Fisheries and Oceans Canada / Pêches et Océans Canada
Science / Sciences

C S A S / **S C C S**

Canadian Science Advisory Secretariat / **Secrétariat canadien de consultation scientifique**

Research Document 2009/048 / **Document de recherche 2009/048**

Factors influencing the Effectiveness of Marine Mammal Observers on Seismic Vessels, with examples from the Canadian Beaufort Sea

Facteurs influençant l'efficacité des observateurs de mammifères marins sur les navires sismologiques, avec des exemples pour la mer de Beaufort canadienne

Lois A. Harwood[1] and Amanda Joynt[2]

Fisheries and Oceans Canada, Western Arctic Area
[1]Arctic Aquatic Research Division, Yellowknife, NT X1A 1E2
[2]Fish Habitat Management, Inuvik, NT X0E 0T0

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

La présente série documente les fondements scientifiques des évaluations des ressources et des écosystèmes aquatiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at:

Ce document est disponible sur l'Internet à:

http://www.dfo-mpo.gc.ca/csas/

ISSN 1499-3848 (Printed / Imprimé)
ISSN 1919-5044 (Online / En ligne)
© Her Majesty the Queen in Right of Canada, 2009
© Sa Majesté la Reine du Chef du Canada, 2009

Correct citation for this publication:

Harwood, L.A., and Joynt, A. 2009. Factors influencing the effectiveness of Marine Mammal Observers on seismic vessels, with examples from the Canadian Beaufort Sea. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/048. iv + 9 p.

ABSTRACT

The Statement of Canadian Practice (SOCP) with Respect to the Mitigation of Seismic Sound in the Marine Environment requires a qualified Marine Mammal Observer (MMO) be on board a seismic vessel to verify that the safety zone (SZ) is clear for at least 30 minutes before the seismic air source array(s) is activated. A MMO is an individual trained to identify and document different species of marine mammals that are expected to be present in the area where a marine seismic survey will take place. Visual monitoring of the SZ and adjacent waters by MMOs is intended to establish and, when visual conditions allow, maintain a zone around the sound source and seismic vessel that is clear of marine mammals and sea turtles, thereby reducing or eliminating the potential for injury. The effectiveness of MMO mitigation is influenced by a number of environmental factors, including amount of daylight, sea state, swell height and visibility (fog, rain, glare, snow). In the Canadian Beaufort Sea, one or more of the factors described above could reduce the effectiveness of MMO mitigation, in approximately these proportions: 25-60% MMO down-time due to darkness, 25-40% down-time due to sea states/swell height, and 10% down-time due to poor visibility associated with fog. An assessment of the coincidence of these factors over the course of a seismic season(s) has not yet been attempted. There is a paucity of literature on the effectiveness of MMO mitigation with regard to such topics as (1) observer fatigue, (2) shift/watch duration, (3) effectiveness of single vs. multiple MMOs, (4) the height on the vantage point, and (5) the amount and type of training that is required. Examples from other jurisdictions are helpful, and include recommendations for two to three MMOs on an active seismic ship (with shifts), vantage points as high as possible and practical, that MMOs position themselves to afford 360° view of the sea surface, that shifts do not exceed four hours, and that recommended optical equipment be used. Standardization of MMO requirements is needed, although even this would not ensure that MMOs have the necessary skills, experience or communication skills to be most effective. Minimum training, standardized forms and competency standards are also required. The benefit of the continued involvement of Aboriginal observers cannot be overstated.

