HOW MUCH POLAR BEAR MATERNAL DENNING HABITAT COULD BE ALTERED BY OIL AND GAS EXPLORATION IN THE ARCTIC NATIONAL WILDLIFE REFUGRE

by

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Abstract

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Brandie Horn

There are 19 subpopulations of polar bears worldwide, two of them are located in the State of Alaska, United States: the Chukchi Sea (CS) and the Southern Beaufort Sea (SBS) populations. The SBS population is located between Icy Cape, Alaska and the eastern Canadian border. This area is the coastal plains of the Arctic National Wildlife Refuge and is designated at Area 1002. Area 1002 has been a place of interest for oil and gas exploration since the 1980's. Since then, there has been a push and pull over this area to stay undeveloped and identified as a wilderness or for it to be opened up to oil and gas exploration. Due to legislation in 2017, Area 1002 was opened for leasing to oil and gas exploration. Area 1002 is the coastal plains of the Arctic National Wildlife Refuge which has taken on increasing importance for the land based maternal den sites for the SBS polar bears. Climate change has diminished availability for maternal denning habitat on the ice because of changes in sea ice. In this study governmental and non-governmental research data was used to create an ArcGIS map that displays how much of the maternal denning habitat could be altered by the industrial infrastructure of oil and gas exploration. This study found that Area 1002 has 945 acres suitable for maternal den sites. The footprint of the industrial infrastructure according to the Audubon scenario map is 4,575 acres and would disturb 3 acres of maternal denning habitat.

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It has been a long road; it all began in 2020. I had every intention to graduate the following year. I was able to present and even participate in the Zoom graduation for 2021. Then life just happens, but here we are at the end of 2023 moving into 2024 and I have finally completed my Masters in Environmental Studies!! There is no way I could have done this alone. Mike Ruth thank you for all your support and interest in my topic during the ArcGIS process. Averi, thank you for being available and sending me words of motivation, understanding, and support. Kevin, thank you for being flexible throughout this process. Ralph, thank you is not a big enough statement for everything you have done for me over the years. I am very grateful to have you as my reader and advisor. Your dedication, encouragement, patience, and overall "let's get this done" attitude has been my drive to keep moving forward. And here we are. You are amazing! My best friend and husband Chris your support, nurturing, and overall understanding has made this whole adventure manageable. Without your support and motivation none of this would have been something I thought I could achieve. I love you. I also have to thank our fur babies Turco, Phoebe, and Darringer. You're such good companions, always there to make me smile when I am stressing and catch my tears when I am overwhelmed. Thank you all!

Chapter 1: Introduction

Author's Note

My interest in polar bears began in the fall of 2010. I was transitioning from the United States Marine Corps (USMC) back to the civilian world and had no long-term goals other then I wanted to work with animals. Luckily, a few months before your contract ends, the USMC sends you to classes that help you plan for the next steps. I went to these classes with a fellow Marine that I worked with throughout my career. In class one day we were talking about what would happen next and I told him that I had no clue other than I wanted to work with animals. He pulled out his phone and shared some photos of a friend that works for an organization (I can't remember the name) tagging brown bears. That was it, I wanted to work somewhere I could collect data on bears or at least some other predator. I immediately started searching the internet for ideas, where to start, who to talk to, and most importantly what animal would keep me passionately making forward progress.

During this search I stumbled upon a (new to me) warning of global warming. I was a skeptic. I thought the planet has cycles, and we were just going through one. What really caught my attention was the picture next to the headline, it was a polar bear. He was strolling across the sea ice looking me in the eyes. That was my "aha" moment. I instantly did what anyone else would, started looking for documentaries on polar bears. I remember the first series I watched, *Planet Earth* with David Attenborough, this was my first impactful learning experience about global warming and how it was affecting the animal world. After learning that the Arctic and Antarctic have been experiencing impacts more rapidly, I knew that the polar bear would be my driving force for years to come, and it has. Throughout my educational career I have used every opportunity to learn about polar bears and their environment. I am now living in Alaska (the only

state in the United States of America with polar bears), finishing my Master thesis, and looking forward to continuing my pursuit in career with polar bears.

Thesis Introduction

Throughout my research I have found that there are several factors that impact the population status and dynamic of polar bears. Polar bear populations span throughout the Northern Hemisphere with a range limited to areas where sea ice occurs (Amstrup, 2003). Currently, 19 distinct subpopulations of polar bears live in five different countries and carry an international status of vulnerable (Durner, Laidre, & York, 2016). They are the only bear classified as a marine mammal. This is because they are among the most ice-dependent Arctic marine mammals. They require sea ice as a substrate for long-distance movements, mating, some maternal denning, and for access to their primary prey (ringed and bearded seals). Climate change is reducing polar bear habitat and access to food. The reduction in sea ice has decreased the area for polar bears to hunt and den. Their main source of prey, the ring and bearded seals, are also ice depended and are becoming harder for the polar bear to hunt in the traditional ways and locations. Tourism has played a role in creating more human encroachment on their habitat. Hunting has historically placed pressures on some subpopulation but has since been regulated. All of these factors contribute to the overall well-being of the species.

Arctic Sea Ice

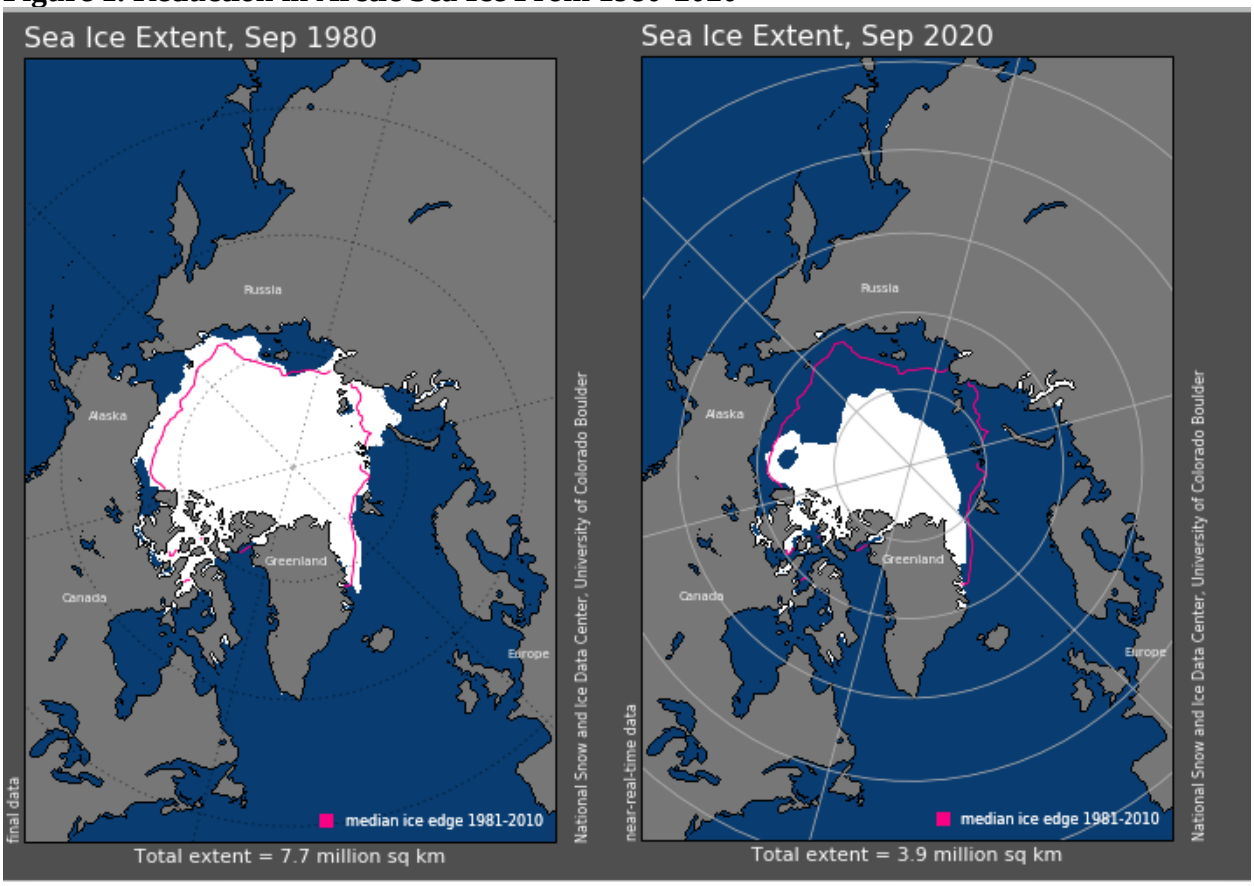
According to the Intergovernmental Panel on Climate Change (IPCC) there is no question whether the global climate is changing. While changes in the global climate are natural the current rate of change is accelerated due to anthropogenic activities. Activities, such as burning fossil fuels, are releasing excess carbon dioxide and other greenhouse gases into the atmosphere (Archer, 2016). These greenhouse gases absorb infrared radiation and trap heat in the

atmosphere. This is causing the rate of change in the global climate to increase, and the last decade was the warmest on record (Greene & Jacobs, 2021). This shift in the global climate is increasing global temperature, warming the oceans, shrinking ice sheets, causing extreme weather events, increasing sea level rise, and reducing Arctic Sea ice.

One thing that makes polar bears particularly vulnerable to changes in sea ice is their hunting strategies. They eat as much as they can in spring and summer, when seals are having their pups, putting on fat that will help them get through the rest of the year. As the ice is missing or thinner and drifting longer distances, polar bears cannot catch as many seals. This causes them to use more energy than they can replenish, reducing their overall health and chances that a females will reproduce.

Arctic sea ice extent has reduced at an average rate of 13% per decade (Greene & Jacobs, 2021). The reduction of Arctic Sea ice minimums from 1980 to 2020 can be seen in Figure 1. While Arctic Sea ice has natural seasonal variation in extent with March having the largest range and September having the smallest range (Stroeve, et al., 2008), reports have shown that September Arctic Sea ice extent has declined by 40% over the last four decades and its thickness has reduced by 85% from 1975 to 2012 (Semmler, et al., 2016).

Figure 1. Reduction in Arctic Sea Ice From 1980-2020



Note. Arctic sea ice reaches its minimum each September, declining at a rate of 13% per decade from 1980 to 2010. Using the sea ice index tool from the National Snow and Ice Data Center (NSIDC) the above maps show a comparison of September sea ice in 1980 and 2020 (Fetterer, Knowles, Meier, Savoie, & Windnagel, 2017 updated daily). The pink line shows the median ice edge from 1981-2010.

Arctic sea ice changes have been associated with nutritional stress on individuals and populations of polar bears (Hunter, et al., 2010). For example, due to the summer retreat of sea ice from continental-self waters the Southern Beaufort Sea polar bear population is forced to either remain with the lingering sea ice or move to land (Bromaghin, et al., 2015). Most of the Southern Beaufort Sea population remains with the sea ice. The growing distance between the shore and the summer pack ice increases the potential for long-distance swimming that is energetically expensive adding to nutritional stress causing reduced body size, growth, and survival of young (Bromaghin, et al., 2015).

Food Source

Polar bears' main food source are ringed and bearded seals. Polar bears hunt them in two different ways, both are dependent on the sea ice. Seals cut breathing holes in the ice using the sharp claws on its fore flippers and its teeth. They keep these breathing holes open all winter to give them the ability to come to the surface and breathe. Polar bears locate these breathing holes using their sense of smell and wait for the seals to surface at these openings. Polar bears also stalk their prey while they are basking on ice while they are sleeping. The bear will slowly crawl or swim to the seal and with an eruption of speed attacks the seal. During spring polar bears can build up their fat reserves before winter by preying on seal pups born on the sea ice. As the Arctic continues to warm and sea ice is reduced there are longer ice-free periods. This causes the polar bear to stretch the limits of their fat reserves.

