Review of the SAE proposal for **SEISMIC EXPLORATION ON THE COASTAL PLAIN**
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Summary

SAExploration proposes to conduct a winter-time 3-Dimensional (3D) seismic survey of the coastal plain of the Arctic National Wildlife Refuge (Arctic Refuge). The posted plan of operations and seven-page proposal describing this activity lack adequate detail to address the multitude of potential impacts of such a large winter time operation on the sensitive tundra of the Arctic Refuge coastal plain. Here, I review the potential for the SAE proposed 3D survey to adequately mitigate impacts on maternal denning polar bears. This is an important topic for several reasons: Polar bears are listed as a threatened species under the U. S. Endangered Species Act (ESA), and they have depleted status under the U.S. Marine Mammal Protection Act (MMPA); the Southern Beaufort Sea (SBS) population of polar bears recently declined by approximately 40% as a result of global warming induced sea ice loss; poor survival of polar bear cubs during their first year of life is an important driver of recently observed declines in the SBS population and in other regions of the Arctic; and, the Arctic Refuge coastal plain region has long been known as an important polar bear maternal denning area, and hence an important source of the reproduction/recruitment necessary to maintain the SBS population. Therefore, human activities that could reduce production and survival of cubs born in maternal dens on the Arctic Refuge could have negative population level

effects. SAE proposes to protect polar bears from adverse impacts by conducting an aerial survey, with forward looking infrared (FLIR) imagery, before on the ground activities begin. Although methods are not clearly specified, SAE proposes to further protect polar bears in dens with visual surveys (scouting) when their advance survey crews enter the proposed testing area at the start of operations. Even multiple FLIR surveys would be inadequate to assure detection and avoidance of all dens, especially across such an extensive landscape. And, polar bear dens cannot typically be detected with visual methods except when pregnant females are excavating dens in autumn and when mothers and cubs emerge in spring. Therefore, attempts by seismic crews to visually detect polar bear families before the den emergence period in spring would risk disturbance at a critical time of development for young cubs and place SAE at regulatory risk under both the ESA and the MMPA. Hence, the SAE proposal is inadequate to assure that the 3D testing operations will not impact some denned polar bears. Sea ice loss can only continue to drive the status of this population downward in the medium and longer terms. Protecting maternal denning habitat is a central objective of the polar bear Conservation Management Plan (U. S. Fish and Wildlife 2016), recognizing that negative impacts on maternal denning bears or their cubs, resulting from inadequate measures to detect and protect dens, could further reduce cub survival, and accelerate population decline—negatively impacting the likelihood of recovering the SBS population as mandated by the Conservation Management Plan (U.S. Fish and Wildlife (2016).

Introduction

Across most of their range, pregnant female polar bears excavate dens in snow and ice in early winter (Harington 1968; Lentfer and Hensel 1980; Ramsay and Stirling 1990; Amstrup and Gardner 1994). They give birth in those dens during midwinter (Harington 1968; Ramsay and Dunbrack 1986) and emerge from dens when cubs are approximately three months old. Polar bear cubs are born very undeveloped (altricial) and unable to survive rigors of the Arctic winter outside the shelter of the den. The time spent in maternal dens is a critical period in their life cycle because, during denning, polar bears are unable to simply move away from a potential disturbance without substantial risk to newborn cubs. Amstrup and Gardner (1994) reported mortalities of cubs born to radio-collared polar bears that were forced from their dens prematurely, verifying that the extended period of denning after birth is essential to early cub survival.

Industrial operations like seismic testing, therefore, are a potential threat to denning polar bears (Stirling 1990, Stirling and Andriashek 1992, Amstrup 1993, Amstrup and Gardner 1994). This is especially true in Alaska, where "den concentration areas" are absent. These concentration areas, typical of some other Arctic regions, can be placed off limits to human activities or protected with other restrictions. However, snow accumulation sufficient for denning in northern Alaska occurs mainly in narrow linear patches of coastal and riverbank habitats that are widely scattered across broad reaches of coastal terrain (Amstrup and Gardner 1994, Durner et al. 2001, 2003).

