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PREVALENCE AND SPATIO-TEMPORAL VARIATION OF AN ALOPECIA SYNDROME IN POLAR BEARS (*URSUS MARITIMUS*) OF THE SOUTHERN BEAUFORT SEA

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ABSTRACT: Alopecia (hair loss) has been observed in several marine mammal species and has potential energetic consequences for sustaining a normal core body temperature, especially for Arctic marine mammals routinely exposed to harsh environmental conditions. Polar bears (*Ursus maritimus*) rely on a thick layer of adipose tissue and a dense pelage to ameliorate convective heat loss while moving between sea ice and open water. From 1998 to 2012, we observed an alopecia syndrome in polar bears from the southern Beaufort Sea of Alaska that presented as bilaterally asymmetrical loss of guard hairs and thinning of the undercoat around the head, neck, and shoulders, which, in severe cases, was accompanied by exudation and crusted skin lesions. Alopecia was observed in 49 (3.45%) of the bears sampled during 1,421 captures, and the apparent prevalence varied by years with peaks occurring in 1999 (16%) and 2012 (28%). The probability that a bear had alopecia was greatest for subadults and for bears captured in the Prudhoe Bay region, and alopecic individuals had a lower body condition score than unaffected individuals. The cause of the syndrome remains unknown and future work should focus on identifying the causative agent and potential effects on population vital rates.

Key words: Alopecia, Arctic, disease, polar bears, skin lesion, *Ursus maritimus*.

INTRODUCTION

Observations of alopecia (i.e., focal hair thinning and loss) have been reported for several species of marine mammals including northern elephant seals (*Mirounga angustirostris*), Australian fur seals (*Arctocephalus pusillus doriferus*), southern sea lions (*Otaria flavescens*), grey seals (*Halichoerus grypus*), ringed seals (*Pusa hispida*), and Pacific walrus (*Odobenus rosmarus*) (Bergman and Olsson 1985; Nettleton et al. 1995; Beckmen et al. 1997; Lynch et al. 2011; Pistorius and Baylis 2011). In some cases, alopecia has been associated with elevated concentrations of polychlorinated biphenyls (e.g., Bergman and Olsson 1985; Beckmen et al. 1997), a group of lipophilic persistent organic pollutants known to concentrate in marine food webs (Ruus et al. 2002) and interfere with thyroid hormone homeostasis (Routti et al. 2010). Other cases of alopecia have been attributed to nutrient deficiencies (Trites and Donnelly 2003), parasitic agents (e.g., Dailey 2001), and fungal infection of the hair shaft (Guillot et al. 1998). However, in many cases the causative agent of alopecia remains unknown, which further complicates efforts to understand its epidemiology.

Alopecia is a concern for marine mammals because of the primary role of hair in thermoregulation (Hind and Gurney 1997; Rosen et al. 2007). Individuals with alopecia may have difficulty maintaining adequate thermoregulation (e.g., Lynch et al. 2011) and thus expend additional energy to sustain a constant core body temperature (Beauplet et al. 2003). The elevated energy demands on alopecic animals could have an adverse effect on body condition (e.g., Lynch et al. 2011). Polar bears (*Ursus maritimus*) routinely move between sea ice and open water (i.e., leads and polynyas) which can result in a wide temperature gradient between the body core and the external environment

(Øritsland 1970; Blix and Lentfer 1979), and lead to a substantial increase in thermoregulatory costs for alopecic polar bears, particularly during winter.

We describe an alopecia syndrome observed in polar bears captured in the Alaska portion of the southern Beaufort Sea (SB) from 1998 to 2012. Here we 1) describe the clinical appearance of the syndrome, 2) estimate prevalence by demographic class, 3) assess spatial and temporal variation in prevalence, and 4) characterize the effect of alopecia on body condition. In 2008, polar bears were listed as "threatened" under the US Endangered Species Act. If a disease were to emerge that had the potential to negatively affect polar bear health, there would be a pressing need to identify its etiology and take action to mitigate adverse effects.

MATERIALS AND METHODS

Study area

The study area ranged from Demarcation Point (140°W) at the US-Canada border in the east to Point Barrow (156°W) in the west, and included the Alaska portion of the SB subpopulation of polar bears. Polar bears were captured from 1998 through 2012 (Fig. 1). The spatial distribution of sampling effort was largely consistent over the course of the study. Capture extended from shoreline to approximately 135 km out over sea ice, but the seasonality of captures varied. For all years, captures occurred during spring (20 March–5 May), with additional captures occurring in fall (typically September or October) of 1999, 2000, 2001, 2008, and 2009.

