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Southern Beaufort Sea Polar Bears - Draft SAR - 22 June 2017.pdf
Amstrup et al. 2004 - Bioscience.pdf
Bromaghin et al. 2015 - Eco Apps.pdf
Conservation Council for Hawaii v NMFS.pdf
Denning Bears Analysis - 13Sept2018.docx
Denning Map.pdf
Durner et al. 2003 - Arctic.pdf
Final Rule MMPA 101(a)(5).pdf
MMPA Implementing Regulations on Incidental Take.pdf
Natural Resources Defense Council v Evans.pdf
Proposed Rule MMPA 101(a)(5).pdf
Robinson et al . 2014 - Bioscience.pdf
Rode et al. 2018 - JMamm.pdf
Rode et al. 2018b - Global Change Biology.pdf
Schiedler 2013 - Section 6 FLIR Report.pdf
Briefing Document October 2018.docx

Hi Greg,

I tried several ways to zip this stuff into one file but at the end of the day, it was funky It is a result of some issue with the new zip program, 7zip, so I didn't want to take any chances. Therefore, I've attached all files to this email (about 20MBs worth). There should be 16 files, 15 of which are supporting docs and 1 of which is the actual briefing paper. I've labelled them in what I hope is an obvious format so you can send them forward.
I should be up for another hour or so in hopes that I'm not dreaming about FLIR, "negligible impact", or mismatched toppers. If you need anything or have questions, please let me know. Otherwise, I'll be in the office by 8am at the latest.

Cheers,
Patrick

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POLAR BEAR (*Ursus maritimus*): Southern Beaufort Sea Stock

STOCK DEFINITION AND GEOGRAPHIC RANGE

Polar bears are found throughout the circumpolar arctic and occur in 19 relatively discrete subpopulations (http://pbsg.npolar.no/en/status/; Obbard et al. 2010), also known as stocks (Figure 1). Polar bear ranges are extensive and individual activity areas can be large (up to 167,000 km^2) (Garner et al. 1990, Amstrup et al. 2000). Six polar bear stocks have ranges extending into two or more countries (Amstrup et al. 1986, Amstrup and Demaster 1988, Obbard et al. 2010). Two polar bear stocks occur in Alaska, the Southern Beaufort Sea (SBS) and the Chukchi/Bering Seas (CBS) stocks (Figure 1). Together, the two stocks range throughout the Beaufort and Chukchi Seas, including the nearshore habitats. The stocks overlap seasonally in the eastern Chukchi and western Beaufort Seas. The SBS stock is managed by the United States and Canada and is also referred to as the Southern Beaufort Sea subpopulation when described by the International Union for Conservation of Nature, Polar Bear Specialists Group (IUCN-PBSG; Aars et al. 2006).

The distinction between the SBS and CBS stocks was originally determined by: (a) movement information collected from capture-recapture studies of adult female bears (Lentfer 1983); (b) physical oceanographic features that segregate stocks (Lentfer 1974); (c) morphological characteristics (Manning 1971; Lentfer 1974; Wilson 1976); and (d) variations in levels of heavy metal contaminants of organ tissues (Lentfer 1976, Lentfer and Galster 1987).

An extensive area of overlap between the Southern Beaufort Sea stock and the Chukchi/Bering seas stock occurs between Point Barrow and Point Hope, centered near Point Lay (Garner et al. 1990, Garner et al. 1994, Amstrup 2000, Amstrup et al. 2000, 2001a, 2002, 2004, 2005). Telemetry data indicates that adult female polar bears marked in the Southern Beaufort Sea spend about 25% of their time in the northeastern Chukchi Sea, whereas females captured in the Chukchi Sea spend only 6% of their time in the Southern Beaufort Sea (Amstrup 1995).

Despite their overlap in ranges (Figure 2), the existence of two stocks is further supported by more recent information on contaminants (Evans 2004a, b; Kannan et al. 2007), movement data from satellite-linked collars (Garner et al. 1994, Amstrup et al. 2004, 2005), and population responses to sea ice loss (Rode et al. 2014).

Contaminants

Mercury (Hg), selenium (Se), and cadmium (Cd) concentrations in polar bear liver and kidney tissues were significantly higher in the SBS stock than in the CBS (Evans 2004a, Kannan et al. 2007), while the concentration of vanadium (V) in kidney tissue was higher in the CBS stock than in the SBS (Evans 2004a). In addition, Kannan et al. (2007) reported concentrations of trace elements of silver (Ag), bismuth (Bi), barium (Ba), copper (Cu), and tin (Sn) were significantly higher in the CBS stock than the SBS stock.

In a separate study, Evans (2004b) analyzed the persistence of organochlorine (OC) contaminants, including polychlorinated biphenyls (PCB) congeners; dichlorodiphenyltrichloroethane (DDT) and its metabolites, including dichlorodiphenyldichloroethylene (DDE); and chlordane-related compounds (CHL) in polar bears from both stocks. While concentrations of OCs in the SBS and CBS stocks were relatively low compared to other polar bear stocks, concentrations of OCs were higher in the SBS than in the CBS stock.

Genetics

Several modern studies have investigated the genetics of polar bears throughout their range. Analysis of mitochondrial DNA and microsatellite DNA loci indicates little differentiation between the SBS and CBS polar bear stocks (Cronin et al. 1991, 2006, Scribner et al. 1997). Using 16 variable microsatellite loci, Paetkau et al. (1999) observed small differences in genetic distances between the SBS stock and CBS stock; however, a lack of dramatic genetic variation led researchers to conclude that polar bears belong to a single evolutionary significant unit. More recently Peacock et al. (2015) and Malenfant et al. (2016) characterized genetic structure of polar bears subpopulations into large clusters. Peacock et al. (2015) identified four clusters, Malenfant et al. (2016) identified six clusters), with the SBS and CBS occupying the same cluster in both studies. While genetically similar, demographic and movement data indicate a degree of site fidelity, suggesting that the stocks may be managed separately.

Distribution

The SBS polar bear stock is distributed predominantly throughout the central Beaufort Sea region. The western edge of their range is near Icy Cape. Amstrup et al. (2000) reported that the eastern boundary of the Southern Beaufort Sea stock occurred south of Banks Island and east of the Baillie Islands, Canada. However, analysis of polar bear movements using satellite telemetry from 2000 to 2006 (Amstrup et al. 2004, 2005), capture-recapture data (Regehr et al. 2006, Stirling et al. 2007), and harvest information suggest the eastern boundary for the SBS stock may be more appropriately located further west, near the village of Tuktoyaktuk, Canada. Nonetheless, until scientific review by the IUCN-PBSG accepts the eastern shift in the range of the SBS stock we continue to use the previously published boundaries for the SBS stock delineated by Amstrup et al. (2000; Figure 2), the eastern edge of which lies south of Banks Island and east of the Baillie Islands in Canada.

Responses to Changing Sea Ice Conditions

In response to changes in sea ice characteristics and declines in sea ice habitat over the continental shelf during the summer and late autumn (Stroeve et al. 2014), some polar bears of the SBS stock have shifted their ranges to search for seals on ice and to access the remains of subsistence-harvested bowhead whales on land (Schliebe et al. 2008, Atwood et al. 2015a). Changes in distribution and movements, including increased land use during the summer, are expected to occur with increasing frequency in the future (Durner et al. 2009, Amstrup et al.

2007, Schliebe et al. 2008, Atwood et al. 2015a).

In addition, polar bears from the SBS stock have historically denned on both the sea ice and land, but thinning of sea ice in recent years may have contributed to a decline in the proportion of polar bears denning on the sea ice. Fischbach et al. (2007) found that the proportion of dens on the pack ice declined from 62% during the period from 1985 to 1994 to 37% during the period from 1998 to 2004. Currently, the primary terrestrial denning areas for the SBS stock in Alaska occur on the barrier islands from Barrow to Kaktovik, and along coastal areas up to 25 miles inland, including the Arctic National Wildlife Refuge to Peard Bay, west of Barrow (Amstrup and Gardner 1994, Amstrup 2000, Durner et al. 2001, 2006, 2013).

Polar bears are generally expected to experience nutritional stress as loss of Arctic sea ice continues (e.g., Stirling and Parkinson 2006, Amstrup et al. 2010, Rode et al. 2010). In some regions ice loss has apparently led to negative demographic effects (Regehr et al. 2007, 2010, Bromaghin et al. 2015), while in other regions polar bear subpopulations appear stable or increasing (Stirling et al. 2011, Peacock et al. 2013, Rode et al. 2014). In a recent study, Rode et al. (2014) found that SBS stock bears were responding differently to changing sea ice conditions compared to bears in the CBS stock. During the period from 2008 to 2011, bears inhabiting the Chukchi Sea were in better condition, larger, and appeared to have higher reproductive rates than bears inhabiting the southern Beaufort Sea (Rode et al. 2014).

In another study investigating climate effects on bears, Hunter et al. (2010) used the relationships between sea ice and polar bear vital rates estimated during the period from 2001 to 2006 to project the long-term status of the SBS stock under sea ice conditions as forecast by global climate models. The projection suggested there could be a high probability of significant population decline in the 21st century for the SBS stock. More recently, Bromaghin et al. (2015) analyzed demographic data from 2001 to 2010, and found similar evidence to Regehr et al. (2010) for expected low survival of all sex and age classes of polar bears in the mid-2000s. However, Bromaghin et al. (2015) also found survival of most sex and age classes of polar bears in the SBS stock increased during the period from 2007 to 2010, despite continued declines in the availability of sea ice.

POPULATION SIZE

Polar bears occur on sea ice at low densities throughout much of their range (DeMaster and Stirling 1981). Accurate estimates of abundance for the SBS stock have been difficult to obtain because of low population densities, inaccessibility of habitat, movement of bears across management and international boundaries, and budget limitations (Amstrup and DeMaster 1988, Garner et al. 1992). Research on the SBS stock began in 1967 and is one of only four polar bear subpopulations with long term (greater than 20 years) data.

Long term capture-recapture studies in the Beaufort Sea have provided several estimates of abundance of the SBS stock; however, direct comparison may be inaccurate due to varied sampling strategies and analyses. Amstrup et al. (1986) estimated abundance of the SBS stock to be 1,778 bears during the period from 1972 to 1983. The abundance in 1992 was estimated at 1,480 animals (Amstrup (1995). In 2001, Amstrup (USGS, unpublished data) approximated an abundance of 2,272 bears based on an estimate of 1,250 females and a sex ratio of 55% females (Amstrup et al. 2001b). In 2006, a capture-recapture study that sampled American and Canadian portions of the Beaufort Sea region from 2003 to 2006 estimated abundance of the SBS stock in 2006 to be 1,526 individuals (Regehr et al. 2006). A subsequent capture-recapture analysis during the period from 2004 to 2010 suggested a reduction in survival and abundance from 2004 through 2007 and subsequently, the population appeared to stabilize with improved adult and cub survival (Bromaghin et al. 2015). From this analysis they calculated an abundance estimate of approximately 900 bears in 2010 (Bromaghin et al. 2015). Possible negative biases in abundance estimates may exist due to variation in the intensity and geographic coverage of capture-recapture sampling (specifically, a lack of systematic sampling in some portion of the stock's Canadian range during the period from 2007 to 2010; Bromaghin et al. 2015). Thus, such possible negative biases necessitate a cautious interpretation of trends and point estimates of abundance for the SBS stock. Conservatively, the decline in abundance of the SBS stock seemed unlikely to have been less than 25%, but may have approached 50% (Bromaghin et al. 2015). Abundance estimates in Bromaghin et al. (2015) and previous analyses were based on capture-recapture sampling that ended at Barrow and did not extend farther west to where some polar bears from the SBS stock may be found. Data collection is ongoing and updated population estimates are expected in the future.

Minimum Population Estimate

Under the Marine Mammal Protection Act of 1972, as amended (MMPA), a "minimum population estimate" (N_{MIN}) is defined as "an estimate of the number of animals in a stock that is based on the best available scientific information on abundance, incorporating the precision and variability associated with such information; and provides reasonable assurance that the stock size is equal to or greater than the estimate."

For polar bears in the SBS stock, the most recent population estimate is approximately 900 animals in 2010, based on analysis of data during the period from 2001 to 2010 (Bromaghin et al. 2015). The corresponding N_{MIN} is calculated based on the lower 20th percentile of the sampling distribution for population size, using the methods of Wade (1998), as follows: $N_{MIN} = N/\exp(0.842 * (\ln(1+CV(N)^2))^{½})$ = 782 animals, where N = 900 animals and the coefficient of variation (CV) = 0.17 (Bromaghin et al. 2015).

This estimate may be biased low because the western extent of the study area (Point Barrow) fell short of the SBS stock range, which extend west of Point Barrow to Icy Cape (Obbard et al. 2010).

Current Population Trend

Although no quantitative information is available to estimate population status prior to the 20th century, polar bear harvest during that period was largely conducted by Alaskan Natives for subsistence (Schliebe et al. 2006), and the stock is, therefore, believed to have existed at or near its environmental carrying capacity. Harvest by non-Alaska Natives became common in the early 1960s, and the size of the stock declined substantially (Amstrup et al. 1986, Amstrup 1995). Sport harvest in Alaska was eliminated after passage of the MMPA in 1972, and the SBS stock increased in numbers for the following 20 years. This increase was based on: (a) capture-recapture data; (b) observations by Alaska Natives and residents of coastal Alaska and Russia; (c) live-capture of polar bears per unit effort indices (USGS unpublished data); (d) reports from Russian scientists (Uspenski and Belikov 1991); and (e) harvest statistics. Additionally, recapture data from the SBS stock indicated a population growth rate of 2.4% from 1981 to 1992 (Amstrup 1995).

However, the SBS stock experienced little or no growth during the 1990s (Amstrup et al. 2001b). Evidence suggests that SBS stock experienced negative effects from habitat loss due to climate change. Declines in body size, body condition, and recruitment in recent decades have been associated with declining sea ice availability (Regehr et al. 2006, Rode et al. 2010, 2014). Further, Regehr et al. (2010) suggested several years of reduced sea ice in the mid-2000s were associated with low breeding probability and survival, leading to a negative population growth rate.

Relationships between sea ice and polar bear population dynamics in the southern

Beaufort Sea are complex and likely reflect a combination of factors, such as ecological variation and density effects. Reduced spatial and temporal availability of sea ice is expected to be an increasingly important factor in population dynamics of SBS stock polar bears. As the climate continues to warm, polar bears will likely experience reduced access to prey, reduced cub survival, and deficient body condition. Based on all available data, the IUCN-PBSG considered the current trend of the SBS population to be in decline (PBSG 2015). The Service supports this determination.

CURRENT AND MAXIMUM NET PRODUCTIVITY RATES

Direct estimates of maximum net productivity rates (R_{MAX}) are not available for the SBS stock, although values can be inferred based on capture-recapture studies in the region and knowledge of polar bear population dynamics. The following information was used to estimate R_{MAX}. During the period from 1981 to 1992 the population of SBS stock was increasing and vital rates of polar bears were as follows: average age of sexual maturity (females) was 6.0 years; average cub of year (COY) litter size was 1.7; average reproductive interval was 3.7 years; and average annual natural mortality ranged from 1.0-3.0% for adult age classes (Amstrup 1995). Using these data, Amstrup (1995) projected an annual intrinsic growth rate (i.e., natural mortality excluding human-caused mortality) of 6.0% for the SBS stock. More recently, survival and reproductive rates for the SBS stock for the period from 2004 to 2006 (Regehr et al. 2010) indicated that, under favorable sea ice conditions, the population was capable of increasing between 6.0% and 7.5% annually (Hunter et al. 2010). Because the SBS stock was not at a greatly reduced density when any of the preceding estimates were made, these estimates are likely lower than the maximum intrinsic growth rate for the population. For the purpose of this assessment, we use R_{MAX} of 7.5% as the current net productivity rate for the SBS stock but acknowledge that potential current and future effects of sea ice loss could lead to lower realized growth rates (Regehr et al. 2010, 2015 Bromaghin et al. 2015).

POTENTIAL BIOLOGICAL REMOVAL (PBR)

The MMPA defines Potential Biological Removal (PBR) level as the product of the minimum population estimate of the stock, one-half the maximum theoretical or estimated net productivity rate of the stock at a small population size, and a recovery factor (F_R) of between 0.1 and 1.0: $PBR = N_{MIN} \times 0.5R_{MAX} \times F_R$. Wade and Angliss (1997) recommend a default recovery factor (F_R) of 0.5 for a threatened population or when the status of a population is unknown. Therefore, we have calculated a PBR of 14 bears per year for the SBS stock using a N_{MIN} of 782, a R_{MAX} of 7.5%, and a F_R of 0.5.

ANNUAL HUMAN CAUSED MORTALITY AND SERIOUS INJURY

Fisheries Information

Polar bear stocks in Alaska have no direct interaction with commercial fisheries activities. Consequently, the total fishery mortality and serious injury rate for the SBS stock is zero.

Total Mortality

1. **Native Subsistence Harvest**

Alaska Natives have hunted polar bears for subsistence purposes for centuries (Lentfer 1976), and polar bears continue to be an important resource for the Inupiat and Yupik peoples of coastal communities throughout northern and western Alaska (Brower et al. 2002, Johnson 2002). Polar bears provide a source of meat and raw materials for clothing and handicrafts, and polar bear hunting is a source of pride, prestige, and accomplishment for Native hunters. Although polar bear hunting was prohibited by the MMPA in 1972, an exemption was made for Alaska Natives living in coastal communities to allow them to hunt polar bears for subsistence purposes and for the creation and selling of authentic native articles of handicraft and clothing, provided that take was not accomplished in a wasteful manner.

For the SBS stock, subsistence harvest is addressed through an agreement between the Inuvialuit of Canada and the Inupiat of Alaska (I-I Agreement; Brower et al. 2002). In 2010, Commissioners of the I-I Agreement recommended that the combined U.S.-Canada quota be reduced from 80 bears to 70 bears, shared equally between the countries (USFWS 2011). In Canada, the boundary of the SBS stock with the neighboring NBS stock was adjusted through polar bear management by-laws in the Inuvialuit Settlement Region in 2013, affecting Canadian quotas and harvest levels from the SBS stock. For the most recent 10-year period, 2006-2015, an average of 19 bears per year were removed from the U.S. portion of the SBS stock (see Figure 3, which provides the annual estimated removals above each graph bar). The average sex composition of removals during this period was 27% female, 50% male, and 23% unknown. During the same time period the average Canadian harvest for the Southern Beaufort Sea was 14.2 bears per year with a sex ratio of 56 males to 44 females.

2. Other Mortality

Other forms of bear removals include those associated with accidental mortality during scientific research, during industrial activities, defense of life, and placement of orphaned cubs. Two research-related mortalities have occurred between 2005 and 2015. One removal occurred in 2005 and the other removal happened in 2009. Two mortalities occurred as a result of deterrence activities. In 2011, a bear was killed during a deterrence action by an oil and gas company. In 2012, another bear was killed during a deterrence action by a village bear patrol.

Although depleted species may not be taken from the wild for the purpose of public display, under section 109(h) of the MMPA, orphaned cubs can be removed from the wild if a determination is made that removal is in the best interest of the cub. Such a situation occurred in 2011, when an orphaned cub was removed from the Beaufort Sea coast and placed into a public display facility after it was discovered near an industrial facility.

In 2012, one adult female and her two-year old male cub were found dead on an island near industry facilities. The true cause of their deaths remains unknown.

In 2014, two defense-of-life mortalities by non-Alaska Natives occurred with humans engaged in recreational activities. The first incident occurred in August 2014 at Bullen Point and the second occurred a week later in the Arctic National Wildlife Refuge.

STATUS OF STOCK

On May 15, 2008 (73 FR 28212), the Service listed all polar bears across their range as "threatened" under the Endangered Species Act of 1973, as amended (ESA). Due to this listing under the ESA, the polar bear is considered "depleted" under the MMPA, and the SBS stock is considered to be a strategic stock under the MMPA.

Conservation Issues and Habitat Concerns

1. **Climate Change**

Polar bears are adapted to life in a sea ice environment. They depend on the sea ice-dominated ecosystem to support essential life functions. Sea ice provides a platform for hunting, denning, feeding, and resting; seeking mates and breeding; movement to terrestrial maternity denning areas; and long-distance movements (Stirling and Derocher 2012). The sea ice ecosystem supports ringed seals (*Phoca hispida*), the primary prey for polar bears, and other marine mammal prey (Thiemann et al. 2008, Rode et al. 2014). In 2012, the National Marine Fisheries Service (NMFS) listed two prey species of polar bears, the Arctic subspecies of ringed seal (*Phoca hispida hispida*) and the Beringia distinct population segment (DPS) bearded seal

(*Erignathus barbatus nauticus*), as threatened species under the ESA (77 FR 76706 and 77 FR 76740; December 28, 2012). Both species were listed due to climate change. The U.S. District Court for the District of Alaska vacated the listing under the ESA for the Beringia DPS bearded seal on July 25, 2014 and for the Arctic ringed seal on March 11, 2016. NMFS appealed both decisions. However, on October 24, 2016, the Ninth Circuit Court review of the Beringia DPS bearded seal case reversed the judgment of the U. S. District Court decision and found that the listing decision was reasonable, upholding federal protection of the subspecies under the ESA.

Sea ice is rapidly diminishing throughout the Arctic (Stroeve et al. 2012) and large declines in polar bear habitat have occurred in the southern Beaufort and Chukchi Seas between the period from 1985 to 2006 (Durner et al. 2009). In addition, it is predicted that the greatest declines in 21st century polar bear habitat will occur in Chukchi and southern Beaufort Seas (Amstrup et al. 2007, Durner et al. 2009, Douglas 2010). Patterns of increased temperatures, earlier onset of and longer open water periods, later onset of freeze-up, increased rain-on-snow events, and potential reductions in snowfall are occurring. In addition, positive feedback systems (i.e., the sea-ice albedo feedback mechanism) and naturally occurring events, such as warm water intrusion into the Arctic and changing atmospheric wind patterns, can operate to amplify the effects of these phenomena. The following changes have been documented in the southern Beaufort Sea: increased fragmentation of sea ice; an increase in the extent of open water areas seasonally; reduction in the extent and area of sea ice in all seasons; retraction of sea ice away from productive continental shelf areas during the summer; reduction of the amount of multi-year ice, and declining thickness and quality of shore-fast ice (Parkinson et al 1999, Rothrock et al. 1999, Comiso 2003, Fowler et al. 2004, Lindsay and Zhang 2005, Holland et al. 2006, Comiso 2006, Serreze et al. 2007, Stroeve et al. 2008).

The SBS stock appears to be experiencing effects of changing sea ice conditions (Hunter et al. 2010, Regehr et al. 2010, Rode et al. 2010, 2014, Bromaghin et al. 2015). Although relationships between sea ice and vital rates for polar bears are more complex than previously hypothesized (Bromaghin et al. 2015), sea ice loss and associated ecological changes are expected to have the greatest impact on SBS stock population dynamics, and long-term polar bear population declines are forecast if sea ice loss continues (Amstrup et al. 2007, Hunter et al. 2010). The SBS stock appears to be vulnerable to large-scale, dramatic seasonal fluctuations in ice movements; decreased abundance and access to prey; and increased energetic costs of hunting. Hence, the Service is working with multiple partners on measures to protect polar bears and their habitats.

2. Subsistence Harvest – Combined U.S. and Canada

Recognition that management of polar bears in the SBS stock is shared between Canada and Alaska led to the development of the Inuvialuit-Inupiat Agreement (I-I Agreement) between the Inuvialuit of the Inuvialuit Game Council, Canada, and the Inupiat of the North Slope Borough, Alaska, in 1988 (I-I Agreement, Nageak et al. 1991, Treseder and Carpenter 1989, Prestrud and Stirling 1994, Brower et al. 2002). During the period from 1988 to 2014 (the most current data), the combined Alaska and Canada mean harvest from the SBS stock has been approximately 56 bears per year (USFWS unpublished data). During the more recent time period (2006-2015), removals due to human causes have been lower (approximately 33 bears per year in Alaska and Canada). The harvest in Canada is regulated by a quota system (Prestrud and Stirling 1994, Brower et al. 2002), which has resulted in accurate harvest reporting, strict controls on harvest, and efficient monitoring and enforcement. The harvest quota established under the I-I Agreement in Alaska is voluntary and less efficient, overall, compared to the Canadian system (Brower et al. 2002).

Given the change of management boundary between the SBS and NBS stocks in Canada and evidence for population decline of the SBS stock (Bromaghin et al. 2015), harvest quotas should be reassessed to ensure harvest remains at a sustainable rate. Additionally, population data for the SBS stock need to be updated. The Service and its partners, including the North Slope Borough and Inuvialuit Game Council, are currently conducting harvest risk analyses and working with stakeholders to identify potential adaptive management strategies for the SBS stock.

3. Oil and Gas Development

Oil and gas development and shipping occur within the range of SBS stock polar bears. Increases in circumpolar Arctic oil and gas development, coupled with increases in shipping due to the lengthening open water season, increase the potential for an oil spill to negatively affect polar bears and their habitat. Oiled polar bears are unable to effectively thermoregulate, and may be poisoned by ingestion of oil during grooming or eating contaminated prey (St. Aubin 1990). In addition, polar bears can be attracted to petroleum products and actively investigate oil spills. They also are known to consume foods fouled with petroleum products (St. Aubin 1990; Derocher and Stirling 1991).

The Service works to monitor and mitigate potential impacts of oil and gas activities on polar bears through Incidental Take Regulations (ITRs), as authorized under the MMPA. Under these regulations, oil and gas activities must: 1) ensure impacts to small numbers of polar bears remain negligible, 2) minimize impacts to their habitats, and 3) ensure no unmitigable adverse impact on polar bear availability for Alaska Native subsistence use. The ITR program also requires monitoring and reporting to provide a basis for the evaluation of potential impacts of current and future activities on polar bears. The Service has concluded that at current levels, oil and gas exploration posed a relatively minor threat to the bears of the SBS stock (81 FR 52276; August 5, 2016). Current ITRs for the southern Beaufort Sea region will expire in 2021.

While polar bears could be impacted by future onshore or offshore oil spills, historically the SBS polar bear stock has not been impacted by oil spills in the Beaufort Sea. Between 1985 and 2013, eight crude oil spills of amounts greater than 500 barrels occurred on the North Slope of Alaska, within the range of the SBS stock (BOEM 2014). These spills posed little risk to polar bears and no impact to polar bears from the spills were documented because the spills occurred in heavily industrialized areas during times of the year when polar bear use was low. In addition, no offshore exploration wells have been drilled (an activity which would increase the risk of an offshore oil spill) in the Beaufort Sea since 2003 (BOEM 2014).

Nonetheless, oil spills remain a concern for polar bears throughout their range. Polar bears are most vulnerable to oil spills during times when they aggregate near onshore food resources, such as autumn polar bear aggregations near subsistence-harvested bowhead whale carcasses at Point Barrow, Cross Island, and Kaktovik (76 FR 47010; August 3, 2011). Potential impacts from an oil spill depend on the size, location, and timing of spills relative to polar bear distributions; and also on the effectiveness of spill response and clean-up efforts. Bears could also be affected indirectly either by food contamination or by chronic lasting effects caused by exposure to oil (St. Aubin 1990).

Although the probability of an oil spill affecting a significant portion of Alaska's polar bears in the foreseeable future is low, we recognize that the potential impacts from such a spill could be significant, particularly if subsequent clean-up efforts were ineffective. At present, the Service is working with industry, oil spill response agencies, public display facilities, and others to increase response capabilities for dealing with oiled or compromised bears in the event of a spill. In addition, the Service has updated its polar bear oil spill response plan. This plan is meant to help prepare and improve the Service's response capabilities by describing appropriate response strategies, clarifying response roles, obtaining the necessary training, and improving our capability for holding and treating oiled bears.

4. Shipping

Loss of Arctic sea ice has resulted in an increase of open water, which, in turn, has led to an increase in Arctic shipping. Given projections of an ice-free Arctic in summer months between 2020 and 2050 (Overland and Wang 2013) and an ice-free Arctic in the near future (Smith and Stephenson 2013), the increase in shipping is expected to continue at a rapid pace. Potential effects of shipping on polar bears include disturbance, increased fragmentation of sea ice habitat (from icebreakers), pollution, and the introduction of waste/marine litter (PBRS 2015). Increased vessel traffic will also increase the chances of an oil spill from a vessel sinking, a tanker accident, ballast discharge, or discharges during the loading and unloading of oil at ports.

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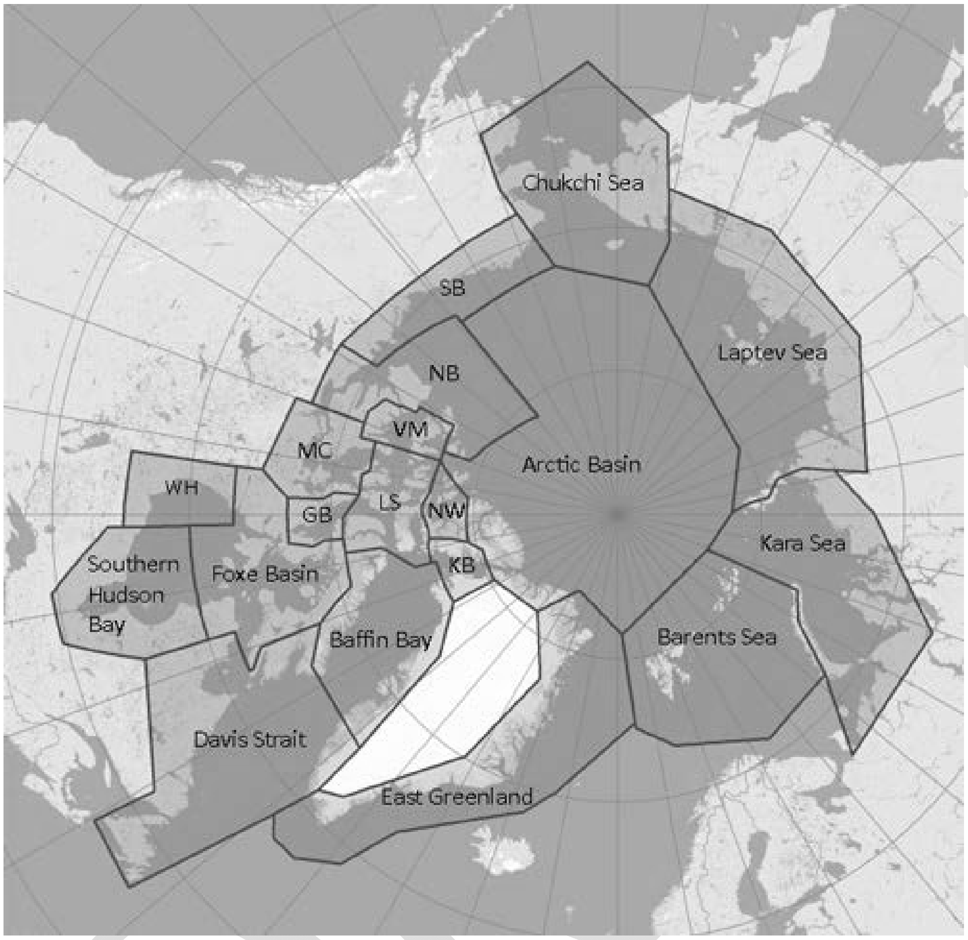

Figure 1. Map of the polar bear subpopulations: Southern Beaufort Sea (SB), Chukchi Sea, Laptev Sea, Kara Sea, Barents Sea, East Greenland, Northern Beaufort (NB), Kane Basin (KB), Norwegian Bay (NW), Lancaster Sound (LS), Gulf of Boothia (GB), McClintock Channel (MC), Viscount Melville (VM), Baffin Bay, Davis Strait, Foxe Basin, Western Hudson Bay (WH), and Southern Hudson Bay (source: Polar Bear Specialist Group: http://pbsg.npolar.no/en/status/population-map.html).

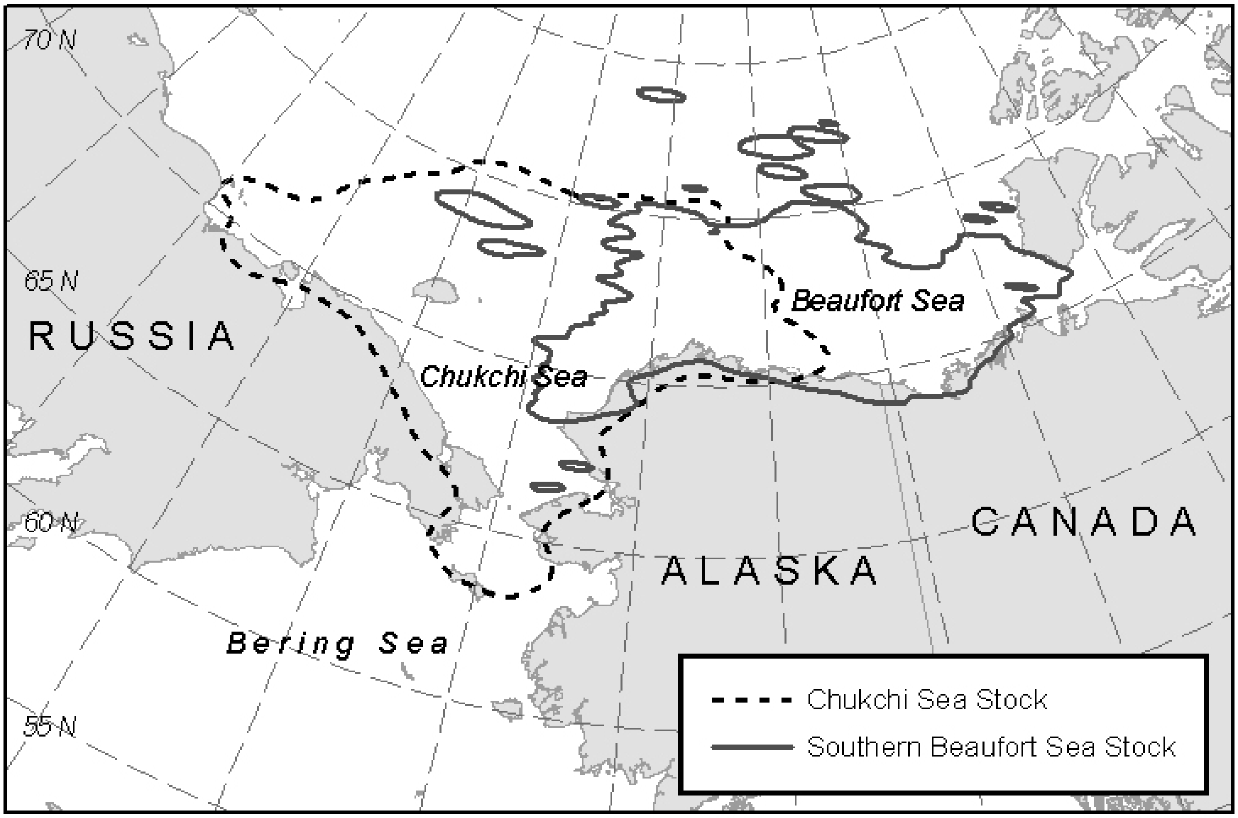

Figure 2. Approximate distribution of polar bears (the Southen Beaufort Sea and Chukchi/Bering Sea polar bear stocks) in Alaska. Distributions are based on the 95% annual contours of utilization distributions developed from 1985 to 2003 satellite-collar data (Amstrup et. al 2004).

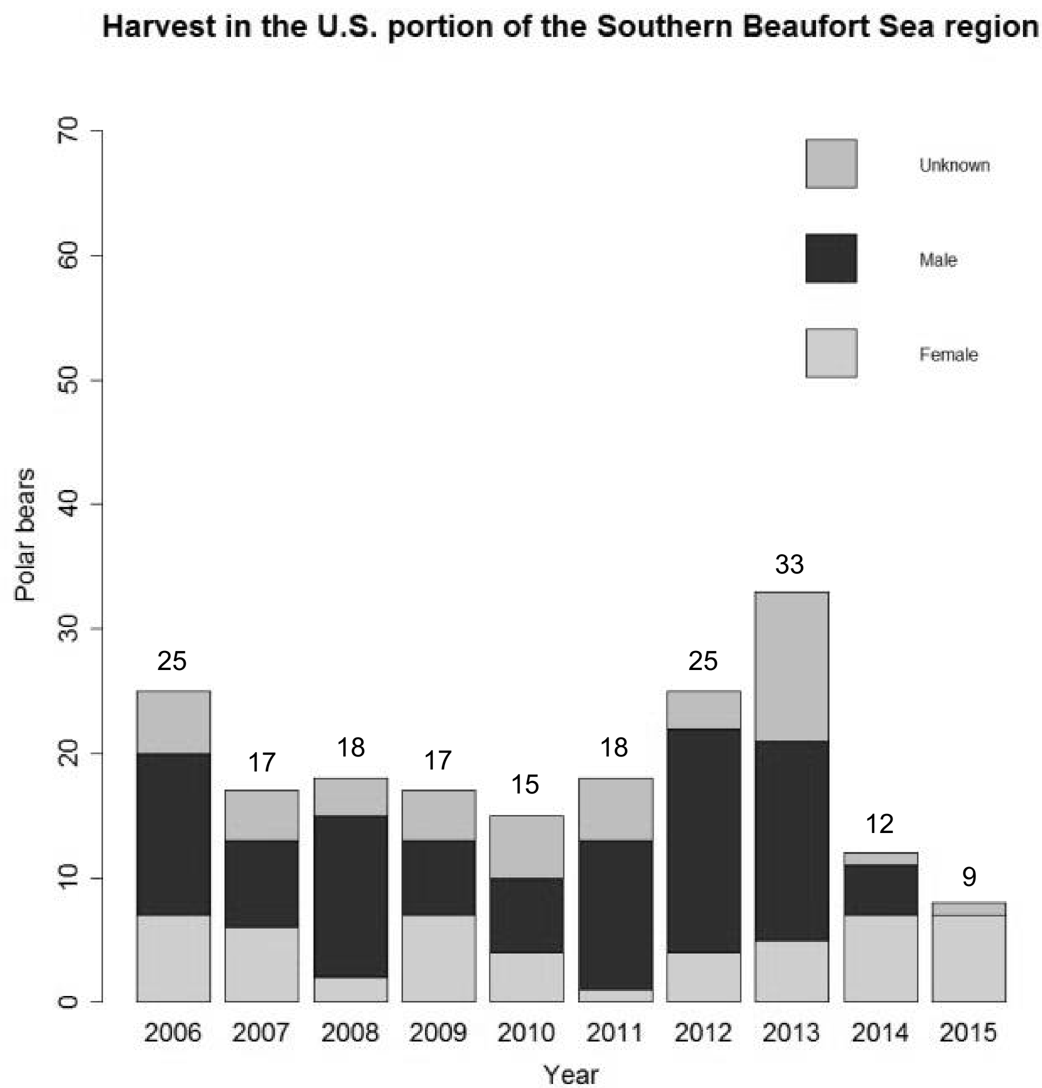

Figure 3. Polar bear harvest in the U.S. portion of the Southern Beaufort Sea stock, 2006-2015.

Detecting Denning Polar Bears with Forward-Looking Infrared (FLIR) Imagery

STEVEN C. AMSTRUP, GEOFF YORK, TRENT L. McDONALD, RYAN NIELSON, AND KRISTIN SIMAC

Polar bears give birth in snow dens in midwinter and remain in dens until early spring. The survival and development of cubs is dependent on a stable environment within the maternal den. To mitigate potential disruption of polar bear denning by existing and proposed petroleum activities, we used forward-looking infrared (FLIR) viewing to try to detect heat rising from dens. We flew transects over dens of radio-collared females with FLIR imager–equipped aircraft, recorded weather conditions at each observation, and noted whether the den was detected. We surveyed 23 dens on 67 occasions (1 to 7 times each). Nine dens were always detected, and 10 dens visited more than once were detected on some flights but not on others. Four dens were never detected (17 percent), but three of those were visited only under marginal conditions. The odds of detecting a den were 4.8 times greater when airborne moisture (snow, blowing snow, fog, etc.) was absent than when it was present, and they increased 3-fold for every 1°C increase in temperature–dew point spread. The estimated probability of detecting dens in sunlight was 0. Data suggested that FLIR surveys conducted during optimal conditions for detection can produce detection rates approaching 90 percent and thus can be an important management and mitigation tool.

Keywords: polar bear, infrared imagery, maternal denning, human impacts, management

Petroleum developments span approximately 200 kilometers (km) of the Alaskan Beaufort Sea coastal area and are proposed for dramatic expansion. Such operations are a potential threat to denning polar bears (Stirling 1990, Stirling and Andriashek 1992), which construct maternal dens in snowbanks in autumn (Amstrup and DeMaster 1988), give birth to altricial young in midwinter, and emerge from dens by early April (Blix and Lentfer 1979, Amstrup 1993, Amstrup and Gardner 1994). In Alaska, dens are not concentrated in mountains, as they are in most other locations (Uspenski and Chernyavski 1965, Uspenski and Kistchinski 1972, Larsen 1985, Ovsyanikov 1998). Nor are they associated with particular vegetation types (Ramsay and Andriashek 1986). Rather, 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 flat terrain (Benson 1982, Amstrup 1993, Amstrup and Gardner 1994, Durner et al. 2001, 2003). These banks are largely invisible under the snow in winter, and their scattered distribution confounds efforts to locate dens with visual techniques (Ramsay and Stirling 1990, Amstrup and Gardner 1994, Clark et al. 1997).

We have mapped suitable habitats for polar bears (Amstrup 1993, Durner et al. 2001, 2003) and shown that much more denning habitat is available than is used in any one year. These maps allow developers to avoid many areas suitable for denning. Nonetheless, because it can be very expensive to reroute roads and so on to avoid mapped habitats, managers regularly ask whether banks or bluffs that are "in the way" of particular industrial activities actually hold dens. Until now, radio telemetry has been the only method allowing identification of dens in early winter, when most industrial land uses are planned. Collaring and following all females in the population, however, is prohibitively expensive and unacceptable as a routine management practice.

Watts (1983) reported that polar bears emit approximately 200 watts of heat energy while denning. He also reported that den temperatures were as much as 30°C higher than ambient levels, and that surface temperatures over a den averaged 10°C warmer than in snowbanks adjacent to the den. We hypothesized that modern forward-looking infrared (FLIR) imagers might detect that heat and thereby provide another method for detecting which banks actually hold dens. The term *FLIR* refers to fast-framing thermal imaging systems, as distinguished from downward-looking thermal mapping systems or single-framing thermographic cameras (FLIR

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Systems undated [a]). FLIR imagers can be mounted on aircraft or other fast-moving platforms, their field of view can be adjusted independent of the platform carrying them, and they can write images to television-compatible recorders. Older FLIR instruments have already shown promise in both marine mammal and terrestrial wildlife applications (Wyatt et al. 1980, Trivedi et al. 1982, Kingsley et al. 1990, Naugle et al. 1996). In this article, we describe efforts to test the effectiveness of newer FLIR imagers in another application: the detection of denning polar bears along Alaska's North Slope.

Locating dens

We captured polar bears by injecting immobilizing drugs (tiletamine hydrochloride plus zolazepam hydrochloride) with projectile syringes fired from helicopters (Larsen 1971, Schweinsburg et al. 1982, Stirling et al. 1989). Capture protocols were approved by independent animal care and welfare committees. Polar bears were captured in coastal areas of the Beaufort Sea between Barrow, Alaska, and the Canadian border, from March through May and from October and November in the years 1996 through 2001. Satellite and VHF radio transmitters were attached to solitary adult female polar bears with neck collars (Amstrup et al. 2000). Using a combination of satellite and aerial radiotelemetry, we tracked pregnant, radio-collared females to their dens. During the course of FLIR surveys we detected additional, previously unknown dens.

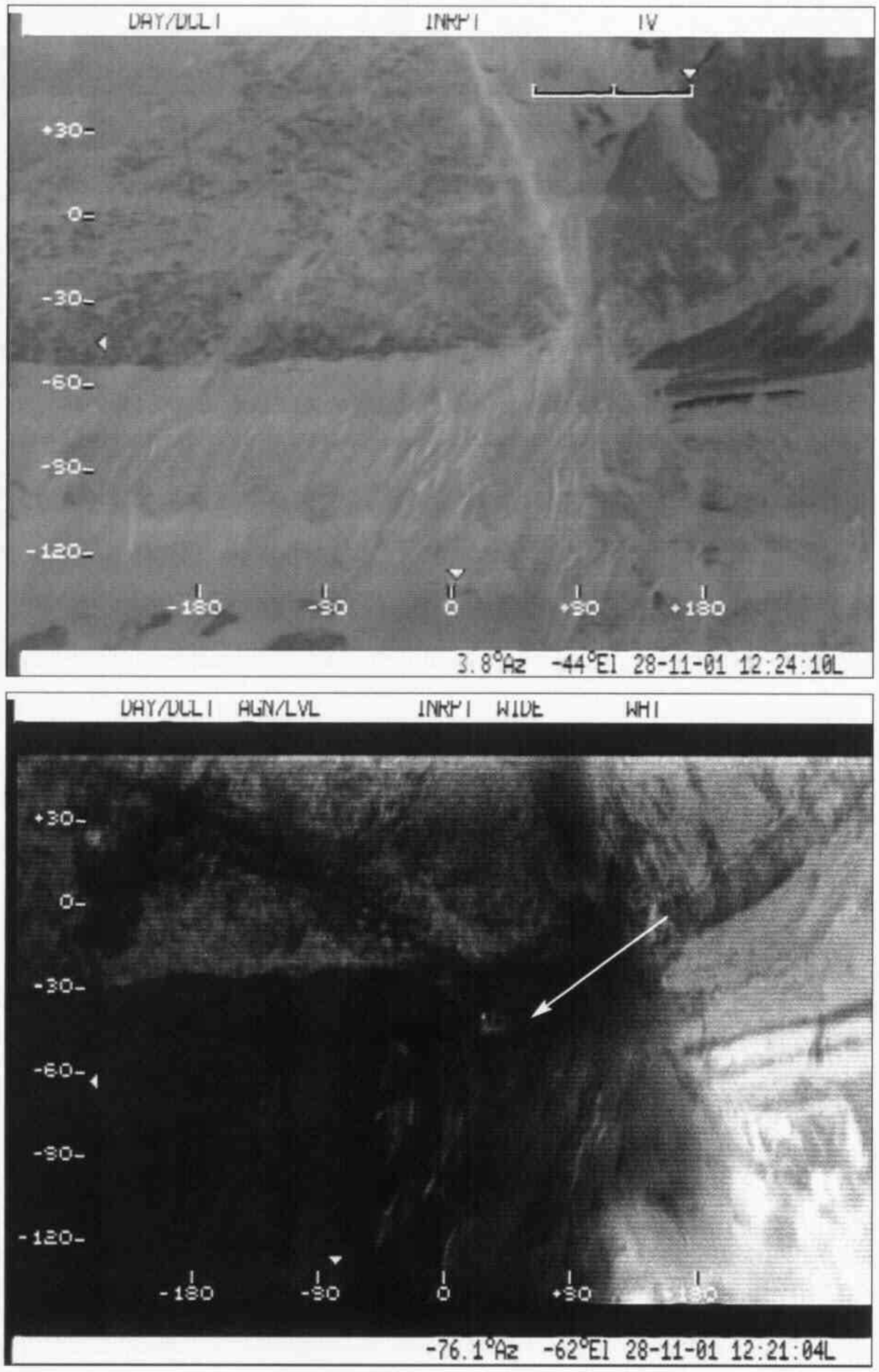

Figure 1. Video image of the snowdrift along the south shore of a coastal island (top) and forward-looking infrared (FLIR) image of the same location (bottom). The FLIR image reveals the heat emitted by a polar bear maternal den, and the arrow indicates the relative "hot spot" created by the body heat of the bear. The distance between reticule marks is approximately 18 meters.

Surveying dens

We assessed the effectiveness of the FLIR Safire II, AN/AAQ-22 (see *www.flir.com*), by flying transects over known denning locations during the winters from 1999 to 2001. The Safire, which operates in the 8- to 14-micron wavelength range, can detect differences in temperature down to 0.1°C under ideal circumstances, according to the operations manual (FLIR Systems undated [b]). The Safire was gimbal mounted under the nose of a Bell 212 helicopter. This mounting system allowed the imager to be directed independent of the attitude of the aircraft and in any direction below the horizontal plane of the aircraft.

We evaluated the FLIR imager in transect and hovering flight modes. We flew transects along bank features (Durner et al. 2001, 2003) holding known dens. We oriented the aircraft, as much as possible, so that the prominent snowdrifts likely to hold dens were below and to the side of the aircraft. This oblique view allowed us to focus the FLIR imager approximately perpendicular to the face of the drifts we were searching. To prevent FLIR operators from easily keying in on den locations and to simulate searches for unknown dens, we surveyed portions of bank habitats at least 1.6 km on either side of known dens. Also, during November 2001, we surveyed bank habitats along more than 175 km of coastline where no collared bears were known to be denning. The 2001 surveys and the transect sections adjacent to known dens allowed us to detect dens of noncollared bears.

When a thermal signature, or "hot spot," was seen on a transect, we hovered over the spot at a variety of altitudes and angles to adjust the image and determine whether we were seeing a den or some other source of heat differential. Tape segments were recorded and labeled for both flight modes. Known dens were recorded as "detected" or "not detected" on the basis of flight notes and subsequent tape review. Hot spots not known to be dens also were recorded on tape. We recorded weather conditions during each survey occasion. The records we compiled from the weather reporting station geographically closest to each survey flight included ambient temperature, wind speed, wind direction, visibility, percentage of cloud cover, cloud ceiling elevation, relative humidity, and dew point. Dew point, the temperature to which a given parcel of air must be cooled for saturation to occur, incorporates the effect of pressure and temperature on relative humidity. We recorded the presence of moisture in the form of blowing or falling snow, airborne ice crystals, or fog at the site of each transect. If any of these conditions, either singly or in combination, was detectable, airborne moisture was recorded as present. Similarly, if the sun was above the horizon and shining on the snow surface (even with cloud cover present), the variable "sun" was recorded as present.

Figure 2. Forward-looking infrared image of two polar bear dens in the snow bank on the south shore of an Alaskan coastal island. The bright den in the center of the image is open, and the den at the right tip of the island is partially or completely covered by snow. Note the detail of polygon tundra, the dark drift of snow along the tundra bank, and the relative brightness or warmth of the sea ice at the bottom edge of the figure. The distance between reticule marks is approximately 18 meters.

After the bears left their dens in spring, we attempted to visit each den and hot spot located the preceding winter. At that time, we recorded the amount of snow overlying the lair. We also attempted to visit many of the dens in the summer after snowmelt. During those visits, we were able to record additional characteristics of the den location and also to check the soil and vegetation for evidence of denning activity (Durner et al. 2003).

Polar bears in the Beaufort Sea region of Alaska and Canada frequently den on the sea ice as well as on land (Amstrup and Gardner 1994). Early in the study we abandoned attempts to detect dens in the ice environment because of the array of competing heat signatures. FLIR systems detect a difference in temperature between adjacent sites in the field of view. In winter, the ocean is relatively hot; and cracks, holes, and pressure ridges in the sea-ice surface created an infinitely variable mosaic of hot, warm, and cold spots in the FLIR screen. We once captured a clear image of the den of a collared bear high in a pressure ridge of landfast ice. Extremely cold weather and tight ice, along with ideal atmospheric conditions, must have contributed to that successful detection, because during later visits we were unable to distinguish the den from major heat sources throughout the pressure ridge and surrounding area. We also failed to differentiate the heat signatures of other dens that had been visually observed on landfast ice. Similarly, we consistently failed to detect the dens of two radio-collared bears denning on drifting pack ice. The heat signatures from these dens may have appeared on the FLIR screen. Because of the abundance of competing hot spots, however, we were unable to determine whether or not we were seeing them. These early experiences mandated that we limit our FLIR testing to dens on land.

Data analyses

Analyses were performed using S-Plus (ver. 2000; *www.insightful.com*) and SAS (ver. 8; *www.sas.com*). We first calculated descriptive statistics and examined our data in a univariate context. Differences in values of individual continuous variables (e.g., cloud cover or ceiling) were tested with the Student's t-test. We tested for frequency differences in individual categorical variables (e.g., presence or absence of airborne moisture or sunlight) between occasions when dens were detected and when they were not with Fisher's exact test

(Zar 1984). All variables were then cast in a Pearson correlation matrix to search for collinearity. One member of each pair of variables with correlation coefficients of at least 0.70 was deleted from consideration for additional multivariate analyses.

We modeled detection of dens in a multivariate context with logistic regression (McCullagh and Nelder 1989). Although most FLIR images were acquired during darkness, eight attempts to detect dens were made after sunlight had begun to light up the snow surface, and no dens were detected during these attempts. Logistic regression is not possible when responses associated with a single level of a categorical variable are either all successes or all failures. Failure to detect any dens when the sun was shining on the snow meant that our logistic regression models applied only to nonsunny periods.

We assessed the probability of detecting a polar bear den during nonsunny times, with a stepwise selection procedure (Neter et al. 1996, Ramsey and Schafer 1997). This modeling procedure considered environmental covariates for each recorded video segment. In other words, our sampling units were the video segments from each flight over each den. Covariates considered during the modeling process included *air_moist* (the presence or absence of airborne moisture); *spread* (the temperature–dew point spread); *visibility* (reported visibility); and *wind* (reported wind speed). Cloud ceiling data were missing in 23 cases and thus were not considered. Cloud cover data were found to be highly correlated ($P = 0.71$) with *air_moist* and were therefore not considered in modeling. Temperature and dew point individually were not considered because *spread* was a function of both. We did not include snow depth because only one measurement (made at the end of each field season) was available for each den, and we had no way to assess possible differences among survey flights. At each step in the variable selection process, the most significant variable (not already included) entered the model if its significance level was less than $\alpha = 0.10$. Additionally, at each step any variable in the model was eliminated if its significance became greater than $\alpha = 0.10$. The stepwise variable selection procedure was carried out using the SAS routine *Proc Logistic.*

Because the coefficients in logistic regression do not affect responses linearly (as they do in linear normal theory regression, for example), we assessed the importance of each covariate in the final model by calculating odds and odds ratios. In logistic regression the outcomes are either 0 (no detection) or 1 (detection). The term *odds* means simply the probability of obtaining a 1 divided by the probability of obtaining a 0. In this FLIR application, the odds of detecting a den were computed (probability of detection [Pr(detection)] divided by [1 – Pr(detection)]). Then, to help explain the role of covariates in the final model, we calculated the odds ratio of seeing a den at one level of a covariate to the odds of seeing it at the next incremental level of the covariate (e.g., odds of seeing a den when *spread* = 2 divided by the odds of seeing a den when *spread* = 1).

Sunlight seemed to have a profound effect on FLIR performance. Because we could not evaluate the effect of sun in a multivariate context and therefore could not assess its added contribution to odds of detection, we wanted to provide some measure of the precision of our estimated probability of detection in sunny times. We did this by inverting a one-sided binomial hypothesis test (Lehmann 1986, p. 93) to estimate a 95 percent confidence interval for the probability of detecting a den during sunny times. The lower value of our confidence interval was 0, our point estimate. We computed the upper value of the confidence interval, by iteratively guessing at the value of an upper bound, p_u, until the hypothesis H_0 ($p \geq p_u$) was rejected at the $\alpha = 0.05$ level of significance in favor of the hypothesis H_1 ($p < p_u$). For example, assume n (here, $n = 8$) FLIR video segments were recorded during sunny times, and we identified a_0-occupied polar bear dens on those n videos (here, $a_0 = 0$). The upper $(1 - \alpha)$ percent confidence limit was the smallest value of p_u that satisfied the condition for rejection of H_0; that is,

$$\sum_{x=0}^{a_0} b(x,n,p_u) \leq \alpha,$$

where the probability of observing x successes in n trials from a binomial distribution with probability p_u was:

$$b(x,n,p_u) = \frac{n!}{x!(n-x)!} \, p_u^{\,x}(1-p_u)^{n-x}.$$

Den observations recorded

During this study we located 19 polar bear maternal dens on land by radio telemetry. Bad weather, poor-quality radio fixes, difficult terrain, and a malfunctioning tape player prevented us from securing FLIR images at four dens of radio-collared polar bears. During attempts to view the 15 remaining dens, we observed 12 previously unknown hot spots that we concluded, either in flight or upon subsequent review of FLIR tapes, were polar bear dens. Dens (and targets presumed to be dens) appeared as small bright (hot) spots, usually with fuzzy boundaries, within a normally dark (cold) band of drifted snow (figures 1, 2). We attempted to visit all of the hot spots at least twice with FLIR imager–equipped aircraft. Such revisits eliminated most hot spots from our list or increased our confidence in calling a hot spot a den.

Spring and summer surveys confirmed that only three unknown hot spots were not polar bear dens. Because of weather and other logistical limitations, each of these three had been visited only once with FLIR. The thermal differentials at those three sites turned out to be the result of, respectively, an empty steel barrel, a large boulder partially embedded in an unstable permafrost bank, and a piece of sloughed tundra lying partway down a permafrost bank. We failed to obtain evidence confirming whether a fourth previously unknown hot spot was a den. We flew over that fourth hot spot twice, with the FLIR imager, en route to a known den. We simply missed this hot spot during tape reviews conducted in the field, and did not notice it until final review of both tapes at the end of the field season. At that time,

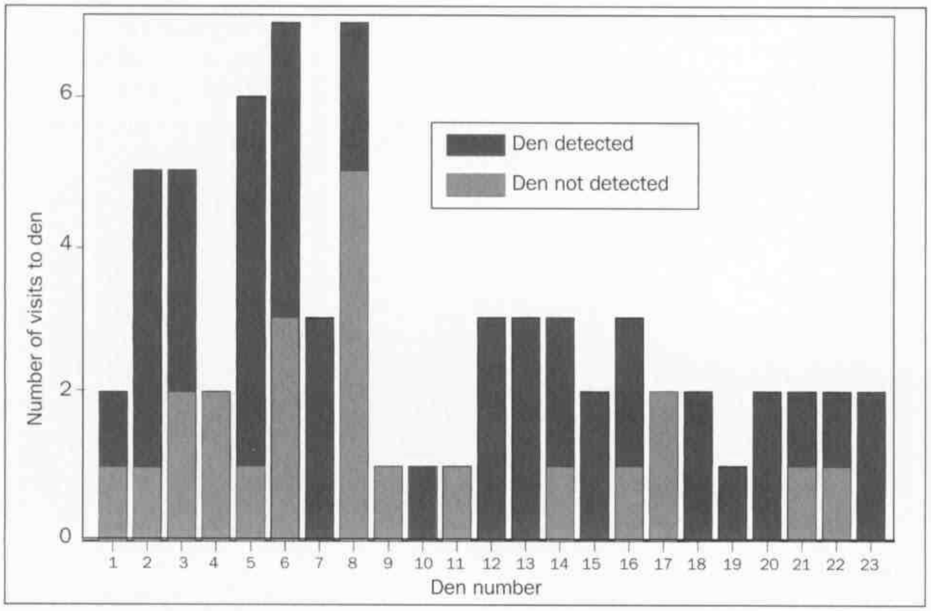

Figure 3. Summary of detections and detection failures for 23 polar bear dens along Alaska's northern coast surveyed with forward-looking infrared imagery during the winters of 1999 and 2001.

revisiting and reexamining it in hover flight mode were not possible. This hot spot was viewed in transect flight mode only, but it appeared to have had all the earmarks of a den. Because we did not hover over it, as we had over other hot spots, however, and because we were unable to return to the site in either spring or summer to search for evidence of polar bear use, we could not conclude whether or not it was an occupied den.

We surveyed the other 23 dens on 67 occasions (1 to 7 times each). Six of these dens were occupied by unknown bears and the remaining 17 dens by 15 radio-collared bears. Collared bears occupied one den each, except for bear 20330, which denned three times during the study. The number of viewing occasions at each den was inversely proportional to the distance of the den from the home base of the helicopter used for the FLIR missions. Reaching more distant dens resulted in increased difficulties with weather and other logistics. Figure 3 summarizes the frequency of detection for the 23 dens surveyed. Four dens (17 percent) were never detected with FLIR. Two of these were visited on two occasions, the other two only once. Two dens visited one time each were detected on those single visits. Four dens visited twice were detected both times. Three dens visited three times were detected on each visit. Detection success of the other 10 dens was mixed. Bear 20330, the known individual tracked to multiple dens, was detected on at least one visit to each of her three dens and also not detected on at least one visit to each.

Analyses of individual covariates

When evaluated singly, in the two-sample t context, only wind speed and temperature–dew point spread differed significantly between detection and nondetection events. The mean wind speed (11 knots per hour [kts/hr]) on occasions when we did not see dens was significantly higher than on occasions when we did see dens (6 kts/hr) ($t = 2.897$, degrees of freedom [df] = 65, $P = 0.0051$). Similarly, the mean spread between temperature and dew point on occasions when dens were not seen (2.56°C) was significantly narrower than the mean spread (3.01°C) when dens were seen ($t = 2.891$, df = 65, $P = 0.0052$). It stands to reason that there should be an inverse relationship between depth of snow over the bear and heat transmission to the snow surface. The range of depths recorded, however, was apparently below any threshold that, by itself, prevents detection by FLIR imaging. Mean snow depth over detected dens was 40 centimeters (cm) and only 31 cm over undetected dens; the greatest depth (96 cm) was recorded over a detected den. Depth differences between detected and undetected dens were not significant ($t = -1.001$, df = 18, $P = 0.383$).

Airborne moisture was detectable on 12 of 23 (52 percent) occasions when dens were not seen and on only 15 of 44 (34 percent) occasions when they were seen. The two-sided Fisher's exact test, however, suggested this difference was not significant ($P = 0.1931$), indicating that the absence of air moisture alone did not explain the detection of known dens. Sunlight was present on 8 of 23 (35 percent) occasions when dens were not seen, and on none of the occasions when dens were seen. According to Fisher's exact test, this difference was highly significant ($P = 0.00008$). The probability of seeing an occupied polar bear den on FLIR video that was recorded in sunlight was estimated to be 0. The upper 95 percent confidence bound on the probability of detecting a den when sun was shining on the snow was 0.313 (see table 1).