RÉSUMÉ

L’Énoncé des pratiques canadiennes d’atténuation des ondes sismiques en milieu marin exige qu’un observateur de mammifères marins (OMM) qualifié soit à bord d’un navire sismologique pour vérifier si la zone de sécurité (ZS) est libre d’animaux pendant au moins 30 minutes avant l’activation du ou des bulleurs. Un OMM est une personne qui a été formée en vue d’identifier et de documenter les diverses espèces de mammifères marins qu’on s’attend à retrouver dans la zone où sera fait un levé sismique en mer. L’objet de la surveillance visuelle de la ZS et des eaux adjacentes par les OMM est de déterminer et, lorsque les conditions visuelles le permettent, de préserver autour de la source sonore et du navire sismologique une zone exempte de mammifères marins et de tortues marines, ce qui diminuera ou éliminera le risque de blessures. Plusieurs facteurs environnementaux ont des incidences sur l’efficacité de l’atténuation des ondes possible grâce aux OMM, y compris la quantité de lumière du jour, l’état de la mer, la hauteur de la houle et la visibilité (brouillard, pluie, éblouissement, neige). Dans la mer de Beaufort canadienne, un ou plusieurs des facteurs indiqués ci-dessus pourraient diminuer l’efficacité de l’atténuation par les OMM selon, approximativement, ces proportions : entre 25 et 60 % de temps d’arrêt de l’OMM en raison de la noirceur, entre 25 et 40 % de temps d’arrêt en raison de l’état de la mer/la hauteur de la houle et 10 % de temps d’arrêt en raison de la mauvaise visibilité due au brouillard. On n’a pas encore tenté d’évaluer la coïncidence de ces facteurs au courant d’une ou de plusieurs saisons de levés sismiques. Il existe peu de documentation sur l’efficacité de l’atténuation par les OMM relativement aux facteurs comme (1) la fatigue de l’observateur, (2) la durée du quart/de l’intervalle, (3) l’efficacité d’un seul OMM comparativement à plusieurs, (4) la hauteur du point d’observation et (5) la durée et le type de formation nécessaire. Des exemples fournis pour d’autres territoires sont utiles et ils comprennent des recommandations : avoir deux ou trois OMM sur un navire de sismologie en activité (avec des quarts), avoir des points d’observation pratiques et le plus élevé possible, s’assurer que les OMM sont placés de manière à avoir une vue à 360° de la surface de la mer, limiter la durée des quarts à au plus quatre heures et utiliser l’équipement optique recommandé. Il est nécessaire d’uniformiser les exigences pour les OMM, malgré le fait que même cela ne suffira pas à s’assurer que les OMM ont les compétences, l’expérience ou les aptitudes nécessaires pour la communication afin d’être le plus efficace possible. Il est aussi nécessaire d’avoir une formation minimale, des formulaires uniformisés et des normes en matière de compétences. On ne saurait trop insister sur l’avantage de la participation continue des observateurs autochtones/des Premières nations.

INTRODUCTION

A Marine Mammal Observer (MMO) is an individual trained to identify and document different species of marine mammals that are expected to be present in the area where a seismic survey will take place. The Statement of Canadian Practice (SOCP) (DFO 2008a; 2008b) with Respect to the Mitigation of Seismic Sound in the Marine Environment requires a qualified MMO be on board a seismic vessel to verify that the safety zone (SZ) is clear for at least 30 minutes before the seismic air source array (s) is activated (Section 6 b (i) (ii)). Visual monitoring of the SZ and adjacent waters by MMOs is intended to establish and, when visual conditions allow, maintain a zone around the sound source and seismic vessel that is clear of marine mammals and sea turtles, thereby reducing or eliminating the potential for injury.

If marine mammals enter the prescribed SZ, the MMO has the authority from the seismic operators to invoke an immediate shutdown of the seismic source array in order to protect the marine mammals from the possibility of hearing damage (Lawson and McQuinn 2004). Section 6 b (ii) (see text box below) of the SOCP states that regular MMO monitoring is required if the seismic survey is of a power to meet a threshold requirement for a Canadian Environmental Assessment. This level is 275 kPa at 1 m from source (or >226 dB re 1μPa$_{rms}$).