Tourism

In 2008, the term "last chance tourism" was created, connecting travelers to the North with a desire to see these animals before they are gone (D'Souza, Dawson, & Groulx, 2021). Tourists are drawn to locations whose landscapes, natural systems, or cultures are vulnerable to changes caused by global warming or other anthropogenic factors. With climate change continuing to negatively impact polar bears, more tourists are travelling to northern regions for a chance to see them in their natural habitat before they are extinct (D'Souza, Dawson, & Groulx, 2021). This creates a paradox due to the dependence on energy-intensive modes of transportation and accommodations. Increasing industry, tourism, and commerce in the Arctic brings humans and polar bears into closer proximity and increases the potential for negative interaction (Durner, Laidre, & York, 2016) The number of cruise ship passengers has increased from 15,000 in 1997

to 30,000 in 2015 and winter tourism (including snowmobiling) has also doubled in recent years (Durner, Laidre, & York, 2016).

Hunting

Indigenous people have harvested polar bears for over 10,000 years (Derocher & Lynch, 2012). Polar bears provide Indigenous people with meat, raw material for clothing, and handicrafts. Hunting the polar bear promotes pride, prestige, and accomplishment for the Native hunters (U.S. Fish and Wildlife, 2017). Since polar bears spend most of their lives on the sea ice dependent on it for food and habitat, they are the only bear species to be classified as marine mammals. Being classified as a marine mammal allows them protection under the Marine Mammal Protection Act (MMPA) of 1972 The MMPA prohibited hunting of polar bears in the United States with an exemption of Alaska Natives. This exemption allows Alaska Natives living in the coastal communities to hunt polar bears for subsistence purposes and must harvest the bears in a non-wasteful manner (U.S. Fish and Wildlife, 2017).

A sustainable harvest quota has been established to ensure Indigenous people can still exercise their right to this culturally valuable species. This quota is usually between 3% to 5% of the population (Derocher & Lynch, 2012). The percentage varies depending on population, reproductive and survival rates, and proportions of females taken. If only females are harvested the percentage is reduced to 1.5% of the population (Derocher & Lynch, 2012).

Alaskan Polar Bears

In August of 2020, plans were finalized to allow drilling in Area 1002 of the Arctic National Wildlife Refuge (ANWR) coastal plains located in northern Alaska next to Canada. Under the plan, approximately 1.6 million acres of the coastal plain would be opened to oil and gas operations (HR1, 2017). According to United States Fish and Wildlife Services (USFWS), 77%

of the Area 1002 has been designated as critical denning habitat for the Southern Beaufort Sea (SBS) subpopulation of polar bear (U.S. Fish and Wildlife Services, 2010). This provided the context of the research to focus of my thesis on the SBS subpopulation and the specific area of ANWR, Area 1002. Since the decision made in August of 2020 a change in administration for the country resulted in the suspension of leasing land tracts in ANWR Area 1002 as of June 2021 (U.S. Department of the Interior, 2021). This decision to suspend activity in Area 1002 happened after 11 tracts of land were leased out. According to the United States Department of the Interior Bureau of Land Management approximately 552,000 acres totaling roughly $14.4 million dollars were leased out (U.S. Department of the Interior, 2021). This suspended any activity from taking place on these leased tracts. This tension and controversy over the decision to drill or not to drill is a historic trend in this location.

In 2010, the northern coast of Alaska was designated as critical denning habitat for the two populations for polar bear that live withing the United States of America, the Chukchi Sea (CS) and the Southern Beaufort Sea (SBS) populations (U.S. Fish and Wildlife Services, 2010). This is due in part to the fact that pregnant female polar bears use this area to create maternal dens during the winter. This brings me to my research question, how much polar bear maternal denning habitat could be altered by oil and gas exploration in Area 1002 of the Arctic National Wildlife Refuge, Alaska. This information could be used as a platform for understanding how this added impact could place further stress to SBS polar bear subpopulation.

Conclusion

In conclusion there are many factors that contribute to the changes in the polar bears' habitat and food availability which influences their overall population dynamics. This thesis will focus on the maternal denning habitat located in Area 1002 of the Arctic National Wildlife Refuge

(ANWR). Maps will be created from preexisting data collected on maternal den sites within Area 1002 and a scenario map created by the Audubon Society of what the industrial infrastructure (i.e. oil fields, roads, pipeline, water treatment plants, docks, and gravel mines) could look like Area 1002. After analyzing this data, the results could show how much denning habitat could be at risk.

Within the following chapters the information will be geared toward the SBS population in Alaska. Chapter 2 will bring together the knowledge gained from the literature review specifically pertaining to Area 1002 and the SBS subpopulation of polar bears. It will go over the legislative history of Area 1002, population dynamics of the SBS subpopulation of polar bears, and how the SBS polar bear use the land in Area 1002. Chapter 3 will describe how the data for this study was collected, details about the study area, explain how the data was processed within the Geographic Information System (GIS). Chapter 4 will use maps to examine the results and findings from the data processed in GIS. Chapter 5, the final chapter, will discuss the important takeaways from the research along with ideas for future research.

Chapter 2: Literature Review

This chapter of the thesis examines the relevant literature as it pertains more specifically to the research question: Will the infrastructure from the proposed oil and gas exploration in Area 1002 of the Arctic National Wildlife Refuge located in Alaska reduce the availability of maternal denning habitat for the Southern Beaufort Sea population of polar bears? First, a history of Area 1002 within ANWR will set the stage for understanding the push and pull of Area 1002 within changing policy agendas proposed by Presidents and the United States Congress to be used for oil and gas extraction. Second, background on the two polar bear population within the United States of America, Chukchi Sea and Southern Beaufort Sea polar bear populations will be

explored. While both of these populations are located in Alaska the focus will begin to narrow onto the Southern Beaufort Sea population dynamics and denning behaviors because this is the population that depends on Area 1002. Lastly, the importance of Area 1002 to the Southern Beaufort Sea polar bear population in Alaska will be explained.

Legislation and ANWR

The Arctic National Wildlife Range (ANWR) was first established in 1960 due to the nationwide interest in preserving the area's wildlife, wilderness, and recreational values (PLO 2214, 1960). In 1980, the Alaska National Interest Lands Conservation Act (ANILCA) doubled the Range's size and redesignated the area as the Arctic National Wildlife Refuge (ANWR), affirming the strong national interest in preserving this area. The ANILCA also contained a provision, Section 1002, mandating study of the refuge's coastal plain for potential oil and gas development, making ANWR the subject of one of the nation's longest and most contentious environmental debate (Bengston, Fan, & Kaye, 2010). This section of the ANILCA is what gave the name of Area 1002 to the coastal plains within ANWR. There have been numerous pieces of legislation documenting this push and pull over Area 1002 for oil and gas versus designating it wilderness. The following section will go through the history of said controversy.

Alaska Native Claims Settlement Act

In 1971, Congress enacted to Alaska Native Claims Settlement Act (ANCSA). The purpose of the ANCSA was to distribute land to Native corporations created by the Act (PL 92-203, 1971). The ANCSA directed the Bureau of Land Management (BLM) to transfer 45.5 million acres of public land to village and regional Native corporations. Native village corporations were entitled to the surface lands and Native regional corporations were entitled to selected mineral right. Typically, regional corporations received the mineral rights beneath the

village corporation surface lands (U.S. Congressional Research Service, 2018). Pre-1971 refuges were not available and other lands were substituted for them. ANCSA Section 22(g) provided that surface lands that were transferred within a refuge created before 1971 were subject to that refuge's regulations. The restriction on subsurface selection and section 22(g) limited Native claims regarding oil development (U.S. Congressional Research Service, 2018).

Alaska National Interest Lands Conservation Act

In 1980, Congress enacted the Alaska National Interest Lands Conservation Act (ANILCA), this expanded the Arctic National Wildlife Range to the south and west by 9.2 million acres and renamed the area the Arctic National Wildlife Refuge (ANWR) (PL 94-487, 1980). Section 702(3) of ANILCA redesignate the original 9 million acre defining 8 million acres of the original Wildlife Range as wilderness area and 1.57 million acres of coastal plains as Section 1002 (PL 94-487, 1980). This will henceforth be known as Area 1002. This started the debate over the use of Area 1002, one group wanted it to be designated as wilderness area and the other group supported energy development. The Department of Interior completed a study in 1987 known as the 1002 Report or Final Legislative Environmental Impact Statement and recommended Area 1002 be open for full energy development (Department of the Interior, 1987). For the future of Area 1002, the most significant aspect of ANILCA is section 1003. This section prohibits oil and gas production along with leasing or other development leading to production of oil and gas within the whole ANWR, unless authorized by an Act of Congress (PL 94-487, 1980).

Chandler Lake Agreement of 1983

Per the ANCSA, the Kaktovik Inupiat Corporation (KIC) had selected surface rights of lands near the northern boundary of ANWR's Area 1002 amounting to three townships. Due to

ANWR being created before ANCSA, the Arctic Slope Regional Corporation (ASRC) was prohibited from the mineral rights below the three townships (U.S. Congressional Research Service, 2018). ANILCA authorized KIC to select more lands within Area 1002. These additional 19,500 surface acres along with the three townships already owned by KIC brought the total to 92,000 acres (U.S. Congressional Research Service, 2018). In 1983, an agreement between the United States and the ASRC known as the Chandler Lake Agreement. This gave ASRC the mineral rights beneath the KIC surface lands, even though they fell in the refuge area created prior to ANCSA. The Chandler Lake Agreement prohibited development of the ASRC lands in ANWR unless Congress opened ANWR for energy development (U.S. Congressional Research Service, 2018).

Prior to the 115th Congress

In more recent years the debate continued. The 109th Congress was active from 2005 to 2007. They introduced reconciliation bills under the budget process that included H.R. 6, H.R. 2863, and H.R. 5429. These bills would have provided an expedited opening of Area 1002 to development to address national energy needs or policy goals. Two other bills, H.R. 567 and S. 261, would have designated Area 1002 as wilderness (U.S. Congressional Research Service, 2018). In the end, the 109th Congress did not pass or sign any bills into law.

The 110th Congress (active from 2007 – 2009) had a concurrent resolution that was rejected by the House would have adjusted budget levels to assume increased revenues from opening ANWR to leasing and exploration. The Senate rejected motions that would have opened ANWR to energy development (U.S. Congressional Research Service, 2018). Two other bills would have designated the area as wilderness. Again, in the end, the 110th Congress did not enact any changes to ANWR.

The 111th Congress (2009 – 2011) brought forth 17 bills pertaining to ANWR, but none were reported out of committee to the House or Senate (U.S. Congressional Research Service, 2018). From 2011- 2013, during the 112th Congress, one bill (H.R. 3407) regarding ANWR was reported from the committee. This was to open Area 1002 to energy leasing, with Bureau of Land Management (BLM) as the lead agency. H.R. 3407 would have required the Secretary of the Interior to order the leasing program in a way that would not harm fish and wildlife, their habitat, and the environment. Two other bills would have designated the area as wilderness (U.S. Congressional Research Service, 2018). Yet again, 112th Congress did not enact any changes to ANWR. The 113th Congress (2013 – 2015) saw 15 bills dealing with ANWR, 13 were promoting development and 2 promoted wilderness designation. No bills were sent out of committee to the House or Senate (U.S. Congressional Research Service, 2018).

