climate change
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Temporal Trends in the Body Condition of Southern Hudson Bay Polar Bears

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INTRODUCTION

Ecological change in the Arctic as a result of climatic warming has been suggested as a significant threat to the conservation of polar bears (*Ursus maritimus*) (Lunn et al. 2002). The impacts of climatic warming on Canadian polar bear populations may occur first near the southern edge of the range in James Bay and Hudson Bay (Stirling and Derocher 1993, Arctic Climate Impact Assessment 2004, Derocher et al. 2004). In particular, the break-up of sea ice earlier in the year is believed to reduce opportunities for polar bears to feed and store fat needed for prolonged fasting during the ice-free season (Stirling et al. 1999). If polar bears have access to their primary prey, ringed seals (*Pusa hispida*) (Stirling and Archibald 1977), for a shorter period then it is likely that they will have difficulty gaining sufficient body mass during the ice-covered period, which may have effects at both the individual and population level. For example, Stirling et al. (1999) documented a long-term decline in body condition and evidence of reduced reproductive success in polar bears from the Western Hudson Bay population, which they attributed to a trend towards earlier melting of the sea ice in summer in western Hudson Bay.

More recently, Gough et al. (2004) and Gagnon and Gough (2005) demonstrated trends towards earlier break-up in James Bay, along the southern shore of Hudson Bay, and in western Hudson Bay during the period 1971-2003. Trends towards later freeze-up were found for northern and northeastern Hudson Bay (Gagnon and Gough 2005); trends in other areas of Hudson Bay were not statistically significant but were in the direction of later freeze-up. Over the past 3 decades, break-up dates are occurring earlier by about 9.5 days per decade in northern James Bay and by between 5 and 8 days per decade along the southern Hudson Bay coast of Ontario.

Declining body condition in Western Hudson Bay polar bears (Stirling et al. 1999) and the recently documented trends in break-up and freeze-up dates for eastern Hudson Bay and James Bay suggest that there

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should be evidence of declines in body condition of bears from the Southern Hudson Bay population. Indeed, there are recent anecdotal reports of polar bears sighted along the Ontario coast that are perceived to be in poor condition (M. E. Obbard, unpublished data; Fig. 1). Here we investigate evidence for change in body condition in Southern Hudson Bay polar bears by comparing data from an earlier study conducted from 1984-86 (Kolenosky et al. 1992) with data from recent field work conducted from 2000-05.

STUDY AREA AND METHODS

The study area extended along the Ontario coastline from Hook Point (ca. 54° 50'N 82° 15'W) on northwestern James Bay to the Hudson Bay coast at the Ontario–Manitoba border (ca. 56°50'N 89° W) (Fig. 2). The study area included offshore spits and small islands, and inland areas up to 40 km inland from the coast. From 1984-1986, polar bears were captured by darting from a Bell 206L helicopter and immobilised using a mixture of ketamine hydrochloride and xylazine hydrochloride (Lee et al. 1981). Immobilisation was reversed by intravenous injection of yohimbine hydrochloride (Ramsay et al. 1985). From 2000-2005, bears were immobilised by darting from a Bell 206L helicopter using Telazol® (ZT) (Stirling et al. 1989), or a mixture of Telazol® and xylazine hydrochloride (XZT) (Cattet et al. 2003). The xylazine in XZT immobilisations was reversed with atipamezole (Cattet et al. 2003). Handling procedures were approved annually by the Animal Care Committee of the Ontario Ministry of Natural Resources (OMNR) and followed the guidelines of the American Society of Mammalogists (Committee for Field Methods in Mammalogy 1987).

Standard morphometric measurements were taken, including straight-line body length (SLBL) and total body mass (TBM). SLBL was measured to the nearest centimetre as the dorsal straight-line distance from the tip of the nose to the end of the last tail vertebra using a metal measuring tape. All bears were measured while sternally recumbent with the back legs extended behind and the front legs forward. TBM was measured to the nearest 500 g by suspending the bear from either a spring-loaded weigh scale (1984-86), or an electronic load cell scale (2000-05). During weighing, bears were placed in a semi-supportive sling and lifted by chain pulley until clear of the ground (Fig. 3). A Body Condition Index (BCI) value (Cattet et al. 2002) was calculated for each

Figure 1. Adult male polar bear apparently in poor body condition sighted along the Ontario coast near Fort Severn, fall 2005. (Photo credit: T. Miles)