These banks are largely invisible under winter snow. Distinguishing which banks may hold polar bear maternal dens, in any one winter, therefore, is essentially impossible and largely prevents locating dens with visual techniques (Amstrup et al. 2004). The Arctic Refuge coastal plain (and adjacent areas) has long been known as important polar bear denning habitat (Amstrup 1993, Amstrup and Gardner 1994), but locating dens on the Arctic Refuge coastal plain is even more complex than in other parts of Alaska's Arctic slope. Durner et al. (2006) found that the density of denning habitat is higher than most other regions of northern Alaska, and the distribution is more complex. With more abundant, and more complex, denning habitat, identifying den locations on the Arctic Refuge coastal plain when they are totally covered by winter snow, presents an especially difficult challenge.

Polar bears in northern Alaska may enter dens as late as mid-December and can remain in dens until mid-April (Amstrup and Gardner 1994). Throughout most of this time they are invisible under the snow. Amstrup et al. (2004) tested whether FLIR imaging, could detect otherwise invisible dens in mid-winter and meet the challenge of locating dens so that they can be protected from possible disturbances. Below, I highlight that while FLIR can detect many dens under some circumstances, it cannot detect all dens and has significant limitations. The proportion of dens that can be detected with FLIR relies on intensity of survey efforts and the degree of assurance that surveys of all potential denning areas are conducted under optimal weather conditions. Despite published descriptions of these “optimal” conditions (Amstrup et al. 2004, York et al, 2004, Robinson et al., 20014), the track record of recent FLIR surveys conducted by industry shows best practices have not been followed during operational applications. More volatile recent winter weather conditions in Arctic Alaska also have reduced the temporal windows of “optimal” conditions, further complicating application of FLIR methods. Therefore, there is no assurance that all dens will be located using FLIR and that some dens could be negatively impacted during the SAE proposed survey activities. Because the Southern Beaufort Sea subpopulation of polar bears is declining, it must be assumed that added impacts from the SAE proposal could have negative population effects.

Effectiveness of a FLIR survey to detect polar bear dens on the Arctic Refuge coastal plain

Amstrup et al. (2004) evaluated effectiveness of FLIR for detecting maternal dens by flying multiple survey flights over 23 polar bear dens for which exact location was known in advance of testing. Although these known dens were visited multiple times (67 total) four (17%) of them were never detected, and it is significant that just two (50%) of four dens that were visited on only one occasion were detected. Because researchers knew the locations of these dens in advance they could set up flights for ideal view angle and altitude. Yet, they still detected only half of them—suggesting that a 50% detection rate is probably close to the highest that could reasonably be expected from a single survey effort.

During the 63 flights over the 19 dens that were visited multiple times, Amstrup et al. (2004) failed to detect the den on 21 (33%) of the multiple visits. Hence, even with multiple visits, they detected dens *with known locations* only 67% of the time. Despite identifying optimal conditions for den detection by FLIR, Amstrup et al. (2004) and York et al. (2004), recognized that even under ideal conditions, some dens would never be detected with FLIR due to depth of snow or competing nearby hot spot signatures etc. They also concluded, however, that FLIR surveys might produce detection rates approaching 90%. This hypothesized upper limit of detection probability depended on making enough flights to assure that every area of potential habitat could be covered under optimal conditions. Clearly, however, one survey effort could not be expected to detect all dens in a complex area like the Arctic Refuge. With only one survey, den detection rates are unlikely to exceed 50%.

