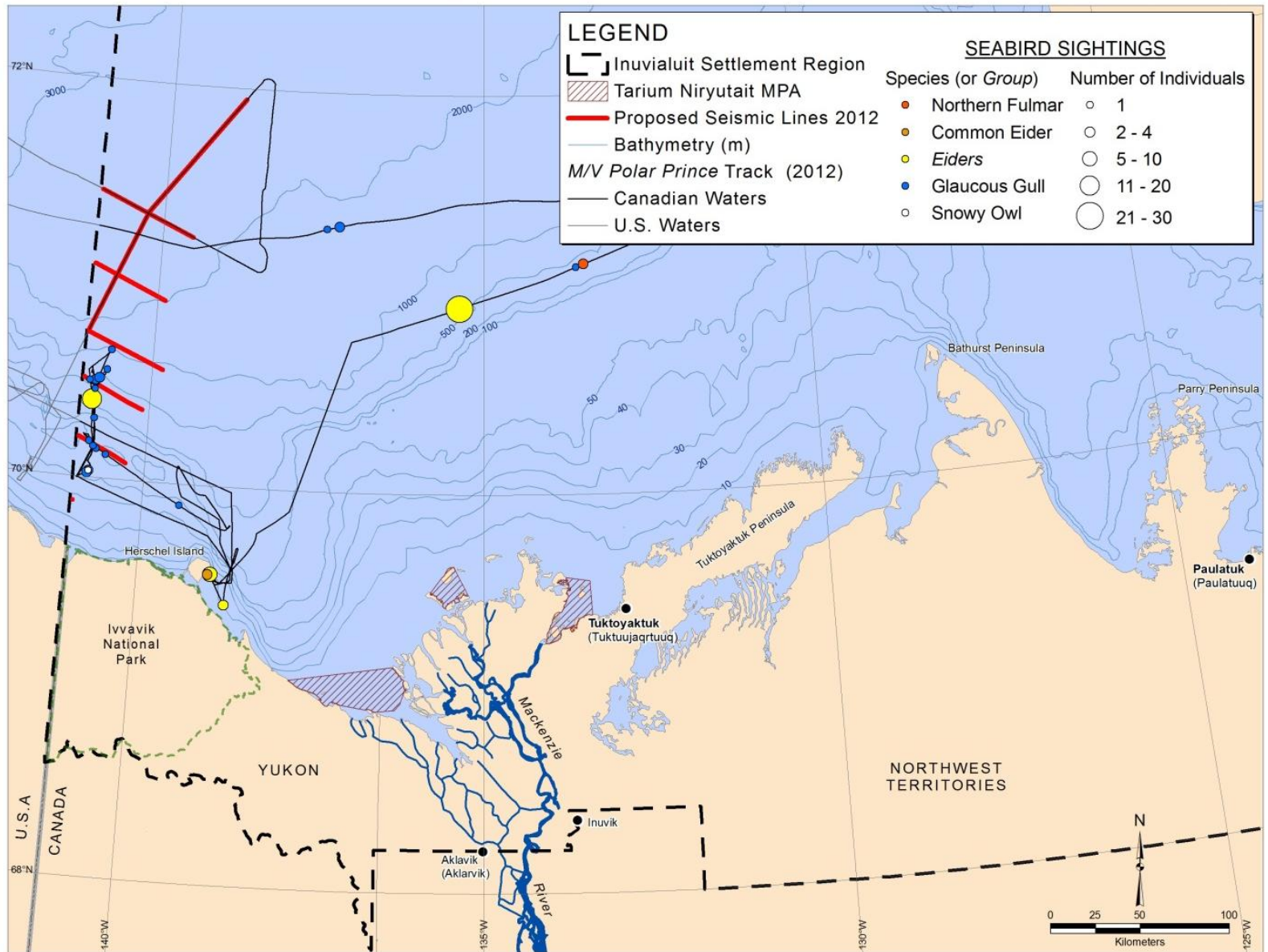


FIGURE 18. Locations of seabird sightings recorded by MMOs on the M/V Polar Prince during GXT's 2012 seismic program.

