Ocean & Coastal Management 102 (2014) 55–57

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Opinion paper

Linking marine mammal and ocean health in the 'New Normal' arctic

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ARTICLE INFO

Article history:
Available online

ABSTRACT

The 'New Normal' Arctic ecosystem and the reliance of indigenous people on marine mammals for subsistence makes urgent the need for a comprehensive marine mammal health monitoring program linked to regional ocean observing systems. An Arctic-focused Marine Mammal Health Map (MMHM) framework could be initiated via expansion and coordination between regional Ocean Observing Systems and Community-based Monitoring Programs. In the US, this approach would build upon three activities currently supported by the Alaska Ocean Observing System (AOOS): ocean data access, community based monitoring and spatial tools for data visualization. The new MMHM framework would support a more holistic understanding of climate change impacts to ocean ecosystems, aid in the prioritization of management efforts to mitigate impacts to marine mammals and complement marine ecosystem monitoring programs fostered by the Arctic Council and UNESCO. Ultimately, we advocate for the inclusion of MMHM products as 'essential ocean variables' in the Global Ocean Observing System (GOOS).

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A rise in reporting of diseases in marine animals has raised concerns that ocean health is deteriorating (Harvell et al., 1999; Gulland and Hall, 2007). Whether the increase in reports represents a real degeneration in marine mammal health is unclear. This uncertainty is due to a dearth of information on the true incidence of marine mammal diseases and the existence of few long-term records for tracking their health (Gulland and Hall, 2007). These deficiencies result from the absence of directed marine mammal health monitoring and a lack of data integration across disciplines, including ocean ecology (Altizer et al., 2013). Although upper-trophic species are now recognized as sentinels of marine ecosystem variability (Moore et al., 2014), marine mammal health assessment information is currently excluded from the Ocean Health Index[2] and is not in consideration as an 'essential ocean variable' by the Global Ocean Observing System (GOOS).[3]

Wildlife diseases can alter animal population dynamics, result in species' extinction and precipitate ecosystem shifts (Harvell et al., 1999; Post et al., 2013). Wildlife health is in turn influenced by ecosystem disruptions, especially those causing changes in pathogen evolution and transmission, or host metabolism and immunity. The latter are strongly impacted by nutritional status, which in turn is influenced by prey availability and environmental conditions (Post et al., 2013). Among emerging marine mammal pathogens, the majority are zoonotic (Tryland et al., 2013); i.e., transmissible to humans. Pathogens isolated during recent large die-offs of marine mammals (termed Unusual Mortality Events, UME, in the U.S) have had the potential to cause disease in humans. For example, in 2011 a UME of 162 seals in the northwest Atlantic was caused by avian influenza H3N8, indicating emergence of a novel viral strain capable of infecting mammals, thus potentially humans (Anthony et al., 2012). In addition to pathogens, UMEs can also be caused by toxins. For example, in 1998 over 400 California sea lions died from ingestion of domoic acid, a biotoxin produced by algae that also causes neurological disorders in people (Scholin et al., 2000).

In 2011, a UME in Arctic seals and walruses was characterized by skin lesions and mortality, the cause of which remains unknown.[4]

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[2] http://www.oceanhealthindex.org/.

[3] http://www.ioc-goos.org/index.php?option=com_content&view=article&id=431:sustained-and-systematic-monitoring-of-the-biological-and-biogeochemical-ocean-defining-essential-ocean-variables&catid=67&Itemid=100106&lang=en.

[4] http://alaskafisheries.noaa.gov/protectedresources/seals/ice/diseased/factsheet112211.pdf.

http://dx.doi.org/10.1016/j.ocecoaman.2014.08.011
0964-5691/Published by Elsevier Ltd.

The timing of this Arctic UME in the months following the Fukushima Daiichi nuclear disaster raised concern over potential effects of radiation, including risks to human health for indigenous people dependent upon these animals for food. Furthermore, this UME coincided with reports of the Arctic marine ecosystem entering a 'New Normal' state (Jeffries et al., 2013), characterized by dramatic loss of sea ice, rising sea temperatures and concerns about ocean acidification (IPCC AR5, WGII[5]). The ecological consequences of this ecosystem shift are just beginning to be evaluated (Post et al., 2013), with impacts to and resilience of marine mammal species uncertain (Burek et al., 2008; Moore and Huntington, 2008). Investigators agreed that determining the cause of the Arctic UME could have been aided by concurrent data on ecosystem status and baseline pathogen prevalence.

While the impacts to marine mammal health are yet unclear, animals are responding to the 'New Normal' Arctic ecosystem. For example, in response to extreme seasonal sea ice retreats, walruses now haul out by the thousands along the NW Alaska coast in late summer (Jay et al., 2012) and temperate cetacean species routinely occur north of the Bering Strait (Clarke et al., 2013). In 2010, satellite tagged bowhead whales from Atlantic and Pacific populations met in the Northwest Passage, an overlap thought precluded by sea ice since the Holocene (Heide-Jørgensen et al., 2012). Changes such as these will alter the risk of infectious disease and exposure to toxins for arctic marine mammals (Burek et al., 2008). However, integration of information from local observations and across science disciplines is required to evaluate impacts to and vulnerability of marine mammal populations.

In the 'New Normal' Arctic, marine mammals also face increasing risks from offshore anthropogenic activities (Reeves et al., 2014). The rapid decline in seasonal sea ice has spurred interest in commercial shipping and offshore industrial development. These activities expose marine mammals to various novel stressors including ship collision, toxins and invasive species from ballast water, increased underwater noise and the potential for exposure to oil and to dispersants in the case of an accident. Potential impacts of commercial shipping on marine mammals has received focused attention from both the Arctic Council and the International Maritime Organization, during development of a Polar Code for safe maritime operations.[6] Recommendations on how to mitigate these negative impacts often include the need for sustained monitoring to "track responses" to disturbance (Reeves et al., 2014). However, unless observed responses are linked to broader studies of marine mammal and ocean health it will be impossible to clearly link cause and effect.