Research published 14 years ago and refined 4 years ago (Amstrup et al. 2004, York et al. 2004, Robinson 2014) emphasized the need to take advantage of optimum ambient conditions. Yet, despite identifying conditions when FLIR performance is greatest, and strongly recommending future flights stick to those conditions, these and other best practices have not been incorporated into industry applications of FLIR searches for maternal dens. Consequently, in practice the den detection rate of FLIR has been unacceptably low. Between 2004 and 2016, FLIR surveys conducted in advance of various oil field operations along Alaska's north slope correctly identified 12 maternal dens but missed 11 dens (essentially the 50% detection rate predicted above) that were within the survey areas. These surveys also identified 22 "hotspots" that were presumed to be maternal dens but turned out not to be dens. So, not only did these surveys miss almost as many dens as they detected (11 versus 12), they also led to much wasted time and effort—as staff attempted to monitor and avoid sites that were not dens at all.

In February of 2018, the USFWS contracted a 10-day intensive FLIR survey over portions of the Arctic Refuge coastal plain and adjacent habitat that is known to be used frequently by denning females. Ten hotspots were recorded (Owyhee Air Research, Inc. 2018), but only 2 actually turned out to be dens. There were no known (by radio telemetry) dens in the area searched, so we cannot know how many dens this FLIR survey aircraft actually flew over. However, on average up to 31 denning bears (see below comments about den distribution on and adjacent to the Arctic Refuge Coastal

Plain) could have been in the area within which this FLIR survey was conducted, suggesting several dens were probably missed.

In addition to the need to perform surveys under optimal atmospheric conditions, the observation platform is a critical component of successful FLIR surveys. All surveys completed for the Amstrup et al. (2004) analysis were performed with helicopters. Helicopters allow essentially infinite variation of view angle and speed. They also allow fixed spot hovering and easy visual ground observations to help assess whether a detected hot spot in the snow is created by an obvious feature on the ground. Although covered dens are not visible under the snow, many other objects or features that generate warm signatures in FLIR (e.g. exposed boulders, snow cornices, and even abandoned oil drums) can be identified visually to avoid creating a “false-positive” or presumed den where there is none. Modern FLIR imagers have a visual video mode. But, there is no substitute for being able to simply look out the window to get the best sense of whether a FLIR target is a den. These nimble flight capabilities of helicopters maximize efficacy of FLIR surveys and were strongly recommended in the FLIR operations protocol developed after testing was completed (York et al. 2004). Despite recommendations, all operational surveys have been conducted with fixed wing aircraft. Fixed wing aircraft typically require flight at higher altitude, have much greater restrictions on approach speed and view angles, and of course cannot hover. The typically more restricted visibility from fixed wing aircraft, prevents focusing on suspicious spots, and higher flight altitude along with faster speeds limit the ability to visually check suspected hotspots from the air.

Another challenge to FLIR capabilities is the changing weather in the Arctic. In nearly 20 years since the initial FLIR testing (Amstrup et al. 2004), weather patterns in northern Alaska have changed dramatically. During aerial surveys and helicopter capture work, conducted as part of long term research conducted by the U.S. Geological Survey, field work has increasingly been hampered by increasing fog, clouds and humidity that have accompanied warmer temperatures. There is far less of the crisp cold and dry weather that characterized winter and spring on the Arctic coastal plain in the 1980s and 1990s.

Even under ideal conditions, FLIR surveys will not be perfect, and airborne moisture severely limits FLIR effectiveness (Amstrup et al. 2004). Theoretically, FLIR detection should be most effective in early winter when snow cover over dens is minimal. But early winter especially is characterized by much airborne moisture including precipitation, fog, and clouds—limiting FLIR effectiveness. Therefore, the changing Arctic weather conditions further limit the utility of FLIR as a den detection and protection tool. The 10-day survey effort in February 2018 was plagued by clouds and fog that limited FLIR and even flight capabilities. This provided additional verification of the shortcomings in using FLIR surveys to screen areas for maternal dens, and the need to develop more robust tools.

Given the track record for FLIR application in Alaska, given the more abundant and complex denning habitat of the Arctic Refuge (than in most places FLIR has been applied) and given the increasing proportions of unacceptable weather, a single FLIR survey of the expansive and complicated Arctic Refuge coastal plain, or even multiple surveys could not, with confidence, determine locations of all occupied dens, and could miss 50% of dens that are actually present.