Modeling den detection with multiple covariates

Some insights regarding the ability of our measured covariates to explain detection by FLIR imaging were obtained from the above individual comparisons. Recognition of possible interactions among our covariates, however, mandated modeling approaches in which all covariates were eligible to be considered. After removing the 8 observations associated with sunny conditions, 59 observations were available for this model fitting. The final logistic regression model for the probability that an occupied polar bear den was seen on the FLIR video recorded during nonsunny times was

$$\hat{p} = \frac{\exp[-2.8576 + 1.1237(spread) + 1.5692(air\_moist = 0)]}{1 + \exp[-2.8576 + 1.1237(spread) + 1.5692(air\_moist = 0)]}$$

(eq. 1).

Standard errors for coefficients in the final model were 0.5401 for *spread* and 0.6846 for *air_moist*. Table 2 summarizes descriptive statistics for the covariates appearing in this model. The odds ratio point estimate for *spread* was 3.08, indicating that for every 1 degree (°C) increase in the difference between temperature and dew point, the odds of detecting a den increased 3.08 times. Calculation of this odds ratio can be illustrated in three steps. First, the probability of detecting a den when *spread* = 1 was estimated, according to equation 1, as

$$\hat{p} = \frac{0.848}{1.848} = 0.459.$$

The odds of an event is the ratio of the probability that the event occurs to the probability that the event does not occur, so the odds of detecting a den when *spread* = 1 is

$$\frac{0.459}{1 - 0.459} = 0.848.$$

Second, when *spread* increases to 2°C, the probability of detecting a den was estimated, according to equation 1, as

$$\hat{p} = \frac{2.609}{3.609} = 0.7229.$$

The odds of detecting a den when *spread* = 2 is

$$\hat{p} = \frac{0.723}{1 - 0.723} = 2.61.$$

Finally, the odds ratio for a one-unit increase in spread from 1°C to 2°C is

$$\frac{2.61}{0.845} = 3.08.$$

Some algebra reveals that odds ratios are easily calculated for a one-unit increase in a predictor variable by simply exponentiating the coefficient value of that predictor variable (raising *e* to the value of the coefficient); for example, $e^{1.1237}$ = 3.08. The odds ratio for smaller changes in temperature–dew point spread also can be calculated as above. For example, the odds ratio for a 0.5°C increase in *spread* (the difference between the mean temperature–dew point spread of detected and undetected dens) was estimated as 1.75. Therefore, the odds of a trained biologist detecting a den increased 75 percent for every 0.5°C increase in *spread*.

Similarly, the odds ratio for *air_moist* was $e^{1.5692}$ = 4.803, indicating that the odds of a trained biologist detecting a den were approximately 4.8 times higher when there was no visible moisture in the air at the time the video was recorded than when there was moisture in the air. Confidence intervals (95 percent) on odds ratios were 1.067–8.867 for *spread* and 1.255–18.375 for *air_moist*.

Table 1. *Upper confidence limit (shaded line), calculated with the inversion of hypothesis method, for the probability of detecting a denning polar bear with forward-looking infrared imagery during sunny conditions (n = 8 and x = 0).*

p_u	$n!/[x!(n-x)!]$	p_u^x	$(1 - p_u)^{n-x}$	Probability
0.1	1	1	0.43047	0.430467
0.2	1	1	0.16777	0.167772
0.3	1	1	0.05765	0.057648
0.31	1	1	0.05138	0.05138
0.312	1	1	0.0502	0.0502
0.313	1	1	0.04962	0.04962
0.314	1	1	0.04904	0.049045
0.32	1	1	0.04572	0.045716
0.35	1	1	0.03186	0.031864

Interpretations and conclusions

Although they showed some promise, early infrared sensors did not reliably detect either white-tailed deer (*Odocoileus virginianus*) or mule deer (*Odocoileus hemionus*) (Wyatt et al. 1980, Trivedi et al. 1982). Naugle and colleagues (1996) and Wiggers and Beckerman (1993), however, demonstrated that newer FLIR scanners were more reliable in detecting heat signatures of deer. Similarly, Kingsley and colleagues (1990) demonstrated that an older FLIR imager mounted on a helicopter did detect some under-snow lairs of ringed seals (*Phoca hispida*); they also reported that the thickness of snow over the lair, ambient temperature, wind, and sunlight prevented seal lairs from being detected consistently enough to allow census by FLIR surveys. Ringed seal lairs occur exclusively in the sea-ice environment. Our preliminary testing with a newer FLIR imager indicated that there were too many competing heat signatures in that environment to consistently detect denning polar bears. Hence, failure to consistently detect lairs of the much smaller ringed seal in sea-ice habitats is not surprising. In the assortment of hot spots detectable on the sea ice, observers cannot be certain they are seeing a lair, even if it is visible on the monitor.

Whereas even modern FLIR devices may not be satisfactory for distinguishing dens of either seals or polar bears on the sea ice, we found that FLIR imaging was effective in detecting dens on land. Bears denning on land generally are surrounded by colder and more uniform substrates than seals or bears occupying subnivian lairs at sea. Polar bears also are larger and presumably emit more heat than ringed seals. The potentially greater thermal contrast of denned bears, the more uniform backdrop of land, and the more advanced equipment used in this study combined to create a useful tool for detecting polar bears in land dens in early winter, before construction projects and seismic surveys typically occur. Fortunately, it is the dens on land that are the greatest management concern related to industrial development in the north. Sea-ice dens are, by virtue of their location, relatively insulated from human activities.

We recognize that our FLIR surveys were not 100 percent effective in detecting dens even when we knew they were there, and we do not expect that current FLIR technologies could ever detect all dens regardless of ambient conditions. However, we believe FLIR imaging has an important place in the management of human activities that could adversely affect polar bears denning on land.

The four dens (17 percent) that we failed to detect during our study were visited a total of six times. The first of these dens was initially visited immediately after a blizzard with extensive blowing and falling snow. Surface snow temperatures apparently had not stabilized, and the ground surface was extensively mottled with a windrow pattern of alternate bands of newer warm snow and older colder snow. This windrow effect on the snow surface often was apparent on the FLIR monitor even when wind speeds were below those that result in obvious blowing snow, and it seemed to persist for hours after wind speeds subsided. That may partially explain why our *t*-test suggested that dens were less detectable under elevated wind conditions. Additionally, this survey was conducted despite a cloud ceiling of only 400 feet and a temperature–dew point spread of only 2.2°C. The only other time we were able to get to this den, the sun was shining. Clearly, neither of these visits maximized our odds of detecting the den.

Table 2. Descriptive statistics for variables in a final logistic regression model.

Variable	Set	Number: Den seen	Den not seen	Total
air_moist	Yes	15	10	25
	No	29	5	34
Total		44	15	59

Variable	Statistic	Value of statistic: Den seen	Den not seen	All observations
spread	Minimum	1.67	1.67	1.67
	Median	3.33	2.22	3.00
	Mean	3.00	2.64	2.91
	Maximum	3.89	3.89	3.89

Note: Eight dens that were undetected when visited while the sun was shining are not included.

The second and third dens that went undetected were visited only once each. Both of those flights occurred despite airborne moisture visible in the FLIR monitor. Our detection model verifies that the odds of seeing these dens were nearly five times lower than would have been the case had we visited them on days without airborne moisture. The fourth den that escaped detection was visited twice. On the first visit, the temperature–dew point spread was only 2.2°C, less than the mean value for dens that were not detected. The second visit, however, occurred under conditions that should have been favorable for detection, yet we did not see the den.

Five of these six den visits were during weather conditions we have shown to compromise the effectiveness of FLIR imaging, and only one of these four dens was ever visited when conditions were deemed favorable. Although additional visits might not have allowed us to detect the den that was visited once during good conditions, the odds of detecting the other three dens visited only in poor conditions would have been more than three times greater had we been able to visit them under better weather conditions. With detection of some or all of those, our overall den detection rate would have increased to a value between the 83 percent we observed and the 96 percent that would have resulted from three added detections. We cannot be sure that added visits under conditions maximizing the odds of detection would have resulted in successful detections of those three dens. However, the great expense of rerouting roads and other development projects around potential denning habitat suggests that developers would make the investments necessary to visit potential den sites under ideal conditions rather than be required to change development plans. Therefore, in real-world applications where big money is at stake, an increase in the overall detection rate to at least 90 percent seems highly probable. That level of detectability clearly would be significant in efforts to minimize disruptions of denning polar bears.

Logistical constraints prevented acquisition of sufficient data to quantify the probabilities of false positives—that is, calling a thermal signature a den when it is not. It is reassuring, however, to recognize that in conducting hundreds of kilometers of FLIR surveys, we misidentified only three such thermal signatures. During this study, nearly all of the hot spots initially identified as suspected dens were confirmed not to be dens after additional visits. The three misidentified hot spots remained on our list of possible dens because we were unable to revisit them. Our experiences at other sites, however, make us confident that repeated visits to the misidentified sites would have resulted in their removal from the list of suspected dens. Had such hot spots occurred in habitats that were proposed for disturbance, the great costs required to reroute projects around them assure that repeated surveys would have been done to reveal whether or not they were dens. Likewise, we are confident that the fourth unknown hot spot would have been revisited in a real management situation before avoidance measures were taken. Hence, our experiences in this study suggest that the risks of false positives are low.

Because polar bears roam over large areas at low densities, general surveys for bears or their dens would not be practical even with new FLIR technologies. Polar bears, however, den primarily in steep bank faces (along streams, lakeshores, and coastlines of the mainland and some offshore islands) that have been identified and mapped across a large section of Alaska's North Slope (Durner et al. 2001). Therefore, high-sensitivity FLIR imagery applied to those mapped habitats provides the first real tool for detecting polar bears in dens early enough in winter to alter the paths of human activities and thereby protect denning bears. With denning habitats either mapped or clearly described, many human activities that might affect denning bears would be routed around those preferred habitats, thereby avoiding the possibility of negative impact. If plans for a road or other development project include traversing such habitat, FLIR surveys of the development corridor can help show which of the pieces of that habitat must be avoided because of known dens. Such efforts can assure that the effect of human activities on denning polar bears is minimal.

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Polar bear population dynamics in the southern Beaufort Sea during a period of sea ice decline

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Abstract. In the southern Beaufort Sea of the United States and Canada, prior investigations have linked declines in summer sea ice to reduced physical condition, growth, and survival of polar bears (*Ursus maritimus*). Combined with projections of population decline due to continued climate warming and the ensuing loss of sea ice habitat, those findings contributed to the 2008 decision to list the species as threatened under the U.S. Endangered Species Act. Here, we used mark–recapture models to investigate the population dynamics of polar bears in the southern Beaufort Sea from 2001 to 2010, years during which the spatial and temporal extent of summer sea ice generally declined. Low survival from 2004 through 2006 led to a 25–50% decline in abundance. We hypothesize that low survival during this period resulted from (1) unfavorable ice conditions that limited access to prey during multiple seasons; and possibly, (2) low prey abundance. For reasons that are not clear, survival of adults and cubs began to improve in 2007 and abundance was comparatively stable from 2008 to 2010, with ~900 bears in 2010 (90% CI 606–1212). However, survival of subadult bears declined throughout the entire period. Reduced spatial and temporal availability of sea ice is expected to increasingly force population dynamics of polar bears as the climate continues to warm. However, in the short term, our findings suggest that factors other than sea ice can influence survival. A refined understanding of the ecological mechanisms underlying polar bear population dynamics is necessary to improve projections of their future status and facilitate development of management strategies.

Key words: abundance; Arctic; climate warming; Cormack-Jolly-Seber; demographic modeling; Horvitz-Thompson; mark–recapture; sea ice; survival; Ursus maritimus.

Introduction

The polar bear (*Ursus maritimus*) is a universally recognized symbol of the Arctic. Polar bears prefer sea ice concentrations exceeding 50% in the shallow, productive waters over the continental shelf (Sakshaug 2004, Durner et al. 2009), where ice provides a platform from which polar bears can efficiently hunt marine mammals (see Plate 1). Their primary prey are ringed (*Pusa hispida*) and bearded (*Erignathus barbatus*) seals, although diet varies regionally with prey availability (Thiemann et al. 2008, Cherry et al. 2011).

Polar bears are vulnerable to the loss of sea ice, which is projected to induce substantial declines in abundance by mid-century (Amstrup et al. 2008, Hunter et al. 2010) unless global greenhouse gas levels are reduced (Amstrup et al. 2010). Global temperatures will rise as atmospheric greenhouse gas concentrations increase (Pierrehumbert 2011), and the Arctic has warmed at twice the global rate (IPCC 2007), in part due to positive feedback mechanisms referred to as Arctic Amplification (Serreze and Francis 2006, Perovich and Polashenski 2012). Since the advent of satellite observations in 1979, the spatial extent of Arctic sea ice during the autumn ice minimum declined by over 12% per decade through 2010 (Stroeve et al. 2012), a rate of loss greater than predicted by climate models (Stroeve et al. 2007, Overland and Wang 2013). Coastal areas are experiencing longer ice-free periods (Markus et al. 2009), and the remaining ice is increasingly composed of thin, first-year ice (Maslanik et al. 2007, 2011) with greater potential for rapid melt in subsequent years (Stroeve et al. 2012). Projections of global warming and sea ice loss led to the species being listed as threatened under the U.S. Endangered Species Act in 2008, increasing global awareness of its status, and elevating the importance

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of monitoring by circumpolar nations (Vongraven et al. 2012).

Amstrup et al. (2008) introduced a classification of polar bear habitat into ecoregions based on broad seasonal patterns of sea ice dynamics that is useful for understanding regional differences in polar bear ecology (Fig. 1). However, populations sharing an ecoregion may experience localized combinations of environmental and ecological conditions that elicit different responses. For example, in the seasonal ice ecoregion (Fig. 1), where sea ice melts completely in summer and forces all bears ashore until ice re-forms in autumn, reduced access to prey during prolonged ice-free periods is negatively affecting the status of some populations (Stirling et al. 1999, Regehr et al. 2007, Rode et al. 2012), while high prey abundance may be forestalling declines in other populations (Peacock et al. 2013). In the divergent ice ecoregion (Fig. 1), polar bears still have access to some ice all year, although its availability over the continental shelf during summer and autumn is increasingly limited (Markus et al. 2009). Despite extensive sea ice loss throughout the divergent ice ecoregion (Markus et al. 2009, Stammerjohn et al. 2012), an expansive continental shelf and high productivity may have enabled the Chukchi Sea population to maintain condition and recruitment more effectively than the neighboring southern Beaufort Sea (SBS) population (Rode et al. 2014).

The SBS population is one of 19 recognized worldwide (Obbard et al. 2010), and it has been studied more intensively than most. The population is thought to have been overharvested prior to the passage of the U.S. Marine Mammal Protection Act in 1972 (Amstrup et al. 1986), and to have generally increased in abundance thereafter through the late 1990s (Amstrup et al. 2001). Estimates from the mid-2000s suggested that abundance had stabilized and possibly declined (Regehr et al. 2006).

Recent investigations of the SBS population have revealed early indications of the effects of climate-induced changes in the characteristics and availability of sea ice. Fischbach et al. (2007) documented a shift in the distribution of maternal dens from multiyear pack ice to terrestrial locations, perhaps in response to the reduced availability of ice suitable for denning (Amstrup and Gardner 1994). The summer retreat of sea ice from continental-shelf waters now forces polar bears to either remain with the remnant ice in the central Polar Basin or move to land; both options are hypothesized to reduce fitness compared to historical patterns of habitat availability and use. Although most SBS polar bears currently remain with the sea ice, a growing proportion of the population is utilizing terrestrial habitat (Schliebe et al. 2008; USGS, *unpublished data*) and accessing remains of subsistence-harvested bowhead whale (*Balaena mysticetus*) carcasses (Herreman and Peacock 2013). The increasing distance between shore and the summer pack ice increases the potential for long-distance swimming (Pagano et al. 2012), which elevates susceptibility to adverse weather (Monnett and Gleason 2006) and is energetically expensive (Durner et al. 2011). Nutritional stress also appears to be increasing (Cherry et al. 2009, Rode et al. 2014), and may be responsible for observations of reduced body size, growth, and survival of young (Rode et al. 2010, 2014). Regehr et al. (2010) associated reduced ice over the continental shelf in 2004 and 2005 with reductions in survival (Amstrup and Durner 1995, Amstrup et al. 2001).

We investigated the population dynamics of SBS polar bears from 2001 to 2010 using Cormack-Jolly-Seber (CJS) mark–recapture models (Lebreton et al. 1992, Amstrup et al. 2005) to (1) determine whether low survival rates reported for 2004 and 2005 (Regehr et al. 2010) persisted into subsequent years, (2) assess the recent trend in abundance, and (3) refine our understanding of the relationship between sea ice and polar bear survival. The spatial and temporal extent of sea ice over the continental shelf generally declined during this period, and we evaluated the utility of measures of ice availability to explain temporal patterns in survival. Our findings provide new information on population status, as well as insights into the ecological mechanisms underlying population dynamics of polar bears.

Methods

Study area

The Beaufort Sea (Fig. 1), unlike most marginal seas in the Polar Basin, has a narrow continental shelf with a steep shelf-break that plummets to some of the deepest waters of the Arctic Ocean (Jakobsson et al. 2008). Pacific waters enter the Arctic Ocean via the Bering Strait and the remnant of the Alaska Coastal Current flows eastward along the shelf (Schulze and Pickart 2012). Nearshore waters carry substantial freshwater inputs, including terrestrial carbon and nitrogen, from the Mackenzie River and numerous smaller river systems (Dunton et al. 2006). Offshore, the anti-cyclonic Beaufort Gyre (Proshutinsky et al. 2002, Giles et al. 2012) and the Transpolar Drift Stream (Serreze et al. 1989) govern sea ice motion basin-wide.

During spring, primary production in the SBS is dominated by ice algae (Horner and Schrader 1982). Wind-induced current reversals and storm events pump nutrient-rich basin waters onto the continental shelf, supporting production throughout the year and seeding the algal bloom the following year (e.g., Sigler et al. 2011, Tremblay et al. 2011, Schulze and Pickart 2012, Pickart et al. 2013*a*, *b*). Climate warming is increasing primary productivity (Tremblay et al. 2011, Nicolaus et al. 2012, Pickart et al. 2013*a*) and altering its composition (Lasternas and Agustí 2010). Open water at the interface of land-fast ice and pack ice is an additional source of primary production (Palmer et al. 2011), and these areas are important for numerous Arctic species (Stirling 1997). Zooplankton are thought to underutilize primary production in Arctic ecosystems, thereby favoring a rich benthos (Grebmeier et al. 2006, Logerwell et al. 2011). Arctic cod (*Boreogadus saida*) are the most abundant fish in pelagic waters (Jarvela and Thorsteinson 1999, Parker-Stetter et al. 2011). Ringed and bearded seals are resident year-round (Stirling et al. 1982, Frost et al. 2004), while beluga (*Delphinapterus leucas*) and bowhead whales migrate into the SBS during summer (Luque and Ferguson 2009, Ashjian et al. 2010). Polar bears are an apex predator of this food web, which may be sensitive to perturbation due to its simple structure and strong interspecific dependencies (Banašek-Richter et al. 2009).

Data sources

U.S. Geological Survey (USGS) researchers captured polar bears in the U.S. portion (Alaska) of the SBS (Fig. 1) from approximately late March to early May annually from 2001 to 2010. The communities of Barrow, Deadhorse, and Barter Island (Kaktovik) were used as operational bases each year, excluding Barrow in 2001 and Barter Island in 2006. Helicopters were used to search the sea ice for polar bears, ranging as far as ~160 km from the coast. Bears were immobilized with Telazol (Pfizer Animal Health, New York, New York, USA) administered with projectile syringes fired from a helicopter (Stirling et al. 1989) and given lip tattoos and ear tags with unique identification numbers. Satellite radio collars were affixed to a subset of adult females captured, except in 2010. Captures were generally nonselective with respect to sex and age class, although females wearing radio collars were often targeted to facilitate collar retrieval. Field procedures were approved by the independent USGS Alaska Science Center Animal Care and Use Committee.

Researchers from Environment Canada (EC) and the University of Alberta (UA) conducted mark–recapture activities in the Canadian portion of the population range (Fig. 1) using similar methods in April and May from 2003 to 2006. The combined efforts of USGS, EC, and UA resulted in the distribution of capture effort throughout the majority of the SBS population range in those years. UA researchers continued to capture polar bears in Canada from 2007 to 2010, although subadults and females were preferentially targeted, and capture effort did not extend into the easternmost portion of the study area. Animal welfare committees of EC and UA approved bear capture and handling protocols in Canada.

We modeled the population dynamics of SBS polar bears using two combinations of data. The first data set (USGS) was compiled from USGS captures in the United States portion of the study area. Capture methods were consistent throughout the study period, and these data were therefore expected to provide the most reliable assessment of trends in survival and abundance, although estimates were applicable only to the portion of the population available for capture within the United States. The second data set (USA and Canada [USCA]), was compiled from the data collected by all three entities. The USCA data had greater spatial coverage and the potential to produce estimates germane to the entire SBS population. However, the geographic and temporal discontinuities in capture effort and differential selectivity for age and sex classes in some years presented modeling challenges, especially with respect to estimation of recapture probabilities and abundance.

Mark–recapture modeling

We estimated the survival and abundance of SBS polar bears using open-population Cormack-Jolly-Seber (CJS) models (Lebreton et al. 1992, Amstrup et al. 2005), similar to several previous mark–recapture investigations of polar bear populations (e.g., Amstrup et al. 2001, Regehr et al. 2007, 2010, Taylor et al. 2008, Stirling et al. 2011). Multiple observations of an individual within a calendar year were amalgamated into a single capture record for that year and the history of annual capture indicators was constructed for each animal. We used information on harvests of marked bears to terminate subsequent modeling of their capture histories.

CJS models are composed of sub-models for survival and recapture probabilities, which are typically expressed as linear functions of explanatory variables (covariates) via a logistic link function (Lebreton et al. 1992). Covariates were either single variables or groups of related variables that were employed simultaneously, so we used a single term to reference either case (Table 1; Appendix A). We utilized the regression parameterization of CJS models (McDonald and Amstrup 2001, Amstrup et al. 2005) because of the flexibility with which it incorporates covariates. Parameters of the logistic functions were estimated using maximum likelihood. Survival and recapture probabilities were estimated from the parameters of the logistic functions, and abundance estimates were derived from the estimated recapture probabilities using the Horvitz-Thompson estimator (Horvitz and Thompson 1952, McDonald and Amstrup 2001).

Survival probability models

We constructed survival models from combinations of covariates representing age and sex class effects and forms of temporal structure, and modeled survival probabilities separately for each age class (Table 2). Four age classes were defined: cub (Age0), yearling (Age1), subadult (2 to 4 years old, Age2), and adult (>4 years old, Age3), categories similar to those used in other investigations (e.g., Regehr et al. 2010, Stirling et al. 2011). Survival models also incorporated one of four forms of temporal variation: temporal stratification (TS-sur), a cubic function of year (Time-cubic), and two measures of sea ice availability. Data were too sparse to independently estimate an annual survival probability for each age class, but the covariates TS-sur and Time-cubic provided flexibility to model temporal variation

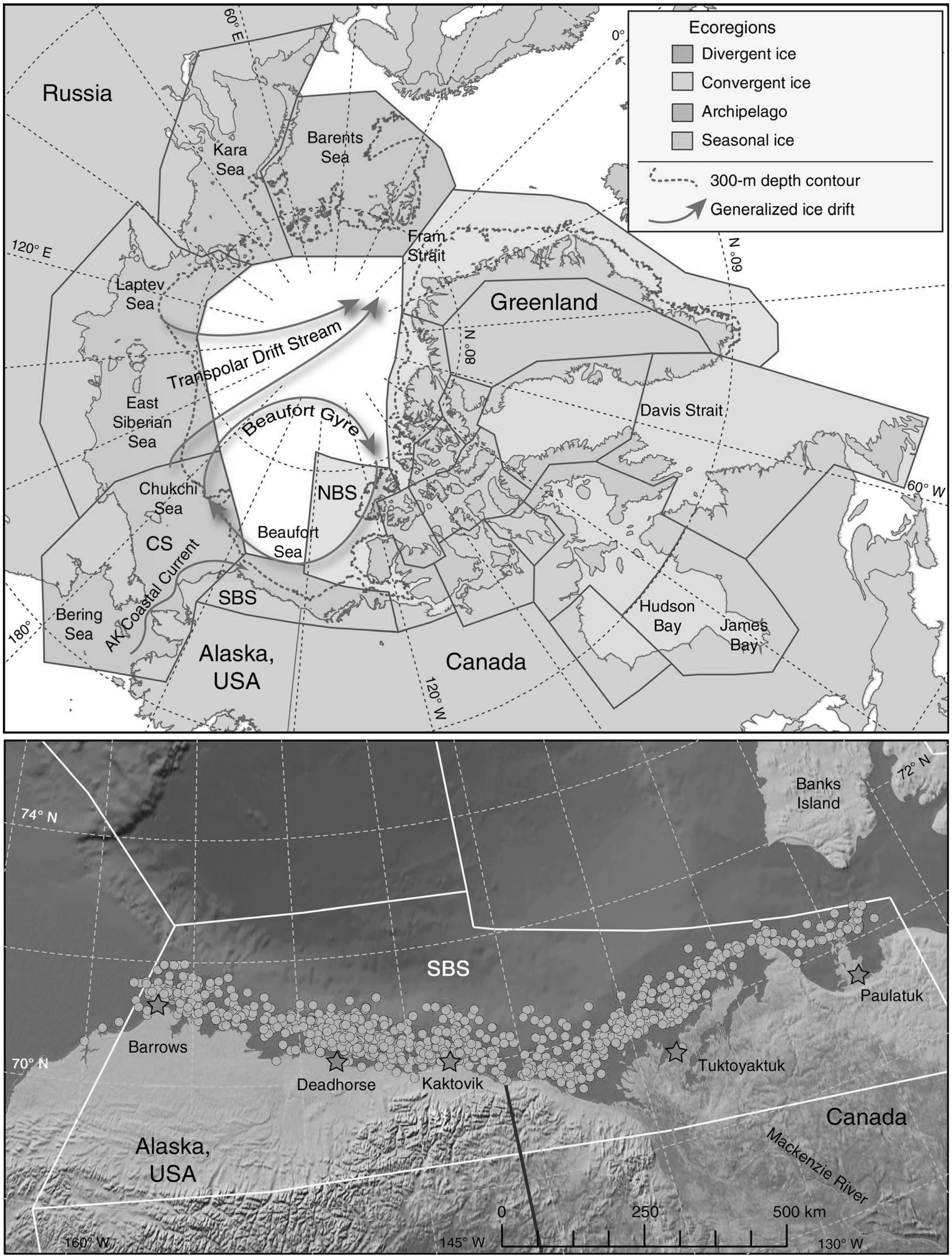

FIG. 1. The upper panel contains a map of the Polar Basin, showing peripheral seas, predominate currents, and ecoregions based upon characteristics of sea ice dynamics. Solid blue lines show the boundaries of polar bear populations recognized by the International Union for the Conservation of Nature, Polar Bear Specialist Group (http://pbsg.npolar.no/en/status/population-map.html). The lower panel shows the range of the southern Beaufort Sea polar bear (*Ursus maritimus*) population defined by the International Union for Conservation of Nature, with a modified western boundary per Amstrup et al. (2008), and locations of polar bear captures from 2001 to 2010 (yellow circles). Abbreviations are: AK, Alaska, USA; NBS, northern Beaufort Sea; and CS, Chukchi Sea.

TABLE 1. Covariates and covariate groups used to model polar bear (*Ursus maritimus*) survival and recapture probabilities, with a brief description, the associated degrees of freedom (df), the data set (USGS, USCA, or both), and component of the CJS model (φ, survival, or *p*, recapture) in which each covariate was used.

Covariate group	Description	df	Data	Model
Age0	a cub, age 0	1	both	φ
Age01.23Fem	a cub or yearling, or subadult or adult female	1	both	*p*
Age01.3Fem	a cub or yearling, or adult female	1	both	*p*
Age1	a yearling, age 1 yr	1	both	φ
Age2	a subadult, age 2–4 yr	1	both	φ, *p*
Age2Fem	a subadult female	1	both	φ, *p*
Age3	an adult, age >4 yr	1	both	φ, *p*
Age3Fem	an adult female	1	both	φ, *p*
BI2006	a home stratum of Barter Island in 2006	1	both	*p*
CA	a home stratum of Canada	1	USCA	*p*
Cap-procliv	a summarization of prior capture history	1	both	*p*
Eff-CA	effort strata in Canada; low, medium, and high	3	USCA	*p*
Eff-US	effort strata in the USA; low, medium, and high	3	both	*p*
Home	indicator of home stratum	3	both	*p*
Melt-season	length of the melt-season each year	1	both	φ
Radio	indicator of an active collar	1	both	*p*
Search	hours searching for bears in the USA and Canada	1	USCA	*p*
Search-US	hours searching for bears in the USA	1	USGS	*p*
Summer-habitat	area of optimal ice habitat each year	1	both	φ
Time	separate probability for each year	9	both	*p*
Time-cubic	linear, quadratic, and cubic functions of time	3	both	φ
TS-sur	temporal strata for U.S. and Canada survival	3	both	φ
UA	sex and age covariates for University of Alberta captures	3	USCA	*p*
US	indicator of U.S. home strata	1	both	*p*

Notes: The covariates comprising each group are defined in Appendix A. Abbreviations are: USGS, U.S. Geological Survey; USCA, USA and Canada; and CJS, Cormack-Jolly-Seber.

using fewer parameters (e.g., Stoklosa and Huggins 2012, Peacock et al. 2013, Thorson et al. 2013). We constructed the ice covariate Summer-habitat by summing monthly indices of the area (km^2) of optimal polar bear habitat over the SBS continental shelf (Durner et al. 2009) for July through October of each year (Fig. 2). We expected this covariate to be informative because it was based on the availability of habitat preferred by radio-collared polar bears. The ice covariate Melt-season measured the time between the melt and freeze onset in the Beaufort Sea each summer (Inner Melt Length; Fig. 2; Markus et al. 2009, Stroeve et al. 2014), obtained courtesy of Dr. Julienne Stroeve (National Snow and Ice Data Center, University of Colorado, *personal communication*). We included Melt-season because it covered a broader geographic region than Summer-habitat and the two covariates were not highly correlated ($r = -0.68$). The means and standard deviations of the ice covariates from 2001 to 2010 were used to normalize their values before analysis.

Recapture probability models

Recapture models incorporated covariates for sex and the four age classes. We constrained recapture probabilities of cubs and yearlings to equal those of adult females because family groups were captured simultaneously (Age01.3Fem). We constructed a group of time-varying indicator covariates (UA) to model potential discontinuities in Canadian recapture probabilities after 2006, because UA researchers targeted females and subadults and expended less capture effort from 2007 to 2010.

Recapture models incorporated two nonparametric forms of temporal structure, either constant through time or a separate probability for each year (Time). In addition, we constructed covariates to model temporal variation arising from heterogeneity in capture effort. The hours spent searching for polar bears in the United States each year was recorded by USGS (Search-US). The total hours

TABLE 2. Covariate structure and associated degrees of freedom (df) used to model survival probabilities for each age class.

Age class	Covariate structure	df
Cub	Age0 × TS-sur	3
Cub	**Age0 + Age0 × Time-cubic**	4
Cub	Age0 + Age0 × Summer-habitat	2
Cub	Age0 + Age0 × Melt-season	2
Yearling	Age1 × TS-sur	3
Yearling	**Age1 + Age1 × Time-cubic**	4
Yearling	Age1 + Age1 × Summer-habitat	2
Yearling	Age1 + Age1 × Melt-season	2
Subadult	Age2 × TS-sur + Age2Fem	4
Subadult	**Age2 + Age2 × Time-cubic + Age2Fem**	5
Subadult	Age2 + Age2 × Summer-habitat + Age2Fem	3
Subadult	Age2 + Age2 × Melt-season + Age2Fem	3
Adult	Age3 × TS-sur + Age3Fem	4
Adult	**Int + Age3 × Time-cubic + Age3Fem**	5
Adult	Int + Age3 × Summer-habitat + Age3Fem	3
Adult	Int + Age3 × Melt-season + Age3Fem	3

Notes: A "+" denotes an additive model, and "×" denotes a covariate interaction. The adult component contains an overall mean (Int) when only continuous temporal covariates are included. See Table 1 for descriptions of covariate abbreviations. Some covariates consisted of multiple related covariates that were always used jointly; definitions are provided in Appendix A. Covariate structures in boldface type were used to assess goodness-of-fit.

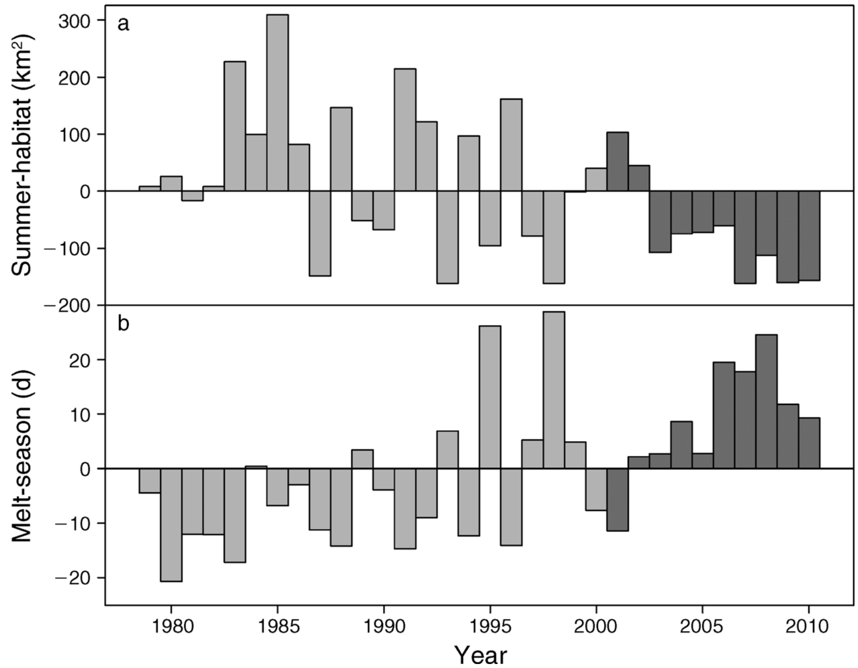

FIG. 2. Anomalies (difference from the mean) of the two sea ice covariates from 1979 to 2010. Normalized values from 2001 to 2010 (dark gray) were used to model polar bear survival probabilities: (a) Summer-habitat, and (b) Melt-season. Summer-habitat was constructed by summing monthly indices of the area (km^2) of optimal polar bear habitat over the SBS continental shelf (Durner et al. 2009) for July through October of each year, and Melt-season measured the time between the melt and freeze onset in the Beaufort Sea each summer.

spent flying in Canada was recorded, and we assumed 60% of flight hours were spent actively searching for polar bears, a percentage derived from USGS flight records. We added the resulting approximation of Canadian search hours to USGS search hours to construct a measure of effort for the entire study area (Search). In addition, we stratified annual search hours in the United States and Canada into low, medium, and high effort categories (Eff-US, Eff-CA), which Stirling et al. (2011) found useful.

We incorporated geographic structure into some models because recapture probabilities vary within the study area (Amstrup et al. 2001). We assigned individuals to a home stratum based on the proximity of their mean capture longitude to the four operational bases (Fig. 1), and used stratum assignments to construct four indicator covariates: Barrow, Deadhorse, Barter Island, and Canada (Home). These covariates reflected coarse variation in recapture probabilities among regions, rather than distinct locations as would be used in multistate models (White et al. 2006). We collapsed the Home covariates into two covariates corresponding to country (US, CA) for some models. In addition, we used an indicator covariate (BI2006) to accommodate the lack of effort from the Barter Island base in 2006.

Two covariates improved model fit so greatly that we included them in all recapture models. The first (Radio) indicated whether a bear was wearing an active radio during the sampling period each year. Instrumented bears were often targeted for sampling to evaluate their condition and retrieve radios, and could therefore have elevated recapture probabilities; similar covariates have been used by other researchers (e.g., Amstrup et al. 2001, Regehr et al. 2010, Stirling et al. 2011). The second covariate (Cap-procliv) modeled potential recapture heterogeneity unexplained by other covariates, using an individual's prior capture history as a measure of its current tendency to be recaptured (Appendix F), indirectly accounting for individual characteristics, such as behavior, that are difficult to quantify.

We constructed models of recapture probability from combinations of four age and sex class effects and eight covariate combinations representing temporal and geographic (abiotic) structure (Tables 3 and 4).

Modeling strategies

We formed CJS models from combinations of survival and recapture sub-models (Tables 2–4). We utilized the plausible combinations (PC) strategy (Bromaghin et al. 2013), with an Akaike's information criterion (AIC_c) model weight (Burnham and Anderson 2002) of 2.5% as an inclusion threshold, to objectively base inference on a reduced model space. Simulation results (Bromaghin et al. 2013) suggest its performance is similar to that of the "all combinations" strategy recommended by Doherty et al. (2012).

We utilized R version 3.0.3 (R Development Core Team 2013) for data manipulation and version 2.14 of the R package mra (*available online*)[9] to estimate model

[9] http://cran.r-project.org/web/packages/mra/index.html

Table 3. Covariate structure and associated degrees of freedom (df) used to model recapture probabilities for the USGS data set.

Source	Covariate structure	df
Age–sex	. . .	0
Age–sex	Age2	1
Age–sex	Age01.23Fem	1
Age–sex	**Age01.3Fem + Age2 + Age2Fem**	3
Abiotic	Int + Radio + Cap-procliv	3
Abiotic	Eff-US + Radio + Cap-procliv	5
Abiotic	Int + Hunt-US + Radio + Cap-procliv	4
Abiotic	Home × US + BI2006 + Radio + Cap-procliv	5
Abiotic	Time + Radio + Cap-procliv	11
Abiotic	Eff-US + Home × US + BI2006 + Radio + Cap-procliv	7
Abiotic	Int + Hunt-US + Home × US + BI2006 + Radio + Cap-procliv	6
Abiotic	**Time + Home × US + BI2006 + Radio + Cap-procliv**	13

Notes: Covariates associated with temporal and geographic structure are collectively referred to as Abiotic. A "+" denotes an additive model and "×" denotes a covariate interaction. The abiotic component contains an overall mean (Int) when only continuous temporal covariates are included. See Table 1 for descriptions of covariate abbreviations. Some covariates consisted of multiple related covariates that were always used jointly; definitions are provided in Appendix A. An ellipsis signifies that no parameters were used to model different recapture probabilities for sex and age classes; all sex and age classes had the same recapture probability. Covariate structures in boldface type were used to assess goodness-of-fit.

parameters (function F.cjs.estim), using the Horvitz-Thompson estimator of abundance (Horvitz and Thompson 1952, McDonald and Amstrup 2001), and compute model-averaged estimates based on AIC_c model weights (function F.cr.model.avg).

We evaluated estimation precision using bootstrap resampling (Chernick 1999), drawing bootstrap samples of capture histories and individual covariates at random with replacement. For each sample, we implemented the PC strategy to select models, estimate the parameters of all selected models, and compute model-averaged estimates (Burnham and Anderson 2002) of recapture, survival, and abundance. Because of the computational burden of this approach, we drew 100 bootstrap samples. We bias-corrected (Chernick 1999) the model-averaged estimates, so their means equaled the original model-averaged estimates, and constructed nonparametric 90% confidence intervals as the 5th and 95th quantiles of the corrected bootstrap estimates.

AIC_c is a relative measure of model suitability, so confidence in the interpretation of AIC_c statistics is enhanced if at least one model provides a reasonable approximation to the data. For each data set, we selected one of the most flexible models and assessed goodness-of-fit using tests implemented in the R package mra (function F.cjs.gof), which are derived from procedures common in logistic regression (Hosmer and Lemeshow 2000, Sakar and Midi 2010).

We assessed the importance of covariates using summed AIC_c model weights (Burnham and Anderson 2002). However, because uninformative covariates accumulate weight when used in combination with informative covariates (Doherty et al. 2012, Bromaghin et al. 2013), we summed weights on the basis of covariate

Table 4. Covariate structure and associated degrees of freedom (df) used to model recapture probabilities for the USCA data set.

Source	Covariate structure	df
Age–sex	UA	3
Age–sex	Age2 + UA	4
Age–sex	Age01.23Fem + UA	4
Age–sex	**Age01.3Fem + Age2 + Age2Fem + UA**	6
Abiotic	Int + Radio + Cap-procliv	3
Abiotic	Int + Hunt + Radio + Cap-procliv	4
Abiotic	Time + Radio + Cap-procliv	11
Abiotic	Home + BI2006 + Eff-CA.1 × CA + Radio + Cap-procliv	7
Abiotic	Int + Hunt + Home + BI2006 + Eff-CA.l × CA + Radio + Cap-procliv	8
Abiotic	**Time + Home + BI2006 + Eff-CA.l × CA + Radio + Cap-procliv**	15
Abiotic	Eff-US × US + Eff-CA × CA + Radio + Cap-procliv	8
Abiotic	Eff-US × US + Home × US + BI2006 + Eff-CA × CA + Radio + Cap-procliv	10

Notes: Covariates associated with temporal and geographic structure are collectively referred to as Abiotic. A "+" denotes an additive model, and "×" denotes a covariate interaction. The abiotic component contains an overall mean (Int) when only continuous temporal covariates are included. See Table 1 for descriptions of covariate abbreviations. Some covariates consisted of multiple related covariates that were always used jointly; definitions are provided in Appendix A. Covariate structures in boldface type were used to assess goodness-of-fit.

combinations (Tables 2–4), rather than individual covariates (Burnham and Anderson 2002).

Complementary analyses to investigate potential bias

Aspects of animal movement and their availability for capture are important considerations in mark–recapture modeling. A pulse of permanent emigration, or temporary emigration near the end of a study, can produce the type of decline in apparent survival reported by Regehr et al. (2010). Although the population level effect of permanent emigration is equivalent to death (e.g., Nichols 2005), understanding population dynamics requires differentiating between them. Similarly, because only the nearshore regions of SBS polar bear habitat can be searched by helicopter (Fig. 1), heterogeneity in habitat preference, temporary emigration, and the nonrandom distribution of individuals could bias parameter estimates. For these reasons, we analyzed available location data from radio-collared female polar bears for signs of pulsed emigration or nonrandom movement that might aid interpretation of parameter estimates.

Abundance estimates in CJS models are derived from recapture probabilities using the Horvitz-Thompson estimator (Horvitz and Thompson 1952, McDonald and Amstrup 2001). Because un-modeled heterogeneity in recapture probabilities can bias abundance estimates, we investigated the reliability of estimated abundance trends by comparing them to simulated abundance projections based on estimated survival probabilities, which are comparatively robust to recapture heterogeneity (Carothers 1979, Abadi et al. 2013), but also see Peñaloza et al. (2014). The projections incorporated a measure of cub production similar to litter production rate (Ramsay and Stirling 1988) and breeding success (Wiig 1998).

Results

Data summary

The USGS data contained information on 715 individual bears that were captured a total of 1049 times (Appendix B). Information on the harvests of 21 marked bears was used to censor their capture histories. The USCA data contained information on 1086 individuals captured a total of 1590 times, and capture histories of 38 bears were censored following their harvests. The number of bears captured annually ranged from 75 to 148 individuals in the USGS data, and from 97 to 291 individuals in the USCA data set (Table 5). The proportion of captured bears that were marked increased during the initial years and stabilized approximately midway through the investigation (Table 5). Additional capture statistics are provided in Appendix B.

Model selection and goodness-of-fit

The PC model selection strategy (Bromaghin et al. 2013) with the USGS data resulted in the retention of 60 survival probability models and 20 recapture probability models. The estimation algorithm failed to converge for one combination of survival and recapture models (for survival, Int + Age3 × Melt-season + Age3Fem + Age2 × Melt-season + Age2Fem + Age1 × Melt-season + Age0 × TS-sur; and for recapture, Time + Age01.23Fem + Radio + Cap-procliv). The model selected to evaluate goodness-of-fit contained 34 parameters (covariate structures listed in boldface type in Tables 2 and 3). The results of goodness-of-fit tests did not raise concerns regarding inadequate model fit. The Osius-Rojek test could not be evaluated (it returned a "not-a-number" code), but the Hosmer-Lemeshow test was not significant ($P = 0.690$), and the Receiver Operating Characteristic (ROC) curve displayed acceptable discrimination (0.736).

For the USCA data, the PC model selection strategy resulted in 47 survival probability models and 4 recapture probability models being selected for further consideration. The model selected to assess goodness-of-fit contained 39 parameters (covariate structures listed in boldface type in Tables 2 and 4). Based on that model, the Osius-Rojek test was moderately significant ($P = 0.036$), but the Hosmer-Lemeshow test was not ($P = 0.276$) and the Receiver Operating Characteristic (ROC) curve displayed acceptable discrimination (0.727), providing no compelling evidence of inadequate model fit.

Survival and recapture probabilities

Model-averaged estimates of survival based on the USGS data differed among age classes and varied through time (Fig. 3, Table 6). Survival of adult bears was high from 2001 through 2003, substantially reduced from 2004 through 2007, and higher but below historical levels in 2008 and 2009 (Amstrup and Durner 1995, Amstrup et al. 2001). Point estimates for males were slightly higher than for females, though confidence intervals broadly overlapped. Model weight was distributed across all forms of temporal structure for adults,

Table 5. The number of southern Beaufort Sea polar bears captured (*N*), and the number (*M*) and percentage (%) that were previously marked, by year in the USGS and USCA data sets.

Year	USGS			USCA		
	N	*M*	%	*N*	*M*	%
2001	135	. . .	. . .	135	. . .	. . .
2002	118	36	30.5	118	36	30.5
2003	107	28	26.2	167	32	19.2
2004	148	39	26.4	291	64	22.0
2005	96	37	38.5	251	81	32.3
2006	90	40	44.4	150	64	42.7
2007	80	29	36.3	116	53	45.7
2008	88	35	39.8	108	49	45.4
2009	112	52	46.4	157	80	51.0
2010	75	38	50.7	97	45	46.4

Note: The first year of tagging was 2001, and recaptures could not occur until 2002 (indicted with ellipses).

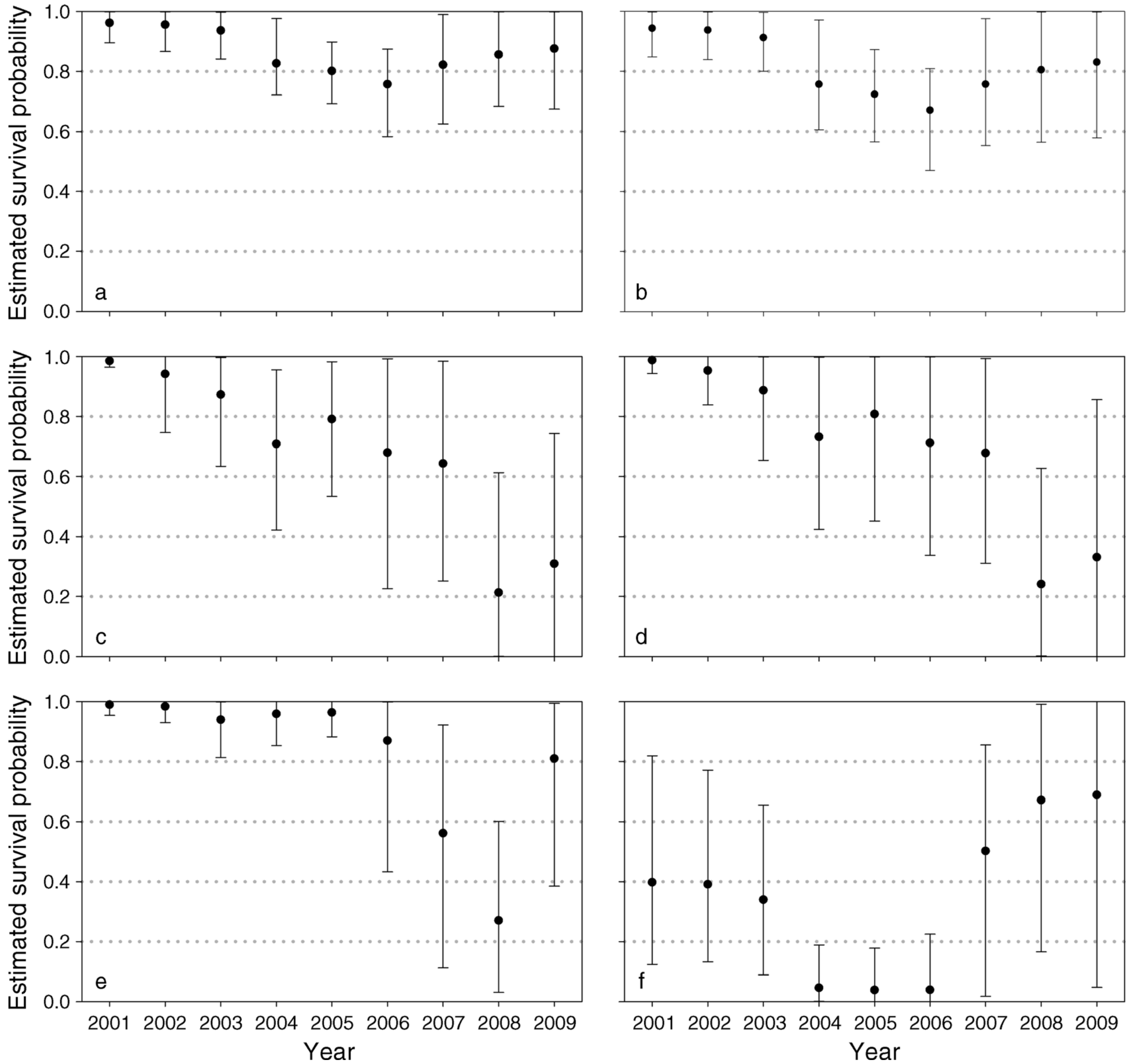

FIG. 3. Model-averaged estimates of annual polar bear survival probability by age class and sex for the U.S. Geological Survey (USGS) data set: (a) adult males, (b) adult females, (c) subadult males, (d) subadult females, (e) yearlings, and (f) cubs. Error bars represent 90% bias-corrected bootstrap confidence intervals based on 100 replications.

TABLE 6. Total corrected Akaike's information criterion (AIC_c) model weight associated with covariate structures of survival probability models, by age class, based on the USGS data set.

Age class	Covariate structure	Weight
Cub	Age0 × TS-sur	0.781
Cub	Age0 + Age0 × Time-cubic	0.219
Yearling	Age1 + Age1 × Melt-season	0.424
Yearling	Age1 + Age1 × Time-cubic	0.245
Yearling	Age1 + Age1 × Summer-habitat	0.215
Yearling	Age1 × TS-sur	0.117
Subadult	Age2 + Age2 × Time-cubic + Age2Fem	0.536
Subadult	Age2 + Age2 × Melt-season + Age2Fem	0.402
Subadult	Age2 × TS-sur + Age2Fem	0.047
Subadult	Age2 + Age2 × Summer-habitat + Age2Fem	0.015
Adult	Age3 × TS-sur + Age3Fem	0.443
Adult	Int + Age3 × Time-cubic + Age3Fem	0.229
Adult	Int + Age3 × Melt-season + Age3Fem	0.210
Adult	Int + Age3 × Summer-habitat + Age3Fem	0.118

Notes: Covariate structures with a weight <0.01 are excluded. A "+" denotes an additive term, and "×" denotes a covariate interaction. The adult component contains an overall mean (Int) when only continuous temporal covariates are included. See Table 1 for descriptions of covariate abbreviations. Some covariates consisted of multiple related covariates that were always used jointly; definitions are provided in Appendix A.

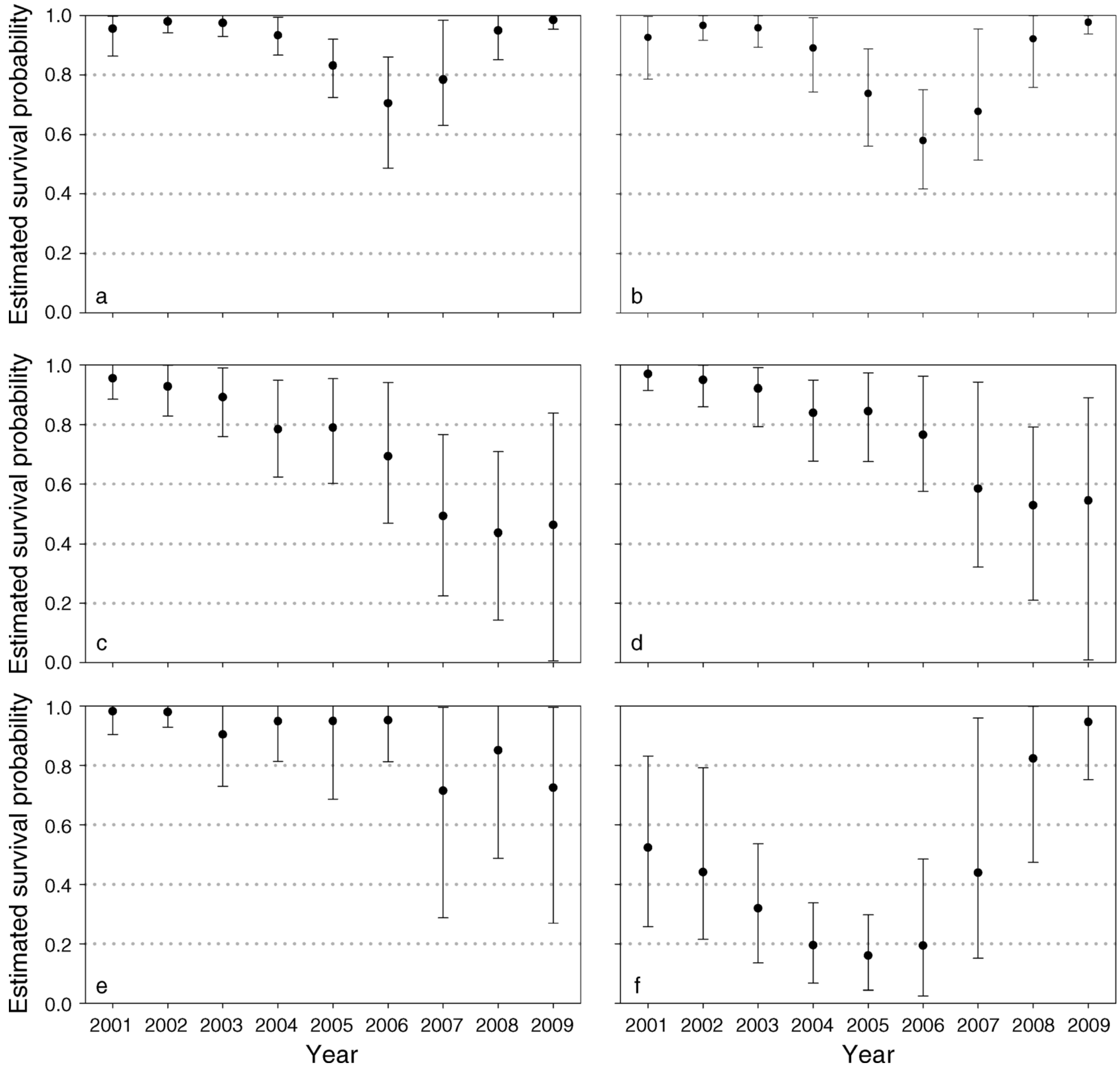

FIG. 4. Model-averaged estimates of annual polar bear survival probability by age class and sex for the USA and Canada (USCA) data set: (a) adult males, (b) adult females, (c) subadult males, (d) subadult females, (e) yearlings, and (f) cubs. Error bars represent 90% bias-corrected bootstrap confidence intervals based on 100 replications.

though temporal stratification (TS-sur) accumulated the most AIC_c model weight ($w = 0.443$). Survival of subadults generally declined, although confidence intervals were broad. Most of the weight for subadults was accumulated by covariate structures incorporating Time-cubic ($w = 0.536$) or Melt-season ($w = 0.402$). Estimates of yearling survival were high during the first half of the study, but lower and more variable in the later years. Model weight for yearlings was distributed across all forms of temporal structure, with Melt-season accumulating the greatest weight ($w = 0.424$). Survival of cubs displayed a temporal pattern similar to that of adults, though the mid-study decline and the rebound in the last years were more exaggerated. The covariates TS-sur ($w = 0.781$) and Time-cubic ($w = 0.219$) accumulated all the weight for cubs.

Model-averaged estimates of survival probabilities based on the USCA data were similar to those obtained with the USGS data (Fig. 4, Table 7). The survival of adults was lower in 2006 and 2007, but higher in 2008 and 2009, compared to the USGS estimates (Fig. 3). The temporal pattern in estimates of cub survival was similar to the pattern obtained with the USGS data, but survival estimates were higher in 2004–2006 and 2008–2009. The form of temporal variation accumulating the most weight for both adults and cubs incorporated the Time-cubic covariate ($w = 0.883$ and $w = 0.872$, respectively). For subadult bears, the top covariate structure ($w = 0.458$) included temporal stratification (TS-sur). This differs somewhat from results obtained with the USGS data, although subadult survival rate estimates trended downward in both cases. The Summer-habitat covariate accumulated the most model weight ($w = 0.583$) for yearlings.

Model-averaged estimates of recapture probabilities and total model weights associated with covariate combinations for both data sets are presented in Appendix C.

TABLE 7. Total AIC_c model weight associated with covariate structures of survival probability models, by age class, based on the USCA data set.

Age class	Covariate structure	Weight
Cub	Age0 + Age0 × Time-cubic	0.872
Cub	Age0 × TS-sur	0.128
Yearling	Age1 + Age1 × Summer-habitat	0.583
Yearling	Age1 + Age1 × Melt-season	0.242
Yearling	Age1 × TS-sur	0.145
Yearling	Age1 + Age1 × Time-cubic	0.030
Subadult	Age2 × TS-sur + Age2Fem	0.458
Subadult	Age2 + Age2 × Melt-season + Age2Fem	0.239
Subadult	Age2 + Age2 × Time-cubic + Age2Fem	0.208
Subadult	Age2 + Age2 × Summer-habitat + Age2Fem	0.095
Adult	Int + Age3 × Time-cubic + Age3Fem	0.883
Adult	Int + Age3 × Melt-season + Age3Fem	0.071
Adult	Age3 × TS-sur + Age3Fem	0.046

Notes: Covariate structures with a weight <0.01 are excluded. A "+" denotes an additive term, and "×" denotes a covariate interaction. The adult component contains an overall mean (Int) when only continuous temporal covariates are included. Some covariates consisted of multiple related covariates that were always used jointly; definitions are provided in Appendix A.

Abundance

Annual abundance estimates based on the USGS data, applicable to the Alaskan portion of the study area, ranged from 376 bears in 2009 to 1158 in 2004 (Fig. 5a). We suspect estimates in the first two years, particularly 2002, were negatively biased by the absence of capture effort from Barrow in 2001, which may have caused an overestimate of recapture probability in 2002 (Appendix C: Figs. C1–C3). In addition, the mixing of marked and unmarked individuals may have been incomplete during the initial years of the study (Appendix D: Fig. D2). The unusually large number of bears captured in 2004 (Table 5) produced a seemingly large estimate with a wide confidence interval. Even though there is uncertainty regarding abundance levels in these years, the broader pattern of a decline in abundance during the middle of the study followed by relative stability at the end of the study was consistent with patterns in survival.

Abundance estimates based on the USCA data ranged from 464 bears in 2002 to 1607 in 2004 (Fig. 5b). As with the USGS data, we suspect estimates for the initial years of the investigation were less reliable than those in the latter years, particularly because no capture effort occurred in Canada before 2003 and our models were not robust to this deficiency. Considering this uncertainty in the earliest estimates, the temporal pattern in abundance resembled that of the USGS estimates and was consistent with patterns in survival. The correlation between USGS and USCA abundance estimates was 0.84 across all years and 0.86 excluding 2002.

Complementary analyses to investigate potential bias

Analyses of location data from radio-collared females produced no strong evidence that temporary emigration or non-random movement negatively biased estimates of survival (Appendix D). An exact test of the hypothesis that equal proportions of collared bears were available for capture each year was not significant ($P = 0.990$), implying that a pulse of permanent emigration did not occur in the middle of the investigation. We did, however, find indications of nonrandom movement between nearshore and offshore habitats among consecutive years. Although such nonrandom movement can bias estimates of recapture and survival probabilities, our data are consistent with conditions in which bias in survival probabilities is small (modest state transition probabilities; Kendall et al. 1997, Schaub et al. 2004).

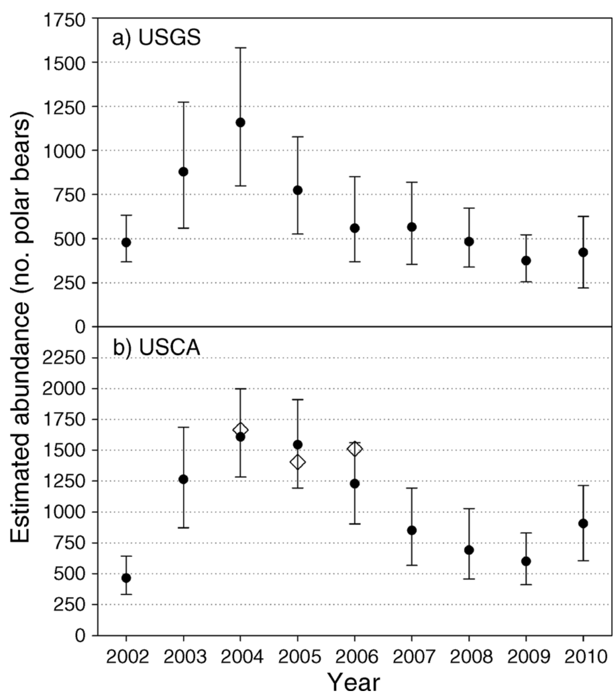

FIG. 5. Model-averaged estimates of polar bear abundance based on (a) the USGS data set and (b) the USCA data set. Error bars represent 90% bias-corrected confidence intervals based on 100 bootstrap samples. Prior estimates (Regehr et al. 2006) are shown for comparative purposes (open diamonds in panel [b]).