During the 114th Congress (2015 – 2017), the House approved the Revised Comprehensive Conservation Plan (RCCP) for ANWR. This would recommend that Congress designate Area 1002 as wilderness. Two amendments were approved by the House to prohibit use of funds to implement the RCCP, neither became law. An amendment to designate Area 1002 as wilderness did not pass in a recorded vote (U.S. Congressional Research Service, 2018). There were four other bills promoting development and two promoting wilderness designation. No bills were reported by the House or Senate.

Actions of the 115th Congress

In December 2017, PL 115-97 (or H.R. 1) was signed into law. This directs the Secretary of the Interior, acting through the Bureau of Land Management (BLM), to establish and administer a competitive program for the leasing, development, production, and transportation of oil and gas in and from Area 1002 (HR1, 2017). This amends ANILCA to provide that Section

1003, which prohibits oil and gas development in ANWR unless authorized by Congress, does not apply to Area 1002 (U.S. Congressional Research Service, 2018). There were other bills promoting development in Area 1002 introduced that did not make it to the floor and two bills to designate Area 1002 as wilderness.

Arctic National Wildlife Refuge

The Arctic National Wildlife Refuge (ANWR) is approximately 19 million acres of federal land and water in northeastern Alaska that is managed by US Fish & Wildlife Service (USFWS). According to USFWS, ANWR contains five ecological regions: the coastal marine region, coastal plain tundra, alpine zone, forest-tundra transition, and boreal forest. These ecoregions have distinct features that make them important to a wide variety of wildlife (U.S. Fish & Wildlife Service, 2011). The coastal marine region is next to the Arctic Ocean and consists of salt marshes, lagoons, barriers islands, beaches, and river deltas. This ecoregion is valuable to polar bears, fish, and migratory birds. Coastal plain tundra (referred to as the coastal plains) is a treeless, flat to hilly region that, in summertime, caribou and birds raise their young. In winter this ecoregion is where pregnant polar bears create maternal dens (U.S. Fish & Wildlife Service, 2011). The alpine zone contains the Brooks Range Mountains. They are the are the northern most extreme of the Rocky Mountains and home to Dall sheep, grizzly bears, wolves, and ground squirrels. The forest-tundra transition has spruce trees interspersed with low tundra plants. Moose and wolves roam in the region year-round. The boreal forest is a mix of spruce, birch, and aspen trees. It is the only extensively forested area in ANWR, and its residence ranges from moose to songbirds (U.S. Fish & Wildlife Service, 2011).

In 1943, the federal government enacted Public Land Order (PLO) 82 which protected approximately 67 million acres of public and private land in Alaska, "…from sale, location,

selection, and entry for use in connection…" of World War II (PLO 82, 1934, p. 1599). Through PLO 2214, in 1960, the Arctic National Wildlife Range was established containing 8,900,000 acres in northern Alaska with the purpose, "…to preserve wildlife, wilderness, and recreational value…" (PLO2214, 1960, p. 12598). President Nixon signed the Alaska Native Claims Settlement Act (ANCSA) in 1971 resulting in 44 million acres of government land to be transferred to Alaska Native regional and village corporations (HR10367, 1971). Then in 1980, the Alaska National Interest Lands Conservation Act (ANILCA) redesignated the Arctic National Wildlife Range as part of the larger Arctic National Wildlife Refuge (ANWR) increasing its size by 9.2 million acres (U.S. Congressional Research Service, 2018). This brought the total acreage of the ANWR to about 18 million acres. Section 702(3) of the ANILCA designates 8 million acres of ANWR as "proposed wilderness" and that is now identified as the Mollie Beattie Wilderness area within the ANWR (Congress, 1980). Between 1983 and 1988 another 1 million acres would be added to the southern half of the refuge bringing the total area to roughly 19 million acres. The northern most 1.57 million acres of ANWR was defined as Coastal Plains under Section 1002 of the ANILCA (Congress, 1980). The 1.57 million acres of the Coastal Plains were not included in the wilderness designation and was open to surface exploration for oil and gas (Congress, 1980). These 1.57 million acres of Coastal Plains will be referred to as Area 1002 throughout the remainder of this thesis. In summary, ANWR is federally owned land that totals approximately 19 million acres within that; 8 million acres are designated as wilderness and 1.57 million acres are Coastal Plains.

Originally, ANWR had four objectives that guided the management of the entire Refuge: (a) to conserve animals and plants in their natural diversity, (b) ensure a place for hunting and gathering activities, (c) protect water quality and quantity, and (d) fulfill international wildlife

treaty obligations" (Congress, 1980, p. 562). Then in 2017 under the Tax Cuts and Jobs Act (TCJA), a fifth objective was added, "…to provide oil and gas program on the Arctic Coastal Plains…" (HR1, 2017). The Arctic Coastal Plains refers to Area 1002 of ANWR. According to United State Geological Survey (USGS) Area 1002 has an estimated 7.7 billion barrels of oil (BBO) that are technically recoverable. This means the 7.7 BBO in Area 1002 has been evaluated as being recoverable using current technology when cost and price are not a consideration (U.S. Congressional Research Service, 2018).

There are two different types of recoverable oil: technically and economically. The idea of technically recoverable oil differs from the economically recoverable oil because the latter will be affected by the oil market. When the oil prices are high it is more feasible to produce oil and therefore more oil will be produced; on the other hand, when the oil prices are low, less oil will be produced because it is less economical. In the most recent analysis from USGS, conducted in 2005, Area 1002 had an estimated 7.1 BBO with a small chance that 10.7 BBO would be recoverable (United States Geological Survey, 2005). According to the Alaska Department of Revenue, in 2005 the average price of oil coming from the Alaska North Slope (ANS) was $55.08 per barrel. In December 2017, when TCJA was enacted the price of oil coming from the ANS was $64.41 per barrel (Alaska Department of Revenue, 2023). Just west of Area 1002 is Prudhoe Bay, Alaska. Prudhoe Bay is the largest oil field in North America covering approximately 210,000 acres on the state-owned portion of coastal plains. The Prudhoe Bay oil field was discovered in 1967 and is now estimated to have held 14 BBO that was economically recoverable oil (U.S. Congressional Research Service, 2018). In comparison, Area 1002 is said to have 7.7 BBO spread over the 1.57 million acres. This means that there will be a

dispersion of multiple smaller fields possibly making development more expensive. This also has the potential to expand the area in which environmental effects occur.

Polar bear

Polar bear, *Ursus maritimus*, populations span throughout the Northern Hemisphere with a range limited to areas where sea ice occur (Amstrup, 2003). Currently, 19 distinct subpopulations of polar bears live in five different countries and carry an international status of vulnerable (Durner, Laidre, & York, 2016). Within the United States, two subpopulations of polar bear live in Alaska: the Chukchi Sea (CS) and the Southern Beaufort Sea (SBS) population According to the Alaska Department of Fish and Game, the CS population remains data deficient with no estimate of population size and SBS population continues to decline with habitat loss due to climate change as the main contributor (Durner, Laidre, & York, 2016). The CS and SBS populations have been listed as threatened since 2008 under the Endangered Species Act and are also protected under the Marine Mammal Protection Act due to the loss of sea-ice due to climate change (Durner, Laidre, & York, 2016).

The CS polar bears are located in the Chukchi Sea between the Bering and eastern Siberian seas (Durner, Laidre, & York, 2016) within the Polar Basin Divergent Ice ecoregion (Atwood, et al., 2016). Although, recent research has suggested positive nutritional condition and reproduction despite sea-ice loss, the population abundance has never been estimated using empirical methods with a clear spatial and temporal reference, and the IUCN/PBSG lists abundance and trend of the CS population as unknown (Regehr, et al., 2018). The most recent attempt to estimate the CS population abundance was conducted from 1986-1993. Due to low recapture rates and movements of the bears into and out of the study area, the study lacked ample information to estimate demographic parameters. The demographic parameters include

population size, density, fecundity, age structure, mortality, and sex ratio. This information would give researchers the data needed to estimate abundance (Regehr, et al., 2018). This study provided the first population estimate for management and conservation officials (Regehr, et al., 2018).

The SBS polar bear is located between Paulatuk and Baillie Island, Northwest Territories, Canada and Icy Cape, Alaska, USA (Durner, Laidre, & York, 2016) within the Polar Basin Divergent Ice ecoregion (Atwood, et al., 2016). Based on radio-tracking and mark-recapture data, the SBS population was estimated to be 1,800 bears in 1986 (Amstrup, Stirling, & Lentfer, 1986). Radio telemetry data and observations suggested that this population was increasing through the mid-1990s. Then in 2006, mark-recapture studies indicated a population of 1,526 individuals. As of 2010, the SBS population was estimated at 907 polar bears (Bromaghin, et al., 2015). Decline in population size is linked to changes in sea ice throughout the Arctic (Bromaghin, et al., 2015). While the availability of their food source, the ringed (*Pusa hispida*) and bearded (*Erignathus barbatus)* seal, is connected to the trend in sea ice. It is the change in availability of sea ice itself that is the major threat to the population.

Polar bears prefer sea ice concentrations of about 50% that is over the continental shelf's shallow, productive waters (Bromaghin, et al., 2015). This shallow productive water is home to the polar bears primary food source, the ringed and bearded seals (Bromaghin, et al., 2015). Polar bears put on the majority of their body fat in late spring and early summer recaching a 1:1 ratio of body fat to lean body mass (Pagano, et al., 2018). It is estimated that a single female bear on the spring sea ice requires an average of either one adult ringed seal, three subadult ringed seals, or nineteen newborn ringed seal pups every 10 to 12 days to maintain her body condition (Pagano, et al., 2018). In the early summer polar bears typically need to kill an adult or subadult

ringed seal every five days (Pagano, et al., 2018). These numbers are again to maintain her body condition, if the polar bears do not consume this amount, they begin losing about 10% of their body mass daily (Pagano, et al., 2018).

Polar bear populations have male-based operational sex ratio with approximately two males for every female. This is due to the prolonged mother-offspring bond (Molnar, Derocher, Lewis, & Taylor, 2008). Polar bear cubs spend about 2.5 years with their mothers before they are weaned (Stirling, Spencer, & Andriashek, 2016). Females reach the age of sexual maturity between 3 and 5 years old and males begin breeding between ages 8 and 10 years old (Amstrup, 2003). Females typically have their first litter between ages 5 and 6 then give birth every 2-3 years. The lifespan of polar bears are 25-30 years allowing females to have about 5 litters during their lifetime (Amstrup, 2003).

Non-Denning Behavior

Polar bears occur in low densities throughout the Arctic with approximately 0.0041 bear/km^2 due to their non-territorial behavior they travel roughly 100,000 km^2 a year (Regehr, et al., 2018). Their non-territorial behavior causes their mating behavior to differ from other bear species. While terrestrial bears have somewhat fixed home ranges that overlap with potential mates (Laidre, et al., 2012), variability in sea ice makes it impossible for polar bears to have fixed home ranges making it difficult for males to know where to find available females (Stirling, Spencer, & Andriashek, 2016). Male polar bears pick a direction moving in a straight line for days only veering off to check for female tracks. It is unknown what cues males obtain from the tracks, but it is suggested that there are hormones within the female's urine or scent pads on her feet (Laidre, et al., 2012).