The Statement of Canadian Practice (DFO 2008a) specifies the following with respect to Safety zone and start up mitigation measures:

6. Each seismic survey must:

    a. establish a safety zone which is a circle with a radius of at least 500 metres as measured from the centre of the air source array(s); and

    b. for all times the safety zone is visible,

        i. a qualified Marine Mammal Observer (MMO) must continuously observe the safety zone for a minimum period of 30 minutes prior to the start up of the air source array(s), and

        ii. maintain a regular watch of the safety zone at all other times if the proposed seismic survey is of a power that it would meet a threshold requirement for an assessment under the *Canadian Environmental Assessment Act*, regardless of whether the Act applies.

MMO efforts to detect and act upon marine mammal sightings within the SZ are only effective during periods of visibility (Lawson and McQuinn 2004; Thomson and Davis 2001). The effectiveness of MMO mitigation during periods of visibility is in turn influenced by a number of factors, environmental and relating to the observers themselves. This paper explores the various factors that can influence the effectiveness of MMO mitigation measures outlined in the SOCP, according to these two factor groupings, with particular examples from recent experience in the southeastern Beaufort Sea.

These factors are important to understand and quantify because if the effectiveness of the MMO mitigation is compromised, impacts on marine mammals can include permanent or temporary hearing loss, masking vocalizations/communications, and/or disturbance/displacement of individuals from critical feeding, breeding or migration habitats (Gordon *et al*. 2004; Weilgart 2007; Tyack 2008; Abgrall *et al*. 2008).

As challenging as it is to collect empirical data to assess the effects of anthropogenic noise on individual marine mammals, understanding the biological consequences to those individuals, and to populations, remains speculative at best (Wright 2006; Nowacek *et al*. 2007; Gordon *et al* . 2004, Tyack 2008, Weilgart 2007). There are studies now available which report a disconnect between short term responses and long term trends in bottlenose dolphins exposed to long term disturbance (Bejder *et al*. 2006). Thus, measurable acute, short-term responses (e.g., changes in respiration patterns, diving patterns), such as noted in bowheads exposed to seismic noise in the Beaufort Sea (Richardson *et al*. 1985: 1986; Richardson and Wursig 1997; Reeves *et al*. 1984; Richardson *et al*. 1987), are not necessarily proxies for assessing population-level effects. The percentage of serious [sic] population declines that would not be detected in cetaceans ranges from 72-90% with current monitoring efforts (Taylor *et al*. 2007, as cited in Weilgart 2007). Population-level changes are the metric used in the SOCP (Section 8b, see text insert) for all species other than those identified as threatened or endangered under the *Species at Risk Act*; this is likely immeasurable in many cases.

Mitigation Measures

8. The air source array(s) must be shut down immediately if any of the following is observed by the Marine Mammal Observer in the safety zone:

    a. a marine mammal or sea turtle listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; or

    b. based on the considerations set out in sub-section 4(b), any other marine mammal or sea turtle that has been identified in an environmental assessment process as a species for which there could be significant adverse effects.

4. All seismic surveys must be planned to avoid:

    a. a significant adverse effect for an individual marine mammal or sea turtle of a species listed as endangered or threatened on Schedule 1 of the *Species at Risk Act*; and

    b. a significant adverse population-level effect for any other marine species.

ENVIRONMENTAL FACTORS

The effectiveness of MMO mitigation measures is influenced by a number of environmental factors, including amount of daylight, sea state, swell height and visibility (fog, rain, glare, snow).

Darkness: Although several references described technologies attempted for the detection of marine mammals at night using various night-vision devices, there is agreement in most references that the ability of MMOs to detect marine mammals is severely reduced at night (Harris *et al*. 2001; Thomson and Davis 2001; Lawson and McQuinn 2004). The degree of influence of the darkness factor on the success of MMO mitigation varies with the amount of daylight, which is in turn dictated by latitude and season. In the Western Canadian Arctic, when open-water seismic operations are usually underway by mid-August, there is daylight approximately 75% of the time. By mid-September, the amount of daylight decreases to 56%, and by the end of the seismic survey in early October, there is daylight only about 40% of the time. Thus in the southeastern Beaufort Sea, it is estimated that MMO mitigation measures are lacking for 25-60% of the time for a typical 60-day seismic survey season, due to darkness.