Data collection

Polar bears were encountered from a helicopter and immobilized with tiletamine hydrochloride plus zolazepam hydrochloride (Telazol®, Fort Dodge Animal Health, Fort Dodge, Iowa, USA, and Warner-Lambert Co., Groton, Connecticut, USA) using projectile syringes fired from a dart gun. Bears were ear-tagged with an identification number that was also tattooed on the inner surface of the lip. We determined body weight using a scale and collected morphometric measurements. Cubs-of-the-year (COY) were always with their mothers and could be visually aged without error (Ramsay and Stirling 1988). Some bears had been captured and marked in previous years, so their age was determined from their capture history. For other bears, we extracted a vestigial premolar and determined age by analysis of cementum annuli (Calvert and Ramsay 1998). We assigned bears to five age classes: adult (≥5 yr), subadult (3–4 yr), 2-yr-old, yearling, and COY. We classified body condition using a subjective fatness index: we palpated the body and assigned individuals a score from 1 (extremely thin) to 5 (obese) based on the distribution of adipose tissue around the body (Stirling et al. 2008). This index correlates positively with lipid concentration of adipose tissue in polar bears (McKinney et al. 2014).

We inspected all animals for distinguishing marks (e.g., scars, fresh wounds), lesions, and patches of hair loss. From alopecic individuals, we collected plucks of hair from the edge of the affected area, along with a skin scrape and two replicates (when possible) of lesion biopsies. We collected plucks of hair from unaffected areas on alopecic animals and from a subsample of unaffected individuals to serve as controls. From 1998 to 2010, we stored skin scrapes in methanol, and biopsy and lesion replicates in 10% formalin. In 2012, we collected fresh skin scrapes, hair, and biopsies that were not preserved so that routine bacterial and fungal cultures could be run. Additionally, we collected oral, nasal, and rectal swabs and stored them in RNAlater® (Qiagen, Hilden, Germany). Samples stored in 10% formalin were kept at room temperature prior to analysis; samples stored in RNAlater® were immediately snap-frozen and stored at −80 C prior to analysis.

Pathology

Hair samples were analyzed by placing hair bundles on a glass slide with a small amount of immersion oil and observing the hair shafts under the light microscope. Biopsy tissue samples were processed by routine methods for paraffin wax embedding. Sections (4–5 μm) were stained with hematoxylin and eosin. All sections were also stained with periodic acid-Schiff and Gram stains to assist in the detection of bacteria and fungi. Histologic sections were analyzed by light microscopy by two board-certified veterinary pathologists (K.B.H. and V.S.B.).

Prevalence

We calculated apparent prevalence as the percentage of bears captured that had signs of alopecia. We used Fisher's exact tests for each sex to determine if the occurrence of alopecia was independent of age class and year and

