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Spatial restrictions and temporal planning as measures to mitigate potential effects of seismic noise on cetaceans: a working example from the Canadian Beaufort Sea, 2007-2008

Restrictions spatiales et panification temporelle pour atténuer les impacts potentiels des ondes sismiques sur les cétacés : exemple pratique en provenance des eaux canadiennes de la mer de Beaufort, 2007-2008

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ABSTRACT

The Statement of Canadian Practice (SOCP) (DFO 2008) with respect to the Mitigation of Seismic Sound in the Marine Environment specifies the minimum mitigation requirements to be met during the planning and conduct of marine seismic surveys in Canada. These requirements are intended to complement existing environmental assessment processes, including those defined in settled land claims such as the Inuvialuit Final Agreement (IFA). Section 13(b) of the Statement recognizes additional or modified environmental mitigation measures to be necessary in certain situations.

Since 2006, seismic operators in the Canadian Beaufort Sea have worked closely with Fisheries and Oceans Canada (DFO) to develop a mitigation regime specific to the area and operational situations. Enhancements to the SOCP mitigation requirements include spatial restrictions and temporal planning around critical marine mammal habitat, communication strategies, and the use of multiple safety zones specific to the Beaufort Sea's bathymetry and seafloor substrates (Lawson 2009). DFO conducted systematic aerial surveys in 2007 and 2008, with the results being used to define bowhead whale (*Balaena mysticetus)* feeding aggregation areas in the southeastern (SE) Beaufort Sea. This formed part of the mitigation strategy, and in particular contributed to industry and DFO's determination of spatial and temporal restrictions for the planning and conduct of the seismic surveys.

RÉSUMÉ

L'Énoncé des pratiques canadiennes d'atténuation des ondes sismiques en milieu marin (MPO, 2008) précise les exigences minimales en matière de mesures d'atténuation à respecter durant la planification et la réalisation de levés sismiques en mer au Canada. Ces exigences complètent les processus actuels d'évaluation environnementale, y compris ceux prévus dans les revendications territoriales réglées telles que la Convention définitive des Inuvialuit (CDI). Le paragraphe 13(b) de l'Énoncé reconnaît que des mesures supplémentaires ou modifiées peuvent être nécessaires dans certaines situations pour atténuer les impacts sur l'environnement.

Depuis 2006, les utilisateurs des canons à air dans les eaux canadiennes de la mer de Beaufort travaillent en étroite collaboration avec Pêches et Océans Canada (MPO) afin d'élaborer un régime d'atténuation des impacts propre à des situations locales ou opérationnelles. Des restrictions spatiales et une planification temporelle auprès de l'habitat essentiel des mammifères marins, des stratégies de communication ainsi que l'utilisation de multiples zones de sécurité adaptées à la bathymétrie et au fond océanique de la mer de Beaufort (Lawson, 2009) sont au nombre des améliorations apportées aux exigences en matière d'atténuation de l'Énoncé des pratiques canadiennes. Les relevés aériens systématiques menée par le MPO en 2007 et en 2008 ont permis de localiser les aires d'alimentations utilisées par un groupe de baleines boréales (*Balaena mysticetus)* dans le sud-est de la mer de Beaufort. L'exercice, qui fait partie de la stratégie d'atténuation des impacts, a notamment aidé l'industrie et le MPO à établir des restrictions spatiales et temporelles pour la planification et la réalisation des levés sismiques.

INTRODUCTION

The Bering-Chukchi-Beaufort (BCB) population of bowhead whales is listed as a Species of Special Concern under Schedule 1 of Canada's *Species At Risk Act* (January 2008). Bowhead whales that occur in the SE Beaufort Sea belong to this population (Moore and Reeves 1993). They spend part of their annual cycle in Alaska and Russia, as well as in Canada where they summer in open-water habitat in the SE Beaufort Sea and Amundsen Gulf (Fig. 1).