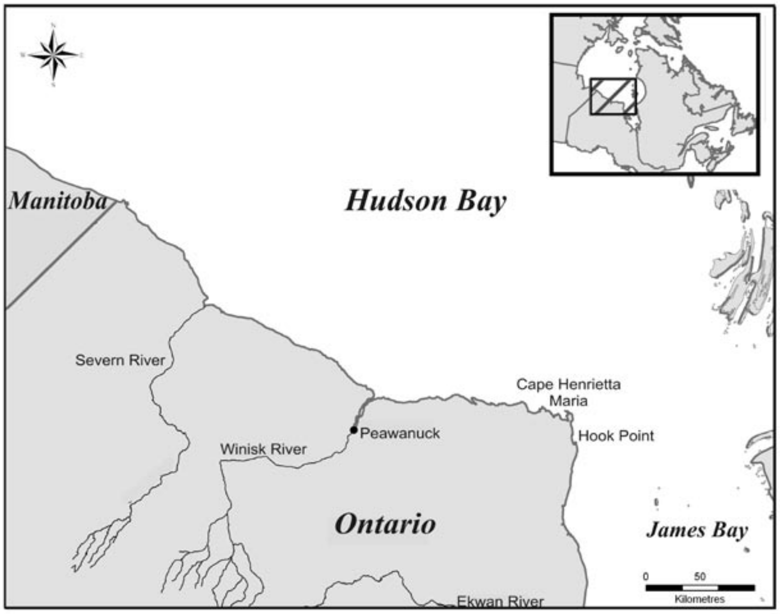

Figure 2. Study area along Ontario coast from Hook Point on James Bay to the Ontario/Manitoba border.

animal using a model that predicts the standardised residual from the regression of body mass against body length, an index of body condition with a strong association with true body condition in polar bears, defined as the combined mass of fat and skeletal muscle relative to body size. BCI is unbiased by body length enabling meaningful comparisons among age and sex classes of bears. BCI can have a value from –3.0 to +3.0.

BCI values were compared between periods (1984-86 vs. 2000-05), and among age and reproductive classes using a 2-way Analysis of Variance (ANOVA) with Julian day of capture included as a covariate. Animals were grouped into the following categories for analysis: Solitary Female (SF) – adult females alone, often evaluated in the field as being pregnant due to obesity; Adult Female (AF) – adult females accompanied by either cubs-of-the-year or yearling cubs; Males (M) – adult males; Subadults (SA) – subadult bears; All

Figure 3. Weighing adult male polar bear using a supportive sling and chain hoist, September 2003. (L to R: D. Holtby, T. Moody, L. Walton, and C. Chenier). (Photo credit: M. Obbard)

categories (ALL) – all age and reproductive or sex classes combined. Bears ≥ 5 years of age were considered to be adults. The subadult category included cubs-of-the-year, yearlings, and bears 2–4 years old.

We used dates of breakup and freeze-up of the annual ice provided in Gough et al. (2004) when comparing BCI values with timing of ice melt and with duration of ice cover in the previous winter. Breakup was defined as the date by which the melting ice covered only 50% of the water (Etkin 1991, Stirling et al.1999, Gough et al. 2004). Freeze-up was defined as the date by which the ice cover in the region had increased to cover 50% of the water. We determined duration of ice cover in the winter prior to the field season in which bears were captured as the number of days between freeze-up the previous fall and breakup in the subsequent summer.

RESULTS AND DISCUSSION

Average body condition for all age and reproductive classes combined was significantly poorer for Southern Hudson Bay bears captured from 2000 to 2005 than for bears captured from 1984 to 1986 (2000–05: BCI = +0.03±0.03, n = 450 vs. 1984–86: BCI = +0.84±0.04, n = 298) (Table 1, Fig. 4). The mean BCI value for all classes combined differed significantly among years ($P < 0.001$) as follows: (1984, 1986) > (1985, 2002) > (all other years) (Tukey's HSD, $P \leq 0.05$; Table 2).

For individual age and reproductive classes considered separately, average body condition in the period from 2000-2005 was significantly poorer than in the period from 1984-86 (Table 1, Fig. 4). The differences between periods were significantly greater for the SF, AF, and SA classes than for the M class of bears ($P = 0.015$; Table 1). The magnitude of change in mean BCI value from 1984–86 to 2000–05 was greatest for solitary females (-0.92), followed by subadults (-0.89) and adult females accompanied by young (-0.75). The decline in mean BCI value was least for adult males (-0.54).

These results indicate that body condition for all age and reproductive classes of polar bears has declined considerably since the mid-1980s and suggest that the decline has been most dramatic for pregnant females

Table 1. Mean Body Condition Index (BCI) values[a] for polar bears of the Southern Hudson Bay population captured from July to October in two time periods, 1984-1986 and 2000-2005.