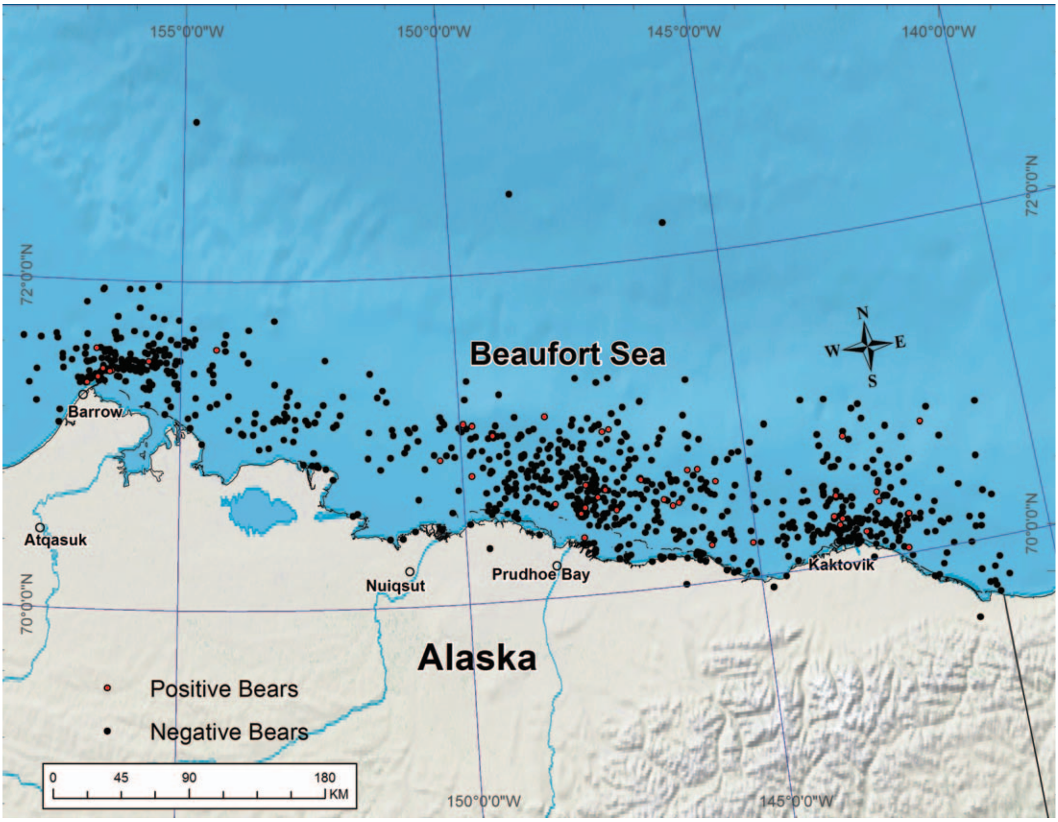

FIGURE 1. Study area and distribution of alopecia-positive and -negative polar bears (*Ursus maritimus*) captured in the southern Beaufort Sea, Alaska, USA, 1998–2012.

used the Cochran-Armitage test to determine if trends were present in the number of alopecia cases. We used adjusted residuals for describing and making inferences about the true association structure among the response variables (Agresti 2002).

We used generalized linear models within a model selection framework (Burnham and Anderson 2002) to test hypotheses about differences in probability of occurrence of alopecia by demographic, spatial, and temporal factors. Variables used in modeling included sex, age-class, year of capture, and capture location. To assign bears to a capture location, we divided the study area into three evenly spaced sectors (Barrow, Prudhoe Bay, and Kaktovik). We determined the midpoint of each sector and used a clustering routine in a geographic information system (GIS) to assign bears to sectors based on capture location coordinates. The clustering approach allowed us to objectively assign bears to a location sector based on the location of capture rather than the logistical base (Barrow, Prudhoe Bay, or Kaktovik) from which flights originated.

We developed, a priori, a set of biologically plausible candidate models (Table 1) and used Akaike's information criterion values (Akaike 1973) corrected for small sample bias (AIC_c) to aid in determining top models. We considered models with ΔAIC_c values >2.0 to measurably differ in information content (Burnham and Anderson 2002). We used AIC_c to rank and compare models based on ΔAIC_c and normalized Akaike weights w_i, and used the sum of all w_i for each variable to rank them in order of importance. When faced with model uncertainty, we used model averaging to account for variation to estimate probability of occurrence more robustly (Burnham and Anderson 2002; Arnold 2010). We ensured model fit by testing with the Hosmer and Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 2000). Models with poor goodness-of-fit (i.e., $P \geq 0.05$) were not used for ranking and comparison.

Spatial analyses

Prudhoe Bay is at the approximate geographic center of the study area (Fig. 1) and

TABLE 1. A priori models relating sex, age class, capture location, and year to the prevalence of alopecia in polar bears (*Ursus maritimus*) in the southern Beaufort Sea, Alaska, USA, 1998–2012.

Model	Hypothesis description	Model variables
1	Prevalence varied by capture location	Location
2	Prevalence varied by sex	Sex
3	Prevalence varied by year	Year
4	Prevalence varied by age class	Age
5	Prevalence varied additively with year and age class	Year, age
6	Prevalence varied additively with year and sex	Year, sex
7	Prevalence varied additively with year and location	Year, location
8	Prevalence varied additively with location and sex	Location, sex
9	Prevalence varied additively with location, sex, and age class	Location, sex, age
10	Prevalence varied additively with location, sex, age class, and year	Location, sex, age, year
11	Prevalence varied additively with sex and age class	Sex, age
12	Prevalence varied additively by age class, year, and sex	Age, year, sex

should represent the mean center of occurrence of cases detected each year in Alaska in the absence of spatial heterogeneity. We used a GIS to plot geo-referenced capture locations and derive standard deviational ellipses and mean centers of occurrence for each year in which there were ≥3 cases. Standard deviational ellipses measure the orientation of case distribution. We used the ellipses to determine if a directional trend in case distribution existed over the years. We calculated the direction between mean centers by deriving the angle between centers as described in Guerra et al. (2003), and converting angles to degrees using a reference angle of 0° (true north). We used the Watson-Williams test to determine if the angle of rotation differed between the yearly mean centers.