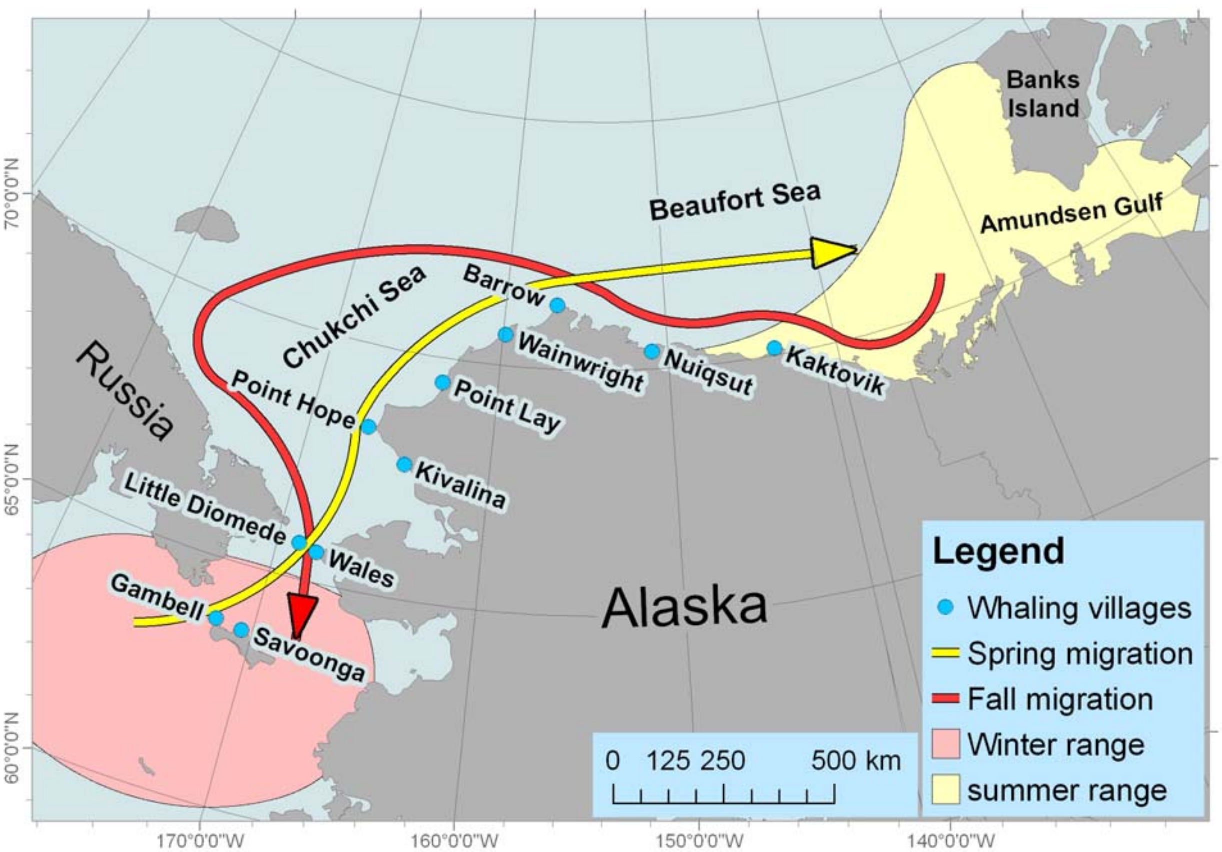


Fig. 1. Range of the BCB population of Bowhead whales (map courtesy L. Quakenbush, Alaska Dept. of Fish and Game)

The BCB bowhead whale population is presently recovering from decimation by commercial whalers in the late 1800s and early 1900s. This population represents over 90% of the world's remaining bowheads, and is subject to a subsistence hunt by Alaskan Inupiat during spring and fall. Inuvialuit of Aklavik, NT, Canada also harvested one bowhead whale in each of 1991 (Freeman *et al.* 1992) and 1996 (Harwood and Smith 2002). Prior to that, the last bowhead taken in the Western Canadian Arctic was at Baillie Islands in 1925 (Harwood and Smith 2002).

BCB bowhead whales migrate to the Beaufort Sea each summer to feed; form large loose aggregations in the offshore Canadian Beaufort Sea from approximately mid-August to late September (Richardson *et al.* 1987; Harwood and Smith 2002). The aggregations form in areas where oceanographic conditions favour the concentration of crustaceous zooplankton, their main prey item (Thomson *et al.* 1986). Not all areas are attractive to bowheads in all years, due to varying oceanographic conditions. The older, mature animals tend to be found in feeding areas further offshore (e.g., off the Tuktoyaktuk Peninsula), whereas subadults tend to occur in near-shore feeding areas (e.g., off the Yukon coast) (Ford *et al.* 1988; Cubbage and Calambokidis 1987). In the SE Beaufort Sea, some feeding aggregation areas are located in offshore waters which have been subject to seismic exploration activity in the 1980s, 2001, 2006-2008, and which are likely to be subject to shipping and seismic activities in the near and distant future.

On their return fall migration to the Bering Sea, bowheads also feed in favoured areas along the migration route between Kaktovik and Barrow, Alaska (Lowry *et al.* 2004). This stock is also subject to shipping and seismic activities in the Alaskan Beaufort and Chukchi seas during their fall migration. Spring and fall migration routes and wintering areas identified to date are available from a satellite telemetry study underway at this time and coordinated by Alaska Dept. of Fish and Game http://www.wildlife.alaska.gov/index.cfm?adfg=marinemammals.bowhead).

Seismic Mitigation Regime in the Canadian Beaufort Sea

Recognizing the ineffectiveness of marine mammal observer (MMO) surveillance during periods of darkness and poor visibility (Harwood and Joynt 2009), seismic operators in the Canadian Beaufort Sea have worked closely with DFO in 2007-2008 to develop a mitigative regime to address this limitation of the MMO program. The approach follows on a mitigation measure described in the SOCP in the Planning Seismic Surveys section, Section 5 (d) (below). The operators and their contractors have worked closely with DFO, and conducted seismic surveys in defined bowhead whale aggregation areas *only* during times of full safety zone (SZ) visibility. The aggregation areas are determined as early as possible within the season by DFO's aerial surveys, and the definition of feeding areas is determined collaboratively with DFO and operators as soon as the survey data are available.