Sea state and swell height: A number of studies have documented that ship-based detection of marine mammals becomes increasingly difficult as sea state, wave heights and wind speeds increase (Thomson and Davis 2001; Lawson and McQuinn 2004). Sea state and swell height were significant factors influencing perpendicular sighting distances on shipboard surveys for cetaceans (Barlow *et al*. 2001) and aerial surveys for belugas (DeMaster *et al*. 2001). Encounter rates change dramatically with increasing sea states, decreasing more than 10 fold from Beaufort Scale (BF) 0-1 to BF 5 (Barlow *et al*. 2006). Stone and Tasker (2006) discounted all MMO data collected when sea states exceeded BF 3, when the swell was greater than 2 m, and when visibility was less than 5 km. The Western Gray Whale Advisory Panel (2007) states that detection probabilities were not affected when sea states were BF 3 or less, but that detectability was affected at higher sea states and when visibility was <1 km. Sea states in the Beaufort Sea have been measured to exceed 1 m (>BF 4) approximately 25% of the time in August, and 40-48% of the time in September (Melling 2008; Parker and Alexander 1983). Thus in the southeastern Beaufort Sea, it is estimated that MMO mitigation measures would be compromised for approximately 25-48% of the time due to sea state and/or swell height.

Visibility (Glare/Fog/rain/snow): Visual surveillance by the MMOs is also impacted when visibility is reduced because of fog, rain, snow or glare (Barlow *et al*. 2001). This factor is likely location-specific, and in some cases may not be as important as other factors described above (Barlow *et al*. 2001). These authors modelled a number of factors which influenced the perpendicular sighting distance of cetaceans, including the presence of fog/rain in primary search area of 3 nmi around the ship. This factor was one of eight factors included in their model, but its effect on perpendicular distance was apparently not as important as Beaufort Scale of Wind Force as it was included later or not at all in a stepwise inclusion of variables in the selection of the best model.

Fog is a common occurrence in Arctic waters in summer, in both near shore and offshore areas, and frequently hampers the conduct of aerial and shipboard surveys (Harwood *et al*. 2009; Harris *et al*. 2007; 2008) in the southeastern Beaufort Sea in recent years. It forms where wind is moving air from areas of warmer water, where it has picked up moisture via evaporation, to areas of lower surface temperature (such as near ice edges). The latter may be associated with upwelling cold water from deeper in the ocean, or with encroachment of the pack ice. With stronger winds, such as are characteristic of the changing climate, the surface layer of the atmosphere is mixed to greater depth, and either thickening the fog layer, or causing it to lift off the surface to form a low deck of stratus cloud is common.

Fog reduces or eliminates the ability of MMOs to detect marine mammals in their search areas. Parker and Alexander (1983) report visibility of <3.7 km 23% of the time during August, and 18% during September for their offshore Marine Area 3, the southeastern Beaufort Sea. For the 0600 to 2200 h daily weather reporting period at the coastal community of Tuktoyaktuk, NT, fog was reported on average for 8% of the reporting periods in August and 9.7% of the reporting periods for September (2005-2007) (http://www.weatheroffice.gc.ca/canada_e.html). Thus in the southeastern Beaufort Sea, it is estimated that MMO mitigation measures might not be possible for approximately 10% of the time due to reduced visibility associated with fog.