The concept of 'One Health', the idea that human and animal health are connected and both affected by the environment, is becoming widely accepted (Gibbs, 2014; Sleeman, 2013). In terrestrial ecosystems, studies on disease prevalence and epidemiology have revealed the impacts of climate change on animal health (Altizer et al., 2013; IPCC AR5, WGII[5]). A similar approach is needed to investigate the effects of climate change on marine mammal health. The question is: how do we do this?

One approach is to establish a framework whereby existing observation and research programs in Oceanography, Ecosystem Processes, and Marine Mammal Health are linked to foster information flow across disciplines (Fig. 1). In this model, oceanographic conditions such as sea temperature and chemical composition are connected to measures of marine mammal body condition and contaminant burdens via investigations of ecosystem processes. A step toward more formal tracking of Marine Mammal Health in the

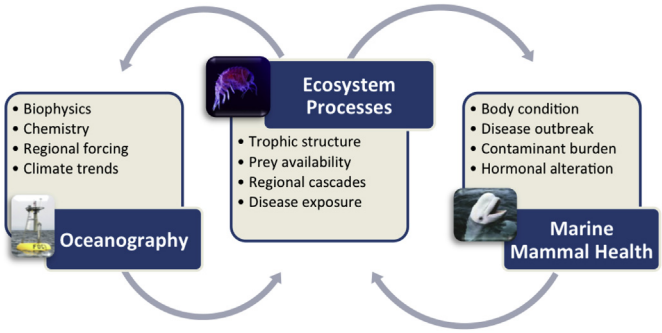

Fig. 1. Conceptual diagram of Marine Mammal Health Map (MMHM) framework showing links and feedbacks among research and observations focused on Oceanography, Ecosystem Processes and Marine Mammal Health.

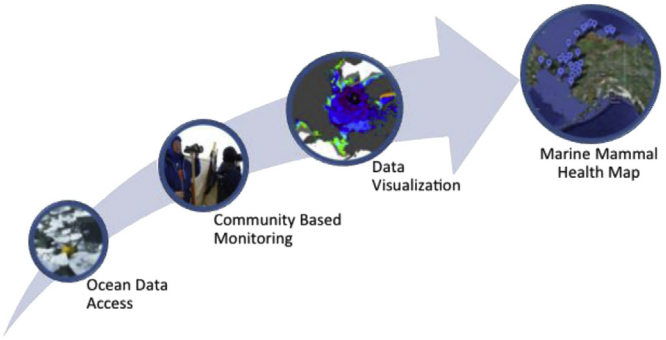

Fig. 2. Development of an arctic-focused Marine Mammal Health Map (MMHM) framework, via expansion and coordination of activities supported by the regional Alaska Ocean Observing System http://www.aoos.org/.

context of Ocean Health is underway in collaboration with the Central and Southern California Coastal Ocean Observing Systems,[7] demonstrating how marine mammal health can be linked to harmful algal blooms and thus to ecosystem and ocean observations.

In the 'New Normal' Arctic, there is an urgent need to integrate existing information to support a more holistic understanding of marine mammal and ocean health. Specifically, the call for a predictive framework to anticipate impacts of climate change on infectious diseases in terrestrial ecosystems (Altizer et al., 2013) should be extended to the marine realm, especially in the Arctic where the climate change signal is strongest and issues of food safety are particularly acute among indigenous people who rely on marine mammals for cultural and nutritional subsistence. The initiation of a Marine Mammal Health Map (MMHM) program is a key step towards developing predictive capability for marine ecosystems (Norris et al., 2014). An arctic-focused MMHM could be initiated via expansion and coordination among three activities currently supported by the Alaska Ocean Observing System (AOOS)[8]: ocean data access, community based monitoring and spatial tools for data visualization (Fig. 2). A northward extension of the community-based Bering Sea Sub-Network[9] would be most advantageous, given that a fundamental goal of that system is to provide "*a means for remote indigenous villages around the Bering Sea to communicate their observations on the environment and*

[5] http://ipcc-wg2.gov/AR5/.
[6] http://www.pame.is/index.php/projects/arctic-marine-shipping/amsa/.
[7] http://www.sccoos.org/projects/mmhealth/.
[8] http://www.aoos.org/.
[9] http://bssn.net/.

subsistence harvest" An arctic-focused MMHM framework would support both a better understanding of climate change impacts to ocean ecosystems and the prioritization of management efforts to mitigate impacts to marine mammals. Further, a program linking marine mammal and ocean health in the Pacific Arctic could provide a foundation for pan-Arctic ecosystem tracking that specifically includes indigenous knowledge, as envisioned by UNESCO[10] and working groups of Arctic Council.[5,11]

The time has come for Big Science in wildlife health (Sleeman, 2013). This can be achieved only by the long-term, systematic collection of health data coupled to routine integration of information from multidisciplinary research programs and local observations supported by governance structures (Sleeman, 2013). We strongly recommend taking immediate steps towards this goal through the development of a MMHM program to track marine mammal health in the context of indigenous knowledge and oceanographic research in a time of rapid alteration of Arctic marine ecosystems. Ultimately, we advocate for the inclusion of MMHM products as 'essential ocean variables' in the Global Ocean Observing System (GOOS).[3]

Acknowledgments

We have benefitted for discussions with numerous colleagues during the preparation of this paper. We thank all those colleagues, but emphasize that the opinions expressed here are ours alone and not those of our affiliate institutions.

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