PLATE 1. Large male polar bear (*Ursus maritimus*) on the sea ice of the southern Beaufort Sea. Photo credit: U.S. Geological Survey, Alaska Science Center.

The results of population projections were largely consistent with the estimated trends in abundance (Appendix E). Projected abundance increased during the initial years of the study, though more slowly than suggested by the abundance estimates, supporting our conjecture that abundance estimates in the earliest years were negatively biased. Projected abundance declined through the middle of the study, and then stabilized. The correlation between abundance estimates and the projections based on the USGS data set was 0.85 across all years and 0.90 excluding 2002; the corresponding correlations for the USCA data set were 0.89 and 0.95.

Discussion

Methodological effectiveness

We constructed covariates to account for multiple sources of heterogeneity in recapture probabilities that could otherwise bias survival and abundance estimates (Abadi et al. 2013). Recapture probabilities were allowed to vary by sex and age class. Covariates indexed both capture effort and nonparametric temporal structure, and geographic covariates accounted for previously discovered regional differences in recapture probabilities (Amstrup et al. 2001). The covariate Cap-procliv (Appendix F) indirectly accounted for potential sources of heterogeneity we could not measure. Collectively, these covariates accounted for several known or potential sources of heterogeneity, and any bias originating from un-modeled heterogeneity is likely to be small compared to the temporal variation in survival and abundance estimates.

We found no compelling evidence that emigration or nonrandom movement meaningfully biased estimates. Neither analysis of movement data (Appendix D), nor patterns in recapture rates (Appendix B) revealed a pulse of permanent emigration that could explain the mid-study decline in survival. Similarly, a pulse of immigration followed shortly by permanent emigration, which could explain the high USGS abundance estimate in 2004 and the mid-study decline in survival, is unlikely to have occurred given joint consideration of movement data and recapture rates. The most likely sources of immigrants are the neighboring northern Beaufort and Chukchi Seas (Fig. 1), but large-scale immigration from these regions seems unlikely because their ecological conditions are thought to be more favorable than in the SBS (e.g., Stirling et al. 2011, Rode et al. 2014). In addition, our estimates did not exhibit the decline in apparent survival near the end of the investigation that is indicative of temporary emigration (e.g., Langtimm 2009, Kendall et al. 2013). Analyses of movement data suggested that Markovian dependency in the probability of being available for capture between consecutive years remains a potential source of bias (Schaub et al. 2004). However, we view these results with some caution because of the small sample sizes and prior evidence that bears prefer ice in waters over the narrow continental shelf (Durner et al. 2009). Further, there is no reason to suspect that behavior leading to nonrandom movement during the spring capture season changed during the investigation, implying that trends in survival and abundance would not be appreciably affected even if some bias is present. In summary, although we are aware of the potential influence of temporary emigration and nonrandom movement, we believe any bias from these sources is likely to be small compared to the magnitude of temporal variation and trends in survival and abundance estimates.

We believe that the assumptions of the Horvitz-Thompson abundance estimator (Horvitz and Thompson 1952, McDonald and Amstrup 2001) were satisfied. Covariates were utilized to model several known and potential sources of heterogeneity in recapture probabilities, so there is no reason to suspect they are systematically biased. The CJS model conditions on initial captures and estimates subsequent recapture probabilities, while the Horvitz-Thompson estimator applies estimated recapture probabilities to both initial captures and recaptures (McDonald and Amstrup 2001). A behavioral response to initial capture that lowers recapture probabilities therefore has the potential to positively bias abundance estimates. However, our capture methods largely preclude such a behavioral response. Bears are often located by following fresh tracks in snow. There are patches of rough ice in which bears could attempt to hide, if they were not being tracked, but we have not observed hiding behavior. Most bears move away as the helicopter approaches, though some display curiosity or aggression toward it. In addition, we are unaware of any information that suggests our abundance estimates are unrealistically high.

Insights into ecological mechanisms

The previously reported low survival of SBS polar bears in 2004 and 2005 (Regehr et al. 2010) continued into 2007, at levels substantially less than earlier estimates for this population (Amstrup and Durner 1995, Amstrup et al. 2001). Annual survival of cubs during that period was estimated to be <0.2 based on the USCA data and near zero with the USGS data. Indeed, only 2 of 80 cubs in the USGS data observed from 2003 to 2007 are known to have survived to an older age class (Appendix B: Fig. B1). Such poor recruitment, combined with reduced survival of other age classes, must have substantially impacted abundance, and our abundance estimates declined accordingly during those years. Estimated survival of adults and cubs from both data sets began to improve in 2007, with estimates based on the USCA data suggesting a somewhat stronger recovery, although confidence intervals overlap broadly. This potential divergence may be an early indication of regional differences in ecosystem function and polar bear response that may become more apparent as the Arctic continues to warm.

Several independent sources of information are consistent with reduced survival during the middle of the study period. Cherry et al. (2009) found physiological indications of nutritional stress to be two to three times greater in 2005 and 2006 than in the 1980s. Regehr et al. (2006) reported observations of starvation during this period, and unusual incidents of polar bears stalking and killing other bears occurred in 2004 (Amstrup et al. 2006). Stirling et al. (2008) reported a case of cannibalism and several instances of polar bears penetrating unusually thick ice barriers to reach ringed seal lairs between 2003 and 2007, predatory behavior that is energetically inefficient and a likely indication of nutritional stress. A similar instance of ice penetration was observed in the SBS in 1975 (Stirling et al. 2008), during a period of low seal production and reduced polar bear cub survival throughout the Canadian portion of the Beaufort Sea (Stirling 2002). Similar low productivity of ringed seals and reduced survival of polar bear cubs were documented in the Canadian portion of the Beaufort Sea again in the mid-1980s (Smith 1987, Stirling 2002).

Factors leading to improved survival beginning in 2007 are difficult to identify, but there are indications of a transition at this time. Pilfold et al. (2014) reported a shift in the distribution of seal kill sites among land-fast and pack ice between the periods 2003–2006 and 2007–2011, and more kill sites were located in the latter period. The pattern and occurrence of open-water lead systems and ice deformation within the central Beaufort Sea changed in 2006 (Mahoney et al. 2012). Similarly, Melling et al. (2012) reported unusual atmospheric and oceanographic conditions in the Beaufort Sea during 2007. Ringed seal productivity within Amundsen Gulf in the eastern SBS was low in 2005 and 2006, but improved in 2007 (Harwood et al. 2012), although this was attributed to localized ice conditions and is not thought to be indicative of the low ringed seal production broadly observed in the 1970s and 1980s (Stirling 2002). Potential linkages between these indicators of a transition in the 2006–2007 time frame and polar bear survival may become apparent as our understanding of Arctic ecology improves.

Improved survival after 2007 might be partially attributable to either density-dependent mechanisms or the altered characteristics or behavior of surviving individuals. Reduced competition for limited resources resulting from lower abundance may have increased survival at the end of the study period. Similarly, consecutive years of unfavorable conditions may have eliminated the less fit individuals from the population, with the survivors collectively displaying seemingly enhanced survival. Finally, some individuals may have adopted behavior that increased their survival. For example, a growing proportion of the population utilizes terrestrial habitat after ice retreats from the continental shelf in summer (USGS, *unpublished data*). These bears have access to subsistence-harvested bowhead whale carcasses at discrete locations along the Alaskan coast (Herreman and Peacock 2013), an energy-rich alternative food source (Bentzen et al. 2007) that may enhance survival. Bears utilizing terrestrial habitat in summer may also have earlier access to seals in autumn. Landfast ice begins to form over coastal waters earlier than the expanding pack ice provides bears summering on perennial ice deep in the Polar Basin with access to continental shelf waters. Such behavioral tendencies are likely to be adopted by dependent young and may therefore become increasingly common.

Subadults, unlike adults and cubs, did not display increased survival during the latter years of our investigation. Newly independent and inexperienced individuals are likely to be less efficient hunters, and less capable of competing for limited resources or retaining control of kills, than adults (Stirling 1974), and may be more susceptible to unfavorable conditions. Subadults are also less likely to utilize crowded feeding sites such as bowhead whale remains. Sea ice covariates were more strongly associated with the survival of subadults than adults, which is consistent with findings that the body condition of growing bears is more closely linked to ice conditions than that of older bears (Rode et al. 2010). The lack of an improvement in subadult survival may be, in part, a residual effect of poor conditions in prior years. Yearlings that survived to subadult status during years of low survival may have been in inadequate condition to survive independently. Regardless of cause, the status of subadults in the SBS population merits monitoring, because their continued low survival could ultimately lead to further declines in abundance.

Polar bears depend on sea ice for several aspects of their life history, and multiple characteristics of sea ice can be expected to influence their vital rates, potentially via mechanisms that are complex and nonlinear (e.g., Ellis and Post 2004, Tyler et al. 2008, Derocher et al. 2013). The duration of ice-absence from the continental shelf is thought to directly affect polar bear condition and vital rates through reduced access to prey (Regehr et al. 2010, Rode et al. 2010, 2012). Observations of polar bears and seal kills in low-concentration, unconsolidated ice (Chukchi Sea in 2009, SBS in 2010; S. C. Amstrup, G. M. Durner, and E. V. Regehr, *unpublished field observations*) testify to the high value of sea ice in biologically productive shelf waters. However, other aspects of sea ice are undoubtedly important. Extensive ice rubble and rafted floes during winter and spring are thought to have led to past declines in polar bear productivity in the SBS (Stirling et al. 1976, Amstrup et al. 1986, Stirling 2002), as well as during our investigation (Stirling et al. 2008). The increased frequency and severity of storms (Sepp and Jaagus 2011, Thomson and Rogers 2014) combined with thinner and more mobile pack ice (Spreen et al. 2011), both consequences of climate warming, are likely to result in a greater prevalence of deformed ice in winter and spring that may result in lower quality ringed seal birth lair habitat and subsequent reductions in reproductive success. Similarly, continued warming may increase the frequency of unsuitable snow and ice conditions for maintenance of ringed seal lairs (Stirling and Smith 2004, Hezel et al. 2012). The increased vulnerability of ringed seal pups to predation could temporarily enhance polar bear survival, though it would likely also lead to subsequent reductions in prey abundance. Finally, access to terrestrial denning sites can be limited by ice conditions (Derocher et al. 2011).

Despite the known importance of sea ice, measures of ice availability did not fully explain short-term demographic patterns in our data, suggesting that other aspects of the ecosystem contribute importantly to the regulation of population dynamics. Prey abundance can obviously affect bear condition and survival independently, to an extent, of sea ice conditions. Numerous factors such as warming-induced increases in primary productivity (Zhang et al. 2010), phenology-based trophic mismatches (Post et al. 2013), changing disease vectors (Jensen et al. 2010), increased contaminant transport (Sonne 2010), and expanding human activity in the Arctic (Smith and Stephenson 2013) may interact with the primary effects of sea ice conditions and prey accessibility. As the Arctic continues to warm, ecosystem structure and function can be expected to respond (e.g., Lasternas and Agustí 2010, Hezel et al. 2012, Carroll et al. 2013, Hinzman et al. 2013, Ji et al. 2013, Iverson et al. 2014, Nahrgang et al. 2014), perhaps in ways that are difficult to foresee. Although sea ice availability is expected to be the dominant driver of population dynamics over the long term (Amstrup et al. 2008, Stirling and Derocher 2012), other aspects of the ecosystem can be expected to either mitigate or exacerbate the effects of sea ice loss in the short term. The changing Arctic ecosystem may induce increased short-term variation in vital rates and elevate the risk of abrupt population decline (Derocher et al. 2013).

Conclusions

Our results collectively suggest that polar bears in the SBS experienced a significant reduction in survival and abundance from 2004 through 2007. However, suspected biases in the abundance estimates for the earliest years of the investigation, potential biases in the USCA estimates in the latter years, and statistical variation associated with estimates necessitate cautious expression of the magnitude of population decline. Conservatively, the decline seems unlikely to have been $<25\%$, but may have approached 50%. Improved survival and stability in abundance at the end of the investigation are cause for cautious optimism. However, given projections for continued climate warming (IPCC 2013), polar bear ecology in the SBS and elsewhere in the Arctic is expected to become increasingly forced by sea ice loss (Amstrup et al. 2008, Stirling and Derocher 2012). Behavioral plasticity and ecosystem productivity may enable some populations to temporarily maintain recruitment and abundance, despite deteriorating habitat conditions (e.g., Rode et al. 2014), but seem unlikely to counterbalance the extensive habitat degradation projected to occur over the long term (IPCC 2013). Continued research into the ecological mechanisms underlying polar bear population dynamics is necessary to refine projections of their future status and develop appropriate strategies for their management.

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Supplemental Material

Ecological Archives

Appendices A–F are available online: http://dx.doi.org/10.1890/14-1129.1.sm

Estimation of Incidental Take

The general approach to quantifying take was as follows: 1) determine the number of animals in the project area, 2) assess the likelihood of, nature, and degree of exposure, and 3) evaluate the probable responses to, 4) calculate the amount of take. Our evaluation of take included quantifying the number of responses, and life stage affected, that met the criteria for Level A harassment (potential death or injury), or Level B harassment (potential disruption of a biologically significant behavioral pattern), factoring in the degree by which effective mitigation measures reduce the amount or consequences of take. This evaluation was focused on individual animals. The next steps were to: 5) determine whether this take will be of a small number relative to the size of the population (or stock), and 6) determine whether take will have a negligible impact on the population, both of which are determinations required under the MMPA.

Characterizing Take

Level A Harassment

Extreme behavioral reactions capable of causing injury are characterized as Level A harassment events. Examples include, but are not limited to, separation of mothers from dependent cub(s) (Amstrup 2003), activities that result in mothers leaving the den early (Amstrad and Gardener 1994, Rode et al. 2018), or prolonged or repeated interruptions in nursing or resting (cubs), both of which can negatively affect cub survival. Human interactions can also directly result in Level A mortality of polar bears. Examples include defense of life situations, efforts to deter bears from a work area for safety, running over a den, or activities that result in a mother abandoning her cubs, which would result in the death of the cubs.

Level B Harassment

An individual polar bear's reaction to activities will depend on its prior exposure to human activities, its need or motivation to be in the particular area, its physiological status, and other intrinsic factors. The location, timing, frequency, intensity, and duration of the encounter are among the external factors that will also influence the animal's response.

Relatively minor reactions such as increased vigilance or a short-term change in direction of travel are not likely to disrupt biologically significant behavioral patterns and the Service does not view such minor reactions as likely to result in a Level B take by harassment.

Reactions that disrupt biologically significant behaviors for the affected animal meet the criteria for Level B harassment under the MMPA. Reactions that indicate Level B take of polar bears in response to human activity include, but are not limited to:

- Fleeing (running or swimming away from a human or a human activity)
- Displaying a stress-related behavior such as jaw or lip-popping, front leg stomping, vocalizations, circling, intense staring, or salivating
- Abandoning or avoiding preferred movement corridors such as ice floes, leads, polynyas, a segment of coast line, or barrier islands
- Using a longer or more difficult route of travel instead of the intended path

- Interrupting breeding, sheltering, feeding, or hunting
- Moving away at a fast pace (adult) and cubs struggle to keep up
- Ceasing to nurse or rest (cubs)
- Ceasing to rest repeatedly or for a prolonged period (adults)
- Loss of hunting opportunity due to disturbance of prey
- Any interruption in normal denning behavior that does not cause den abandonment or early departure.

This list is not meant to encompass all possible behaviors and other situations may result in Level B take. It is also important to note that depending on the duration and severity of the above-described behaviors, Level A take could occur.

Take of Polar Bears during Winter

Denning bears

NUMBER OF DENS

We developed a framework to estimate how many polar bear dens might potentially be disturbed by seismic activity that is planned for the Coastal Plain in winter. This framework relied on two pieces of information. The first was an estimate of the number of dens in a given year within the Coastal Plain derived from peer-reviewed studies. The second was an estimate of the probability of detecting known dens using aerial infrared (AIR) camera technology based on data in Amstrup et al. (2004).

While there have been no formal analyses to estimate the number of polar bears that den on the Coastal Plain of the Refuge, a number of studies have published parameters that can be used to develop such an estimate. The parameters required to develop an estimate of the number of dens include:

- Estimated population size (Bromaghin et al. 2015)
- Proportion of adult females in the population (Bromaghin et al. 2015)
- Breeding probability of adult females (Regehr et al. 2010)
- Proportion of dens that occur on land vs. sea ice (Olson et al. 2017)
- Proportion of land based dens that occur in the Coastal Plain of the Refuge (Durner et al. 2010)

Bromaghin et al. (2015) estimated the size of the SBS subpopulation to be 907 polar bears (90 percent Confidence Interval: 606 to 1212) in 2010. Additionally, Bromaghin et al. (2015) provided information on the number of adult females that were captured each year from 2001 to 2010. These data indicated that that approximately 35.1 percent (SD=3.8) of the population consisted of adult females. Using these data to determine the percent of adult females (PAF) in the population assumes that captured individuals comprised a representative sample of the population.

Regehr et al. (2010) provided estimates of breeding probability for adult females in the SBS subpopulation. This includes two components; 1) the probability of a female without cubs breeding and producing a litter, and 2) the probability of a female that has lost her cubs but rebreeds in a given year. Regehr et al. (2010) reported estimates of these parameters of 0.44 (PbreedO; 90 percent CI: 0.33–0.56) and 0.10 (Pbreed1; 90 percent CI: 0.02–0.38), respectively.

Based on collar data from SBS bears from 2007 to 2013, Olson et al. (2017)

found that 55.2 percent (16 of 29) of adult females denned on land versus sea ice (Pland=0.55). The proportion of dens that occur in the Coastal Plain was derived from the U.S. Geological Survey published database of all known dens for bears in the SBS subpopulation from 1910 to 2010 (Durner et al. 2010). We restricted the data to only dens from 2000 to 2010 that were detected by satellite radio collars as the proportion of denning on land has increased with declining sea ice conditions (Olson et al 2017). We restricted our analysis to only collared bears to avoid skewing den observations towards communities or areas with industrial activity, where dens might be more readily observed. Between 2000 and 2010, there were a total of 39 satellite radio collared polar bears that denned on land, and of those, 9 occurred in the Coastal Plain, resulting in an estimate of 23.1 percent of land-based SBS polar bear dens occurring in the Coastal Plain in any given year (PCoastal Plain=0.231). This estimate assumes that the den data obtained from VHF and satellite radio collars are representative of the entire population, and not just those in the area where bears are available to be captured and collared.

Based on the information above, the number of dens in the Coastal Plain was derived from the following calculations. First, we estimated the number of adult females (NAF) in the population:

Equation 1: $NAF=N2010\times PAF$

$NAF=907\times 0.35=317.5.$

We then, we estimated the number of adult females that bred (Nbreed) in a given year:

Equation 2: $N_{breed} = N_{AF} \times P_{breedO} + N_{AF} \times P_{breedO} \times P_{breedI}$

$N_{breed} = (317.5 \times 0.437) + (317.5 \times 0.437 \times 0.104) = 153.2.$

Next, we estimated the number of denning females that occur on land (Nland):

Equation 3: $N_{land} = N_{breed} \times P_{land}$

$N_{land} = 153.2 \times 0.552 = 84.5.$

Finally, we estimated the total number of land based dens that would occur in the Coastal Plain in a given year (NCoastal Plain):

Equation 4: $N_{Coastal\ Plain} = N_{land} \times P_{Coastal\ Plain}$

$N_{Coastal\ Plain} = 84.5 \times 0.231 = 19.5.$

Given the above calculations, the total number of polar bear dens estimated to occur in the Coastal Plain in a given year is 19.5. Because you cannot have a partial den, we rounded this number up to 20 dens as a conservative estimate of the total number of dens expected to occur in the Coastal Plain in any one year.

OVERLAP OF ACTIVITIES WITH DENS

Timing—SAE has proposed to conduct seismic activities between January 2019 and May 31, 2019 and December 2019 and May 2020, which overlaps with the polar bear maternal denning period. Mean date of entrance into dens by polar bears was 15 November ±1.9 days (n=215) and mean date of emergence from dens was 1 March ±2.1 days (n=179) (Rode et. al 2018). After emerging, females remain near the den site for an average of 8 days ±5 days, presumably to allow the cubs to acclimate (Smith 2007).

Some of SAE's work will likely extend into the spring beyond the polar bear denning season. The latest known den departure date of a SBS polar bear was April 20, as reported by oil and gas industry observations. If SAE's project season extends throughout the proposed periods (Jan. 2, 2019–May 31, 2019 and Dec. 1, 2019–May 31, 2020), and progress is steady, then approximately 11 percent of the work could occur outside the denning period of polar bears.

However, the specific progression of SAE's seismic work across the Coastal Plain is not known. Therefore, we could not assume that any of the denning habitat would be avoided by conducting all work in an area after the denning period. SAE has provided a suggested progression of work. Their suggested scenario begins from an inland snow road in the southwestern quadrant, moves eastward, then northward, and then exits the Coastal Plain along a coastal sea-ice route through the northwestern quadrant. Following this progression, work after the denning period would occur in the northwest quadrant. SAE is proposing to attempt to conduct seismic surveys across the entire Coastal Plain in the winter of 2018/2019 but if the work cannot all be completed in one winter, they will return in the winter of 2019/2020 to finish whatever remains. Therefore, we could not predict the actual proportion of area that SAE's proposed work would occur outside of the denning period. Therefore, we did not assume any avoidance of denning habitat through project timing.

Repeated Effects across Years—Estimation of the number of dens in the project area and those potentially exposed to effects assumes that work will not be repeated in the same area across years. This assumption is likely to be violated if work occurs during both winter seasons. The most likely type of repeated work will be transportation along a main snow road or sea ice route. The amount of area affected will depend on the amount and location of work completed in the first winter and the field conditions in the second winter, among other factors. Given this uncertainty, and to ensure that take is not underestimated, we assumed that work would be conducted in the second winter, and that a transit route following SAE's example progression would be used in both years.

To determine the additional number of bears that would be exposed due to activities occurring across years, we first plotted an east/west inland path across the Coastal Plain using ArcGIS 10.5®. This line was approximately 100 miles long. The return path was routed along the coast, based on SAE's suggested progression of work. The return route was also plotted and estimated to be 127 miles long. Dens within one mile on either side of a snow or ice road are at greatest risk of being disturbed, so the total area within one mile on either side of the plotted route was calculated using geometry tools in ArcGISAm 10.5®. The estimated area was 1165.8 km^2 (450.1 mi^2). This is approximately 17 percent of project area, i.e. the entire Coastal Plain area 450.1÷2602=0.17). Therefore, the total number of dens exposed to the repeated project activities increased by 17 percent. This yields (19.5+(19.5×0.17))=22.8. Because one cannot take a partial den, we rounded this up to 23 dens, or 3 additional dens affected by the project activities that are repeated across years. The adjustment of the number of denning bears due to repeated activities across two years assumes that the area of the repeated activities within the overall project area is a suitable proxy for the number of dens that may be disturbed.

Spatial Overlap—SAE proposes to collect seismic data throughout the Coastal Plain. SAE also proposes to conduct AIR surveys of all polar bear denning habitat within the Coastal Plain (as identified by Durner et al. 2006) and will establish a 1-mi buffer around the location of any detected den. Once dens are identified during an AIR survey, they (along with an associated 1-mile buffer) will be excluded from SAE's project activities. While these dens could be disturbed during the AIR survey itself (see *Take During "Spring" and "Fall"*), we assumed that dens mitigated in this manner would not be impacted by activities outside of the AIR survey itself.

Similar AIR surveys and 1-mi buffers are typical of the mitigation requirements for Industry operators who receive Letters of Authorization (LOAs) under the SBS Incidental Take Regulations (ITRs) in other areas of Alaska's North Slope. We assumed that the AIR survey proposed by SAE will be conducted following approved methodology and with similar intensity to those currently conducted by Industry and addressed under the existing SBS ITR.

To estimate the number of polar bear dens that might be disturbed by seismic activity, we used the following equation:

Equation 5: $Dens\_Dis = NCoastal\ Plain \times (1 - AIR\_Detect\_Prob)$,

where Dens_Dis is the number of dens that will potentially be disturbed by seismic activity in the Coastal Plain, NCoastal_Plain is the total number of land based dens in the Coastal Plain in a given year as determined by Equation 4 (i.e. 19.5 rounded to 20), and AIR_Detect_Prob is the probability of detecting a den using AIR surveys. To estimate the probability that a den is detected by a single AIR survey, we obtained data from Figure 3 in Amstrup et al. (2004) detailing the number of detections of known dens during multiple AIR surveys. We then used these data to run a binomial statistical model. This resulted in an estimate of the probability of a (known) den being detected during a single AIR survey being 0.62 (95 percent credible interval: 0.51 to 0.73).

Equation 6: $Dens\_Dis = 20 \times (1 - 0.62) = 7.6$.

The number of dens potentially disturbed was then rounded up because the project will not affect a partial den, and rounding ensures we are not underestimating the effects of the proposed action. Therefore, after AIR surveys, 8 dens would remain undetected within the project area if work is completed within 1 year. We used the same approach to estimate numbers of dens if work occurred across two years. Given the estimate of 23 dens in the Coastal Plain from the previous section, we estimated that 9 dens would remain undetected within the project area ($23 \times (1 - 0.62) = 8.9$; rounded up equals 9) if work occurred across two years.

To determine the overall number of bears that may be affected by SAE's project during the denning season, we multiplied the number of undetected dens by the number of bears per den. This portion of the assessment addresses effects during winter, after the cubs have been born. Rode et al. (2014) found that female polar bears have an average of 1.8 cubs per litter. Therefore, the total number of bears that may be disturbed is 23 if work is completed in 1 year or 26 if work occurs in 2 years ((8+(8×1.8)=22.4 or 9+(9×1.8)=25.2, rounded up).

Exposure to winter operations

This section describes the nature of possible encounters between denning polar bears and the SAE project, and it estimates the likelihood of exposure.

Den Collapse—SAE's seismic operations will consist of tracked or rubber-tired vehicles driving along transect lines. The snowpack beneath these vehicles will be compacted by the weight of the vehicle. Although the vehicles are designed to reduce the ground impact, polar bear dens are not designed to withstand additional weight. Therefore, we assumed that den collapse is probable if driven over by a vehicle.

We estimated the likelihood of this occurrence by estimating the proportion of the ground lying beneath the transect lines. The seismic layout was described in SAE's petition as 28 parallel receiver lines, each 29.1-km (18.1-mi) long, spaced 201 m (660 ft) apart. The source vehicles would travel along approximately 147 shorter transects, each 0.8-km (0.5-mi) long and spaced 201 m (660 ft) apart, oriented perpendicular to the receiver lines to create a grid across part of each layout.

To estimate the probability of a polar bear den being run over by a vehicle, we took a modelling approach. We began by importing a shapefile of the SAE project area into program R (statistical computing program). We then laid parallel east-west transects across the project area shapefile, spaced 201 m (660 ft) apart, as described in SAE's petition. Each transect was 10 ft wide to account for the size of the vehicle's physical footprint. On top of each 29^{th} east-west transect, we then overlaid parallel north-south transects, spanning across five of the east-west transects. The area under the transects was calculated from these dimensions as 2.8 km^2 (1.1 mi^2) within a layout of approximately 164.2 km^2 (63.3 mi^2). Extrapolating to the size of the project area provides an estimate of ground impact of 116 km^2 (44.8 mi^2) or 1.72 percent of the project area.

Based on our assumption that eight dens would not be detected prior to seismic activities if work is completed in 1 year, we simulated eight randomly distributed dens across the project area. We did this 1,000 times and determined the number of iterations when ≥ 1 den overlapped with the seismic vehicle footprints. Vehicle transects intercepted one or more simulated dens in 137 of 1,000 iterations, resulting in an estimated probability of 0.14 that at least one den will be run over during SAE's seismic activities.

Polar bears select bluffs, stream banks, and other areas with sufficient terrain to collect drifting snow (Durner et al. 2006). Seismic vehicles will select routes along transects that minimize terrain. Drifting snow can also smooth rough terrain features and facilitate vehicle travel. Based on a preliminary analysis, the assumption that dens are located randomly with respect to the vehicle routes will likely result in underestimation of the probability that dens are run over. However, we cannot correct for this bias in our estimate due to the uncertainty in SAE's project description and the uncertainty of polar bear den distribution within the Coastal Plain.

Conversely, these calculations address the footprint of vehicles during a single-pass seismic survey only and do not account for travel between transect lines or to and from the layout area. These calculations do not evaluate effects of pre-survey scouting and ice checking, transportation of personnel, equipment and supplies, transportation to, from, and between camps, airstrips, water sources, and staging areas, or any other travel. They also do not account for increased effects during a second year of work. The total amount of necessary travel to accomplish the surveys is unknown. These factors result in underestimation of the probability that dens might be run over.

Other Stressors—The remaining denning polar bears are those that are not detected during AIR and avoided and are not within the physical footprint of the activities. It may be possible to detect these dens during visual observation by ground crews, but snow cover makes visual den detection difficult and unlikely, particularly prior to den emergence. Undetected denning bears may be exposed to the sights, sounds, smells, and vibrations of the seismic operations. Snow cover attenuates sound and vibration, reducing the intensity of exposure. Blix and Lentfer (1992) suggested that sound produced by seismic operations would generally be undetectable from within a closed den beyond 100 m from the activities. Information on the denning ecology of polar bears collected since this study indicates that hibernation in denning female polar bears is not continuous. Females periodically move about the den. They may reopen the den several times, particularly in spring during the den emergence period (Aars 2013).

We compiled information on known occurrences of den disturbance in order to assess the likelihood of exposure to SAE's winter activities. Information was available from 32 dens from published literature (Smith 2007, Amstrup 1993, Belikov 1974), reports from polar bear biologists, and observations reported by North Slope Industry operations on file with the Service MMM. Records spanned 1974–2018. The type of disturbance, the timing of the disturbance event, the observed response of the polar bears, and distance of the disturbance to the den were recorded. Den disturbances in autumn were excluded from the dataset; those effects are assessed in the forthcoming section titled *Take during Spring and Fall*.

The records described disturbances of polar bears denning at a variety of distances from a source of disturbance. Of four records involving seismic operations, one record described a disturbance caused by seismic activities 1 km (0.6 mi) from the den. The dataset also included disturbances caused by polar bear research and other types of oil and gas activities. Although the underlying motivation for the activities differed, many of the proximal causes of disturbance were similar. For instance, disturbances from vehicles were associated with both industry and research. We considered activities within 1.6 km (1 mi) of a den to be capable of disturbing polar bears.

Durner et al. (2006) describes the distribution of denning bears across the Coastal Plain. They mapped areas where snowdrifts of sufficient depth for a den could occur. Such habitats were distributed uniformly and comprised 0.29 percent of the coastal plain between the Canning River and the Canadian border. SAE's seismic transects will be spaced approximately 201 m (660 ft) apart and will cover the entire project area. All dens not detected by AIR or collapsed by vehicles are likely to be within 101 m (330 ft) or less of a seismic transect. Thus, no denning bears will be isolated from SAE's activities, and all dens that are not detected by AIR surveys and mitigated with buffers will be exposed to SAE's activities. Therefore a total of 8 adults and 15 cubs will be exposed to SAE's winter seismic work if activities are completed in one year (8×1.8=14.4 rounded up to 15), and 9 adults and 17 cubs will be exposed if activities occur over two years (9×1.8=16.2 rounded up to 17).

RESPONSES

This section estimates the responses of denning polar bears to sources of disturbance associated with SAE's project to calculate the number of potential takes. The responses of females and cubs to SAE's activities will depend on the timing and circumstances of the encounter, as well as the tolerance of the individual bears. Denning bears that are not detected during AIR surveys may exhibit responses varying from Level A lethal take, Level A injurious take, Level B take.

Examples of possible Level A lethal take include physically running over dens (see above section) as well as disturbances that cause a female to abandon cubs resulting in the death of the cubs. Examples of Level A injurious take include disturbances that result in early departure from the den site by the female and cubs, which has negative consequences to cub survival and recruitment (Rode et al 2018). Level B take may occur if, for example, females respond to disturbance by showing a stress response, such as increased vigilance, which causes cubs to cease nursing or resting, increased activity in the den, or exiting the den temporarily. See also "Level B Harassment" in *Characterizing Take.*

Den Collapse—The scenario with the most severe consequence is a den collapse caused by a vehicle. Den collapse would almost certainly injure, if not kill, the cubs and female. The female would also likely be injured or killed if she did not flee the den prior to it being run over, and therefore we assumed that all den occupants would constitute Level A take in the event that a den is physically run over during SAE's activities. The likelihood that a single den will lie beneath the seismic vehicle tracks was estimated above to be 0.14. To evaluate whether this 14% probability is sufficient for a den collapse to be considered likely, we took a risk assessment approach (e.g. Burgman 2005, EPA 1999). This approach allows interpretation of probability with consideration of consequences. In this framework, a low probability event with severe consequences can constitute a high level of risk. Given that the consequence of a den collapse is death of a mother and cubs, we considered this to be a high risk of Level A take of one den, or up to 3 polar bears (1 female plus 1.8 cubs, rounded up to 3).

Predicting behavioral responses in the Coastal Plain—In previous analyses of impacts of oil and gas activities on polar bears (see 81 FR 52276, August 5, 2016), we have relied heavily on information provided by Industry observers to draw conclusions about behavioral responses to industry activities. In most situations, the behaviors of polar bears near Industry activities on the North Slope would be expected to be the same as the reactions of bears to similar activities in the Coastal Plain. In both areas, denning bears and females with small cubs are likely to be the demographic group most sensitive to disturbance. However, a fundamental difference exists between denning bears in the Coastal Plain and those that den on the North Slope. Denning bears on the North Slope are often bears that chose to den in areas where the sights, sounds and smells of human Industry were present when the female selected the den site. Reactions of denning bears to human disturbances on the North Slope may differ from responses of denning bears in the Coastal Plain, as the Coastal Plain is currently absent of Industrial activity.

In our analysis, we considered the full database of Industry reports that we have previously used to evaluate responses of bears to disturbances, but given the current lack of Industrial activity in the Coastal Plain, we also evaluated all available data reflecting conditions more similar to those currently experienced in the Coastal Plain. We evaluated whether den disturbances near pre-existing or recurring Industry activities had different outcomes than den disturbances away from Industry activities. To do this, we re-evaluated all available reports of den encounters, including those from Industry, to consider whether the encounters took place near established facilities or recurring Industry activities. Den locations were considered near a facility if they occurred within 5 km (3.1 mi). In total, of 32 documented den disturbances, 29 were reported for which we could determine the proximity to Industry. Of these, 20 were near industry (see Table 1), likely owing to the increased detection probability. The responses of bears at these locations ranged from den abandonment to no noted response. Den disturbances near Industry were less likely to result in abandonment than those away from Industry. Therefore, the subset of den disturbances informed the likelihood of outcomes.

Table 1. Response and outcome of denning polar bears to winter and spring den disturbances. Percentages represent the proportion within each the column.

Outcome	Near industry	Away from industry	Unknown vicinity to Industry	Total with Known Outcomes	Total
Den abandonment and loss of cubs	1 (5%)	4 (44%)	0	5 (20%)	5 (16%)
Possible den abandonment	10 (50%)	4 (44%)	2 (67%)	16 (64%)	16 (50%)
No abandonment indicated	3 (15%)	1 (11%)	0	4 (16%)	4 (13%)
Unknown if abandoned early	6 (30%)	0	1 (33%)		7 (22%)
Total	20	9	3	25	32

Den Abandonment—Among 32 total den disturbances (25 with known outcomes), there were five instances for which there was reason to conclude that human disturbances caused den abandonment. Den abandonment results when a female polar bear abandons the den after the cubs are born and before they are able to survive outside of the den. Den disturbances resulting in abandonment were documented at distances as far as 400 m (0.25 miles) from the source. Four of the five cases occurred away from Industry areas.

In one case, the female departed the den only hours after the first emergence of the cubs; on average, females stay 8 days after emergence (Smith 2007). In another instance, a polar bear abandoned the den without her cubs 8 days after being immobilized and collared (Belikov 1976). Another collared bear was found far from her den with no cubs in February, which is too early for most cubs to survive. Investigation of her den yielded evidence of vehicle traffic within 250 m (820 ft) of the den site and a well-traveled vehicle path at a distance of 450–500 m (0.28–0.31 mi) from the den site

(Amstrup 1993). In the fourth instance, seismic workers in a remote area investigated and confirmed a possible den site while others on the project saw a female dragging a dead cub. In the fifth instance, the female was seen without cubs after a local hunter had travelled by snow machine near the den site and later reported seeing a bear running from the den location (Amstrup 1993). In total, den abandonment and possible cub mortality occurred in 16 percent (5 of 32) of all den disturbance reports from Industry (regardless of location) and in 44 percent (4 of 9) of den disturbances occurring away from Industry.

Assuming that the data for den disturbances away from Industry is most reflective of behavioral responses in the Coastal Plain, we expect 44 percent of den encounters during SAE's winter seismic work will result in den abandonment.

Early Den Departure—Disturbances to denning polar bears may result in early departure of the mother from the den with her cubs. Early departure is likely to reduce cub survival. Rode et al. (2018) found that adequate time in a den is necessary to optimize cub development for withstanding harsh Arctic spring conditions and to synchronize emergence with peak prey availability. The mean date of initial emergence from dens was March 1, and females observed with cubs at 100 days post denning had remained in dens on average 15.0 ± 7.6 (SE) days longer and emerged later than females without cubs.

Most documented encounters with denning polar bears occur in the spring after the female has opened the den but before she departs for the sea ice. This is likely because the bears are more visible and easier to detect at this time. Many den disturbances occurring earlier than this are likely to go undocumented. There have been many documented instances of females leaving a den site within a week following disturbance. Belikov 1974 states that, “The females disturbed by man do not necessarily abandon their dens immediately, but may do so 1 to 3 days later. Occasionally after disturbance, they remain in the den up to 8 days and, in exceptional cases, for a longer period.”

The rate at which females abandon dens early cannot be precisely estimated, as in most cases the duration of the bears’ stay in the den is unknown, and there is no way to determine if emergence is earlier than the bear intended. Without knowing the female’s intended departure date, we cannot estimate the likelihood that den departure was eminent and cannot remove those instances from evaluation of possible take associated with reduced cub survival due to early departure.

To estimate the number of early den departures, we examined the den disturbance dataset described previously. Disturbances in winter or spring were evaluated to determine if there was evidence of early departure from the den site. Possible early departures included departures within 8 days of disturbance, departures occurring earlier than mid-March, and cases in which the activities were reported to have caused the family group to leave the den site.

In total, early den departure and associated decreased cub survival occurred in 64 percent (16 of 25) of all den disturbance reports with known outcomes; 7 of the 32 cases had no information about the outcome. Of den disturbances occurring away from Industry, 44 percent (4 of 9) resulted in possible early den departure. Assuming that the data for den disturbance away from Industry is most reflective of behavioral responses in the Coastal Plain, we expect 44 percent of den encounters during SAE's winter seismic work to result in early den departure.

Biological Consequences of Den Abandonment or Early Den Departure—Den abandonment is likely to occur for extremely sensitive females or very intense or repeated disturbances near a den. Den abandonment results in a high degree of stress for the female and will usually result in death of cubs, and therefore results in Level A take of both. Early den departure results in Level A injurious take to cubs, but the impacts to the adult female are less severe. For this reason, this outcome is associated with Level B take of the female and Level A take of cubs. Some females may be quite tolerant of disturbance.

Belikov (1974) described observations of a polar bear when she denned in the fall after she opened the den in the spring. Belikov reported, "Despite disturbance caused by observers, she did not abandon her refuge. She sometime came out in the snow to exercise and to clean her hair of grease and dirt, but she quickly re-entered the den when disturbed. The denning period of this bear was 183 days from 14 October 1971 to 14 April 1972." This research was conducted in Russia, and this bear was not from the SBS stock, but the case demonstrates the behavioral plasticity of polar bears.

Although some females have shown tolerance to disturbances while denning, particularly those that chose to den in areas with existing Industry activities, all such disturbances have the potential to disrupt biologically significant behaviors, especially nursing, and are therefore expected to result in Level B harassment of the female. Consequently, den abandonment and early den departure are likely to result in Level B take of adults and Level A take of cubs.

Total Take of Denning Bears

The total number of dens estimated to occur in the Coastal Plain is 20 if work is completed in 1 year or 23 if work occurs in a second year. Of those, the number that will remain undetected after accounting for AIR mitigation is 8 if work occurs in 1 year or 9 if work is done in 2 years. If one den collapses under the weight of a passing vehicle, 7 and 8 dens remain respectively. All of these will be exposed to SAE's activities. As described above, den abandonment or early den departure results in Level A take for cubs and Level B take for females. A mother and cubs may experience one, but not both, of these effects (i.e. either a mother will abandon her cubs in the den or the mother and cubs may depart the den early).

In total, den abandonment or possible den departure occurred in 84 percent (21 of 25) of all den disturbance reports with known outcomes (regardless of location) and in 88 percent (8 of 9) of den disturbances occurring away from areas of established Industry. If similar proportions of dens that remain undetected by AIR have similar outcomes in response to SAE's winter seismic work, regardless of location, an estimated 16 instances of Level A take and 7 Level B takes are expected (Table 2). If work occurs in more than one year, Level A take would rise to 18 and Level B to 8 (Table 3).

However, the data for den disturbances away from Industry is most reflective of behavioral responses in the Coastal Plain. Therefore, we expect 88 percent of den disturbances during SAE's winter seismic work to result in Level A take of cubs and

Level B take of adults. If SAE's winter activities occur during 1 year, an estimated 4 dens will experience lethal take of cubs due to abandonment, and 4 dens will experience injurious take due to early departure of the family group (each group (7×0.44=3.08); rounded up to 4). If work occurs in two years, eight dens would likewise be abandoned or the mother and cubs will depart early (8×0.88=7.04; rounded up to 8). Each den will contain 1 female and 1.8 cubs. Therefore, if work occurs during either 1 or 2 years, an estimated 8 females will experience Level B take and an estimated 19 cubs will experience Level A take (Table 4 and Table 5).

Table 2. Total number of Level A and Level B takes of denning polar bears that would occur from SAE winter seismic work if work were completed in 1 year. This table uses the proportions of all known outcomes presented in Table 1.

CAUSE	No. of Dens Exposed	Probability of Response	Dens Taken	Dens Taken, Rounded up	No. of Bears		Calculation	Bears Taken, Rounded up	LEVEL
Den collapse			0.14[a]	**1**	Females	1	1 x 1.0 = 1.0	**1**	A - Lethal
					Cubs	1.8	1 x 1.8 = 1.8	**2**	A - Lethal
Den Abandon	7 x	0.20 =	1.40	**2**	Females	1	2 x 1 = 2.0	**2**	B
					Cubs	1.8	2 x 1.8 = 3.6	**4**	A - Lethal
Early Departure	7 x	0.64 =	4.48	**5**	Females	1	5 x 1 = 5	**5**	B
					Cubs	1.8	5 x 1.8 = 9	**9**	A - Injurious
Total take of undetected dens due to disturbance					**Level A = 16** (7 Lethal, 9 Injurious) **Level B = 7**				

[a]This proportion comes from the "Exposure to Winter Operations - Den Collapse" Section.

Table 3. Total number of Level A and Level B takes of denning polar bears that would occur from SAE winter seismic work if work were completed in 2 years. This table uses the proportions of all known outcomes presented in Table 1.

CAUSE	No. of Dens Exposed	Probability of Response	Dens Taken	Dens Taken, Rounded up	No. of Bears		Calculation	Bears Taken, Rounded up	LEVEL
Den collapse			0.14[a]	**1**	Females	1	1 x 1.0 = 1.0	**1**	A - Lethal
					Cubs	1.8	1 x 1.8 = 1.8	**2**	A - Lethal
Den Abandon	8 x	0.20 =	1.6	**2**	Females	1	2 x 1 = 2.0	**2**	B
					Cubs	1.8	2 x 1.8 = 3.6	**4**	A - Lethal
Early Departure	8 x	0.64 =	5.12	**6**	Females	1	6 x 1 = 6.0	**6**	B
					Cubs	1.8	6 x 1.8 = 10.8	**11**	A - Injurious
Total take of undetected dens due to disturbance					**Level A = 18** (7 Lethal, 11 Injurious) **Level B = 8**				

[a]This proportion comes from the "Exposure to Winter Operations - Den Collapse" Section.

Table 4. Total number of Level A and Level B takes of denning polar bears that would occur during SAE's winter seismic work if completed in 1 year. This table uses the proportions presented in Table 1 of polar bears denning away from industry.

CAUSE	No. of Dens Exposed		Probability of Response		Dens Taken	Dens Taken, Rounded up	No. of Bears		Calculation	Bears Taken, Rounded up	LEVEL
Den collapse					0.14[a]	**1**	Females	1	1 x 1.0 = 1.0	**1**	A – Lethal
							Cubs	1.8	1 x 1.8 = 1.8	**2**	A - Lethal
Den Abandon	7	x	0.44	=	3.08	**4**	Females	1	4 x 1 = 4.0	**4**	B
							Cubs	1.8	4 x 1.8 = 7.2	**8**	A - Lethal
Early Departure	7	x	0.44	=	3.08	**4**	Females	1	4 x 1 = 4	**4**	B
							Cubs	1.8	4 x 1.8 = 7.2	**8**	A - Injurious

Total take of denning polar bears due to disturbance — **Level A = 19** (11 Lethal, 8 Injurious) **Level B = 8**

[a]This proportion comes from the "Exposure to Winter Operations - Den Collapse" Section of the ITR.

Table 5. Total number of Level A and Level B takes of denning polar bears that would occur during SAE's winter seismic work if completed in 2 years. This table uses the proportions presented in Table 1 of polar bears denning away from industry.

CAUSE	No. of Dens Exposed		Probability of Response		Dens Taken	Dens Taken, Rounded up	No. of Bears		Calculation	Bears Taken, Rounded up	LEVEL
Den collapse					0.14[a]	**1**	Females	1	1 x 1.0 = 1.0	**1**	A – Lethal
							Cubs	1.8	1 x 1.8 = 1.8	**2**	A - Lethal
Den Abandon	8	x	0.44	=	3.52	**4**	Females	1	4 x 1 = 4.0	**4**	B
							Cubs	1.8	4 x 1.8 = 7.2	**8**	A - Lethal
Early Depart	8	x	0.44	=	3.52	**4**	Females	1	4 x 1.0 = 4	**4**	B
							Cubs	1.8	4 x 1.8 = 7.2	**8**	A - Injurious

Total take of denning polar bears due to disturbance — **Level A = 19** (11 Lethal, 8 Injurious) **Level B = 8**

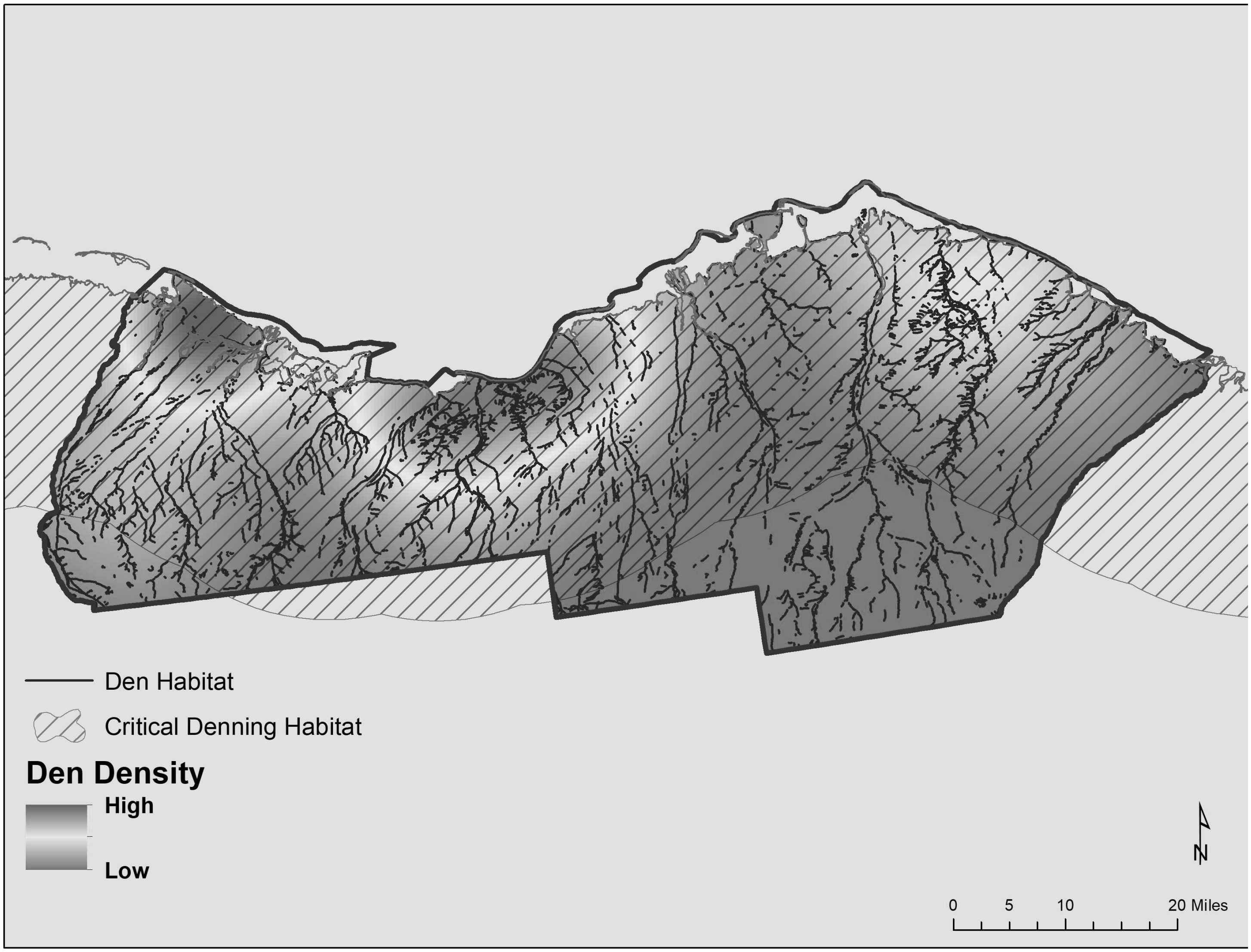
[a]This proportion comes from the “Exposure to Winter Operations - Den Collapse” Section of the ITR.

CRITICAL ASSUMPTIONS

There are a number of other assumptions the Service made regarding the analysis of take of denning bears. First, the estimate of the number of dens in the Coastal Plain is not based on an estimate from a designed study, but rather derived from multiple parameters estimated in multiple analyses. Each estimate has an associated margin of error, which contributes to uncertainty.

Second, the estimate of effects to dens that are not detected by AIR assumes an average detection rate of 62 percent. It is possible, given the amount and complexity of habitat in the Coastal Plain compared to that elsewhere on the North Slope, that AIR surveys will be unable to fly 100 percent of the denning habitat identified in Durner et al. (2006) or achieve a 62 percent rate of detection. AIR detection rates are likely to be lower in areas with more terrain. The Coastal Plain has more cut stream banks and river channels than does the North Slope Industrial area where Amstrup's (2004) work was done. Amstrup et al. (2004) estimated this rate of den detection based on a helicopter AIR survey of known den sites. The dens in the Coastal Plain will be in unknown locations and surveys will likely be conducted from a fixed-wing platform. It is therefore possible that the probability of detecting a den with a single AIR survey will be less than 0.62. However, AIR imaging technology has improved since Amstrup's (2004) work, likely increasing the effectiveness of den detection when using modern AIR technology. Combined, these factors suggest that the estimated number of dens that will remain undetected by AIR in this analysis may be biased high or low, and the degree of bias is unknown.

Third, our evaluation of den disturbance outcomes differed from previous assessments because we did not categorize the outcomes of den disturbances based on indications that the female successfully departed with cubs. Instead, we considered whether the departure occurred within a few days of a disturbance or earlier than expected. This evaluation was based on new information about cub survival in relation to the length of the denning period (Rode et al. 2018). We recognize that this approach may result in overestimation of effects due to the assumption that all such departures were a result of disturbance, rather than a coincidental alignment of timing of departure with the timing of a disturbance event. We based our assessment on the best available data on den disturbance outcomes, for which there was no way to determine what proportion of departures were coincidental. Therefore, this analysis used assumptions that err on the side of not underestimating Level A take of cubs.


Den Habitat
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Habitat Characteristics of Polar Bear Terrestrial Maternal Den Sites in Northern Alaska

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ABSTRACT. Polar bears (*Ursus maritimus*) give birth to and nurture their young in dens of ice and snow. During 1999–2001, we measured the structure of 22 dens on the coastal plain of northern Alaska after polar bear families had evacuated their dens in the spring. During the summers of 2001 and 2002, we revisited the sites of 42 maternal and autumn exploratory dens and recorded characteristics of the under-snow habitat. The structure of polar bear snow dens was highly variable. Most were simple chambers with a single entrance/egress tunnel. Others had multiple chambers and additional tunnels. Thickness of snow above and below dens was highly variable, but most dens were overlain by less than 1 m of snow. Dens were located on, or associated with, pronounced landscape features (primarily coastal and river banks, but also a lake shore and an abandoned oil field gravel pad) that are readily distinguished from the surrounding terrain in summer and catch snow in early winter. Although easily identified, den landforms in northern Alaska were more subtle than den habitats in many other parts of the Arctic. The structure of polar bear dens in Alaska was strikingly similar to that of dens elsewhere and has remained largely unchanged in northern Alaska for more than 25 years. Knowledge of den structure and site characteristics will allow resource managers to identify habitats with the greatest probability of holding dens. This information may assist resource managers in preventing negative impacts of mineral exploration and extraction on polar bears.

Key words: Arctic National Wildlife Refuge, den habitat, maternal den, National Petroleum Reserve – Alaska, polar bear, *Ursus maritimus*, Prudhoe Bay

RÉSUMÉ. Les ourses polaires (*Ursus maritimus*) donnent naissance et nourrissent leurs petits dans des tanières de glace et de neige. De 1999 à 2001, on a mesuré la structure de 22 tanières situées sur la plaine côtière de l'Alaska septentrional après que les familles d'ours polaires eurent évacué leurs tanières au printemps. Au cours des étés de 2001 et de 2002, on s'est à nouveau rendus sur les sites de 42 tanières de mise bas et d'exploration automnale et on a mesuré les caractéristiques de l'habitat situé au-dessous de la neige. La structure des tanières d'ourses polaires variait considérablement. La plupart étaient de simples cavités qui possédaient un tunnel servant à la fois d'entrée et de sortie. D'autres comportaient plusieurs salles et des tunnels supplémentaires. L'épaisseur de la neige au-dessus et au-dessous des tanières était très variable, mais dans la plupart des cas, la couverture de neige était inférieure à 1 m. Les tanières étaient situées sur des reliefs prononcés ou y étaient associées (surtout les rives côtières ou les berges de fleuves, mais aussi le bord d'un lac et le remblai de gravier d'un champ pétrolifère abandonné), qui se détachent nettement du paysage alentour en été et qui retiennent la neige au début de l'hiver. Même si elles étaient facilement identifiables, les formes de relief propices à l'établissement de tanières dans l'Alaska septentrional étaient plus discrètes que les habitats de tanières situés dans bien d'autres régions de l'Arctique. La structure des tanières d'ourses polaires en Alaska offrait une ressemblance frappante avec celle des tanières creusées ailleurs et elle est restée largement inchangée dans le nord de l'Alaska pendant plus de 25 ans. Les connaissances sur la structure des tanières et les caractéristiques des sites permettront aux gestionnaires de ressources de distinguer les habitats qui sont le plus susceptibles d'abriter des tanières. Cette information peut aider ces gestionnaires à prévenir les retombées négatives sur l'ours polaire de l'exploration et de l'exploitation minières.

Mots clés: Arctic National Wildlife Refuge, habitat propice aux tanières, tanière de mise bas, National Petroleum Reserve – Alaska, ours polaire, *Ursus maritimus*, Prudhoe Bay

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INTRODUCTION

Over most of their range, pregnant polar bears (*Ursus maritimus*) create dens in autumn snowdrifts. They give birth to altricial young in mid-winter and occupy the den for three to four months following parturition. Survival and development of neonates is dependent on the relative warmth and stable environment within the maternal den (Blix and Lentfer, 1979). Female polar bears are faithful to general geographic areas, rather than to specific locations, and return to the same substrate (land versus sea ice) for consecutive denning (Amstrup and Gardner, 1994). In the

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southern Beaufort Sea, the polar bear population comprises fewer than 2500 individuals with ranges extending from Barrow, Alaska (159° W) to Tuktoyaktuk, Northwest Territories (132° W), and north to approximately 74° N (Amstrup et al., 2001). Approximately half of annual maternal dens of this population occur on land or on landfast ice (Amstrup, unpubl. data; Amstrup and Gardner, 1994). Terrestrial denning appears to be increasing in the Beaufort Sea (Stirling and Andriashek, 1992; Amstrup and Gardner, 1994). Maternal denning in northern Alaska, unlike that in known den concentration areas of other regions of the polar basin (Harington, 1968), is sparsely distributed within a narrow margin of coastal habitat (Amstrup and Gardner, 1994). Most of those dens, however, occur between 147° W and the Canadian border (Amstrup and Gardner, 1994). Most polar bear terrestrial den habitat in Alaska lacks the steep relief typical of concentrated denning areas on Herald Island (Ovsyanikov, 1998), Wrangel Island (Uspenski and Kistchinski, 1972), and the islands of the Svalbard archipelago (Larsen, 1985). Alaskan den sites do not show an association with tall vegetation, which is characteristic of den sites in Hudson Bay (Clark et al., 1997). Snow accumulation sufficient for denning in northern Alaska results from drift caused by predominantly east or west winds and occurs mainly along coastal or river banks and bluffs (Benson, 1982; Durner et al., 2001). As in other areas, the distribution of snow determines the distribution of dens (Belikov, 1980; Lentfer and Hensel, 1980; Hansson and Thomassen, 1983). The relative scale of banks on the coastal plain of northern Alaska is generally subtle; however, suitable den habitat is detectable during the snow-free season and may be identified on high-resolution aerial photography (Durner et al., 2001). This identification requires knowledge of the minimum requirements for snow den structures and the underlying landforms necessary to support those conditions. These landforms are broadly dispersed, but not uniformly distributed, across northern Alaska (Durner et al., 2001:119).

In Alaska, petroleum activities currently span approximately 200 km of the Beaufort Sea coast, and proposed developments would more than double the area. Oil lease sales have recently begun west of Prudhoe Bay in the National Petroleum Reserve – Alaska (NPRA). The "1002" area of the Arctic National Wildlife Refuge (ANWR), considered potentially the most important field of recoverable oil and gas in the United States, may contain over nine billion barrels of oil (Clough et al., 1987). This area is also home to 34% of the polar bears that den on land in Alaska (Amstrup, 1993; Amstrup and Gardner, 1994; Amstrup, unpubl. data).

The annual recruitment from dens on the ANWR is a significant contribution to the population of polar bears in the southern Beaufort Sea (Amstrup, 1993). The 1987 Legislative Environmental Impact Statement to the United States Congress on oil development in the 1002 area hypothesized that "pipelines and roadways may prevent female polar bears from moving to and from inland denning areas," that "exploration, construction, and production in the immediate vicinity of polar bear dens could cause the bears to abandon dens," and that "production activities could create disturbances that would likely keep bears from returning to those preferred denning areas" (Clough et al., 1987:129). In addition, Clough et al. (1987:130) state: "Some adverse effects on polar bears could be reduced by documenting den locations and use areas so that oil-development activities avoid them to the maximum extent possible. Avoidance of suitable denning habitat is most important." They also state that "conflicts with bears...could be minimized by limiting construction activities during the denning period," and that "such data [relevant to movements and behavior] would be invaluable in learning how to predict and minimize adverse effects of industrial activities on polar bears" (Clough et al., 1987:130).

In previous papers, we have discussed polar bear movements, distribution, and the timing and location of polar bear dens (Amstrup, 1993; Amstrup and Gardner, 1994; Amstrup et al., 2000; Durner et al., 2001). Here we discuss the broader issue of den use areas (Clough et al., 1987), in further efforts to assure that our knowledge base can help protect polar bears in perpetuity.

The potential for direct and indirect interactions between polar bears and humans can only increase with greater numbers of people and more area under development. While production from established facilities continues throughout the year, most petroleum exploratory and construction activities occur during winter. This timing minimizes impacts on most Arctic habitats and wildlife, but increases the potential for disturbance of polar bear maternal dens. Direct consequences of disturbing maternal dens may include den abandonment and mortality of young. Durner et al. (2001) began to classify, describe, and map suitable denning habitats on Alaska's northern coast. That work, however, was based on examination of relatively few dens that had been occupied mainly during the 1980s (See shaded area on Fig. 1). In this study, we used a larger number of recently discovered dens to refine our previous knowledge of habitat characteristics at den sites (Durner et al., 2001) and describe more thoroughly the structure of polar bear snow dens in northern Alaska (Lentfer and Hensel, 1980).