> Canadian Statement of Practice
> Planning Seismic Surveys
>
> Mitigation Measures
>
> 5. Each seismic survey must be planned to avoid:
>
>   d. displacing a group of breeding, feeding or nursing marine mammals, if it is known there are no alternate areas available to those marine mammals for those activities, or that if by using those alternate areas, those marine mammals would incur significant adverse effects; and

Aerial surveys are standardized among years and conducted according to the same methods and format as surveys that were flown in 1981-1986 (Davis *et al.* 1982; Harwood and Ford 1983; McLaren and Davis 1985; Harwood and Borstad 1985; Harwood 1989; Duval 1986; Ford *et al.* 1988). Surveys are timed for early to mid-August to overlap with the time when bowhead whales first begin to aggregate (Bradstreet and Fissel 1986; 1987). The 2009 survey is slated for mid-August. Ideally, replicated surveys are undertaken in any given year to explore changes in whale distribution over the course of the summer and into the fall. DFO is presently examining the spatial variation in the location of bowhead whale feeding aggregation areas, using data from 1981-1986 and 2007-2008. In addition, a separate analysis comparing aerial survey sightings and concurrent shipboard sightings has been initiated. Finally, another component of DFO's work on these aspects involves the sampling of zooplankton from bowhead whale feeding aggregation areas, to examine prey availability therein. Together these studies will enhance our understanding of the late summer use of the Beaufort Sea by bowhead whales and allow us to refine mitigation measures that are presently in place in specific areas in the Beaufort Sea.

SURVEY METHODS

A systematic strip-transect aerial survey of the SE Beaufort Sea in Canada was conducted on 22-23 August 2007 and 2-20 August 2008, using an effective strip width of 2 km (1 km per side, offset from the track line by 50 m) as measured during similar surveys (in some cases the same observers) in 1981-1986 (Harwood and Borstad, 1985; Davis *et al.* 1982; Harwood and Ford 1983; Ford *et al.* 1988)). The objective of the surveys was to update knowledge of the distribution and use of the Beaufort Sea by bowhead whales since the last comprehensive survey was flown in this area in 1986. Data were also collected in support of a concurrent bowhead whale satellite tagging study, and as described earlier, to contribute to the mitigation plan for seismic surveys in the Canadian Beaufort Sea. The third and final year of the aerial surveys is planned for August 2009.

The 2-km strip (1 km per side) was defined by marks on the aircraft bubble windows, established while the plane was stationary, and were offset from the flight path by 50 m due to reduced downward visibility under the aircraft (Ford *et al.* 1988). The observers' head positions were 'fixed' by instructing them to initially establish and maintain the desired head position according to the window marks, and this was checked during the survey by each individual observer.

A total of 24 north-south transect lines were flown in each survey, spaced at intervals of 15' longitude (Fig. 3). The southern endpoint for each offshore transect was the 5 m isobath. The northern endpoint for the offshore transects was set as 25 km beyond the shelf break, except offshore of the Yukon coast where the northern endpoints were set at 70°30' N and over waters 1000 m deep. Fog and/or low cloud precluded reaching the northern endpoints of transects 1-16 on all survey flights attempted in 2008.

Two de Havilland Twin Otter aircraft, each with two primary observers viewing through bubble windows, were used to conduct the survey. Each aircraft was equipped with a GPS (Global Positioning System) for navigation and a radar altimeter for maintenance of the desired survey altitude of 305 m altitude above sea level (ASL). Surveys were not attempted if ceilings were lower than 152 m, if there was fog, or if sea state exceeded 3 on the Beaufort Scale of Wind Force. Target ground speed for the survey was 200 km/h. Surveying was attempted only when sea states were Beaufort 0 (calm, sea like a mirror), 1 (light air, ripples but without crests), 2 (light breeze, small wavelets with crests that do not break), or 3 (gentle breeze, large wavelets with crests that are beginning to break). All observers used polarized sunglasses to minimize the effects of glare. Individual hand-held Garmin GPSMap 76 units were used by each observer to record sighting locations for all of the bowhead whales and beluga whales that were sighted. Tape recorders, digital watches and coordinates requested of pilots were used as back up for recording sighting locations.

Primary observers were instructed to record only bowhead or other whale sightings (number, species, number in group, direction and rate of movement, other), and to avoid taking their eyes off the search area during the transect strip. Only the observations of bowheads that were made by the two primary observers were used for the calculation of bowhead densities and identification of feeding areas.

A strip transect method was used, mainly to ensure that observers did not interrupt their searches to take time-intensive perpendicular distance readings (Krzysik 1998) and thus lose time and focus. In addition, this followed the same method that was used for bowhead whale surveys in the SE Beaufort Sea during the 1980s (Renaud and Davis 1981; Davis *et al.* 1982; Harwood and Ford 1983; McLaren and Davis 1985; Harwood and Borstad 1985; Duval 1986; Ford *et al.* 1988). Lateral detection distance analyses (Davis *et al.* 1982; Harwood and Borstad 1985; Ford *et al.* 1988) indicate that under optimum sighting conditions, bowhead detectability is consistent across the strip outward to at least 1000 m per side Thus the assumption of equal detectability across our 1000 m wide strip, from 50-1050 m, is reasonable and at the same time ensured consistency with past surveys and no interruptions for inclinometer reading.