Body condition

We used paired *t*-tests to compare the fatness index of cases and controls (bears without alopecia) that were matched by age and sex. Following Lynch et al. (2011), we matched case-control pairs for age and sex based on the order in which they were captured so that matched pairs were captured within a relatively short time. Each bear was used only once for this analysis. We also pooled case-control pairs and used a three-way analysis of variance to further explore the influence of age, sex, and year and respective pairwise interactions on fatness index. We used Kolmogorov-Smirnov and Levene's tests to check data for normality and homogeneity of variances, respectively. We accepted statistical significance at $\alpha=0.05$.

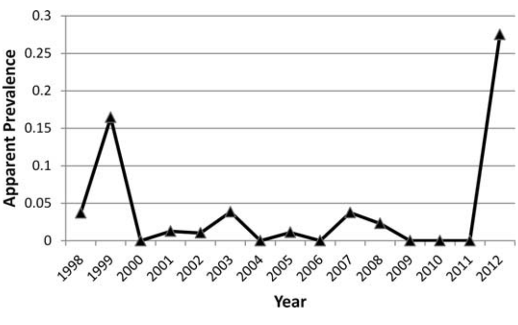

FIGURE 2. Annual variation in apparent prevalence of alopecia in polar bears (*Ursus maritimus*) captured in Alaska's southern Beaufort Sea, USA, 1998–2012.

RESULTS

From 1998 through 2012, 49 of the 1,421 bears captured or recaptured were classified as having alopecia for an overall apparent prevalence of 3.45%. Peaks in prevalence occurred in 1999 (16%) and 2012 (28%); no cases were detected in 2000, 2004, 2006, and 2009–11 (Fig. 2). Over the course of the study, we recaptured 12 (11 adults and one subadult) bears that had been previously classified as alopecic but had recovered by the time of recapture. The time between capture and recapture ranged 0.5–10 yr ($\bar{x}=4$ yr, SE=0.7). Five of the 10 bears were recaptured 1 yr after being classified as alopecic and appeared to have recovered completely. Only one case of alopecia was observed in a bear captured during the fall ($n_{\text{captures}}=212$; prevalence: 0.5%), so we

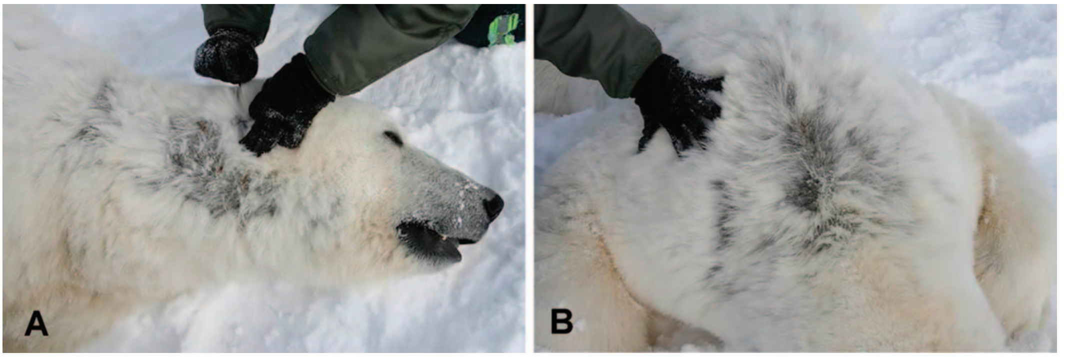

FIGURE 3. Appearance and distribution of alopecia in southern Beaufort Sea polar bears (*Ursus maritimus*) in Alaska, USA, 1998–2012. (A) Thinning of hair at the base of neck over the shoulder blades. (B) Patchy hair loss on the side of the neck.

restricted analyses to spring captures ($n_{captures}$=1,232; n_{cases}=48; prevalence: 3.9%).

Pathology

Alopecia varied in severity and most commonly presented as bilaterally asymmetrical loss of guard hair and thinning of the undercoat along the dorsoventral axis of the head and neck (Fig. 3A, B). Compared to unaffected bears, biopsies from alopecic individuals had a preponderance of telogen follicles, follicular and epidermal hyperkeratosis, and occasional follicular dysplasia characterized by thickening and irregularity of the trichilemmal keratin with frequent, irregular extrusions of trichilemmal keratin into the outer root sheath (Fig. 4A–C). Some affected bears had crusting and oozing lesions, which typically included chronic proliferative dermatitis characterized by acanthosis, hyperkeratosis, and chronic perivascular inflammation (Fig. 4D), typical of pruritic lesions. There was some evidence of colonization of hair shafts by bacteria and fungi, but it did not appear to be associated with inflammation except in cases of furunculosis secondary to self-trauma. No mites, lice, or other ectoparasites were detected.