Males have been documented tracking over 90 miles before catching up with a female. Once a male finds a female courting begins. Courtship between polar bears differs depending on if the female has previously bred. Females that have previously bred run off forcing the male to follow. Females are more agile than males and this is believed to be a test of the male's fitness (Derocher & Lynch, 2012). Females that have not previously bred flee causing the male to be more forceful until she finally agrees. Males that find females with cubs that are close to weaning, must run the cubs off before the female will be interested in mating (Stirling, Spencer, & Andriashek, 2016).

On average females only breed every three years due to polar bear cub's lengthy association with its mother (Stirling, Spencer, & Andriashek, 2016). This causes the operational sex ratio to be skewed with more males than females available to breed. Male rivalry for mates is often intense causing wounds that sometimes lead to death. Wounding is more common in polar bears versus other bear species due to the lack of defined territories and lack of hierarchical social structure (Stirling, Spencer, & Andriashek, 2016).

A behavior called mate guarding is popular in polar bears. This results in mating pairs remaining together for about two weeks (Stirling, Spencer, & Andriashek, 2016). Males will drive females into isolated areas to keep her secluded, away from other males. If the pair is disturbed by another male the pair will flee together if they are well bonded. If not, the female stands aside while the males sort thing out (Laidre, et al., 2012).

The spring sea ice is used by polar bears to find a mate and reproduce. Although they mate in spring, due to a process called delayed implantation the fertile egg does not implant until the following fall (Spady, Lindburg, & Durrant, 2007). Implantation of the fertile egg only happens if the mother has obtained enough fat reserves to survive and care for her cubs during

the denning season (Lambert, 2009). The delay in fetal development is a mechanism to synchronize birthing in polar bears with that of their principal prey species, the ring and bearded seals (Smith & Aara, 2015). It also gives polar bears that have lost dependent offspring an opportunity to mate later in the same year and optimize reproductive fitness (Smith & Aara, 2015).

Denning Polar Bear

During the harsh winter months in the Arctic, pregnant polar bears create maternal dens to birth and care for offspring. (Amstrup, 2003). At the end of fall the pregnant polar bear choses a den site in snowdrifts along coastal bluffs, in hills near sea ice, or in banks of snow on frozen sea ice (Stirling, 2011). Mother bears will give birth, usually to twins, in December and the family remains in the den until April (Lambert, 2009). While pregnant polar bears are in their maternal dens, males and nonpregnant females continue wandering the ice looking for mates and feeding.

Maternal dens are made in snow and ice that melt during the spring and summer. This makes it impossible for maternal dens to be reused and forces a pregnant female to create a new maternal den every year she is pregnant. Due to the fact that the maternal dens disappear in the warmer months, this causes pregnant polar bears to become loyal to general geographic areas and return to the same ground type and cover for repeated denning (Durner, Amstrup, & Fischbach, 2003). Approximately half of annual maternal dens of the SBS population occur on land or sea ice attached to the coastline and this number is increasing for the SBS population (Durner, Amstrup, & Fischbach, 2003). Shifts in the distribution of maternal dens to terrestrial locations due to climate change are reducing the availability of ice suitable for denning (Fischbach, Amstrup, & Douglas, 2007).

A study conducted by Druner et al. in 2003 found that the structure of individual polar bear dens varied significantly (Durner, Amstrup, & Fischbach, 2003). The presence of a primary chamber where the family group spent most of the winter was common to all dens, but a few had secondary chambers they looked to be used near the end of the denning period. Primary and secondary chambers are oval with average internal dimensions of 79 cm heigh, 148 cm length, and 127 cm wide (Durner, Amstrup, & Fischbach, 2003).

Area 1002 and SBS population of polar bear

In his 1993 study Steven Amstrup stated that "Loss of a large portion of the present productivity of polar bear denning on ANWR would undermine recruitment in the SBS population. Data indicated that many denned bears exposed to human activities are likely to be affected in ways that alter their productivity" (Amstrup, 1993, p. 250). The author observed human disturbances including aircraft, train, snow machine, foot traffic, oil field operations, seismic surveys, and field surveys (Amstrup, 1993). While data indicated that human activity does not affect productivity of the mothers already denning, it is the loss of denning habitat that will reduce the productivity of the SBS polar bear population.

Since Amstrup's 1993 work, studies have been conducted that mimic the audibility of industrial noise on polar bear maternal den structures. In 2020 Owen et al., constructed dens to assess differences in noise propagation and found that aircraft had the highest probability of being detected by denning polar bears when distances were less than 1.6 km and ground sources had the highest probability detected at distances less than 0.8 km (Owen, et al., 2020). Their results demonstrate the importance of buffer zones around polar bear dens to minimize the potential for den disturbances (Owen, et al., 2020).

Conclusion

In conclusion, the listing of polar bears could have a significant impact on energy development in Area 1002 because of the importance of Area 1002 as a location for dens of pregnant female polar bears. Female polar bears are known to abandon their dens when disturbed. If the cubs are young and unable to maintain their body temperature, abandonment of a den would probably be fatal (Amstrup, 1993). The establishment of Area 1002 as critical habitat for the polar bear provides the ESA with a formidable role in overseeing federal activities, such as energy development in the area. Under ESA, federal agencies must avoid actions that jeopardize listed species or that destroy or adversely modify their designated critical habitat. Due to the changing sea ice conditions off the coast of Alaska scientists are noting during their research that pregnant female polar bears moving more of their dens to locations onshore. They are also noting that females that traditionally den west of Prudhoe Bay oil field have moved their dens east, onto or near the Area 1002 (U.S. Congressional Research Service, 2018). This shift could increase the importance of the Refuge's coastal plain to the polar bear population and add to the significance of consultation under ESA in any federal action related to exploration.

Chapter 3: Methods

The primary purpose of this research is to analyze and map SBS polar bear maternal den sites and denning habitat in Area 1002, then overlay potential oil and gas infrastructure to better understand how the oil and gas infrastructure could affect polar bear maternal denning habitat. This research utilizes data previously collected from other researchers to include polar bear den site data from Durner et. al (2020), photo derived denning habitat data from Durner and Atwood (2018), and a scenario map from Audubon Alaska (Audubon, 2019). This chapter will describe

the methods used in data collection, creation of geospatial habitat map with ESRI product ArcGIS, then overlay the Audubon scenario map using ArcGIS to better understand how much SBS maternal denning habitat could be affected by oil and gas infrastructure within Area 1002.

Data Collection

Den Sites

Denning site data has been collected and shuffled through different agencies over the decades. From 1965 – 1972 the data was maintained by the Alaska Department of Fish and Game (ADFG). In 1972, after the Marine Mammal Protection Act (MMPA) was passed, U.S. Fish and Wildlife (USFW) took over until 1993. In 1993 a special department within USFW, the National Biological Research, maintained the data until 1996. In 1996, the U.S. Geological Survey (USGS) took over and is the current sustainer of the data (Durner, et al., 2020). Observation methods used to collect the data also varied from interviews of coastal residents and guides of polar bear hunters, industry personnel, fixed-wing aircraft surveys of nearshore habitat, mark/recapture methods, radio transmitters, and GPS collars (Durner, et al., 2020). This data will be used to illustrate how Area 1002 has been used by polar bears for maternal denning in the past. Due to the fact that polar bears do not reuse dens site but rather return to the same substrate in a geographic area it is not possible to predict exactly where a den will be constructed (Durner, Amstrup, & Fischbach, 2003).

Denning Habitat

Denning habitat data by Durner and Atwood (2018) used ESRI, mapping software, live coverage features to showing maternal denning habitat created from photograph interpretation method for Area 1002. This photograph interpretation method used high-resolution color aerial photographs (scale: 1 cm = 178.6 m) to examine Area 1002 for den habitat (Duner & Atwood,

2018). Photos were taken with a certified cartographic camera from an aircraft flown at 2743 meters above the mean terrain level (Duner & Atwood, 2018). Den habitat was located on the photos with a pocket stereoscope and by interpretation of vegetation patterns. Linear features that showed elevation changes of one meter or more were annotated on photos. Once identified on the photos, denning habitat was digitized and transferred to 1:63 360 base map as line features resulting in a final format as ARCVIEW shapefiles (Duner & Atwood, 2018). These shapefiles are used during my mapping analysis (ESRI, Redlands, California).

Audubon Scenario Map

In November 2017, new federal legislation was approved to open Area 1002 of ANWR to oil and gas development. The bill states that surface development would be limited to a 2,000-acre footprint (PL 115-97, 2017). According to the Audubon Alaska this is deceptive because in reality the full 1.57 million acres that is Area 1002 would be subject to leasing and exploration. The Audubon Alaska states that the misleading 2,000 acres estimate does not include gravel mines, roads, or pipelines (Audubon, 2019). To add to this, the oil within Area 1002 is not in one location but rather spread out throughout. This requires infrastructure that would spread throughout Area 1002. To help the public visualize this Audubon Alaska created a scenario map (Audubon, 2019). This shows a hypothetical scenario of how development could span Area 1002 of ANWR. About 2,000 acres of well pads, airstrips, and other infrastructure are shown in context with connecting roads, pipelines, and gravel mines not subject to the 2,000-acre cap (Audubon, 2019).

Study Area

Area 1002 of the ANWR is a smooth coastal plain located in northeastern Alaska that rises from the Beaufort Sea coastline to an elevation of 183 meters (Wilson & Durner, 2020). It is

north of the Brooks Range and south of the Beaufort Sea, with an eastern boundary of Aichilik River and western boundary of the Canning River (Duner & Atwood, 2018). Average monthly precipitation is highest during summer and snowfall is greatest in the month of October. Temperatures are warmest in July and coldest in February with an average maximum and minimum temperatures of 7°C and -26°C (Wilson & Durner, 2020).

Area 1002 is visited by large mammals that include caribou (*Rangifer tarandus*), grizzly bears (*Ursus arctos*) and polar bears along with fifty-seven species of birds (Wilson & Durner, 2020). Area 1002 is comprised of coastal tundra and upland vegetation. Much of this area is classified as wetlands with major terrain types that include foothills, floodplains, hilly coastal plains, thaw-lake plains, and mountains (Wilson & Durner, 2020). Lagoons and lakes begin to freeze in September and the surface ground remains frozen until June. Sea ice begins to reform near shore beginning in October (Wilson & Durner, 2020).

According to Wilson and Durner (2020), seasons for polar bears in this region are established by the changes in the sea ice. Winter is the period of maximum sea ice extent (January – April), spring is when the sea ice begins to melt and retreat north (May – July), summer is the period with minimum sea ice extent (August – September), and autumn as the period when sea ice begins to reform (October – December).

GIS Process

Preparation

In preparation for geospatial analysis, all data was reviewed for relevance and formatted for the appropriate coordinate system and a basemap was created. Formatting the data, the appropriate coordinate system is important because, a coordinate system is an outline consisting

of points, lines, and/or surfaces, and a set of rules, used to define the position of points in space. In ArcGIS, a coordinate system is a reference system that locates a position in space and defines the relationships between positions. It allows individual datasets to be georeferenced to one another. Georeferencing is the term used for aligning geographic data to the coordinate system allowing it to be viewed, queried, and analyzed with other geographic data. This was all done on the map which is at the basis of GIS visual and geographic context, it is where all of the data is imported to. When the data is imported to a map it creates attributes, which are nonspatial information about a geographic feature usually in the form of a table. These attribute tables are then used to create features on map. The features are symbols that represent data on the map. After these features were created, I used the buffer tool to create different size buffers around different features. The buffer tool allows you to create a determined zone around a feature on a map. All of this is done in ArcGIS to create layers, which are visual representations of geographic datasets in a digital map.

