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Distribution of endemic cetaceans in relation to hydrocarbon development and commercial shipping in a warming Arctic

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ABSTRACT

The Arctic is one of the fastest-changing parts of the planet. Global climate change is already having major impacts on Arctic ecosystems. Increasing temperatures and reductions in sea ice are particular conservation concerns for ice-associated species, including three endemic cetaceans that have evolved in or joined the Arctic sympagic community over the last 5 M years. Sea ice losses are also a major stimulant to increased industrial interest in the Arctic in previously ice-covered areas. The impacts of climate change are expected to continue and will likely intensify in coming decades. This paper summarizes information on the distribution and movement patterns of the three ice-associated cetacean species that reside year-round in the Arctic, the narwhal (*Monodon monoceros*), beluga (white whale, *Delphinapterus leucas*), and bowhead whale (*Balaena mysticetus*). It maps their current distribution and identifies areas of seasonal aggregation, particularly focussing on high-density occurrences during the summer. Sites of oil and gas exploration and development and routes used for commercial shipping in the Arctic are compared with the distribution patterns of the whales, with the aim of highlighting areas of special concern for conservation. Measures that should be considered to mitigate the impacts of human activities on these Arctic whales and the aboriginal people who depend on them for subsistence include: careful planning of ship traffic lanes (re-routing if necessary) and ship speed restrictions; temporal or spatial closures of specified areas (e.g. where critical processes for whales such as calving, calf rearing, resting, or intense feeding take place) to specific types of industrial activity; strict regulation of seismic surveys and other sources of loud underwater noise; and close and sustained monitoring of whale populations in order to track their responses to environmental disturbance.

1. Introduction

Polar amplification of climate change is having major implications for the wildlife and people of the Arctic region. Global warming, and in particular the reduction of multi-year ice and the seasonal sea ice extent and duration, has already begun to influence human activities in this region. Increased tourist traffic, shipping, exploration, and development will lead to more frequent and severe conflicts with Arctic marine wildlife. Arctic marine mammals, like other Arctic vertebrates, are specially adapted to take advantage of the climatic conditions that have prevailed in the Arctic for millions of years [1]. Arctic endemic whales, phocid seals, walruses (*Odobenus rosmarus*), and polar bears (*Ursus maritimus*) are of great interest and conservation concern for several reasons, including their role in the functioning of Arctic ecosystems, their importance in subsistence economies and cultures of some northern hunting communities, and their appeal as icons of tourism and subjects of scientific study. All of these

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animals have been important to northern nations as sources of oil, hides, and other valuable products and have provided important cultural elements and resources for coastal aboriginal communities.

Numerous recent studies have highlighted the threat to Arctic marine mammals posed by climate change (e.g. [2–9]). This review was stimulated by the need for a better understanding of the implications of ongoing environmental changes in the Arctic for cetaceans in order to develop effective conservation and management policies.

Three species of cetaceans occur year-round in the Arctic: the bowhead whale (*Balaena mysticetus*), the only baleen whale resident in the Arctic, and the narwhal (*Monodon monoceros*) and white whale or beluga (*Delphinapterus leucas*), two closely related toothed whales. All three species are restricted to high latitudes of the Northern Hemisphere and therefore can be regarded as Arctic endemics even though some populations (of belugas in particular) occur in sub-Arctic or northern cold temperate regions (e.g. southern Hudson Bay, Cook Inlet, southern Bering Sea, Sea of Okhotsk, south-western Greenland, River and Gulf of St. Lawrence). Many other cetacean species enter Arctic waters seasonally (e.g. gray whales, *Eschrichtius robustus*; blue whales, *Balaenoptera musculus*; humpback whales, *Megaptera novaeangliae*; common minke whales, *Balaenoptera acutorostrata*; killer whales, *Orcinus orca*; northern bottlenose whales, *Hyperoodon ampullatus*), but this paper focuses only on the three resident Arctic species.

