Viewpoint

Reply to response to Dyck et al. (2007) on polar bears and climate change in western Hudson Bay by Stirling et al. (2008)

M.G. Dyck [a,*], W. Soon [b,**], R.K. Baydack [c], D.R. Legates [d], S. Baliunas, T.F. Ball [e], L.O. Hancock [f]

[a] Environmental Technology Program, Nunavut Arctic College, Box 600, Iqaluit, Nunavut X0A 0H0, Canada
[b] Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA
[c] Clayton H. Riddell Faculty of Environment, Earth, and Resources, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada
[d] Office of the State Climatologist, University of Delaware, Newark, DE 19716-2541, USA
[e] 205 27 Songhees Road, Victoria British Columbia, V9A 7M6, Canada
[f] MSN H-5-503, 1818 H Street, NW, Washington, DC 20433, USA

ABSTRACT

We address the three main issues raised by Stirling et al. [Stirling, I., Derocher, A.E., Gough, W.A., Rode, K., in press. Response to Dyck et al. (2007) on polar bears and climate change in western Hudson Bay. Ecol. Complexity]: (1) evidence of the role of climate warming in affecting the western Hudson Bay polar bear population, (2) responses to suggested importance of human–polar bear interactions, and (3) limitations on polar bear adaptation to projected climate change. We assert that our original paper did not provide any "alternative explanations [that] are largely unsupported by the data" or misrepresent the original claims by Stirling et al. [Stirling, I., Lunn, N.J., Iacozza, I., 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climate change. Arctic 52, 294–306], Derocher et al. [Derocher, A.E., Lunn, N.J., Stirling, I., 2004. Polar bears in a warming climate. Integr. Comp. Biol. 44, 163–176], and other peer-approved papers authored by Stirling and colleagues. In sharp contrast, we show that the conclusion of Stirling et al. [Stirling, I., Derocher, A.E., Gough, W.A., Rode, K., in press. Response to Dyck et al. (2007) on polar bears and climate change in western Hudson Bay. Ecol. Complexity] – suggesting warming temperatures (and other related climatic changes) are the predominant determinant of polar bear population status, not only in western Hudson (WH) Bay but also for populations elsewhere in the Arctic – is unsupportable by the current scientific evidence.

The commentary by Stirling et al. [Stirling, I., Derocher, A.E., Gough, W.A., Rode, K., in press. Response to Dyck et al. (2007) on polar bears and climate change in western Hudson Bay. Ecol. Complexity] is an example of uni-dimensional, or reductionist thinking, which is not useful when assessing effects of climate change on complex ecosystems. Polar bears of WH are exposed to a multitude of environmental perturbations including human interference and factors (e.g., unknown seal population size, possible competition with polar

bears from other populations) such that isolation of any single variable as the certain root cause (i.e., climate change in the form of warming spring air temperatures), without recognizing confounding interactions, is imprudent, unjustified and of questionable scientific utility. Dyck et al. [Dyck, M.G., Soon, W., Baydack, R.K., Legates, D.R., Baliunas, S., Ball, T.F., Hancock, L.O., 2007. Polar bears of western Hudson Bay and climate change: Are warming spring air temperatures the ''ultimate'' survival control factor? Ecol. Complexity, 4, 73–84. doi:10.1016/j.ecocom.2007.03.002] agree that some polar bear populations may be negatively impacted by future environmental changes; but an oversimplification of the complex ecosystem interactions (of which humans are a part) may not be beneficial in studying external effects on polar bears. Science evolves through questioning and proposing hypotheses that can be critically tested, in the absence of which, as Krebs and Borteaux [Krebs, C.J., Berteaux, D., 2006. Problems and pitfalls in relating climate variability to population dynamics. Clim. Res. 32, 143–149] observe, ''we will be little more than storytellers.''

Published by Elsevier B.V.

1. Introduction

Stirling et al. (2008) contains claims that are inconsistent with the underlying data and the papers they refer to; most of which were written by Stirling and colleagues themselves. For example, in their abstract, Stirling et al. (2008) argue that the ''decline'' in the WH polar bear (Ursus maritimus) population has ''accelerated over time''. However, Fig. 1, adopted directly from Regehr et al. (2007), shows that the decline has been constant.

Our paper set out to answer the question posed in the title of our paper – ''Polar bears of western Hudson Bay and climate change: Are warming spring air temperatures the 'ultimate' survival control factor?'' – by examining the original hypothesis contained in Stirling et al. (1999) and the later extrapolations by Derocher et al. (2004). We concluded that it is neither correct nor useful to over-emphasize global warming (as caused by anthropogenic emissions of CO_2) as the predominant explanatory variable for both climatic and polar bear population changes in the WH region. Extrapolating from the highly limited understanding of the WH regional polar bear population and climate to the situation occurring elsewhere in the Arctic is premature and speculative. Rosing-Asvid (2006) offered similar criticisms and alternative interpretations[1] of data presented in Stirling et al. (1999).