Secondary observers recorded off- transect information, seal sightings, assisted with recording of notes, times and positions, ice conditions, weather, took photos, and made other observations. Again, to ensure a consistent and uninterrupted search, we did not depart from the transect lines to circle groups of whales that were sighted. An on-board intercom system ensured communication among all observers and pilots on each aircraft, on all flights.

GPS waypoints for all bowhead and beluga sightings were downloaded from the GPS units carried in the aircraft, summarized in Excel, and plotted using ESRI (2004). Bowhead whale sightings were assigned to the appropriate 20 km × 20 km grid cell according to the method described by Robertson and Robertson (1987) and Harwood (1989), and evaluated by LGL Ltd after the method described in Anselin (1995). Densities of surfaced bowheads were calculated for each 2 km x 20 km transect segment within each grid cell using the standard ratio method (Caughley 1977; Buckland *et al.* 2001), as

$D = n / a$, *where*

D= *density of bowheads on transect segment*
n = *no. of surfaced bowheads counted on the strip*
a = *area of transect strip*

The resulting bowhead whale transect segment densities in each grid cell surveyed for 2007 and 2008, including buffer zones, were the basis for the mitigation maps below that were prepared and signed off by DFO, industry, and the seismic proponent in each of August 2007 and 2008.

The buffer zone is applied by DFO Habitat Management and operators to ensure that feeding areas that might be located near the boundary of a grid cell are included in the 'full visibility' mitigation approach. It may be possible in the future to use satellite imagery to define oceanographic 'hot spots' attractive to feeding bowhead whales, feeding areas, with appropriate ground-truthing using aerial and/or shipboard observations.

RESULTS

<u>2007-2008</u>

Systematic strip-transect aerial surveys of the SE Beaufort Sea in Canada were flown 22-23 August 2007 (7,166 km^2) and 2-20 August 2008 (4,703 km^2). All 24 north-south transect lines were flown in August of both years, providing approximately 10% survey coverage from the Alaska-Canada border east to the Bathurst Peninsula, and from the 5 m isobath seaward approximately 100 km and/or to beyond the shelf break. Primary observers recorded 132 bowhead whales on-transect (38 off-transect) in 2007 and 136 bowheads on-transect (13 off-transect) in 2008 (Fig. 2a and Fig. 3a).

Survey conditions were good to excellent for spotting whales on all transect lines in both surveys, although in 2008, there were unavoidable interruptions in survey progression due to weather-induced delays (the eastern portion of the study area was flown on 2 August, the western portion on 20 August, and the central portion 4 and 9 August) (Fig. 3). Also, low ceilings/fog prevented flying the surveys along northern portions of the western transect lines in 2008, which made it impossible to conduct the survey over waters within one of the main oil and gas lease areas and the shelf break zone north of the Mackenzie Delta.

On-transect sightings made by primary observers were assigned to the 20 km $\times$ 20 km grid cells, and densities of surfaced bowheads were calculated for each grid cell with survey coverage (n=199 in 2007; n=148 in 2008). Our working definition of a bowhead whale feeding aggregation area ($\geq$5 surfaced bowheads/100 km^2 surveyed) indicated bowheads occurred in three main feeding aggregations in the SE Beaufort Sea each August in 2007 and 2008. The proportion of the grid cells with survey coverage in which bowheads were aggregated was 11.1% in 2007 and 12.8% in 2008. In both years, bowheads aggregated offshore of the Tuktoyaktuk Peninsula in waters mainly 20-50 m deep.

The data from 2008 cannot be viewed as a ‘snapshot’ of whale distribution due to the time elapsed between surveying in different parts of the study area – essentially the distribution maps reflect the distribution of whales at the different times of the survey of specific parts of the study area. However, whale sighting locations from the Patriot and the Binhai did indicate that whale aggregation areas did persist into September, at least off the Tuktoyaktuk Peninsula and in Mackenzie Canyon (as per the weekly MMO reports, Binhai and Patriot, 2008). It is our intention to examine the persistence of aggregations following the final year of the survey (2009), and the comparison of 2007 and 2008 ship and aerial data has been started.

This study was not designed or intended to estimate stock size, however the number of bowhead whales sighted on-transect in 2007 and 2008 was approximately twice that seen on similar surveys flown in the 1980s. A census (visual and acoustic) to update the estimate of stock size is planned for 2010 by the North Slope Borough, Alaska.

The locations of aggregation areas differed between 2007 and 2008, except in both years the largest and most persistent aggregations were located offshore of the Tuktoyaktuk Peninsula primarily in waters shallower than 100 m. In 2007, aggregations also occurred in near-shore Yukon coastal waters between Komakuk Beach and Shingle Point, and near the shelf-break north of the Mackenzie River estuary. In 2008, bowheads were aggregated in the Mackenzie Canyon and Kugmallit Canyon. Bowheads were also known to aggregate in at least one area not covered by our survey flights in each year (offshore NW Banks Island in 2007; offshore Cape Bathurst 2008).