Effectiveness of advance crew "visual searches" to detect polar bear dens on the Arctic Refuge coastal plain

By the time field work on the SAE seismic survey begins, the vast majority of dens will be drifted over with snow and visually undetectable. By mid-winter, snow drifts containing dens are indistinguishable from any other snow drift (Amstrup and Gardner 1994, Amstrup et al. 2004). There is no evidence that visual surveys by SAE advance survey crews could be effective in locating dens missed by FLIR. They therefore are likely only to detect dens if their activity disturbs the denned bears and causes them to open or emerge from their dens. Because advance survey crews are likely to drive lighter and quieter vehicles, than the other machines to follow, this opens up the possibility that undetected dens will be disturbed later during full operations, and by heavier vehicles that may precipitate significant impacts (see below).

Potential for seismic activities to disturb undetected dens

Tolerance of denned bears to disturbance

Available observations suggest that polar bears are more likely to abandon dens, due to outside disturbances, early in the denning season. Before they give birth, polar bears have relatively little maternal investment in a particular den site (Belikov 1976, Amstrup (1993, 2003), and it may be relatively easy for a female bear to relocate and establish a new den. Later in winter, cubs have been born and more snow has accumulated on top of the den, hiding it from view. With young helpless cubs that are dependent on their mother for warmth and sustenance, moving becomes a very risky business that can result in the death of cubs (Amstrup 2003). For those reasons, maternal bears appear very reluctant to leave dens in mid-winter or early spring (Amstrup 1993, Amstrup et al. 2004).

The few documented records of close encounters with occupied dens corroborate the concept that many maternal polar bears are reluctant to leave their dens until they are ready. In 1984, B.P. Kelly observed a female bear and single cub depart a den after close approach by a large helicopter on 8 March. Kelly entered the den and made some measurements. On 11 March he returned to the den to make more measurements but upon entering the den realized the bears were back. Even after this close encounter these bears remained in the den at least until 13 March (Amstrup 1993), suggesting a great degree of tolerance for disturbance or attachment to the den. On April 6, 2001, S. C. Amstrup fell through the roof of an occupied maternal den. His research team had been monitoring the den for some time and assumed it was abandoned. The previously visible exit had blown full of snow and Amstrup was probing the snow and digging test holes to locate the den in anticipation of entering and measuring it. Suddenly Amstrup fell through the den roof and realized the den was still occupied. Fortunately, no one was hurt, but this bear demonstrated great tolerance of activities near and right above her den. It was not until the roof of the den collapsed and a researcher fell into the den that she emerged. Similarly, B. J. Kirschhoffer and R. Robinson attempted to measure a den on 29 March 2009, only to find it still occupied. Because they intended to measure the interior of the den and didn't want to alter the natural dimensions, they began digging an access hole in the snow at a different location than the entrance constructed by the bear. When they broke through into the lair, they immediately saw the mother bear and withdrew. They had approached the den on snow-mobiles, and later realized they had parked on top of the den. Despite probing with a metal rod to locate and outline the structure and despite considerable walking around and digging, and despite coming face to face with an intruding researcher, the family remained in the den.

Polar bears also can be quite tolerant of intensive over-snow activities. Amstrup (1993) reported on an unmarked bear that emerged from but remained at her den as a survey party traveling in a 7000 kg tracked vehicle and two light snow machines approached to within 65 meters on 19 March 1993. The survey party, staking seismic shot lines at the time, withdrew upon seeing the bear and ceased nearby operations. The mother bear remained in and around the den until the morning of 21 March, when she and her two cubs walked north to the sea ice. Records verified that the same survey crew passed within 46 meters of the den on 9 March, and had surveyed the lines 270 meters and 135 meters from the den on 13 and 18 March without noticing that the den was open.