5. ACKNOWLEDGEMENTS

We thank the captains and crews of the *Geo Arctic* and *Polar Prince* for their support during this project. The client reps aboard the *Geo Arctic*, Kevin Simpson and David Muttitt, were very helpful in coordinating seismic operations with marine mammal monitoring. We also thank the ice pilots: Neil Hillier, Stanley Parkinson and Norm Thomas for their assistance and professionalism during the monitoring program. We are grateful for the hard work and diligence of Darren Ireland, Lauren Bisson, and Marc Bourdon (all from LGL Alaska Research Associates Inc.), and Ed Nelson (ION Geophysical), Dean Kennedy (GXT), and Rob Pitt (GXT) – they provided valuable support prior to and during the field season. We also thank all of the MMOs who participated in the project: Joe Beland, Tim Burris, Colin Gordon, Meike Holst, Freddie Kaleak, JoeRoy Kimiksana, Spencer Mangelana, Heather Smith and Suzanne Yin. They were essential to the completion and success of this endeavor. Finally, we thank Mark Fitzgerald, Colin Jones, and Kelly Rawlinson from Upun-LGL Limited for assisting in the processing and mapping of the data, as well as Anne Wright, also from Upun-LGL Limited, for formatting the report.

6. REFERENCES

- Beland, J.A., D.S. Ireland and L.N. Bisson. 2013. Monitoring, Mitigation, and Data Analysis Methods. (Chapter 4) *In*: Beland J.A., L.N. Bisson, D.S. Ireland and D. Hannay. (eds.) Marine mammal monitoring and mitigation during a marine seismic survey by ION Geophysical in the Arctic Ocean, October-November 2012: 90-day report. Rep. by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for ION Geophysical, NMFS., and USFWS. LGL Rep. No. P1236. 156 p. + appendices.
- Bisson, L.N., J.A. Beland and D.S. Ireland. 2013. Background and Introduction. (Chapter 1) *In*: Beland J.A., L.N. Bisson, D.S. Ireland and D. Hannay. (eds.) Marine mammal monitoring and mitigation during a marine seismic survey by ION Geophysical in the Arctic Ocean, October-November 2012: 90-day report. Rep. by LGL Alaska Research Associates Inc., LGL Ltd., and JASCO Research Ltd. for ION Geophysical, NMFS., and USFWS. LGL Rep. No. P1236. 156 p. + appendices.
- BREA (Beaufort Regional Environmental Assessment). 2013. Database and atlas of the birds of the Canadian Beaufort Sea. Available at: <http://www.beaufortrea.ca/research/database-and-atlas-of-the-birds-of-the-canadian-beaufort-sea/>. Accessed: March 2013.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2012. Canadian Wildlife Species at Risk, October 2012. Committee on the Status of Endangered Wildlife in Canada, Ottawa, Ont. iii + 98 p.
- COSEWIC (Committee on the Status of Endangered Wildlife in Canada). 2013. Candidate Wildlife Species. Available at: http://www.cosewic.gc.ca/eng/sct3/index_e.cfm. Accessed: February 2013.
- FJMC (Fisheries Joint Management Committee). 2001. Beaufort Sea Beluga Management Plan. Fisheries Joint Management Committee, Inuvik, N.W.T. iv + 28 p.
- GC (Government of Canada). 2013. Species at Risk Public Registry: A to Z Species Index. Available at: http://www.sararegistry.gc.ca/sar/index/default_e.cfm. Accessed: February 2013.
- Gordon, J., D. Gillespie, J. Potter, A. Frantzis, M.P. Simmonds, R. Swift and D. Thompson. 2004. A review of the effects of seismic surveys on marine mammals. *Mar. Technol. Soc. J.* 37(4):16–34.
- Greene, C.R., Jr. and W.J. Richardson. 1988. Characteristics of marine seismic survey sounds in the Beaufort Sea. *J. Acoust. Soc. Am.* 83:2246–2254.