Differences between years are believed to be linked to changes in oceanographic conditions which concentrate the zooplankton prey sought by bowheads (Thomsen *et al.* 1986). In 2008, the locations of bowhead whale feeding aggregations were communicated within 24 hr to the *MV Nahidik* (oceanographic sampling vessel) to facilitate their sampling of zooplankton amongst feeding whales (B. Williams, DFO, Institute of Ocean Sciences, Sidney BC V8L 4B2 pers. comm.).

1981-1986

Aerial survey data from 1981-1986 in the SE Beaufort Sea have been compiled and standardized recently and preliminary maps showing the location of aggregation areas for those years are shown in Fig. 4a. The results of the more recent surveys in 2007 and 2008 are presented in the same format in Fig. 4b. The objective of these analyses, a work in progress (DFO), is to examine temporal changes/similarities in bowhead distribution, with the aim of being able to predict bowhead whale aggregation areas in the future. Along with real-time ship-based MMO data, and our growing knowledge of oceanography and the factors that concentrate zooplankton making certain areas attractive to bowhead whales, it may be possible in the future to predict (and subsequently ground-truth) where bowhead whales will aggregate to feed, rather than conducting extensive and expensive regional aerial surveys each year.

(a)

(b)

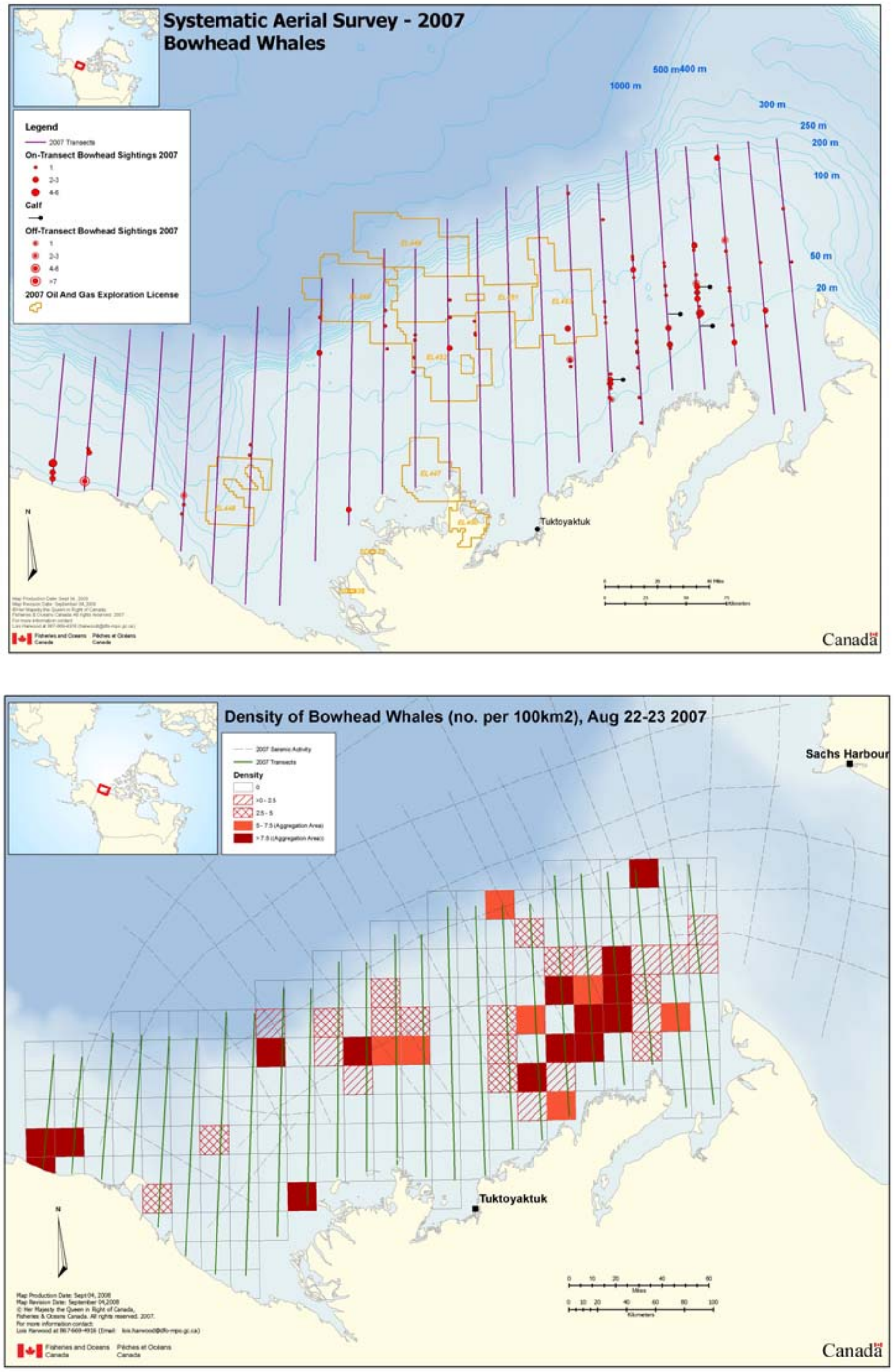
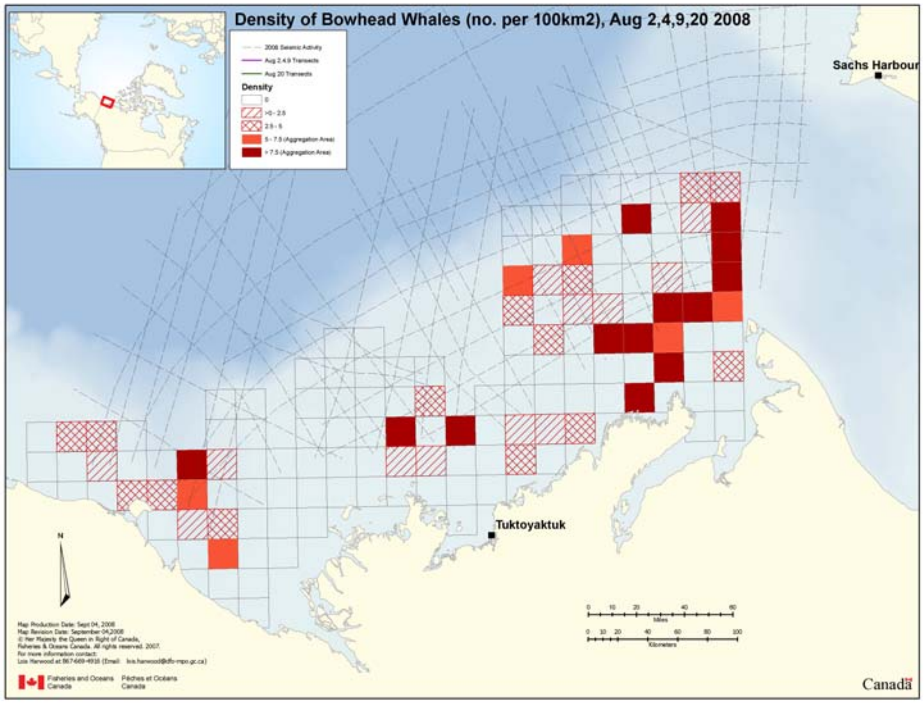