There was a variable degree of anagen follicle formation indicating initiation of the next hair cycle and formation of new hair shafts. Trichograms of affected animals demonstrated fewer guard hairs in affected samples, light yellow-brown discoloration of the hair shafts and bulbs, and fragmentation of the medulla in existing underfur hair shafts. The peripheral ends were often frayed, indicating breakage (trichomalacia or self-trauma). In 1999, trichograms placed in dermatophyte test media were negative for growth of dermatophytes.

Demographic analyses

No cases of alopecia were observed in family groups that included COY so we pooled all COY, yearlings, and 2-yr-olds into a "dependent young" class for demographic analysis. Alopecia status (positive or negative) was not independent of age for males (n=659, df=2, χ^2=9.39, P=0.009) or females (n=762, df=2, χ^2=12.40, P=0.002) (Fig. 5). For males, the estimated odds of alopecia occurring in subadults were eight times greater than for dependent young and two times greater than for adults. For females, the odds of alopecia occurring in subadults were 18 and three times greater than for dependent young and adults, respectively. Cochran-Armitage tests indicated an absence of trends in yearly counts of alopecia cases for both males (z=0.20, P=0.84) and females (z=−1.26, P=0.27).

Based on Hosmer-Lemeshow tests, models that included the variable *year* displayed poor fit and were deleted from

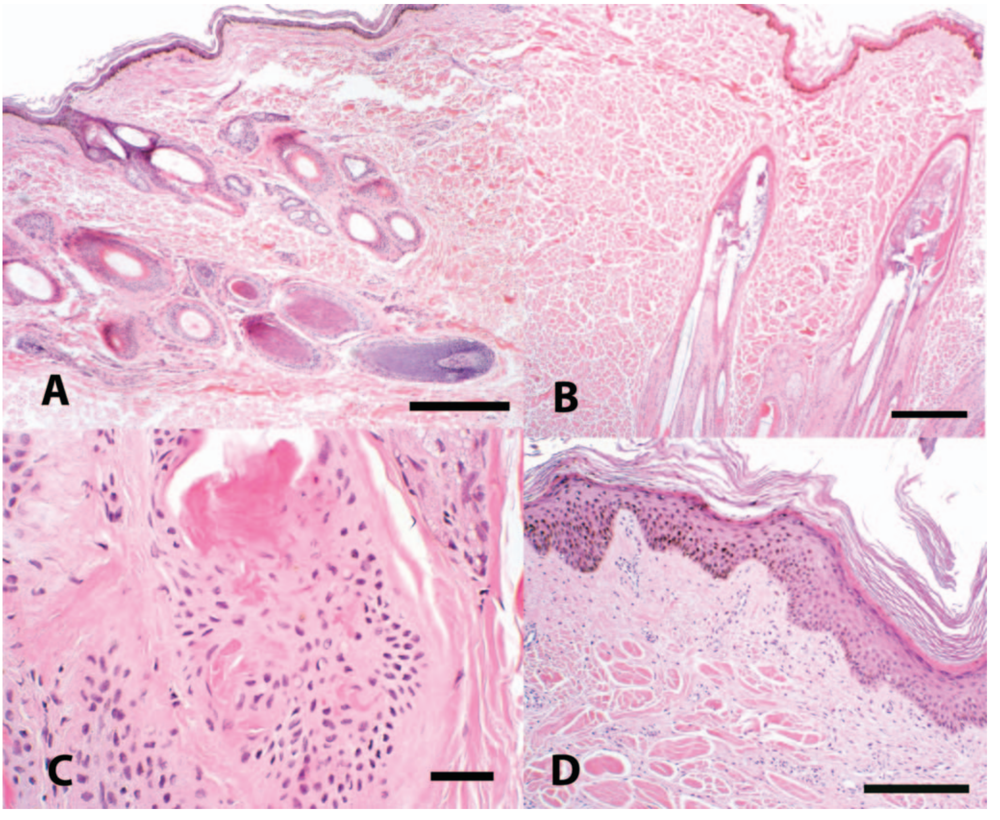

FIGURE 4. Skin biopsies from affected and unaffected polar bears captured in the southern Beaufort Sea, Alaska, USA, in the spring of 2012. (A) Note large, well-developed anagen follicles in the deeper dermis, thin epithelium, and minimal keratin on the surface of the unaffected individual (bar=200 μm). (B) Biopsy from an alopecic polar bear exhibits sparcity and dysplasia of the follicles and very little anagen follicle development (bar=500 μm). (C) Follicular dysplasia and intranuclear clearing (bar=50 μm). (D) Biopsy from a bear that had a proliferative change with some crusting that included thickening of the epithelium, excess keratin, fibrosis, and inflammation (bar=300 μm).