To give visual references and geographical location, boundaries of the Arctic National Wildlife Refuge (ANWR), Mollie Beattie wilderness area within the ANWR, and Area 1002 were obtained as a geographic information system (GIS) shapefile (ESRI, Redlands, California) form the U.S. Fish and Wildlife Service (USFW, 2019). Shapefiles are vector data storage formats for storing the location, shape, and attributes of geographic features. After the boundaries were implemented importation of the data set began.

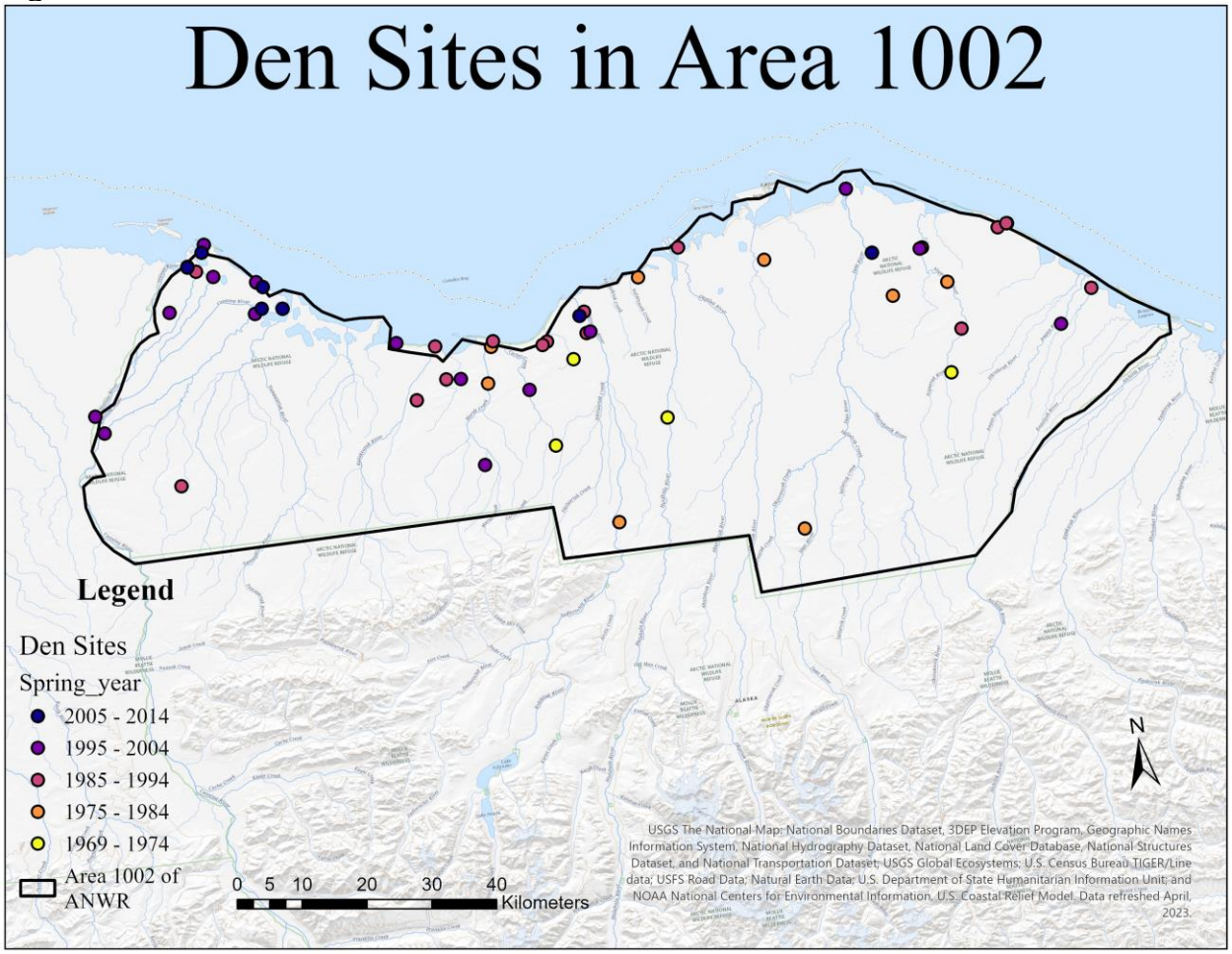
There was a total of 530 data points for maternal den sites from 1910 – 2018. Based on location, 54 data points from 1951 – 2014 were used in this study as they were located within Area 1002. All of the photo interpreted data collected by Duner and Atwood (2018) for denning habitat was used since the data was collected specifically on Area 1002 (Duner & Atwood,

2018). The Audubon scenario map information was ground trothed using terrain on a base map within ESRI ArcGIS then the data for each type of infrastructure was given a latitude and longitude. After these things were accomplished, the different layers were analyzed to show how much of the denning habitat could be altered by the oil and gas infrastructure. The following section will describe in more detail the steps that were taken.

Mapping

After the data was uploaded and organized into the GIS project, multiple layers were created. The different layers are visual representations of geographic data sets. The first layer consists of the denning sites found within Area 1002 from 1951 – 2014. This was accomplished by importing the longitudinal and latitudinal data from an Excel file that accompanied the den site data from previous den sites. (Durner, et al., 2020). It is important to remember that dens are not reused, this data is used to show the polar bears denning over time and later to ground troth the denning habitat. The full data set for the den sites was already in an Excel format making it easy to add this data to the map. A Geoprocessing tool was used to convert the longitude and latitude of the Excel file into locations on the map. Next the data was narrowed down to what was pertinent to the study area, Area 1002. Using the "select an attribute" tool a polygon was drawn around the boundary for Area 1002, this highlighted all of the data points within the study area. These data points were then turned into a new Excel file that could be uploaded into ArcGIS in the same way the full data set was. After that I used graduated symbols to create five classes that symbolize den sites that were found during a span of time. This created the den sites in Area 1002 map (Figure 2).

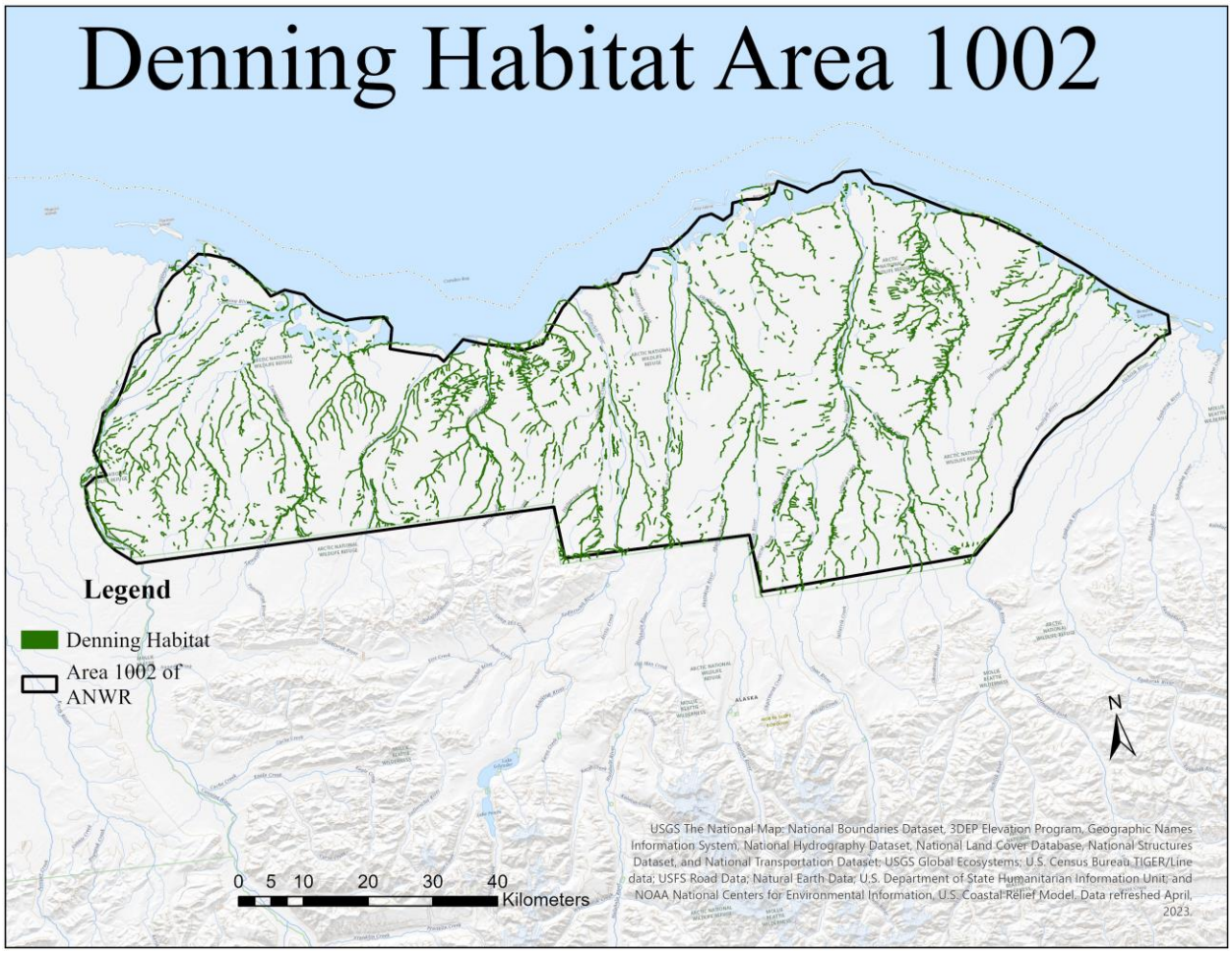
Figure 2. Den Sites in Area 1002



Note: Distribution of polar bear maternal dens (colored circles) discovered between 1910 and 2018 (Durner, et al., 2020) in Area 1002 (black outline) of the ANWR. There are 54 maternal den sites located in Area 1002 according to the data used for this study collected by Durner, et al. (2020). Darker colored (purple) circles are dens discovered during more recent years and lighter circles (yellow) are dens older den sites. It is important to note that polar bears do not reuse dens rather return to the same area and substrate for repeated denning.

The second layer was the denning habitat shapefile created by Durner and Atwood during their work in 2018. This was already in the form of a shapefile it was imported into the base map. After it was imported, I changed the color and added a 1.26-meter buffer around the data. This buffer was chosen to match the den width size found by Durner et al. (2002). This allows me to account for area that would be needed inside of the habitat for creating dens (Figure 3).