Fig. 2. (a) Bowhead whales sighted during systematic aerial surveys in the offshore Beaufort Sea 22-23 August 2007, and (b) estimated bowhead whale grid cell densities based on surfaced whales on 2 km × 20 km transect segments within those grid cells.

(a)



(b)

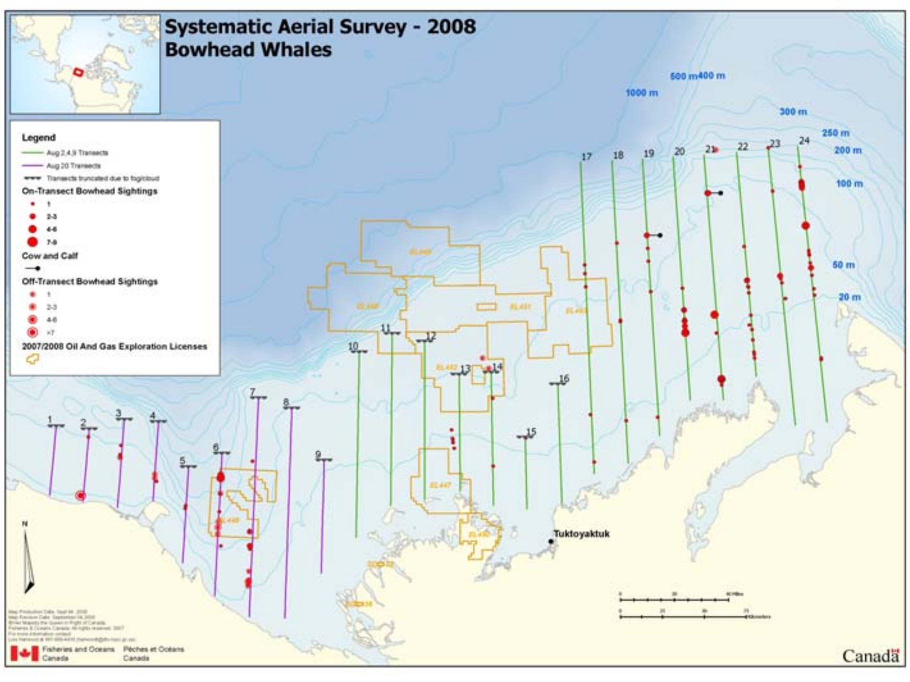
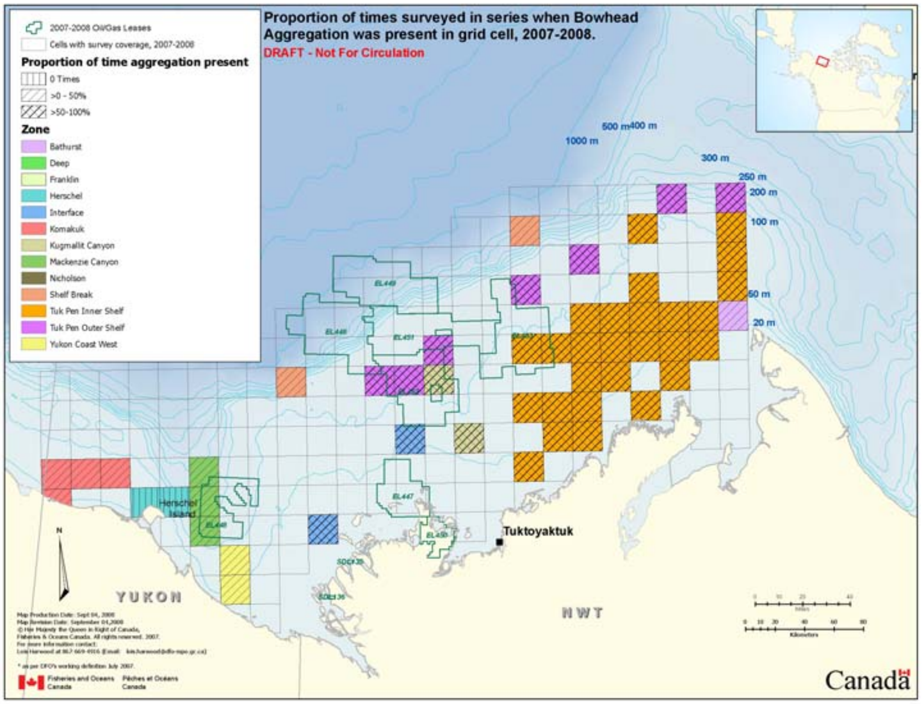