METHODS

Locating Dens

We captured polar bears by injecting immobilizing drugs—tiletamine hydrochloride plus zolazepam hydrochloride (Telazol®, Warner-Lambert Co.)—with projectile syringes fired from helicopters (Stirling et al., 1989). Capture protocols were approved by independent animal care and welfare committees. Polar bears were captured in

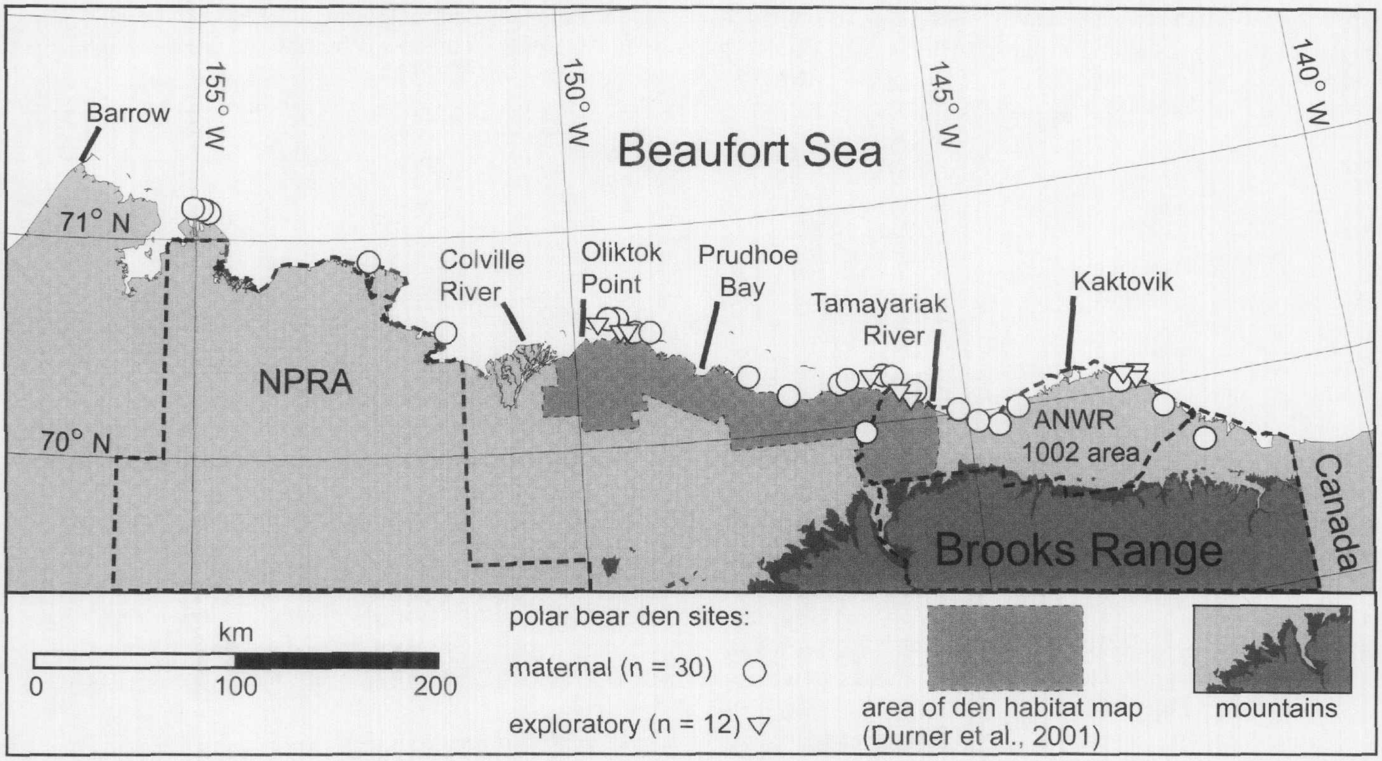

FIG. 1. Distribution of polar bear maternity dens and autumn exploratory dens examined in this study on 30 July–2 August 2001 and 13–15 July 2002. Dens were located by USGS personnel conducting field research from 1997 to 2002. Also shown are place names indicated in the text.

the Beaufort Sea and adjacent areas (Fig. 1) during March-May and October-November in 1997–2001. Satellite radio transmitters attached to neck collars, or VHF radio collars, were applied to solitary adult female polar bears (Amstrup et al., 2000).

Polar bear dens were located in three ways. We followed radio-collared pregnant females to dens by a combination of satellite and aerial radio-telemetry. We detected a few previously unknown dens while flying numerous transects over dens of radio-collared females during a survey designed to test the effectiveness of Forward-Looking Infrared sensors (FLIR Systems, Inc., Portland, Oregon) for locating maternal dens. We also obtained visual observations (incidentally, during capture and radio-tracking efforts) of a small number of dens occupied by bears that were not wearing radio-collars. Den sites were classed as either maternal dens (where a bear spent the majority of the winter and departed after the time when birth would be expected) or exploratory dens (places that a bear investigated during autumn as possible den sites but did not occupy during winter).

Den Structure

After the departure of the family in spring, we visited dens on the ground to measure and describe their structure. The location of each den was determined with a global positioning system (GPS) receiver set on averaging mode (either a military-grade PLGR, Type HNV-560C, Rockwell International, Cedar Rapids, Iowa; or civilian Garmin III Plus, Garmin International, Olathe, Kansas). Weather prevented us from visiting all dens on the ground in spring. Exact positions of those that we could not visit were determined during several aerial overpasses in GPS-equipped fixed-wing aircraft or helicopters approximately 30 m above ground level. We photographed, measured, and sketched all dens visited on the ground. We recorded tunnel height and width; length of den (including the main chamber); main chamber length, height, and width; and depth of snow over the main chamber and tunnels. We also recorded the existence of secondary chambers; the presence of stains from fur oils, urine, and feces; and evidence of digging by cubs.

Den Site Habitat

We revisited polar bear maternal den sites during the snow-free season by small, motorized boat or by flying to each site in a Bell 206 L helicopter. We landed nearby and approached each den site on foot. We focused data collection on the broad-scale habitat features that would be most useful for later remote-sensing analysis. We recorded slope of the habitat at the den site; length of the hypotenuse of the habitat feature (straight-line distance from the top to the bottom of the feature, following the slope of the feature); and slope of landscape above and below the den site. We also recorded whether the habitat feature was stable (generally vegetated and non-sloughing), active

TABLE 1. Measurements of polar bear maternal den snow structures (cm) recorded in northern Alaska during March and April in 1999–2001. Length of den includes both tunnels and chambers. Snow depth is the minimum measurement over tunnels and primary and secondary chamber ceilings.

	Number of Measurements	Mean	S.D.	Minimum	Maximum
Height of tunnel	17	49	10	36	66
Width of tunnel	19	126	56	45	290
Length of den	20	587	200	273	893
Height of chamber	19	79	13	53	103
Width of chamber	24	127	24	78	190
Length of chamber	24	148	31	110	240
Snow depth above tunnel	18	68	89	10	400
Snow depth above chamber	25	72	87	10	400

(with sloughing due to river currents or wave action), or partially stable (with incomplete sloughing). Landscape and vegetation characteristics (Jorgenson et al., 1994) above, below, and at the den site were also recorded. Height of the feature was either measured at the site or calculated as the side of a right triangle. Hypotenuse length was determined with a fiberglass measuring tape. Slope was measured with an inclinometer (Suunto Co., Finland). Aspect (averaged to cardinal points) and slope were recorded in degrees.

Throughout this paper, we frequently refer to "bank" habitat. A bank is defined as any abrupt change in topography that may catch drifting snow. Our definition includes, but is not limited to, coastal bluffs, river banks and bluffs, stream banks, and lake shores.

RESULTS

Den Structure

We examined 22 maternal dens in terrestrial habitat during late March and early April in 1999–2001. We attempted to visit all dens as soon as possible after the departure of the family group; however, weather often delayed our travel to den sites. As a result, wind-borne snow partially filled some dens and prevented us from collecting all the measurements that we intended to record. We were, however, able to obtain most measurements of important features from most dens (Table 1).

The structure of individual polar bear dens varied greatly, but the presence of a chamber where the family group spent most of the winter was common to all dens (Fig. 2). Four dens had secondary chambers apparently used near the end of the denning period. The primary and secondary chambers were oval, with average internal dimensions of 79 cm height, 148 cm length, and 127 cm width (Table 1). Primary chambers were distinguished from secondary chambers by the presence of ice in the floor and ceiling and were often discolored by fur oils and urine. Primary chambers usually included a nest-like depression where the adult and cubs spent most of their time. Cub feces were observed in primary chambers of three dens. These characteristics were not as pronounced or were absent in secondary chambers. Occasionally, soil was exposed under the floor or at the back wall of the primary chamber. Tunnels averaged 126 cm in width by 49 cm in height. Other features varied greatly among dens. Total length of the den interior (including tunnels and main chamber) ranged between 273 and 893 cm. Six dens had more than one exit, and four showed evidence of small excavations made by cubs. Mean minimum snow depths above chamber and tunnel ceilings were 72 and 68 cm, respectively.

Den Site Habitat

We revisited 35 den sites on the coastal plain of northern Alaska between 30 July and 2 August 2001. We revisited an additional seven den sites on 13–15 July 2002. The dens occurred between 142°06′ W and 154°59′ W and were situated 0–24.7 km (mean ± S.D. = 1.7 km ± 4.5 km) from the Beaufort Sea coastline (Fig. 1). Den site elevation ranged from 0 to 108 m (mean ± S.D. = 10 m ± 24 m) above sea level. Thirty sites were maternal dens and 12 sites were exploratory dens. We located 20 dens by conventional radio tracking, 19 by opportunistic encounters during research activities, and 3 while conducting FLIR surveys. Although there is some error in GPS positioning, we are confident that we returned to the actual sites used by bears. Our confidence was reinforced by observations of polar bear fur and feces, and sometimes shallow depressions on the ground, at 19 maternal dens. Depressions appeared to have been created simply through compaction of soft tundra vegetation by direct contact with the bear's body. This evidence was apparent after two summers at two den sites on stable habitat. A shallow soil excavation and traces of fur were found at one exploratory site.

All den sites were on landscape features that were easy to distinguish from the surrounding terrain in summer. In winter, however, many of the features where dens occurred were filled with drifted snow and only marginally detectable. Most dens were located on coastal banks (n = 29), major river and floodplain banks (n = 8), and tributaries (n = 2). Two dens were on lake shores and another on the edge of an abandoned oil field gravel pad. Thirty-one den sites occurred on active banks (Fig. 3), eight on stable banks (Fig. 4), and three on partially stable banks. Bank height ranged from 1.4 to 33.0 m (mean ±

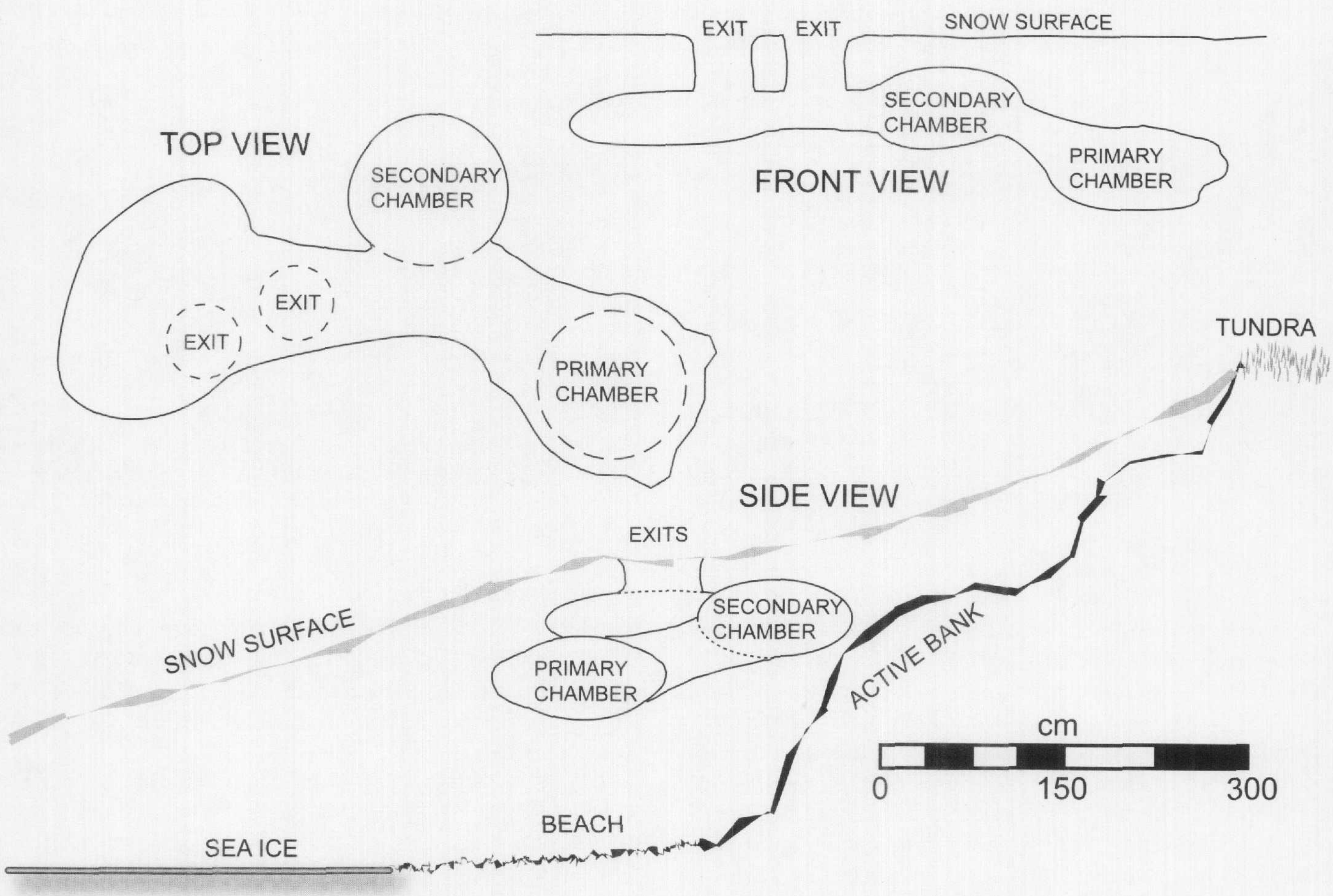

FIG. 2. Diagrams of a polar bear maternal den near Prudhoe Bay, Alaska, 10 April 2000.

S.D. = 4.4 ± 5.3 m). Bank slope ranged between 8° and 48° (mean ± S.D. = 32.2 ± 9.0°). The aspect of dens was determined largely by the east-to-west orientation of the coast and the south-to-north orientation of rivers. Of the 42 dens, 5 dens faced east, 7 west, 13 north, and 17 south. All sites had minimal topographic relief above (range: 0–8°, mean ± S.D. = 1.6° ± 1.5°) and below (range: 0–8°, mean ± S.D. = 1.5° ± 2.3°) the slope where the den was located.

Habitat above the slope adjacent to the den was generally upland tundra composed of moist sedge (*Carex* sp.)–willow (*Salix* sp.), *Dryas* sp.–sedge–willow, or a similar complex of low forbs, grasses, and prostrate willows (Jorgenson et al., 1994). Vegetation on the slope (stable and semi-stable slopes only) was usually a continuation of the above-slope habitat. Habitat below the slope typically included a beach, river bar, floodplain, or body of water (lake, river, or tidewater). When present, vegetation below the slope was composed of wet sedge communities. In general, any vegetation at a den site could be characterized as low (< 0.2 m, visual estimate) tundra plant communities typical of the northern coastal plain. At one site, however, the vegetation above the slope was composed of willows and dwarf birches (*Betula* sp.) approximately 1 m in height.

DISCUSSION

Den measurements recorded in this study indicate that the structure of terrestrial dens in Alaska has not changed at least since the 1970s. Ten maternal dens inspected by Lentfer and Hensel (1980) had chambers whose mean height (78 cm), length (180 cm), and width (162 cm) were close to our mean values (Table 1). Likewise, although den habitat in northern Alaska may differ from that of other denning areas, the structure of polar bear dens in Alaska is similar to that in other locales. Larsen (1985) reported the ranges of chamber heights and widths as 70–130 cm and 110–220 cm, respectively. Polar bear dens on Wrangel Island (Uspenski and Kistchinski, 1972) had comparable chamber height (80 cm), length (165 cm), and width (140 cm) measurements. Harington (1968) recorded somewhat larger dimensions (mean values: height, 97 cm; length, 205 cm; width, 151 cm) for 14 dens in the Canadian High Arctic. Three dens (30%) measured by Lentfer and Hensel (1980) had more than one chamber. Multiple chambers have been reported from Wrangel Island (Uspenski and Kistchinski, 1972) and northern Canada (Harington, 1968). Only four (18%) of the dens we examined had secondary chambers. Exit tunnels described by Lentfer and Hensel (1980) for polar bear dens in Alaska had an

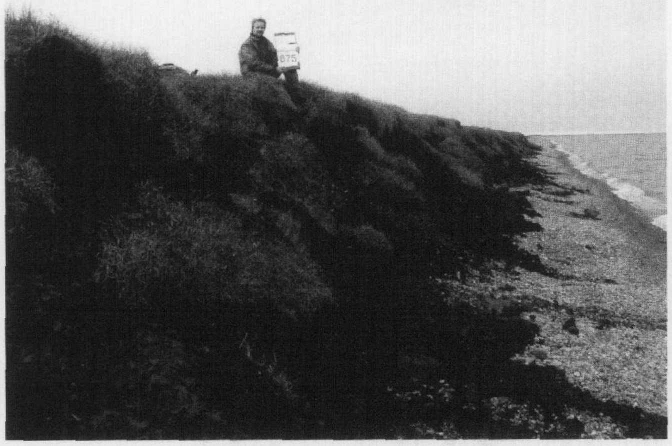

FIG. 3. Polar bear maternal den site on active coastal bank in Arctic National Wildlife Refuge, Alaska, 31 July 2001.

FIG. 4. Polar bear den site on stable lake shore near Prudhoe Bay, Alaska, 30 July 2001.

average height of 62 cm and width of 87 cm. Harington (1968) reported a tunnel height of 56 cm and width of 59 cm. Den tunnels in Svalbard ranged from 70 to 100 cm in diameter (Larsen, 1985). Polar bear dens on Wrangel Island (Uspenski and Kistchinski, 1972) had tunnel heights of 50–60 cm and widths of 70–110 cm. These dimensions differed little from the mean tunnel height and width (49 and 126 cm) that we measured at maternal dens. Our observation of digging activity by cubs (in four dens) is also consistent with other reports (Harington, 1968; Lentfer and Hensel, 1980; Hansson and Thomassen, 1983).

The presence of "ventilation holes" in polar bear dens has been observed in several regions of the Arctic (Harington, 1968; Uspenski and Kistchinski, 1972; Lentfer and Hensel, 1980). During FLIR surveys in January and November 2001, we noted small openings in the roofs of five dens. These openings could have served a ventilation function and were of a size that a female bear could have created by using her paws to scrape a hole in the ceiling of the den. The openings also could have resulted from accidental collapse of the roof due to digging by bears to enlarge the den. The holes observed over two dens seen in January were not there when the dens were first discovered. They remained open for a few days, and then apparently drifted closed. These openings appear similar to those described in two maternal dens by Lentfer and Hensel (1980). Bears may occasionally create small temporary openings in their dens, perhaps for thermoregulation and air transport (Lentfer and Hensel, 1980), but our observations suggest that they do not continuously maintain them. It is not clear to us what mechanism may have resulted in the long, narrow ventilation holes described by Harington (1968), and how it would be possible for bears to maintain them. Ventilation holes were not observed in polar bear maternal dens in Svalbard (Hansson and Thomassen, 1983). While small openings in the den may facilitate gas exchange and thermoregulation, the low frequency of encounters with this feature suggests that ventilation holes are usually ephemeral or nonexistent in maternal dens. Most likely, necessary gas and heat exchange is typically accomplished through the porous surrounding snow.

The depth and density of snow surrounding a maternal den determines the relative warmth that a polar bear experiences (Harington, 1968). Blix and Lentfer (1979) reported that temperature within a snow column was warmer near the underlying substrate (either land or sea ice) and approached ambient temperatures close to the snow surface. The dens that we observed to be in contact with the ground may be explained as attempts by the adult bear to seek an optimal thermal zone. The range of snow depths we report here (Table 1) is similar to those reported in other regions of the Arctic (Harington, 1968; Uspenski and Kistchinski, 1972; Hansson and Thomassen, 1983). This suggests that, while the underlying habitat may vary greatly among the regions where polar bears den, the requirements for maternal den structures are similar throughout the range of polar bears. Harington (1968) reported that extremely hard snow or very soft snow was unsuitable for denning. The numerous autumn exploratory dens we observed may be cases where a bear began digging into a snow berm, only to determine that the snow was too soft or too hard.

Polar bears in northern Alaska chose maternal den sites on bank features that can be readily distinguished from the dominant landscape during the snow-free season. At all sites examined during this study, we were impressed by the consistency of three measured variables: 1) the relative steepness of the den habitat; 2) the relative flatness of terrain above and below the slope; and 3) the change in elevation, or height, of the bank feature. All den sites in this study occurred on features that could be classified as bank habitat. Durner et al. (2001) reported that 28% of maternal dens occurred at sites other than banks or bluffs, where there was little topographic relief (i.e., "other" habitat). Those den site locations were made before 1997 and were determined by marking a point on a USGS 1:63 000 map while circling the den in a fixed-wing aircraft or helicopter. Because of the method used, locations of some dens included in the earlier study were not as accurate as locations determined by GPS in this study. Durner et al. (2001) were not able to identify and digitize "other" habitat consistently, which suggests that 28% of denning habitat (classified as "other") was omitted from their map. However, our failure in this study to locate any dens in "other" habitat, despite a larger sample size and greater location accuracy, suggests that the omission of "other" habitat by Durner et al. (2001) is not a shortcoming; instead, their depiction of maternal den habitat distribution is more accurate than the authors realized. Bears will seldom den in habitat that is not capable of catching large snowdrifts. On the other hand, the minimum values of chamber height (53 cm) and snow depth above the chamber (10 cm) in Table 1 indicate that bears are capable of creating dens adjacent to banks lower than those we report here (bank height range: 1.4 m to 33 m). Our measurements of den dimensions and those reported from Svalbard (Larsen, 1985) suggest a conservative approach to habitat delineation that includes minimally acceptable den habitat in a management plan.

Durner et al. (2001) reported ranges of 1.3 to 34 m for bank height and 15.5° to 50° for slope. Bank height and slope that we measured fell largely within those ranges. Also, Durner et al. (2001) described landscape features above and below the slope as "relatively level ground." Inclinometer measurements made during this study corroborated that result at all of the den sites we visited. This low-relief topography generally extended more than 100 m from the den location. This observation is in concordance with data from Svalbard, where most dens occurred on slopes adjacent to flat mountaintops (Larsen, 1985). Durner et al. (2001) reported that some dens occurred in microhabitat, i.e., in small gullies or polygon troughs adjacent to prominent banks. Three dens that we measured also occurred in similar features, suggesting that gullies and tundra polygon troughs may sometimes be important snow-catching agents. We did not attempt to define or measure microhabitat because it was always associated with major landscape features that we could readily identify and measure on the ground and on aerial photos.

Maternal den habitat is a requirement of polar bear life history that can be identified, and its identification should be a prerequisite of any management scenario. Petroleum activities may soon include much of the southern Beaufort Sea coast of Alaska. If this occurs, knowledge of den chronology and recognition and avoidance of den habitat will be essential to minimize industrial impacts on denning polar bears (Clough et al., 1987). This paper provides information that, when used in conjunction with den habitat mapping techniques (Durner et al., 2001), may help to achieve that objective.

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Fish and Wildlife Service
DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

50 CFR Parts 18, 228, and 402

Incidental Take of Endangered, Threatened and Other Depleted Marine Mammals

Friday, September 29, 1989

RIN 1018-AB05
AGENCIES: Fish and Wildlife Service (FWS), Interior; National Marine Fisheries Service (NMFS), NOAA, Commerce.

ACTION: Final rule.

SUMMARY: Regulations are issued to implement amendments enacted in 1986 to the Marine Mammal Protection Act of 1972 (MMPA) and Endangered Species Act of 1973 (ESA). These amendments provide a mechanism for allowing certain takings of endangered, threatened and other depleted marine mammals incidental to activities other than commercial fishing operations. Previously, the incidental taking of depleted marine mammals was not allowable under the terms of the MMPA. This rule amends existing procedures governing incidental take authorizations.
EFFECTIVE DATE: October 30, 1989.

FOR FURTHER INFORMATION CONTACT:Patricia Montanio, Protected Species Management Division, Office of Protected Resources and Habitat Programs, National Marine Fisheries Service, 1335 East-West Highway, Silver Spring, MD 20910, 301-427-2322, or Robert Peoples, Division of Fish and Wildlife Management Assistance, U.S. Fish and Wildlife Service, Department of the Interior, Mail Stop—820 Arlington Square, 18th and C Streets, NW., Washington, DC 20240, 703-358-1718.

SUPPLEMENTARY INFORMATION: Proposed regulations on the Incidental Take of Endangered, Threatened and Other Depleted Marine Mammals were published on March 15, 1988 (53 FR 8473-8477). The original May 16 close of the comment period was extended until July 5, 1988 (53 FR 17964-17965). More than 20 entities, including conservation groups, Federal, state and local government agencies, private industry and other interested parties commented on the proposed rule. These comments are summarized along with responses in the discussions below.

General Requirements and Processes
FWS and NMFS share responsibilities under the MMPA (16 U.S.C., 1361 et seq.) and ESA (16 U.S.C. 1531 et seq.). NMFS is responsible for species of the order Cetacea (whales and dolphins) and the suborder Pinnipedia (seals and sea lions) except walrus. FWS is responsible for the dugong, manatees, polar bear, sea and marine otters and walrus. Depending on the animals involved, the term "Service" used in this document may refer to FWS and/or NMFS.

Section 101(a)(5) of the MMPA allows for the taking of marine mammals incidental to non-commercial fishing activities under certain circumstances; Section 7(b)(4) of the ESA allows, under certain circumstances; for the taking of endangered and threatened species incidental to activities that have Federal involvement or control. If a marine mammal species is listed as endangered or threatened under the ESA, the requirements of both the MMPA and ESA must be met before the incidental take can be allowed.

Summary of Amendments

Prior to amendment, section 101(a)(5) of the MMPA applied only to non-depleted species. Under section 3(1)(C) of the MMPA, all endangered and threatened marine mammals are by definition depleted. Since the more restrictive provisions of the MMPA prevail, the ESA provisions alone could not be used to authorize the incidental taking of endangered or threatened marine mammals.

Public Law 99-659, title IV, section 411 (approved November 14, 1986) amended section 101(a)(5) of the MMPA and made conforming changes to sections 7(b)(4) and 7(o) of the ESA. The primary change was to allow the taking of depleted as well as non-depleted species of marine mammals incidental to specified activities (other than commercial fishing operations) under certain conditions. The amendments also changed some of the conditions under which incidental taking can be allowed.

General Comment: One commenter believed that there should not be any taking, hunting or killing of endangered, threatened or depleted species.

Under the 1986 Amendments, Congress provides an exception for the incidental, but not intentional, taking of small numbers of depleted marine mammals under limited circumstances. Although we anticipate most taking to be by harassment only, the amendment is not limited to non-lethal takings.

MMPA—Section 101(a)(5) Process

Under section 101(a)(5) of the MMPA, the Service can allow the taking of small numbers of marine mammals incidental to a specified activity (other than commercial fishing) within a specified geographical area. For the Service to consider allowing an incidental taking, a written request for specific regulations must be submitted to the Service containing detailed information on the activity as a whole and impacts of the total potential take. The Service will evaluate the impacts resulting from all persons conducting the specified activity, not just the impacts from one entity's activities. If the Service makes certain findings, specific regulations will be issued that, among other things, establish permissible methods of taking and other means of effecting the least practicable adverse impact on the species. After regulations are issued, individual Letters of Authorization must be obtained from the Service by those conducting the activity.

Procedural regulations implementing this provision of the MMPA are found at 50 CFR 18.27 for FWS and at 50 CFR part 228 for NMFS.

Processing time: In the preamble to the proposed rule, the Service advised requestors that the regulatory process for specific regulations can take a year or more. Many commenters believed this to be excessive resulting in unnecessary time and financial costs to applicants and delayed the identification and development of hydrocarbon resources. Further, two commenters believed that the lengthy review process does not account for the urgency of some situations, such as platform removals for safety or reuse purposes, or operational constraints due to weather and ice conditions in Alaska. They argued that Congress intended that the Service act expeditiously on requests.

The Service will complete the process as quickly as possible and will provide the applicant with a proposed schedule, if requested. Although regulations have been issued in as little as six months, the process generally takes longer because of the time necessary to complete the environmental and regulatory reviews and provide an opportunity for public comment on the proposed rule. Therefore, the Service believes one year is a realistic estimate. Knowing the potential time requirements, applicants can plan their activities accordingly. Since the MMPA process can be conducted simultaneously with other requirements, early initiation of the MMPA process will avoid delaying approval and implementation of specific activities. Once regulations are established governing a specific activity, Letters of ***40339** Authorization can be issued quickly and can accommodate specific urgencies.

Comment Periods: Under 50 CFR 228.4(b), NMFS publishes a notice of receipt of request for regulations and solicits information. Public comments are also accepted on the proposed findings and regulations. The FWS, on the other hand, does not require publication of a notice of receipt of request and generally solicits comments only on its proposed findings and regulations (50 CFR 18.27(d)(2)). This is the only difference between NMFS and FWS processes, which is relatively minor reflecting standard agency procedures. Some commenters opposed the initial comment period established by NMFS since it is not mandated under the MMPA or Administrative Procedure Act and could delay issuance of final regulations.

The NMFS approach is consistent with its general approach to regulations—providing the public with an advance notice of a rulemaking where possible. The NMFS believes that the first comment period facilitates gathering all available information prior to developing the required regulatory and environmental analyses and publishing a proposed rule. No minimum time for the initial comment period is established in the NMFS regulations. Therefore, in unusual or critical situations, this comment period could be less than the usual 30 days. In addition, drafting the required environmental and regulatory documents could begin during the comment period, resulting in no significant delay to the process.

Application assistance: Commenters suggested that applicants be encouraged to consult with the Service in preparing a request to identify sources of information and to ensure an adequate request.

The Service agrees, but does not believe that this needs to be stated in the regulations. The Service will assist potential applicants by explaining requirements and identifying sources of information. Potential applicants are encouraged to contact the Service and the Service's Regional Offices for assistance.

Completeness of request: One commenter believed that the Service should be required to determine the completeness of a request within 15 days. If found incomplete, the Service would notify the applicant with an explanation of what is required to make the request complete.

The Service will review requests and notify applicants as soon as practicable of any additional information required. However, information needs (such as the feasibility of implementing certain mitigating measures) may become apparent anytime during the regulatory process. Therefore, the Service reserves the option to request additional information when required, rather than just within the first 15 days.

Denial of requests: Some commenters believed that the regulations should require that denials of requests for specific regulations along with the findings in support of that decision be published and made available to the applicant.

The Service agrees and has added new §§18.27(d)(4) and 228.4(d) requiring publication in the Federal Register of any decision to deny a request along with the basis for denying the request.

Required information: One commenter believed that the information required in § 18.27(d) (vi), (vii) and (viii) and § 228.4(a) (9), (10) and (11) dealing with suggested means of mitigating and monitoring impacts should be optional, since these discussions would be more productive after the applicant has an opportunity to consult with the Service and subsistence users.

The Service believes the applicant should be required to identify mitigating measures and ways to monitor impacts to assist the Service in developing the most workable regulations. The applicant's detailed knowledge of the proposed activity provides a good basis for such initial proposals. Including these suggestions for comment and further discussion as the process continues will serve to enhance and facilitate the process of developing regulations. Therefore, the Service has retained these questions.

Total impacts: One commenter believed that the current reference to "cumulative" impacts in the information required under §§ 18.27(d) and 228.4 should be deleted.

As used in these sections, cumulative impacts was intended to mean the total impacts resulting from the activity as a whole, not just the impacts resulting from one individual's or company's participation. It was not intended to mean the impacts resulting from the activity in conjunction with unrelated ongoing or projected activities (as the term is used under NEPA). Therefore, the word cumulative has been deleted and the sentence clarified to request information on the "activity as a whole, which includes, but is not limited to, an assessment of total impacts by all persons conducting the activity." (See also "Cumulative Impacts" discussion below.)

Burden of proof: In the preamble to the proposed rule, the Service stated that the applicant has the burden to demonstrate, through the best scientific information available, that only a negligible impact is reasonably likely to occur. Commenters suggested that only the best presently available, readily obtainable information should be required in requests, and that applicants should not be required to conduct research if information gaps exist. Commenters also objected to the applicant having the burden to demonstrate negligible impact, and believed it is the responsibility of the Service.

In response to the commenters' concerns, the Service notes that its "best available scientific evidence" standard used to determine the completeness of a request in the MMPA regulations is similar to the "best available scientific and commercial data" standard that is used in the Section 7 (ESA) consultation regulations. Therefore, the Service intends to use the principles described in the following excerpt from the preamble to the consultation regulations when additional data is needed to complete a request for specific regulations under this final rule:

A Service request for additonal data will not be used as a vehicle for burdening applicants with unnecessary studies and inordinate delays * * *. As in the Pittston case [Roosevelt Campobello International Park Commission v. EPA, 684 F.2d 1041 (1st Cir. 1982)], these requirements will be limited to readily obtainable data that would assist the Service in formulating its biological opinion [under Section 7(b) of the ESA] * * *. [A]s in Pittston, a distinction must be made between requests for special research projects and requests for routine, customary data collection activities.

51 FR 19926, 19952 (June 3, 1986).

Only the best available information needs to be submitted with a request, and conducting research is not a requirement. The Service believes it is the responsibility of the applicant to provide the required information and to demonstrate negligible impact since the applicant is requesting authority to take the marine mammals and is the beneficiary of such authority. The Service will also consider information submitted by other interested parties or otherwise available. If the information submitted by the applicant together with any other information available to the Service is not sufficient to support a negligible impact finding, regulations cannot be issued. In this case, additional studies may be needed to support a negligible impact finding.

It should also be noted that Congress placed a continuing burden on those operating under the authority of Section 101(a)(5) to "engage in appropriate ***40340** research designed to reduce the incidental taking of marine mammals pursuant to the specified activity concerned." H.R. Rep. No. 228, 97th Cong., 1st Sess. 20 (1981).

Placing the burden on the applicant to demonstrate negligible impact is consistent with other take authorizations under the MMPA. Under Section 104(d)(3), permit applicants "must demonstrate to the Secretary that the taking * * * will be consistent with the purposes of this Act and the applicable regulations established under section 103 of this title." In the 1971 House Report, Congress explained this basic concept:

Before any marine mammal may be taken, the appropriate Secretary must first establish general limitations on the taking, and must issue a permit which would allow that taking. In every case, the burden is placed upon those seeking permits to show that the taking should be allowed and will not work to the disadvantage of the species or stock of animals involved. If that burden is not carried—and it is by no means a light burden—the permit may not be issued. The effect of this set of requirements is to insist that the management of the animal populations be carried out with the interests of the animals as the prime consideration.

H.R. Rep. No. 707, 92d Cong., 1st Sess. 18 (1971).
U.S. Citizen: As stated in the preamble to the proposed rule, under section 101(a)(5) of the MMPA only U.S. citizens are eligible to apply for Letters of Authorization. Commenters believed that the definition of U.S. citizens in the regulations is unduly restrictive since it requires that companies or corporations be controlled by U.S. citizens. Commenters pointed out that this is inconsistent with regulatory practice under the Outer Continental Shelf Lands Act (OCSLA) which requires only that the company be organized under the laws of the United States to be considered a U.S. citizen. Commenters believed that Congress intended that all holders of offshore leases be eligible for a small take authorization under the MMPA, and, therefore, the MMPA regulatory definition should be made consistent with the OCSLA definition.

The Service agrees that a change in the definition may be appropriate. However, since this change was not discussed in the proposed rule and is a potentially significant modification, the Service is addressing this issue in a separate proposed rulemaking to avoid delay in publication of this final rule. That proposed rule was published in the Federal Register on August 17, 1989 (54 FR 33949).

Impact on Species or Stock
Before the Service may allow a taking of marine mammals under the authority of section 101(a)(5) of the MMPA, it must find that the total taking expected from the specified activity will have a negligible impact on the species or stock. After a thorough review of the public comments on this issue, the Service adopts its proposed definition of “negligible impact.”

Under the Service's regulatory definition, a finding of negligible impact would require that the impact resulting from the specified activity cannot reasonably be expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival. The Service believes that this definition of negligible impact follows congressional intent when enacting Public Law 99-659.

Effects on annual rates of recruitment or survival: Several commenters contended that the proposed definition of negligible impact was too lenient because it suggested that only effects on annual rates of recruitment or survival will be considered. The commenters urged the Service to add back to the definition the standards used to determine negligible impact under the 1981 MMPA Amendments—that the impact from the taking had to be “so small, unimportant, or of so little consequence as to warrant little or no attention.” 50 CFR 228.3 (1987) (NMFS regulations); accord, id. § 18.27(c) (FWS regulations).

The Service, while sympathetic with the concerns expressed by the commenters, believes that the clear congressional intent behind the 1986 Amendments was to alter the standard for determining negligible impact. In addition, the basic amendment to section 101(a)(5) of the MMPA expanded the coverage of this incidental take provision to depleted as well as non-depleted species, requiring a corresponding change in the approach to assessing negligible impact. To capture the intent of the amendment, the Service has adopted, substantially without change, the definition of negligible impact set out in the Senate's “Section-by-Section Analysis,” 132 Cong. Rec. S16305 (Oct. 15, 1986).

Species specific factors/indirect effects: Several commenters noted that the factors analyzed to understand the expected impacts will vary widely from species to species. They also stated that a complete assessment of effects must cover the full range of factors that support recruitment and survival, including an assessment of indirect effects on habitat, behavioral patterns, breeding and feeding, and special management considerations (e.g., impacts on recovery plan objectives or other management initiatives).

The Service agrees with these comments. Although the 1986 Amendments deleted the reference to "habitat" from the determination of negligible impact, the stated reason for this change confirms that the factors indicated by the commenters, such as effects on habitat, remain important in the assessment of negligible impact:

A minor impact upon a small segment of habitat might be found to be more than negligible under the prior standard, even if it has no impact upon the overall population utilizing the habitat. But it is also the case that populations could be affected a[d]versely by actions that damage rookeries, mating grounds, feeding areas and areas of similar significance. The Secretary shall take those impacts into accounts [sic] when making a "negligible impact" determination under section 105(A)(5)(i) [sic]. Because these factors are to be taken into account, in making such a determination, subparagraph (a)(2)(A) of this section deletes the phrase "and its habitat" from subparagraph 5(A)(i) [sic] of the MMPA.

132 Cong. Rec. S16305 (Oct. 15, 1986). The Service does not believe that it is necessary to amend the regulatory language to reflect the above factors; it is sufficient to note that the Service will consider these factors when determining negligible impact.

Impact on optimum sustainable population (OSP): An OSP determination is not required to make a negligible impact finding. In the preamble of the proposed rule, the Service provided some illustrative examples of how the negligible impact test would be applied depending on whether the particular marine mammal stock was within or below its OSP range. 53 FR 8473, 8474 (Mar. 15, 1988). Citing the management goal of the MMPA—the maintenance or attainment of an OSP level for each population stock of marine mammals (see sections 2(2) and 2(6) of the MMPA)—the Service set out the following general analytical framework for applying the definition of negligible impact:

If a request for specific regulations under section 101(a)(5) involves potential impacts to a "depleted" population, then a determination of negligible impact can be made only if the permitted activities are not likely to significantly reduce the increase of that population or prevent it from ultimately achieving its OSP; on the other hand, if a "nondepleted" population is involved, then a determination of negligible impact can be made only if the permitted activities are not likely to reduce that population below its OSP.

***40341** 53 FR at 8474. The Service provided this proposed analytical framework to elicit public comment so that the final rule could more fully explore the application of the negligible impact test. Since these examples attracted a wide spectrum of views on the basic meaning of the 1986 Amendments and negligible impact, the Service will now clarify the analytical approach it will follow in making this essential finding.

Several commenters, citing the complex and controversial nature of the OSP concept, asserted that OSP should not be used as the framework for determining negligible impact, especially since no mention is made in section 101(a)(5) of OSP. Many of the commenters emphasized that Congress intended a simplified process that focused on impacts on annual rates of recruitment or survival rather than on impacts to OSP. One commenter argued that Congress rejected an analytical approach based on OSP by failing to pass H.R. 1027, 99th Cong., 1st Sess. (1985), which would have authorized incidental takes under the MMPA "if the proposed incidental take would not impede the species' ability to eventually attain its optimum sustainable population." H.R. Rept. No. 124, 99th Cong., 1st Sess. 13 (1985).

The Service notes that H.R. 1027 would have provided an exception to the taking prohibitions of both the ESA and the MMPA through the section 7 consultation process. The rulemaking process of section 101(a)(5) of the MMPA would not have been required. The Service believes that the congressional choice of imposing an additional regulatory process before authorizing the incidental taking of listed marine mammals reflected a concern for the need for more safeguards rather than a concern for simplification.

The Service did not intend, however, to imply that a formal determination of OSP was necessary in order to make the negligible impact finding. Section 101(a)(5)(C)(ii) of the MMPA clearly exempts the issuance of specific regulations from compliance with the formal rulemaking requirements of section 103 of the MMPA. The Service's factual examples illustrating a proposed analytical framework for the determination of negligible impact did not involve the formal determination of OSP. The first example involved depleted populations and how impacts to recruitment rates and survival would be treated; an OSP determination was not needed because one need only establish that the total take would not “significantly reduce the increase of that population” and would not prevent ultimate achievement of OSP. This conceptual framework for depleted species focuses on the absence of “significant” reductions to the rate of long-term population increases and the absence of barriers to the attainment of OSP.

In response to several comments, the Service notes that the same analytical framework for depleted species applies to stocks of unknown status, since it is not OSP that is at issue, but rather that the incidental taking would not prevent the population from attaining or maintaining its OSP.

Therefore, an OSP determination is not necessary in making a negligible impact finding. Qualitative judgments will be made on a case-by-case basis on how the anticipated incidental taking will affect the status and population trends of the species or stocks concerned. Many factors are used in this determination, including, but not limited to, the status of the species or stock relative to OSP (if known), whether the recruitment rate for the species or stock is increasing, decreasing, stable or unknown, the size and distribution of the population, and existing impacts and environmental conditions.

Several commenters concurred with the Service's analytical framework for depleted species, with one commenter stressing the need to ensure that a depleted population will increase toward its OSP at an acceptable rate. However, one commenter stated that the Service's approach was not consistent with section 2(2) of the MMPA, which mandates that “[f]urther measures should be immediately taken to replenish any species or population stock which has already diminished below [its OSP].” Two commenters argued that the only way to satisfy these conservation goals of the MMPA is to establish that the level of incidental take has only a negligible impact on the rate of recovery for the species or stock. Contending that a distinction must be made among stocks that are increasing, decreasing, or stable in the level of recruitment, they stated that a negligible impact should involve effects that do not impede a stock from achieving OSP at the same rate and in the same manner that would occur in the absence of the proposed incidental take.

The Service agrees that distinctions need to be made among stocks that are increasing, decreasing, or stable when determining negligible impact. In order to make a negligible impact finding, the proposed incidental take must not prevent a depleted population from increasing toward its OSP at a biologically acceptable rate. Consistent with this view, the Service believes that insignificant reductions in the rate of the population increase (i.e., net recruitment) do not become significant impacts on a depleted stock because the stock would not increase toward its OSP as rapidly as it would in the absence of the incidental take. To adopt the commenters' formulation, one would have to find that the impacts of incidental take have “no effect” on the rate of population growth for a depleted stock; i.e., there would be “no effect” on the stock's “rate of recovery.” The statutory standard does not require that the same recovery rate be maintained, rather that no significant effect on annual rates of recruitment or survival occurs. For stable or declining populations, a finding of negligible impact may be more difficult than for increasing populations. Section 101(a)(5) clearly indicates that some level of adverse effects involving the take of depleted marine mammals can be authorized as long as the impact is “negligible.”

The plain language of section 2(2) does not suggest a more stringent standard. That section indicates a concern for the immediate initiation of steps to replenish a depleted species or stock—a concern which is addressed in the Service's analytical framework since significant reductions in recruitment rates are not considered negligible. Further, section 2(2) does not mandate the immediate taking of all steps to attain an OSP level for all depleted stocks; such a reading of the purposes and policies of the MMPA would displace the clear congressional intent behind section 101(a)(5), which was designed to alleviate conflicts, where the impacts are negligible, between activities (other than commercial fishing) that involve the incidental taking of marine mammals and the strict moratorium against taking.

One commenter suggested that a more appropriate standard for determining negligible impact for a depleted stock would be whether the level of incidental taking is likely to substantially reduce the rate of population growth. By substituting “substantial” for the Service's term “significant,” the commenter argues that statistically measurable effects would not necessarily cause an applicant to be ineligible for a take under section 101(a)(5). The commenter further recommended that a level of acceptable take—within the range of 10 to 50 percent of annual recruitment—be prescribed in the regulations.

***40342** The Service does not share the commenter's concerns. The absence of substantial reductions in population growth does not automatically correspond with a negligible impact; significant adverse effects, although not substantial in nature, can prevent the Service from finding negligible impact. Further, the Service declines to prescribe acceptable taking levels. Such numerical limits would ignore the significant differences in the status and population dynamics among the various marine mammal stocks and the type of taking (i.e., harassment versus mortality) or other impacts. The determination of negligible impact must take into account the status and the particular biological requirements of the species or stock, as well as the effects of the incidental taking on the rate of recruitment.

The second example presented in the preamble of the proposed rule involved the determination of negligible impact with respect to a non-depleted stock of marine mammals. If a particular stock were known to be within its OSP range, then the Service believes a finding of negligible impact can only be made if the permitted activities are not likely to reduce that stock below its OSP. However, not all takings that do not reduce the population below its OSP would be considered negligible.

The Service's analytical framework for non-depleted stocks recognizes that healthy marine mammal populations that have reached an equilibrium level usually experience fluctuations in population numbers within some normal range due to a variety of environmental and biological factors. Such fluctuations may involve short-term population declines that do not pose a risk to the stocks remaining within the limits of OSP. The Service believes that minimal impacts on a healthy stock caused by incidental taking can still be considered negligible if such taking does not cause the population to fluctuate beyond normal limits. In other words, for a population stock that is at its OSP level, slight impacts on the stock resulting from incidental take do not rise to the level of “adverse effects” on annual rates of recruitment or survival if the population stock is maintained at essentially the same level.

One commenter opposed the Service's approach to non-depleted stocks by arguing that it is too permissive. Contending that the Service's analytical framework could allow a stock to be reduced from 95 to 60 percent of carrying capacity in determining negligible impact, the commenter noted that such a significant population decrease would have to be evaluated through the waiver process in section 101(a)(3) of the MMPA.

The Service agrees that the commenter's extreme example would not be eligible for treatment under the “small take” provisions of section 101(a)(5) of the MMPA; such large takes should be instead considered under the waiver procedures in sections 101(a)(3) and 103 of the MMPA. As explained above, the key factor is the significance of the level of impact on rates of recruitment and survival. Only insignificant impacts on long-term population levels and trends can be treated as negligible.

Several commenters stated that the Service's “dual standard” for assessing negligible impact was inappropriate because Congress intended a uniform system.

The Service's examples in the proposed rule were intended to show how a negligible impact finding might be approached in different situations. This is not a dual standard, but, instead, the illustration of how to apply the rule in contrasting fact situations. Again, the formal determination of OSP is not a prerequisite to issuing specific regulations.

Cumulative impacts: In determining impact, the Service must evaluate the “total taking” expected from the specified activity in a specific geographic area. The estimate of total taking involves the accumulation of impacts from all anticipated activities that are expected to be covered by the specific regulations. In other words, the applicant's anticipated taking from its own activities is only one part of the story; the total takings expected from all persons conducting the activities to be covered by the regulations must be determined.

Several commenters asked that the Service clarify the concept of “total taking” by amending the definition of negligible impact.

The Service declines to do so because it believes that the definition of negligible impact is effective as written since it clearly states the impacts “resulting from the specified activity” as discussed above.

Two commenters asked how to assess the degree of impacts in the situation where, although separate activities by themselves pose negligible impacts, a combination of impacts poses a significant impact on the species or stock.

The Service agrees with the commenters that the impacts of incidental take from successive or contemporaneous activities must be added to the baseline of existing impacts to determine negligible impact. While the impacts of a particular activity may be fairly minor, they may in fact be more than negligible when measured against a baseline that includes a significant existing take of marine mammals from the other activities.

The commenter believed that the regulations should identify an order of priority for various types of taking (e.g., subsistence taking and incidental taking) and describe how allowable takes will be allocated to each type of activity. Another commenter argued that the 1986 Amendments do not estabish a priority system for takings, incidental or intentional.

The Service notes that ongoing authorized activities are factored into the baseline of existing impacts to determine negligible impact of a requested activity. To the extent that subsistence is part of the baseline, subsistence takes are accommodated and allocation between subsistence and incidental taking is not necessary.

Some commenters asked the Service to limit the determination of negligible impact to direct impacts of the specified activity and to exclude cumulative effects resulting from future, unrelated activities.

As discussed previously, the Service must look at both direct and indirect effects, but not the cumulative effects, in making findings under section 101(a)(5) of the MMPA concerning negligible impact. The Service will consider cumulative effects that are reasonably foreseeable when preparing its analysis under the National Environmental Policy Act. Additionally, cumulative effects that are reasonably certain to occur and “effects of the action” will be considered in any necessary consultation under section 7(a)(2) of the ESA. 50 CFR 402.02, 402.14(g) (3), (4) (1987); 51 FR 19926, 19932-33 (June 3, 1986) (preamble discussion in the section 7 regulations). In view of the above, the Service does not believe it is necessary to add a discussion on cumulative effects to the definition of negligible impact.

Impact on individuals: As stated in the preamble of the proposed rule, the negligible impact finding is made with respect to impacts to the marine mammal species or stock and not with respect to impacts to individual animals. Some commenters believed that this should be clearly stated in the regulations, rather than just in the preamble.

The Service declines to add a statement to the regulatory definition of negligible impact because the preamble ***40343** discussion and the definition clearly state that only impacts that "adversely affect the species or stock" are considered.

One commenter noted that, in many cases, available scientific information on the size and population dynamics of a particular stock may be inadequate to assess the degree of impacts posed by incidental take. In those cases, the commenter suggested that the Service should assess impacts based upon a consideration of impacts to individual animals.

The Service disagrees. If information is lacking to define a particular population or stock of marine mammal, then impacts resulting from incidental take should be assessed with respect to the species as a whole. See 132 Cong. Rec. S16304-05 (Oct. 15, 1986).

Addressing the degree of information needed to assess the impacts of incidental take, one commenter noted that the Service may deny a request for specific regulations only if the record reflects a valid scientific basis for the conclusion that a more than negligible impact would be posed to the overall population.

Although the commenter is correct that the focus should be on impacts to the overall population, the burden will be on both the applicant and the Service to show that information exists in the administrative record to support a negligible impact finding. See earlier discussion on "Burden of Proof."

One commenter believed that the use of OSP as described in the preamble to the proposed rule would shift the focus away from consideration of population impacts.

The Service disagrees. As explained earlier, an OSP determination is not required to make a negligible impact finding. The Service will use all available information concerning a population, including its status relative to OSP (if known).

Speculative impacts: A variety of comments were received on the issue of how speculative impacts should be treated in determining negligible impact. Several commenters argued that the regulations should clearly state that speculative or conjectural effects will not be considered in evaluating impacts. One commenter added that negligible impact should be found when the probability of occurrence of an impact is low whereas the potential impact may be significant. However, other commenters, citing the lack of definitive data on the population dynamics of some marine mammal populations, suggested that the Service should err on the side of caution when labeling certain impacts as "speculative" or "conjectural." One commenter stated that the allowance of incidental taking of a depleted species when the impacts of such taking cannot presently be assessed would be in violation of both the MMPA and the ESA.

The Service believes that the discussion regarding speculative impacts in the preamble of the proposed rule accurately interpreted the legislative intent behind the 1986 Amendments:

If potential effects of a specified activity are conjectural or speculative, a finding of negligible impact may be appropriate. A finding of negligible impact may also be appropriate if the probability of occurrence is low but the potential effects may be significant. In this case, the probability of occurrence of impacts must be balanced with the potential severity of harm to the species or stock when determining negligible impact. In applying this balancing test, the Service will thoroughly evaluate the risks involved and the potential impacts on marine mammal populations. Such determinations will be made based on the best available scientific information.

53 FR at 8474; accord, 132 Cong. Rec. S16305 (Oct. 15, 1986). The Service recognizes the tension that exists between development interests and wildlife resource interests when restrictions on development are predicated upon the existence of adverse impacts that are speculative in nature. To resolve these difficult situations, the legislative history of the 1986 Amendments endorsed the use of a balancing approach to weigh the likelihood of occurrence against the severity of the potential impact:

The degree of certainty of occurrence required in these judgments should be inversely proportional to the resultant harm to the overall population.

132 Cong. Rec. S16305 (Oct. 15, 1986). In applying this balancing test, the Service must, of necessity, evaluate each request for specific regulations on a case-by-case basis.

Impact on Habitat

The amendments deleted the required finding that the specfied activity have only a negligible impact upon the marine mammal habitat. Under the previous standard, a minor impact on a small segment of habitat might be found to be more than negligible and the incidental take prohibited even if the overall impact on the species or stock utilizing the habitat was negligible. Nevertheless, impacts on rookeries, mating grounds, feeding areas and areas of similar significance could have adverse effects on the species or stock. As discussed in the "Impacts on Species or Stock" section above, impacts on habitat are part of the consideration in making the finding of negligible impact on the species or stock. Further, even if the impact is determined to be negligible, specific regulations must include measures to ensure the least practicable adverse impact on the habitat.

Definition: Commenters believed that the definition of negligible impact should specify that impacts on habitat will not be considered unless they have a greater than negligible impact on the marine mammal population as a whole.

The Service believes the definition of negligible impact reflects this and no changes are necessary.

Required information: Since impacts on habitat are considered only in the context of impacts on the species, one commenter believed that the Service should delete the requirement, in a request, for information concerning impacts on habitat (§ § 18.27(d) (iv), (v) and 228.4(a) (7), (8)). Commenters also believed that the information required should be restricted to impacts that can be expected to adversely affect the overall population through effects on rates of recruitment or survival or should be restricted to the impacts on exisiting rookeries, mating grounds, feeding areas, and areas of similar significance.

The Service believes the existing information required should be retained. A description of the impacts on the habitat and the effects of any loss or modification of habitat on the marine mammal populations is needed in the Service's evaluation of negligible impact. If the impacts on habitat are not likely to result in more than a negligible impact on the population, then they will not be a basis for denying a request. However, the Service still has an obligation to require measures to ensure the least practicable adverse impact on the habitat, whether or not it causes more than a negligible impact on the populations, paying particular attention to rookeries, mating grounds, and areas of similar significance.

Relation to critical habitat: Commenters suggested that the preamble clarify that impacts on habitat are considered in the broad biological sense. They stated that effects on critical habitat would be considered in the ESA Section 7 consultation process.

Impacts on the population of the loss or modification of any part of the population's habitat are considered in determining negligible impact. "Critical habitat" is a regulatory determination under the ESA. Section 7 requires that Federal agencies ensure that their activities are not likely to jeopardize the continued existence of endangered or ***40344** threatened species or result in the destruction or adverse modification of their critical habitats. Only impacts on those areas designated as critical habitat are considered in the determination of destruction or adverse modification. However, impacts on the species of the loss or modification of any part of habitat is evaluated in the determination of jeopardy.

Impact on Subsistence Uses

The amendments changed the standard used to evaluate the impact on subsistence uses from "negligible impact" to "not having an unmitigable adverse impact." To determine that an unmitigable adverse impact on subsistence uses exists, two elements must be present. First, the impact resulting from the specified activity must be likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (1) causing the marine mammals to abandon or avoid hunting areas, (2) directly displacing subsistence users, or (3) placing physical barriers between the marine mammals and subsistence hunters. Second, it must be an impact that cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

Those conducting the specified activity, the involved Federal agencies, and the affected subsistence users, are encouraged to meet and develop mutually agreeable conditions which satisfy the operational, scientific or other needs of the activity and the requirements of subsistence users.

Unmitigable adverse impact: One commenter suggested that, consistent with the legislative history of the amendments, the definition of "unmitigable adverse impact" should be clarified to specify that an impact must result from the specified activity rather than from environmental or other factors.

The Service agrees that only impacts on subsistence uses resulting from the specific activity should be considered in determining if an unmitigable adverse impact exists. Environmental and other factors not related to the specific activity are evaluated only in determining existing baseline conditions and availability. Since the regulatory definition clearly states that "unmitigable adverse impact" means an impact "resulting from the specified activity," no changes are warranted.

One commenter suggested that mitigation should not require the elimination of an impact. Rather, reducing the impact such that subsistence needs can be met would be sufficient in the commenter's opinion.

The new standard of "unmitigable adverse impact" does not require the elimination of adverse impacts, only mitigation sufficient to meet subsistence requirements. However, the amendments also require that the specific regulations governing an activity include measures to ensure the least practicable adverse impact on the availability of marine mammals for subsistence uses, even if the activity will not otherwise have an unmitigable adverse impact. Hence, any adverse impacts would have to be mitigated to the extent practicable.

Another commenter stated that to reflect congressional intent, the definition of "unmitigable adverse impact" should specify that animals would have to vacate a hunting area rather than just avoid it. In addition, the number of marine mammals that would have to abandon or avoid a hunting area to constitute an adverse impact should be a criterion in the regulations according to the commenter.

The legislative history of the amendments emphasizes the availability of "sufficient numbers" of marine mammals to meet the subsistence needs of the community. In this context, "vacate" was intended to connote both the temporary and permanent absence of marine mammals from subsistence hunting areas. Hence, the terms "abandon" and "avoid" are more precise than "vacate"—abandonment of habitat involves forsaking an area completely, while avoidance includes temporary absence from or bypassing an area.

Specifying the number, proportion, or some other quantification of animals avoiding or abandoning an area that would constitute an adverse impact is difficult. The value assigned such a criterion would vary depending on the specific circumstances, including actual subsistence needs, the extent of the area avoided by the marine mammals, and whether or not animals remain available in other areas. If appropriate and feasible, such a criterion will be established during the development of specific regulations for an activity. Since it may not be possible to establish such a criterion in all instances, it is not required in these regulations.

Cultural subsistence: A commenter suggested that cultural aspects of dependence on marine mammals should be reflected in the definition of subsistence needs in addition to the nutritional and other physical attributes usually associated with this term. This commenter added that since the cultural significance of subsistence harvests is to a great extent specific to individual communities, the impacts of a specified activity on subsistence uses must be assessed locally.

The finding of an unmitigable adverse impact considers the availability of the species for subsistence needs and is not based on cultural considerations. To the extent that opportunities to meet the subsistence needs of the community remain available, however, many of the cultural dimensions of subsistence use would be accommodated. “Availability” provides opportunities for traditional hunts and for the Native community to transmit its hunting-based culture to each new generation. In keeping with the emphasis in the legislative history, the definition of unmitigable adverse impact has been modified to emphasize “availability.” Such emphasis will accommodate many of the cultural dimensions of subsistence uses of marine mammals. Although the amendments changed the standard for evaluating impacts on subsistence uses from “negligible impact” to “unmitigable adverse impact,” the availability of marine mammals for subsistence harvest remains a central consideration.

Coordination with subsistence users: A commenter suggested the language from the preamble encouraging the agency, applicant and affected subsistence users to agree upon terms and conditions for activities which satisfy their subsistence, operational, scientific and other needs be incorporated into the regulations.

Such coordination could be effective in identifying and achieving consensus regarding subsistence mitigation measures to be incorporated in specific regulations. For instance, though not required under the regulations, affected native interests and applicants could agree that the availability of marine mammals could be achieved by means other than the traditional distribution of the animals. The Service encourages, and as appropriate will participate in, such cooperative ventures. Language has been added to §§ 18.27(d)(1)(vi) and 228.4(9) to encourage, but not require, such coordination.

Mitigating Measures

The preamble of the proposed rule discussed mitigating measures in three contexts. With regard to negligible impact determinations, if the impact of a specified activity would be rendered negligible by mitigating measures when that requirement would not otherwise be satisfied, the Service may make a negligible impact finding subject to successful implementation of those mitigating measures. In evaluating ***40345** impacts on subsistence uses of marine mammals, the Service must find that the specified activity will not have an unmitigable adverse impact. Finally, the amendments require that specific regulations governing a specified activity include measures to ensure the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses. Mitigating measures are intended to ensure the availability of enough animals to meet subsistence needs and to minimize impacts on the species or stock and subsistence users.

Support mitigating measures: One commenter endorsed the requirement for mitigating measures to reduce the impact of specific activities on marine mammal populations, habitats and subsistence uses to negligible levels. The commenter suggested that if it is determined that mitigating measures have been or could be effective, those measures should be required in specific regulations and as a condition for issuing any Letter of Authorization.

The Service agrees. The regulations require the inclusion of mitigating measures, as appropriate, in specific regulations and as a condition for issuing Letters of Authorization.

Service's responsibility to identify mitigating measures: A commenter suggested that the Service has the responsibility to identify mitigating measures. While the requester and the Service, in many instances, share responsibility for identifying mitigating measures, the commenter argued that the Service is vested with the ultimate responsibility to search for appropriate mitigating measures before denying a request for specific regulations.

The Service disagrees. Since the applicant is most familiar with the nature and extent of the activity contemplated and has the detailed knowledge of possible alternatives to that activity and the impacts on marine mammals, the applicant is in the best position to identify and assess mitigating measures. In addition, as the primary beneficiary of any incidental take authorization, the applicant should be ultimately responsible for identifying such measures. Nevertheless, the Service will consider all available information in assessing the adequacy and effectiveness of measures to mitigate the adverse impacts of the proposed taking and in developing specific regulations.

Required coordination with applicant: To facilitate coordination, a commenter proposed that requesters be advised of any mitigating measures contained in a proposed rule at least 10 days prior to publication in the Federal Register. Under this procedure, if the requester, within 10 days of such notification, finds the mitigating measures to be inappropriate or economically prohibitive, publication may be delayed to communicate these concerns to the Service.

The Service finds it unnecessary to delay the rulemaking process given the requirement for public comment on the proposed rule, including any mitigating measures. In addition, the applicant could always petition for further review.

Letters of Authorization

This rule makes technical modifications to two paragraphs in the existing regulations (50 CFR 18.27(f) and 228.6) related to Letters of Authorization. The changes are intended to make the language in those paragraphs consistent with the new definitions of "negligible impact" and "unmitigable adverse impact" and the use and interpretation of those terms elsewhere in the regulations. Although not discussed in the preamble to the proposed rule, there were several comments related to Letters of Authorization.