SUMMARY

There are no mitigation measures in the SOCP that prohibit active seismic surveys at night, or during periods of low or no visibility, and/or periods of high sea states. This means that under the SOCP, seismic surveys can and do proceed with little or no surveillance for marine mammals entering the SZ. In the Canadian Beaufort Sea, one or more of the factors described above could reduce the effectiveness of MMO mitigation, in approximately these proportions: 25-60% MMO down-time due to darkness, 25-40% down-time due to sea states/swell height, and 10% down-time due to poor visibility associated with fog. The sum of these factors on MMO effectiveness has not been specifically assessed, and would vary within and among seismic survey seasons. An assessment of the coincidence of these factors over the course of a seismic season(s) would be prudent, and industry working in the Beaufort Sea is encouraged to attempt these analyses with this objective in mind.

An Example from the Canadian Beaufort Sea: Recognizing the ineffectiveness of MMO surveillance during periods of darkness and poor visibility, seismic operators in the Canadian Beaufort Sea have worked with DFO to develop a mitigative regime to address this limitation of their MMO programs. Their approach follows a mitigation measure described in the SOCP in the Planning Seismic Surveys section Section 5 (d) (DFO 2008a). The operators and their contractors have worked with DFO in developing the approach of conducting seismic surveys in defined bowhead whale aggregation areas only during times of full SZ visibility. The aggregation areas are determined as early as possible within the season by DFO-coordinated aerial surveys (Harwood *et al*. 2009), and the determination/definition of feeding areas is done collaboratively with DFO and operators after the survey data are available. It is clear from the number of shutdowns in 2006 (n=3), 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 bowhead whale feeding habitats occurred 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) could have been exposed to sound source levels exceeding 180 dB.

As a means of assessing the effectiveness of this case-specific approach to mitigation, a comparison of the 2007 and 2008 bowhead whale feeding aggregation areas (as determined through systematic aerial surveys), and the locations of cetaceans sighted by ship-board MMOs in the same season has been initiated by DFO. An overlay of aggregation and non-aggregation areas determined using the two different methods of aerial and ship-board observations, were in agreement 75% of the time in 2007 (106/142) and 58% of the time in 2008 (52/89). Short-term or local changes in oceanography, short-term or local changes in whale distribution, and gaps in temporal aerial survey coverage (such as was necessary due to weather in 2008) are probable explanations for matching in 2008 being lower than matching in 2007. The approach of spatial restrictions during the seismic survey and temporal restrictions during planning is a working example of how an adaptive mitigation measure can be used to enhance protection of marine mammals in important feeding aggregation areas without unjustifiably constraining industry activity.

Clearly, visibility in the SZ is crucial to ensure effective implementation of mitigation measures. Mitigations specific to the species and habitats affected by a particular seismic survey area can

be developed on a case-by-case basis that recognizes the paramount importance of full visibility of the SZ in feeding aggregation areas if they are known or can be reasonably defined or predicted.

OBSERVER FACTORS

The SZ must be of a 'practical' size, so that MMOs can effectively scan and detect marine mammals therein, during periods of visibility. Even under ideal conditions, not all surfaced marine mammals are detected by observers. Still others remain below the surface during the ship's pass, and are therefore not visible to ship-board observers (Oleson *et al*. 2007; Hammond *et al*. 1995).

Compton *et al*. (2008) recommend using a SZ that is of a size that can be efficiently monitored by MMOs given practical considerations, such as visual acuity and sighting conditions. The effective search width for beaked whales is typically no larger than 1-2 km from the ship, even for observers using high-powered binoculars, and under excellent or good sighting conditions (Barlow and Gisiner 2006). For seals, Harris *et al*. (2001) found that sighting rates declined at lateral distances of >250 m from the seismic vessel during shipboard surveys in the Alaskan Beaufort Sea. Clearly, with less than ideal sighting conditions, and increasing distance from ships, an unknown and presumably variable proportion of surfaced marine mammals are not detected by MMOs in any given program.

