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# Potential impacts of offshore oil spills on polar bears in the Chukchi Sea☆

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ABSTRACT

Sea ice decline is anticipated to increase human access to the Arctic Ocean allowing for offshore oil and gas development in once inaccessible areas. Given the potential negative consequences of an oil spill on marine wildlife populations in the Arctic, it is important to understand the magnitude of impact a large spill could have on wildlife to inform response planning efforts. In this study we simulated oil spills that released 25,000 barrels of oil for 30 days in autumn originating from two sites in the Chukchi Sea (one in Russia and one in the U.S.) and tracked the distribution of oil for 76 days. We then determined the potential impact such a spill might have on polar bears (*Ursus maritimus*) and their habitat by overlapping spills with maps of polar bear habitat and movement trajectories. Only a small proportion (1–10%) of high-value polar bear sea ice habitat was directly affected by oil sufficient to impact bears. However, 27–38% of polar bears in the region were potentially exposed to oil. Oil consistently had the highest probability of reaching Wrangel and Herald islands, important areas of denning and summer terrestrial habitat. Oil did not reach polar bears until approximately 3 weeks after the spills. Our study found the potential for significant impacts to polar bears under a worst case discharge scenario, but suggests that there is a window of time where effective containment efforts could minimize exposure to bears. Our study provides a framework for wildlife managers and planners to assess the level of response that would be required to treat exposed wildlife and where spill response equipment might be best stationed. While the size of spill we simulated has a low probability of occurring, it provides an upper limit for planners to consider when crafting response plans.

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The extent of summer sea ice in the Arctic Ocean has been greatly reduced over the past decade due to global warming (Overland and Wang, 2013; Stern and Laidre, 2016). Further declines are expected in the coming decades until sea ice is nearly absent during summer months in the Arctic (Laliberté et al., 2016; Overland and Wang, 2013). As a result, the Arctic Ocean ecosystem is anticipated to experience extensive ecological change (Post et al., 2013) including population reductions (Kovacs et al., 2011; Regehr et al., 2016), and the northward range expansion of marine species (Wassmann et al., 2011). Reduced summer sea ice extent will also increase human access to the Arctic Ocean. Shipping routes that were once impassible due to sea ice will soon become viable (Smith and Stephenson, 2013) and areas once inaccessible for offshore oil and gas development will soon be ice-free long enough to allow for development (Harsem et al., 2015; National Research Council, 2014). These anthropogenic activities increase the potential for oil spills to impact the marine ecosystem.

While economic opportunities in the Arctic Ocean are increasing, there is concern that the ability to respond to marine oil spills is insufficient given the limited infrastructure in the region (Knol and Arbo, 2014; National Research Council, 2014). Thus, if an offshore spill were to occur, it is unlikely that it could be contained early enough to limit exposure to wildlife. There is currently limited information on what impact an offshore oil spill would have on marine mammal populations in the Arctic (Huntington, 2009). The information that does exist suggests varying levels of impact across species (Geraci and Smith, 1976; Hurst et al., 1991; Øritsland et al., 1981).

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Given the potential negative consequences of an oil spill on marine wildlife populations in the Arctic, it is important to develop and maintain plans on how to respond to oiled wildlife in the event of a spill. This requires an understanding of how habitat could be affected, what areas are most likely to be contaminated, and how many animals might be exposed to sufficient oil to require capture and decontamination. Such proactive assessments will help those responsible for clean-up efforts anticipate the level of response and equipment that will be required, and where that equipment should be stationed for efficient deployment during oil spill response efforts. This information would also help provide wildlife managers with an understanding of the population-level effects on a species if an offshore spill occurred.

Most studies examining impacts to wildlife from energy development are retrospective (Northrup and Wittemyer, 2013) and thus unable to help mitigate the impact if an accident occurs. Indeed, few studies have attempted to understand the magnitude of impact an offshore oil spill in the Arctic would have on wildlife, although Amstrup et al. (2006) conducted a study to determine how many polar bears (*Ursus maritimus*) might be exposed to oil if a spill were to occur in the Beaufort Sea. They estimated 0–74 polar bears (with a skew towards lower values) could be exposed to oil from a 5900 barrel spill in September or October. While there have been planning efforts initiated for how to respond to an oil spill in the Chukchi Sea by management agencies (U.S. Fish and Wildlife Service, 2015), a similar analysis to Amstrup et al. (2006) has not occurred in the adjacent Chukchi Sea even though there have been offshore exploratory activities in recent years and increased interest in the oil potential of the region (Verzhbitsky et al., 2012).