Modification of Letters of Authorization: One commenter suggested that the regulations should provide for modification of Letters of Authorization as an alternative to withdrawal or suspension. In particular, it was proposed that these authorization documents should not be suspended unless the Service finds there are no additional or alternative mitigating measures which would alleviate the need for such action.

Current procedures allow the modification of Letters of Authorization to reflect changed conditions through withdrawal and reissuance as long as the incidental take levels or other requirements of the specific regulations are not violated. If Letters of Authorization are withdrawn or suspended on a class basis, a rulemaking to establish new specific regulations can be initiated. In some cases this approach would be preferable since a comprehensive reevaluation would be required on whether the specified activity is still having a negligible impact.

Public comment on emergency withdrawal or suspension of Letters of Authorization: A commenter suggested that the emergency withdrawal or suspension authority in 50 CFR 18.27(f)(6) and 228.6(f) be curtailed by requiring that the Service, based on the best scientific information available, find that there is an immediate and substantial risk to the well-being of the marine mammal populations involved without such emergency action.

Such a finding is, in effect, required under present law and regulations. Moreover, due to the potentially serious consequences of withdrawal or suspension of Letters of Authorization, the Service would make every effort to provide notice and an opportunity where possible for public comment under the provisions of 50 CFR 18.27(f)(5) and 228.6(e). However, if an emergency exists, the Service is required by the provisions of section 101(a)(5)(C)(i) of the MMPA to take appropriate action to protect marine mammals. Hence, the Service must retain authority for emergency withdrawal or suspension to address situations where species or populations would be threatened by lack of prompt action.

ESA—Section 7 Process

As stated above, the regulations governing small takes of marine mammals now include depleted as well as non-depleted marine mammals. Consultation under section 7 of the ESA is also necessary if the issuance of regulations under section

101(a)(5) of the MMPA is a Federal action that involves the incidental taking of endangered or threatened marine mammals. In addition to satisfying the MMPA criteria, incidental take of endangered or threatened species also must comply with section 7 of the ESA.

Under section 7(a)(2) of the ESA, Federal agencies are required to consult with the Service to insure that any action they authorize, fund or carry out is not likely to jeopardize the continued existence of an endangered or threatened species or result in the destruction or adverse modification of critical habitat. Although this consultation is primarily between the Federal agency and the Service, applicants for Federal licenses, permits or funding are encouraged to participate. The Federal agency initiates formal consultation by a written request to the Service that includes detailed information concerning the potential effects of the proposed action. Consultation should be concluded within 90 days.

After consultation, the Service issues its biological opinion which includes an assessment of impacts and its conclusion on whether or not the action is likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat. In those cases where the Service concludes that an action (or the ***40346** implementation of reasonable and prudent alternative(s)) is not likely to result in jeopardy or adverse modification but may result in the incidental take of endangered or threatened species, the Service includes an incidental take statement in the biological opinion as required by section 7(b)(4). Compliance with the terms and conditions specified in the incidental take statement exempts the Federal agency and any permit or license applicant involved from the taking prohibitions of the ESA up to the level specified in the incidental take statement.

Coordination Between the ESA and MMPA

One of the purposes of the amendments to the MMPA and the ESA was to clarify the relationship between these statutes so that decision processes under each would be coordinated and integrated to the maximum extent practicable. The ESA alone does not provide authority for the incidental take of endangered or threatened marine mammals—the requirements of both the MMPA and ESA must be met. The incidental take statement issued under the authority of the ESA will include terms and conditions with which a Federal agency or applicant must comply. The amendment added a provision to section 7(b)(4) which directs that the provisions of section 101(a)(5) of the MMPA must be completed before the incidental take of endangered or threatened marine mammals is allowed. In addition to the reasonable and prudent measures to minimize the impact of the incidental take, an incidental take statement will include measures which are required to comply with section 101(a)(5) of the MMPA and applicable regulations. The difficulty of coordinating the ESA consultation and MMPA exemption processes is that section 7(b) of the ESA generally requires that consultation be completed within 90 days while the MMPA regulatory process is much longer.

Delay of section 7 process: One commenter stated that the preamble implied that initiation of section 7 consultation would be delayed until the MMPA process was well underway. They stated that the processes should be conducted simultaneously and that the ESA process should begin immediately upon submission of the MMPA request.

Because of the timing discrepancy between the two processes reflecting procedural differences maintained by Congress, the MMPA section 101(a)(5) process cannot be completed as expeditiously as the ESA process. However, the legislative history offers options on how to handle the timing discrepancies between the two Acts, two of which were summarized in the preamble to the proposed rule. The first is to consider initiating the MMPA section 101(a)(5) process in advance of the ESA section 7 process. In this way, the MMPA requirements can be incorporated into the ESA incidental take statement when the biological opinion is issued and subsequent revisions would not be necessary. Another option is to have the Federal agency and the Service agree to extend the consultation under section 7(b)(1)(A) to accommodate completion of the section 101(a)(5) regulations. The consent of any permit or license applicant is required for an extension of more than 60 days. An additional option involves early consultation under section 7(a)(3) of the ESA. Under this approach, a preliminary biological opinion could be issued on the prospective agency action. When the section 101(a)(5) process is completed, the biological opinion would be reviewed and the ESA section 7(b)(4) incidental take statement amended or added, as appropriate. These, or similar options, will be available to the agency and the applicant as appropriate.

Issuance of incidental take statements: One commenter pointed out the different approaches taken by NMFS and FWS in how they handle the incidental take statements included in the biological opinion, and urged that these regulations established a consistent policy. Another commenter argued that the ESA biological opinion should be completed within the required time limits and the incidental take statement added to the opinion upon completion of the MMPA process.

The Service agrees with these comments and, therefore, in the future, neither agency will issue an incidental take statement in the biological opinion if consultation is completed before the section 101(a)(5) regulations are issued. The biological opinion will later be amended to include the incidental take statement.

One commenter said that section 7 of the ESA requires the timely issuance of biological opinions and incidental take statements.

The Service agrees and will continue to issue biological opinions within the section 7 timeframe. However, the portion of the incidental take statement dealing with marine mammals will be added to the biological opinion after the MMPA requirements have been satisfied.

Section 7(o) of the ESA

Section 7(o) of the ESA, as amended, specifies that any taking in compliance with the terms and conditions of an incidental take statement is not a prohibited taking under the ESA. No other ESA permit or authorization is required of the Federal agency or applicant in carrying out the action if the incidental take statement applies and if the action complies with the terms and conditions of that statement. The biological opinion plus the incidental take statement operate as an exemption under section 7(o)(2) of the ESA. The new § 402.14(i)(5) clarifies this provision.

Private actions: In the preamble to the proposed rule, the Service cited the following example concerning private actions. Section 10(a) of the ESA allows the Service to issue permits for the taking of endangered species incidental to an otherwise lawful non-Federal action within the United States and its territorial sea, subject to certain conditions. In 1982, Congress added this provision to allow incidental taking associated with private actions that are not subject to the section 7 consultation process.

If an endangered or threatened marine mammal may be taken incidentally to a private action, regulations under section 101(a)(5) of the MMPA would be required. Consultation under section 7 of the ESA would be conducted since issuance of the MMPA regulations is a Federal action. The incidental take statement issued with the biological opinion would address taking concerns under the ESA, and a section 10 permit would not be required.

Two commenters disagreed with this interpretation, contending that it would allow wholly non-Federal activities to be relieved of section 10 requirements (except for the necessity of obtaining MMPA incidental taking authority), most notably the conservation plan obligations.

This implies that private activities are subject to stricter protection standards than activities with Federal involvement. This contention misconstrues the purpose and effect of section 10 provisions relating to private actions. These provisions were added by Congress to allow persons engaged in activities with no discretionary Federal involvement the same access to ESA exemptions and provisions as those engaged in activities requiring Federal approval or scrutiny. There is no indication in the ESA or its legislative history that Congress intended to set up substantially different or stricter protection standards for private ***40347** activities by requiring a conservation plan. In commenting on the standards to be used in granting section 10 permits for private activities, the House Report states the following:

The [S]ecretary would base his determination on whether or not to grant the permit under the same standard as found in section 7(a)(2) of the Act, that is, whether or not the taking would jeopardize the continued existence of the species. To issue the permit, the Secretary would also have to find that the taking would be incidental to another activity and that the applicant would minimize the taking to the maximum extent practicable.

H.R. Rep. No. 567, 97th Cong., 2nd Sess. 31 (1982).
Section 7 and section 10 are designed to achieve the same objectives through different procedural means. The conservation plan requirement is the means for ensuring effective and timely Federal involvement in an otherwise private activity. For those activities already subject to such involvement through regulations or permits, there is no need for a separate conservation plan. Under both sections 7 and 10, the endangered and threatened species are afforded the same level of protection.

To require a separate section 10 permit in addition to section 101(a)(5) regulations and a section 7 consultation would serve only to increase the administrative burden on the applicant and the government with no corresponding benefit to endangered or threatened marine species.

Exceeding Take Limits
One commenter suggested that the regulations should specify what will happen when an incidental take level is exceeded, and that this be the same for all incidental take authorizations under both the MMPA and ESA.

The Service agrees that provisions for addressing excessive incidental take should be consistent for authorizations under MMPA regulations and ESA incidental take statements. The MMPA and ESA incidental take processes are similar in that when an incidental take authorization is exceeded, the activity must be reevaluated. However, if the activity continued during such a reevaluation, then any resultant taking would be subject to penalties under the ESA and/or the MMPA.

Under section 7 of the ESA, consultation must be reinitiated immediately by the Federal agency if the incidental take level is exceeded (see 50 CFR § 402.14(i)(4)). Exceeding the level of anticipated taking does not, by itself, require the stopping of an ongoing action during reinitiation of consultation. However, any further taking resulting from the activity would be illegal under the ESA. If formal consultation is reinitiated, section 7(d) of the ESA again takes effect. That provision prohibits the Federal agency or applicant from making any irreversible or irretrievable commitment of resources which has the effect of foreclosing the formulation or implementation of any reasonable or prudent alternatives which would avoid violating section 7(s)(2).

The parallel language in section 101(a)(5) of the MMPA requires withdrawal or suspension of Letters of Authorization either on an individual or class basis if, after notice and public comment, it is found that the impact of the authorized incidental take is more than negligible (see 50 CFR 18.27(f)(5) and 228.6(e)). The Southern Sea Otter Translocation Project, an issue raised by the commenter, involves a fundamentally different situation in that it is an experimental effort authorized by a special statute and by a scientific research permit.

Sea Otter Management Zone
In 1986, Public Law 99-625 was passed by Congress to govern the translocation of southern sea otters for research and recovery purposes. The FWS has established an experimental population of sea otters around San Nicolas Island, Ventura County, California.

One commenter stated that these regulations should not apply to activities within the management zone for the experimental population of the sea otter.

There are two zones established by the translocation project. The first area is the translocation zone around San Nicolas Island that has a baseline at the 15-fathom isobath with the boundaries extending 10 to 15 nautical miles from the baseline. The second zone surrounds the translocation zone and is an otter-free or management zone, encompassing all marine waters subject to U.S. jurisdiction from Point Conception south.

Within the translocation zone, except for defense-related actions and actions initiated prior to the passage of Public Law 99-625, the consultation provisions of section 7(a)(2) of the ESA and the provisions of the MMPA apply. Within the management zone, unless the proposed action may affect the "parent population" (see 50 CFR 17.84(d)(1)(iv), the provisions of section 7(a)(2) of the ESA and the restrictions on incidental taking under the MMPA do not apply. However, the section 7(a)(4) requirement to confer applies to Federal activities within the management zone and to defense-related activities in either zone.

Regulatory Changes

These regulations amend 50 CFR parts 18, 228 and 402 to implement the 1986 Amendments to section 101(a)(5) of the MMPA and sections 7(b)(4) and 7(o) of the ESA. Basic processes for authorizing incidental take under both ESA and MMPA remain the same; the primary changes are (1) allowing the incidental take of depleted marine mammals, and (2) changing the findings that must be made to allow a take.

Authority citation: Commenters noted that the authority citation for 50 CFR part 228 should be 16 U.S.C. 1371(a)(5), rather than the entire MMPA, since the criteria to be considered are entirely within section 101(a)(5).

The Service disagrees. Although the criteria are all contained within section 101(a)(5), the enforcement and penalty provisions of the MMPA also apply to activities conducted under section 101(a)(5).

Classification

The Department of the Interior, as lead agency, has prepared an environmental assessment on this rule. On the basis of this assessment, it has been determined that this is not a major Federal action significantly affecting the quality of the human environment within the meaning of section 102(2)(C) of the National Environmental Policy Act of 1969 (NEPA). Therefore, an environmental impact statement need not be prepared. The regulations are procedural and, by themselves, do not authorize the taking of depleted marine mammals. Issuance of specific regulations under section 101(a)(5) of the MMPA allowing a taking would require compliance with NEPA, including the preparation of a separate environmental assessment or impact statement if required.

NEPA compliance: One commenter believed that the issuance of specific regulations allowing an incidental take should not require the preparation of a separate environmental assessment or impact statement. It was stated that given the thresholds of negligible impact on a species or stock and no unmitigable adverse impact on subsistence users, requests under section 101(a)(5) would appear to qualify for categorical exclusion treatment under the Council for Environmental Quality's regulations, and the Service should amend its NEPA regulations accordingly.

Since the Service must analyze the proposal for specific regulations to make the determination that the proposal has only a negligible impact on a species or stock and does not have an unmitigable ***40348** adverse impact on subsistence users, the NEPA process will be used to facilitate those determinations. The issuance of specific regulations allowing incidental take would normally only require the preparation of an environmental assessment. Thus, the Service does not believe a categorical exclusion is warranted or that its NEPA regulations need to be amended.

It has been determined that these regulations do not constitute a major rule as defined in Executive Order 12291. The Department of the Interior has certified under the terms of the Regulatory Flexibility Act (5 U.S.C. 601 et seq.) that the regulations will not have a significant economic impact on a substantial number of small entities. The amendments of rules governing the take of small numbers of marine mammals incidental to specified activities will have little, if any, economic effect. Direct costs will be those associated with subsequent preparation of applications for "Specific Regulations" and "Letters of Authorization." However, those costs are not likely to approach the $100 million annual threshold for these rules to be considered a major rule in accordance with E.O. 12291. As most of the applicants under the revised rule, as at present, are likely to be oil and gas corporations and their contractors, they would not be considered small entities under the Regulatory Flexibility Act.

The regulations in 50 CFR parts 18 and 228 contain a collection of information requirement subject to Office of Management and Budget (OMB) clearance under the Paperwork Reduction Act (44 U.S.C. 3501 et seq.). The information collection requirement in 50 CFR 18.27 is approved under OMB control number 1018-0070 and the information requirement in 50 CFR part 228 is approved under OMB control number 0648-0151. Public reporting burden for this collection of information is estimated to average 80 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Protected Resources and Habitat Programs, National Marine Fisheries Service, 1335 East-West Highway, Silver Spring, MD 20910; the Information Collection Clearance Officer, U.S. Fish and Wildlife Service, Department of the Interior, Mail Stop—220 ARLSQ, 18th and C Streets, NW., Washington, DC 20240; and to the Paperwork Reduction Project, Office of Information and Regulatory Affairs, Office of Management and Budget, Washington, DC 20503.

The amendment of part 402 does not contain information collection requirements requiring OMB approval under the Paperwork Reduction Act.

The analyses under NEPA, E.O. 12291 and the Regulatory Flexibility Act are available for review (see FOR FURTHER INFORMATION CONTACT).

The primary authors of this final rule are Robert Peoples, Nancy Sweeney, and Michael Young, Department of the Interior, and Patricia Montanio and Gene Martin, Department of Commerce.

List of Subjects

50 CFR Part 18
Administrative practice and procedure, Alaska, Exports, Imports, Intergovernmental relations, Marine mammals, Transportation.

50 CFR Part 228
Administrative practice and procedure, Marine mammals, Outer continental shelf oil and gas exploration.

50 CFR Part 402
Endangered and threatened wildlife, Fish, Intergovernmental relations, Plants (agriculture).

Regulation Promulgation
Accordingly, the Service amends 50 CFR parts 18, 228 and 402 as shown below.

PART 18—MARINE MAMMALS
1. The authority citation for 50 CFR part 18 is revised to read as follows:

Authority: 16 U.S.C. 1461 et seq.

2. In § 18.27, paragraph (a) is amended by removing the words “Pub. L. 97-58” and “non-depleted”; paragraph (b), including the note following that paragraph, is revised; in paragraph (c), the definition of “negligible impact” is revised, the definition of “specified activity” is amended by removing the word “non-depleted” wherever it occurs, and a new definition for “unmitigable adverse impact” is added in alphabetical order; paragraph (d) is amended by removing the word “non-depleted” wherever it appears; the second sentence of the introductory text to paragraph (d)(1) is revised; a sentence is added to the end of paragraph (d)(1)(vi); a new paragraph (d)(4) is added; and paragraphs (d)(3), (e)(1), (f)(2), and (f)(5)(ii) are revised, to read as follows:

§ 18.27 Regulations governing small takes of marine mammals incidental to specified activities.
* * * * *
(b) Scope of Regulations. The taking of small numbers of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act may be allowed only if the Director of the Fish and Wildlife Service (1) finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses; (2) prescribes regulations setting forth permissible methods of taking and other means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance; and (3) prescribes regulations pertaining to the monitoring and reporting of such taking.

Note: The information collection requirement contained in this § 18.27 has been approved by the Office of Management and Budget under 44 U.S.C. 3501 et seq. and assigned clearance No. 1018-0070. The information is being collected to describe the activity proposed and estimate the cumulative impacts of potential takings by all persons conducting the activity. The information will be used to evaluate the application and determine whether to issue Specific Regulations and, subsequently, Letters of Authorization. Response is required to obtain a benefit.

The public reporting burden from this requirement is estimated to vary from 2 to 200 hours per response with an average of 10 hours per response including time for reviewing instructions, gathering and maintaining data, and completing and reviewing applications for specific regulations and Letters of Authorization. Direct comments regarding the burden estimate or any other aspect of this requirement to the Information Collection Clearance Officer, U.S. Fish and Wildlife Service, Department of the Interior, Mail Stop—220 ARLSQ, 18th and C Streets NW., Washington, DC 20240, and the Office of Management and Budget, Paperwork Reduction Project (Clearance No. 1018-0070), Washington, DC 20503.

(c) * * *

“Negligible impact” is an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

“Unmitigable adverse impact” means an impact resulting from the specified activity (1) that is likely to reduce the ***40349** availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mammals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

(d) * * *

(1) * * * Requests shall include the following information on the activity as a whole, which includes, but is not limited to, an assessment of total impacts by all persons conducting the activity:
* * * * *
(vi) * * * (The applicant and those conducting the specified activity and the affected subsistence users are encouraged to develop mutually agreeable mitigating measures that will meet the needs of subsistence users.);
* * * * *
(3) The Director shall evaluate each request to determine, based on the best available scientific evidence, whether the total taking will have a negligible impact on the species or stock and, where appropriate, will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses. If the Director finds that mitigating measures would render the impact of the specified activity negligible when it would not otherwise satisfy that requirement, the Director may make a finding of negligible impact subject to such mitigating measures being successfully implemented. Any preliminary findings of "negligible impact" and "no unmitigable adverse impact" shall be proposed for public comment along with the proposed specific regulations.

(4) If the Director cannot make a finding that the total taking will have a negligible impact in the species or stock or will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses, the Director shall publish in the Federal Register the negative finding along with the basis for denying the request.

(e) * * *

(1) Specific regulations will be established for each allowed activity which set forth (i) permissible methods of taking, (ii) means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, and (iii) requirements for monitoring and reporting.
* * * * *
(f) * * *

(2) Issuance of a Letter of Authorization will be based on a determination that the level of taking will be consistent with the findings made for the total taking allowable under the specific regulations.
* * * * *
(5) * * *

(ii) The taking allowed is having, or may have, more than a negligible impact on the species or stock, or where relevant, an unmitigable adverse impact on the availability of the species or stock for subsistence uses.
* * * * *

PART 228—REGULATIONS GOVERNING SMALL TAKES OF MARINE MAMMALS INCIDENTAL TO SPECIFIED ACTIVITIES

3. The authority citation for 50 CFR part 228 is revised to read as follows:

Authority: 16 U.S.C. 1361 et seq.

§ 228.1 [Amended]

4. Section 228.1 is amended by removing the words "Pub. L. 97-58" and "non-depleted."

5. Section 228.2 is revised to read as follows:

§ 228.2 Scope.

The taking of small numbers of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act may be allowed only if the National Marine Fisheries Service (a) finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses; (b) prescribes regulations setting forth permissible methods of taking and other means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance; and (c) prescribes regulations pertaining to the monitoring and reporting of such taking. The specific regulations governing specified activities are contained in subsequent subparts to this part 228.

6. In § 228.3, the definition of "negligible impact" is revised; the definition of "specified activity" is amended by removing the word "non-depleted" wherever it occurs; and a new definition for "unmitigable adverse impact" is added in alphabetical order, to read as follows:

§ 228.3 Definitions.

* * * * *

"Negligible impact" is an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

* * * * *

"Unmitigable adverse impact" means an impact resulting from the specified activity (1) that is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mammals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

7. In § 228.4, paragraph (a)(1) is amended by removing the word "non-depleted"; the second sentence of paragraph (a) introductory text is revised; a sentence is added to the end of paragraph (a)(9); paragraph (c) is revised; and a new paragraph (d) is added, to read as follows:

§ 228.4 Submission of requests.

(a) * * * Requests shall include the following information on the activity as a whole, which includes, but is not limited to, an assessment of total impacts by all persons conducting the activity:

* * * * *

(9) * * * (The applicant and those conducting the specified activity and the affected subsistence users are encouraged to develop mutually agreeable mitigating measures that will meet the needs of subsistence users.);

* * * * *

(c) The Assistant Administrator shall evaluate each request to determine, based on the best available scientific evidence, whether the total taking will have a negligible impact on the species or stock and, where appropriate, will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses. If the Assistant Administrator finds that mitigating measures would render the impact of the specified activity negligible when it would not otherwise satisfy that requirement, the Assistant Administrator may make a finding of negligible impact subject to such mitigating measures being successfully implemented. Any preliminary findings ***40350** of "negligible impact" and "no unmitigable adverse impact" shall be proposed for public comment along with the proposed specific regulations.

(d) If the Assistant Administrator cannot make a finding that the total taking will have a negligible impact on the species or stock or will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses, the Assistant Administrator shall publish in the Federal Register the negative finding along with the basis for denying the request.

8. In § 228.5, paragraph (a) is revised to read as follows:

§ 228.5 Specific regulations.

(a) Specific regulations will be established for each allowed activity which set forth (1) permissible methods of taking, (2) means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, and (3) requirements for monitoring and reporting.

* * * * *

9. In § 228.6, paragraphs (b) and (e)(2) are revised to read as follows:

§ 228.6 Letters of Authorization.

* * * * *

(b) Issuance of a Letter of Authorization will be based on a determination that the level of taking will be consistent with the findings made for the total taking allowable under the specific regulations.

* * * * *

(e) * * *

(2) the taking allowed is having, or may have, more than a negligible impact on the species or stock, or, where relevant, an unmitigable adverse impact on the availability of the species or stock for subsistence uses.

* * * * *

PART 402—INTERAGENCY COOPERATION—ENDANGERED SPECIES ACT OF 1973, AS AMENDED

10. The authority citation for part 402 continues to read as follows:

Authority: 16 U.S.C. 1531 et seq.

11. In § 402.14, paragraph (i)(1) is revised, the second sentence of paragraph (i)(3) is revised, and a new paragraph (i)(5) is added, to read as follows:

§ 402.14 Formal consultation.

* * * * *

(i) * * *

(1) In those cases where the Service concludes that an action (or the implementation of any reasonable and prudent alternatives) and the resultant incidental take of listed species will not violate section 7(a)(2), and, in the case of marine mammals, where the taking is authorized pursuant to section 101(a)(5) of the Marine Mammal Protection Act of 1972, the Service will provide with the biological opinion a statement concerning incidental take that:

(i) Specifies the impact, i.e., the amount or extent, of such incidental taking on the species;

(ii) Specifies those reasonable and prudent measures that the Director considers necessary or appropriate to minimize such impact;

(iii) In the case of marine mammals, specifies those measures that are necessary to comply with section 101(a)(5) of the Marine Mammal Protection Act of 1972 and applicable regulations with regard to such taking;

(iv) Sets forth the terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agency or any applicant to implement the measures specified under paragraph (i)(1)(ii) and (i)(1)(iii) of this section; and

(v) Specifies the procedures to be used to handle or dispose of any individuals of a species actually taken.

* * * * *

(3) * * * The reporting requirements will be established in accordance with 50 CFR 13.45 and 18.27 for FWS and 50 CFR 220.45 and 228.5 for NMFS.

* * * * *

(5) Any taking which is subject to a statement as specified in paragraph (i)(1) of this section and which is in compliance with the terms and conditions of that statement is not a prohibited taking under the Act, and no other authorization or permit under the Act is required.

* * * * *

Dated: July 10, 1989.

Susan Recce Lamson,

Assistant Secretary for Fish and Wildlife and Parks, Department of the Interior.

Dated: August 8, 1989.

James W. Brennan,

Assistant Administrator for Fisheries, National Oceanic and Atmospheric Administration.

[FR Doc. 89-23067 Filed 9-28-89; 8:45 am]

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products imported into the United States before the date on which notice is published in the FEDERAL REGISTER of the proposed rulemaking with respect to the designation of the species of stock concerned as depleted or endangered:

(c) Section 18.12(b) shall not apply to articles imported into the United States before the effective date of the foreign law making the taking or sale, as the case may be, of such marine mammals or marine mammal products unlawful.

§ 18.26 Collection of certain dead marine mammal parts.

(a) Any bones, teeth or ivory of any dead marine mammal may be collected from a beach or from land within ¼ of a mile of the ocean. The term ''ocean'' includes bays and estuaries.

(b) Marine mammal parts so collected may be retained if registered within 30 days with an agent of the National Marine Fisheries Service, or an agent of the U.S. Fish and Wildlife Service.

(c) Registration shall include (1) the name of the owner, (2) a description of the article to be registered and (3) the date and location of collection.

(d) Title to any marine mammal parts collected under this section is not transferable, unless consented to in writing by the agent referred to in paragraph (b) of this section.

[39 FR 7262, Feb. 25, 1974, as amended at 51 FR 17981, May 16, 1986]

§ 18.27 Regulations governing small takes of marine mammals incidental to specified activities.

(a) *Purpose of regulations.* The regulations in this section implement Section 101(a)(5) of the Marine Mammal Protection Act of 1972, as amended, 16 U.S.C. 1371(a)(5), which provides a mechanism for allowing, upon request, during periods of not more than five consecutive years each, the incidental, but not intentional, taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region.

(b) *Scope of regulations.* The taking of small numbers of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act may be allowed only if the Director of the Fish and Wildlife Service (1) finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses; (2) prescribes regulations setting forth permissible methods of taking and other means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance; and (3) prescribes regulations pertaining to the monitoring and reporting of such taking.

NOTE: The information collection requirement contained in this §18.27 has been approved by the Office of Management and Budget under 44 U.S.C. 3501 *et seq.* and assigned clearance No. 1018–0070. The information is being collected to describe the activity proposed and estimate the cumulative impacts of potential takings by all persons conducting the activity. The information will be used to evaluate the application and determine whether to issue Specific Regulations and, subsequently, Letters of Authorization. Response is required to obtain a benefit.

The public reporting burden from this requirement is estimated to vary from 2 to 200 hours per response with an average of 10 hours per response including time for reviewing instructions, gathering and maintaining data, and completing and reviewing applications for specific regulations and Letters of Authorization. Direct comments regarding the burden estimate or any other aspect of this requirement to the Information Collection Clearance Officer, U.S. Fish and Wildlife Service, Department of the Interior, Mail Stop—220 ARLSQ, 18th and C Streets NW., Washington, DC 20240, and the Office of Management and Budget, Paperwork Reduction Project (Clearance No. 1018–0070), Washington, DC 20503.

(c) *Definitions.* In addition to definitions contained in the Act and in 50 CFR 18.3 and unless the context otherwise requires, in this section:

Citizens of the United States and *U.S. citizens* mean individual U.S. citizens or any corporation or similar entity if it is organized under the laws of the United States or any governmental unit defined in 16 U.S.C. 1362(13). U.S. Federal, State and local government agencies shall also constitute citizens of the United States for purposes of this section.

Incidental, but not intentional, taking means takings which are infrequent, unavoidable, or accidental. It does not mean that the taking must be unexpected. (Complete definition of take is contained in 50 CFR 18.3.)

Negligible impact is an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

Small numbers means a portion of a marine mammal species or stock whose taking would have a negligible impact on that species or stock.

Specified activity means any activity, other than commercial fishing, which takes place in a specified geographical region and potentially involves the taking of small numbers of marine mammals. The specified activity and specified geographical region should be identified so that the anticipated effects on marine mammals will be substantially similar.

Specified geographical region means an area within which a specified activity is conducted and which has similar biogeographic characteristics.

Unmitigable adverse impact means an impact resulting from the specified activity (1) that is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mammals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

(d) *Submission of requests.* (1) In order for the Fish and Wildlife Service to consider allowing the taking by U.S citizens of small numbers of marine mammals incidental to a specified activity, a written request must be submitted to the Director, U.S. Fish and Wildlife Service, Department of the Interior, Washington, DC 20240. Requests shall include the following information on the activity as a whole, which includes, but is not limited to, an assessment of total impacts by all persons conducting the activity:

(i) A description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals;

(ii) The dates and duration of such activity and the specific geographical region where it will occur;

(iii) Based upon the best available scientific information;

(A) An estimate of the species and numbers of marine mammals likely to be taken by age, sex, and reproductive conditions, and the type of taking (*e.g.,* disturbance by sound, injury or death resulting from collision, etc.) and the number of times such taking is likely to occur;

(B) A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks likely to be affected by such activities;

(C) The anticipated impact of the activity upon the species or stocks;

(D) The anticipated impact of the activity on the availability of the species or stocks for subsistence uses;

(iv) The anticipated impact of the activity upon the habitat of the marine mammal populations and the likelihood of restoration of the affected habitat;

(v) The anticipated impact of the loss or modification of the habitat on the marine mammal population involved;

(vi) The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and, where relevant, on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance. (The applicant and those conducting the specified activity and the affected subsistence users are encouraged to develop mutually agreeable mitigating measures that will meet the needs of subsistence users.);

(vii) Suggested means of accomplishing the necessary monitoring and reporting which will result in increased knowledge of the species through an analysis of the level of taking or impacts and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity; and

(viii) Suggested means of learning of, encouraging, and coordinating research opportunities, plans and activities relating to reducing such incidental taking from such specified activities, and evaluating its effects.

(2) The Director shall determine the adequacy and completeness of a request, and if found to be adequate, will invite information, suggestions, and comments on the preliminary finding of negligible impact and on the proposed specific regulations through notice in the FEDERAL REGISTER, newspapers of general circulation, and appropriate electronic media in the coastal areas that may be affected by such activity. All information and suggestions will be considered by the Fish and Wildlife Service in developing final findings and effective specific regulations.

(3) The Director shall evaluate each request to determine, based on the best available scientific evidence, whether the total taking will have a negligible impact on the species or stock and, where appropriate, will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses. If the Director finds that mitigating measures would render the impact of the specified activity negligible when it would not otherwise satisfy that requirement, the Director may make a finding of negligible impact subject to such mitigating measures being successfully implemented. Any preliminary findings of "negligible impact" and "no unmitigable adverse impact" shall be proposed for public comment along with the proposed specific regulations.

(4) If the Director cannot make a finding that the total taking will have a negligible impact in the species or stock or will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses, the Director shall publish in the FEDERAL REGISTER the negative finding along with the basis for denying the request.

(e) *Specific regulations.* (1) Specific regulations will be established for each allowed activity which set forth (i) permissible methods of taking, (ii) means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, and (iii) requirements for monitoring and reporting.

(2) Regulations will be established based on the best available scientific information. As new information is developed, through monitoring, reporting, or research, the regulations may be modified, in whole or part, after notice and opportunity for public review.

(f) *Letters of Authorization.* (1) A Letter of Authorization, which may be issued only to U.S. citizens, is required to conduct activities pursuant to any specific regulations established. Requests for Letters of Authorization shall be submitted to the Director, U.S. Fish and Wildlife Service, Department of the Interior, Washington, DC 20240. The information to be submitted in a request may be obtained by writing the Director. Once specific regulations are effective, the Service will to the maximum extent possible, process subsequent applications for Letters of Authorization within 30 days after receipt of the application by the Service.

(2) Issuance of a Letter of Authorization will be based on a determination that the level of taking will be consistent with the findings made for the total taking allowable under the specific regulations.

(3) Notice of issuance of all Letters of Authorization will be published in the FEDERAL REGISTER within 30 days of issuance.

(4) Letters of Authorization will specify the period of validity and any additional terms and conditions appropriate for the specific request.

(5) Letters of Authorization shall be withdrawn or suspended, either on an individual or class basis, as appropriate, if, after notice and opportunity for public comment, the Director determines: (i) The regulations prescribed are not being substantially complied with, or (ii) the taking allowed is having, or may have, more

than a negligible impact on the species or stock, or where relevant, an unmitigable adverse impact on the availability of the species or stock for subsistence uses.

(6) The requirement for notice and opportunity for public review in paragraph (f)(5) of this section shall not apply if the Director determines that an emergency exists which poses a significant risk to the well-being of the species or stocks of marine mammals concerned.

(7) A violation of any of the terms and conditions of a Letter of Authorization or of the specific regulations may subject the Holder and/or any individual who is operating under the authority of the Holder's Letter of Authorization to penalties provided in the Marine Mammal Protection Act of 1972 (16 U.S.C. 1361–1407).

[48 FR 31225, July 7, 1983, as amended at 54 FR 40348, Sept. 29, 1989; 55 FR 28765, July 13, 1990; 56 FR 27463, June 14, 1991]

Subpart D—Special Exceptions

§ 18.30 Polar bear sport-hunted trophy import permits.

(a) *Application procedure.* You, as the hunter or heir of the hunter's estate, must submit an application for a permit to import a trophy of a polar bear taken in Canada to the U.S. Fish and Wildlife Service, Office of Management Authority, 4401 N. Fairfax Drive, Arlington, Virginia 22203. You must use an official application (Form 3–200) provided by the Service and must include as an attachment all of the following additional information:

(1) Certification that:

(i) You or the deceased hunter took the polar bear as a personal sport-hunted trophy;

(ii) You will use the trophy only for personal display purposes;

(iii) The polar bear was not a pregnant female, a female with dependent nursing cub(s) or a nursing cub (such as in a family group), or a bear in a den or constructing a den when you took it; and

(iv) For a polar bear taken after April 30, 1994, you made sure the gall bladder and its contents were destroyed;

(2) Name and address of the person in the United States receiving the polar bear trophy if other than yourself;

(3) For a polar bear received as an inheritance, documentation to show that you are the legal heir of the decedent who took the trophy;

(4) Proof that you or the decedent legally harvested the polar bear in Canada as shown by one of the following:

(i) A copy of the Northwest Territories (NWT) hunting license and tag number;

(ii) A copy of the Canadian CITES export permit that identifies the polar bear by hunting license and tag number;

(iii) A copy of the NWT export permit; or

(iv) A certification from the Department of Renewable Resources, Northwest Territories, that you or the decedent legally harvested the polar bear, giving the tag number, location (settlement and population), and season you or the decedent took the bear;

(5) An itemized description of the polar bear parts you wish to import, including size and the sex of the polar bear;

(6) The month and year the polar bear was sport hunted;

(7) The location (nearest settlement or community) where the bear was sport hunted;

(8) For a female bear or a bear of unknown sex that was taken before January 1, 1986, documentary evidence that the bear was not pregnant at the time of take, including, but not limited to, documentation, such as a hunting license or travel itinerary, that shows the bear was not taken in October, November, or December or that shows that the location of the hunt did not include an area that supported maternity dens; and

(9) For a female bear, bear of unknown sex, or male bear that is less than 6 feet in length (from tip of nose to the base of the tail) that was taken prior to the 1996/97 NWT polar bear harvest season, available documentation to show that the bear was not nursing, including, but not limited to, documentation, such as a certification from the NWT, that the bear was not taken while part of a family group.

53 FR 8473-02, 1988 WL 274588(F.R.)
PROPOSED RULES
DEPARTMENT OF THE INTERIOR
Fish and Wildlife Service
DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
50 CFR Parts 18, 228, and 402

Incidental Take of Endangered, Threatened and Other Depleted Marine Mammals

Tuesday, March 15, 1988

***8473** AGENCIES: Fish and Wildlife Service (FWS), Interior; National Marine Fisheries Service (NMFS), NOAA, Commerce.

ACTION: Proposed rule.

SUMMARY: Regulations are proposed to implement recent amendments to the Marine Mammal Protection Act of 1972 (MMPA) and Endangered Species Act of 1973 (ESA). These amendments provide a mechanism for allowing certain incidental takings of endangered, threatened and other depleted marine mammals. Previously, the incidental taking of depleted marine mammals was not allowable under the terms of the MMPA. This rule proposes to amend existing procedures governing incidental take authorizations.
DATE: Comments on the proposed rule must be received by May 16, 1988.

ADDRESSES: Comments should be submitted to the Director, Office of Protected Resources and Habitat Programs, National Marine Fisheries Service, Washington, DC 20235.

Documents supporting this proposed rule are available for review at the above address and the Division of Fish and Wildlife Management Assistance, U.S. Fish and Wildlife Service, Department of the Interior, Room 1430, Washington, DC 20240.

Comments on the information collection requirements of 50 CFR Part 228 should be submitted to the Office of Information and Regulatory Affairs of OMB, Washington, DC 20503, Attention Desk Officer for NOAA.

FOR FURTHER INFORMATION CONTACT:Patricia Montanio, Protected Species Management Division, Office of Protected Resources and Habitat Programs, NMFS, 202-673-5348, or Robert Peoples, Division of Fish and Wildlife Management Assistance, FWS 202-343-6307.

SUPPLEMENTARY INFORMATION:

Existing Requirements and Processes

FWS and NMFS share responsibilities under the MMPA (16 U.S.C. 1361 et seq.) and ESA (16 U.S.C. 1531 et seq.). Under the ESA, most marine species are under the jurisdiction of NMFS and all other species are under the jurisdiction of FWS. Under the MMPA, NMFS is responsible for species of the order Cetacea (whales and dolphins) and the suborder Pinnipedia (seals and sea lions) except walrus. FWS is responsible for the dugong, manatees, polar bear, sea and marine otters and walrus. Depending on the animals involved, the term "Service" used in this document may refer to FWS and/or NMFS.

Section 101(a)(5) of the MMPA allows for the incidental taking of marine mammals under certain circumstances; section 7(b)(4) of the ESA allows for the incidental taking of endangered and threatened species under certain circumstances. If a marine mammal species is listed as endangered or threatened under the ESA, the requirements of both the MMPA and ESA must be met before the incidental take can be allowed.

MMPA—Section 101(a)(5)

Under section 101(a)(5) of the MMPA, the Service can allow the taking of small numbers of marine mammals incidental to a specified activity (other than commercial fishing) within a specified geographical area. For the Service to consider allowing an incidental taking, a written request for specific regulations must be submitted to the Service containing detailed information on the activity in general and impacts of the total potential take. If the Service makes certain findings, specific regulations will be issued that, among other things, establish permissible methods of taking and other means of affecting the least ***8474** practicable adverse impact on the species. Requestors are advised that the regulatory process takes at least one year.

After regulations are issued, individual Letters of Authorization must be obtained from the Service by those conducting the activity. Only U.S. citizens are eligible to apply for Letters of Authorization.

Procedural regulations implementing this provision of the MMPA are found at 50 CFR 18.27 for FWS and at 50 CFR Part 228 for NMFS.

ESA—Section 7(b)(4)

Under section 7(a)(2) of the ESA, Federal agencies are required to consult with the Service on any action authorized, funded or carried out by such agencies that may affect endangered or threatened species or critical habitat. Although this consultation is primarily between a Federal agency and the Service, applicants for Federal licenses, permits or funding are encouraged to participate. The Federal agency initiates formal consultation by a written request to the Service that includes detailed information concerning the proposed action and its potential effects. Consultation should be concluded within 90 days.

After consultation, the Service issues its biological opinion which includes an assessment of impacts and its conclusion on whether or not the action is likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat. If the proposed action is not likely to result in jeopardy but may result in the taking of endangered or threatened species, the Service must issue an incidental take statement under section 7(b)(4). Compliance with the terms and conditions specified in the incidental take statement exempts the Federal agency and any permit or license applicant involved from the taking prohibitions of the ESA up to the level specified in the incidental take statement.

Joint FWS-NMFS regulations governing the section 7 consultation process are found in 50 CFR Part 402.

Summary of Amendments

Prior to amendment, section 101(a)(5) of the MMPA applied only to non-depleted species. Under section 3(1)(C) of the MMPA, all endangered and threatened marine mammals are by definition depleted. Since the more restrictive provisions of the MMPA prevail, the ESA provisions alone could not be used to authorize the incidental taking of endangered or threatened marine mammals, even if the anticipated take would result in only negligible impacts.

Public Law 99-659, Title IV, section 411 (approved November 14, 1986) amended section 101(a)(5) of the MMPA and made conforming changes to sections 7(b)(4) and 7(o) of the ESA. The primary change was to allow the taking of depleted as well as non-depleted species of marine mammals incidental to certain activities under certain conditions. The amendments also changed the conditions under which incidental taking can be allowed.

Impact on Species or Stock

In order to allow a taking under section 101(a)(5) of the MMPA, the Service must find that the total taking will have a negligible impact on the species or stock. The party seeking authorization has the burden to demonstrate, through the best scientific information available, that only a negligible impact is reasonably likely to occur.

The proposed definition of "negligible impact," which differs from the present definition, would implement the specific legislative intent behind Pub. L. 99-659 and is taken from the Senate Section by Section Analysis (see 132 Cong. Rec. S16304-5, October 15, 1986).

A finding of negligible impact means that the impact resulting from the specified activity cannot reasonably be expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival. This finding is made with reference to the marine mammal species or stock (as defined in section 2(10) of the MMPA) and not with reference to the effects on individual animals. If potential effects of a specified activity are conjectural or speculative, a finding of negligible impact may be appropriate. A finding of negligible impact may also be appropriate if the probability of occurrence is low but the potential effects may be significant. In this case, the probability of occurrence of impacts must be balanced with the potential severity of harm to the species or stock when determining negligible impact. In applying this balancing test, the Service will thoroughly evaluate the risks involved and the potential impacts on marine mammal populations. Such determinations will be made based on the best available scientific information.

Finally, if mitigating measures would render the impacts of a specified activity negligible when it would not otherwise satisfy that requirement, the Service may make a negligible impact finding subject to such mitigating measures being successfully implemented.

To properly interpret and implement the Senate Report language on "negligible impact," the Service believes that the analysis of any adverse effects to recruitment or survival must be conducted within the framework of the management goal to the MMPA, i.e., the maintenance or attainment of an optimum sustainable population (OSP) level for each population stock of marine mammals (see sections 2(2) and (6) of the MMPA). Therefore, the Service would generally apply the proposed definition of "negligible impact" in the following manner: if a request for specific regulations under section 101(a)(5) involves potential impacts to a "depleted" population, then a determination of negligible impact can be made only if the permitted activities are not likely to significantly reduce the increase of that population or prevent it from ultimately achieving its OSP; on the other hand, if a "nondepleted" population is involved, then a determination of negligible impact can be made only if the permitted activities are not likely to reduce that population below its OSP.

Impact on Habitat

The amendments deleted the required finding that the specified activity have only a negligible impact upon the marine mammal habitat. Under the previous standard, a minor impact to a small segment of habitat might be found to be more than negligible and the incidental take prohibited even if the overall impact on the species or stock utilizing the habitat was negligible. Nevertheless, impacts to rookeries, mating grounds, feeding areas and areas of similar significance could have adverse effects on the species or stock. Thus, impacts to habitat will be considered in making the finding of negligible impact to the species or stock. Further, even if the impact is determined to be negligible, specific regulations must include measures to ensure the least practicable adverse impact on the habitat.

Impact on Subsistence Uses

The amendments changed the standard used to evaluate the impact on subsistence uses from “negligible impact” to “not having an unmitigable adverse impact.” To determine that an unmitigable adverse impact to subsistence uses exists, two elements must be present. First, the impact resulting from the specified activities must be likely to reduce t he availability of the species to a level insufficient for a ***8475** harvest to meet subsistence needs by (1) causing the marine mammals to abandon or avoid hunting areas, (2) directly displacing subsistence users, or (3) placing physical barriers between the marine mammals and subsistence hunters. Second, it must be an impact that cannot be sufficiently mitigated by other measures to allow subsistence needs to be met.

In addition, the amendments require the specific regulations governing a specified activity to include measures to ensure the least practicable adverse impact on the availability of the species for subsistence uses, even if the activity will not otherwise have an unmitigable adverse impact. These mitigating measures are intended to allow the harvest of enough animals to meet subsistence needs and to minimize impacts on the species or stock and subsistence users. Those conducting the specified activity, the involved Federal agencies, and the affected subsistence users are encouraged to meet and develop mutually agreeable conditions which satisfy the operational, scientific or other needs of the activity and the requirements of the subsistence users.

Coordination Between the ESA and MMPA

Another purpose of the amendments of the MMPA and the ESA was to clarify the relationship between these statutes so that decision processes under each would be coordinated and integrated to the maximum extent practicable. The ESA alone does not provide authority for the incidental taking of endangered or threatened marine mammals, even if the anticipated take would not jeopardize the species or population. To ensure coordination with the MMPA, section 7(b)(4) of the ESA was amended to require that the incidental take of endangered or threatened marine mammals not be authorized until the MMPA section 101(a)(5) process is completed and measures necessary to comply with the MMPA authorization are specified in the ESA incidental take statement. Therefore, in addition to reasonable and prudent measures to minimize the impact of the incidental take, an incidental take statement will include measures which are required to comply with section 101(a)(5) of the MMPA and applicable regulations.

The difficulty of coordinating the ESA consultation and MMPA exemption processes is that section 7(b)(1)(A) of the ESA generally requires that consultation be completed within 90 days while the MMPA regulatory process is much longer. Since Congress intended that the ESA consultation process proceed in a timely manner, the Service will issue the biological opinion and, if appropriate, issue an incidental take statement prior to completion of the MMPA section 101(a)(5) process. However, no incidental take of marine mammals would be allowed under authority of the ESA until the findings and conditions in the incidental take statement were subsequently revised to reflect the outcome of the MMPA section 101(a)(5) process.

To reduce the timing discrepancy between th e two processes, the MMPA section 101(a)(5) process should be initiated well in advance of the ESA section 7 process. In this way, the MMPA requirements can be incorporated into the incidental take statement when the biological opinion is issued and subsequent revisions would not be necessary. As an alternative, the Federal agency and the Service may agree to extend the consultation under section 7(b)(1)(A) to accommodate completion of the section 101(a)(5) regulations. The consent of any permit or license applicant is required for an extension of more than 60 days.

Section 7(o) of the ESA

Section 7(o)(2) of the ESA, as amended, specifies that any taking in compliance with the terms and conditions of an incidental take statement is not a prohibited taking under the ESA. No other ESA permit or authorization is required of the Federal agency or applicant in carrying out the action if the incidental take statement applies and if the action complies with the terms and conditions of that statement. The biological opinion plus the incidental take statement operate as an exemption under section 7(o)(2) of the ESA. A new § 402.14(i)(5) is proposed to clarify this provision.

For example, section 10(a) of the ESA allows the Service to issue permits for the taking of endangered species incidental to an otherwise lawful non-Federal action within the United States and its territorial sea, subject to certain conditions. In 1982, Congress added this provision to allow incidental taking associated with private actions that are not subject to the section 7 consultation process. If an endangered or threatened marine mammal may be taken incidentally to a private action, regulations under section 101(a)(5) of the MMPA would be required. Consultation under section 7 of the ESA would be conducted since issuance of the MMPA regulations is a Federal action. The incidental take statement issued with the biological opinion would address taking concerns under the ESA, and a section 10 permit would not be required.

Proposed Regulatory Changes

These regulations propose to amend 50 CFR Parts 18, 228 and 402 to implement the above changes to section 101(a)(5) of the MMPA and sections 7(b)(4) and 7(o) of the ESA. Basic processes for authorizing incidental take under both ESA and MMPA remain the same; the primary changes are (1) allowing the incidental take of depleted marine mammals, and (2) changing the findings that must be made to allow a take.

Classification

The Department of the Interior, as lead agency, has prepared a draft environmental assessment on this proposed rule. A determination will be made at the time of the final rule as to whether or not this is a major Federal action significantly affecting the quality of the human environment within the meaning of section 102(2)(C) of the National Environmental Policy Act of 1 969 (NEPA). The proposed regulations are procedural and, by themselves, do not authorize the taking of depleted marine mammals. Issuance of specific regulations under section 101(a)(5) of the MMPA allowing a taking would require compliance with NEPA, including the preparation of a separate environmental assessment or impact statement, if required.

It has been determined that these regulations do not constitute a major rule as defined in Executive Order 12291. The Department of the Interior has certified under the terms of the Regulatory Flexibility Act (5 U.S.C. 601 et seq.) that the proposed regulations will not have a significant economic impact on a substantial number of small entities. The proposed amendments or rules governing the take of small numbers of marine mammals incidental to specified activities will have little, if any, economic effect. Direct costs will be those associated with subsequent preparation of applications for “Specific Regulations” and “Letters of Authorization.” However, those costs are not likely to approach the $100 million annual threshold for these rules to be considered a major rule in accordance with E.O. 12291. As most of the applicants under the revised rule, as at present, are likely to be oil and gas corporations and their contractors, they would not be considered small entities under the Regulatory Flexibility Act.

The regulations in 50 CFR Parts 18 and 228 contain a collection of information requirement subject to Office Management and Budget (OMB) clearance under the Paperwork ***8476** Reduction Act (44 U.S.C. 3501 et seq.). The information collection requirement associated with the amendment of Part 18 contained in this proposed rule has been approved by the Office of Management and Budget under 44 U.S.C. 3501 et seq. and assigned clearance number 1018-0070. The information requirement in Part 228 is approved under OMB control number 0648-0151. The amendment of Part 402 does not contain information collection requirements requiring OMB approval under the Paperwork Reduction Act.

The analyses under NEPA, E.O. 12291 and the Regulatory Flexibility Act are available for review (see ADDRESSES).

The primary authors of this proposal are Robert Peoples, Nancy Sweeney, and Michael Young, Department of the Interior, and Patricia Montanio and Gene Martin, Department of Commerce.

List of Subjects

50 CFR Part 18
Administrative practice and procedure, Alaska, Exports, Imports, Intergovernmental relations, Marine mammals, Transportation.

50 CFR Part 228
Administrative practice and procedure, Marine mammals, Outer continental shelf oil and gas exploration.

50 CFR Part 402
Endangered and threatened wildlife, Fish, Intergovernmental relations, Plants (agriculture).

Proposed Regulation Promulgation
Accordingly, the Service proposes to amend 50 CFR Parts 18, 228 and 402 as shown below.

PART 18—MARINE MAMMALS
1. The authority citation for 50 CFR Part 18 is revised to read as follows:

Authority: 16 U.S.C. 1361 et seq.
50 CFR § 18.27
2. In § 18.27, paragraph (a) is amended by removing the words "Pub. L. 97-58" and "non-depleted"; paragraph (b), including the note following that paragraph, is revised; in paragraph (c), the definition of "negligible impact" is revised, the definition of "specified activity" is amended by removing the word "non-depleted" wherever it occurs, and a new definition for "unmitigable adverse impact" is added in alphabetical order; paragraph (d) is amended by removing the word "non-depleted" wherever it appears; and paragraphs (d)(3), (e)(1), (f)(2), and (f)(5)(ii) are revised, to read as follows:
50 CFR § 18.27

§ 18.27 Regulations governing small takes of marine mammals incidental to specified activities.
* * * * *
(d) Scope of regulations. The taking of small numbers of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act may be allowed only if the Director of the Fish and Wildlife Service:

(1) Finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses;

(2) Prescribes regulations setting forth permissible methods of taking and other means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance; and

(3) Perscribes regulations pertaining to the monitoring and reporting of such taking.

Note: The information collection requirement contained in this § 18.27 has been approved by the Office of Management and Budget under 44 U.S.C. 3501 et seq. and assigned clearance No. 1018-0070. The information is being collected to describe the activity proposed and estimate the cumulative impacts of potential takings by all persons conducting the activity. The information will be used to evaluate the application and determine whether to issue Specific Regulations and, subsequently, Letters of Authorization. Response is required to obtain a benefit.

(c) * * *

“Negligible impact” is an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.
* * * * *
“Unmitigable adverse impact” means an impact resulting from the specified activity (1) that is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mam mals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to allow subsistence needs to be met.

(d) * * *

(3) The Director shall evaluate each request to determine, based on the best available scientific evidence, whether the total taking will have a negligible impact on the species or stock and, where appropriate, will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses. If the Director finds that mitigating measures would render the impact of the specified activity negligible when it would not otherwise satisfy that requirement, the Director may make a finding of negligible impact subject to such mitigating measures being successfully implemented. Any preliminary finding of negligible impact shall be proposed for public comment along with the proposed specific regulations.

(e) * * *

(1) Specific regulations will be established for each allowed activity which set forth (i) permissible methods of taking, (ii) means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, and (iii) requirements for monitoring and reporting.
* * * * *
(f) * * *

(2) Issuance of a Letter of Authorization will be based on a determination that the level of taking will be consistent with the findings made for the total taking allowable under the specific regulations.
* * * * *
(5) * * *

(ii) The taking allowed is having, or may have, more than a negligible impact on the species or stock, or where relevant, more than an unmitigable adverse impact on the availability of the species or stock for subsistence uses.
* * * * *

PART 228—REGULATIONS GOVERNING SMALL TAKES OF MARINE MAMMALS INCIDENTAL TO SPECIFIED ACTIVITIES

3. The authority citation for 50 CFR Part 228 is revised to read as follows:

Authority: 16 U.S.C. 1361 et seq.
50 CFR § 228.1

§ 228.1 [Amended]
50 CFR § 228.1

4. Section 228.1 is amended by removing the words “Pub. L. 97-58” and “non-depleted.”
50 CFR § 228.2
5. Section 228.2 is revised to read as follows:
50 CFR § 228.2

§ 228.2 Scope.
The taking of small numbers of marine mammals under section 101(a)(5) of the Marine Mammal Protection Act may be ***8477** allowed only if the National Marine Fisheries Service:

(a) Finds, based on the best scientific evidence available, that the total taking during the specified time period will have a negligible impact on the species or stock and will not have an unmitigable adverse impact on the availability of the species or stock for subsistence uses;

(b) Prescribes regulations setting forth permissible methods of taking and o ther means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance; and

(c) Prescribes regulations pertaining to the monitoring and reporting of such taking. The specific regulations governing specified activities are contained in subsequent subparts to this Part 228.
50 CFR § 228.3
6. In § 228.3, the definition of “negiligible impact” is revised; the definition of “specified activity” is amended by removing the word “non-depleted” wherever it occurs; and a new definition for “unmitiagble adverse impact” is added in alphabetical order, to read as follows:
50 CFR § 228.3

§ 228.3 Definitions.
* * * * *
“Negligible impact” is an impact resulting from the specified acivity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.
* * * * *
“Unmitigable adverse impact” means an impact resulting from the specified activity (1) that is likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by (i) causing the marine mammals to abandon or avoid hunting areas, (ii) directly displacing subsistence users, or (iii) placing physical barriers between the marine mammals and the subsistence hunters; and (2) that cannot be sufficiently mitigated by other measures to allow subsistence needs to be met.
50 CFR § 228.4
7. § In § 228.4, paragraph (a) is amended by removing the word “non-depleted” wherever it appears, and paragraph (c) is revised to read as follows:
50 CFR § 228.4

§ 228.4 Submission of requests.
* * * * *
(c) The Assistant Administrator shall evaluate each request to determine, based on the best available scientific evidence, whether the total taking will have a negligible impact on the species or stock and, where appropriate, will not have an unmitigable adverse impact on the availability of such species or stock for subsistence uses. If the Assistant Administator finds that mitigating measures would render the impact of the specified activity negligible when it would not otherwise satisfy that requirement, the Assistant Administrator may make a finding of negligible impact subject to such mitigating measures being successfully implemented. Any preliminary finding of negligible impact shall be proposed for public comment along with the proposed specified regulations.
50 CFR § 228.5

8. In § 228.5, paragraph (a) is revised to read as follows:
50 CFR § 228.5

§ 228.5 Specific regulations.
(a) Specific regulations will be established for each allowed activity which set forth (1) permissible methods of taking, (2) means of effecting the least practicable adverse impact on the species and its habitat and on the availability of the species for subsistence uses, and (3) requirements for mon itoring and reporting.
* * * * *50 CFR § 228.6
9. In § 228.6, paragraphs (b) and (e)(2) are revised to read as follows:
50 CFR § 228.6

§ 228.6 Letters of authorization.
* * * * *
(b) Issuance of a Letter of Authorization will be based on a determination that the level of taking will be consistent with the findings made for the total taking allowable under the specific regulations.
* * * * *
(e) * * *

(2) The taking allowed is having, or may have, more than a negligible impact on the species or stock, or, where relevant, more than an unmitigable adverse impact on the availability of the species or stock for subsistence uses.
* * * * *

PART 402—INTERAGENCY COOPERATION—ENDANGERED SPECIES ACT OF 1973, AS AMENDED
10. The authority citation for Part 402 continues to read as follows:

Authority: 16 U.S.C. 1531 et seq.
50 CFR § 402.14
11. In § 402.14, paragraph (i)(1) is revised, the second sentence of paragraph (i)(3) is revised, and a new paragraph (i)(5) is added, to read as follows:
50 CFR § 402.14

§ 402.14 Formal consultation.
* * * * *
(i) * * *

(1) In those cases where the Service concludes that an action (or the implementation of any reasonable and prudent alternatives) and the resultant incidental take of listed species will not violate section 7(a)(2), and, in the case of marine mammals, where the taking is authorized pursuant to section 101(a)(5) of the Marine Mammal Protection Act of 1972, the Service will provide with the biological opinion a statement concerning incidental take that:

(i) Specifies the impact, i.e., the amount or extent, of such incidental taking on the species;

(ii) Specifies those reasonable and prudent measures that the Director considers necessary or appropriate to minimize such impact;

(iii) In the case of marine mammals, specifies those measures that are necessary to comply with section 101(a)(5) of the Marine Mammal Protection Act of 1972 and applicable regulations with regard to such taking;

(iv) Sets forth the terms and conditions (including, but not limited to, reporting requirements) that must be complied with by the Federal agency or any applicant to implement the measures specified under paragraphs (i)(l)(ii) and (i)(l)(iii) of this section; and

(v) Specifies the procedures to be used to handle or dispose of any individuals of a species actually taken.
* * * * *
(3) * * * The reporting requirements will be established in accordance with 50 CFR 13.45 and 18.27 for FWS and 50 CFR 220.45 and 228.5 for NMFS.
* * * * *
(5) Any taking which is subject to a statement as specified in paragraph (i)(l) of this section and which is in compliance with the terms and conditions of that statement is not a prohibited taking under the Act, and no other authorization or permit under the Act is requ ired.
* * * * *
Dated: January 4, 1988.

William P. Horn,

Assistant Secretary, Fish and Wildife and Parks, Department of the interior.

Dated: February 16, 1988.

William E. Evans,

Assistant Administrator for Fisheries, National Oceanic and Atmospheric Administration.

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Factors Influencing the Efficacy of Forward-Looking Infrared in Polar Bear Den Detection

RUSTY ROBINSON, TOM S. SMITH, RANDY T. LARSEN, AND BJ KIRSCHHOFFER

Female polar bears construct maternal dens in snowdrifts in autumn. Forward-looking infrared (FLIR) has been used to locate dens to prevent disruption of denning by human activities, but the results have been mixed. To identify limitations and optimal conditions for locating dens, we took handheld FLIR images of three artificial dens under varied conditions. We tested variables hypothesized to influence detectability with linear models using the zero-inflated negative binomial distribution. Solar radiation, wind speed, and den wall thickness reduced the likelihood of detecting dens. The negative effect of wind speed on detectability increased with increasing distance. To maximize the efficacy of ground-based FLIR, den surveys should be conducted when solar radiation is less than 16 watts per square meter (night) and when wind speed is less than 10 kilometers per hour. Adherence to these guidelines will maximize the protection that FLIR can afford to denning bears.

Keywords: Alaska, handheld FLIR, maternal den, polar bear, Ursus maritimus

Pregnant polar bears in the southern Beaufort Sea and the adjoining coastal areas use dens from October through November (Amstrup and Gardner 1994). Cubs are born in midwinter and remain at the den until March or April (Blix and Lentfer 1979, Amstrup 1993, Amstrup and Gardner 1994, Smith et al. 2007). A disturbance while den sites are active may have greater negative effects on survival and reproduction than one at any other time of year (Linnell et al. 2000). Disturbance may result in displacement, exposure to the elements and predation, family dissolution, and cub abandonment and subsequent death. Consequently, the ability of scientists to identify den sites is key to limiting negative influences from disturbance.

Expanding petroleum exploration along Alaska's North Slope area coupled with a shift to terrestrial dens (Amstrup and Gardner 1994, Fischbach et al. 2007) heightens the likelihood of bear–human interactions. Furthermore, industry can be required to limit or cease activities in the vicinity of known dens or can be fined for den disturbance by the US Fish and Wildlife Service, the regulatory agency tasked with managing polar bears. Consequently, much work has been done to identify and map suitable denning habitat in order to avoid potential conflicts with and to mitigate the disturbance of polar bears (Amstrup 1993, Durner et al. 2001, 2003, Blank 2012). Denning habitat occurs in areas such as riverbanks and coastal bluffs, where drifting snow accumulates (Amstrup 1993, Amstrup and Gardner 1994, Durner et al. 2001, 2003). Forward-looking infrared (FLIR) has been used to survey denning habitat and locate dens prior to constructing ice roads and other production efforts (Amstrup et al. 2004).