- Harris, R.E., A. Lewin, P. Abgrall, M. Fitzgerald and D. Hauser. 2009. Marine Mammal Mitigation and Monitoring for GX Technology's Canadian Beaufort Span 2-D Marine Seismic Program, Open-water Season 2008. Rep. by LGL Limited, King City, ON for GX Technology Corporation, Houston, TX. LGL Rep. No. TA4460-2A. 86 p. + appendices.
- LGL. 2007. Project Description for the proposed GX Technology Beaufort Span 2-D Marine Seismic Program, Open-water Season 2007. Rep. by LGL Limited, King City, ON and Canning and Pitt Associates, St. John's, NL for GXT, Houston, TX. LGL Rep. No. TA4460-1. 154 p. + appendices.
- LGL. 2008. Project Description for the proposed GX Technology Beaufort Span 2-D Marine Seismic Program, Open-water Season 2008. Rep. by LGL Limited, St. John's, NL and King City, ON for GXT, Calgary, AB. LGL Rep. No. TA4460-2. 165 p. + appendices.
- LGL, Inuvialuit Environmental & Geotechnical Inc., and Canning and Pitt Associates. 2006. Project Description for the proposed GX Technology Beaufort Span 2-D Marine Seismic Program. Open Water Season 2006/2007. Report prepared by LGL Limited, environmental research associates, King City, ON, Inuvialuit Environmental & Geotechnical Inc., Inuvik, Northwest Territories, and Canning and Pitt Associates, St. John's, NL for GX Technology, Houston, TX. 150 p. + appendices.
- Matthews, M-N.R. and A.O. MacGillivray. 2012. ION Beaufort Span 2012 Acoustic Modeling: Distances to rms SPL Thresholds for a 4380 in³ airgun array towed at a depth of 12 m. JASCO Document 00464, Version 1.0. Technical report by JASCO Applied Sciences for LGL Alaska Research Associates Inc. v + 19 p.
- NMFS. 2000. Small takes of marine mammals incidental to specified activities; marine seismic-reflection data collection in southern California/Notice of receipt of application. Fed. Regist. 65(60, 28 Mar.):16374-16379.
- NWT SARC (Northwest Territories Species at Risk Committee). 2013. Species assessments. Available at: <http://nwtspeciesatrisk.ca/tiki/tiki-index.php?page=SARC>. Accessed February 2013.
- Richardson, W.J., C.R. Greene, Jr., C.I. Malme and D.H. Thomson. 1995. Marine Mammals and Noise. Academic Press, San Diego. 576 p.
- Southall, B.L., A.E. Bowles, W.T. Ellison, J.J. Finneran, R.L. Gentry, C.R. Greene Jr., D. Kastak, D.R. Ketten, J.H. Miller, P.E. Nachtigall, W.J. Richardson, J.A. Thomas and P.L. Tyack. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. *Aquat. Mamm.* 33(4):i-iv, 411-522.
- Stone, C.J. and M.L. Tasker. 2006. The effects of seismic airguns on cetaceans in UK waters. *J. Cetac. Res. Manage.* 8(3):255-263.
- Upun-LGL. 2010. Project Description for the proposed GX Technology Beaufort Span Canada West 2010 2-D Seismic Program. Rep. by Upun-LGL Limited, Inuvik, NWT and King City, ON for GXT, Calgary, AB. LGL Rep. No. UA0004-1. 183 p + appendices.
- Working Group on General Status of NWT Species. 2011. NWT Species 2011-2015 – General Status Ranks of Wild Species in the Northwest Territories. Department of Environment and Natural Resources, Government of the Northwest Territories, Yellowknife, NT. 172 p.