This review summarizes what is known about, and maps, the current ranges of the three Arctic cetacean species. It then identifies areas where two specific types of human activity – oil and gas development and commercial shipping – overlap with those ranges. Both categories of industrial activity have the potential to affect marine mammals in multiple ways, and both will almost certainly contribute to the cumulative impacts of rapidly changing environmental conditions on the local or regional whale populations. Oil and gas development, from its initial prospecting phase involving marine seismic surveys through to the construction of artificial islands or offshore drilling platforms, and into the actual extraction and transport of hydrocarbon products phase, affects the acoustic environment and broader ecology of whales over considerable distances. These activities also put them at risk of ship strikes and increase the potential for exposure to spilled or leaked oil and other harmful substances. Commercial vessel traffic also adds underwater noise and increases the risk of ship strikes and pollution by oil and other contaminants. In short, the expansion of industrial and commercial activity in the Arctic, facilitated by the rapid, climate-induced retreat of sea ice cover, is bound to transform the marine environment in the North from its currently near-pristine state to one that has much higher levels of anthropogenic sound and is more crowded and hazardous for marine wildlife. This has implications not only for the conservation of these whales and their habitat, but also for the human communities that depend on marine mammals for nutritional sustenance and cultural cohesion in many Arctic regions.

For a working definition of the Arctic, this review uses boundary lines developed by the Arctic Council's Working Group on the Conservation of Arctic Flora and Fauna (CAFF), which combine climatic and bio-geographical criteria [10]. Although CAFF boundary lines occur on all of the distribution maps presented, the depictions of whale distributions represent the full ranges of the three species both within and outside the CAFF region. Our depictions of hydrocarbon development and shipping activity primarily cover areas inside the CAFF boundary but also include some contiguous temperate areas (linked to the Arctic by major currents) and the seasonally ice-covered Okhotsk Sea.

2. Materials and methods

2.1. Whale distribution maps

Production of the three maps of whale distribution was an iterative process. Initially, ArcGIS 9.3.1 was used to create a series of maps showing the year-round distribution of the three species based on the literature. The draft maps were sent to species experts and stakeholder groups for review, and revised drafts were prepared based on the feedback received and the co-authors' collective knowledge. The revised draft maps were sent to additional experts for further review (see Acknowledgments). Revised versions of the maps were then generated using ArcGIS 10. The resultant maps show annual ranges and main summer distributions, with migration routes largely subsumed within the annual ranges. It is important to note that the distribution maps were not derived directly from point (e.g. sightings, catches) or tracking (i.e. telemetry) data, and no attempt was made to produce density 'surfaces' or to rank the functional importance of different parts of the distribution (e.g. to identify 'critical habitat'; cf. [11]).

The problem of determining the relative importance of different areas within a species' or a population's entire range is a familiar one, but beyond the scope of this paper; in any event, for many regions the knowledge base is not sufficient to conduct such assessments. Although there are many records of extralimital occurrences of all three species over the past few centuries, these 'outliers' are not mapped herein because of the difficulty of interpreting their significance or relevance. Given the availability of considerable information on commercial catches of bowhead whales over the last few centuries, areas where these whales were encountered regularly by whalers historically are included in the range map, but are differentiated from currently occupied regions if they have not been re-occupied by significant numbers of whales since the end of commercial whaling. No similar attempt was made to map areas formerly inhabited by belugas from which they were effectively extirpated, such as south-western Greenland [12].

2.2. Hydrocarbon development map

Data were compiled on the distribution of oil and gas deposits and development activity in the Arctic (and adjacent cold temperate regions), including projects that are (a) already in production, (b) in an exploratory or verification phase, and (c) at the lease-sale or offering stage (see Appendix A). Locations of oil and gas wells and lease areas were downloaded from the websites of relevant data custodians for each region of the Arctic (see Appendix A). Where data were not readily available as GIS files, information from maps and reports available online were digitized to produce GIS files. The resultant dataset is by no means comprehensive, but it is a reasonable representation of the distribution of the main oil and gas industry activities and interests in the Arctic, based on available data as of late May 2013.

Potential future development is also highlighted via the presentation of data on hydrocarbon provinces (variably referred to as basins or regions, depending on the source), which were digitized from published maps [13]. In order to match the extent of the cetacean ranges in the western North Atlantic, the Atlantic Margin hydrocarbon basin off eastern Canada [14] was added to the dataset. Suitable maps or spatial data on hydrocarbon basins in the Sea of Okhotsk were not available, so this region was excluded from our examination of bowhead whale and beluga ranges in relation to oil and gas provinces.

The resultant overview map of hydrocarbon resources includes a layer showing the major known hydrocarbon provinces in the Arctic, as well as lease areas (including areas that have been leased, and areas that government authorities deem to be