Fig. 3. (a) Bowhead whales sighted during systematic aerial surveys in the offshore Beaufort Sea 2-20 August 2008, and (b) estimated bowhead whale grid cell densities based on surfaced whales on 2 km × 20 km transect segments within those grid cells.

(a)



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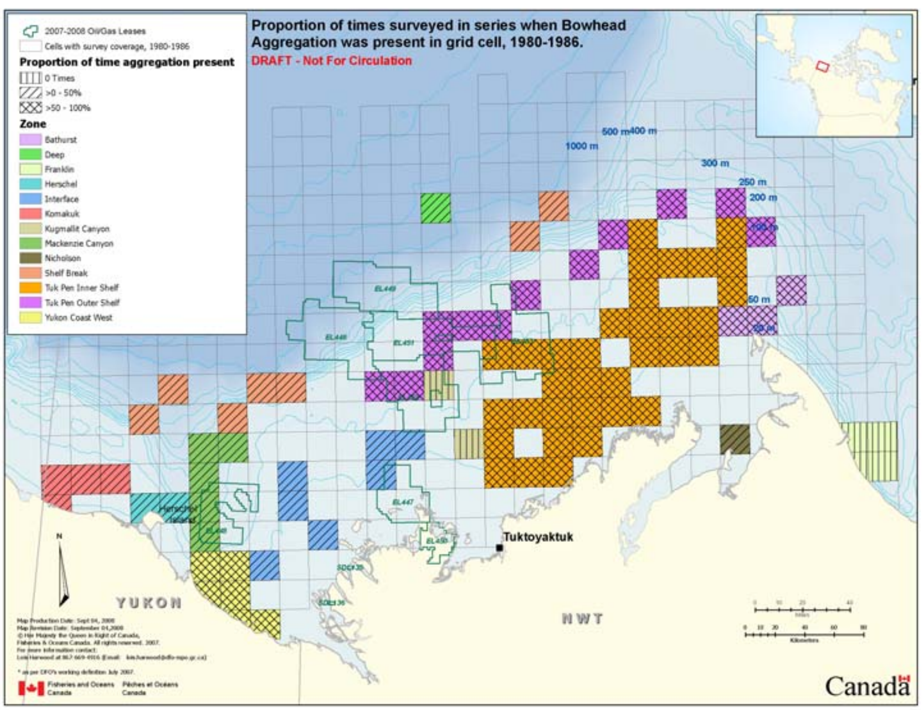

Fig. 4 (a) Preliminary maps showing locations in the SE Beaufort Sea where bowhead whale aggregations were detected during aerial surveys 1980-1986 and (b) 2007-2008 (data sources listed in text).

SEISMIC MITIGATION

Results from the 2007 and 2008 aerial surveys were integrated into the mitigation plan of the seismic operators in the Canadian Beaufort Sea. Areas that were defined as ‘feeding areas’ according to our working definition are outlined in green (Fig 5). The maps were prepared by the operator (ION Geophysical (GXT)) and their contractor LGL, and signed off by regulators in DFO. The seismic operator’s strategy for mitigation, once the aerial survey results were available, was to ensure that all seismic surveys within bowhead whale aggregation areas were completed only during periods of full visibility. If MMOs could not view the entire safety radius, a shut down of the seismic survey was implemented until full visibility was regained. No adjustments were made for sea state.