Figure 3. Denning Habitat Area 1002

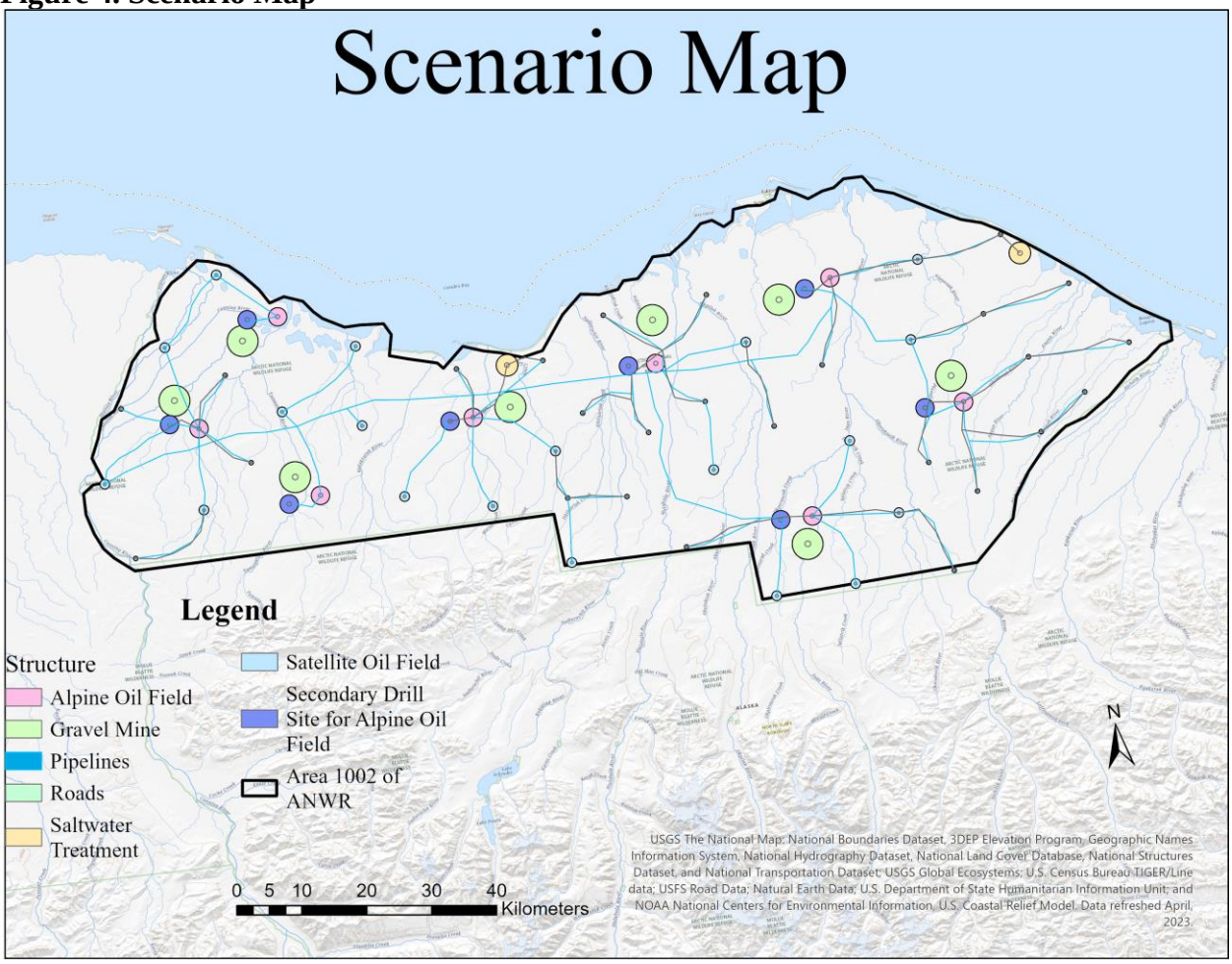


This is a map of the denning habitat data from Durner and Atwood (2018). The green lines show the denning habitat with 1.26-meter buffer to account for the area needed for den site measurements found by Durner et al. (2002). Based on this data set Area 1002 is approximately 1.6 million acres and has 945 acres of suitable denning habitat.

The third layer was created by georeferencing the Audubon scenario map to the basemap. The scenario map was in the form of a PDF. This file was uploaded into the mapping project. After it was uploaded control points were used to align geographic data from the scenario map onto the basemap. The use of control points is crucial when georeferencing because they are points of known accuracy on the map. I chose to use points along Area 1002's border as control points for this step. After georeferencing the Audubon Alaska scenario map coordinates were

collected for each structure, road, and pipeline the scenario map referenced. The coordinate information was converted to a comma separated values (.csv) file in excel then uploaded into ArcGIS. Unique primary symbology for structures, roads, and pipeline were set. Structures were also given a graduated symbology to visualize the different acreages they take up. The ArcGIS buffer tool was used to create a polygon of the pipelines, roads, photo derived data, and structures. Pipeline buffer is set to 1.23 meters to match the width of the Trans Alaskan Pipeline System, road buffer is set to 7.5 meters to match the width of two lanes on a federal interstate system, the photo derived data has a 1.26-meter buffer to match den site measurements found by Durner et al. (2002), all structures received a buffer that matched to acreage describe on the scenario map (Figure 4).

Figure 4. Scenario Map



Note. Map demonstrates how industrial infrastructure in Area 1002 could alter the coastal plains. There are eight alpine type oil fields each with a secondary drill site that are 82 acres each, nineteen satellite oil fields at 37 acres each, twenty-six satellite oil fields at 11 acres each, two saltwater treatment plants at 100 acres each, eight gravel mines at 150 acres each, roads at 651 acres, and pipelines at 223 acres. This totals 4,575 acres that could be altered (Audubon, 2019).

After all of the layers were completed, I used the intersect tool to find where the data sets overlapped. The intersecting data will give us the area within suitable maternal denning habitat that would be altered and ultimately unsuitable for polar bear maternal dens. These maps and data will be discussed in the results chapter.

How the Data was Used

ArcGIS was used to combine the photo derived data of the denning habitat in Area 1002 (Duner & Atwood, 2018), historical den sites in Area 1002 (Durner, et al., 2020), and a scenario map that demonstrates how an industrial footprint could alter in Area 1002 (Audubon, 2019) and impact maternal denning habitat. After georeferencing the scenario map coordinates were collected for each structure, road, and pipeline the map referenced. The coordinate information was converted to a comma separated values (.csv) file in excel then uploaded into ArcGIS. Unique primary symbology for structures, roads, and pipeline were set. Structures were also given a graduated symbology to visualize the different acreages they take up. The ArcGIS buffer tool was used to create a polygon of the pipelines, roads, photo derived data, and structures. Pipeline buffer is set to 1.23 meters to match the width of the Trans Alaskan Pipeline System, road buffer is set to 7.5 meters to match the width of two lanes on interstate, the photo derived data has a 1.26-meter buffer to match den site measurements found by Durner et al. (2002), all structures received a buffer that matched to acreage describe on the map (Audubon, 2019). The ArcGIS intersect tool was used to find where denning habitat and industrial footprint intersect by overlaying both variables, the industrial infrastructure and denning habitat.

Conclusion

In conclusion, previously collected data and a scenario map were moved into one map to provide not only a visual but quantifiable number to how much maternal denning habitat would be altered if Area 1002 is opened up for oil and gas exploration. The first layer consists of the denning sites found within Area 1002 from 1951 – 2014. Due to the fact that dens are not reused, this shows how the dens have moved within Area 1002 over time. The second layer was the denning habitat shapefile created by Durner and Atwood during their work in 2018. Knowing that pregnant polar bears are unable to reuse dens and that they return to locations and substrate,

this helps to predict where future dens will occur. The third layer was created by georeferencing the Audubon scenario map to the basemap. The scenario map shows how the industrial infrastructure could occur in Area 1002. The next chapter will demonstrate how these three layers interact and show how much denning habitat could be altered by the industrial infrastructure.

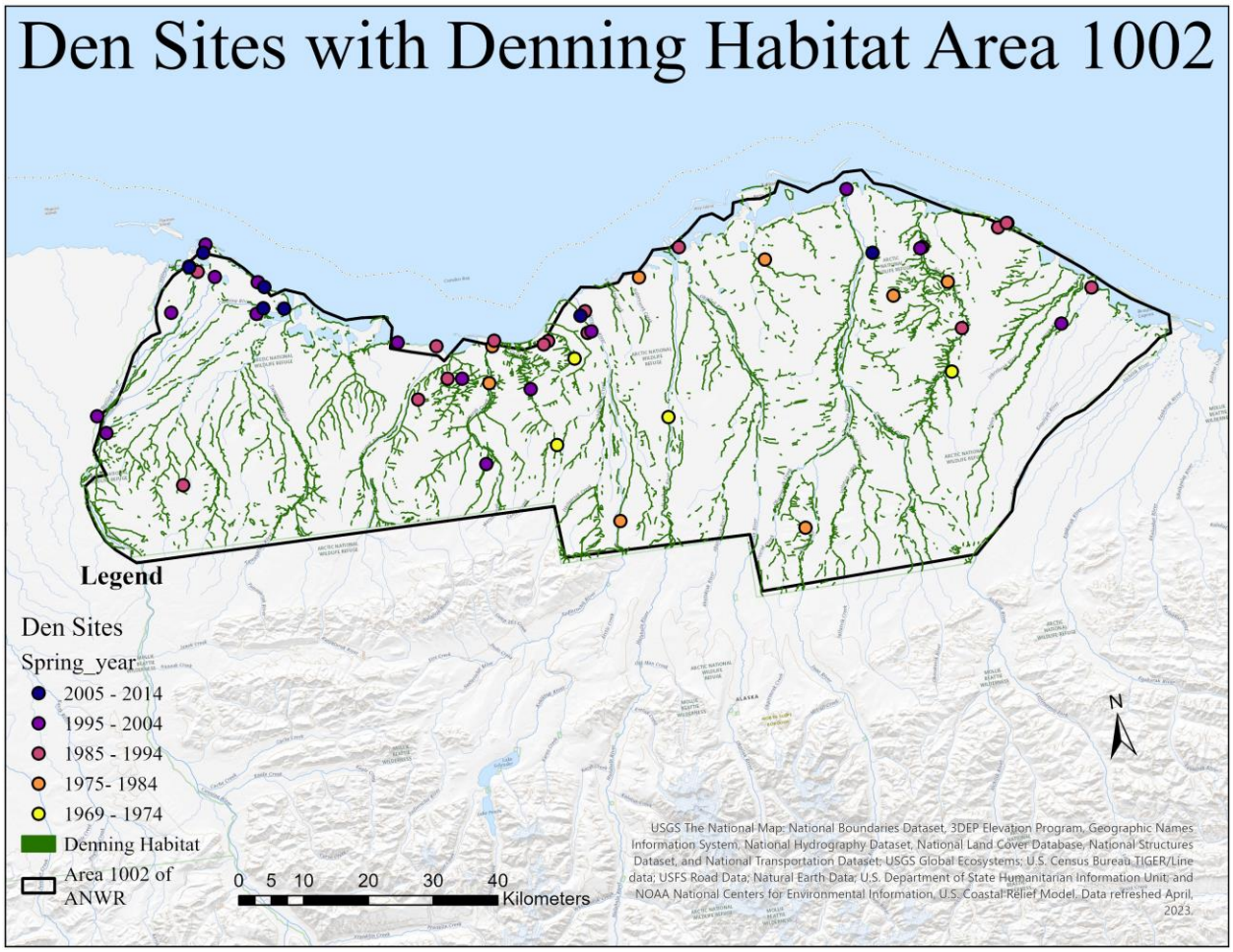
Chapter 4: Results

In this chapter the results from the mapping and data will discuss the results found after mapping the data and using different georeferencing tools in ArcGIS. This result map was created by over layering the layers created in the methods sections and using different geoprocessing tools to create an area that can be quantified into acres for area that could be impacted by oil and gas exploration in Area 1002. The first step in finding the results was to overlay the den sites with denning habitat to be sure that these two variables were in fact relatable (Figure 5). Secondly, I removed the den sites layer from the map and overlaid the scenario map with the denning habitat data to show how much habitat would be distributed (Figure 6). Thirdly, I used the geoprocessing tool to show how much of the data intersected and produced a final layer that results in how many acres will be disturbed according to the data used (Figure 7).