FLIR imagers can be mounted on vehicles (e.g., aircraft, trucks, track vehicles) or can be handheld; these platforms have proven to be useful for identifying and locating polar bear dens. FLIR imagers are capable of detecting the very slight temperature differences (changes as small as 0.01 degree Celsius [°C]) on the surface of a snow bank resulting from denned polar bears (Amstrup et al. 2004). Temperature differences are shown in the imager's display as varying shades of color, with lighter colors representing warmer temperatures. In the FLIR imager, polar bear dens generally appear as light-colored hot spots, with soft edges that gradate into the surrounding darker, colder terrain (see figure 2 in Amstrup et al. 2004). To optimize den detectability with handheld FLIR, it is important to identify factors that influence the image quality. Although atmospheric conditions (i.e., relative humidity, temperature, dew point, precipitation, wind) have been known to influence the effectiveness of aerial FLIR when they are used for den detection, the critical thresholds for detection have not been identified (Amstrup et al. 2004). The purpose of the present study is to model the variables that influence the ability of handheld FLIR to detect dens and to identify the optimal conditions for conducting polar bear den surveys with handheld FLIR.

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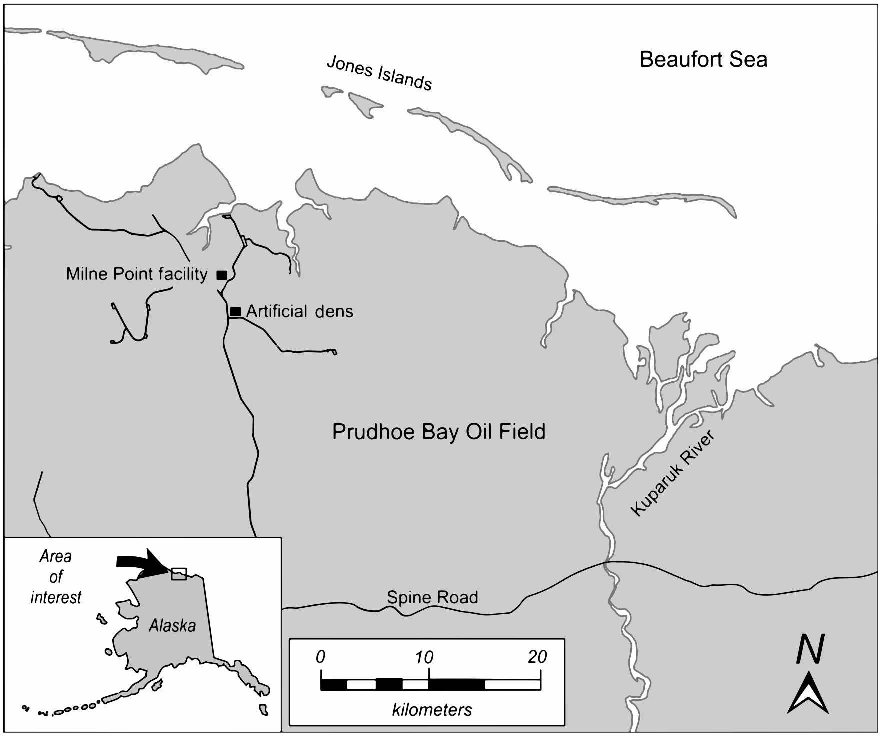

Figure 1. Study area south of Milne Point, Alaska, where artificial den forward-looking infrared sampling took place in March 2010.

The study area was located west of Prudhoe Bay, Alaska, in the Prudhoe Bay oil field. This area is composed largely of BP (formerly British Petroleum) lease lands that have been developed for oil exploration and production, including scattered gravel pads and industrial facilities, linked by 4800 kilometers (km) of pipeline and roads. Our study took place approximately 1.6 km south of the BP Milne Point processing facility (70.4587 degrees north, 149.4414 degrees west; figure 1). For the construction of artificial dens for this study, we selected a snowdrift approximately 60 meters (m) long and 4 m high. The artificial dens were excavated approximately 20 m from a small, unheated structure that provided electricity for den heaters.

Excavating dens

In February 2010, we excavated three artificial polar bear dens with initial snow wall thicknesses of 25, 50, and 75 centimeters (cm) in a south-facing snowdrift. To construct these dens, we excavated from the top of the drift down 2 m using snow shovels and snow saws. The initial dimensions of each den were approximately 1 × 1 × 2 m (figure 2). The dens were excavated 3 m apart (from edge to edge). We placed a 200-watt ceramic heater in each den, simulating the heat generated by a denning polar bear (Watts 1983). We used measuring sticks to monitor changes in den wall thickness throughout the sampling period as snow depth changed because of wind and snowfall. Each measuring stick had a stopper on the end inside the den that we pulled tight against the inner wall after the dens had melted to a stable size and before any sampling began. For the duration of the study, the den chamber access shafts were sealed with plywood lids over which snow was backfilled for insulation. After turning the heaters on, we allowed the den temperatures to stabilize for 2 weeks (a conservative time frame based on previous trials that we had performed) prior to sampling. We began sampling den heat loss with FLIR on 11 March 2010. After the study was concluded, we opened the dens and ensured that the stoppers were still against the inner wall and that the wall thickness measurements were accurate.

Den sampling

Using a FLIR ThermaCAM P65HS thermal imager (FLIR Systems, Boston, Massachusetts) with a 72 millimeter infrared lens, we sampled one or more times daily (mean [*M*] = 3). Sampling was scheduled at stratified intervals with consideration of *solar time*, the time relative to the sun's position in the sky, thus was the variation in solar radiation accounted for (figure 3). During each sample period, we recorded images from three distances: 60 m, the minimum distance that the US Fish and Wildlife Service allowed (through permit MA225854) for handheld FLIR surveys for polar bear dens; 100 m; and 200 m. A laser rangefinder was used to determine the distance. To ensure accurate thermal readings, we entered the required parameters into the imager settings, including the air temperature, the relative humidity, the distance, the emissivity, and the reflected temperature, before each sampling period. Excluding these parameters does not affect the visual appearance of the image that is saved to the imager but does affect the accuracy of specific pixel temperatures used in later analysis. The air temperature and relative humidity were determined using a Kestrel 3000 weather meter (Nielsen-Kellerman, Birmingham, Michigan). *Emissivity*, a measure of a substance's ability to release thermal energy, was set to .85 for snow, as was specified by the manufacturer of the FLIR device. The reflected temperature was calculated according to the FLIR manual instructions by facing the FLIR imager in the opposite direction of the snowdrift, setting the emissivity to 1, adjusting to near focus, saving an image, and using the box function to calculate an average temperature. In addition to air temperature and relative humidity, we recorded the wind speed and the temperature–dew point spread (the dew point subtracted from the air temperature) with the same weather meter, placed at the 100-m sampling location at the same height as the FLIR imager. The presence of precipitation was noted, and the solar radiation data were provided by a research weather

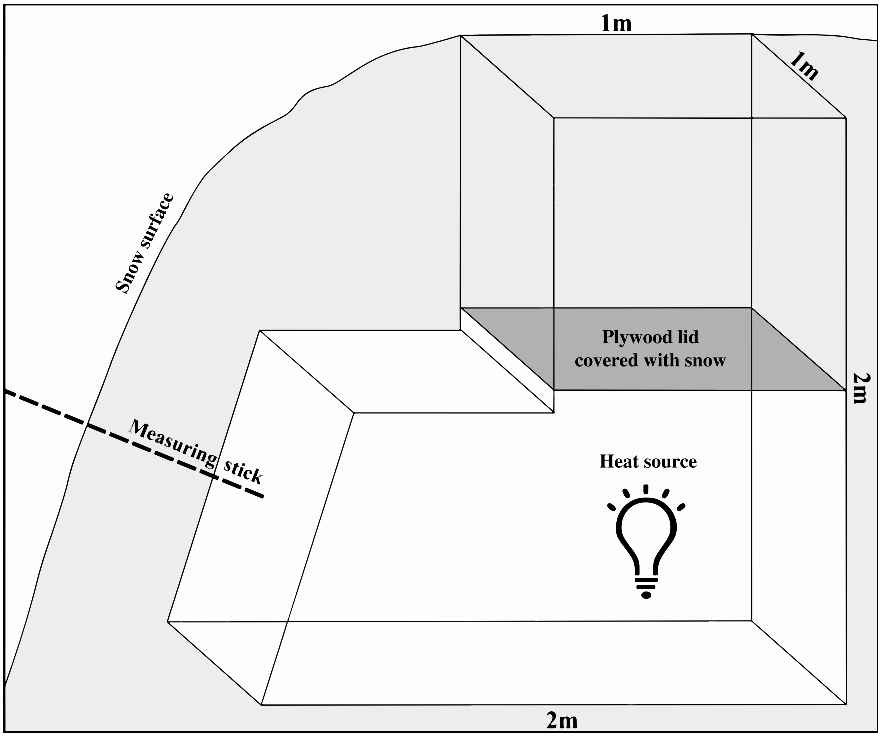

Figure 2. Artificial snow den structure used to test the efficacy of handheld forward-looking infrared for detecting polar bear maternal dens. The shaded area represents snow cover. Abbreviation: m, meters.

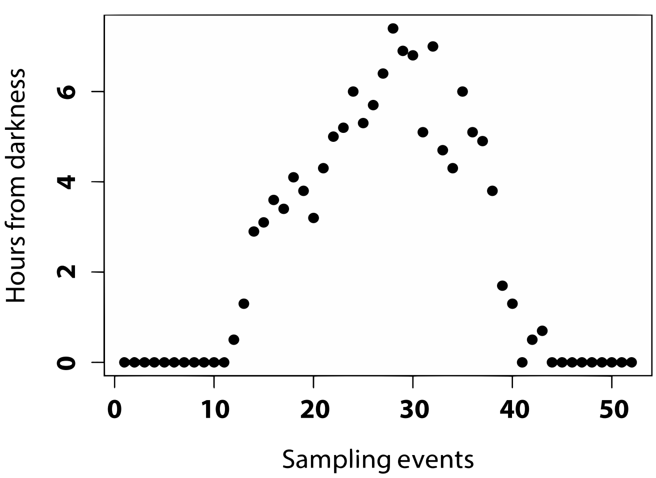

Figure 3. Sampling time distribution in relation to solar time used in forward-looking infrared sampling of artificial dens.

station at BP's F-Pad facility, 11 km from the study site, after the handheld sensor that we were using had failed. The solar sensors at the weather station were oriented horizontally, not perpendicular to the frontal slope of the artificial dens, but still gave consistent and reliable readings relative to the solar radiation received at the den sites. Resting the imager on posts marking each sample distance, we recorded images at each distance. The den wall thickness was recorded by walking along the top of the snowdrift and peering over the side of the drift to view the measuring stick protruding from each den. These measurements were taken directly after the conclusion of each sampling event to ensure that the thermal properties of the dens were not disturbed before or during sampling. We never walked on or otherwise disturbed the surface of the drift being sampled.

After data collection, we downloaded the images and assigned each a detectability score. We first determined whether a hot spot was detectable to the human eye in each sample image. If it was not, the image was automatically given a detectability score of 0. If a hot spot was visible, we calculated the detectability score using FLIR Quick Report (FLIR Systems), a software package used to organize and analyze thermal images taken with FLIR cameras. The software features an area tool that highlights an area of interest and exports temperature data for each pixel. We created a rectangle that encompassed a typical hot spot at each distance (26 × 41 pixels for 60 m, 21 × 28 for 100 m, 12 × 16 for 200 m). This rectangle was centered over each hot spot and the pixel temperatures were exported for the next step of the analysis. The mean background temperature of the surrounding snowdrift was determined in the same manner. To determine a detectability score for each hot spot, we subtracted the mean background temperature of the snowdrift from the temperature of each pixel within the hot spot to calculate the total change in temperature for all of the pixels within the hot spot, thus generating a sum total temperature above background for each den image (i.e., the detectability score).

Statistical analysis

We were unable to identify the den's hot spot (i.e., the detectability score was 0) in many images. As a result, we used linear models with the zero-inflated negative binomial distribution for the error structure in our modeling. Advances with linear models that use zero-inflated distributions (e.g., zero-inflated negative binomial or zero-inflated Poisson distribution) provide a solution to count data with excess zeroes (Lambert 1992, Welsh et al. 1996). With these models, one can evaluate the influence of explanatory variables on both the count response and the probability of a zero count. Zero-inflated models estimate a point mass at zero in addition to standard distributional estimates and have been successfully used with ecological data in a variety of settings (Welsh et al. 1996, Martin et al. 2005, Arab et al. 2008). These methods

Table 1a. Supported models (W_i > 0.01) for the detectability (count) analysis, artificial den forward-looking infrared sampling at Prudhoe Bay, Alaska, March 2010.

Model number	Variables	AICc	ΔAICc	W_i
26	Precipitation, solar radiation, wind speed	468.65	0.00	0.74
28	Solar radiation, den wall thickness, wind speed	471.14	2.49	0.21
16	Precipitation, solar radiation	475.37	6.72	0.03
32	Precipitation, solar radiation, temperature–dew point spread	476.81	8.16	0.01

Abbreviations: AICc, Akaike's information criterion adjusted for a small sample size; ΔAICc, the change in the AICc value compared with the top model; W_i, the AICc weight.

Table 1b. Supported models (W_i > 0.01) for the distance analysis, artificial den forward-looking infrared sampling at Prudhoe Bay, Alaska, March 2010.

Model number	Variables	AICc	ΔAICc	W_i
9	Precipitation, wind speed	794.80	0.00	0.15
1	Wind speed	794.86	0.06	0.15
10	Humidity, wind speed	795.59	0.79	0.10
8	Solar radiation, wind speed	796.42	1.61	0.07
23	Precipitation, temperature–dew point spread, wind speed	796.42	1.62	0.07
29	Humidity, precipitation, wind speed	796.61	1.8	0.06
11	Den wall thickness, wind speed	796.81	2.01	0.06
30	Precipitation, den wall thickness, wind speed	796.85	2.04	0.06
7	Temperature–dew point spread, wind speed	796.97	2.16	0.05
26	Precipitation, solar radiation, wind speed	796.98	2.17	0.05
24	Humidity, temperature–dew point spread, wind speed	797.55	2.75	0.04
31	Humidity, den wall thickness, wind speed	797.62	2.82	0.04
27	Humidity, solar radiation, wind speed	797.75	2.94	0.04
22	Solar radiation, temperature–dew point spread, wind speed	798.35	3.55	0.03
28	Solar radiation, den wall thickness, wind speed	798.42	3.61	0.03
25	Temperature–dew point spread, den wall thickness, wind speed	798.95	4.15	0.02

Abbreviations: AICc, Akaike's information criterion adjusted for a small sample size; ΔAICc, the change in the AICc value compared with the top model; W_i, the AICc weight.

reduce bias in the parameter estimates associated with large numbers of zeroes.

To assess the influence of factors on detectability, we used an information-theoretic approach, Akaike's information criterion, adjusted for small sample size, to rank the models (Akaike 1973, Burnham and Anderson 2002). We constructed 40 models in total (table 1a and 1b) by including permutations of the six variables of interest (solar radiation, wind speed, den wall thickness, relative humidity, temperature–dew point spread, and the presence of precipitation) while excluding models with more than three variables (the maximum allowable number of parameters) and one model with a convergence error. We then averaged over all of the models for each den using the MuMin package (*http://cran.r-project.org/web/packages/MuMIn/index.html*) and the glmmADMB package (*http://glmmadmb.r-forge.r-project.org*) in the R programming language (version 2.10.0, R Foundation for Statistical Computing, Vienna, Austria) to evaluate the direction and strength of associations between the explanatory variables and den detectability. We also used the pscl (*http://pscl.stanford.edu*), calibrate (*http://CRAN.R-project.org/package=calibrate*), and MASS (*http://cran.r-project.org/web/packages/MASS/index.html*) packages in R to perform the analyses. This modeling was performed only with the 100-m data. The images taken from 60 and 200 m were used to analyze the effects of each variable as distance increased.

As the sampling distance changed, variation in the detectability coefficients largely became a function of the number of pixels within the standardized area-tool rectangle used for each distance instead of actual trends. As a result, it became necessary to exclude distance as a variable of interest in our modeling approach and to analyze it separately. The same models and methods were used for this analysis (table 1b), but it included only den images that contained hot spots visible to the human eye (n = 102), so we did not

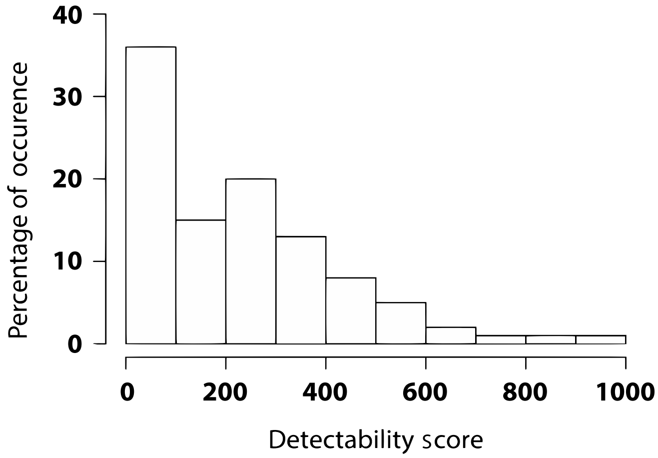

Figure 4. Detectability scores from the forward-looking infrared imaging samples at a 100-meter distance.

include a zero-inflated portion in this modeling approach. Forty-one models were included in this analysis. As the distance increased between an artificial den and the FLIR imager, the atmospheric effects also increased. To account for this in our analysis, we compared declines in the actual detectability score with the score declines that would be expected without atmospheric effects. Because an image taken at 200 m contains only 30% of the pixels that are contained in a 60 m image (60 ÷ 200), the detectability score at 200 m would be 30% of the 60 m score. To determine the relative influence of atmospheric conditions, we calculated the percentage of actual score decline compared with the predicted score decline without atmospheric influence by dividing the actual score decline (200 m score ÷ 60 m score) by the predicted score decline (0.30). Therefore, a lower percentage would theoretically signify a greater effect of atmospheric conditions on the detectability of the hot spot. We averaged over all of the models and assessed each variable for significance ($\alpha = .05$). We also analyzed the effect of den wall thickness on detectability by regressing the detectability scores and the den wall thickness to estimate the thresholds of detection.

Modeling of covariates

Over a period of 19 days, we conducted 52 sampling sessions. All three dens were measured during each sampling period. The detectability scores ranged from 0 to 927, although 33% of the sample images yielded a detectability score of 0. The resulting frequency histograms of detectability scores were typical of those associated with zero-inflated data (figure 4). The solar radiation ranged from 0 to 320.3 watts per square meter (W/m^2), the wind speed ranged from 2.4 to 32.5 km per hour, precipitation was present during 19 sampling events, the relative humidity ranged from 68.8% to 86.2%, the den wall thickness ranged from 30 to 80 cm, and the temperature–dew point spread ranged from 0.5°C to 9.3°C during the sampling period.

After reopening the dens at the conclusion of the study, we found that all three dens had melted out to similar volume approximations (M = 3.32 m^3, standard deviation [SD] = 0.14) because of heater effects and were within the range of natural den chambers previously reported in the southern Beaufort Sea and eastern Canada (Harington 1968, Durner et al. 2003). In addition, we noted that a 2.5-cm-thick ice lens had formed on the inner surface of each chamber, which also occurs in actual polar bear dens (Harrington 1968, Durner et al. 2003).

The best-fit model for detectability was the same for each den and included solar radiation, wind speed, and the presence of precipitation (table 1a). Wind speed was negatively correlated ($p < .01$) with detectability. Solar radiation was negatively correlated with detectability in den 1 ($p < .01$) but not in dens 2 and 3. The den wall thickness was negatively correlated with detectability in den 3 ($p < .05$) but not significantly in dens 1 and 2. The temperature–dew point spread and relative humidity were positively correlated with detectability, but only the temperature–dew point spread correlation was significant ($p < .05$) and only in den 1. In the zero-inflated portion of this model, wind speed, solar radiation, den wall thickness, and temperature–dew point spread were positively correlated with the probability of a 0 score. However, the only variables for which there was a significant effect were solar radiation ($p < .01$) in all three dens and den wall thickness ($p < .05$) in dens 1 and 3. Thickness was strongly correlated with detectability in den 2 ($p < .1$). Humidity and the presence of precipitation were negatively correlated with the probability of obtaining a zero score, neither of which was significant.

After averaging the coefficients of all three den analyses, we found that there were significant effects for solar radiation, wind speed, and den wall thickness (table 2). Solar radiation negatively affected the detectability scores for the count portion of the models (figure 5), with a 1-W/m^2 increase in solar radiation decreasing detection by a factor of 0.998 ($p < .05$). In the zero-inflated portion of the models, solar radiation was positively correlated with obtaining a 0 score, with a 1-W/m^2 increase in solar radiation increasing the odds of a den receiving a 0 score (i.e., of not being detected) by a factor of 1.027 ($p < .01$). Wind speed was negatively correlated with detectability in the count portion of the model (figure 6), with a 1-km-per-hour increase in wind speed decreasing den detection by a factor of 0.954 ($p < .01$). Den wall thickness was positively correlated with the probability of a 0 score. A 1-cm increase in den wall thickness increased the odds of a den receiving a 0 score by a factor of 1.485 ($p < .05$). We found the mean point of den wall thickness at which the dens became undetectable to be 90 cm.

For the distance portion of the analysis, the best-fit model included wind speed and precipitation. Wind speed was the only variable that was significant (figure 7). It was negatively correlated with detectability and was included in all

Table 2. Model-averaged coefficients with associated p*-values from forward-looking infrared sampling of artificial polar bear dens at Prudhoe Bay, Alaska, March 2010.*

	Count				Zero-inflation			
Variable	**Estimate**	**Standard error**	***z***	***p***	**Estimate**	**Standard error**	***z***	***p***
Intercept	6.54	0.57	17.54	$<2e^{-16}$	–6.61	9.27	0.97	.37
Wind speed	–0.05	0.01	3.98	<.01	0.04	0.12	0.37	.71
Solar radiation	$-1.86e^{-03}$	0.00	2.10	<.05	0.03	0.01	3.08	<.01
Precipitation	–0.16	0.19	0.77	.47	–22.61	5045.00	$4.33e^{-03}$	1.00
Temperature–dew point spread	0.09	0.05	1.78	.08	0.01	0.49	0.22	.83
Humidity	0.85	2.82	0.30	.76	–22.28	21.07	1.01	.35
Den wall thickness	–0.04	0.03	1.30	.30	0.36	0.17	2.03	<.05

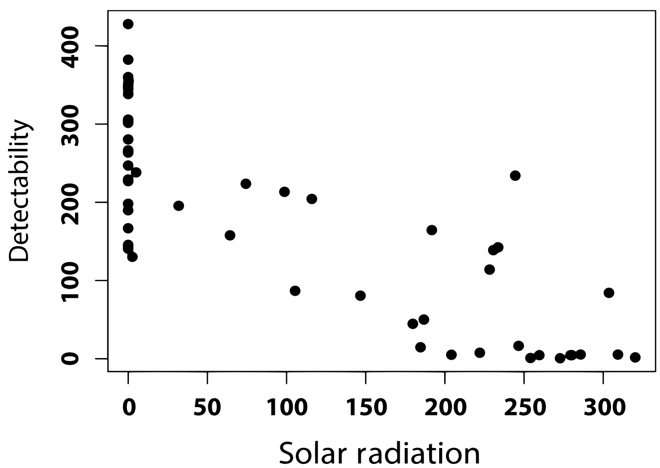

Figure 5. The relationship between solar radiation (in watts per square meter) and den detectability for all three dens at a 100-meter distance.

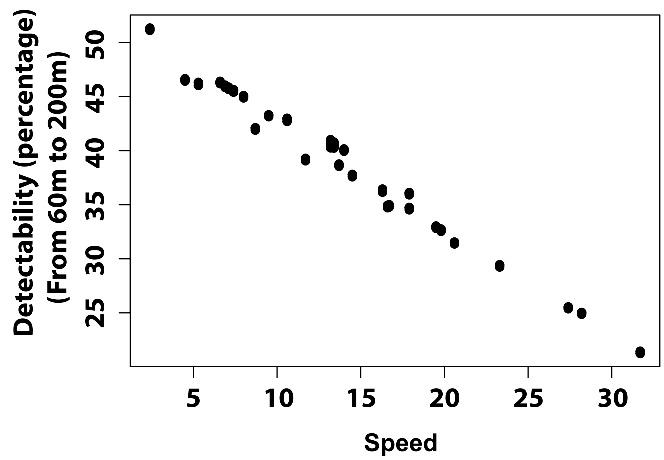

Figure 7. The relationship between wind speed (in kilometers per hour) and den detectability as distance increased.

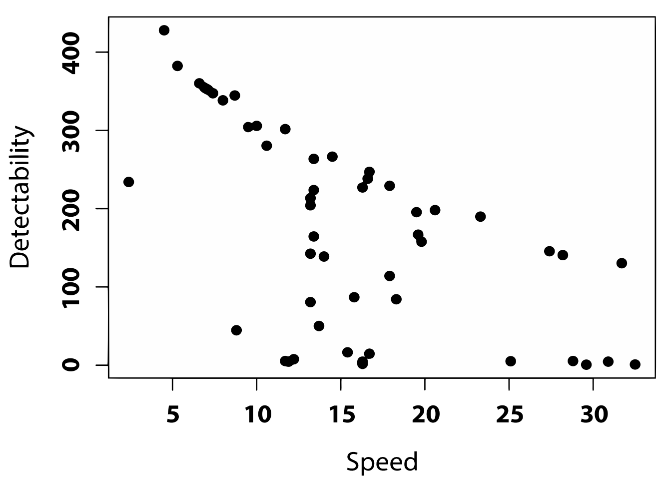

Figure 6. The relationship between wind speed (in kilometers per hour) and den detectability for all three dens at a 100-meter distance.

16 supported models (table 1b; greater than 99% weight). A 1-km-per-hour increase in wind speed increased the spread between the predicted and the actual detectability by a factor of 0.404 ($p < .01$).

Conclusions

Amstrup and colleagues (2004) identified solar radiation, airborne moisture, and temperature–dew point spread as important factors in polar bear den detection using aircraft-based FLIR. Our findings are similar with regard to both solar radiation and temperature–dew point spread, although we did not use airborne moisture as a metric. Rather, we used precipitation (falling or suspended moisture) as one metric and wind speed, which accounts for blowing snow, as another. We did not find precipitation alone to have a significant effect in any of our models. However, only light precipitation occurred during our sampling sessions, which probably limited our ability to evaluate its influence. Poor FLIR performance has been observed during moderate snowfall in the attempted detection of

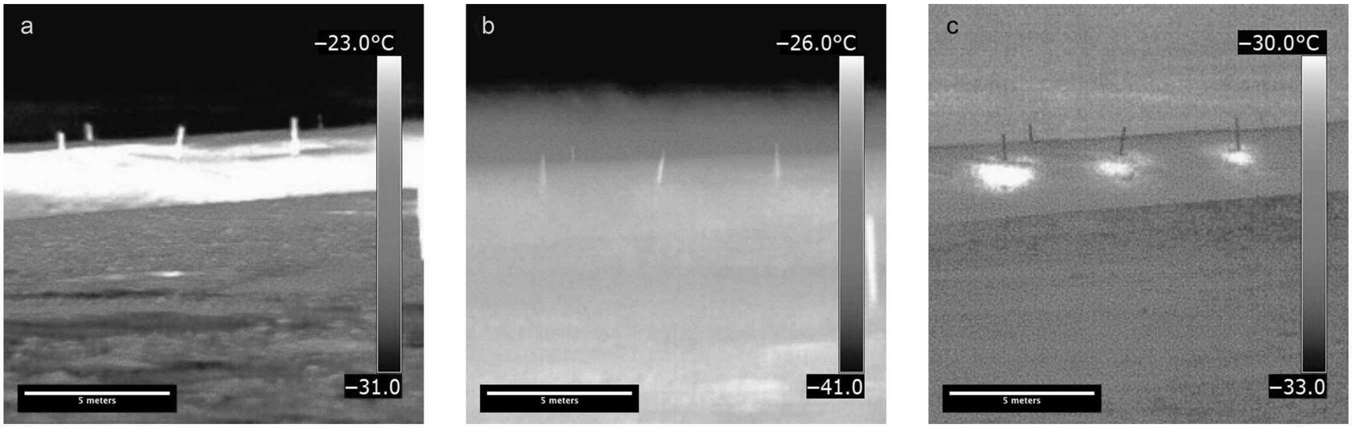

Figure 8. Infrared images of artificial dens at a 100-meter distance showing (a) sunny conditions, (b) windy conditions, and (c) optimal conditions. Abbreviation: °C, degrees Celsius. Photographs: Rusty Robinson.

actual polar bear dens (Smith et al. 2007). Therefore, precipitation and its intensity should also be considered (Amstrup et al. 2004).

Solar radiation and wind speed were the most important factors influencing artificial polar bear den detection using FLIR (figures 8–10). Of the den images in which the dens were not detectable (n = 47), 94% had solar radiation greater than 100 W/m^2. Conversely, only 39% of detectable den images (n = 109) had solar radiation greater than 0 W/m^2. Regardless of all other variables, 96% of the dens sampled at night (n = 69) were detectable at some level. Den detectability scores were 2.7 times higher in hours of darkness than when sunlight was present. Because of convection and blowing ground snow (i.e., wind-driven snow close to the ground), wind had a negative effect on den detectability in general and as horizontal distance to the den increased in particular. However, detectability as vertical distance increases may not be affected by wind as much as it is with horizontal increases. Imagers on the ground are subject to compounding ground snow particles as distance increases, whereas an aircraft-based imager may be subject only to the blowing snow directly over the den. Even if this is the case, convection and the constantly moving particles will still have a negative effect on detection, and we recommend that windy conditions be avoided altogether, regardless of the imaging platform.

Ice lens formation on the inner surfaces of natural polar bear dens has been reported (Harington 1968, Durner et al. 2003), but polar bears will usually scrape at the walls and ceilings with their claws, leaving little if any ice. The influence of ice on den detectability was not tested, but, because den wall thickness had a significant effect in the zero-inflated portion of our modeling, it is possible that ice also has an effect on detectability. This could result in a difference in heat dissipation relative to natural dens. In spite of this concern, we think that our artificial dens simulated real dens adequately to evaluate useful detection methods. Specific thresholds may need further testing.

The snow depth above the chamber of a polar bear den can vary greatly (M = 72 cm, SD = 87) and has been measured up to 400 cm (Durner et al. 2003). This suggests that a large portion of dens have wall thicknesses greater than 90 cm and would probably go undetected regardless of survey conditions. During the course of this study, den wall thickness fluctuated as much as 16 cm with changing wind, and a single windstorm before the study began added 4 horizontal meters and 2 vertical meters of snow to our sample snowdrift. We recommend conducting FLIR surveys as early as possible in the denning period, when the snow depth over dens is expected to be at winter minimums (Uspenski and Kitchinski 1972).

In order to reach maximum detectability (in the top 10% for each den at 100 m), we recommend that managers tasked with locating polar bear dens using handheld FLIR do so between dusk and dawn when the wind is slower than 10 km per hour. The mean solar radiation for the top 10% of the detectability scores was 16 W/m^2, with all but one top score occurring at night. If surveys must be conducted during daylight hours, time periods near dawn or dusk with heavy cloud cover should be sought in order to minimize the effects of solar radiation. Although all of our measurements were collected on the ground, they largely corroborate past work (Amstrup et al. 2004) and our observations with aerial FLIR. Our findings here probably apply to aerial FLIR, as well. We think that by following these recommendations, polar bear den detection will be optimized, thus will potential negative impacts associated with the interactions of denning polar bears and industry be avoided.

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Den phenology and reproductive success of polar bears in a changing climate

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Synchrony between reproduction and food availability is important in mammals due to the high energetic costs of gestation and lactation. Female polar bears (*Ursus maritimus*) must accumulate sufficient energy reserves during spring through autumn to produce and nurse cubs during the winter months in snow dens. Adequate time in a den is important to optimize cub development for withstanding harsh Arctic spring conditions and to synchronize emergence with peak prey availability, which occurs in May and June. During 1985–2013, den phenology was investigated using temperature data collected on satellite collars deployed on adult female polar bears in the southern Beaufort Sea (SB) and Chukchi Sea (CS). We examined relationships between den phenology, reproductive success (cub production and post-emergence survival), and environmental factors (weather and sea-ice conditions). Females observed with cubs emerged later and remained in dens on average 15.0 ± 7.6 (*SE*) days longer than females seen without cubs. Females occupying land-based dens, where estimated snowfall was greater, had higher reproductive success. Recently, female polar bears have increased land-based denning in the SB. Females in CS emerged later from dens than SB females, consistent with better female body condition and higher cub survival in the CS. During years with a greater area of autumn sea ice, reproductive success was higher at land-based versus sea-ice dens, suggesting continued decline in sea ice could negatively affect recruitment. However, further research is needed to better understand mechanistic relationships. Because females emerging later from dens had higher reproductive success, den duration could be a useful metric in population monitoring.

Key words: habitat, polar bear, reproduction, snow, temperature, ursid, *Ursus maritimus*

Climate change has been associated with changes in the phenology of numerous species (Parmesan and Yohe 2003). Warming temperatures are correlated with advances in spring events, particularly at higher latitudes, with examples that include earlier budding and flowering of plants, and changes in timing of hibernation, migration, and breeding (Parmesan 2006; Johnson et al. 2017). Temporal changes in important biological functions can disrupt tight trophic coupling (i.e., mutualistic or predator–prey interactions) when resources become available at the wrong time or place (Sydeman and Bograd 2009). Such trophic asynchrony can have population-level effects by reducing foraging efficiency, ultimately affecting reproductive success and survival (Durant et al. 2007; Sydeman and Bograd 2009).

Bears in Arctic and temperate regions are obligate seasonal breeders that typically mate in the spring and summer and produce cubs in dens during the winter months (Spady et al. 2007). During winter denning, females do not eat or drink, and survive solely on stored energy while undergoing delayed implantation, gestation, parturition, and lactation (Nelson et al.

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1983; Spady et al. 2007). Cubs are born as small, altricial neonates and dens provide shelter during cub growth (Ramsay and Dunbrack 1986; Messier et al. 1994). Food availability for females prior to denning and after den emergence appears to affect cub production (Robbins et al. 2012) and survival of cubs after den emergence. Females that give birth to cubs need to replenish lost energy reserves to support lactation (Elowe and Dodge 1989; McDonald and Fuller 2005). Thus, females have to obtain sufficient food during the autumn to survive and produce cubs during the winter denning period (i.e., not enter the den too early and run out of fat reserves). In addition, females cannot emerge from the den before cubs have sufficiently developed and adequate food resources are available.

Pregnant female polar bears create dens in snow that provide a sheltered environment from harsh Arctic conditions (Ramsay and Stirling 1988). Because females rely on energy reserves to support cub production and growth, autumn body condition of pregnant females is an important factor affecting cub size, litter size, and subsequent survival (Derocher and Stirling 1996; Robbins et al. 2012). Pregnant females in poor condition (< 20% body fat) cannot produce cubs (Robbins et al. 2012), but previous studies suggested that the threshold for reproductive failure is low and that most females that enter dens produce cubs (Derocher et al. 1994). Growth rate of cubs is related to their mother's condition (Robbins et al. 2012) and body mass of cubs is a predictor of cub survival (Derocher and Stirling 1996). Polar bear cubs increase their body mass by up to 4 times between spring and autumn and nursing provides the majority of calories for growth (Derocher and Stirling 1998). In western Hudson Bay, 25% of spring-captured females lost their entire litter by the autumn. The loss of the entire litter post-emergence accounted for the majority of females observed without cubs in the autumn. Effects of limited food resources during the autumn prior to and the spring following denning on maternal milk quantity and quality appear to be the primary cause of mortality in juvenile polar bears (Derocher et al. 1993; Derocher and Stirling 1996). Thus, a female's body condition at entry into a den is a critical factor determining whether she produces cubs and their chance of survival during their first year.

The duration a female spends in the den may also affect cub survival and be dependent on food availability prior to den entrance. Brown (*Ursus arctos*) and black bears (*U. americanus*) delay entry to a den when food is abundant in the autumn, presumably to maximize energy reserves prior to denning (Van Daele et al. 1990; Schooley et al. 1994; Friebe et al. 2014; Pigeon et al. 2016; Johnson et al. 2017). Further, parturient female brown and black bears tend to emerge later from dens than males and non-reproductive females (Johnson and Pelton 1980; Garrison et al. 2007; Waller et al. 2012; Friebe et al. 2014; Johnson et al. 2017), suggesting that extended denning supports cub development. Polar bears emerge from dens between March and May, which coincides with a period of increasing prey availability; ringed seals (*Phoca hispida*) begin pupping and ringed and bearded seals (*Erignathus barbatus*) haul-out on the ice to molt during this period (Stirling and Archibald 1977; Smith 1980, 1987). Derocher and Stirling (1996) suggested that polar bear mothers and cubs depart for sea ice, instead of nursing at the den site, to obtain necessary food resources in the spring. Larger, more developed cubs are less susceptible to heat loss (Blix and Lentfer 1979) and may have improved abilities to travel on sea ice. Thus, cub survival may be maximized for females that obtain the greatest energy reserves prior to entering a den and therefore can remain in dens longer, allowing cubs to fully develop, and maximizing overlap with spring food availability.

The effects declining extent of sea ice (Durner et al. 2009; Laidre et al. 2015) and changes in snowfall patterns on land and sea ice (Webster et al. 2014) may have on the timing and duration of denning are not well understood. Polar bears in several regions, including the Chukchi Sea (CS) and southern Beaufort Sea (SB) and western Hudson Bay, spend more time on land during the months preceding denning than they have in the past (Rode et al. 2015b; Atwood et al. 2016), which can affect female body condition prior to denning (Stirling et al. 1999). On land, polar bears primarily rest (Whiteman et al. 2015; Ware et al. 2017) and feed minimally on terrestrial food resources (Rode et al. 2015a). Those bears that remain with the sea ice during the Arctic sea-ice minimum (prior to denning) exhibit declines in activity and appear to have reduced access to prey (Whiteman et al. 2015; Ware et al. 2017). Links between availability of sea ice in autumn, female body condition, and cub survival were documented in western Hudson Bay, but are less clear in other populations where monitoring of female body condition prior to den entry is less feasible. Bromaghin et al. (2015) identified reduced cub survival as a factor affecting population decline in the SB. Polar bears have also changed their denning behavior in some areas, including selection of den locations at higher latitudes (Derocher et al. 2011; Rode et al. 2015b) and elevations (Escajeda 2016), increased selection of land-based dens (Fischbach et al. 2007; Rode et al. 2015b; Olson et al. 2017), and changes in the time of entry to the den (Escajeda 2016). The implications of these changes on cub production and survival are unclear.

We examined relationships between the timing and duration of maternal denning and reproductive success (i.e., whether a female produced cubs and whether they survived for the first 100 days following den emergence) in the CS and SB subpopulations over 28 years. In these 2 subpopulations, females denned both on the sea ice and on land. Information on female body condition just prior to denning is limited, but bears in both subpopulations have altered habitat use during the months preceding denning (Rode et al. 2015b; Atwood et al. 2016). We hypothesized that a shorter denning period was associated with lower reproductive success in polar bears, either because a female did not produce cubs or she left the den with cubs that were less developed and thereby, less vigorous for surviving harsh Arctic spring conditions. Further, we hypothesized that a female's denning period was related to food availability in autumn, which affected her body condition at the time of den entry and the amount of energy reserves available for the denning period. We sought to understand the factors that may influence the timing and duration of denning, including whether a bear denned on land or sea ice, and relationships with weather and sea-ice conditions. Because polar bears den in snow, we hypothesized that snowfall could be a factor affecting the timing and duration of denning. Lastly, because female body condition, cub survival, and recruitment differed between the 2 subpopulations (Rode et al. 2014) and because summer habitat use and denning sites have changed in these subpopulations (Fischbach et al. 2007; Rode et al. 2015b; Olson et al. 2017), we hypothesized that the timing and duration of denning was associated with the observed differences in reproductive success.

Materials and Methods

Satellite radiocollar location data have been used to identify denning behavior in brown and black bears (Ciarniello et al. 2005; Johnson et al. 2017), but because some female polar bears den on the sea ice, ice movement precludes identifying denning behavior using satellite radiocollar location data. Therefore, we estimated the timing and duration of denning using air temperature-sensor data collected from collared female polar bears as described below. Temperature data from collars of denning bears exhibit distinguishable, prolonged increases compared to the colder, more fluctuating ambient temperatures recorded on collars of non-denning bears (Olson et al. 2017). Estimates of the dates of den entry and emergence using temperature data (as described in greater detail below) likely represent the time frame that a polar bear is consistently in a den rather than the time frame a bear is at a den location, which has been described for other bear species that den on stable habitats (Ciarniello et al. 2005; Johnson et al. 2017). Because temperature has not been used previously to identify the timing and duration of denning, we compared temperature-based estimates of the denning period with location-based estimates for polar bears that denned on land, where sea-ice drift would not affect location data. The results of this comparison were used to assess the accuracy of our temperature-based approach recognizing that a bear may occur at a den site and not be in the den.

Bears were captured on the sea ice during spring (mid-March to mid-May) and occasionally during autumn (August to November) in the Alaska portion of the SB during 1985–2013, with the exception of 1993, 1995, 1996, and 2010. Captures occurred in the CS and northern Bering Sea during 1986–1995 and during 2008–2013 on or near Wrangel Island, Herald Island, the Alaskan mainland coast, St. Lawrence Island, Alaska, and the northeast Chukotkan coast. Body condition just prior to den entry was not known for most females because most were captured and collared during the previous spring. Bears were located via helicopter, immobilized, and adult females were fitted with satellite radiocollars (Telonics, Inc., Mesa, Arizona). Immobilization procedures and collar deployments are further described in Rode et al. 2015b and Olson et al. (2017). The methods for capture and handling bears used in this study conformed to the guidelines of the American Society of Mammalogists for the use of wild mammals in research (Sikes et al. 2016), were conducted under USFWS research permits MA 690038 and 04608, and followed protocols approved by Animal Care and Use Committees of the USGS and the USFWS.

Location data from radiocollars were used to assign bears to a subpopulation. Satellite radiocollars (Telonics, Inc.) provided either Argos (www.argos-system.org) or Global Positioning System (GPS) locations every hour to every 5 days. Location data were filtered to remove implausible locations using the Douglas Argos-Filter algorithm, which retained all standard quality class locations (classes 3, 2, and 1; < 1,500 m error), rejected all class Z locations, and retained class A and B locations if they were corroborated by a consecutive location within 10 km, or if movement rates were < 10 km/h and turning angles were not extremely acute (Rode et al. 2015b). Bears were assigned to a subpopulation based on whether the majority of their locations occurred within the SB or CS subpopulation boundaries as defined by the International Union for the Conservation of Nature's Polar Bear Specialist Group (Obbard et al. 2010; Ware et al. 2017; Fig. 1).

Temperature data were recorded every 20 min by a thermistor integrated into a GPS radiocollar or transmitted once per 4 to 7 h daily duty cycle for Argos collars. The mean number of temperatures taken per day of data acquisition was 5.5 ± 0.03 (*SE*). However, the frequency of temperature data often was reduced once a bear entered a den due to attenuation of the signal required for satellite reception. Dens were built in the snow regardless of whether a female denned on land or sea ice. Thus, signal attenuation was expected to be similar on these 2 substrates.

Estimating den timing.—We used statistical methods to identify maternal denning behavior (as described in Olson et al. 2017), entry into dens, emergence from dens, and denning duration using air temperature-sensor data from polar bear collars. This process quantified the expected mean and variation in temperature for non-denning bears, and identified bears as denning when air temperatures rose approximately 9°C above this expected range (referred to as a control limit—Olson et al. 2017) for a prolonged period (Fig. 2). When compared to direct observations of denning behavior, this temperature-based approach accurately classified denning and non-denning behavior in 94.5% of 73 bears (Olson et al. 2017). Per the methods of Olson et al. (2017), we excluded potential denning events that lasted less than 34 days, which could have eliminated some bears that entered dens but did not produce cubs, or abandoned the den early. We assumed that all denning events were likely maternal denning attempts because shelter denning (i.e., denning for reasons other than to give birth to cubs) is rare in the CS and SB (Olson et al. 2017). Entrance into a den was defined as the median date between the last temperature observation within control limits and the first observation above control limits. Similarly, emergence from a den was estimated as the median date between the last observation above control limits and the first observation to return within control limits. The total den duration was defined as the number of days between entrance into and emergence from a den (Fig. 2). This value most likely represented the time

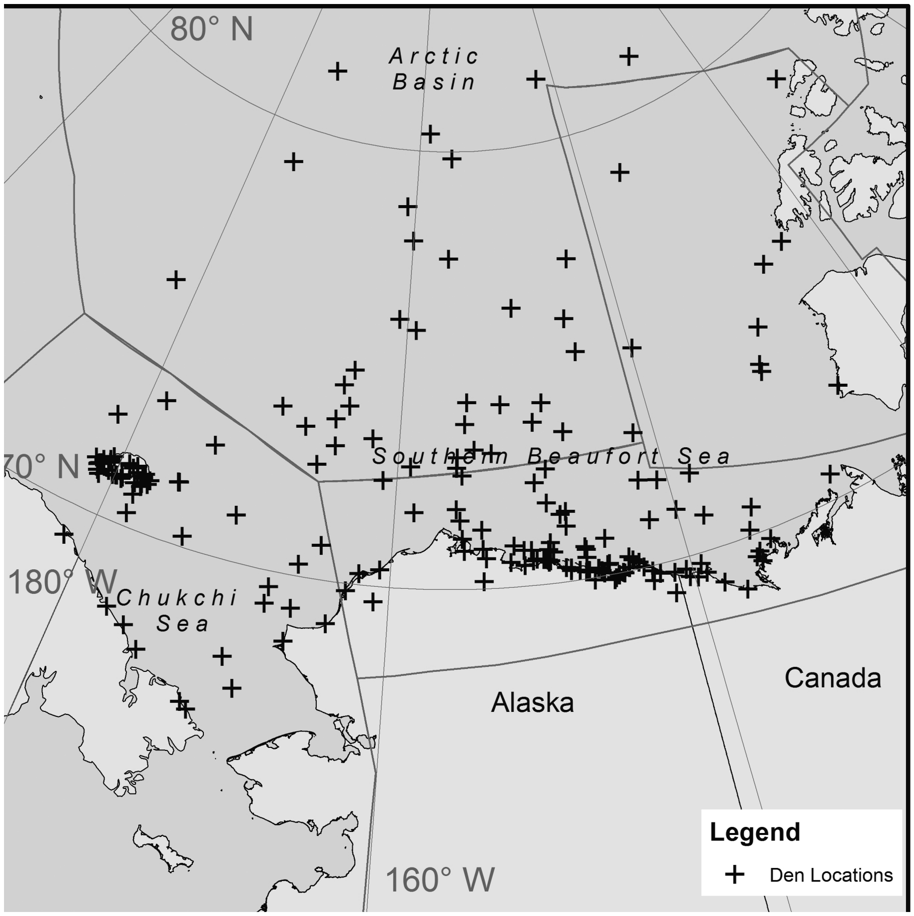

Fig. 1.—Locations of maternal dens of polar bears (*Ursus maritimus*) identified using temperature-sensor data collected from satellite radiocollars deployed on adult female polar bears in the Chukchi Sea and Beaufort Sea subpopulations. Red lines indicate IUCN Polar Bear Specialist Group identified subpopulation boundaries.

that a bear remained consistently within a den rather than the total amount of time a bear could have spent at the den location in preparation for or subsequent to denning.

Dens were assigned as occurring on land or sea ice using GPS and Argos locations as described in Olson et al. (2017). Location data were filtered as described above, and if at least 1 observed location at the start of, during, or at the end of the denning period identified via temperature data occurred on land and locations preceding or subsequent to denning demonstrated a trajectory to or from that location, we assumed the den occurred on land (Olson et al. 2017). Dens that did not occur on land were designated as sea-ice dens.

Assessing the accuracy of temperature-based denning estimates.—Temperature-based estimates of entrance into a den, emergence from a den, and denning duration were compared to location-based estimates using satellite collar location data of bears that denned on land and provided location data at least every 3 days. Bears that denned on sea ice could not be included in this comparison because ice drift precludes detection of denning behavior from location data. Location data were filtered as described above. Locations within a 1,500-m radius of the den location were queried, and we estimated the den entry and emergence dates as the first and last locations within that radius, respectively.

Assessing female reproductive success.—Females that entered dens were considered reproductively successful if they were subsequently observed with dependent young within 100 days post-emergence (hereafter, "reproductive success"). Individuals that denned, but were observed without dependent cubs within 100 days following den emergence were considered unsuccessful. Differences in reproductive success were a consequence of both whether a female produced cubs and cub survival. Reproductive success was visually confirmed via VHF radiotracking or random encounter during ongoing mark-recapture efforts. Because mortality rates for cubs within their first year can be as high as 40–75% (Ramsay and Stirling 1988; Elowe and Dodge 1989; Wiig 1998), the time between denning and subsequent observation could have influenced observations of reproductive outcomes. Thus, we measured the number of days between den emergence and subsequent observation of females to determine potential effects on the observation of cubs and included these values in analyses of the factors influencing reproductive success.

Differences between subpopulations and trends over time.—We were interested in whether the timing and duration of denning differed between subpopulations or over time. Because the proportion of females denning on land and sea ice differed between the 2 subpopulations, we included den substrate

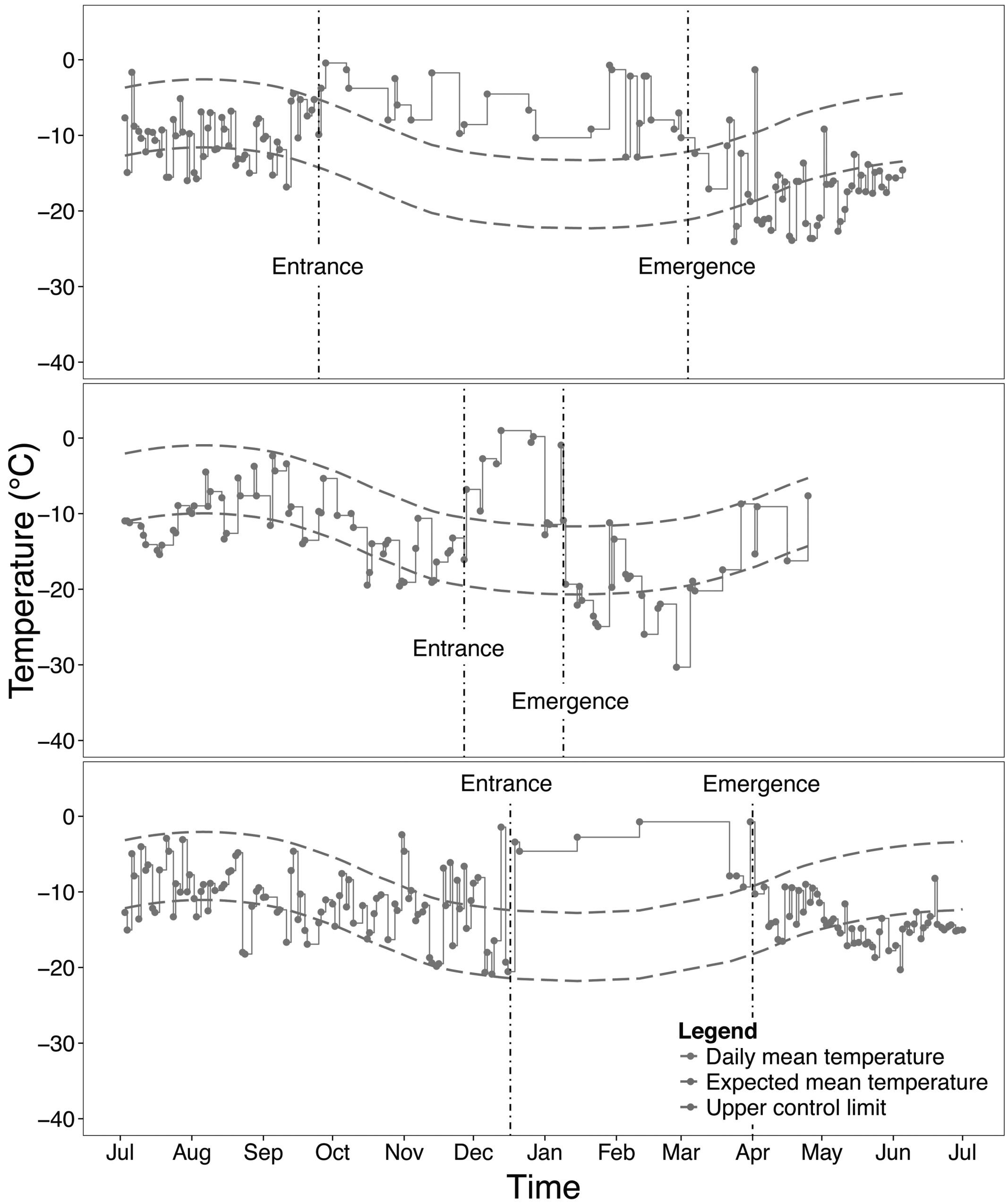

Fig. 2.—Examples of control charts with temperature data measured by thermistors onboard satellite collars fitted to adult female polar bears (*Ursus maritimus*) used to identify denning and to estimate entrance into and emergence from dens. Entrance and emergence dates were estimated as the median date between observations within and above control limits at the start and end of a denning event (shown as horizontal dashed lines).

(0 = sea ice, 1 = land) as a fixed-effect covariate in models as described below (see "Statistical analysis"). Further, we were interested in whether the timing and duration of denning differed between substrates independent of subpopulations and trends over time, so we conducted direct comparisons between land and sea-ice dens. Finally, in a separate analysis described below, we examined whether the timing and duration of denning was related to spatial variation in weather and sea-ice conditions.

Environmental factors influencing denning.—Polar bears require sea ice to access ice-associated seals, which are their primary prey (Thiemann et al. 2008). However, data on annual variation in seal abundance are lacking for these regions. Because the most significant loss of sea ice in the Arctic has occurred during the summer months (Stern and Laidre 2016), the extent of sea ice could affect predation success and deposition of energy reserves prior to denning. Therefore, we created an index of autumn food availability during the year each bear denned by estimating the amount of sea ice over the shallow continental shelf, the preferred habitat of polar bears (Durner et al. 2009). The percentage of the continental shelf covered by sea ice of ≥ 15% concentration during October and November (prior to den entry) was summarized using daily sea-ice concentration data from the National Snow and Ice Data Center (Cavalieri et al. 1996; accessed 16 October 2014). These values were annual measures applied to each bear during the years they denned and, therefore, were not specific to a bear's den location. A similar metric was related to denning distribution (Rode et al. 2015b) and body condition (Rode et al. 2014).

Snowfall and air temperatures near the den have been associated with variability in the timing of denning in brown bears, despite denning occurring primarily in earthen dens (Zedrosser et al. 2006; Evans et al. 2016; Pigeon et al. 2016). Snowfall could be particularly important for polar bears because they den in the snow either on land or on the sea ice. Although the depth of snow required for polar bear denning is unknown and measurement of snow depth across the landscape is not possible, we examined whether an estimate of snowfall might relate to the duration and timing of denning because the amount of snowfall could affect the availability of adequate snow for denning. Therefore, we estimated snowfall and temperature at den locations using air temperature and precipitation data from the North American Regional Reanalysis (Mesinger et al. 2006), extracted using the Movebank Environmental Data Portal (Dodge et al. 2013). Weather variables were calculated as the inverse-distance weighted average among values from 4 NARR grid points (32 km resolution) surrounding each bear's den location. We extracted air temperature and precipitation data at a level of 2 m a.s.l. and at 3-h intervals between October and March for each bear's den location during the years in which they denned. For bear's that denned on the sea ice, a location identified early in the denning period was used and the cumulative amount of precipitation was calculated when air temperature was below freezing (0°C). Between 1 October and 15 November of each year was designated as "autumn snowfall" and between 1 October and 1 March of each year was referred to as "spring snowfall." The latter time frame was used to estimate accumulated snowfall prior to the period of emergence from dens. We assumed that precipitation below freezing would be in the form of snow rather than rain. The mean date of entry into dens was 15 November, and the mean date of emergence from dens was 1 March, thus we examined potential snowfall levels prior to these dates.

Statistical analysis.—Paired *t*-tests were used to compare the dates of entrance and emergence from dens, and the total duration of denning estimated using collar temperature data with those estimated using location data of females that denned on land. This comparison was used to assess the accuracy of temperature-based estimates of the timing and duration of denning.

We compared temperature-based estimates of the duration and timing of denning between reproductively successful and unsuccessful females using logistic regression (0 = observed with cubs and 1 = not observed with cubs) with the number of days post-emergence when the observation occurred and den substrate as a covariate. In a separate logistic regression, we examined potential influences of weather on reproductive success because these variables were spatially and temporally explicit. Variables were considered to be collinear if condition indices were > 15, variance proportions > 0.3, tolerances < 0.1, and variance inflation factor > 10. If collinearity occurred, variables were included in separate models. We did not employ model selection based on reasons similar to those outlined in Hobbs et al. (2012) and the few variables in the model, but rather examined whether these hypothetical factors that could affect reproductive success were significant at $P \leq 0.05$ and improved the model fit based on changes in the Akaike information criterion (AIC) value.

We used a general linear model (GLM) to compare entrance into dens, emergence from dens, and denning duration between the 2 subpopulations and to examine patterns over time. Models included year, population, den substrate (i.e., land or sea ice), and a year-by-population interaction. Den substrate was included to account for variability in the proportion of bears denning on land versus sea ice, which has changed over time (Rode et al. 2015b; Atwood et al. 2016). The interactive effect between population and year was included to allow for potential differences in trends over time between subpopulations. This effect was removed from the model if it was not significant and did not further reduce the AIC value of the model. We conducted an analysis of variance (ANOVA) to compare entrance into dens, emergence from dens, and denning duration between dens on sea ice and land. Finally, a GLM was used to examine potential effects of weather and sea-ice conditions on spatial and temporal variation in den entrance and emergence dates independent of potential variation over time, across den substrates, or between subpopulations (i.e., these variables were excluded from the model). Mean October air temperature, autumn snowfall, and October–November ice conditions were included in the model for entrance into dens and mean March air temperature, spring snowfall, and October–November ice conditions were included in the model for emergence from dens. Collinearity was examined and model selection was conducted as described above. Sea-ice conditions were included in models for both entrance and emergence because they were used as a proxy for autumn food availability, which could affect energy reserves of females and, thereby, both the timing of entrance and emergence. Because polar bears in this region have increased use of land during the summer for denning in recent years in relation to declines in summer and autumn availability of sea ice (Rode et al. 2015b; Atwood et al. 2016), these 2 factors were potentially correlated. Further, because den substrate is a binary variable, addressing this potential collinearity is complex. Therefore, the potential relationships between autumn sea-ice conditions and denning entrance, emergence, and duration were run separately for sea-ice and land-based dens. Further, to understand the role these variables might play in any observed variation in the timing and duration of denning across substrates, subpopulations, or over time, we compared weather and sea-ice conditions across these variables.

The Olson et al. (2017) algorithm for identifying denning behavior used SAS/*STAT* software. All other statistical analyses were performed using *SPSS* (*IBM SPSS* Statistics Version 24.0.0.0). All analyses were conducted at the alpha equals 0.05 level of significance.

Results

Assessing the accuracy of temperature-based denning estimates.—Temperature-based estimates of the time of entrance into dens for land-based dens did not differ from estimates based on location data (paired *t*-test: $t_{30} = -0.36$, $P = 0.72$). However, temperature-based estimates of the time of emergence from dens were 2.8 days earlier than estimates using location data ($t_{33} = 2.1$, $P < 0.0001$), which could reflect the difference between emergence from dens and abandonment or be a consequence of the less-than-daily location data for some individuals. Location data were collected daily for 17 bears, every 2 days for 5 bears, and every 3 days for the remaining 9–12 bears in this analysis. All subsequent analyses described below used temperature-based estimates of the duration and timing of denning due to its accuracy for both land- and sea-ice-based dens.

Assessing reproductive success.—Data on reproductive success were available for 72 bears, 8 of which were assigned to the CS subpopulation and 64 of which were assigned to the SB subpopulation. There was no difference in the mean date of entrance into dens between bears that successfully produced cubs (17 November; $n = 50$) and those that were observed without cubs (15 November; $n = 21$; $F_{1,69} = 0.05$, $P = 0.83$). However, bears later observed with cubs ($n = 50$) emerged 14.9 ± 5.0 ($\bar{X}$ ± *SE*) days later than females without cubs ($n = 21$; $F_{1,63} = 9.0$, $P = 0.004$), and had an overall denning duration 15.0 ± 7.6 days longer than bears observed without cubs ($F_{1,63} = 3.9$, $P = 0.05$). The earliest estimated date of emergence from a den for a female later observed with cubs was 8 January, with a duration of 61 days. The shortest estimated denning duration for a reproductively successful female was 42 days. The timing of observations post-emergence did not differ between females observed with cubs and those observed without cubs (logistic regression: $\beta = 0.005 \pm 0.009$ days; $P = 0.56$). However, we retained this metric as a covariate in models of reproductive success.

Reproductive success was higher for females denning on land than on sea ice (logistic regression: $\beta = 2.5 \pm 0.8$, $P = 0.001$; Fig. 3); however, when accounting for this difference there was no effect of autumn ice conditions ($\beta = 0.02 \pm 0.02$, $P = 0.30$). No weather variables were related to reproductive success (all *P*-values > 0.05). Mean denning duration for females that produced cubs that survived until observation post-emergence was 113.8 ± 3.8 days (range: 42–157; $n = 48$), with post-emergence observations occurring within a mean of 37.4 days post-emergence. Mean denning duration of females that were later observed without cubs was 98.9 ± 7.4 days (range: 47–161; $n = 21$). Of females with den durations < 100 days, 43.8% were later observed with cubs compared to 78.2% of females with durations > 100 days.