In the Canadian Beaufort Sea, lateral and radial sighting distances for bowhead whales and beluga whales are collected by MMOs, but these data have not yet been analysed with this particular analysis in mind. Bowhead whales are regularly sighted by MMOs from seismic ships in the Beaufort Sea (Harris *et al*. 2007; 2008), in contrast to belugas which are seen much less often. This is in sharp contrast to concurrent aerial surveys which detect belugas in abundance, and suggests that the belugas are likely avoiding sources of underwater shipping noise which in this case included an active seismic ship (Miller *et al*. 2005; Harris *et al*. 2007; 2008; Harwood *et al*. 2009).

Barlow *et al*. (2001) reported that the difference among individual observers was one of two significant factors influencing perpendicular sighting distances for shipboard surveys in the Pacific in 1986-1996. Individual differences would reflect the visual acuity, experience, training, concentration, and state of rest/fatigue. With regard to sighting rates for beaked whales off the coast of California, Barlow *et al*. (2006) found observer experience (grouped as first-time observers, observers with at least four months experience, observers with at least 12 months experience) to be a highly significant factor explaining differences in sighting rates ($p<0.0001$). Beaked whale sighting rates for experienced observers were approximately twice that of inexperienced observers (Barlow *et al*. 2006).

Sighting method had the second largest effect on detectability (next only to species) in an evaluation of the factors influencing lateral sighting distances of cetaceans on shipboard surveys in 1986-96 in the eastern Pacific (Barlow *et al*. 2001). In dedicated surveys for cetacean abundance, such as SCANS, 6 trained observers working in 2 independent teams of 3 were engaged in observing 180^{o} ahead of the vessel (Hammond *et al*. 1995). Even under these conditions, a significant portion of the sightings were missed. It is difficult or impossible for a single observer to cover 360^{o} reliably, especially as the best vantage points are often obscured by elements of the ship's structure (Lewis *et al*. 1998; Harris *et al*. 2001).

There is a paucity of literature on the effectiveness of MMO mitigation with regard to such topics as (1) observer fatigue, (2) shift/watch duration, (3) effectiveness of single vs. multiple MMOs, (4) the height on the vantage point , and (5) the amount and type of training that is required. There are numerous suggestions for these aspects in the literature, which are largely program-specific (Compton *et al*. 2008; Thomson and Davis 2001; Harris *et al*. 2001; Lawson and McQuinn 2004; Weir and Dolman 2007).

The SOCP is a framework that prescribes a qualified MMO (DFO 2008a; 2008b). Standardization of MMO requirements is needed, although even this would not ensure that MMOs have the necessary skills, experience or communication skills to be most effective. Minimum training, standardized forms and competency standards are also required. DFO has initiated a process to standardize MMO training, similar to other jurisdictions (Joint Nature Conservancy Committee; Scanning Ocean Sectors). The benefit of the continued involvement of Aboriginal observers cannot be overstated, allowing for additional training to ensure scientific rigour and at the same time bringing local expertise to bear on MMO work.

Examples from other jurisdictions are also helpful, and include recommendations for 2-3 MMOs on an active seismic ship (with shifts), vantage points as high as possible and practical, that MMOs position themselves to afford 360° view of the sea surface, that shifts do not exceed four hours, and that recommended optical equipment be used (Lawson and McQuinn 2004; Weir and Dolman 2007; Compton *et al*. 2008; Thomson and Davis 2001, Western Gray Whale Advisory Panel 2007; Barlow and Forney 2007).

ACKNOWLEDGEMENTS

Dr. H. Melling (DFO) provided data and analysis regarding environmental conditions in the Canadian Beaufort Sea. M. Dyck, J. Martin and J. Ludberg (all DFO) assisted with obtaining references. L. Nichol, M. Hammill, J. Lawson and J.F. Gosselin (DFO) reviewed earlier drafts of this paper.

REFERENCES

Abgrall, P., Mouton, V.D., and Richardson, W.J. 2008. Updated Review of scientific information on impacts of seismic survey sound on marine mammals, 2004-present. Unpublished report Dept of Fisheries and Oceans, by LGL Ltd, Box 457, King City, Ontario, Canada, L0G 1K0. . 27 p + app.