Figure 5 is a map that shows how past den sites align with the denning habitat. The green lines indicate denning habitat as captured in photo derived data collected by Durner and Atwood (2018). Distribution of polar bear maternal dens (colored circles) discovered between 1969 and 2014 (Durner, et al., 2020) in Area 1002 (black outline) of the ANWR. There are 54 historical maternal den sites located in Area 1002 according to the data used for this study collected by

Durner, et al. (2020). Darker colored (purple) circles are dens discovered during more recent years and lighter circles (yellow) are dens older den sites. It is important to note that polar bears do not reuse dens rather return to the same area and substrate for repeated denning. It was important to map these two variables together as a way to verify that the habitat has been used for past den sites.

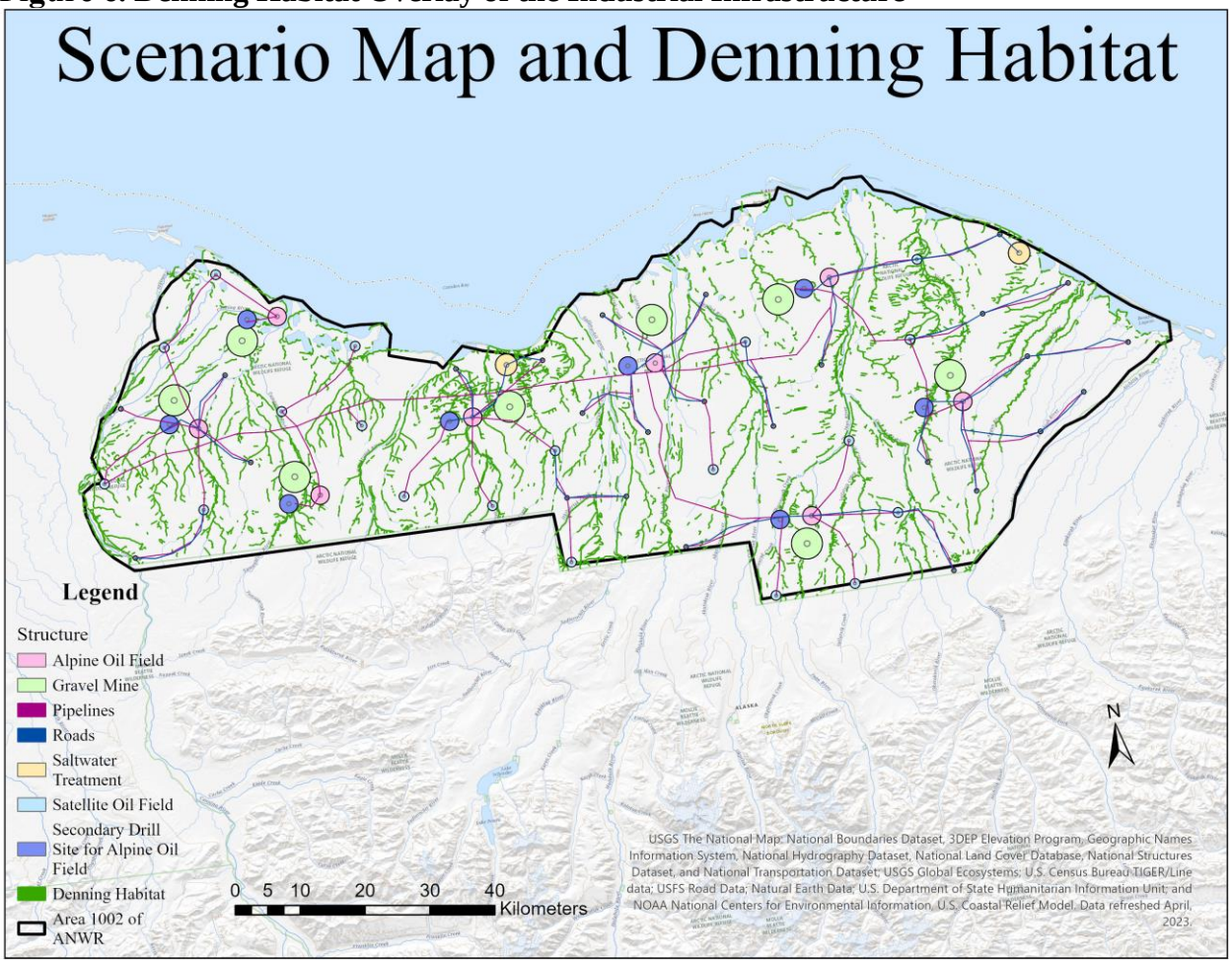
Figure 5. Den Sites with Denning Habitat Area 1002



Note. The purpose of this map is to show how past den sites align with the denning habitat. The green lines indicate denning habitat as captured in photo derived data collected by Durner and Atwood (2018). Distribution of polar bear maternal dens (colored circles) discovered between 1969 and 2014 (Durner, et al., 2020) in Area 1002 (black outline) of the ANWR. There are 54 maternal den sites located in Area 1002 according to the data used for this study collected by Durner, et al. (2020). Darker colored (purple) circles are dens discovered during more recent years and lighter circles (yellow) are dens older den sites. It is important to note that polar bears do not reuse dens rather return to the same area and substrate for repeated denning

Figure 6 shows how the industrial infrastructure, as depicted in the scenario map, would interact with the suitable polar bear denning habitat. Each structure and road were given a graduated symbol that reflects the acreage used for each structure according to the scenario map. There are eight alpine type oil fields each with a secondary drill site that are 82 acres each, nineteen satellite oil fields at 37 acres each, twenty-six satellite oil fields at 11 acres each, two saltwater treatment plants at 100 acres each, eight gravel mines at 150 acres each, roads at 651 acres, and pipelines at 223 acres (Audubon, 2019). The green lines show the denning habitat with 1.26-meter buffer to account for the area needed for den site measurements found by Durner et al. (2006).

Figure 6. Denning Habitat Overlay of the Industrial Infrastructure

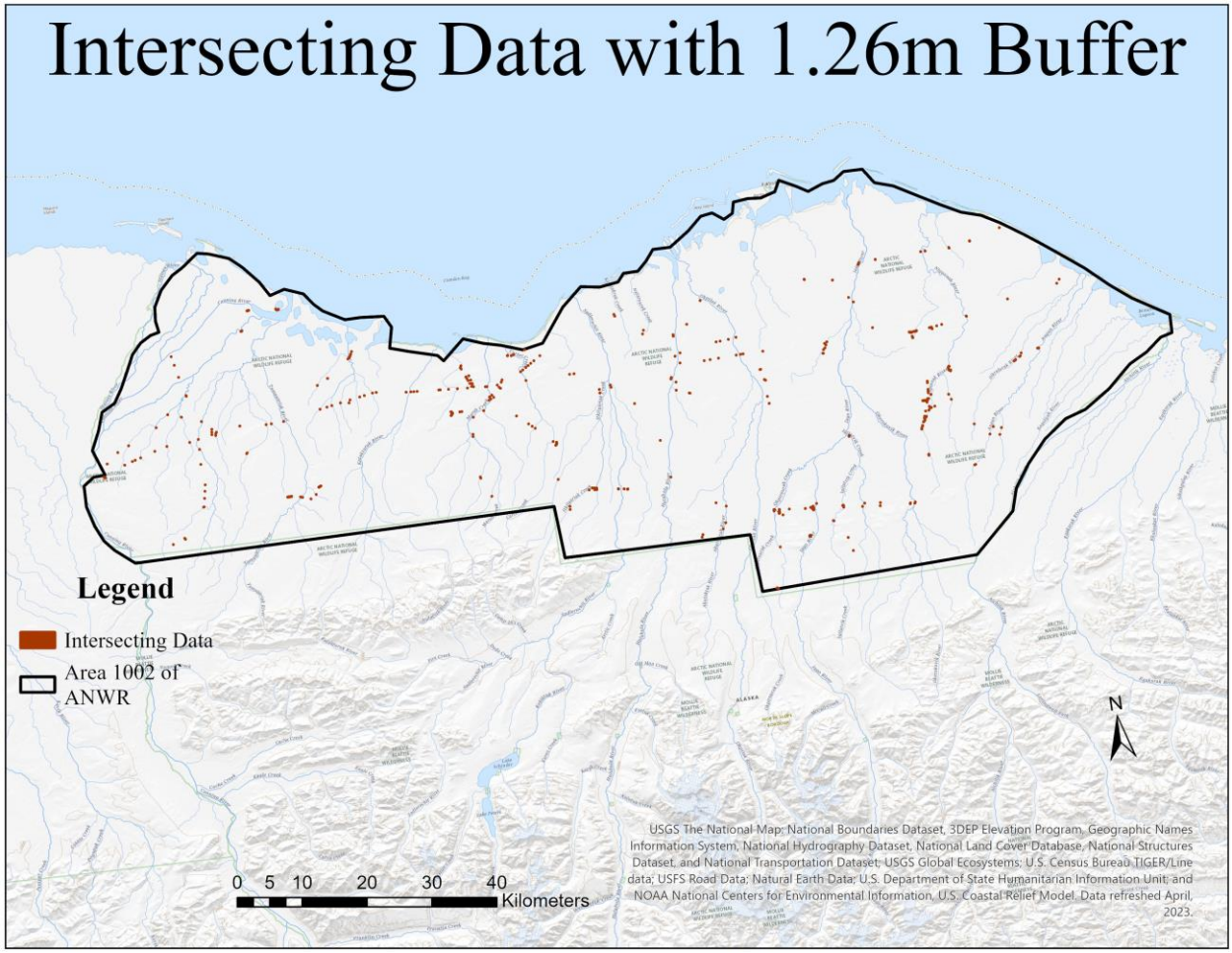


Note: This map shows how the industrial infrastructure, as depicted in the scenario map, would interact with the suitable polar bear denning habitat. Each structure and road were given a graduated symbol that reflects the size of each structure. There are eight alpine type oil fields each with a secondary drill site that are 82 acres each, nineteen satellite oil fields at 37 acres each, twenty-six satellite oil fields at 11 acres each, two saltwater treatment plants at 100 acres each, eight gravel mines at 150 acres each, roads at 651 acres, and pipelines at 223 acres (Audubon, 2019). The green lines show the denning habitat with 1.26-meter buffer to account for the area needed for den site measurements found by Durner et al. (2006).

Now that all of the data are on one map two geoprocessing tools were used to create a final layer that would demonstrate how much denning habitat could be altered. The two geoprocessing tools that were used were the intersect tool and the dissolve tool. The intersect tool was used to show the areas where features from different layers overlap. The output from this tool is a new layer. I then used the dissolve geoprocessing tool on this new layer. The

dissolve tool allows you to remove unnecessary boundaries between features. This allowed the points made from the intersect tool to create their own single polygon. Figure 7 shows the result and is then interpreted that 3 acres of denning habitat would be altered using the before mentioned parameters.

Figure 7. Results of Intersecting Data 1.26m Buffer



Note: The intersecting data map with a 1.26-meter buffer shows locations that overlap when the scenario map and denning habitat layers are combined onto one map. The ArcGIS output of the intersecting data is a new layer called intersecting data and is represented by the brown dots on the map. After the layer was created the dissolve geoprocessing tool was used to remove unnecessary boundaries between features. This allowed the points to create their own single polygon. The result is then interpreted that 3 acres of denning habitat would be altered using the above-mentioned parameters.

Results

Area 1002 is 1,608,249 acres and contains 945 acres of suitable habitat for polar bear maternal den sites. Based on the structure, roads, and pipeline mapped out by the scenario map provided by Audubon approximately 651 acres will be attributed to roads, 223 acres will be attributed to pipeline, and 3,701 acres will be attributed to structures totaling 4,575 acres being disturbed. The industrial footprint will take up 0.28% of the whole Area 1002 and maternal denning habitat takes up only 0.06%. When these two variables intersect 3 acres of the maternal denning habitat is disturbed using a 1.26-meter buffer based on den measurements.

