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Seasonal vessel activity risk to seabirds in waters off Baffin Island, Canada

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ABSTRACT

Millions of seabirds use the waters off Baffin Island. Considering current and future vessel activity in this region, it is important to understand where vulnerability to anthropogenic threats is highest to enable sound wildlife management and regulatory decisions. Using kernel density analysis on at-sea survey data spanning 1970 to 1983 and 2007 to 2016, we identified marine areas of high density for five of the most abundant species sighted: Dovekie *Alle alle*, Thick-billed Murre *Uria lomvia*, Black-legged Kittiwake *Rissa tridactyla*, Northern Fulmar *Fulmarus glacialis* and Black Guillemot *Cepphus grylle*, in summer (June–August) and fall (September–November). We quantified the level of vessel activity from vessel traffic data spanning 2011 to 2015. Overlapping these data layers, we identified regions where high vessel activity posed the highest risk to these species. Navy Board Inlet, Eclipse Sound, Frobisher Bay, Hudson Strait and the northern Labrador Shelf were consistently identified as areas of highest risk to multiple species of seabirds in summer and autumn. These waters not only encompass important summer foraging areas near colonies and post-breeding/migratory habitat but are also frequently navigated by vessels servicing busy communities. The level of vessel activity we found for the study area is relatively low compared to waters where many Arctic species overwinter (e.g., Thick-billed Murres off Newfoundland and Labrador). However, identifying current high-risk areas in Arctic waters is important for the conservation and management of Arctic seabirds as industrial and commercial development in this region expands and leads to higher levels of vessel activity.

1. Introduction

Seabirds spend most of their lives at sea where they are exposed to anthropogenic threats such as bycatch in fisheries (Hedd et al., 2016; Žydelis et al., 2013; Croxall et al., 2012), oiling from large scale events (Montevecchi et al., 2012; Piatt and Ford, 1996), chronic oiling (Fox et al., 2016; Wiese and Ryan, 2003), wind turbines (Furness et al., 2013; Garthe and Hüppop, 2004; Masden et al., 2009), offshore oil and gas platforms (Ronconi et al., 2015; Wiese et al., 2001), disturbance caused by vessel traffic (Ronconi and St. Clair, 2002; Schwemmer et al., 2011; Velando and Munilla, 2011), and at a larger scale, climate change (Keogan et al., 2018; Croxall et al., 2012). As the cumulative human impacts on the world's oceans increase (Halpern et al., 2015), researchers have begun mapping seabird vulnerability and risk from anthropogenic threats (Fox et al., 2016; Lieske et al., 2014; Renner and Kuletz, 2015). Risk is defined as the probability of adverse consequences (e.g. death, lower reproductive success), and is a product of the probability of occurrence and the expected ecological consequence (Michel et al., 2009; Renner and Kuletz, 2015). To identify marine regions of high anthropogenic risk, two things must be evaluated: species' sensitivity (degree to which a species responds to a pressure) and vulnerability (probability of being exposed to a pressure to which a species is sensitive) (Garthe and Hüppop, 2004; Zacharias and Gregr, 2005), both of which influence the expected ecological consequence.

Regions of high anthropogenic risk to seabirds have been identified in many parts of the world's oceans, but only recently have efforts been made to examine seabird vulnerability to human disturbance in the Arctic, where levels of human disturbance are currently considered to be low (Halpern et al., 2008). To date, most efforts examining vulnerability of seabirds to human activity in the Canadian Arctic have focused solely on a single stressor, marine pollution (Mallory et al. 2015; Braune et al. 2014; Provencher et al. 2014; Trevail et al., 2015), leaving a critical source of potential mortality, the cumulative anthropogenic risk of vessel-related threats, largely ignored. Declining sea ice in the Arctic has led to increased vessel activity in this region (*e.g.*, cargo, passenger, tanker, fishing) within the last 25 years (Pizzolato et al.,