**APPENDIX A:
SUMMARY OF VESSEL ACTIVITIES DURING GXT'S 2012 CANADIAN BEAUFORT
SEA SEISMIC SURVEY.**

Date (2012)	<i>Geo Arctic</i>	<i>Polar Prince</i>
11 Oct	Departed Nome.	Departed Nome.
12–14 Oct	In transit to Canada.	In transit to Canada.
15 Oct	In transit to Canada.	22:22 – Entered Canadian Beaufort Sea.
16 Oct	02:44 – Entered Canadian Beaufort Sea. Anchored near Herschel Island waited for <i>Polar Prince</i> to fuel up.	Attempted to receive fuel near Herschel Island. Unable to fuel up due to rough weather.
17 Oct	Received fuel from fuel barge, then headed north to deploy streamer.	Anchored near Herschel Island.
18 Oct	Streamer deployed and retrieved.	Received fuel, then headed north to join <i>Geo Arctic</i> .
19 Oct	10:43–12:49 – Seismic testing.	Drifted at shallow water SSV site.
20 Oct	10:36–15:06 – Seismic testing. 15:07–15:53 – Mitigation airgun while in transit to start of shallow water SSV line in poor visibility. 15:54 – Began ramp up, followed by shallow water SSV line. 18:17 – MMO watch ended due to darkness-- array remained active on SSV line. 20:38 – Left Canada, array remained active on SSV line.	Deployed buoys at shallow water SSV site.
21 Oct	11:59 – Entered Canada. 12:00–13:00 – Transferred two crew members to <i>Polar Prince</i> . Headed towards deep water SSV line. 14:36 – Left Canada.	Received two crew members from <i>Geo Arctic</i> . Transited to deep water SSV site, then returned to shallow water SSV site.
22 Oct	19:08 – Entered Canada. Array activated along shallow SSV line from west to east. 23:08 – Finished shallow water SSV line, and activated mitigation airgun while in transit to deep water SSV line.	Transited to deep water SSV site.
23 Oct	02:49 – Began ramp-up for 20 km deep water SSV line (dark, no MMO watch). 03:19 – Began 20 km deep water SSV line (dark, no MMO watch). 08:20 – Left Canada, array activated along 20 km deep water SSV line (dark, no MMO watch). 09:04 – Entered Canada, ramped up for next deep water SSV line. 09:22–10:11 – Surveyed 5 km deep water SSV line. 11:30–12:45 – Ramped up and surveyed last line for deep water SSV test. Deployed streamer.	Recovered shallow water SSV buoys, then transited to Herschel Island.
24 Oct	12:45 – Ramped up and surveyed line 6220, headed west. 18:31 – Left Canada, still surveying.	Anchored off Herschel Island, waiting for weather to break for crew transfer to shore.

Date (2012)	<i>Geo Arctic</i>	<i>Polar Prince</i>
25–30 Oct	In U.S. Beaufort Sea.	Anchored off Herschel Island until 29 Oct. Began transit to Sachs Harbour for crew transfer.
31 Oct	02:17 – Entered Canada, surveyed line 5250 (dark, no MMO watch). 09:19 – Finished line 5250. Mitigation airgun on periodically during day as we headed to next line because of poor visibility due to snow. 19:32 – Ramped up and surveyed line 6325, headed west (dark, no MMO watch).	Crew transferred at Sachs Harbour. Began transit west to meet up with <i>Geo Arctic</i> .
1 Nov	04:57 – Left Canada, still surveying line 6325 (dark, no MMO watch).	Transited west to join <i>Geo Arctic</i> .
2 Nov	In U.S. Beaufort Sea.	Transited west to join <i>Geo Arctic</i> .
3 Nov	In U.S. Beaufort Sea.	00:36 – Left Canada. 12:30 – 1km in front of <i>Geo Arctic</i> .
4–6 Nov	In U.S. Beaufort Sea.	In U.S. Beaufort Sea.
7 Nov	16:49 – Entered Canada, surveyed line 7000 (dark, no MMO watch).	16:11 – Entered Canada, in front of <i>Geo Arctic</i> on line 7000.
8 Nov	03:08 – Finished surveying line 7000 (dark, no MMO watch). 10:13–11:59 – Seismic testing followed by mitigation airgun. 14:21–14:38 – Seismic testing. 16:04 – Mitigation airgun turned on in transit to line 2800 as visibility decreasing. 17:03 – Ramped up and started surveying line 2800 (dark, no MMO watch).	Escorted <i>Geo Arctic</i> on lines 7000 & 2800.
9 Nov	09:49 – Light enough to begin MMO watch, still surveying line 2800. 11:21 – Left Canada, surveying line 2800, headed west. *END OF SURVEY ACTIVITY IN CANADA*	Escorted <i>Geo Arctic</i> on line 2800. 10:12 – Left Canada. *END OF SURVEY ACTIVITY IN CANADA*
10–20 Nov	Completed survey activities in U.S. Beaufort Sea, transited to Dutch Harbor, AK. Disembarked in Dutch Harbor on 20 Nov 2012.	

Note: times are in AKDT. The vessels remained on AKDT for the duration of the survey.