In this study we attempt to understand the impact to polar bears in the Chukchi Sea from a worst case discharge (WCD) oil spill and inform management agencies of the magnitude of impact such a spill might have. Companies are required to develop WCD scenarios as part of any offshore oil and gas development in U.S. federal waters. Although unlikely to occur, they represent a reasonable worst case scenario to estimate potential impacts to wildlife. Therefore, our objectives were to simulate WCD oil spills at two different sites in the Chukchi Sea to determine, 1) the probability of oil reaching different areas of the Chukchi Sea, 2) how long it would take for oil to reach those regions, 3) the amount of important polar bear habitat that could be exposed to oil, and 4) what proportion of the polar bear population might come into contact with oil. Our goal was not to estimate the actual number of animals or area of habitat that would be affected by an offshore oil spill, but rather to determine what levels might be reasonable to expect if a WCD spill were to occur.

## 1. Materials and methods

### 1.1. Oil spill modeling

We modeled hypothetical oil spills at two locations in the Chukchi Sea (Fig. 1). Exploratory drilling occurred near the first site (i.e., within ~20 km), Crackerjack (N71.13, W166.14), in the 1980s and was also listed as a site for exploration drilling by Shell Gulf of Mexico Inc. in their 2010 exploratory drilling program (Minerals Management Service, 2009). The second site was located within the Yuzhno Chukotsky Lease block southeast of Wrangel Island in Russian waters (N70.20, W175.56; Fig. 1). This location was created under a cooperative agreement with Rosneft and ExxonMobil as part of a plan to develop hydrocarbon resources in the Russian Arctic shelf (Exxon Mobil, 2013). In recent years, there has been increased interest in offshore drilling in the Russian Arctic, including lease areas in the Chukchi Sea (Tippee, 2013). While neither site we analyzed is currently being actively developed, the waters adjacent to the sites provide important habitat to polar bears (Rode et al., 2015; Wilson et al., 2014). It is therefore an opportune time to determine what level of impact an offshore spill at each site could have on polar bears to help inform future offshore drilling plans in the region and response efforts in the event a large oil spill ever occurred.

A full description of the oil spill modeling efforts we employed are detailed in French-McCay et al. (2017a). Here we provide a brief synopsis. To model oil spills at these locations, we used results of modeling by French-McCay et al. (2017a), which employed the OILMAPDEEP model (Crowley et al., 2014; Spaulding et al., 2000) to calculate the behavior and dilution of the released oil and gas mixture in the buoyant plume from such a discharge near the release site. Those model results indicated that the plume from discharges at both locations would surface within an hour of release. Thus, the oil spill model was initiated from just below the water surface (1m) with a median droplet size of 1817 microns (French-McCay et al., 2017a). To model the transport, fate, and distribution of oil, we used the Spill Impact Model Application Package (SIMAP; French-McCay, 2004; French-McCay et al., 2017a). The SIMAP model has been validated with numerous actual oil spills (French-McCay et al., 2017b, 2004; French and Rines, 1997; McCay, 2003) and has been used in many risk assessment studies (French-McCay et al., 2005), including in the Arctic (French-McCay et al., 2014; French-McCay et al., 2017b). In the model, the distribution and fate of oil was primarily affected by wind, ocean currents, and sea ice. Oil moves with the surface currents and wind for water with no ice, or that has sea ice with a concentration <30%. If sea ice concentration is $\geq$ 30%, however, ice is assumed to have ample spatial coverage to trap oil between floes and oil is transported with the ice using ice-movement velocities. If oil came into contact with land fast ice (i.e., ice that is affixed to land and does not move), the model assumed the oil became entrapped and remained immobile until the ice melted and pack ice retreated north. In the presence of sea ice, oil weathering processes (e.g., evaporation and emulsification) and physical processes such as spreading and entrainment are slowed proportionate to the degree of ice coverage. See Appendix S1 for details on sources of environmental data (e.g., currents, ice, and wind) used in the SIMAP model.

We simulated spills as underwater blowouts releasing 25,000 barrels of Prudhoe Bay crude oil per day for 30 days beginning in October during autumn (i.e., the transition period between open water and the ice-covered seasons). This discharge scenario represents the WCD described in the Chukchi Sea Regional Exploration Program Oil Spill Response Plan (Shell Gulf of Mexico Inc., 2015). Worst case discharges are defined by the Bureau of Ocean Energy Management (BOEM) as the daily rate of an uncontrolled flow of oil from all producible reservoirs into the open wellbore. Because a similar WCD analysis was not conducted for the simulated Wrangel spill site, we used the same WCD scenario as defined for the Crackerjack site.

We tracked the fate and distribution of released oil for a period of 76 days after the initial blowout. We employed a stochastic approach to estimating the probable trajectory and distribution of spills from each site by sampling 100 random start times in October between 2008 and 2014 and using water current, ice, and wind data that corresponded to the period of the selected start date (see below). The random start time allowed for the same type of spill to be analyzed under varying conditions. We therefore were able to estimate probabilities of the distribution of oil based on a range of realized environmental conditions. The output of the model was the daily distribution of individual spillets (i.e., discs with a given radius and mass of oil). We then synthesized these spillets to obtain the daily mass of oil within a grid of 1 $km^2$ pixels.

We classified oil into two different classes (i.e., medium and

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