1. Meeting the Challenge of a Changing Arctic

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1.1 Arctic Marine Biodiversity and Invasive Alien Species: What's at Stake?

The Arctic Ocean and adjacent seas are unique and vulnerable marine ecosystems that present distinct challenges for effective invasive alien species management. The circumpolar Arctic, as defined by Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council, covers 14.8 million km^2 of land and 13 million km^2 of ocean roughly equalling an area three times the size of Europe (CAFF 2002; Figure 1). However, the Arctic Ocean is the world's smallest and is a unique marine ecosystem characterized and influenced by an extreme and highly variable climate resulting in seasonal ice-cover over its continental shelves and year-round ice cover over its center. Due to this ice-cover and the extreme seasonality of solar radiation, the Arctic Ocean experiences wide spatial and intra-annual variation in primary production with low productivity year-round in the central basin and high productivity in the summer season in the outer reaches of the Arctic Ocean and adjacent seas (e.g. Bering and Barents Seas) (Meltofte 2013). The Arctic Ocean is also characterized and influenced by large, seasonal inputs of freshwater from major continental river basins which play a significant role in physically structuring Arctic marine waters. These unique features have resulted in a correspondingly unique flora and fauna with an estimated 2,000 species of algae, tens of thousands of species of microbes and 5,000 marine animal species found in Arctic marine waters (Meltofte 2013), many of which have evolved to be highly adapted to the extreme and highly variable physical and climatic nature of Arctic marine ecosystems (e.g. Polar Bear, Narwhal, Walrus, Arctic Cod). During the short summer breeding season, 279 species of birds, many of which are seabirds, arrive from as far away as South Africa, Australia, New Zealand, and South America to take advantage of the long days and intense period

of productivity (Petersen *et al*. 2004). Several species of marine mammals, including grey and humpback whales, and harp and hooded seals, also migrate annually to the Arctic. Arctic marine ecosystems are also unique in that they have, to date, experienced relatively little resource exploitation and are in a relatively pristine condition.

Figure 1: CAFF Designated Area

From CAFF International Secretariat.

The Arctic, however, has entered into a period of intense and accelerating change with climate change at the forefront. In the past 100 years, average Arctic temperatures have increased at almost twice the average global rate (IPCC 2007). Over the past thirty years, seasonal minimal sea ice extent in the Arctic has decreased by 45,000 km2 /year (Stroeve *et al*. 2007). The magnitude and pace of these changes is already exerting major influences and stresses on Arctic ecosystems. Some of the most rapid ecological changes associated with warming to date have occurred

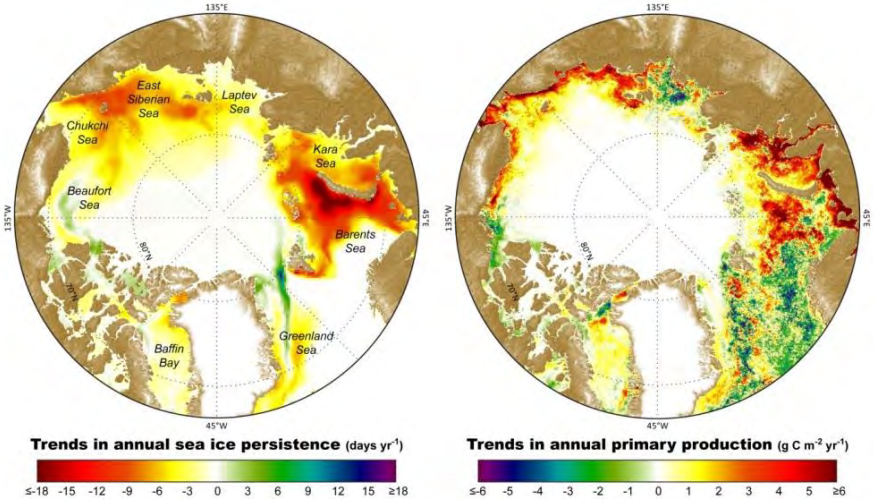
in Arctic marine environments. For example, net marine primary production has increased by an average of 20% across the Arctic between 1998 and 2009 and is strongly correlated with areas of sea-ice retreat (Frey *et al*. 2011; Figure 2). In some areas, the peak of marine primary production is occurring 50 days earlier than average and this may present some challenges (e.g. trophic mismatch[1]) for species who migrate annually to Arctic seas to take advantage of this (Frey *et al*. 2011). In addition, northward movements of non-native, sub-Arctic species have been detected in recent years. For example, in the Beaufort Sea, six fish species have extended their range from the Bering and Chukchi Seas to the Beaufort Sea as sea-ice has retreated and marine environmental conditions have consequently changed (Logerwell 2008). Orca whale sightings in the Eastern and Central Arctic (e.g. Hudson Bay, Hudson Strait, Foxe Basin, James Bay) have dramatically increased in the past 100 years (Higdon and Ferguson 2009; Figure 3).