Barlow J., and Forney, K.A. 2007. Abundance and population density of cetaceans in the California Current ecosystem. Fish. Bull. 105:509-526

Barlow, J., and Gisiner, R. 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. J. .Cet. Res. Manage. 7:239-249.

Barlow, J., Gerrodette, T., and Forcada, J. 2001. Factors affecting perpendicular sighting distances on shipboard line-transect surveys for cetaceans. J. Cet. Res. Manage. 3(2): 201-212.

Barlow, J., Ferguson, M.C.. Perrin, W.F., Balance, L., Gerrodette, T., Joyce, G., Macleod, C.D., Mullin, K., Palka, D.L., and Waring, G. 2006. Abundance and densities of beaked and bottlenose whales (family Ziphiidae). J. Cet. Res. Manage. 7(3): 263-270.

Bejder, L., Samuels, A., Whitehead, H., Gales, N., Mann, J., Connor, R., Heithaus, M., Watson-Capps, J., Flaherty, C., and Krutzen, M. 2006. Decline in relative abundance of bottlenose dolphins exposed to long-term disturbance. Cons. Biol. 20: (6): 1791-1798.

Compton, R., Goodwin, L., Handy, R., and Abbott, V. 2008. A critical examination of worldwide guidelines for minimizing the disturbance to marine mammals during seismic surveys. Marine Policy 32: 255-262.

DeMaster, D.P., Lowry, L.F., Frost, K.J., and Bengston, R.A.. 2001. The effect of sea state on estimates of abundance for beluga whales (*Delphinapterus leucas*) in Norton Sound, Alaska. Fish. Bull. 99: 197-201.

DFO 2008a. Statement of Canadian Practice with respect to the Mitigation of Seismic Sound in the Marine Environment. Available: www.dfo-mpo.gc.ca/oceans-habitat/oceans/im-gi/seismic-sismique/statement-enonce_e.asp

DFO 2008b. Background paper for the 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/seismic-sismique/information_e.asp

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R., and Thompson. D. 2004. A review of the effects of seismic surveys on marine mammals. Mar. Tech. Soc. J. 37:16-34.

Hammond, P., Benke, H., Berggren, P., Collet, A., Heide-Jorgensen, M.P., Heimlich-Boran, S., Leopold, M., and Oien, N. 1995. The distribution and abundance of harbour porpoises and other small cetaceans in the North Sea and adjacent waters. Report 92-2/UK/027 (SCANS). Europen Commission LIFE Project.

Harris, R.E., Miller, G.W., and Richardson, W.J. 2001. Seal responses to airgun sounds during summer seismic surveys in the Alaskan Beaufort Sea. Mar. Mamm. Sci. 17(4): 795-812.

Harris, R.E., Elliott,T., and Davis, R.A. 2007. Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, in open-water season 2006. Unpubl. rep. by LGL Ltd, Box 457, King City, Ontario, Canada, L0G 1K0.

Harris, R.E., Lewin, A., Hunter, A., Fitzgerald, M., Davis, A.R., Elliott, T., and Davis, R.A. 2008. Results of mitigation and monitoring program, Beaufort Span 2-D marine seismic program, in open-water season 2007. Unpubl. rep. by LGL Ltd, Box 457, King City, Ontario, Canada, L0G 1K0.

Harwood, L., Joynt, A., Kennedy, D., Pitt, R., and Moore, S. 2009. 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. DFO Can. Sci. Advis. Sec. Res. Doc. 2009/040. iv + 14 p.

Lawson, J., and McQuinn, I. 2004. Review of the Potential Hydrophysical-related Issues in Canada, Risk to Marine Mammals and Monitoring and Mitigation Strategies for Seismic Activities. Can. Sci. Advis. Sec. Res. Doc. 2004/121. 59 p.