Perhaps the mother bear tolerated the early activities near her den because she was waiting for her cubs to have sufficient strength and mass to survive outside the den. The peak of emergence in the 1980s and early 1990s was 5 April and the earliest known emergence in those years was 13 March. Therefore, a 19 March den opening and a 21 March den departure were within the window of normal den emergence and exit times. The 21st of March may just have been when this bear's cubs were ready to leave the den. Alternatively, the level of noise from the tracked vehicle and the associated survey activities may have exceeded the disturbance levels of the earlier nearby activities, and prompted her to open her den when other nearby activities did not.

The fact that this bear tolerated multiple close vehicle approaches also might also reflect some degree of habituation to gradually intensifying sounds and vibrations from over snow vehicles. Smith et al. (2007) observed that 2 maternal bears exposed to ice road traffic in northern Alaska, were significantly less wary after den emergence and showed fewer vigilant behaviors than bears not exposed to industrial activities. These two bears had emerged from their dens but, as polar bears often do, they remained in the denning area and continued to use the den as a shelter for a few days. Smith et al. (2007) suggested there could be negative consequences to habituation that would result in paying less attention to the environment.

Reluctance to abandon a den can be viewed as “tolerance” of disturbances near dens, and bears may just hold tight and be fine while industrial activities occur nearby. But when the disturbance is both intensive and expansive, like 3D seismic testing, that apparent tolerance could have negative consequences. Available observations illustrate that some bears will not leave until the den is actually invaded. Whether from an innate feeling of security in a den or habituation to noises and vibrations of vehicles moving around them; the “comfort level” many polar bears show with activities outside their dens could result in waiting too long to leave a den when the disturbance is truly dangerous for them. It seems the heavy vehicle and activities associated with surveying the seismic lines only 65 meters from the den described above were the impetus for this bear to emerge, her behavior and other observations suggest however her den could have been runover had the seismic survey path been displaced 65 meters. In that circumstance, even if the female bear was able to leave a den ahead of oncoming vehicles, her departure threshold might have been exceeded so suddenly as to prompt hurried evacuation resulting in cubs being left behind and either crushed or abandoned.

Published accounts (Amstrup 1993) and other events recorded above testify to the fact that many maternal polar bears will tolerate high levels of disturbance near their dens. There is a great deal of variation however, in how protective mother bears are of cubs. Amstrup (1993) also reported on 2 female bears that may have abandoned dens without cubs after relatively mild industrial disturbance. We know that very small cubs cannot survive outside the den (Amstrup and Gardner 1994), and we suspect but cannot quantify that cub survival may be compromised if a female leaves her den, along with her cubs, before she feels her cubs are ready. During years of research in Alaska I noted several very small cubs that survived only short periods after den emergence. These cubs whose mothers emerged from dens very thin and probably not producing adequate milk, had more difficulty keeping up with their mother as she moved on the ice to hunt and were clearly more vulnerable than larger cubs. Polar bear cubs grow rapidly because they receive extremely rich milk from their mothers (Ramsay and Dunbrack 1986). Every additional day in the protection of a den, therefore, can benefit cub survival potential, and a too-early emergence even if cubs are able to move away with their mother, can reduce post-emergence survival.

Numbers and distribution of dens on the Arctic Refuge Coastal Plain

Due to declining availability of sea ice habitat, the Southern Beaufort Sea polar bear population has declined from an estimated 1800-2000 bears in the 1980s to around 900 now (Amstrup et al. 1986, Bromaghin et al. 2016). In the 1980s, as many as 142 polar bears may have been denning in Alaska or offshore of Alaska each winter (Amstrup et al. 1986). Of those, 46% or 65 dens may have been on land each winter. With ongoing decline in sea ice availability and its suitability for denning, bears are increasingly choosing to den on land (Amstrup and Gardner 1994, Fischbach et al. 2007, Olson et al. 2016). Of 94 maternal dens located by radio telemetry and catalogued (Durner et al. 2010) in and adjacent to Alaska, between 1998 and 2010, only 22 (23%) were found on sea ice. Of the 72 (77%) dens on land (dens on land-fast ice very near shore are included as land), three dens were in Canada just east of Arctic Refuge. The remaining 69 dens included 21 or 30% on the Arctic Refuge coastal plain. An additional nine bears denned just west of the boundary of Arctic Refuge along barrier islands and the coastal bluffs. Hence, 43% of Alaska's land denning bears were on or immediately adjacent to the Arctic Refuge coastal plain.