These rapid changes associated with a changing climate are expected to make Arctic marine ecosystems more vulnerable to invasive alien species. For example, the prospect of ocean acidification in Arctic waters is expected to result in the consequent reduction in the biomass of benthic calcifying organisms which could lead to greater opportunities for invasive alien species to take hold in Arctic marine sediments (Fabry *et al*. 2009). Further, a number of marine invasive species are found in sub-Arctic and temperate waters and, with warming sea-surface temperatures in the Arctic, the potential for their northward expansion increases (de Rivera *et al*. 2011). The northward movement of non-native species and introduction of truly invasive species risks the displacement of native Arctic species through increased competition, direct predation or through the introduction of new animal diseases. Species likely to be most affected by these changes are those with limited distributions, calcifying organisms or with specialized feeding habits that depend on ice foraging and those expected to experience altered recruitment timing and growth rates (Stachowicz *et al*. 2002). Limited functional redundancy in Arctic ecosystems makes them particularly vulnerable as the loss of a single species could have dramatic and cascading effects on an ecosystem's state and function (Post *et al*. 2009). All of these fundamental characteristics of Arctic marine ecosystems and the rapid changes they

[1] Trophic mismatch – changes in seasonality of resource availability lead to constraints for wildlife unable to shift their life histories to take advantage of this shift in timing.

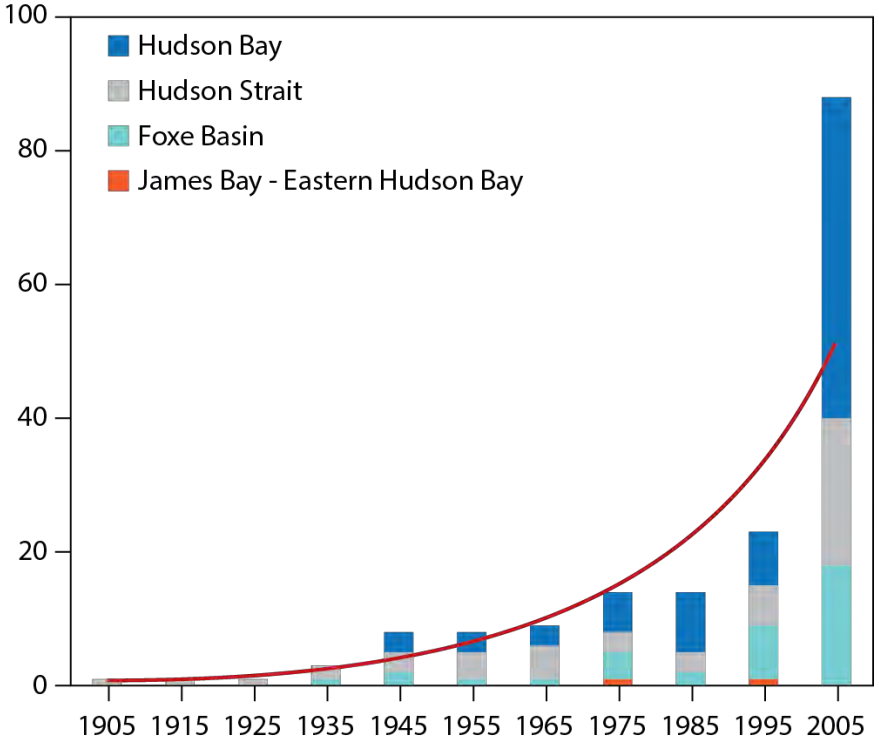
are experiencing, have the potential to make Arctic marine ecosystems and the biodiversity they support more vulnerable to an emerging threat – invasive alien species. A warming Arctic and an ever-expanding global economy also facilitates increased human activity in Arctic marine waters (e.g. shipping, oil and gas exploration, shore-based developments, ports, etc.), which is expected to increase the potential for the transport and establishment of invasive alien species into a degraded Arctic marine ecosystem. Indeed, increases in the amount of ship activity in Arctic waters have been increasing in recent years (Meltofte 2013; Figure 4).

Figure 2: Trends in annual sea ice persistence and net primary marine production



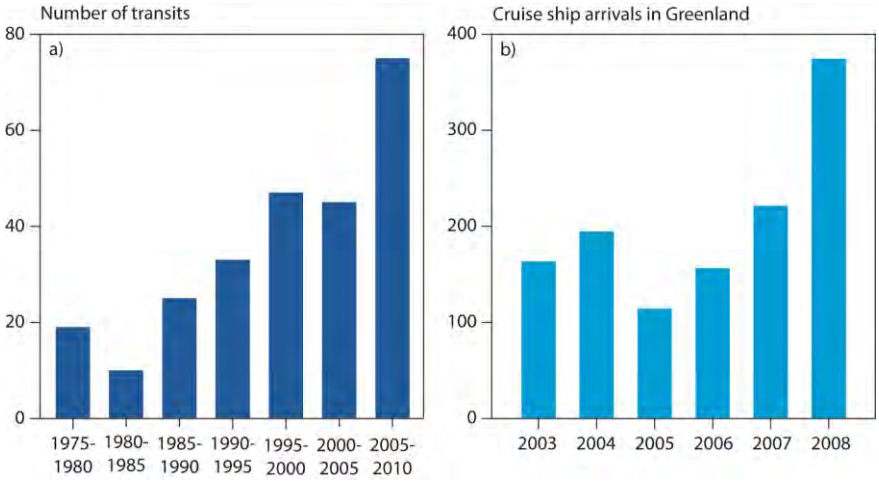
With permission from Frey *et al*. 2011. Arctic Report Card 2011.