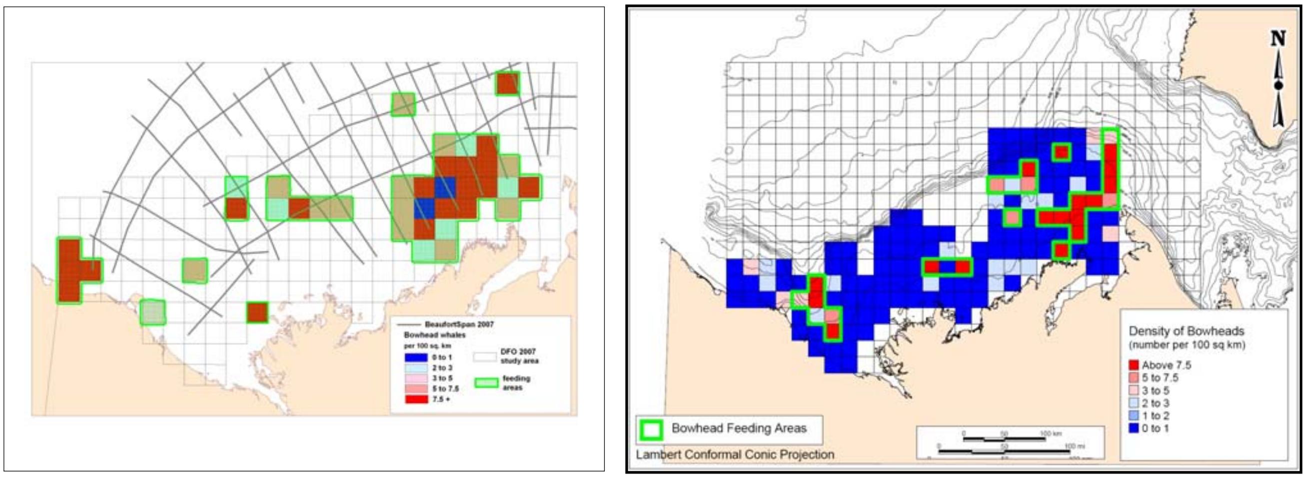

Fig. 5. Bowhead whale feeding areas defined for 2007 and 2008 seismic seasons, and used in the seismic mitigation efforts in those years.

It is apparent from the number of shutdowns in 2007 (n=13) and 2008 (n=23, involving 42 whales) (Harris *et al.* 2007; 2008; GXT weekly MMO reports, 2008), that bowhead whales (and to a lesser extent beluga whales) do enter the SZ, and presumably they do so at the same rate whether it is day, night, foggy, clear, calm or stormy. Had portions of the above seismic surveys in 2007 and 2008 occurred in bowhead whale feeding habitats during night time or during periods with little or no visibility, MMO mitigation would have been absent or compromised, and these particular whales (58 bowheads, 8 belugas in total) would have likely been exposed to sound source levels exceeding 180dB. The shutdowns occurred in areas where whales aggregated, indicating that the mitigation strategy to place restrictions within feeding areas was effective.

The preferred progression for an aerial survey in the Beaufort Sea is east-to-west, within the shortest time frame possible. There is also some coordination with industry in the planning stages, for example to make every attempt to include lease areas in the target survey area. Seismic operators can and do commission their own aerial surveys, for example to add to baseline data on whale distribution in their lease areas or beyond. DFO must be included in any surveys that are conducted if the intention is to adjust or amend the agreed-upon mitigation strategy.

INDUSTRY PERSPECTIVE

Considering the high costs (because of lost time) of any survey shutdown, whether because of darkness or a whale entering the SZ, it is important to plan the timing and location of seismic survey lines so that the survey can proceed as efficiently as possible while applying all required environmental mitigations. Once the bowhead aggregation areas are defined, they are plotted on the survey charts and become another “feature” of the survey’s operating environment. Having such clearly defined areas where the full visibility mitigation is in effect allows the seismic operator a greater degree of certainty when developing the current survey strategy.

In the Canadian Beaufort Sea this is particularly important for seismic operators who must also plan acquisition in light of moving ice packs, the subsistence beluga hunt, other marine mammal shutdowns, diminishing hours of daylight and unpredictable weather conditions, all within a very narrow survey window (typically August to early October).

SUMMARY & CONCLUSIONS

- Bowheads use the Canadian Beaufort Sea each summer for feeding and they aggregate in relatively few (3-4) localized areas (using only 10-15% of grid cells with survey coverage) for approximately 6-8 weeks annually, during the months of August-September.

- There appears to have been an increase in the number of bowhead whales using the SE Beaufort Sea for feeding in 2007 and 2008, compared with similar counts conducted in the Canadian Beaufort Sea in the 1980s.

- Open-water seismic programs (towed air gun arrays) are increasing in number and scope in the Canadian Beaufort Sea.

- Replicated aerial surveys for bowhead whales and other marine mammals are planned for August 2009, and are expected to be used in the same manner for mitigation of seismic surveys in those years.

- The propensity of bowheads to aggregate, and a real-time knowledge of the aggregation areas they are using in a given year, has provided an opportunity to establish mitigation procedures that are more restrictive *within* localized bowhead feeding areas, so as to minimize the risk of injury to feeding whales, and so as not to constrain industrial activity in areas unlikely attractive to feeding whales.

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