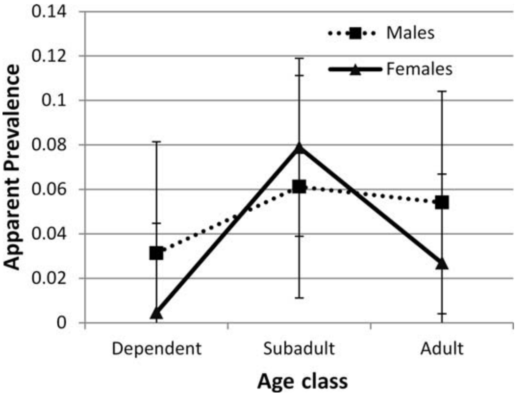

FIGURE 5. Mean prevalence and standard error of alopecia by age class for male and female polar bears (*Ursus maritimus*) captured in Alaska's southern Beaufort Sea, USA, 1998–2012.

the model set. The remaining generalized linear models indicated the probability that a bear had alopecia was influenced by demography and location. Two models were within 1.2 ΔAIC_c units of each other and thus were comparably supported by the data (Table 2). This top model set collectively accounted for 66% of the total model weight and the variables *sex* and *age-class* were retained in both models. *Location*, a categorical variable representing the general area in which an individual was captured, was retained in the second model (Table 2). Based on the normalized Akaike weights of the three variables that comprised the top model set, *sex*

TABLE 2. General linear models of factors influencing the probability of alopecia in polar bears (*Ursus maritimus*) in the southern Beaufort Sea, Alaska, USA, 1998–2012. Model structure is followed by corresponding model number (i.e., hypothesis description from Table 1), number of parameters (k), Akaike information criterion with a small sample size correction factor values (AIC_c), weights of evidence (w_i), and Hosmer-Lemeshow (HL) goodness-of-fit statistic *P*-value. Models from the a priori set that demonstrated poor goodness-of-fit were deleted from the set.

Model	Model number	k	AIC_c	ΔAIC_c	w_i	HL *P*-value
Sex+age	11	4	391.46	0.00	0.43	0.83
Location+sex+age	9	7	392.70	1.24	0.23	0.93
Sex	2	1	393.59	2.13	0.15	0.87
Age	4	3	394.52	3.06	0.09	0.79
Location+sex	8	6	394.85	3.39	0.08	0.89
Location	1	3	397.97	6.52	0.02	0.91

(w_i=0.89) was most important, followed by *age* (w_i=0.75), and *location* (w_i=0.33). Model-averaged estimates derived from the top model set indicated that the probability that a bear had alopecia was greatest for subadults (β=1.13, SE=0.486) and individuals captured in the Prudhoe Bay (β=0.226, SE=0.109) region of the study site, and lowest for females (β=−0.205, SE=0.095).

Spatial analysis

Enough cases were available to calculate mean centers and standard deviational ellipses for the years 1999, 2003, 2007, 2008, and 2012. Mean centers of cases from 4 yr of the 5 yr (1999, 2003, 2007, and 2012) were located in the Prudhoe Bay sector; the center of 2008 cases was located in the Barrow sector. Mean centers for alopecia-free bears from those same years were all located within the Prudhoe Bay sector. Mean direction and distance traveled of cases varied by year, moving an average of 98.3 km from 1999 to 2012. The Watson-Williams test revealed that mean centers of alopecia and alopecia-free bears were moving in dissimilar directions ($F_{1,9}$=3.31, P=0.001) over the 5 yr. The cumulative mean direction of individuals with alopecia from 1999 to 2012 was 65.33±31.23° (SE), whereas the cumulative mean direction of alopecia-free bears was 292.24±24.17°.

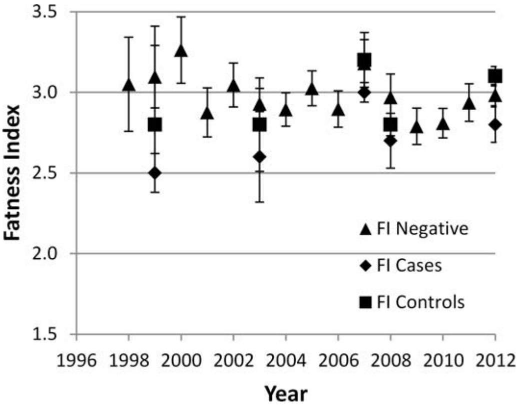

FIGURE 6. Mean fatness index (FI) scores for matched pairs of polar bears (*Ursus maritimus*) with (cases) and without (controls) alopecia and for all unmatched bears without (negative) alopecia captured in Alaska's southern Beaufort Sea, USA, 1998–2012.