The coastal area of Arctic Refuge includes only ~15% of the coastal area of northern and NW Alaska, yet accounts for 30% of dens found on land between 1998 and 2010. Including dens found immediately west of Arctic Refuge on Flaxman and other barrier islands and shore bluffs, accounts for 43%. With three more land-denning bears just east of Arctic Refuge in Canada, it is clear this small portion of coastal habitat is important for denning. Assuming 30% of today's land denning bears den on the Arctic Refuge coastal plain, we could expect 22 dens to be there each winter. We also could expect 31 denning bears on and immediately adjacent to the Arctic Refuge coastal plain each winter.

The density of denning habitat on the Arctic Refuge coastal plain is higher than on other parts of Alaska's north slope (Durner et al. 2006). Denning habitat largely consists of linear features following drainage courses, lake shores and coastal banks, but these features, and their associated denning habitat are so abundant that they can be considered essentially uniform on the Arctic Refuge coastal plain. The SAE proposal calls for 12 linear miles of transect (four miles of receiver line and eight of source line) in each of the 2600 square miles of coastal plain habitat. This means there would be >31,000 miles of transect line over the top of and adjacent to polar bear denning habitat. Seismic transects are not merely lines, however, but must be viewed as strips with varying width. Evidence suggests (see previous section) that a 130 meter (65 meters each side of the line and ~427 feet, or 0.08 miles) wide strip or disturbance zone is associated with each line. Therefore, 97% of each square mile surveyed, or 2520 of the 2600 square mile coastal plain survey area, will be within the zone disturbed by either vibroseis machines or tracked vehicles used to deploy geophones. In other words, nearly the entire coastal plane will see activities that could disturb denning behavior.

Similarly, if we assume an average 10-foot-wide strip-width for vibroseis vehicles and the tracked vehicles used to deploy geophones, survey associated heavy vehicles will run over 59 square miles (2.3%) of Arctic Refuge habitat during the survey. Given the observed reluctance of polar bears to leave their dens, it is highly probable that mortalities (mother bears, cubs or both) will occur if vehicles run over occupied dens. Whether a den is actually impacted by survey strips can only be “yes” or “no.” That is, any one den on the Refuge will either be within the disturbance strip (yes) or outside the disturbance strip (no). This is an example of a “binomial probability problem” and allows straightforward calculation of probabilities that dens will be disturbed. Because 97% of the Arctic Refuge coastal plain will be within the potential disturbance strip width for the combined source and receiver survey lines, it seems logical to assume that almost all bears that choose to den on the coastal plain will be disturbed at some level. On the other hand, the much smaller 2.3% of the coastal plain will have heavy vehicle traffic, will impact fewer dens but at deadly risk. And, we can use the properties of the binomial distribution to quantify both levels of impact.

Available data indicate that 22 polar bears will choose to den on the Arctic Refuge coastal plain each year. Because FLIR surveys are likely to detect only half of those dens (see FLIR section) in advance of the SAE on the ground activities, we can assume that 11 dens will be undetected on the Arctic Refuge coastal plain each year. The uniform distribution of denning habitat (Durner et al. 2006), means we can assume an essentially random distribution of those 11 dens. The proportion of the coastal plain covered by the 10’ wide vehicle path, which corresponds with probable fatal impact, is 0.0227, or 2.27%. The probability P that heavy vehicles would run over one or more dens therefore is 0.0227. If there was only one den on the Refuge the probability of not running over it would be $1-P$ or 0.977. If there were 2 dens randomly located on the refuge the probability of not impacting either would be $(1-0.0227)^2$ or 0.954, and the probability of impacting one or more of them would be $1-(1-0.0227)^2$ or 0.045. The probability of impacting one or more dens increases as the n^{th} power of $1-P$ where n is the number of dens. Therefore, with the anticipated 11 undetected dens the probability that heavy vehicles will drive over one or more will be $1-(1-P)^{11} = 0.226$ or 23%. The mean of the binomial distribution is simply $n*P$ (*n times P*) or 0.253, and the variance is $n*P(1-P)$ or 0.25. On average, therefore, if multiple seismic surveys like this were performed, each would have, a 25% chance that at least one undetected bear den would be run over with likely fatal consequences (Table 1).