Differences between subpopulations and trends over time.—There were no differences in entrance dates for females in the 2 subpopulations (GLM with den substrate as a covariate: $\chi^2 = 0.13$, $P = 0.25$; $n = 215$) and no trends among years ($\chi^2 = 0.02$, $P = 0.90$; $n = 215$). Emergence from dens, however, was 9.4 ± 4.5 (*SE*; $n = 50$) days later in the CS compared to the SB ($\chi^2 = 4.3$, $P = 0.04$; $n = 129$), but did not demonstrate a trend among years ($\chi^2 = 0.78$, $P = 0.38$; $n = 179$). Mean date of entrance into dens was 15 November ± 1.9 days ($n = 215$) and

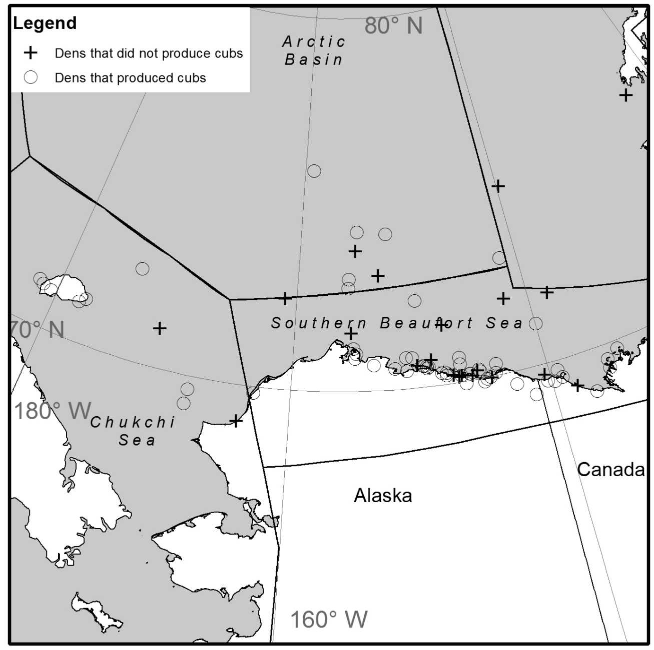

Fig. 3.—Den locations for female polar bears (*Ursus maritimus*) that were observed with (dens that produced cubs) or without cubs (dens that did not produce cubs) following den emergence. Females were observed on average 37 days after emergence from dens.

mean date of emergence from dens was 1 March ± 2.1 days ($n = 179$). Denning duration also did not differ between subpopulations ($\chi^2 = 0.14$, $P = 0.71$; $n = 179$) or among years ($\chi^2 = 0.94$, $P = 0.33$; $n = 179$) and averaged 104.5 ± 2.8 days ($n = 179$). There was no interaction between subpopulation and year, or den substrate (land or sea ice) and subpopulation, in any of the models (all $P > 0.2$), so the interaction was not included.

Environmental factors influencing denning.—Date of entrance into dens did not differ between land ($n = 107$) and sea-ice dens ($F_{1,191} = 1.16$, $P = 0.28$; $n = 108$), but date of emergence was 8.7 days later ($F_{1,160} = 4.70$, $P = 0.03$) and denning duration was 13.6 days longer for land-based dens compared to dens on sea ice ($F_{1,160} = 6.2$, $P = 0.014$; $n = 156$). Weather and ice metrics were not collinear. Date of entrance into dens was positively related to mean temperature in October ($\beta = 0.63 \pm 0.23$, $\chi^2 = 7.7$, $P = 0.006$, $n = 215$), but not autumn snowfall ($\chi^2 = 0.51$, $P = 0.48$) or availability of ice in October–November ($\chi^2 = 0.25$, $P = 0.62$, $n = 215$). The model with the lowest AIC for den emergence included temperature in March ($\beta = 0.42 \pm 0.26$; $\chi^2 = 2.6$, $P = 0.11$, $n = 156$) and availability of ice in October–November ($\beta = -0.16 \pm 0.10$, $\chi^2 = 2.5$, $P = 0.12$, $n = 156$), but neither variable was significant in the model. Because changes in den substrate have occurred simultaneously with declines in availability of sea ice and therefore were potentially related, we examined relationships between autumn sea-ice conditions and time of denning for land- and sea-ice-based dens separately. There was no relationship between autumn sea-ice conditions and date of entrance into dens for land-based ($\beta = -0.20 \pm 0.13$, $\chi^2 = 2.1$, $P = 0.14$, $n = 89$) or sea-ice-based dens ($\beta = -0.11 \pm 0.14$, $\chi^2 = 56$, $P = 0.45$; $n = 73$). Emergence date was later for land-based dens when there was greater availability of sea-ice habitat in October–November ($\beta = -0.29 \pm 0.12$, $\chi^2 = 5.9$, $P = 0.02$, $n = 89$), but there was no relationship for sea-ice-based dens ($\beta = -0.20 \pm 0.15$, $\chi^2 = 1.9$, $P = 0.17$, $n = 73$).

Environmental conditions differed between land- and ice-based dens with mean air temperatures in October 5.7°C warmer ($F_{1,183} = 24.9$, $P < 0.0001$), autumn snowfall 12.3 cm greater ($F_{1,183} = 27.8$, $P < 0.0001$), and spring snowfall 26.1 cm greater ($F_{1,183} = 29.4$, $P < 0.0001$) at land-based versus sea-ice-based dens. There was no difference in temperatures in March between land- and sea-ice-based dens ($F_{1,183} = 1.9$, $P = 0.17$). Conditions also varied between den locations in the CS and SB. Autumn snowfall was 10.1 cm greater ($F_{1,199} = 13.8$, $P < 0.0001$), mean temperature in October was 5.2°C warmer ($F_{1,199} = 18.1$, $P < 0.0001$), spring snowfall was 30.2 cm greater ($F_{1,199} = 44.2$, $P < 0.0001$), and mean temperature in March was 7.1°C cooler ($F_{1,199} = 41.9$, $P < 0.0001$) at den locations in CS compared to those in SB.

Discussion

Later emergence from the den by female polar bears in this study was most strongly associated with their likelihood of successfully producing and raising cubs within the first 100 days post-emergence. All of the females that denned through the end of March (12 of 65) were later observed with cubs, whereas approximately one-half of females that emerged prior to the end of February either never produced cubs or produced cubs that did not survive. Females that denned on land, where estimated snowfall during the weeks prior to and during denning was greatest, had higher reproductive success than females that denned on the sea ice. Because polar bears typically den in the snow rather than the earthen dens common to other bear species, snowfall at den locations could ensure the integrity of the den throughout the duration of the denning period. Further, many of the bears that den onshore in the SB spend the summer and early autumn onshore (Olson et al. 2017) where they have access to subsistence-harvested bowhead whales (Atwood et al. 2016), a unique, predictable food resource. In contrast, females that summer on the sea ice in the SB appear to have reduced access to prey (Whiteman et al. 2015) and some of these remain on the ice to den (Olson et al. 2017). Additionally, polar bears that summer on land appear to have earlier access to prime foraging habitats once the sea ice returns in the early autumn (Schliebe et al. 2008) compared to those that summer and den further north over deep water in the Arctic Basin. The relationship between sea-ice conditions in autumn and date of emergence from dens observed in this study are suggestive that availability of sea ice just prior to denning could contribute to reproductive success of polar bears denning on land, which represents the majority of denning females in these 2 subpopulations. In the CS, > 84% of females den on land and the proportion of land dens has not changed since the 1980s (Rode et al. 2015b). In the SB, land-based denning increased from 34.4% in 1985–1995 to 55.2% in 2007–2013 (Olson et al. 2017), a shift that could be associated with the apparently lower reproductive success of dens on the sea ice.

Food availability also affects the timing of den entry in black and brown bears with greater abundance of food linked to later entry into dens (Van Daele et al. 1990; Schooley et al. 1994; Friebe et al. 2014; Pigeon et al. 2016; Johnson et al. 2017). Although we attempted to use the extent of sea ice over the continental shelf as a proxy for food availability in autumn, there was no relationship between date of entry into dens and food availability, even when accounting for potential differences between land- and sea-ice-based dens. Changing sea-ice conditions over time, differences in potential access to food resources for the 2 subpopulations, different denning habitats (land versus sea ice), and the lack of data on seal abundance complicated the ability to detect whether food availability affected timing of den entry. Alternatively, because polar bears den exclusively to reproduce and not in response to reduced availability of food, this factor could be less important as a cue for denning in polar bears compared to bear species in temperate areas with significant seasonal fluctuations in food availability. Ambient air temperature also appeared to affect the timing of entry into dens, similar to other bear species in more temperate regions (Evans et al. 2016; Johnson et al. 2017). Our estimates of weather variables had coarse spatial resolutions that could have limited the ability to detect relationships with denning entrance, emergence, and duration (i.e., resulted in Type 1 errors). Further, the metric we used for sea-ice conditions was not spatially specific to the den location.

Our temperature-based estimates of entry into and emergence from dens followed expected patterns relative to estimates made using locations of land-based bears and were similar to previous observations made in this region (Amstrup and Gardner 1994). Emergence as identified by temperature-sensor data likely represents the opening of the den cavity and increasing exposure to ambient temperatures, whereas methods based on location data mark the departure from the den locale. Our result that emergence from the den occurred prior to den abandonment is consistent with reports that family groups remain at the den for a time before departing to foraging areas (Uspenski and Kistchinski 1972; Smith et al. 2007).

The length of the denning period varies substantially across populations of brown and black bears (80–197 days—Johnson and Pelton 1980; Schooley et al. 1994; Friebe et al. 2014), which could be the result of latitudinal variation in seasonal food availability (Spady et al. 2007). In contrast, denning in polar bears occurs only in females producing cubs and should be a function solely of the conditions required to maximize reproductive success. Bears and other species with delayed implantation, such as the European badger (*Meles meles*), vary the implantation date, with the fattest females typically implanting earliest allowing the longest growth period for young prior to emerging from the den (Woodroffe 1995; Robbins et al. 2012). Gestation in ursids lasts approximately 60 days (Tsubota et al. 1987; Spady et al. 2007) and females of the genus *Ursus* likely implant after they have entered a den (Kordek and Lindzey 1980; Tsubota and Kanagawa 1993). However, 2 of the 71 females in this study produced cubs after an estimated denning duration of 42 and 59 days, suggesting some flexibility in the den duration required to produce cubs. Although den duration was related to reproductive success, this relationship was weaker than that observed with emergence from dens. On average, denning duration of females that successfully reared cubs was 114 days, which was lower than the mean denning duration for other populations of polar bears (Messier et al. 1994: 186 days for females in the Canadian Arctic archipelago; Wiig 1998: 153 days for females at Svalbard; Escajeda 2016: 167–194 days in Baffin Bay and Kane Basin). The 2 Alaska subpopulations of polar bears we examined could be limited in denning duration by their inability to deposit sufficient fat reserves to support a longer denning period.

The SB subpopulation currently has some of the lowest cub survival rates in the Arctic (Regehr et al. 2017). Although SB polar bears only emerged 9 days earlier than CS bears and had similar denning durations, this difference could be biologically meaningful. SB females are in poorer condition in the springtime than CS females (Rode et al. 2014) and have lower availability of food during that time (Rode et al. 2017). Less is known about differences in body condition and feeding behavior in the summer and autumn, but lower food availability earlier in the year in the SB ecosystem could have cumulative effects on a female polar bear's condition at den entry. Very low cub survival between 2003 and 2007 in the SB was identified as a key factor leading to declines in abundance for that population (Bromaghin et al. 2015). We did not detect a change in den entrance, emergence, or duration over time for either subpopulation in this study. However, 80% of our annual sample sizes were < 10 individuals and considerable variation in denning duration (range 33–219 days) could have limited detection of patterns to those that are large and broad-scale (e.g., sea-ice versus land dens). Further research is needed to understand annual trends in cub production and survival relative to the timing of denning.

Although polar bears in the SB have increased their use of land for denning since the 1980s (Fischbach et al. 2007; Olson et al. 2017), increased swimming has been documented in the summer and early autumn (Pagano et al. 2012). Increased distances between land and sea ice in the summer could impact accessibility to land habitats for denning as loss of sea ice continues (Bergen et al. 2007). Reduced access to denning habitat due to changes in sea ice was a factor contributing to lower density of maternal dens on Hopen Island in the southern portion of the Svalbard Archipelago (Derocher et al. 2011), and land-based habitats for denning, where reproductive success was highest, occur at the southern portion of the range of both subpopulations in this study. Polar bears could be challenged in coping with global warming because they have distinctly seasonal reproductive patterns and reproductive success that is heavily dependent on accumulated stores of body fat (Spady et al. 2007). Thereby, they could be susceptible to asynchrony between prey availability and the timing of denning, as well as direct effects of habitat loss on access to prey. Although reproductive success varied across a wide range of dates of emergence from dens, polar bears emerging later had much higher likelihoods of reproductive success, suggesting that this could be a useful metric to consider in population monitoring.

Acknowledgments

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PRIMARY RESEARCH ARTICLE

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Spring fasting behavior in a marine apex predator provides an index of ecosystem productivity

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Abstract

The effects of declining Arctic sea ice on local ecosystem productivity are not well understood but have been shown to vary inter-specifically, spatially, and temporally. Because marine mammals occupy upper trophic levels in Arctic food webs, they may be useful indicators for understanding variation in ecosystem productivity. Polar bears (*Ursus maritimus*) are apex predators that primarily consume benthic and pelagic-feeding ice-associated seals. As such, their productivity integrates sea ice conditions and the ecosystem supporting them. Declining sea ice availability has been linked to negative population effects for polar bears but does not fully explain observed population changes. We examined relationships between spring foraging success of polar bears and sea ice conditions, prey productivity, and general patterns of ecosystem productivity in the Beaufort and Chukchi Seas (CSs). Fasting status (≥7 days) was estimated using serum urea and creatinine levels of 1,448 samples collected from 1,177 adult and subadult bears across three subpopulations. Fasting increased in the Beaufort Sea between 1983–1999 and 2000–2016 and was related to an index of ringed seal body condition. This change was concurrent with declines in body condition of polar bears and observed changes in the diet, condition and/or reproduction of four other vertebrate consumers within the food chain. In contrast, fasting declined in CS polar bears between periods and was less common than in the two Beaufort Sea subpopulations consistent with studies demonstrating higher primary productivity and maintenance or improved body condition in polar bears, ringed seals, and bearded seals despite recent sea ice loss in this region. Consistency between regional and temporal variation in spring polar bear fasting and food web productivity suggests that polar bears may be a useful indicator species. Furthermore, our results suggest that spatial and temporal ecological variation is important in affecting upper trophic-level productivity in these marine ecosystems.

KEYWORDS
Beaufort Sea, Chukchi Sea, creatinine, feeding, predation, ringed seals, sea ice, urea

1 | INTRODUCTION

Arctic sea ice loss has resulted in significant ecosystem effects (Post et al., 2013) and is expected to continue into the future (Laidre et al., 2015). However, the effects of declining Arctic sea ice on ecosystem productivity appear to vary inter-specifically, spatially, and temporally and are not well understood (Hoegh-Guldberg & Bruno, 2010; Kovacs, Lydersen, Overland, & Moore, 2011; Moore & Huntington, 2008; Post et al., 2013). This variation, in part, is a result of varying rates of sea ice loss across the circumpolar Arctic. For example, the Barents Sea, Laptev Sea, East Siberian Sea, Beaufort Sea, Chukchi Sea (CS), Hudson Bay, and East Greenland Sea are undergoing some of the greatest declines in summer sea ice extent (Laidre et al., 2015; Markus, Stroeve, & Miller, 2009; Stern & Laidre, 2016), yet species-specific effects vary depending on local bathymetry, community composition, and other factors (Kovacs et al., 2011; Rode, Regehr, Douglas, et al., 2014). Primary productivity has been predicted to increase in the Arctic as sea ice loss continues (Arrigo, van Dijken, & Pabi, 2008). However, global warming is expected to result in highly variable and difficult to predict changes in productivity of regional seas due to spatial variation in ice cover, stratification, and wind patterns (Grebmeier, Moore, Overland, Frey, & Gradinger, 2010; Kovacs et al., 2011; Slagstad, Ellingsen, & Wassmann, 2011).

Effects on upper trophic-level fauna from declining sea ice are also not well understood. Pelagic organisms are expected to increase in abundance, whereas benthic organisms are expected to decline (Cooper et al., 2013; Grebmeier, 2012). Cold-water species, such as Arctic cod (*Boreogadus saida*) are predicted to be displaced by warmer-water species (Mueter et al., 2009) as a result of warming ocean temperatures and changes in sea ice distribution (Gaston, Woo, & Hipfner, 2003). Changes in the timing of primary production are expected to negatively affect the zooplankton that Arctic cod rely on (Post et al., 2013), but empirical data suggest some variation in that pattern. For example, in the southern Beaufort Sea, ringed seal (*Pusa hispida*), beluga whale (*Delphinapterus leucas*), and black guillemot chicks (*Cepphus grylle*) that rely heavily on Arctic cod were observed to decline in body condition, growth rates, and/or reproductive success while bowhead whales (*Balaena mysticetus*) which are more dependent on pelagic plankton communities exhibited improvement (Harwood et al., 2015). Furthermore, Arctic char (*Salvelinus alpinus*) exhibited a shift from consumption of Arctic cod to other alternative forage fish (Harwood et al., 2015). In contrast, ringed and bearded seals (*Erignathus barbatus*) in the neighboring, and more southerly extending CS, have increased consumption of Arctic cod, suggesting that cod have not yet been displaced or declined with warming, despite substantial declines in sea ice extent (Crawford, Quakenbush, & Citta, 2015). Understanding marine mammal responses to sea ice loss depends on understanding trophic cascading effects of changing ecosystems (Hoegh-Guldberg & Bruno, 2010; Kovacs et al., 2011), including direct effects on abundance and distribution, as well as prey behavior.

As an apex marine predator occupying a relatively simplified ecosystem (Murphy et al., 2016), polar bears (*Ursus maritimus*) may be a useful indicator of changes in species productivity at lower trophic levels. The ability of a polar bear to hunt depends directly on seal abundance and behavior, and the sea ice conditions that promote successful predation (*i.e*., encounter and capture). Although much attention has been placed on the loss of summer sea ice as a platform for hunting seals (Derocher, Lunn, & Stirling, 2004; Rode et al., 2015; Whiteman et al., 2015), studies in the Beaufort Sea suggest that reductions in polar bear foraging efficiency are occurring during seasons when sea ice loss has been less dramatic. Cherry, Derocher, Stirling, and Richardson (2009) documented reduced spring (i.e., March–April) foraging success evidenced by a greater frequency of fasting over the previous 7 days or more in 2005–2006 compared to 1985–1986. Furthermore, Rode, Pagano, Bromaghin, et al. (2014) and Rode, Regehr, Douglas, et al. (2014) documented that frequencies of fasting in the southern Beaufort Sea (SB) were much higher than those observed in the adjacent CS in recent years. These observations were concurrent with documented declines in polar bear body condition, cub survival, and population size in the SB between the 1980s and 2000s, and with maintained or improved body condition and cub survival in the CS—all during a time when both subpopulations were experiencing substantial summer sea ice loss (Rode, Regehr, Douglas, et al., 2014). However, there has been little change in spring sea ice extent between periods or across regions (Douglas, 2010; Frey, Moore, Cooper, & Grebmeier, 2015), suggesting that other factors related to ecosystem productivity (e.g., seal and Arctic cod abundance) and function (i.e., seal behavior) or the quality of sea ice as a hunting platform (i.e. the availability of pressure ridge, lead systems, stalking cover, etc.), may be influencing spring polar bear feeding behavior.

Spring is the most important, if not critical, foraging period for polar bears in which they gain mass lost over the previous winter (Rode, Regehr, Douglas, et al., 2014), particularly for females emerging from dens with newborn cubs (Pilfold, Derocher, Stirling, Richardson, & Andriashek, 2012; Stirling & McEwan, 1975; Stirling & Øritsland, 1995). Ringed and bearded seals haul-out to molt and pup in the spring, making them more accessible to polar bears than during any other time of the year. Several studies have estimated that adult polar bears need to capture a ringed seal every 5 days during the peak foraging period in late spring and early summer to build up fat reserves to support reproduction and survival during the following winter (Pagano et al., unpublished data; Stirling & Øritsland, 1995). A recent study that tracked the feeding behavior, energetic costs, and body mass change of nine adult females in the SB found that the three that did not eat over a 9-day period lost 10% or more of their body mass (Pagano et al., unpublished data). Thus, reduced frequency of feeding in the springtime appears to have meaningful consequences for individual condition.

Although nearly 40% of the ringed seals killed by polar bears in the Beaufort Sea are pups, older age classes of prey are also important contributors to total biomass consumed (Pilfold et al., 2012). Adult seals are typically killed when hauled out rather than at lairs in the spring (Pilfold et al., 2012), thus factors affecting their haul-out patterns may be important in affecting polar bear predation success. Sea ice availability and quality, prey behavior, and ecosystem productivity may be important factors that combine to determine polar bear predation success.

Here, we examine spring fasting behavior (*i.e*., not having fed for ≥7 days) based on blood serum and creatinine ratios of polar bears in three recognized subpopulations (the Northern Beaufort (NB), SB, and CS) over three decades (1983–2016) as potential indicators of the sea ice and ecosystem changes in these regions. Our objectives were to (i) determine whether the frequency of spring fasting has changed over time or differs among these subpopulations (Rode, Regehr, Douglas, et al., 2014; Stirling, McDonald, Richardson, Regehr, & Amstrup, 2011) which have exhibited different responses to recent sea ice loss, (ii) determine whether environmental and ecological conditions which could affect fasting have changed over time and differ among subpopulations, and (iii) attempt to identify which factors may affect the frequency of fasting including indices of seal productivity, variables related to seal haul-out behavior, and measures of sea ice and weather conditions that could affect local foraging success.

2 | MATERIALS AND METHODS

2.1 | Sample collection and analysis

We analyzed serum samples from polar bears handled during capture–recapture studies between mid-March and early May, in 1985–1996 and 2005–2006 in the NB, 1983–2016 in the SB, and 1987–1993 and 2008–2016 in the Alaska portion of the CS (Figure 1). Polar bears were located from a helicopter and immobilized with a rapid-injection dart (Palmer Cap-Chur Equipment, Douglasville, GA, USA) containing zolazepam-tiletamine (Telazol® or Zoletil®) 1987–2016, or Sernylan, M-99, or phencyclidine prior to 1987. Bears were captured on the sea ice with the exception of 7 of 1448 samples collected from bears on land during the early years of the study (Figure 1). Land-based bears were likely to have denned, but denning effects on fasting were accounted for as described below. In the CS 2008–2016 and in the NB and SB during all years, all sex and age classes were equally targeted for sampling whereas in the CS, capture efforts 1987–1993 targeted primarily adult females (55 of 62 bears captured were females). Studies were conducted under USFWS research permits MA 690038 and 046081 and followed protocols approved by Animal Care and Use Committees of the USGS and the USFWS.

Bears were classified to subpopulations based on range patterns from satellite collar data and ecological features that were associated with range patterns. Bears captured west of −160° longitude were classified as belonging to the CS polar bear subpopulation, bears captured east of −160° and west of −128.2° were classified to the SB subpopulation, and bears captured east of −128.2° were classified to the NB subpopulation. The International Union for the Conservation of Nature's Polar Bear Specialist Group (PBSG) boundary between the CS and SB occurs at approximately −163° longitude (Figure 1), but satellite location data from adult females captured between −160° and −163° longitude (n = 11) suggest they remain primarily in the area designated as the CS subpopulation (Amstrup, McDonald, & Durner, 2004; USGS and USFWS, unpublished data). Similarly, although the SB/NB subpopulation boundary is defined by the PBSG as −121°, bear movement patterns and habitat conditions vary east and west of Ballie Island in response to the Cape Bathurst polynya (Galley, Else, Howell, Lukovich, & Barber, 2012; Stirling, Richardson, Andriashek, & Derocher, 2006) and there have been discussions to change the PBSG subpopulation boundary. Therefore, bears were assigned to the NB subpopulation if their capture location was east of −128.2° and south of 71.5° or east of −132.0° and north of 71.5° (n = 150 bears of 241 assigned to the NB that would have been assigned to the SB subpopulation based on the current IUCN boundary).

A vestigial premolar was extracted for age determination upon first capture, except for dependent young which were aged based on size and dentition. We classified senescent adults as ≥20 years old (Lunn et al., 2016), prime-age adults as 5–19 years old, subadults as independent (*i.e*., without their mother) bears 2–4 years old, and dependent young as cubs age 0–2 years accompanying their mother. Blood was collected in no-additive tubes and centrifuged to separate blood serum from red blood cells. Serum was initially stored in the field for up to 4 weeks at −3 to −5°C and then stored at −80°C until processing. Urea and creatinine are stable in blood during long-term storage at −80°C (see Appendix S1 for a detailed discussion of this topic). However, we examined the potential for previous thawing of samples during long-term storage to affect UC ratios by comparing paired previously thawed and not thawed samples collected from five individuals on the same capture date (Appendix S1). Levels of blood urea nitrogen (BUN) and creatinine were measured in serum using comprehensive rotors with an Abaxis vetscan (Abaxis, Inc., Union City, CA, USA) or via methods described in Cherry et al. (2009). Serum urea was calculated by multiplying BUN × 0.466 (Nelson, Beck, & Steiger, 1984) and divided by serum creatinine to determine a urea:creatinine ratio (hereafter UC ratio); a metric that is commonly used to identify fasting status in polar bears (Cherry et al., 2009; Derocher, Nelson, Stirling, & Ramsay, 1990; Nelson et al., 1984).

Previous studies have used UC ratios of ≤10.0 as indicative of bears that have fasted for ≥7 days (Cherry et al., 2009; Nelson et al., 1984). However, data from captive studies of feeding and fasting polar bears suggest that ratios >10.0 commonly occur when bears are fasting and that there is considerable variation around mean UC ratios for fasting bears (Derocher et al., 1990). Furthermore, recently collected video-collar and body mass data on wild polar bears in the SB demonstrated at least one bear that did not feed for 9 days and had a UC ratio of 10.7 (Pagano et al., in review). Therefore, rather than creating a binary dataset classifying bears as having fasted or not fasted for a ≥7 day period, we used a Bayesian mixture model to estimate the probability of fasting for each bear in our data set (see Statistical analyses).

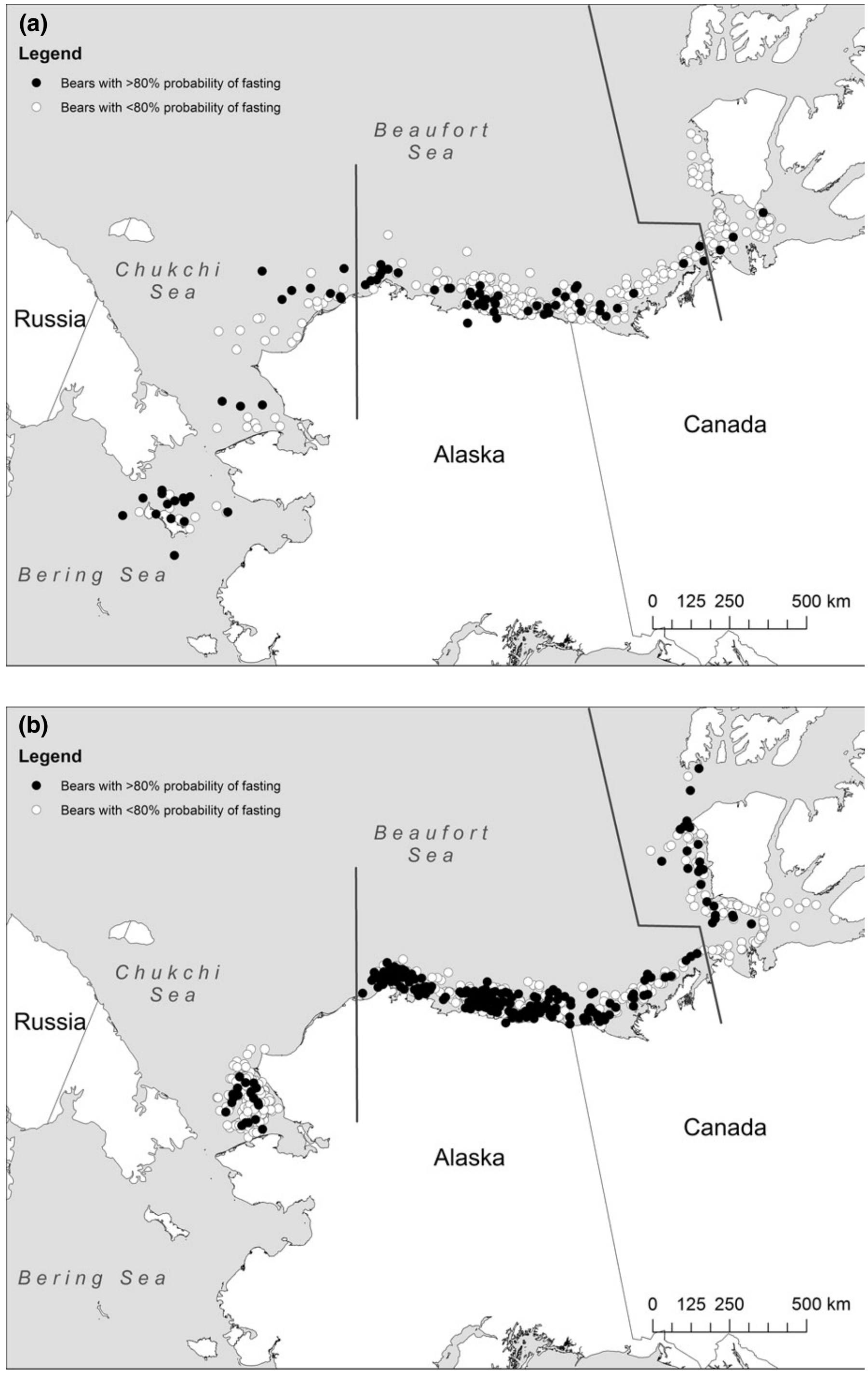

FIGURE 1 Polar bear capture locations in spring (March–May) during 1983–1999 (a) and 2000–2016 (b) in the Beaufort and Chukchi Seas (CSs). Bears whose serum urea to creatinine ratios were associated with a >80% estimated probability of fasting are shown as closed circles and those with <80% probability of fasting are shown as open circles. This threshold was used to aid in visualizing distribution of bears that were likely to be fasting and differences in distribution between time periods that are discussed in the text. Black lines represent delineation between the CS (bears captured west of −160°), southern Beaufort (bears captured between −160° and −128.2°), and northern Beaufort (bears captured east of −128.2°and south of 71.5° or east of −132.0° and north of 71.5°) subpopulations

2.2 | Objective 1: Spatial and temporal patterns in fasting behavior

Our first objective was to determine whether the frequency of fasting differed among the three polar bear subpopulations and/or changed over time. We compared the frequency of fasting among subpopulations and between two time periods: before 2000 and from 2000 to 2016. We chose this period separation for several reasons. There were no data collected in the SB 1993–1997, NB 1986–2004, or in the CS 1994–2007, so a gap in the data set occurred in the mid-late 1990s for all subpopulations. Consistent anomalies in the length of the melt season and availability of summer ice habitat began to occur in approximately 2000 in the Beaufort Sea (Bromaghin et al., 2015; Frey et al., 2015; Pagano, Durner, Amstrup, Simac, & York, 2012; Petty, Hutchings, Richter-Menge, & Tschudi, 2016) and declines in the body condition of beluga whales, ringed seals, and black guillemot chicks occurred between the 1990s and 2000s (Harwood et al., 2015). Polar bear capture locations were similar between the two periods compared in the NB and SB, but differed somewhat in the CS with more bears captured around St. Lawrence Island in Alaska and along the CS/SB subpopulation boundary in the early period compared to the later period. The

TABLE 1 Variables included in models

Variable	Definition
Age	Categorical variable based on a bear's age: subadult = 2–4 years old, adult = 5–19 years old; senescent adult ≥20 years
Sex	Binary variable of a bear's sex: F = female, M = male
Capture date	Ordinal day in which a bear was captured and sampled
Mating	Binary variable of whether a bear exhibited mating behavior or not at the time of capture
Denning	Binary variable of whether a bear denned or not during the prior winter
Population	Categorical variable classifying the subpopulation to which a bear was assigned based on its capture location
Period	Binary variable of an early time period prior to 2000 and a later time period of ≥2000
Mean ice conc	Mean ice concentration (%) within a 100 km radius of a bear's capture location over the 7 days prior to capture
SD ice conc	Standard deviation of ice concentration within a 100 km radius of bear's capture location over the 7 days prior to capture
Mean drift	Mean sea ice drift in km/day within a 100 km radius of a bear's capture location over the 7 days prior to capture
SD drift	Standard deviation in sea ice drift within a 100 km radius of a bear's capture location over the 7 days prior to capture
Temp anomaly	The difference between air temperature 2 m above sea level surrounding a bear's capture location averaged over the 7 days prior to capture and the mean temperature on those 7 days for 1980–2016 (°C)
Wind speed	Wind speed (km/hr) at 10 m above sea level surrounding a bear's capture location averaged over the 7 days prior to capture
Pressure	Pressure (mb) at 2 m above sea level surrounding a bear's capture location averaged over the 7 days prior to capture
Seal pups	Annual % of pups in the open water ringed seal harvest in east Amundsen Gulf of the eastern southern Beaufort Sea from Harwood et al. (2012); Data available 1992–2010 only
Seal ovulating	Annual ovulation rate of mature adult female ringed seals in east Amundsen Gulf of the eastern southern Beaufort Sea from Harwood et al. (2012); Data available 1992–2010 only
Seal index	Annual body condition index based on teeth annuli of ringed seals in the Canadian Beaufort Sea from Nyugen et al. (2017); 1983–2006
Scatterometry	Mean daily difference in qscat horizontally polarized scatterometry images over 7 days prior to capture within a 100 km radius of a bear's capture location. Data available 2000–2013 only
winterAO	Binary variable indicating whether the winter phase (Jan–Mar) of the Arctic Oscillation was negative or positive
AOO	Binary variable indicating whether the Arctic Ocean Oscillation was negative or positive

potential effects of capture location were considered when interpreting differences in the probability of fasting between periods in the CS.

There were several factors that we accounted for that could affect fasting behavior, including age, sex, mating behavior, denning, and capture date. We included age as a categorical variable (categories described under *Sample collection* and in Table 1) and excluded dependent young from the analysis because their feeding status is likely correlated with their mother. Because male polar bears are known to reduce or forego feeding during the mating season (Cherry et al., 2009) which coincides with the spring foraging period (April–June; Stirling, Spencer, & Andriashek, 2016), we included mating as a binary variable. A bear was classified as mating if they were observed pursuing a mate (i.e., for males they were either following the tracks of a female or with a female) or being pursued (a male was observed with a female) or if they were in estrus at the time of capture (females). Subadults and females with cubs or yearlings were assumed not to be mating. Because recording of estrus was not consistent across the study and males that were not observed pursuing a mate at the time of capture may have been involved in mating, many bears had an unknown mating status. We therefore used a Bayesian data imputation procedure (Gelman, Carlin, Stern, & Rubin, 2004) to assign mating status to bears with an unknown status (see Statistical analyses).

Denning throughout the winter occurs almost exclusively by lone females who are presumed to be pregnant and emerge from land or ice-based dens in April. Because females emerging from a den are more likely to exhibit a UC ratio consistent with fasting, we identified females that denned during the prior winter as those with cubs-of-the-year or those wearing radio-collars which demonstrated a winter temperature signature consistent with denning (Fischbach, Amstrup, & Douglas, 2007; Olson et al., 2017). However, lone females that were not collared and observed without cubs could have denned during the prior winter, lost their cubs, and recently emerged from a den. Similar to our method for contending with mating uncertainty, we used a Bayesian data imputation procedure to assign mating status to bears with an unknown status (see Statistical analyses).

We included ordinal capture date as a potential factor affecting the frequency of fasting because ringed seals give birth to and nurse their pups and increasingly haul-out in subnivean lairs and later on the surface of the ice as the spring progresses (Smith 1987; Kelly et al., 2010) which affects polar bear predation success (Pilfold et al., 2012).

2.3 | Objectives 2 & 3: Environmental and ecological factors affecting fasting behavior

We hypothesized that ice and weather conditions that affect seal haul-out behavior (Frost, Lowry, Pendleton, & Nute, 2002) and access to seals, and annual variation in seal productivity could affect fasting behavior. Therefore, we examined air temperature, atmospheric pressure, and wind speed, as well as sea ice concentration, ice drift (km/day), and day-to-day changes in radar scatterometry ice imagery (described more below and in Appendix S1), at each capture location during the 7 days before capture (Table 1; Appendix S1). Weather data at each capture site were obtained from the North American Regional Reanalysis (Mesinger et al., 2006) using the Env-DATA portal (Dodge et al., 2013) at www.movebank.org (accessed November 2016). Sea ice characteristics were quantified within a 100-km radius around each capture location, the average net distance (plus one standard deviation) that polar bears move in 7 days during March and April, excluding the first 7 days post-capture (see Appendix S1; Rode, Pagano, Bromaghin, et al., 2014). Mean (and *SD*) daily sea ice concentration (%) and sea ice drift (km/day) during the week prior to capture were derived for each capture location using 25 km × 25 km resolution grids obtained from the National Snow and Ice Data Center (see Appendix S1). Because ice concentration data alone afford a limited representation of the sea ice environment, we used scatterometry data as an additional metric related to the magnitude of short-term (7 day) sea ice habitat change that may have implications on polar bear foraging success. Scatterometers have been used to characterize sea ice drift, age, surface melt status, and to better resolve small-scale geographic features such as leads and polynyas (see details in Appendix S1). In addition, we examined more broad-scale variables including annual metrics of ringed seal ovulation rates and pup production (Harwood, Smith, Melling, Alikamik, & Kingsley, 2012; Nyugen et al., 2017), as indicators of the health and abundance of ringed seals, winter Arctic Oscillation index (AO Jan–Mar), and Arctic Ocean Oscillation (AOO index, annual average). Ringed seal data collected by Harwood et al. (2012) were sampled in Amundsen Gulf in the eastern Beaufort Sea, whereas samples collected by Nyugen et al. (2017) were from the Canadian portion of the Beaufort Sea. Data on ringed and bearded seal abundance were not available for the Chukchi and Beaufort Seas nor were there comparable (i.e., data collected using the same methods) condition metrics for ringed seals in the Alaska portion of the Beaufort Sea or the CS. See Appendix S1 for more detail on the covariates included in the models.

The available data on ice conditions, weather patterns, and ringed seal ovulation rates and pup production varied spatially and temporally requiring that we examine relationships with spring fasting behavior among several separate models. Although data on patterns of ringed and bearded seal reproduction are available for the CS, both the time scale of available data (2003–2012; Crawford et al., 2015) and differences in the methods used in comparison to the Beaufort Sea prevented inclusion of these variables in a model across all three study regions. Furthermore, scatterometry data were not available until 2000. Therefore, our first model examining environmental and ecological factors affecting fasting included bears from all three regions across the broadest time frame (1983–2016), but excluded indices of seal ovulation rates and measures of sea ice conditions derived from scatterometry data. We ran two additional models with bears in the NB and SB where seal data were available. The two sources of seal productivity data (Harwood et al., 2012; Nyugen et al., 2017) spanned different timeframes (1992–2010 and 1983–2006, respectively) and were potentially correlated. Thus, they were included in separate models. Finally, because scatterometry data were only available starting in 2000, we ran a fourth model including scatterometry data for all three populations during this truncated timeframe.

We ensured that collinearity was controlled for by measuring variance inflation factors (VIF) for all variables, ensuring that no variable had a VIF > 5 (Zuur, Ieno, Walker, Saveliev, & Smith, 2009).

2.4 | Statistical analyses

We used a Bayesian mixture model to determine what factors influenced the probability of fasting in polar bears between the three subpopulations. We modeled UC as a mixture of two gamma distributions dependent on the fasting status of individuals (i);

$$\mathrm{UC}_i \sim \begin{cases} \mathrm{gamma}\left(\frac{\mu_f^2}{\sigma_f^2}, \frac{\mu_f}{\sigma_f^2}\right), \text{if} \quad p_i = 1 \\ \mathrm{gamma}\frac{\mu_{nf}^2}{\sigma_{nf}^2}, \frac{\mu_{nf}}{\sigma_{nf}^2}), \text{if} \quad p_i = 0 \end{cases} \tag{1}$$

where p_i represents the fasting status of individual i (0 = non-fasting, 1 = fasting), μ_f and μ_{nf} are the mean UC for fasting (f) and non-fasting (nf) bears, respectively, and σ_f^2 and σ_{nf}^2 are the variances of UC for fasting and non-fasting bears, respectively. We used informed priors for the mean and variance parameters in equation 1, based on data found in Derocher et al. (1990) for UC values obtained from wild-caught but captive polar bears with known fasting status (i.e., 1 day post-feeding [non-fasting], and an average of 40-days post-feeding [fasting]). In Derocher et al. (1990), UC values were obtained from 13 bears in 2 years which were used to inform the variability in both the mean and standard deviation of the UC ratios. We modeled the prior of μ_{nf} and σ_{nf} as;

$$u_{nf} \sim \mathrm{gamma}\left(\frac{46.6^2}{20.6^2}, \frac{46.6}{20.6^2}\right) \tag{2}$$

and

$$\sigma_{nf} \sim \mathrm{gamma}\left(\frac{19.1^2}{18.0^2}, \frac{19.1}{18.0^2}\right). \tag{3}$$

We modeled the priors of μ_f and σ_f as;

$$u_f \sim \mathrm{gamma}\left(\frac{13.4^2}{3.4^2}, \frac{13.4}{3.4^2}\right) \tag{4}$$

and

$$\sigma_f \sim \mathrm{gamma}\left(\frac{6.1^2}{1.2^2}, \frac{6.1}{1.2^2}\right) \tag{5}$$

where the numerator of u and σ are determined from the mean UC ratios and standard deviations, respectively, and the denominator from the standard deviation of the UC ratios and standard deviations of non-fasting (nf) and fasting (f) bears in Derocher et al. (1990).

To address study objective 1 (identifying spatial and temporal variation in spring fasting behavior), we modeled the probability that an individual was fasting as a function of population, time period, a population–period interaction, sex, age, mating status, denning status, and capture date (defined in Table 1);

$$\mathrm{logit}(p_i) = \beta_0 + \boldsymbol{\beta x_i} + \varepsilon_i \quad (6)$$

where β_0 is an intercept term, $\boldsymbol{\beta x_i}$ is the vector of coefficient estimates multiplied by their associated variable values for individual i, and ε_i is a random effect (Table 2). All β and *e* were given a vague normal prior with mean 0, and variance 10. Objective 3 was addressed via the four models (explained above) with covariates listed in Table 3.

We developed a predictive model for the probability of a bear denning based on the set of bears with known denning status (*d*), with population, period, and capture date serving as predictors;

$$\mathrm{logit}(d_i) = \beta_{d0} + \boldsymbol{\beta_d x_i} \quad (7)$$

We then estimated the denning status for those bears with missing values with a Bernoulli distribution (i.e., Bernoulli(d_i)). Our predictive model for mating status was similar to that of the denning status model, except that we also included denning status and sex as explanatory variables in the model. Based on the estimated probability of mating (*m*), we then determined the mating status of an individual, again with a Bernoulli distribution (i.e., Bernoulli(m_i)). All β for the permutation procedure were given a vague normal prior with mean 0, and variance 10.

Estimates of denning and mating status of bears with missing values were computed iteratively in the Markov Chain Monte Carlo (MCMC) procedure to account for the uncertainty in both factors.

We estimated the posterior distribution for each parameter with MCMC using the package "rjags" (Plummer, 2015) to run the program JAGS (Plummer, 2003) from the R language and environment for statistical computing (R Core Development Team, 2014). We initialized two chains with separate starting values and allowed a burn-in period of 50,000 iterations. We then obtained 50,000 iterations from each chain, and thinned each by 50, resulting in a total of 2,000 samples from the posterior distribution (Appendix S1). We visually assessed each parameter for convergence. We did not employ model selection, based on reasons similar to those outlined in Hobbs, Andrén, Persson, Aronsson, and Chapron (2012). We were not seeking to create the most parsimonious model, but rather to include all parameters known to potentially affect fasting (e.g., mating and capture date, sex, and age; Pilfold, Derocher, Stirling, & Richardson, 2015) and to test hypothetical factors that may affect fasting based on polar bear and seal ecology (as described above). We assessed the importance of each variable based on whether the 95% credible interval (CI) overlapped zero, similar to Hobbs et al. (2012). We standardized all continuous covariates to aid in model convergence and to allow for easier interpretation of the magnitude of influence among covariates. We performed posterior predictive checks (Chambert, Rotella, & Higgs, 2014) to determine how well the model fit our observed data (i.e., UC ratios). We calculated Bayesian *p* values for four test statistics (i.e., mean, standard deviation, discrepancy, and goodness of fit) and considered *p* values for test statistics between 0.1 and 0.9 to indicate a good fit between the model and observed data for a given test statistic (Hobbs & Hooten, 2015). All of the above statistical analyses were conducted in R version 3.3.2.

To better understand whether environmental and ecological conditions experienced by bears during the 7 days prior to capture differed between periods and regions, we ran general linear models with population and period as fixed effects, capture date as a covariate, and a population–period interaction. Capture date were removed from the model if it was not significant at $p < .05$. Models were run in SPSS version 24.0.

TABLE 2 Mean and 95% credible intervals for coefficient estimates from a Bayesian mixture model examining potential changes over time and differences among three populations in the probability of fasting

	Probability of fasting	
Parameter	**Mean**	**95% C.I.**
Intercept	−0.45	−2.58 to 1.60
Population (CS)	−0.39	−2.35 to 1.47
Population (NB)	0.60	−1.61 to 2.64
Period	1.39*	0.40 to 2.44
Sex	−2.56*	−3.59 to −1.67
Capture date	−1.93*	−2.46 to −1.41
Mating	2.28*	0.92 to 3.67
Denning	3.68*	2.30 to 5.28
Population (CS) × Period	−3.24*	−5.33 to −1.01
Population (NB) × Period	−0.79	−3.18 to 1.67
Age (adult)	−0.96	−2.42 to 0.58
Age (subadult)	−2.87*	−4.66 to −1.12

CS, Chukchi Sea; NB, Northern Beaufort. Population coefficient estimates are relative to the southern Beaufort subpopulation and for age are relative to senescent adults. A negative coefficient for sex indicates a lower probability of fasting in females. Probability of fasting declined with capture date and was higher for bears involved in mating or that had denned the prior winter than those that did not. "*" indicates that the 95% credible interval for a parameter's estimation did not overlap 0 and is therefore, important in the model

3 | RESULTS

3.1 | Objective 1: Spatial and temporal variation in fasting behavior

The final data set included urea and creatinine levels from 1,448 serum samples from 1,176 individual adult and subadult bears captured in the CS (n = 296 samples) 1987–1993 and 2008–2016, SB (n = 911) 1983–1992 and 1998–2016, and NB (n = 241) 1985–1996 and 2005–2006. Mating status (i.e., mating or not mating) was known from field observations for 551 of 692 adult female and 164

TABLE 3 Mean and 95% credible intervals for coefficient estimates from a Bayesian mixture model of factors affecting the probability of spring fasting for four models incorporating various environmental and ecological variables described in Table 1

	Model							
	All pops (1983–2016) n = 1448		Beaufort Sea pops with Harwood et al. (2012) seal data (1992–2010) n = 675		Beaufort Sea pops with Nyugen et al. (2016) seal data (1983–2006) n = 831		All pops and scatterometry data (2000–2013) n = 839	
Covariates	Mean	95% C.I	Mean	95% C.I	Mean	95% C.I	Mean	95% C.I
Intercept	0.28	−2.09 to 2.52	−0.44	−3.89 to 3.04	−0.15	−2.87 to 2.43	−0.326	−4.66 to 3.73
Sex	−2.79*	−3.92 to −1.80	−2.25*	−3.80 to −0.79	−2.16*	−3.64 to −0.85	−1.64*	−2.50 to −0.91
Capture date	−1.73*	−2.32 to −1.22	−2.20*	−3.25 to −1.32	−1.72*	−2.59 to −0.96	−2.05*	−3.33 to −1.01
Mating	2.85*	1.25 to 4.66	2.78*	0.36 to 5.36	3.09*	1.16 to 5.22	4.25*	2.28 to 6.62
Denning	4.75*	3.12 to 6.61	4.13*	1.93 to 6.64	4.03*	2.09 to 6.25	5.09*	3.06 to 7.60
Mean ice conc	0.21	−0.33 to 0.76	−0.31	−1.22 to 0.61	0.32	−0.49 to 1.20	−0.18	−1.02 to 0.67
SD ice conc	−0.20	−0.74 to 0.37	−0.12	−1.08 to 0.86	0.10	−0.69 to 0.93	0.50	−0.32 to 1.31
Mean drift	−0.23	−1.08 to 0.53	0.43	−1.03 to 1.80	−0.36	−1.53 to 0.72	0.98	−0.26 to 2.27
SD drift	−0.09	−0.87 to 0.68	−0.85	−2.19 to 0.40	−0.09	−1.23 to 1.07	−1.00	−2.21 to 0.12
Temp anomaly	−0.05	−0.52 to 0.41	0.04	−0.63 to 0.74	0.19	−0.47 to 0.85	−0.28	−0.93 to 0.34
Wind speed	0.61*	0.10 to 1.15	0.19	−0.57 to 1.00	0.40	−0.28 to 1.10	0.21	−0.40 to 0.90
Pressure	−0.04	−0.51 to 0.42	−0.24	−0.93 to 0.44	0.10	−0.50 to 0.72	−0.47	−1.14 to 0.14
winterAO	−0.62	−1.52 to 0.26	0.04	−1.49 to 1.50	1.32	−0.09 to 2.94	−1.78*	−2.93 to −0.64
AOO	−0.53	−1.81 to 0.79	0.20	−2.96 to 3.24	−0.06	−1.76 to 1.68	−0.40	−4.60 to 3.75
Age (adult)	−0.75	−2.29 to 0.82	−0.70	−2.85 to 1.56	−0.70	−2.70 to 1.33	−0.99	−2.87 to 0.89
Age (subadult)	−2.92*	−4.86 to −1.10	−3.39*	−6.84 to −0.50	−2.45*	−4.70 to −0.18	−3.99*	−6.80 to −1.50
Seal pups	–	–	−0.85	−2.08 to 0.31	–	–	–	–
Seal ovulating	–	–	−0.02	−1.08 to 1.01	–	–	–	–
Seal Index	–	–	–	–	−1.30*	−2.05 to −0.63	–	–
Scatterometry	–	–	–	–	–	–	−1.80*	−4.14 to −1.07

Only the "All pops" models include data from all three bear subpopulations, whereas all other models include data from only the Northern and Southern Beaufort Sea subpopulations. Age class coefficients are relative to senescent adults. Different timeframes of data were used to match available data for different covariates of interest (e.g., seal body condition indices, scatterometry data). "*" indicates that the 95% credible interval for a parameter's estimation did not overlap 0 and is therefore, important in the model

of 489 adult male samples. Using our data imputation procedure, we assigned an additional 139 (95% CI = 92–181) adult bears of unknown mating status as "mating" at the time of capture (Table S1) and the remaining 334 bears as not mating. Similarly, denning status was known from field observations for 401 of 692 adult females sampled. We assigned an additional 173 (95% CI = 167–181) adult females as having denned prior to capture (Table S1) and the remaining 157 females as not having denned based on data imputation. We estimated that females traveled 51.6 ± 47.0 (*SD*) km over a 7 day period (n = 13,241 movement measurements). Collar-based movement data were not available for males in this region, but Laidre et al. (2012) found no difference in movement rates of males and females in the spring.

There was no difference in either the serum urea nitrogen (p = .3) or creatinine (p = .7) using a Wilcoxon signed rank paired test suggesting that if thawing had unknowingly occurred it was unlikely to bias our results.

We estimated mean UC ratio for bears identified as fasting and non-fasting to be 12.6 ± 6.8 (mean ± *SD*; 95% CI = 11.3–13.8) and 48.6 ± 32.2 (95% CI = 45.1–52.7), respectively (Figure 2). The percent of bears fasting differed among the three subpopulations and two periods (Table 2). The percent of adult females fasting declined from 53% (42%–64%; n = 55) to 10% (6%–17%; n = 106) in the CS and increased from 30% (22%–39%; n = 136) to 42% (34%–49%; n = 293) and from 13% (3%–27%; n = 40) to 33% (22%–44%; n = 99) in the SB and NB, respectively (Figure 3). The percent of males fasting increased from 44% (34%–55%; n = 55) to 66% (59%–74%; n = 257) and from 27% (12%–40%; n = 39) to 40% (27%–55%; n = 62) between periods in the SB and NB, respectively (Figure 3). The sample size for CS males was too low (n = 7) in the early period for comparison, but was large enough in the recent period to estimate at 34% (24%–44%; n = 128; Figure 3). Sex, denning status, mating status, age class, and capture date also affected fasting (Table 2). Bears that had denned (adult females only) or were involved in mating (adults only) had higher probabilities of fasting than non-denning and non-mating bears, respectively. Males (51.3 ± 38.7%; mean ± *SD*; n = 628) had a higher probability of fasting than females (33.0 ± 35.9%; n = 820). Senescent adults were most likely to be fasting (49.3 ± 39.3%; n = 85), followed by adults (44.4 ± 38.7%; n = 1096), and subadults (23.8 ± 30.7%; n = 267). Finally, polar bears captured later in the year had lower probabilities of fasting than bears captured earlier (Table 2). The model appeared to fit the data well, with Bayesian p values for each of the four metrics indicating a good fit; mean (p = .48), standard deviation (p = .25), discrepancy (p = .21), and goodness of fit (p = .52; Table S2).

3.2 | Objective 2: Spatial and temporal variation in weather and sea ice conditions

Mean sea ice concentration experienced by bears during the 7 days prior to capture was higher in the SB (96.4 ± 3.4%) than the CS (93.1 ± 4.3%) or NB (93.4 ± 4.3%; population–period interaction: $F_{1,1441}$ = 11.7, p < .0001) but several metrics suggested greater variability in sea ice conditions in the CS than the SB or NB. The standard deviation of sea ice concentration was higher in the CS (2.5 ± 1.5%; n = 296) than the SB (1.7 ± 1.6%; n = 972) or NB (1.7 ± 0.9%; n = 180)($F_{2,1443}$ = 38.4, p < .0001) as was 7 day variation in scatterometer images (CS: 0.53 ± 0.32; n = 179; SB: 0.35 ± 0.15, n = 615; NB: 0.34 ± 0.12, n = 100; $F_{2,890}$ = 71.3, p < .0001). Similarly, mean sea ice drift was highest in the CS (3.1 ± 1.3 km/hr, n = 262) compared to the SB (2.9 ± 2.2 km/hr; n = 920) and NB (2.3 ± 1.0 km/hr; n = 115; population–period interaction: $F_{2,1290}$ = 3.1, p = .047) and there was only a marginal difference between subpopulations in the standard deviation of drift (CS: 2.0 ± 0.9 km/hr, SB: 2.0 ± 1.5 km/hr, NB: 1.5 ± 0.9 km/hr; $F_{2,1292}$ = 3.0, p = .05). The NB exhibited the greatest temperature anomalies in the most recent time period (NB: 1.9 ± 2.6°C, n = 100), followed by the CS (0.96 ± 0.31°C, n = 234) and SB (0.4 ± 3.2°C, n = 667; population–period interaction: $F_{2,1441}$ = 13.8, p < .0001). There was no difference in wind speed between subpopulations ($F_{1,1443}$ = 0.05, p = .95). Pressure was lowest in the CS (1013.6 ± 8.8; n = 296), higher in the SB (1018.0 ± 7.1, n = 972), and highest in the NB (1021.1 ± 7.0; n = 180; $F_{2,1444}$ = 39.6, p < .0001).

Mean sea ice concentration around polar bear capture sites increased 1% in the CS and 2.8% in the NB between periods, but exhibited no change in the SB (population*period interaction: $F_{2,1441}$ = 11.7, p < .0001). Sea ice drift decreased in the CS by 0.4 km/hr and increased in the NB and SB by 0.3 and 0.5 km/hr, respectively, between time periods (population*period interaction: $F_{2,1290}$ = 3.1, p = .05). The standard deviation in sea ice concentration and sea ice drift increased between periods (ice concentration: β = 0.33 ± 0.09%, $F_{2,1443}$ = 38.4, p < .0001; drift: period*population interaction: $F_{2,1290}$ = 3.1, p = .05). There was a shift from negative to positive temperature anomalies experienced by bears in all three subpopulations (population*period interaction: $F_{2,1441}$ = 13.8, p < .0001), but this shift was most pronounced in the NB where anomalies averaged −2.4°C in the early period and 1.9°C in the latter period. Wind speeds were also 0.4 km/hr higher across all regions in the most recent time period compared to the past (β = 0.39 ± 0.20; $F_{1,1445}$ = 3.9, p = .049). There was no change in pressure ($F_{1,1443}$ = 0.77, p = .38). Scatterometer data were not available in the early time period for comparison.

3.3 | Objective 3: Relationships between weather, sea ice conditions, seal availability, and polar bear fasting behavior

Similar to the model comparing the probability of fasting across time periods and populations, all models examining environmental and ecological variables in the SB and NB included effects of sex, capture date, mating, denning, and age (Table 3). Of the environmental and ecological variables examined (Tables 1 and 3), wind speed, an index of seal body condition (Nyugen et al., 2017), variation in scatterometer measures of ice conditions, and the winter AO were important in models of fasting (i.e., confidence intervals of coefficient estimates did not overlap zero, Table 3). Bayesian p values indicated good model fits to the data for all metrics except for goodness of fit, which only fit model 1 well (Table S2).

4 | DISCUSSION

Marine mammals have been identified as important sentinels of marine ecosystems (Laidre et al., 2015; Moore et al., 2014). Their broad spatial distribution, long lifespans, and position at higher trophic levels mean that changes in their overall reproductive success,

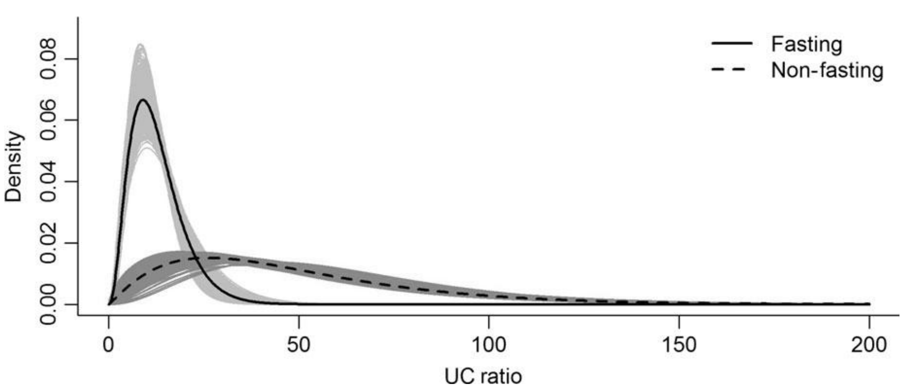

FIGURE 2 Modeled distribution of fasting and non-fasting probabilities based on serum urea and creatinine levels in 1448 samples from subadult and adult polar bears captured in the Chukchi and Beaufort Seas 1983–2016

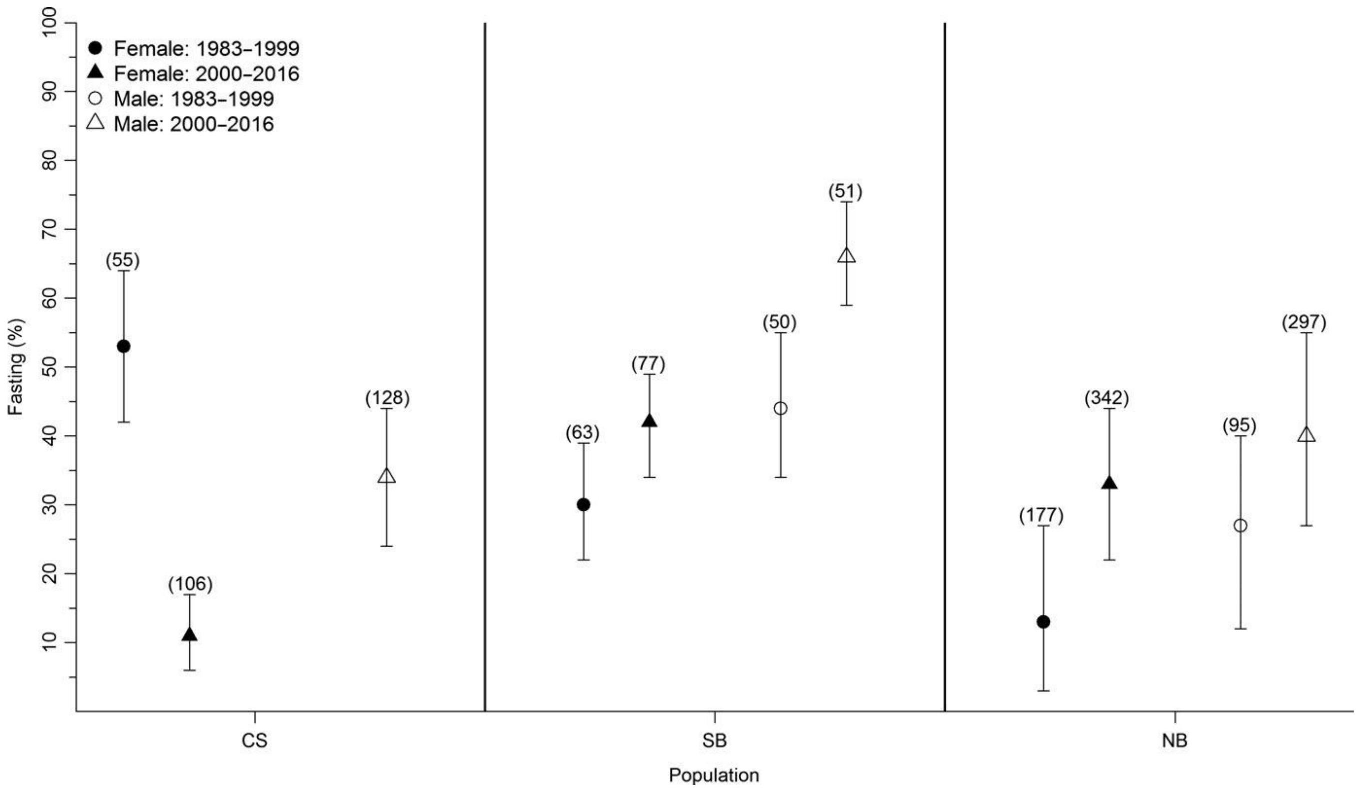

FIGURE 3 The percent of male and female polar bears identified as fasting (%) based on urea:creatinine ratios within blood serum in the Chukchi (CS), Northern Beaufort, and southern Beaufort seas during two time periods, 1983–1999 and 2000–2016

survival of age classes, and population size may be indicative of regional scale changes in the ecosystems in which they reside. Polar pelagic food webs consist of a small number of species where energy flows to higher trophic levels via fewer pathways than more complex systems (Murphy et al., 2016). This results in Arctic systems being sensitive to changes in abundance of keystone species, such as Arctic cod which link lower and higher trophic levels (Murphy et al., 2016). Spring fasting of the three polar bear subpopulations in this study varied temporally and spatially consistent with observed variation in measures of primary productivity and the health of prey and other species within their Arctic food web. Thus, their foraging behavior appeared to track change in the food web during a season when sea ice extent was near its annual maximum. Collectively, these results point to changes in polar bear foraging behavior that are associated with ecosystem productivity. A lack of data on Arctic cod distribution and abundance at region-wide and decadal scales and on other potential ecosystem drivers preclude identification of the proximate mechanisms affecting ecosystem variation.