Body condition

We used 86 individuals for the matched-pair (case-control) comparison of alopecia status on body condition. Mean fatness index values of animals classified as positive (case) for the alopecia syndrome were significantly lower than that of matched animals classified as unaffected (control) (t=−2.94, P=0.005) (Fig. 6). Additionally, values also were influenced by year ($F_{1,85}$=6.16, P=0.01) but not sex ($F_{1,85}$=1.79, P=0.18) or age-class ($F_{3,83}$=1.12, P=0.35), and no interactions were statistically significant. Values for cases were consistently lower than mean values for all control bears within case years. For reference, we also included index values by year for all unaffected bears ("FI negative"; Fig. 6) that were not used in the case-control comparison. We did not detect a difference in fatness index scores for the 11 adults that had been previously classified as alopecic but had recovered by the time of recapture (alopecia positive during initial capture: $\bar{x}_{BCS}$=2.9, 95% confidence interval (CI)=2.6–3.1; alopecia negative during subsequent recapture: $\bar{x}_{BCS}$=3.0, 95% CI=2.7–3.3).

DISCUSSION

The manifestation of alopecia was similar to recent accounts published for pinnipeds (e.g., Lynch et al. 2011, 2012) in that it presented as patchy hair thinning and loss and could be accompanied by pruritic skin. However, it differed in that the distribution was often reduced in polar bears and was bilaterally asymmetrical. There was cause for concern over the occurrence of alopecia in polar bears, particularly given the concomitant occurrence of a similar syndrome in ringed seals in the Chukchi and SB seas. The underlying cause of alopecia in polar bears and northern pinnipeds remains unknown and there is no clinical evidence to suggest they are related. Ringed seals are the primary prey of polar bears in the SB and Chukchi seas. Given the conservation status of the species involved, there is concern over any risk factor that could have the potential to adversely impact population health.

The body condition of alopecic bears was lower than the condition of unaffected bears. Reductions in body condition could result from affected bears expending additional energy to maintain core body temperatures, as has been reported for alopecic pinnipeds (e.g., Lynch et al. 2011). The consistent loss of body heat to the environment by alopecic bears may be exacerbated by the increased frequency of swimming events that have been detected for bears in the SB (Durner et al. 2011; Pagano et al. 2012), resulting from reductions in sea ice extent over the last decade (Stroeve et al. 2014). The thermal conductivity of water is substantially greater than air (Bonner 1984), and repeated movement in and out of water, as well as an increase in the frequency of long-distance swims, may exacerbate heat loss to the environment for alopecic bears. Conversely, reduced body condition could result from other stressors that contribute to alopecia. The body condition of polar bears in the SB has been declining in association with reduced availability of sea ice habitat (Rode et al. 2010). Nutritional limitations mediating body condition may also factor in the occurrence of alopecia (e.g., Goldberg and Lenzy 2010). The exact mechanism of the reduced body condition is not clear and warrants further investigation.

Alopecia occurred more consistently over time in females than in males; we observed cases in females in 8 yr of 15 yr as opposed to 5 yr of 15 yr for males. Yet for all years when cases were observed simultaneously in males and females, prevalence estimates for male age classes were consistently higher. These findings were supported by general linear models, which indicated that sex and age class were the most important determinants of the probability of alopecia. Males were nearly twice as likely to have the syndrome as were females. In part, this may be due to males typically ranging over a larger area than females (Laidre et al. 2012), which may mediate increased exposure to potential disease-causing agents (Altizer et al. 2006; Biek et al. 2006). However, we do not present an analysis of movement data to corroborate this hypothesis. Additionally, the energetic demands of extensive ranging behavior can result in immunomodulation (e.g., lowering of innate immunity; French et al. 2007), possibly leading to immune suppression and vulnerability to infections (Chandra 1996; Demas 2004). Prevalence of alopecia was relatively high for male and female subadults, which lends further credence to the notion that energetically stressed individuals may be more susceptible to the syndrome than are energetically balanced individuals. Subadults would be expected to be vulnerable to energetic stress because they no longer travel and feed with their mothers (e.g., Rode et al. 2010; Thompson et al. 2010). Indeed, an interactive effect of extensive ranging and immunomodulation may be contributing risk factors for the occurrence of alopecia in multiple demographic classes of polar bears in the SB.