Figure 3: Trend in Orca whale (Orcinus orca) observations in the Hudson Bay region, Canada



Sources: Hidgon & Ferguson 2009 and Higdon *et al*. 2012. CAFF 2013. Arctic Biodiversity Assessment: status and trends in Arctic biodiversity. Chapter 14. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

Figure 4: Number of ships a) transiting through the Northwest Passage (five year intervals from 1975 to 2009) and b) landing in Greenland (cruise ships only), from 2003 to 2008



Sources: AMSA 2009 and NORDREG 2009. CAFF 2013. Arctic Biodiversity Assessment: status and trends in Arctic biodiversity. Chapter 14. Conservation of Arctic Flora and Fauna, Akureyri, Iceland.

1.2 Meeting the Challenge of a Changing Arctic

These ongoing and accelerating stressors on Arctic biodiversity provide a challenge in determining how best to respond to and take into account these changes when planning for the sustainable and effective management of the Arctic. To date, most of the focus on Arctic marine conservation issues has been on how to prevent, mitigate and/or adapt to the effects of climate change, over-harvest, contaminants, oil spills, and habitat alteration with little attention paid to the possible impacts and prevention of invasive alien species (Meltofte 2013). And yet, at a global level, invasive alien species are already a major threat to biodiversity, being further exacerbated by climate change (Mainka and Howard 2010) and, in many cases, causing irreversible harm. As a result, many countries are at least beginning to track information on the status of invasive alien species within their borders with many coastal nations having advanced surveillance and prevention programs in place at their port facilities. To date, over 30% of countries have adopted national legislation aimed at controlling invasive alien species (McGeoch *et al*. 2010) including most Arctic countries. However, for the Arctic Ocean, much of which lies beyond national jurisdiction, there remains no clear mechanism to ensure effective prevention, eradication and control of invasive alien species.

The Arctic Council, however, represents an existing cooperative political structure that can be used to achieve effective technical and policy cooperation with regard to the prevention, detection and eradication of invasive alien species in Arctic marine waters. Existing Arctic Council programs, such as CAFF's Circumpolar Biodiversity Monitoring Program (CBMP), have much to offer. For example, the CBMP operates as a pan-Arctic network of scientists and local resource users working together to improve our ability to detect, understand and report on important trends in the Arctic's biodiversity. As part of this, the CBMP has developed the Arctic Biodiversity Data Service (www.abds.is) – an interoperable, distributed, web-based data system where information on native biodiversity and, by extension, invasive alien and non-native species can be quickly and easily shared and presented, serving as a tool to facilitate early detection of emerging trends and thus, effective response. In addition, under Canada's Chairmanship of the Arctic Council from 2013 to 2015, Canada is leading the Safe Arctic Shipping Initiative. While this initiative is currently focused on the prevention of oil spills and other issues, this could present an opportunity to achieve a collaborative and coordinated approach amongst Arctic and non-Arctic nations on the prevention, detection and eradication of invasive alien species. As well, the International Maritime Organization is leading the development of a Polar Code to govern safe shipping practices in Arctic waters and thus, represents another opportunity to implement a coordinated approach to the prevention, detection and eradication of invasive alien species in Arctic marine waters.

In addition to these broad policy initiatives, there is an opportunity to better utilize and organize Arctic residents as key elements of an early detection network. Equipped with GPS enabled smart-phones, Arctic residents, many of which practice traditional lifestyles thereby spending much time on the land, could greatly increase our ability for early detection of potentially invasive as well as non-native species in Arctic waters thus facilitating rapid response.

Beyond this, the negative experience with invasive alien species on most of the rest of the planet means that many examples and tools are available that could easily be adapted for effective use in the Arctic. For example, the Global Invasive Species Database (www.issg.org/database/welcome/) represents an online tool for tracking existing and potential new invasive species and could be a useful tool for risk assessment for the Arctic. Utilizing existing methodology for invasive species indicator development would facilitate better tracking and policy response to emerging trends and issues in Arctic marine invasive species. And finally, Antarctica's approach to detecting and preventing IAS in Antarctic

waters should be investigated to see if these mechanisms and approach could be effectively applied in Arctic waters.

1.3 References

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