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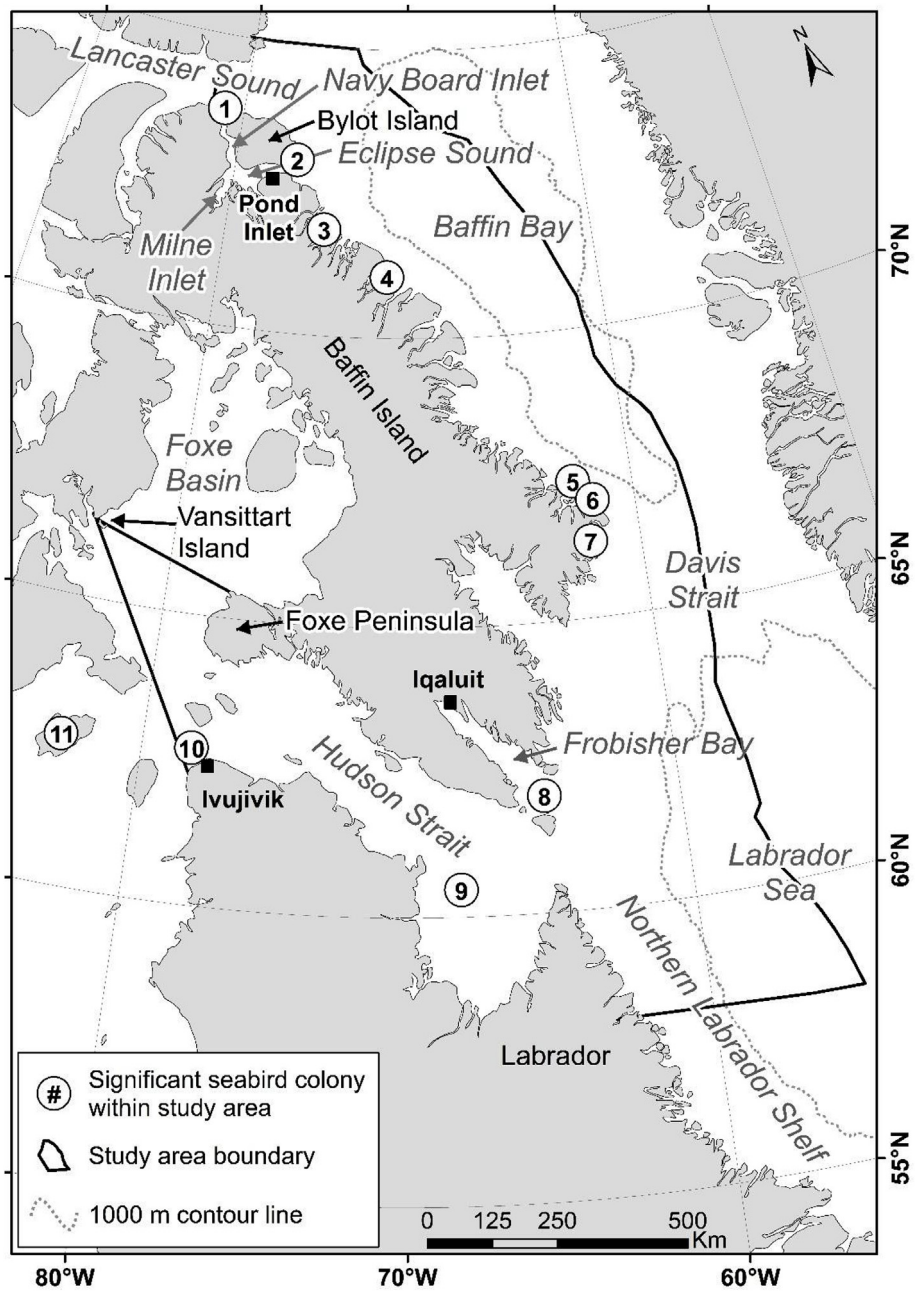

Fig. 1. Water bodies, ports of significance and important seabird colonies with study area.: 1) Cape Hay (Thick-billed Murre, Black-legged Kittiwake); 2) Cape Graham Moore (Thick-billed Murre, Black-legged Kittiwake); 3) Buchan Gulf (Northern Fulmar; 4) Scott Inlet (Northern Fulmar); 5) Cape Searle (Qaqulluit; Northern Fulmar); 6) The Minarets (Akpait; Thick-billed Murre, Black-legged Kittiwake, Northern Fulmar); 7) Exeter Island (Northern Fulmar); 8) Hantzsch Island (Thick-billed Murre, Black-legged Kittiwake); 9) Akpatok Island (Thick-billed Murre); 10) Digges Island (Thick-billed Murre); 11) Coats Island: (Thick-billed Murre).

2016), particularly from increased tourism and resource exploration (Pizzolato et al., 2014).

Increased levels of vessel activity in the Arctic should be of concern since high levels of vessel activity may increase the chances of accidental oil spills; the effects of a catastrophic oil spill on seabirds in Arctic waters is well-documented (Irons et al., 2000; Piatt and Ford, 1996). However, among the most important concerns of vessel traffic is the risk of chronic oiling (Fox et al., 2016; Vollard, 2017), which can lead to high levels of mortality (Wiese and Ryan, 2003) and reduced population growth rates (Wiese et al., 2004). Vulnerability to oiling is based on body size, distribution and life history traits (King and Sanger, 1979), and those species which spend a significant portion of their time on the water, such as alcids, are most susceptible to being oiled (King and Sanger, 1979). Risk of oily discharges from vessels in Canadian waters may increase with proximity to ports and harbours, as seen off the coast of British Columbia, Canada (Serra-Sogas et al., 2014) and is associated with higher levels of vessel activity (Bertazzon et al., 2014). As vessel activity increases in many parts of the Arctic (Huntington et al., 2015; Lasserre and Têtu, 2015; Pizzolato et al., 2016), and Arctic sea routes become more navigable (Aksenove et al., 2017; Smith and Stephenson, 2013; Stephenson et al., 2013), there is a growing need to identify areas with spatiotemporal overlap with seabirds.

Another concern within Arctic waters is the risk of incidental take in emerging fisheries (Chardine et al., 2000; Hedd et al., 2016). Arctic species such as Black-legged Kittiwake *Rissa tridactyla* and Northern Fulmar *Fulmarus glacialis* are particularly vulnerable to incidental take by fisheries, particularly longline operations (Mallory, 2006; Montevecchi, 2002; Žydelis et al., 2013). Other Arctic species, such as