Perhaps the most notable demographic effect on occurrence was the absence of alopecia in all members of family groups that included COY. For polar bears, only pregnant females use dens, which they typically enter in November and exit in late March after giving birth in January (Amstrup 2003). The failure to detect alopecia in family groups with COY suggests that either exposure to the cause of alopecia could have occurred between November and March, when those family groups were in dens and thus not available to be exposed, or pregnant females with alopecia lose their cubs prior to or during denning. Although this observation provides no indication of the etiology of alopecia, note that the sample size of family groups with COY was relatively large ($n=145$; groups sampled in both spring and fall). The only references we found regarding the occurrence of alopecia in free-ranging ursids concern symptoms of an undiagnosed dermatitis associated with hibernating black bears (*Ursus americanus*), which included alopecia of the head, neck, and thorax (Beck 1991; Garrison 2004; Costello et al. 2006). For both species, evidence suggests that the effects of alopecia are typically sublethal with individuals recovering over time. For polar bears, recovery is manifested as the growth of new fur following the spring molt (Born et al. 1991).

Disease is generally characterized by some form of spatio-temporal heterogeneity (Ostfeld et al. 2005). Landscape characteristics such as the juxtaposition and connectivity of habitat patches, the presence of physical or biotic gradients, and patterns of land use can strongly influence disease spread and prevalence (Root et al. 2009; Almberg et al. 2010). The prevalence of alopecia varied through time, with distinctive peaks in 1999 and 2012, which were separated by an intervening period of consistently low prevalence. Additionally, we found that cases of alopecia in fall captures were rarer, although our sample size was much lower. Environmental drivers can generate periodic variation in disease dynamics (e.g., Dushoff et al. 2004; Hoshen and Morse 2004). Temporal variation in the prevalence of alopecia could be caused by seasonal or annual changes in the presence, concentration, or virulence of the causative agent (Altizer et al. 2006), and changes in the functioning of endocrine or immune systems of bears could modulate susceptibility (Bernhoft et al. 2000; Lie et al. 2004). Conversely, alopecia could be secondary to another disease that is affected by the aforementioned factors.

The Arctic marine ecosystem is experiencing dramatic change due to a warming climate, which has been hypothesized to alter exposure levels of marine mammals to toxicants (McKinney et al. 2009), diseases, and parasites (Burek et al. 2008; Stirling and Derocher 2012). The warming trend has resulted in a decline of annual mean September sea ice extent by about -7% per decade from 1979 to 2001, whereas for the period 2002 to 2013, the trend is -14.0% per decade (e.g., Comiso et al. 2008; Stroeve et al. 2012, 2014). The seven lowest September sea ice extents on record have all occurred since 2007. The increased prevalence of alopecia in the spring of 1999 and 2012 followed after unusually warm fall (1998 and 2011) surface air temperatures (SAT) along Alaska's North Slope, which persisted through winter and spring (1999 and 2012) (Lindsay and Zhang 2005; Jeffries et al. 2012). However, fall (October) SAT for the North Slope were also anomalously high for multiple years in between in which no or few cases of alopecia were detected. If alopecia in polar bears is mediated by climate-driven changes to the marine ecosystem, we should expect to see an increase in the frequency of occurrence of the syndrome, and a correlation between prevalence and climate-related metrics.

We detected a general trend of an eastward shift in the mean centers of alopecia cases over time. However, the sample of cases was low, resulting in imprecise standard deviational ellipses (Zimmerman et al. 2011), and polar bears can range over extensive distances in the spring, when most captures occur (Amstrup et al. 2000, 2001; Laidre et al. 2012). Given that bears can, over the course of a month, traverse a distance similar to the distance between mean centers of annual cases, the capture location of affected bears reveals little about where exposure to the causative agent may have occurred.

The cause and consequence of alopecia in polar bears remains unknown. We did detect a decrease in body condition of alopecic bears, but it remains undetermined if the reduction in body condition is a result of alopecia-mediated thermoregulatory stress or due to an underlying disease that resulted in alopecia. Reductions in body condition have been linked to declines in reproductive output in a variety of species (e.g., Guinet et al. 1998; Harwood et al. 2000), including polar bears (Atkinson and Ramsay 1995; Rode et al. 2010). Causal investigations are needed to understand the potential impacts that alopecia may have on polar bear population dynamics. Future work should be broadened into a holistic approach for evaluating cumulative and synergistic effects of multiple stressors on population vital rates.

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