The probabilities that at least one undetected den will be disrupted at the less lethal level (that is within the 427' strip width described above) can be calculated the same way. Because so much of the Arctic Refuge coastal plain (97%) will be included in this category, the probability of this level of impact is far greater than with the 10' strip width. If only one bear denned on the Arctic Refuge coastal plain there would be only a 3% chance of missing it with this survey. The mean of this less lethal level of disturbance is 10.7, if 11 bears denned on the Refuge and the variance is 0.327. In other words, essentially all of the undetected dens on the coastal plain are likely to be impacted at this less lethal level (Table 1). It is critical to point out that a less lethal disturbance does not mean that it could not result in a lethal outcome. This is not a "non-lethal" finding. Rather, it means that the probability of death is lower when a vehicle drives near a den than in those cases where a vehicle drives over a den. Because female bears differ greatly in the degree to which they protect their cubs, some can be expected to simply abandon the den when activity outside is too close for its individual comfort level. It is suspected that some observed bears may have left their dens without cubs after mid-winter activity much farther away from dens than 65 meters (Amstrup 1993), and because earlier departure from a den means that cubs will be smaller and weaker than if they prolonged den residence, we cannot overlook possible fatal consequences from even more distant disturbances.

Table 1. Probabilities that the seismic survey proposed by SAExploration will disturb one or more undetected polar bear dens on the Arctic Refuge Coastal Plain. Lethal disturbances are likely when a heavy vehicle actually runs over a den. On average if there are 11 undetected bear dens on the refuge, a seismic survey like that proposed by SAE has a 25% chance that at least one polar bear will be killed when a heavy vehicle runs over it. Less lethal disturbances are likely when heavy vehicles pass within 65 meters either side (427' strip width) of a den. Because the less lethal strip width covers 97% of the coastal plain it is *virtually certain* that most undetected polar bears in their dens will be disturbed at some level. Some of these disturbances may be

inconsequential. However, effects of an early emergence such as poorer survival of cubs cannot be ruled out (see text), so they should not be considered “non-lethal.”

# DENS PRESENT	DEN RUN OVER	DEN NOT RUN OVER	DEN DISTURBED	DEN NOT DISTURBED
1	0.023	0.977	0.969	0.031
2	0.045	0.955	0.999	0.001
3	0.067	0.933	1.000	0.000
4	0.089	0.911	1.000	0.000
5	0.110	0.890	1.000	0.000
6	0.130	0.870	1.000	0.000
7	0.150	0.850	1.000	0.000
8	0.170	0.830	1.000	0.000
9	0.189	0.811	1.000	0.000
10	0.208	0.792	1.000	0.000
11	0.226	0.774	1.000	0.000
MEAN	0.253		10.66	
VARIANCE	0.247		0.33	

Potential for den disturbances to have a population level effect

The SBS polar bear population has been on a declining trend since the early 2000s (Bromaghin et al 2015). Despite considerable interannual variation in sea ice conditions, the secular warming trend resulting from increasing greenhouse gas concentrations guarantees that the long-term trend in sea ice and polar bear numbers will continue to be downward. Recognizing this, the Polar Bear Conservation Management Plan (U. S. Fish and Wildlife, 2016) warns that without mitigating greenhouse gas rise, it is unlikely that polar bears will be recovered, and calls for prompt action to reduce greenhouse gas emissions. The Conservation Management Plan also calls for specific “on the ground” management measures, that will contribute to the survival of polar bears in the interim (from now until effective greenhouse gas mitigation is in place). The goal of these measures is to retain polar bear numbers so that they will be in the best possible position to recover once Arctic warming is abated. Protecting maternal denning habitat is a key component of on the ground actions mandated by the Conservation Management Plan.