Lewis, T., Gillespie, D., Gordon, J., and Chappell, O. 1998. Acoustic cetacean Monitoring 1996 to 1999: Towards the development of an automated system. Summary Report. Unpubl. rep. for Shell UK Ltd, Contract C10563 by Birmingham Research and Development Ltd.

Melling, H. 2008. Analysis based on DFO observations archived at the Canadian Marine Environmental Data Service: http://www.meds-sdmm.dfo-mpo.gc.ca/meds/Databases/WAVE/WAVE_e.htm

Miller, G.W., Moulton, V.D., Davis, R.A., Holst, M., Millman, P., MacGillivray, A., and Hannay, D. 2005. Monitoring seismic effects on marine mammals – southeastern Beaufort Sea, 2001-2002.*In* Offshore Oil and Gas Environmental Effects Monitoring: Approaches and Technologies. *Edited by* Armsworthy, S.L., Cranford, P.J. and Lee, K. Battelle Press, Columbus, Ohio. pp.511-542

Nowacek, D.P., Thorne, L.H., Johnston, D.W., and Tyack, P.L. 2007. Responses of cetaceans to anthropogenic noise. Mammal Rev. 37(2): 81-115.

Oleson, E.M., Calambokidis, J., Barlow, J., and Hildebrand, J.A. 2007. Blue whale visual and acoustic encounter rates in the southern California bight. Mar. Mamm. Sci. 23(3): 574-597.

Parker, N., and Alexander, J. 1983. Weather, ice and sea conditions relative to Arctic marine transportation. Can. Tech. Rpt. Hydrography and Ocean Sciences 26. 212 p.

Reeves, R.R., Ljungblad, D.K., and Clarke, J.T. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. Polar Record 22 (138): 271-280.

Richardson, W.J., and Wursig, B. 1997. Influences of man-made noise and another human actions on cetacean behaviour. Mar. Freshw. Behav. Physiol. 29: 183-209.

Richardson, W.J., Fraker, M.A., Wursig, B., and Wells, R.S. 1985. Behaviour of bowhead whales (*Balaena mysticetus*) summering the Beaufort Sea: Reactions to Industrial Activities. Biological Conservation 32: 195-230.

Richardson, W.J., Wursig, B., and Green, C.R. Jr. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. J. Acoust. Soc. Am. 79(4): 1117-1128.

Richardson, W.J., Davis, D.A., Evans, C.R., Ljungblad, D.K., and Norton, P. 1987. Summer distribution of bowhead whales, *Balaena mysticetus*, relative to oil industry activities in the Canadian Beaufort Sea, 1980-1984. Arctic 40: 93-104.

Stone, C.J., and Tasker, M.L. 2006. The effects of seismic airguns on cetaceans in UK waters. J. Cet Res Manage 8:255-263.

Thomson, D.H., and Davis, R.A. 2001. Review of the potential effects of seismic exploration on marine animals in the Beaufort Sea. Unpubl. rep. for Dept. of Fisheries and Oceans, Yellowknife, NT by LGL ltd, Box 457, King City, Ontario, Canada. L0G 1K0.

Tyack, P.L. 2008. Implications for marine mammals of large-scale changes in the marine acoustic environment. J. Mammal. 89(3): 549-558.

Weilgart, L.S. 2007. The impacts of anthropogenic ocean noise on cetaceans and implications for management. Can. J. Zool. 85:1091-1116.

Weir, C.R., and Dolman, S.J. 2007. Comparative review of the regional marine mammal mitigation guidelines implemented during industrial seismic surveys and guidance towards a worldwide standard. Journal of International Wildlife Law and Pol.icy 10:1-27.

Western Gray Whale Advisory Panel. 2007. Marine mammal observer programme, SEIC MMO Programme Effectiveness. WGWAP 3/INF.2

Wright, A.J. 2006. A review of the NRC's "Marine Mammal Populations and Ocean Noise: Determining when noise causes biologically significant effects" report. J. Int. Wildl. Law Pol. 9:91-9