	Age and Reproductive Class[b]				
Time	SF	AF	M	SA	All Classes
1984 -86	+1.45±0.17 (13)	+0.55±0.09 (48)	+0.81±0.08 (68)	+0.87±0.05 (169)	+0.83±0.04 (298)
2000 -05	+0.52±0.11 (30)	-0.26±0.07 (91)	+0.30±0.07 (85)	-0.01±0.04 (246)	+0.03±0.03 (452)

[a] Results presented as the mean ± standard error adjusted to Julian day = 251 (Sept. 9) with the sample size in parentheses. BCI values were compared between time periods (1984-86 vs. 2000-05) and between age and reproductive classes using a two-way ANOVA with Julian day of capture included as a covariate. The differences in mean BCI values between time periods were significant (P < 0.001) for each age and reproductive class, as well as for all classes combined. The differences between time periods were significantly greater for the SF, AF, and SA classes than for the M class of bears (P = 0.015).

[b] Age and reproductive classes are solitary adult females (SF), adult females accompanied by offspring (AF), adult males (M), and subadult bears of either sex (SA).

Table 2. Annual Body Condition Index (BCI) values[a] for polar bears of the Southern Hudson Bay population captured from July to October from 1984 to 2005.

	Age and Reproductive Class				
Year	SF	AF	M	SA	All Classes
1984	+1.45±0.26 (4)	+0.69±0.13 (23)	+0.86±0.10 (32)	+0.83±0.06 (90)	+0.83±0.05 (149)
1985	+0.72±0.59 (2)	+0.18±0.0.18 (11)	+0.60±0.14 (17)	+0.68±0.11 (31)	+0.56±0.08 (61)
1986	+1.57±0.22 (7)	+0.65±0.16 (14)	+0.93±0.14 (19)	+1.08±0.09 (48)	+1.01±0.07 (88)
2000	-0.29±0.81 (2)	-0.48±0.23 (7)	-0.13±0.38 (4)	-0.06±0.14 (23)	-0.16±0.12 (36)
2001	+1.23±0.24 (2)	-0.21±0.15 (14)	+0.55±0.36 (4)	+0.04±0.11 (27)	+0.06±0.10 (47)
2002	+1.79±0.43 (4)	-0.02±0.15 (11)	+0.30±0.23 (9)	+0.38±0.10 (26)	+0.38±0.09 (50)
2003	-0.18±0.47 (8)	-0.15±0.13 (27)	+0.33±0.18 (22)	+0.03±0.08 (77)	+0.03±0.07 (134)
2004	+0.29±0.30 (9)	-0.44±0.08 (24)	+0.29±0.12 (34)	-0.14±0.06 (68)	-0.06±0.05 (135)
2005	+0.87±0.16 (6)	-0.40±0.23 (8)	+0.27±0.16 (12)	-0.15±0.13 (24)	+0.04±0.1 (50)

[a] Results are presented as the mean ± standard error adjusted to Julian day = 251 (Sept. 9) with the sample size in parentheses. BCI values were compared among years and between age and reproductive classes using a two-way ANOVA with Julian day of capture included as a covariate. Mean BCI value for all classes combined differed significantly among years (P < 0.001) as follows: (1984, 1986) > (1985, 2002) > (all other years) (Tukey's HSD, P ≤ 0.05).

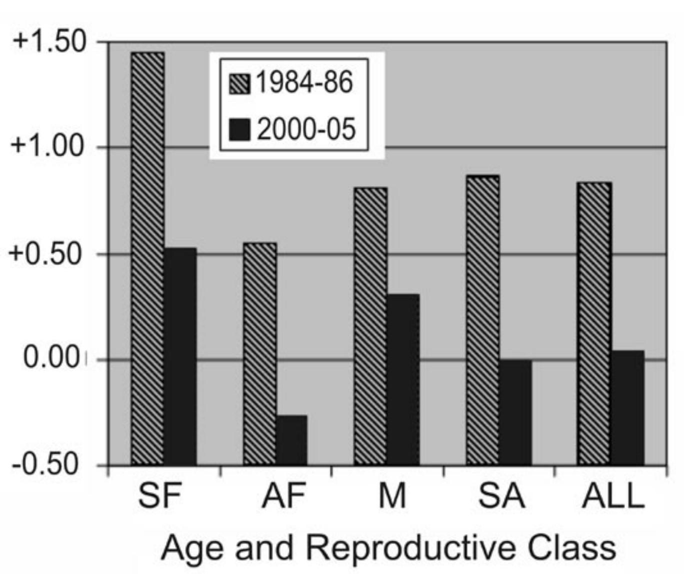

Figure 4. Mean Body Condition Index values for Southern Hudson Bay polar bears, 1984-1986 and 2000-2005 (SF = solitary adult females, AF = adult females with young, M = adult males, SA = subadults, ALL = all classes combined).

and subadult bears—trends that will likely have an impact on reproductive output and subadult survival in the future.