The polar bear is red listed as "vulnerable" by the International Union for Conservation of Nature (IUCN). This study found that Area 1002 is approximately 1.6 million acres with 945 acres that are suitable for maternal den sites (0.6%). The footprint of the industrial infrastructure according to the Audubon scenario map is 4,575 acres (0.29%) and would disturb 3 acres of maternal denning habitat. While this number may seem insignificant when looking at all of the dynamic variables to include climate change, these three acres are an important start to keeping the denning habitat intact.

While three acres might not seem significant, we must keep the big picture in mind. The SBS polar bear population is already in decline due to habitat loss. With sea ice loss at a rate of 13% per decade pushing the den sites to occur more on land. The question is, can the SBS polar bear population afford the disturbance of three acres within Area 1002. Human disturbance in Area 1002 will put added pressure on the SBS population causing a further decline in population.

Chapter 5: Conclusion

Introduction

Polar bears are the most ice-dependent Arctic marine mammal. They require sea ice for long distance movements, mating, maternal denning, and access to their primary food source. Due to the changing climate, there has been a reduction of sea ice. This change in Arctic Sea ice has been associated with nutritional stress in polar bears. As the sea ice disappears polar bears have to spend more time hunting and are not able to catch as much food. This causes them to use more energy than they can replenish, reducing their overall health. When female polar bears do not obtain enough fat reserves in spring when hunting on the sea ice she will not reproduce in the fall. In most populations the females that do reproduce rely on the sea ice for creating maternal dens, where they will stay with their offspring until spring of the next year. As the sea ice is reduced because of climate change it pushes these females to find a new area for denning. Most are moving more inland, which can increase the potential for human-bear interactions.

Outside of the Arctic Sea ice reduction there are other factors that affect polar bear health and populations: prey, tourism, and hunting. Polar bears' main food source are ring and bearded seals. This research did not focus on the availability of food but rather the way polar bears hunt their prey. Polar bears use the sea ice to stalk their prey while they are basking or find their breathing hole and wait for them to emerge. As the Arctic continues to stay warmer longer the ice-free periods are increasing, this is causing the polar bear to stretch the limits of their fat reserves. Also, due to the reduction in Arctic Sea ice a new trend called "last chance tourism" has emerged. "Last chance tourism" refers to tourist who travel to see things before they are gone. With climate change continuing to negatively impact polar bears, more tourists are travelling to

see them in their natural habitat before they are extinct. This increasing industry, tourism, and commerce in the Arctic brings humans and polar bears into closer proximity and increases the potential for negative interactions. Polar bears have been hunted for over 10,000 years. They provide Indigenous people with meat, raw material for clothing, and handicrafts. In 1972 the Marine Mammal Protection Act (MMPA) was passed and prohibited the hunting of polar bears. Polar bears are considered marine mammals because they spend their lives on the sea ice and depend on it for food and habitat. A sustainable harvest quota has been established for the exempt Indigenous people who rely on the polar bear hunt to survive. These are only a few of the things affecting polar bears.

Alaskan Polar Bears

There are 19 subpopulations of polar bears throughout the Northern Hemisphere. Two of the subpopulations are located in Alaska of the United States: the Chukchi Sea (CS) and the Southern Beaufort Sea (SBS) populations. This research focused on the SBS population that is located between Icy Cape, Alaska and the eastern Canadian border. According to a study done in 2010, this population has declined from approximately 1,500 polar bears in 2006 to 907 polar bears. The decline in this population has been linked to changes in Arctic Sea ice. In 2010, the northern coast of Alaska was designated as critical denning habitat for the polar bear populations living in the United States. This is because pregnant female polar bears are loyal to geographic areas to create maternal dens during winter. The particular area the SBS polar bears return to for denning is the coastal plain of the Arctic National Wildlife Refuge, Area 1002.

Arctic National Wildlife Refuge

The Arctic National Wildlife Range was first established in 1960 due to the nationwide interest in preserving the area's wildlife. In 1980, the Alaska National Interest Lands

Conservation Act (ANILCA) designated the area as the Arctic National Wildlife Refuge (ANWR) affirming the nation's interest in preserving this area. This Act contained a provision, Section 1002, that states the refuge's coastal plain for potential oil and gas development. The ANILCA also contains Section 1003 that prohibits oil and gas related activities within the whole ANWR, unless authorized by an Act of Congress. Since, Area 1002 has been the subject of the nation's longest and most contentious environmental debate.

Between 2005 and 2017 there have been 22 federal bills promoting oil and gas development in Area 1002, 10 additional bills promoting Area 1002 to be designated as a wilderness area, and 17 other bills concerning Area 1002 that were not reported out of committee. In December 2017, the 115th Congress signed PL 115-97 into law. This directed the Secretary of the Interior to establish and administer a competitive program for leasing, development, production, and transportation of oil and gas in and from Area 1002. This also amends ANILCA to provide that Section 1003 does not apply to Area 1002. In January 2021 the first lease sale was held, and nine tracts of land were leased out. As of June 2021, the leasing of land and a halt of all activity on leased land was put into place.

Area 1002

The Arctic National Wildlife Refuge (ANWR) is approximately 19 million acres of federal land and water in northeastern Alaska. It is comprised of five ecoregions: the coastal marine region, coastal plain tundra, alpine zone, forest-tundra transition, and boreal forest. These ecoregions have features that make them important to a variety of wildlife. Originally, ANWR had four objectives that guided it: (a) to conserve animals and plants in their natural diversity, (b) ensure a place for hunting and gathering activities, (c) protect water quality and quantity, and (d) fulfill international wildlife treaty obligations. In December of 2017 when the 115th signed PL

115-97 into law a fifth objective was added: to provide oil and gas program on the Arctic Coastal Plains. The Arctic Coastal Plains refers to the coastal plains tundra, also known as Area 1002.

According to the United States Geological Survey (USGS) Area 1002 has an estimated 7.7 billion barrels of oil (BBO) that are technically recoverable. There are two different types of recoverable oil: technically and economically. Technically recoverable oil differs from the economically recoverable because the latter will be affected by the oil market. Just west of Area 1002 is Prudhoe Bay, Alaska. This is the largest oil field in North America covering approximately 210,000 acres on the state-owned coastal plains with an estimate of 14 BBO economically recoverable oil. In comparison, Area 1002 is said to have 7.7 BBO spread over 1.57 million acres. This means that there could be multiple smaller oil fields spread throughout Area 1002 with the potential to cause environmental impacts.

According to Alaska Department of Fish and Game the SBS polar bear population continues to decline with habitat loss as the main contributor. Area 1002, in Alaska's coastal plains, is especially important to the SBS polar bear population. This area is where pregnant females create their maternal dens during the severe winter months in the Arctic. Mother polar bears give birth in December and the family remains in the den until April. The loss of denning habitat to oil and gas development along with the shift of maternal denning on land will reduce the productivity of the SBS polar bear population.

Methods

For this research GIS was used to conduct analysis of the existing data. All data used for this research was preexisting data sets from government research and non-government sources. Historical den sites data for Area 1002 from the United State Geological Survey (USGS) Department was used to show where maternal dens have historically occurred. This data was

used to illustrate how Area 1002 has been used by polar bears for maternal denning in the past. Maternal dens are not reused because they melt in the summer, this makes pregnant polar bears loyal to a location and substrate. This makes it highly critical to understand the habitat around previously recorded den sites. Denning habitat data previously collected though photograph interpretation methods was used to show geographic locations where maternal den sites could be found. Since den sites are not reused this information shows where pregnant females may return to because the substrates are similar and are in geographic locations they are loyal to. To help the public visualize the impact the industrial infrastructure could have on Area 1002 the Audubon Society Alaska created a scenario map. This map shows how the roads, pipelines, oil fields, docks, water treatment plants, and gravel mines could be placed throughout Area 1002 based on the 2017 decision to open Area 1002 to oil and gas exploration.

GIS process

ArcGIS was used to combine the photo derived data of the denning habitat in Area 1002, historical den sits in Area 1002, and a scenario map that demonstrates how industrial infrastructure could alter Area 1002. After georeferencing the scenario map, coordinates were collected for each structure, road, and pipeline the map referenced. Unique primary symbology for structures, roads, and pipelines were set. Structures were also given a graduated symbology to visualize their respective acreages. The ArcGIS buffer tool was used to create a polygon of the pipelines, roads, structures, and photo derived data. This thesis set the pipeline buffer to 1.23 meters to match the width of the Trans Alaskan Pipeline System, road buffer to 7.5 meters to match the width of two lanes on interstate, the photo derived habitat data has a 1.26-meter buffer to match den site width measurements. All structures received a buffer that matched the acreage

described on the scenario map. The ArcGIS intersect tool was used to find where denning habitat and industrial infrastructure intersected by overlaying both variables on the map.

Results

Area 1002 is 1,608,249 acres and contains 945 acres of suitable habitat for polar bear maternal den sites. In 2017 when Area 1002 was opened for oil and gas exploration the bill stated that surface development would be limited to a 2,000-acre footprint. This prompted Audubon Alaska to create a scenario map on how this would look for Area 1002. As stated, the oil in Area 1002 is spread throughout the whole area of Area 1002. Based on the structure, roads, and pipeline mapped out by the scenario map provided by Audubon approximately 651 acres will be attributed to roads, 223 acres will be attributed to pipeline, and 3,701 acres will be attributed to structures totaling 4,575 acres being altered. The industrial footprint will take up 0.28% of the whole Area 1002. Polar bear maternal denning habitat takes up 0.06% of Area 1002. When the variables from the Audubon scenario map are intersected with the polar bear maternal denning habitat 3 acres of the maternal denning habitat is disturbed. What is important to remember here is that the oil and gas exploration is not the only thing potentially affecting the habitat in Area 1002. The changing climate is adding pressure from all directions on the SBS polar bear population. The next question that comes up is can this population afford to lose these three acres?

Future Research

In conclusion, there are some gaps in the data that would be helpful to create a more complete picture of how the SBS population could be affected by the oil and gas exploration of Area 1002. First, due to the fact that the last study on the SBS polar bear population dynamic was in 2016 a current study of the SBS polar bear population dynamics should be conducted to

better understand the current statistics on this population. During this study some of the things I would look for other than number of bears is the male to female ratio, health of the bears, and ages of the bears. This could be achieved by using traditional ecological knowledge (TEK) along with research methods. Secondly, understanding how the changing climate is affecting the main prey of the polar bear; the ring and bearded seals. Understanding if the accessibility to food has changed because of the availability of prey or obtainability of prey would help to know if there is a carrying capacity issue. Thirdly, use the knowledge of food source and habitat availability, along with the population dynamics to formulate a carrying capacity for Area 1002. The information compiled could give a more complete picture and insight as to how the three acres of denning habitat loss would affect the SBS population.

This thesis does not show a significant impact from oil and gas development on SBS polar bear maternal denning habitat. The changes in climate, Arctic Sea ice, food source, and increased land-based den sites establish dynamic circumstances that need a more comprehensive study and analysis. The current hold on leasing tracts of lands in Area 1002 is subject to change based on the priorities of the Presidental Administration and Congress. This thesis has provided an initial analysis of the potential impacts industrial infrastructure could have on the maternal denning habitat in Area 1002. It has also indicated that further research and analysis is needed to show how the dynamic environment will affect the SBS polar bear.

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