In the Beaufort Sea, increases in spring fasting behavior of polar bears occurred concurrent to observed declines in the body condition, growth rates, and/or reproductive success of polar bears (Rode, Amstrup, & Regehr, 2010), ringed seals (Harwood et al., 2012; Nyugen et al., 2017), and three other species linked to the pelagic food web (Harwood et al., 2015). Similarly, in our study, polar bear fasting was directly related to an index of ringed seal body condition. The Beaufort Sea is characterized by a narrow continental shelf that limits benthic habitat for bearded seals and has lower benthic-pelagic coupling, benthic biomass, and chlorophyll-a concentrations in comparison to the CS (Dunton, Goodall, Schonberg, Grebmeier, & Maidment, 2005). Additionally, estimates of ringed seal densities are generally lower and more variable (1.01–1.85 seals/km^2; Frost et al., 2002) than those in the CS (1.62–1.91 seals/km^2; Bengston, Hiruki-Raring, Simpkins, & Boveng, 2005). Higher percentages of bears fasting in the SB compared to the NB are consistent with reduced and stable polar bear populations, respectively (Bromaghin et al., 2015; Stirling et al., 2011). Greater reductions in the western Beaufort Sea ice cover compared to the eastern Beaufort (Hutchings & Rigor, 2012) could play a role in affecting both spring fasting behavior and population status (Stirling et al., 2011).

In the CS, low percentages of fasting polar bears are consistent with evidence that it is one of the most productive regions in the Arctic Ocean (Grebmeier, Cooper, Feder, & Sirenko, 2006) and has experienced increases in primary productivity in recent years as indicated by chlorophyll-a concentrations (Frey et al., 2016). This productivity is believed to be supported by the extensive continental shelf that covers most of the CS in combination with warm water and nutrient influxes from the Bering Sea (Frey et al., 2016; Grebmeier et al., 2006). Polar bears, ringed seals, and bearded seals appear to have maintained or improved body condition in the CS despite recent sea ice loss (Crawford et al., 2015; Rode, Regehr, Douglas, et al., 2014) perhaps buffered by the primary productivity of the region. The observed similarities in patterns of polar bear fasting with those of ocean primary productivity during a time of year when sea ice is not limiting suggest that polar bears could be useful in monitoring the productivity of species within their food chain. Moore et al. (2014) similarly suggested that the diets and condition of upper trophic-level Arctic species can provide evidence of variability in ecosystem productivity.

Declines in the percent of CS females fasting in our study suggest that feeding conditions may have improved over our period of observation. Crawford et al. (2015) documented increased ringed seal condition including thicker blubber and faster growth during 2003–2012 compared to 1975–1984 the former of which affects reproduction (Harwood et al., 2012) and thereby may signal increased seal abundance. These trends may have contributed to the observed decline in fasting of female polar bears over a similar period. However, patterns in fasting relative to capture location (Figure 1) may have inflated the apparent decline. During the early period, bears were captured north of 70° along the SB/CS subpopulation boundary and south of 65° near St. Lawrence Island (Figure 1), areas that were not sampled in the more recent period. Including bears only captured in the same study area during both periods resulted in an apparent decline in the fasting in CS females from 39% to 10%, a pattern that corresponds with increased condition of their prey.

Although the status of prey populations appears to be an important contributor to polar bear spring fasting behavior, scatterometry measures also contributed to observed variation. Greater variability between day-to-day scatterometry images may reflect habitat dynamics such as the opening and closing of leads, drift, and the creation of pressure ridges. Scatterometry and standard deviation in ice drift and mean ice concentration were all higher in the CS compared to the Beaufort Sea. These results support the hypothesis that some variability in ice conditions (i.e., more active ice conditions) are beneficial to successful predation and that ice concentration and extent alone are insufficient to fully characterize foraging habitat quality for polar bears. Further study is needed to identify the specific ice and snow conditions measured in scatterometry data, including the use of higher-resolution data that may be important for polar bears.

Several other factors explained variance in the probability of fasting. Wind speed exhibited relationships with fasting probability when all years (1983–2016) and regions (CS and Beaufort Sea) were combined. Although wind speed did not vary across subpopulations, speed increased between periods and could affect polar bear fasting behavior via declines in haul-out duration of seals (Carlens, Lydersen, Kraffft, & Kovacs, 2006) or disruption of polar bears' olfactory cues (Togunov, Derocher, & Lunn, 2017). Pilfold et al. (2015) similarly documented impacts of wind speed on polar bear predation success and wind has been documented as an important factor for successful predation in other species (Funston, Mills, & Biggs, 2001; Nevitt, Losekoot, & Weimerskirch, 2008). The probability of a predation event for polar bears and ringed seal body condition from the eastern Beaufort Sea have both been shown to have significant relationships with the AO and AOO (Pilfold et al., 2015; Nyugen et al., 2017). These results are consistent with our finding that the winter AO in the Beaufort Sea was correlated with fasting probability.

Fasting varied as a result of both sex and age. Fasting probability may have been higher in males because males were more likely to be fasting (77.2 ± 28.9%) when they were pursuing mates than females that were classified as mating based on estrus (38.1 ± 35.4%). A higher frequency of fasting among senescent adults is likely related to aging effects on the ability to successfully capture seals. Senescent adults have been shown to be in poorer condition than younger adults and have lower rates of survival (Derocher & Stirling, 1994; Lunn et al., 2016). We expected that subadults might show higher fasting probabilities because their hunting skills are still developing. However, subadults may be more likely to obtain food via scavenging. Previous studies suggest that polar bears do not always consume the entirety of their kills (Stirling & McEwan, 1975) which may be likely when prey are large, such as bearded seals which are more commonly preyed upon by adult males (Cherry, Derocher, Hobson, Stirling, & Thiemann, 2011; Thiemann, Iverson, & Stirling, 2008) and when foraging occurs simultaneous to mating (i.e., males may leave prey to pursue mates) as it does in the spring. Compared to subadults, adult females may scavenge less from adult males as a result of habitat segregation (Ferguson, Taylor, & Messier, 1997) to avoid infanticide or conflicts associated with mating season. Although subadults exhibited the lowest probabilities of fasting, our analysis estimated whether a bear fed or not, and not how much they ate. Consequently, even small amounts of scavenging could create a UC ratio indicative of feeding. Pagano et al. (in review) observed that an adult female that scavenged from an old carcass on 1 of 8 days had a UC ratio of 26.1 but lost 12% of her body mass during the same period. Declines in subadult survival in the Beaufort Sea (Bromaghin et al., 2015) suggest that, despite our results of lower probabilities of fasting, this age class may not be faring well in the SB.

Our approach of estimating fasting probabilities and using the distribution of those probabilities to identify fasting and non-fasting bears resulted in higher fasting probabilities than reported in previous studies that used an absolute UC ratio threshold of ≤10.0 to identify fasting behavior (Cherry et al., 2009). However, the mean UC ratios we identified for fasting bears (12.6) were within the range measured by Derocher et al. (1990) of 11.0 and 15.8 for polar bears that had fasted for an average of 44 and 36 days, respectively. Similarly, UC ratios of three video-collared females that did not feed for 7–9 days in the SB were 10.7, 9.5, and 8.9 (Pagano et al., in review). Thus, our approach of estimating fasting probabilities rather than using a specific UC-ratio as a cutoff for identifying fasting and non-fasting bears appears to accurately reflect some of the variability in UC-ratios associated with feeding versus fasting.

Reduced foraging success by bears in the SB may be a contributing factor to a recently observed subpopulation decline (Bromaghin et al., 2015). Pagano et al.'s (in review) observation that bears that did not feed for 9 days and subsequently had serum UC values of 11 or less lost weight, suggests that fasting as defined in our study is likely to be associated with declines in body condition.

Observations of polar bears digging through solid sheets of rafted sea ice to access seals (Stirling, Richardson, Thiemann, & Derocher, 2008), cannibalism events (Amstrup, Stirling, Smith, Perham, & Thiemann, 2006), observations of starved bears (Regehr, Amstrup, & Stirling, 2006), and declines in ringed seal population productivity (Nyugen et al., 2017) provide supporting evidence for reductions in the availability of prey in the Beaufort Sea and increased fasting probabilities observed in the latter part of our study.

Declines in Arctic sea ice extent have occurred more in the summer than during other times of the year (Grebmeier et al., 2010; Stroeve et al., 2012). Accordingly, much attention has been placed on the role of summer sea ice loss in affecting Arctic ecosystems (Laidre et al., 2015; Slagstad et al., 2011). Because polar bears rely year-round on sea ice as a platform to hunt their primary prey, ice-associated seals, many studies have focused on the direct effects of decreased sea ice extent on polar bear behavior and population dynamics (Regehr, Lunn, Amstrup, & Stirling, 2007; Rode et al., 2010; Rode, Pagano, Bromaghin, 2014; Rode, Regehr, Douglas, et al., 2014; Rode et al., 2015; Whiteman et al., 2015). Our results suggest that spatial and temporal ecological variation is important in affecting upper trophic-level productivity in these marine ecosystems and that sea ice loss may have both direct and indirect effects at upper trophic levels. Understanding the role that sea ice loss may play in observed variation in Arctic food webs will be important in predicting the impacts of continued, projected Arctic sea ice loss. Polar bears may be a useful indicator species for tracking broad-scale changes in food web dynamics under the sea ice.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Rode KD, Wilson RR, Douglas DC, et al. Spring fasting behavior in a marine apex predator provides an index of ecosystem productivity. *Glob Change Biol*. 2018;24:410–423. https://doi.org/10.1111/gcb.13933

ALASKA DEPARTMENT OF FISH AND GAME
DIVISION OF WILDLIFE CONSERVATION
PO Box 115526
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Alaska Department of Fish and Game
State Wildlife Grant

Grant Number: **E-16** **Segment Number: 3**

Project Number: 1.0

Project Title: Comparison of techniques to detect denning polar bears

Project Duration: 16 November 2009-31 October 2013

Report Due Date:

Principle Investigator: Richard Shideler

Project Location: North Slope, Alaska

Cooperator: Craig Perham, U.S. Fish & Wildlife Service-Marine Mammals Management

I. PROBLEM OR NEED THAT PROMPTED THIS RESEARCH

On the North Slope, off-road oil and gas exploration and construction activities occur in winter, overlapping the period of maternal denning of polar bears (*Ursus maritimus*). Disturbance of denning bears has occurred in the course of oil exploration and equipment transport activities on the North Slope, although circumstances have not allowed a direct measure of effects on the Beaufort Sea polar bear population. In order to protect denning bears from disturbance and to reduce potential bear-human conflicts with industry personnel, stipulations by government agencies (Alaska Department of Natural Resources [ADNR], U.S. Bureau of Land Management, U.S. Fish and Wildlife Service [USFWS], North Slope Borough) require an avoidance zone of 1.6 km around active bear dens. However, these stipulations presume that the actual den location is known prior to commencement of off-road activities.

Polar bear den habitat along the Beaufort Sea coast has been identified by remote sensing (Durner et al. 2001, 2003, 2006). Approximate den locations of radio-marked bears can be determined by VHF radiotracking or from signals from satellite- or GPS-collared bears. However, the proportion of collared bears to the total number of maternal females in the Beaufort Sea is <10% and most polar bear dens cannot be detected visually. Therefore, accurate methods to detect active bear dens prior to the onset of off-road construction and exploration activities are necessary for industry to avoid conflicts with denning bears and fully comply with agency stipulations. However, in addition to measuring success (i.e., Probability of Detection--POD) of different techniques under experimental or simulated conditions, knowledge about the feasibility of each method's use under a variety of realistic conditions is also important. Furthermore, the measurements of each method's rate of false positives (i.e., the technique identifies an active den when there is none) and false negatives (i.e., the technique fails to identify an active den) are also important to comprehensively assess each technique.

II. REVIEW OF PRIOR RESEARCH

Several methods for polar bear den detection have been employed non-systematically. These include (1) airborne Forward Looking Infrared (FLIR) imaging from helicopter and fixed-wing platforms, (2) ground-based imaging with a hand-held infrared (IR) camera, and (3) scent detection by trained dogs. The U.S. Geological Survey (USGS) demonstrated experimentally that it was possible to use helicopter-based FLIR imagery to detect denning polar bears with success rates up to 83% for true positives, that is the "hotspot" (light-colored shape on the image that indicates an object hotter than its surroundings) on the infrared image was in fact a denned bear; Amstrup et al. 2004). From a sample of 23 dens of marked bears that had been surveyed up to 7 times/den, USGS was able to model the importance of several environmental and operational factors on the POD of a denned bear. These included: (1) surface wind speeds <11 km/hr; (2) dew point-ambient temperature spread of >3ºC ;(3) no visible moisture (e.g., fog, snow, ice crystals); (4) flight during dark or civil twilight; and (5) flight >1 day after a significant wind or snow event that could have heated the snow surface. Furthermore, USGS recommended that FLIR tapes be reviewed after each flight in order to detect low-intensity hotspots that could have been missed during the flight. Airborne FLIR surveys were flown at altitudes of 100–300 m above ground level and slightly offset from the bank, which provided an approximately perpendicular view into the bank habitat being surveyed.

Hand-held infrared (IR) imaging cameras have had mixed success in non-systematic tests on known den locations. Furthermore, environmental (e.g., wind speed, snow conditions, surface vs. air temperature) and operational constraints on successful imaging have yet to be investigated. Both techniques using IR imaging may give false positives that could result in area closures around putative den site which could unnecessarily restrict industry off-road winter activities there. Therefore, a method or methods for ground-truthing IR images must be developed and evaluated. Preliminary tests have employed trained scent dogs to confirm "hotspots" identified from IR imaging as active polar or grizzly bear (*Ursus arctos*) dens, and to identify the precise locations of these (R. Shideler, unpubl.data, ADFG). Preliminary findings suggested that dogs can be effective in confirming active dens and detecting putative dens that were missed by IR detection methods (Perham and Williams 2003, Shideler and Perham 2009). In addition, dogs may be able to "clear" IR false positives, thus allowing industry activities in areas that might have previously been restricted. However, there are limitations on success of dogs as a survey technique. For example, wind, humidity, and/or snow depth may limit scent dispersal or the ability of dogs to localize the source (Pearsall and Verbruggen 1982) and dogs are subject to fatigue, especially in the severe conditions that characterize the North Slope in winter.

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III. APPROACHES USED AND FINDINGS RELATED TO THE OBJECTIVES AND TO PROBLEM OR NEED

OBJECTIVE 1: Evaluate the precision and operational constraints of the 3 techniques available for detecting denning polar bears (airborne FLIR, handheld IR camera, and trained scent dogs) in a study area located in known polar bear denning habitat (Fig. 1). During the summer following each series of test, we walked the perimeter of all islands and the Staging Pad to confirm evidence of a den (i.e., true positive) or, conversely, confirm that there was no den (i.e. false positive). Detection events for confirmed dens are summarized in Table 1.

Job/Activity 1a: Fly aerial FLIR surveys over polar bear denning habitat in the study area.

Accomplishments: In 2010, 2011 and 2012 we chartered an IFR-equipped helicopter and crew, rented a FLIR unit, and contracted with a FLIR operator who also installed the unit in the helicopter. Between February 19-24, 2010 weather conditions on the North Slope became severe, flights were grounded due to lack of visibility, and the surveys had to be cancelled.

Between January 19 and 22, 2011we conducted airborne FLIR surveys on Tigvariak, Foggy, Howe, Cottle, Bertoncini, Bodfish, and Pingok islands and the Staging Pad, a large, abandoned gravel stockpile on the mainland south of Cottle Island (Fig. 1). Temperatures were in the -35ºC to -45ºC range with suspended ice crystals and occasional ice fog. The low temperatures allowed us to make only 1-2 passes around each island before the helicopter turbine exhaust created a condensation trail (“contrail”) along our flight path. The contrail acted like a fog bank to partially block potential IR radiation from being detected by the FLIR unit. In some cases we were able to compensate by flying the leeward side of the island first and allowed the ice fog from the windward side to disperse downwind. We identified 1 “hotspot” each on Howe and Cottle islands and the Staging Pad, and 2 on Foggy Island. We did not detect any hotspots on Pingok Island. Although we intended to re-survey the hotspots, mechanical problems with the helicopter fuel system that were likely exacerbated by the cold weather forced us to end the mission prematurely.

Between January 20 and 22, 2012, we flew airborne FLIR surveys on Foggy, Howe, Cottle, Bertoncini, Bodfish, and Pingok islands and the Staging Pad. Because there was no ice road near Tigvariak Island for access to test either the handheld IR camera or the dogs we dropped the island from the study in 2011-2012. Temperatures were in the −21ºC to −45ºC range with some suspended ice crystals, occasional flurries, and ice fog near human activity areas. Like 2011, the low temperature (~−40°C) on 22 January prevented us from making more than 1–2 passes around each island before the contrail obscured the target. Furthermore, the GPS on the FLIR unit failed as did the laser rangefinder and targeting system. Therefore, we had to estimate the hotspot location and anticipated that the coordinate error could be >100 m from its true location. We identified 6 hotspots on Foggy Island, 1 on Howe Island, 8 on Pingok Island, 1 each on Bertoncini Island and the Staging Pad, 2 on Bodfish Island, and 4 on Cottle Island. On the initial pass at Howe Island we saw a very bright hotspot on the southern edge of the island. As we approached, the image sharpened to reveal a female with 2 older cubs who had apparently excavated a deep day bed in a drift. As she and her cubs walked away the FLIR could detect IR radiation from her tracks crossing the island. We encountered a similar situation at the Staging Pad. As we approached the Staging Pad we observed a bright hotspot on the southeastern edge. This hotspot revealed a subadult bear that had been in a shallow day bed but it moved off as we approached. On the west side of the Staging Pad we noticed a very diffuse but bright glow approximately midway along the higher part of the gravel stockpile where a large drift often forms. This hotspot was in a very large and steep cup-shaped drift at a location where bears had denned in previous years.

Job/Activity 1b: Test imagery from the hand-held IR camera by surveying the study area, prioritizing prospective dens identified from the aerial survey (as near real-time as feasible).

Accomplishments: In 2010 the same storm system that caused us to cancel the airborne FLIR flight also prevented us from obtaining a hand-held survey due not only to safety risk while off-road traveling but also because it would have been almost impossible to acquire an IR image.

Between February 28 and March 2, 2011we completed a hand-held IR survey of Cottle, Bertoncini, Bodfish, and Pingok islands and the Staging Pad. Due to poor weather and scheduling conflicts we could not survey Foggy Island, and did not survey Howe Island until March 26, after the dog survey. Weather conditions for the Cottle Island survey were marginal and we did not detect any putative dens nor could we detect hotspots from the January airborne FLIR survey. On Pingok Island we detected a hotspot on the northeastern side that was not visible on the airborne FLIR videotape. The dogs did not alert on this site, and by the time of the ground survey in August the bluff had eroded far enough to obliterate any evidence of a den. After re-inspection of the IR image, it appeared that the hotspot was actually a false positive likely caused by an anomaly such as a slumped block of turf that created a different IR reflectance than the overlying drift.

We surveyed Howe Island on March 26 when there were > 12 hours of daylight. Within a few hours after sunset bare ground on the bluff surface and some vertical snow/ice surfaces were still radiating heat absorbed earlier in the day. This masked IR radiation from an inhabited den difficult to detect against the background IR radiation. We did not detect a hotspot at the easternmost dog alert; however, as we subsequently discovered on the ground survey, its location in a deep gully blocked a direct view from the sea ice. There was a bright image on the westernmost alert where the female bear had pushed up a cone of snow ("pushup"), visible to the naked eye, at the den. However, the image seemed to be from IR radiation reflected off the pushup rather than radiating from a warm body through the snow. We viewed the middle dog alert location shortly after sundown when there should have been no reflected radiation. The camera detected a visible glow in the drift face that appeared to be radiating through the snow and we considered this site as another putative den.

Because the view is at ground level acquisition of the hand-held IR image is likely subject to the same weather restrictions as that of airborne FLIR and may be even more sensitive than airborne FLIR to snow blowing along the surface.

Job/Activity 1c: Test each of 2 dogs independently on each known or putative polar bear den identified by airborne FLIR or handheld IR camera and place a marker at the location of the dog alert (refer to dog survey protocols, Appendix A).

Accomplishments: In 2010, we surveyed 42.1 km of identified denning habitat (Table 2) in the study area with 2 Karelian Bear Dogs on 24–26 February and 16–22 March. For the Tigvariak and Foggy Island surveys we were able to drive an ice road constructed by ExxonMobil and run the dogs directly to the survey area. For the remaining sites we transported the dogs and emergency gear in a Hagglunds BearCat™ tracked vehicle to a location near the survey start and commenced the survey according to our protocols. The dogs alerted at a hotspot on the Staging Pad that had been identified during an industry FLIR flight, and at a location on Cottle Island that had not been previously identified (Table 1). Neither dog alerted at 2 putative dens on Foggy Island, one of which (the northern site) had been identified during an industry FLIR flight. We ran both dogs two different times on the northern location, and neither dog alerted either time—i.e., a false negative. The industry FLIR flight had not detected the southern site, and the dogs did not alert there either. At a den on Howe Island identified on an industry FLIR flight, a female with 2 cubs emerged the week before our scheduled dog survey time so we did not survey it.

During 2–6 March, 5 April, and 10–11 April 2012 we completed a scent dog survey of 38.5 km (Table 2) of denning habitat on Foggy, Howe, Cottle, Bertoncini, Bodfish and Pingok islands. On Howe Island the dogs alerted on 1 putative den, and did not alert on the hotspots identified during the airborne or hand-held FLIR surveys. The dogs also did not alert on any putative dens or hotspots on Foggy, Cottle, Bertoncini, Bodfish or

Pingok islands. Based on experience over the past decade we expected at least one den on Pingok Island. Although the dogs ran a good line on Pingok Island in the March survey, we elected to re-run the island on 10 April. In spite of near whiteout conditions the dogs covered the island well and, as in March, did not alert on any putative dens or hotspots, nor did they discover dens that would have been abandoned between after the previous survey. On 11 March the dogs resurveyed Cottle Island but did not alert on putative dens or hotspots.

On 6 March, 2012, we surveyed the Staging Pad. One dog alerted at the southern location identified as a hotspot on the hand-held FLIR survey. Neither dog performed a strong alert on the hotspot identified from both airborne and handheld IR surveys on the steep, tall drift on the west side. However, one dog returned to the area above the drift and worked back and forth with his nose low especially interested in the troughs between drifts. He was clearly interested in the scent but we believe the steep, wind-polished drift surface with overhanging cornice prevented him from moving lower on the drift to localize the source. We considered his behavior as an alert although he was prevented from localizing the scent. Furthermore, subsequent inspection of the trackline from his GPS collar clearly shows him concentrating on an area within about 10m above the actual den location.

Between March 7 and 12, 2013, we surveyed the Jones Island group, Howe and Foggy islands, and the Staging Pad. The dogs did not alert on any island locations. However they alerted on a location on the east side of the Staging Pad, which had been missed by an industry airborne FLIR survey. Visual observation by parties not associated with this project confirmed that it was a den—the bear exited the den on March 24.

Job/Activity 1d: Revisit each den the following summer and measure dog detection error and physical and habitat characteristics of each den.

Accomplishments: In August 2009, USFWS-MMM personnel had walked the study area and obtained coordinates of putative 2008–2009 dens and previous and current summer day beds. Therefore, we anticipated that any evidence of dens we found in 2010 or later would be from the previous winter.

From 18–23 August 2010, we walked all den habitat in the study area. Consistent with the dog survey we found no evidence of new dens on Tigvariak, Bertoncini, or Bodfish islands. We found no evidence of additional dens on Howe Island except at the known den. At the Cottle Island alert location, we found suitable habitat and hair, suggesting a true positive. At the Pingok east hotspot, we found suitable habitat but no evidence of a den, consistent with the lack of alert by the dogs—a true negative. At the Pingok west hotspot, where the dogs had expressed some interest but not a full alert, we found a good site for a den but no hair or other evidence. It is possible that this site had been abandoned before cubs were born, or the cubs were stillborn and the female left after the industry airborne FLIR flight in December 2009. We consider this alert inconclusive. At the Staging Pad there was evidence of a huge drift at the hotspot and dog alert and we found hair—another true positive. At Foggy Island-north hotspot we found evidence—hair and cub scat—of a den but neither dog had alerted at this location—a false negative.

During 16–22 August 2012, we walked all denning habitat on Foggy, Howe, Cottle, Bertoncini, Bodfish and Pingok islands and the Staging Pad. We encountered >11 polar bears resting on the Jones Island group (western islands in the study area, Fig. 1) which required "island-hopping" to find safe locations to survey without disturbing the bears. We installed colored-coded markers at den sites from winter 2011–2012. On Howe Island we confirmed the location of the putative den that was detected by the dogs (i.e., true positive) and confirmed results of the scent dog survey in that there was no evidence of a den at the hotspots identified on the airborne or hand-held FLIR surveys (i.e., false positives for IR methods, true negatives for dogs). At the Staging Pad we confirmed the location of the southern den identified by the hand-held FLIR and scent dog (i.e., true positives), and the northern den detected by the 2 IR methods and the scent dog (i.e., true positives).

We found no evidence of dens on the remaining islands in the study area. However, although the dogs had not alerted at the hotspot on the northeast side of Pingok Island that had been identified on the hand-held survey, we were unable to confirm the location as either a false negative or false positive. The northeast (seaward) side of Pingok Island was eroding rapidly and the hotspot coordinate was >30 m in the ocean as of 18 August.

Summer ground surveys to locate dens and to eliminate false positive hotspots confirmed that there were 15 dens within the study area during the course of the study (Table 1). Polar bear dens were detected by all 3 methods, with scent dogs having the highest rate of success (75%) followed by the handheld IR camera (56%). Industry airborne FLIR was more successful (50%) than project FLIR (22%) but for reasons we discuss later, this may reflect availability and operational problems between the two rather than differences in imaging or interpretation.

Results from the field inspection of putative den sites during summer indicated that positive identification of polar bear dens in the summer is not clear-cut. Because polar bears do not excavate dens in soil, evidence of denning visible the subsequent summer consists of presence of hair, cub and adult scat, and/or cub and adult claw marks on the bank adjacent to the snow den. We found ample evidence that polar bears (and a few grizzly bears) used the barrier islands as resting areas during the summer, and that they excavated day beds, deposited scat and hair, and may have scratched in adjacent banks. These signs can occasionally be confused with winter den use. Furthermore, wind and runoff from melting snow and rain as well as wave action from summer storms can erode evidence of the den before it can be confirmed. On the seaward side of several barrier islands (e.g., Pingok, Tigvariak, Howe) rapid coastal erosion would have eroded the bluff adjacent to the putative den before we could have found it.

OBJECTIVE 2: Develop a POD based on meteorological and snow conditions likely to be encountered during a den survey.

Job/Activity 2a: Measure snow conditions near den sites and random sites nearby.

Accomplishments: During the winter surveys we measured snow depth, slope of drift and bank height at selected locations near dens and at other locations in the study area. In addition, during the February and April surveys Dr. Glen Liston, a renowned snow physicist with the Cooperative Institute for Research in the Atmosphere at Colorado State University accompanied us to evaluate snow conditions at selected locations in the study area. Under the auspices of the USFWS's Arctic Landscape Conservation Cooperative and the National Fish & Wildlife Foundation, Dr. Liston has been applying a model of blowing and drifting snow deposition to more accurately predict the presence, timing, and evolution of snow drifts suitable for polar bear dens. We are integrating our snow measurement data and that he has collected while with us to validate his model. That effort is still in progress at this time.

Job/Activity 2b: During the following summer, survey repeatedly-used den habitat to detect signs of den use from the previous winter.

Accomplishments: See Job 1d.

Job/Activity 2c: Measure snow and weather conditions at each site during the ground visits to determine attributes that may affect detection.

Accomplishments: See Job 2b.

Job/Activity 2d: Evaluate the effects of snow conditions on POD by IR methods by constructing and monitoring an artificial snow den with a heat source that mimics a denning bear.

Accomplishments: On 9 December 2010 we excavated and instrumented the artificial den and installed the heaters. We conducted hand-held FLIR surveys on 10 December 2009, and 23 January, 27 February, and 9 April 2010. We recorded air and snow surface temperature and wind direction and velocity. We categorized the images as Very Bright, Bright, Dim, or Invisible at measured intervals of 1–3 m, 10 m, 20 m, 40 m, and 60 m from the den entrance. Images were Very Bright or Bright on both the initial survey and the January 23 survey, Dim at distances ≥10 m on 27 February, and Dim at distance >20 m on 9 April). On 13 December 2011, we excavated an artificial den in a snow drift in a gully near Kuparuk Drillsite 2M. Unlike the previous location in 2009–2010 and 2010–2011, this location ensured a steady source of electrical power without interruption by unsupervised employees. Images on February 22, 2012, were Dim at only 5m and invisible beyond that; yet a fox den nearby had a bright image indicating that the imager was working properly. We later confirmed that there had been a power outage at the drillsite and the outlet breaker had not been turned back on.

OBJECTIVE 3: Provide recommendations to industry regarding den detection methods; complete final report.

Job/Activity 3a: Develop a matrix of den detection techniques suitable for different types of industrial activities.

Accomplishments: My USFWS-Marine Mammals Management cooperator and I have prepared an initial draft of the matrix. Due to the small sample size of detected dens, we cannot compare PODs for the three methods under varying conditions. For example, we do not know the minimum weather conditions and snow depth that would allow acquisition of a handheld IR image. Instead, we are focusing on operational constraints for each method that would optimize detection rates (i.e. true positives), or conversely, reduce false negatives (i.e., assuming no dens when there are).

Job/Activity 3b: Prepare final report.

Accomplishments: Final report completed.

IV. MANAGEMENT IMPLICATIONS

None of the methods tested achieved 100% detection (Table 1), and one den was surveyed with all 3 methods and not detected by any. The discrepancy between the airborne FLIR detection rate for the project and the rate for industry is noticeable, but emphasizes that operational obstacles can have a greater effect on the effectiveness of surveys than image interpretation of other factors. Project airborne FLIR surveys required confirmation of survey dates months in advance whether or not the weather was optimal for image acquisition at flight time. Furthermore, neither the FLIR unit, FLIR operator, or helicopter was resident on the North Slope, and the units had to be fitted onsite. Small electrical or mechanical deviations between the rental FLIR unit and the helicopter's power and electronics delayed surveys when there was a suitable weather window. Charter and rental cost became prohibitive. Clearly, there would be a great advantage to have a helicopter outfitted with a suitable FLIR unit and experienced flight crew that is resident on the North Slope during the 2-3 week period when daylight is optimal for FLIR. Alternatively, development of an Unmanned Aerial Vehicle (UV) that has operational characteristics and imaging capability similar to manned helicopters may be a cost-effective alternative that should be tested.

Although airborne FLIR imagers may be best utilized where there is a long reach of polar bear habitat within an industry area of interest, the other techniques may be more useful on smaller portions or where there is a question about confirming a hotspot. Scent dogs and handheld IR cameras offer reasonable alternatives. However, both methods if not managed properly can increase disturbance at the den. Scent dogs had the highest success rate and can work in weather unsuitable for either IR imager. Nevertheless, at this time we do not understand all the effects of snow depth and characteristics, ice layers or weather influences on the detection probability for either method. Effects of these on handheld IR imagers can be resolved using artificial dens where snow characteristics and surface weather can be more systematically investigated. More experience with both methods is needed especially focusing on conditions that may result in false negatives. Identification of conditions that could lead to false negatives has been under-represented in previous surveys and in this study.

V. SUMMARY OF WORK COMPLETED ON JOBS

JOB/ACTIVITY 1: We conducted airborne FLIR and handheld IR surveys in 2011 and 2012. Although we mobilized for the 2010 surveys a long period of severe weather grounded the helicopter and the tracked vehicle and we were unable to complete either survey. Planned surveys in 2013 were dropped because of funding uncertainties with our USFWS-MMM colleague who could not travel. The airborne FLIR detection rate was only 22% (2 of 9) due to complications with the helicopter, FLIR unit, and weather effects on the image. We do not believe this represents the true effectiveness of airborne

FLIR. The handheld IR imager detection rate was 56% (5 of 9). We conducted dog surveys on 38.5 km of den habitat in 2010 through 2013. The dog detection rate was 75% (9 of 12), making it the most successful method of the 3 tested. We walked the entire study area each summer from 2010 to 2013 in order to ground-truth the surveys. We found evidence of 15 dens (Table 1).

JOB/ACTIVITY 2: We collected weather data at each site we visited on the ground during handheld IR and dog surveys. We collected snow depth at sites near active dens, and measured drift height and length. These data are being used in a model of drifting snow to predict where bears will den. We excavated and instrumented an artificial polar bear den in winters 2010 through 2012. Although we obtained some data, operational problems with reliable power for the heaters and weather-related failures to acquire an image limited our ability to use the information. Nevertheless, we were able to detect the dens at up to 40m under ideal conditions.

JOB/ACTIVITY 3: My USFW cooperator and I have prepared a draft matrix of criteria and methods to be used with each detection technique. These will be included in a technical report that we are also preparing.

VI. ADDITIONAL FEDERAL AID-FUNDED WORK NOT DESCRIBED ABOVE THAT WAS ACCOMPLISHED ON THIS PROJECT

While ground-truth denning habitat we noticed considerable evidence of summer use, primarily day beds, by polar bears and occasionally grizzly bears. Beginning in 2010 we identified day beds with a marker unique to each year, and collected coordinates, a verbal description, and pictures of each site. We intend to analyze these and prepare a technical report or publication with the findings.

During the 4 years that we walked Pingok Island to locate dens, we observed that the northeast side of the island was eroding rapidly. This side consisted of tall (3-5m) peat banks with underlying massive ice lenses. During the 2011 ground survey we installed several unofficial markers at 10m intervals from the bank edge to 35 m inland. By August 2012 all the markers had eroded away and the coordinates of the inland marker were 40 m into the ocean. We calculate that >80 m of bank had eroded since August 2010. In 2013 the northeast portion of Pingok Island had continued to erode, and that erosion seemed to have spread to the southeast (lagoon side) as well. At that rate this portion of the island will be gone within the next decade.

VII. PUBLICATIONS

Although not strictly a publication, a project description and short video are on the ADF&G website:
http://www.adfg.alaska.gov/index.cfm?adfg=wildliferesearch.polarden

VIII. APPENDIX

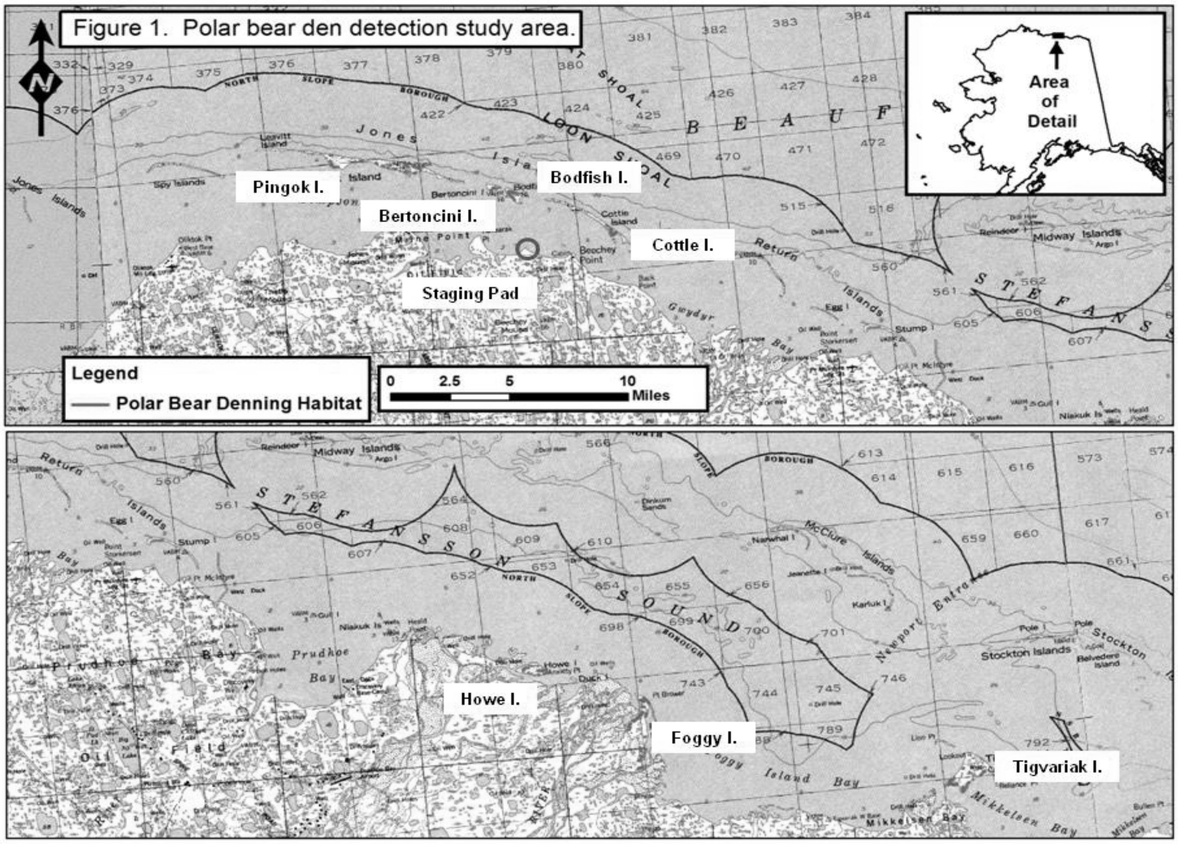

Table 1. Summary of polar bear dens detected by airborne Forward-Looking Infrared (FLIR) imager, handheld Infrared camera, and trained scent dogs. "FLIR-P" is project FLIR flight, "FLIR-I" is industry FLIR flight.

Den ID*	Den Year	Location	Airborne FLIR-P	Airborne FLIR-I	Handheld IR	Scent Dogs	Ground-Truthed
10-01	2009-2010	Howe Island	NS**	Y	NS	NS[1)]	Y
10-07	2009-2010	Foggy Island North	NS	Y	NS	ND**	Y
10-08	2009-2010	Cottle Island	NS	ND	NS	Y	Y
10-09	2009-2010	Foggy Island South	NS	ND	NS	ND	Y
10-10	2009-2010	Staging Pad	NS	Y	NS	Y	Y
11-01	2010-2011	Staging Pad	ND	Y	Y	NS[1)]	Y
11-03	2010-2011	Howe Island East	ND	NS	NS	NS[1)]	Y
11-04	2010-2011	Howe Island AL	ND	NS	ND	Y	Y
11-05	2010-2011	Howe Island Mid	ND	NS	Y[2)]	Y	Y
11-06	2010-2011	Howe Island West	ND	NS	Y[2)]	Y	Y
11-07	2010-2011	Pingok Island	ND	ND	ND	ND	Y
12-01	2011-2012	Staging Pad 1	Y	NS	Y	Y	Y
12-02	2011-2012	Staging Pad 2	ND	NS	Y	Y	Y
12-04	2011-12	Howe Island	Y	NS	ND	Y	Y
13-01	2012-2013	Staging Pad	NS	ND	ND[2)]	Y	Y
Proportion successful by method			2/9=0.22	4/11=0.36	4/9=0.44	9/12=0.75	15/15=1.00

** USFWS-Marine Mammals Management den identification number*

*** NS: not surveyed*

**** ND: surveyed, but not detected*

1. Bear emerged prior to dog survey

2. Surveyed with Handheld IR after dog alert

Table 2. Length of polar bear maternal den habitat surveyed by dogs, 2009–2012.

Location	Distance	
	Miles (mi)	Kilometers (km)
Tigvariak Island*	2.9	4.6
Foggy Island	5.4	8.6
Howe Island	2.4	3.8
Cottle Island	3.3	5.3
Bodfish Island	1.8	2.9
Bertoncini Island	0.9	1.4
Pingok Island	9.1	14.6
Staging Pad	0.5	0.8
Total	26.3	42.1

*Dropped from 2010-2012 surveys due to lack of road access.

APPENDIX A. Dog survey protocols.

General Procedures. Unless conditions dictated otherwise, dogs were run singly. From 2009 through 2011, the dog selected to run the survey was outfitted with a vest containing 2 pockets, each with a Garmin *geko 201*™ GPS unit and chemical hand warmer to keep the unit at operating temperature. Dual units ensured that at least one records the track if the other failed. In 2012 and 2013, the dog wore a Garmin *Astro*™ GPS collar. In order to ensure redundancy, the handler also took a waypoint reading at the putative den location and left a conspicuous marker so the site could be visually located the following summer.

Depending on wind speed and direction, dogs were aligned to run either the top of the bank at the soil/snow interface or along the base of the drift extending outward from the bank to sea ice. Previous experience indicated that bears often excavated laterally into the drift until they hit soil on the bank face. Scent can disperse up this snow/soil interface, and may even exit through ground squirrel burrows, cracks in the bank face, or a crevice created between the bluff face and the drift. Positioning the dog on the base of the bluff allowed it to detect scent that percolated through the snowdrift to the surface and then dispersed in a cone-shaped pattern downwind. The dog handler on a snowmobile followed behind the dog at a distance of 30–50 m to allow the dog to work unimpeded but within voice range. A flanker paralleled the dog/handler team downwind on the sea ice at approximately 50 m–100 m off the bluff bank. The flanker kept track of survey segment beginning and ending waypoints, and scanned ahead for non-hibernating bears that may have been wandering in the area. If these were encountered, the team was to leave immediately. Likewise, when open dens were encountered, the investigators immediately left the area and either ended the survey or resumed at a safe distance from the den.

Description of alert. The Karelian Bear Dogs are hunting dogs bred and trained to chase bears. They do not require a trained alert to detect dens. Their natural response to interesting odors (e.g., fox scat or urine, small mammal carcasses) on the surface or buried under the snow is to dig briefly, sniff and move on. The alert to a den was a similar pattern but at higher intensity and longer duration. The location of their alert was a further clue—e.g., if the location was on or very near the face of a drift or at the drift/soil interface. The dogs alerted to the presence of a den by digging and, occasionally, vocalizing. Dogs were not allowed to dig into the den but were allowed to dig at the surface for several seconds to confirm the location. Occasionally, the source of the alert was questionable and was confirmed by calling the dog off and then allowing it to return within a minute or two. If the dog returned to the same site ("victim loyalty" in Search and Rescue terminology) we consider it a confirmed alert. It was the handler's responsibility to identify the alert and call the dog off so that it did not disturb the bear any more than necessary. Once the location was confirmed, the team immediately left.

Survey conditions. Dogs were worked only when weather and visibility allowed safe operations, during daylight hours, and when temperatures were generally warmer than -35°C and wind <45 km/hr. Immediately prior to each dog survey we measured wind speed and temperature with a Kestrel 2000™ wind gauge. We determined wind direction near ground level by observing the azimuth of blowing snow along the snow surface or indicated by the direction of spray pattern of powdered chalk. We record these not only for scientific interest, but also to align the dogs in the proper position to work downwind of the topographic feature. Although dogs can work in wind speeds up to 45 km/h (>25 mph), winds this strong can create scent eddy currents and by a process called "looping" can deposit the scent several hundred meters away from the scent source, making detection of the actual den location more subject to error.

Measures to reduce den disturbance. We conducted surveys only when visibility was sufficient to detect non-hibernating bears or evidence of dens. Prior to beginning the survey, the flanker circumnavigated the island at 100–200 m from the bluff system to ensure there were no open dens or ventilation holes. If these were encountered the team immediately left the area. The dogs were not allowed to dig into the den. Nevertheless, there was a small possibility that a denning bear may have responded to the noise. There was no way to calculate the level of response of polar bears within the den; however, on surveys conducted by Perham and Williams (2003), Shideler (2007), Shideler and Perham (2008), and Shideler and Perham (2009) none of the 9 bears that were detected by dogs emerged from their dens during or immediately after the survey.

Experience using the Karelian Bear Dogs to detect denning radio-collared grizzly bears was also instructive (Shideler, unpublished data). In all 57 instances in which dogs alerted on occupied grizzly bear dens, no bears emerged from dens. In the case of several radio-collared grizzly bears in dens, the radio signal did not change from inactive to active, suggesting that the bear was not aware of the activity at the surface or it was aware but did not move its head. In the cases in which the signal did change to active, the bears did not emerge even after the investigators left the area. Collectively, these observations suggest that even if the bears were aware of our activity, their responses were mild and they did not abandon the den.

Literature Cited in Appendix A

Perham, C. J., and M. W. Williams. 2003. A preliminary assessment of the use of trained dogs to verify polar bear den occupancy. Report by LGL Alaska Research Associates to ExxonMobil USA and U.S. Fish and Wildlife Service.

Shideler, R. T. 2007. Scent dog survey of maternal polar bear den habitat in the "North Shore" geophysical exploration area, March 2007. Unpublished report by Aklaq Services to Brooks Range Petroleum Company.

———, and C. J. Perham. 2008. Survey of maternal polar bear den habitat between Kaktovik and the KIC Well No. 1, February 2008. Unpublished report by Aklaq Services and USFWS-Marine Mammals Management to Marsh Creek LLC.

———, and ———. 2009. Survey of maternal polar bear den habitat between Atigaru Point and North Kalikpik Well No.1, National Petroleum Reserve-Alaska, March 2009. Unpublished report by Aklaq Services and USFWS-Marine Mammals Management to Marsh Creek LLC.

IX. SIGNIFICANT DEVIATIONS:

Although we intended to expend funding carried over from 2011-2012 to conduct a final airborne FLIR survey in January 2013, the sequestration of federal funding eliminated our USFWS cooperator's travel. Furthermore, because the USFWS-MMM had chartered the helicopter for ground-truthing dens in summer 2013 and that funding was suspended indefinitely, we decided to drop the airborne FLIR and handheld IR surveys in case we would be required to fund the helicopter charter in summer.

Prepared by: Richard Shideler

Date: 31 March 2014

Status of Estimation of Incidental Take of Denning Polar Bears during SAE's Arctic National Wildlife Refuge 1002 Area Seismic Activities – October 4, 2018

THE MMPA: MMPA REGS ON INCIDENTAL TAKE

- The Service is directed to allow incidental taking, for a period of up to 5 years, if we make findings that the total of such taking:
  (1) will affect only **small numbers** of individuals of these species or stocks;
  (2) will have **no more than a negligible impact** on these species or stocks; and
  (3) will not have an **unmitigable adverse impact on the availability of these species for taking for subsistence use by Alaskan Natives**.

- If a finding cannot be made that the total taking will have a negligible impact or will not have an unmitigable adverse impact on the availability of the species for subsistence uses, we are to publish the negative finding, along with the basis for denying the request, in the *Federal Register*.

- Important definitions
  - *Harassment:* any act of pursuit, torment, or annoyance that:
    - has the potential to injure a marine mammal or marine mammal stock in the wild (Level A)
    - has the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (Level B)

- **Negligible impact**: an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival.

- **Potential Biological Removal (PBR):** the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population.
  - PBR is the product of the minimum population estimate of the stock, one-half of the maximum theoretical or estimated net productivity rate of the stock at a small population size, and a recovery factor between 0.1 and 1.0 (PBR = N_{min} x $0.5R_{max}$ x RF). The calculation of PBR in the most recent draft Stock Assessment Report for the Southern Beaufort Sea stock of polar bears is 14 (N_{min} of 782, R_{max} of 7.5% and a default recovery factor (RF) for threated populations of 0.5).
  - During the 10-year period of 2006 – 2015, an average of 19 bears per year were removed from the U.S. portion of the SBS stock and 14.2 bears per year were removed from the Canadian portion of the SBS stock. Defense of life kills have also occasionally occurred for this stock. An average of 0.9 additional bears per year are taken within the U.S. from other human activities (e.g. defense of life, research, etc) raising the U.S. total human-caused removals to 19.9/year. We do

not have an estimate of any additional human-caused non-subsistence takes in Canada.

- **Optimum Sustainable Population**: the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element.

- Considerations (see Supporting Documents)
  - Proposed Rule MMPA 101(a)(5)
  - Final Rule MMPA 101(a)(5)
  - Conservation Council for Hawaii v NMFS
  - Natural Resource Defense Council v Evans

- FR Notice of Proposed and Final Rules involving incidental take of marine mammals under MMPA 101(a)(5)
  - The Service stated that to properly interpret and implement the Senate Report language on "negligible impact", the analysis of adverse effects to recruitment or survival must be conducted within the framework of the management goal to the MMPA (i.e., the maintenance or attainment of an optimum sustainable population (OSP) level for each population stock of marine mammals (see sections 2(2) and (6) of the MMPA)). Therefore, the Service would generally apply the proposed definition of "negligible impact" in the following manner: if a request for specific regulations under section 101(a)(5) involves potential impacts to a "depleted" population, then a determination of "negligible impact" **can be made only if the permitted activities are not likely to significantly reduce the increase of that population or prevent it from ultimately achieving its OSP** (*See* 53 FR 8473, 8474).

- In the preamble to the Final Rule, the Services expressly rejected public comments indicating that OSP should not be part of the analytical approach to determining "negligible impact" (See 54 FR 40338, 40341).

- The Services appeared to indicate that the key was to ensure that "the proposed incidental take must not prevent a depleted population from increasing toward its OSP at a *biologically acceptable rate*" (54 FR 4034).

- The Service agrees that the impacts of incidental take from successive or contemporaneous activities must be added to the baseline of existing impacts to determine negligible impact (54 FR 40342).

- The Service notes that ongoing authorized activities are factored into the baseline of existing impacts to determine negligible impact of a requested activity. To the extent that subsistence is part of the baseline, subsistence takes are accommodated and allocation between subsistence and incidental taking is not necessary (54 FR 40342).

- The probability of occurrence of impacts must be balanced with the potential severity of harm to the species or stock when determining negligible impact. The degree of certainty of occurrence required in these judgements should be inversely proportional to the resultant harm to the overall population (54 FR 40342).

- Conservation Council of Hawaii v NMFS – district Court of Hawaii found NMFS failed to evaluate lethal takes against PBR in violation of the best scientific evidence available.
    - NMFS argued that even if it did make the comparison they would have still authorized – we need to find out what rationale NMFS would have used.

- Natural Resource Defense Council v Evans – case involved a challenge to NMFS's interpretation of Level B harassment, court found that NMFS's interpretation read out the term "potential" because it required an action to actually cause a disturbance.

THE STOCK

- SBS subpopulation of Polar Bears (ESA listed globally, MMPA manages stocks)
    - 907 individuals as of 2010 (see Supporting Documents, Bromaghin et al. 2015)
    - 50% decline in abundance between 1986-2010 (see Supporting Documents, Bromaghin et al. 2015); decline in size and body condition, and increase in spring fasting (see Rode et al. 2018b)
    - Increase in number of bears coming on shore in summer and fall, remaining on shore for a longer period of time, and an increase in the proportion of dens occurring on land compared to sea ice, land dens have greater success than those on ice

- Polar Bears in the Project Area
    - There is significant overlap between the project area, polar bear Critical Habitat, and the USGS denning habitat model (see Supporting Documents, Denning Map)
        - Polar bear Critical Habitat within the 1002 Area was based on polar bear denning habitat

THE ANALYSIS: DRAFT DENNING ANALYSIS (see Supporting Documents, Denning Bears Analysis - 13Sept2018)

- Six Step Approach (NOTE: This analysis only covers the portion of the activities that overlap the denning period and not activities outside of the denning periods as those activities are not currently impacting our determinations)
    1) Determine the number of animals in the project area
    2) Assess the likelihood of, nature, and degree of exposure

3) Evaluate the probable responses
4) Calculate the amount of take (life stage, death, Level A harassment (potential injury), or Level B harassment (potential disruption of a biologically significant behavioral pattern), factoring in the degree by which effective mitigation measures reduce the amount or consequences of take. This evaluation was focused on individual animals. (Pages 1-3 of the analysis)
5) Determine whether this take will be of a small number relative to the size of the stock and
6) Determine whether take will have a negligible impact on the stock.

STEP 1 – NUMBER OF POLAR BEARS IN THE PROJECT AREA (see Supporting Documents, Denning Bears Analysis – 13Sept2018, PAGES 3-6)

- Number of Dens in the 1002 Area = 19.4. We used a ceiling of 20

STEP 2, 3 & 4 – EXPOSURE, RESPONSE AND AMOUNT OF TAKE (see Supporting Documents, Denning Bears Analysis – 13Sept2018, PAGES 6-25)

- Estimated Lethal, Level A, and Level B Take of polar bears during the denning period for dens both near and away from industrial activities
  - Results are based on the assumption that all proposed activities occur within 1 year (see Supporting Documents, Denning Bears Analysis – 13Sept2018, Table 2)
    - Lethal Takes – 7
    - Level A Injurious Takes – 9
    - Level B Takes – 7
  - Results are based on the assumption that all proposed activities occur across 2 years (see Supporting Documents, Denning Bears Analysis – 13Sept2018, Table 3)
    - Lethal Takes – 7
    - Level A Injurious Takes – 11
    - Level B Takes – 8

- Estimated Lethal, Level A, and Level B Take of polar bears during the denning period only for dens away from industrial activities
  - Results are based on the assumption that all proposed activities occur within 1 year (see Supporting Documents, Denning Bears Analysis – 13Sept2018, Table 4)
    - Lethal Takes – 11
    - Level A Injurious Takes – 8
    - Level B Takes – 8
  - Results are based on the assumption that all proposed activities occur across 2 years (see Supporting Documents, Denning Bears Analysis – 13Sept2018, Table 5)

        - Lethal Takes – 11
        - Level A Injurious Takes – 8
        - Level B Takes – 8

SMALL NUMBERS AND NEGLIGIBLE IMPACT DETERMINATIONS

- Small Numbers
    - Use rule of thumb of <12% of the stock based on NRDC v. Evans (see Supporting Documents, National Resource Defense Council v Evans)
    - Will be calculated using ALL aspects of the project – the above analysis is just for denning bears

- Negligible Impact
    - The number of Lethal or Level A takes anticipated reasonably expected to, and reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival? Would authorizing this level of take be likely to significantly reduce the increase of the SBS population or prevent it from ultimately achieving its OSP?
    - If PBR = 14 and US subsistence takes exceeded that (averaged 19/year over the period 2006-2015, see "Potential Biological Removal" discussion above), then would any additional Lethal or Level A takes be reasonably expected to, and reasonably likely to, adversely affect the SBS subpopulation through effects on annual rates of recruitment or survival
    - What would be the legal and biological rationale for determining that some level higher than PBR could be removed from the population without reasonably expecting to, or being reasonably likely to, adversely affect the annual rates of recruitment or survival of the SBS subpopulation?

KEY ISSUES IDENTIFIED

1. Efficacy of FLIR
    a. The Service's MMM draft denning analysis uses an efficacy rate of 62% for aerial Forward Looking Infrared (FLIR) camera surveys for polar bear dens, which was derived from the data used Amstrup et al. (2004).
    b. The paper states "Data suggested that FLIR surveys conducted during optimal conditions for detection can produce detection rates approaching 90 percent and thus can be an important management and mitigation tool." It also includes the following statement. "Therefore, in real-world applications where big money is at stake, an increase in the overall detection rate to at least 90 percent seems highly probable." Steve Wackowski and Mike Gieryic suggest, based on these statements, our analysis should use 90%.

c. This is a key decision as we assume any den detected by FLIR will then be mitigated fully by the imposition of a 1-mile buffer zone. Those that are not detected are those that are then available for possible disturbance from project activities.
d. Based on the analysis of the actual data presented in the paper, and in consideration of what is likely with the proposed project (anticipated weather conditions, single pass FLIR), we believe 62% is the detection rate best supported by information presented in that publication.
e. Importantly, Scheidler (2013, see Supporting Documents) reports that aerial FLIR conducted by industry detected 50% of dens, whereas their project aerial FLIR only detected 22% given poor weather conditions during surveys. Scheidler (2013, see Supporting Documents) also reported that 56% of dens surveyed with handheld FLIR were detected.
f. Robinson et al. (2014, see Supporting Documents) found that den detection based on handheld FLIR was affected by similar weather conditions described in Amstrup et al. (2004, see Supporting Documents). Additionally, they found that den detection was significantly influenced by den wall thickness, and concluded that dens with walls >90cm would likely go undetected. This could account for approximately 25% of dens based on data from Durner et al. (2003, see Supporting Documents).

2. Potential for Den Collapse
   a. The Service's MMM draft denning analysis considers the possibility of a vehicle driving over an undetected den and causing the collapse of that den. That analysis is based on the overlap between undetected dens and the grid caused by SAE's proposed seismic activity. It also includes access roads in the 1002 Area as proposed by SAE. However, due to limitations with the information provided by SAE, it does not include areas traversed by scout vehicles, camps, transit to and from camps, movement of camps, etc. so it is therefore an underestimate of the total area physically impacted by SAE's proposed activities. The analysis of direct impact to polar bear dens to vehicle traffic resulted in a 14% probability of at least one undetected den being underneath one of the grid lines, which represents a conservative estimate of the overall likelihood of such an event.
   b. Mike Gieryic commented that 14% is not likely and therefore this should be discounted.
   c. SAE has provided some additional information on how they intend to conduct their work, particularly as it relates to stream crossings and work in areas of relatively higher slopes. Analysis of this could reduce the potential of collapse to <14%. However, that information is currently not in a usable form.
   d. At the end of the day, how this gets resolved means either 0 or 1 den is categorized as a potential collapse. If a den does collapse due to vehicle traffic, we assumed that the collapse would result in 2.8 lethal takes (a mother and 1.8 cubs). If we consider that this event is unlikely, then this undetected den would be carried over into the next category of exposure (possible abandonment or

early departure) – where there would be a 64% - 88% probability of injury or mortality of cubs depending upon the scenario used.

3. Potential for Den Abandonment and Early Departure
    a. The application indicates that all undetected dens will be exposed to activities within or less than 101m of the den. Our standard mitigation measure to minimize impacts to denning bears is a 1mi (1,609m) buffer in all directions of known dens so it is safe to assume that all undetected dens will be exposed to SAE's proposed activities. The application from SAE is quite general to allow them the flexibility to conduct their work across 2 years with maximum flexibility. Some commenters have suggested that we should make certain assumptions about when and where the work will occur which would result in some of the undetected dens not being exposed to seismic activity because activities would occur outside of the denning period (post April 20).
    b. Our analysis concludes that most undetected dens that are exposed to seismic activity will cause disturbance such that the mothers may abandon the den (resulting in mortality of the cubs) or cause the mother to leave the den early with her cubs (resulting in reduced survival of the cubs = injury).

4. Criteria for Making the Negligible Impact Determination (as required in order to issue regulations)
    a. Overall, our analysis resulted in 16-19 Lethal or Level A takes, primarily of cubs. Based on language in the FR Notices of Proposed and Final Rules involving incidental take of marine mammals under MMPA 101(a)(5) and Conservation Council v NMFS, we believe it is appropriate to consider Potential Biological Removal (PBR) and the baseline level of human-caused removals when considering whether an anticipated number of Lethal and Level A takes represents more than a negligible impact. PBR for the Southern Beaufort Sea stock of polar bears is 14 and the average number of polar bears taken during the Alaska Native subsistence harvest is 19. Furthermore, the total number of polar bears taken in the SBS, including subsistence harvest, defense of life, research takes, unknown takes, etc, is approximately 20. Therefore, there are zero Lethal or Level A Takes that can be authorized and still reach a Negligible Impact determination at this time.

ISSUES THE REMAIN UNRESOLVED

1. Consideration of additional potential mitigation measures
    a. Space and Time
        i. Restricting activities based on space, such as around potential denning habitat or core denning areas, or restricting activities during the denning period could reduce impacts
    b. Multiple FLIR surveys

i. The FLIR detection rate used in our analysis is based on SAE's project proposal (i.e. 1 FLIR survey would occur prior to project activities). However, FLIR detection rates would likely increase if multiple FLIR surveys were conducted. It is important to note that the increased detection rate is not straight forward as some dens are inherently more difficult to detect given depth of dens within the snow as discussed above.

c. Combination of Aerial FLIR and other types of FLIR

   i. There are other types of FLIR that could be considered, including handheld and vehicle mounted FLIR. Detection rates are typically higher for other types of FLIR but they may not feasible on larger scales such as those proposed by SAE.