For the periods 1984-86 and 2000-2003 we examined inter-annual variability in BCI related to timing of ice melt and to duration of ice cover in the previous winter (Table 3). There was a non-significant negative correlation between BCI value and date (as Julian day) of break-up for both 1984-86 (r = -0.5164, P = 0.655) and 2000-03 (r = -0.235, P = 0.765). Similarly, there was a non-significant negative correlation between BCI and duration of ice cover in the previous winter for 1984-86 (r = -0.403, P = 0.736) and 2000-03 (r = -0.354, P = 0.646). These results suggest that neither variation in the sea ice break-up date nor duration of ice cover in the previous winter fully explains the variation in BCI among years. This was so despite the fact that there is strong evidence of a significant trend towards both later freeze-up and earlier break-up (Gough et al. 2004, Gagnon and Gough 2005), and a significant negative trend in body condition when comparing our data from the sampling periods 2 decades apart.

These results suggest that other factors or combinations of factors (that likely include later freeze-up and earlier break-up) affect body condition in Southern Hudson Bay polar bears. One such climatological factor may be related to unusual spring rain events that occur during March or April when ringed seals are giving birth to pups in on-ice birthing lairs (Stirling and Smith 2004). These authors documented a case of heavy spring rains that destroyed the roofs of many ringed seal birthing lairs, providing polar bears with easier access to newborn pups. So, despite weather factors that might contribute to an earlier melt of the sea ice (periods of warm daily air temperatures, spring rains) polar bears might paradoxically have improved hunting success. Other factors such as depth of snow accumulation and roughness of the ice (i.e., flat, stable ice versus rough pressure ice) vary over time and also affect polar bear hunting success (Stirling and Smith 2004, Ferguson et al. 2005).

Additional factors that may affect body condition in polar bears include changes in the abundance and distribution of ringed seals. Little is known of their biology in eastern Hudson Bay, and the last surveys were conducted in the mid-1970s (Smith 1975). It is unknown whether ringed seal populations in eastern Hudson Bay and James Bay have declined since the mid-1980s or whether they undergo annual variation in abundance and distribution. However, there is evidence of reduced pregnancy rates and of reduced pup survival in ringed seals from western Hudson Bay during the 1990s (Ferguson et al. 2005, Stirling 2005).

Table 3. Annual date (Julian day) of break-up of sea ice, duration of ice cover in previous winter, and mean Body Condition Index for Southern Hudson Bay polar bears captured in the subsequent fall, 1984-1986 and 2000-2003.

Year	Break-up date (Julian day)	Duration of ice cover previous winter (d)	Mean Body Condition Index: All age and reproductive classes
1984	July 26 (208)	233	0.83
1985	August 8 (220)	266	0.56
1986	August 3 (215)	256	1.01
2000	July 31 (213)	213	-0.16
2001	July 2 (183)	183	0.06
2002	July 22 (203)	210	0.38
2003	July 21 (202)	239	0.03

Given the large annual variability in body condition, and the relatively short time over which this population was examined, the significance of a trend toward poorer body condition over time is unknown. Nevertheless, these data underscore the importance of long-term monitoring of body condition in polar bear populations.

Future research should address the current size of the Southern Hudson Bay polar bear population, the abundance and distribution of ringed and bearded seals (*Erignathus barbatus)*, and other climatological variables such as precipitation trends, all of which may affect body condition of individual bears in this population. Information on these variables might provide a better understanding of the annual variability in polar bear body condition and of the causal factors behind the significant decline in body condition since the 1980s.

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Tendances temporelles dans la condition physique de l'ours polaire du sud de la baie d'Hudson

Des preuves d'un changement dans la condition physique de l'ours polaire du sud de la baie d'Hudson ont été étudiées en comparant les données sur la longueur du corps mesurée en ligne droite et sur sa masse totale recueillies de 1984 à 1986 à celles enregistrées de 2000 à 2005. Ces mesures ont servi à calculer un coefficient d'embonpoint permettant d'effectuer une comparaison impartiale entre des ours de classes d'âge et de sexe différentes. La condition physique a alors été corrélée avec la date de la fonte de la glace de mer et la durée de sa couverture l'hiver qui a précédé la prise des mesures. Selon les résultats, la condition physique de l'ours polaire du sud de la baie d'Hudson de toutes les classes reproductives et de tous les âges s'est considérablement dégradée depuis le milieu des années 1980. Ce déclin était plus marqué chez les femelles enceintes et les ours subadultes, ce qui peut probablement affecter dans un proche avenir la vie reproductive de l'ours polaire et sa survie au stade subadulte. Ni la variation dans la date de la fonte de la glace de mer ou la durée de la couverture de glace l'hiver ne peut expliquer complètement la variation dans la condition physique de l'ours polaire avec les années. Des recherches à plus long terme, qui tiendraient compte par exemple des tendances globales dans la population des ours polaires, de l'abondance et de la répartition de leurs principales proies et d'autres variables climatiques, seraient nécessaires pour comprendre plus clairement les facteurs déterminants de l'important déclin dans leur condition physique depuis les années 1980.

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