Negative population trends in the SBS stem mainly from sea ice declines that have reduced access to the polar bear's seal prey. Associated nutritional stress, in turn, has been driving lower survival rates—particularly of cubs and other young bears. An obvious manifestation of poor cub survival rates is the very low representation of yearlings in the SBS population after 2001 (Bromaghin et al. 2015). Only 6% of the polar bears captured from 2002 through 2010 were yearlings. A low proportion of yearlings in the population means many cubs are not surviving their first year of life. In contrast to recent years, yearlings represented 13% of bears captured in the SBS between 1981 and 1992—when the SBS population was estimated to be growing (Amstrup 1995). This trend of very low numbers of yearlings is also evident in the Western Hudson Bay population (Stapleton et al. 2014), which has been in a long-term declining mode (Lunn et al. (2016).

Cub survival in the SBS was estimated to be zero during 2004-2006 (Bromaghin et al. 2015). This means that in those years no yearlings were recruited into the population. Cub survival improved in later years of the Bromaghin et al. (2015) study, for reasons that are unclear, but yearling representation for the whole 2002-2010 period was still only about half of historic levels. If yearlings represent only 6% of the current SBS population of around 900, that could mean that in any one year the population would be composed of as few as 54 yearlings. And, 30% or 16 of those would have been born on the Arctic Refuge. Recent low recruitment rates are reflected in the goal of protecting denning bears from negative impacts of human activities—an essential component of the polar bear Conservation Management Plan (U.S. Fish and Wildlife 2016). With habitat quality in temporal decline, and with both the population size and survival rates of cubs at only half of historic levels, negative impacts on denning could accelerate the ongoing declining trend in the SBS population and lower the probability that the SBS population can persist until greenhouse gas levels are stabilized. Any such activity, therefore, should be considered "a population level effect."

The scale of the SAE proposal means that virtually every undetected polar bear den on the refuge will be exposed to a level of activity that has prompted den emergence in the past. And, there is a 25% chance that heavy vehicles could drive over at least one undetected maternal den with fatal consequences. Even if mother bears are able to escape being crushed as a vehicle drives over a den, it is highly unlikely that cubs could do so. Therefore, it is clear that impacts on denning success resulting from this survey could exacerbate the ongoing decline in the SBS population. The SAE seismic survey proposal clearly does not afford maximum possible protection for denning bears, and the actions proposed cannot assure there will not be negative population level effects. Actions that could negatively impact prospects for SBS polar bear persistence would be directly contrary to the stated goal of the Conservation Management Plan (U.S. Fish and Wildlife 2016).

Methodology notes:

My statistics on numbers of polar bear dens were from the USGS polar bear den database (Durner et al. 2010). Specific locations (whether a den was on land or on Arctic Refuge) were determined by locating the reported latitude and longitude locations in the database on a Google Earth interactive map.

Land dens includes dens on land fast ice right next to shore. This because these dens are immediately offshore on ice that doesn't move during winter and because the features on land fast ice that catch snow drifts usually have something to do with the land forms there, even if the den itself was on ice.

Boundaries of the Arctic Refuge were derived from an online interactive map available From the U.S. Fish and Wildlife Service (https://fws.maps.arcgis.com/apps/webappviewer/index.html?id=3eed8d6b30ea443dafe4380d70d0fa5e).

Approximate lengths of the coastlines of the Arctic Refuge and Alaska (from Canada to Pt. Hope) were calculated with the path distance tool in Google Earth.

Binomial analyses follow standard practices available on line or in most textbooks on basic statistics.

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