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Perspective

# Narwhals and seismic exploration: Is seismic noise increasing the risk of ice entrapments?

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ABSTRACT

There is great interest in exploring and exploiting hydrocarbon resources in the Arctic, and one of the main methods of locating and assessing such resources is seismic survey. Marine seismic surveys involve the use of airguns that introduce high-energy noise to the Arctic's largely pristine underwater acoustic environment. Narwhals may be particularly sensitive to this noise but so far no studies have addressed the question of direct effects of high-energy airgun pulses on these animals. We are concerned about the possibility that three large recent ice entrapments were causally linked to seismic survey activities. On these occasions narwhals remained in coastal summering areas until well into the fall and early winter season, delaying their annual offshore migration and becoming lethally entrapped by rapidly forming fast ice. About 1000 narwhals died in an ice entrapment in Canada in 2008 and about 100 in two entrapments in Northwest Greenland in 2009–10. We conclude that studies of the direct effects of seismic surveys on narwhals are urgently needed and should ideally precede further seismic surveys in narwhal habitats.


**Contents**



Some of the largest unexplored geological basins for hydrocarbon development are located in offshore seasonally ice-covered shelf-areas of the Arctic (Gautier et al., 2009; Schenk, 2010). With the prospects for a continued reduction in extent and thickness of sea ice (Perovich and Richter-Menge, 2009), these areas are of increasing interest to the oil and gas industry. On the shelf areas of East and West Greenland alone, it has been estimated that >20 million barrels of undiscovered oil might exist and would be potentially recoverable (Gautier et al., 2009). The prospect of large-scale untapped but accessible hydrocarbon resources in a country with a stable political system has fueled interest in oil and gas exploration in Greenland. Both offshore seismic surveys and exploratory drilling have taken place in West Greenland since 2007 and licensing for areas of East Greenland is expected to take place in 2012 (http://www.bmp.gl/petroleum/).

The underwater environment in the Arctic often has high background sound levels from activity of icebergs, sea ice, wind, waves, and wildlife, but there has been, until recently, relatively little noise of anthropogenic origin (Carey and Evans, 2011; Moore et al., 2012). Despite opening of the Northwest and Northeast Passages (Arctic Marine Shipping Assessment, 2009), the level of shipping activity remains low and is largely limited to the open-water season. Therefore the underwater acoustic environment in much of the Arctic is still nearly pristine, without the chronic noise from shipping, drilling, seismic exploration and sonar. In Baffin Bay large-scale industrial seismic surveys were only recently initiated.

Arctic marine mammals use underwater sounds to locate prey, detect and avoid predators, find openings in sea ice for breathing, and to communicate and maintain contact (Richardson et al.,

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1995). Historically, cetaceans and pinnipeds that live year-round in the Arctic have been exposed to very limited amounts of anthropogenic sound and there is no reason to believe that these animals have become desensitized or habituated to such noise. In fact, there is published evidence of dramatic responses to ship noise by belugas (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) (Finley et al., 1990; Cosens and Dueck, 1993; Lesage et al., 1999) and to airgun pulses by bowhead whales (*Balaena mysticetus*) (Richardson et al., 1995; Blackwell et al., 2010). The effects of anthropogenic noise on several temperate-region species have been studied (Wright et al., 2007; Rolland et al., 2012) but few studies have addressed this issue for Arctic marine mammals. Depending on the type and level of the sound as well as its spatial and temporal character, the impacts on marine mammals may include short- or long-term changes in behavior (i.e. disruption of feeding activity, avoidance, shifts in habitat-use patterns), physical damage to hearing abilities, and masking of important signals. Change in calling behavior is a commonly detected effect of noise exposure.

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

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

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

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

Narwhals remain in the Arctic or sub-Arctic throughout the year. Although they spend approximately half of the year in dense pack ice and have done so for centuries (and presumably for millennia), they are still susceptible to ice entrapment. At intervals, large numbers succumb in this way during the winter (February through April). Ice entrapments are caused by a sudden freeze-up during periods of stable but high atmospheric pressure (Egede, 1788; Porsild, 1918; Siegstad and Heide-Jørgensen, 1994). Ice entrapments are well documented in West Greenland and to some extent also in Canada as these are major events in the lives of people living in Arctic communities. The Disko Bay area of West Greenland has long been the area with the highest incidence of narwhal ice entrapment, and it was the site of the largest such event on record: more than 1000 whales died in a February 1915 ice entrapment in Disko Bay (Porsild, 1918). This bay typically provides excellent feeding conditions for narwhals, and sea ice coverage is highly variable according to the changing strength of the warm Atlantic water and the cold polar currents that meet there. During certain weather conditions in winter, hunters are "on the lookout" for ice-entrapped whales at sites where entrapments are to some extent predictable based on local experience and knowledge. This situation, specifically the high level of local interest and consequent vigilance by people, gives us confidence in asserting that ice entrapments of narwhals occur mainly between February and March and most often in the Disko Bay region of West Greenland. There are few historical records of entrapments north of Disko Bay, none from Qaanaaq (Northwest Greenland) and few from winter in the Canadian high Arctic (Fig. 1).

Three recent ice entrapments of narwhals occurred in summering areas outside the normal range of ice-entrapment events. Two of these took place in the autumn in locations where entrapments of narwhals had not been reported previously. In November 2008 thousands of narwhals were seen moving quickly through the freezing seas near the community of Pond Inlet (northern Baffin Island, Canada) a few days before being entrapped (Watt and Ferguson, 2011). Some of the whales apparently avoided entrapment. However, after the ice had frozen solid, local residents discovered about 1000 narwhals at breathing holes about 50 km from open water. During late September and early October 2008, 2D seismic surveys (m/v Geolog Dmitriy Nalivkin) were underway