We explained in our paper why the purported ''loss'' of September sea ice in the Arctic, as projected by the computer climate models under the scenarios of future rise in atmospheric CO_2, is not relevant for the WH polar bear population. Stirling et al. (2008) continue to frame their hypothesis as ''climate warming in western Hudson Bay is the major factor causing the sea ice to break-up at progressively earlier dates…'' Furthermore, Stirling et al. (2008) have apparently modified their original hypothesis that warming late spring temperatures are the predominant negative effect on polar bear populations by adding another contributing factor—unsustainable annual harvest by Inuit hunters.[2] This new factor posited by Stirling et al. (2008) is fully consistent with our call for extreme caution in promoting a single factor as the cause of the apparent changes in WH polar bear population characteristics.

We recognize the importance of the spring feeding period. A later freeze-up would also be a negative factor. Such an event would cause polar bear condition to deteriorate and possibly lead to the declining numbers of polar bears in the WH regional population; especially because the polar bears

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[1] For example, Rosing-Asvid (2006) commented that ''Newborn ringed seal pups are the most reliable food source for polar bears during early spring, and the positive effects of a warm spring are therefore likely to be common in most areas, but the negative effects (a lack of fat ringed seal pups later in the season) might be less severe in areas where the bears are not forced on land during summer. Off east Greenland, polar bears can hunt throughout most of the summer, and the number of seals increases there during summer as both harp seals (Pagophilus groenlandicus (Erxbelen, 1777)) and hooded seals (Cystophora cristata (Erxbelen, 1777)) from the west Atlantic Ocean seek out the dense drift ice that flows down along the coast. The concentration of harp and hooded seals, as well as bearded seals (Erignathus barbatus (Erxbelen, 1777)), therefore increases as the sea ice shrinks and their densities become higher during mild years with little ice. Polar bears therefore seem to have all the advantages of a trend towards a milder climate in this area, at least initially, until their predation has lowered the ringed seal population significantly.'' (p. 360–361) See more specific criticism of Stirling et al. (1999) by Rosing-Asvid (2006) in Section 2 below.

[2] Dr. Martina Tyrrell of the Scott Polar Research Institute at the University of Cambridge commented that ''Since the late 1960s polar bears in Nunavut/NWT have been hunted according to adaptive management practices, with quotas changing from year to year reflecting changing scientific evidence regarding polar bear numbers. In Arviat, for example, between 1978 and 2006 the quota steadily rose from 15 to 20 and finally 22 bears per year. However, in 2007, the quota was reduced from 22 to 15 and in 2008 it is to be further reduced to 3 (This reflects a Western Hudson Bay-wide quota reduction from 56 in 2006 to 38 in 2007 to 8 in 2008.). I appreciate that the management of polar bears is not perfect, and that the 2005 quota increases were as much about politics as about evidence. I am also not in a position to comment on the sustainability of this hunt, but I simply want to make the point that it has been managed, and that hunting takes place under a strictly enforced management regime. Further, unlike some other species, hunting transgressions rarely if ever occur and the rules are adhered to across the board. …The point I'm making is that Stirling et al.'s reference to unsustainable harvest by Inuit hunters places blame on Inuit who have conducted most of their hunting under a strictly enforced management regime, while historically, up to the middle part of the 20th century, non-indigenous people were hunting bears in the absence of conservation rules and guidelines.'' (email communication 8th April 2008).
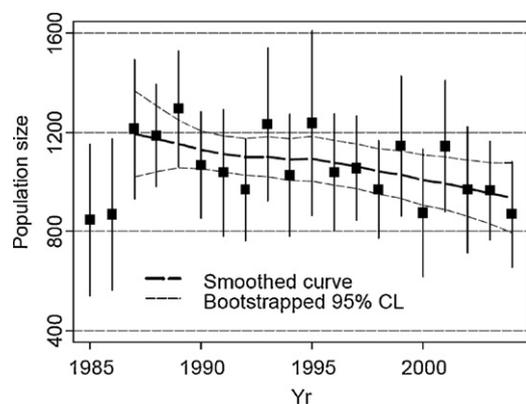
Fig. 1 – Estimates of the western Hudson Bay polar bear population from the domain-limited capture–recapture study by Regehr et al. (2007) [see our reply in Section 2.3 below for further information and discussion].

would likely have much less to eat during the ice-free periods from late spring through fall. However, we were unable to confirm any substantive warming trends for fall temperatures at Churchill. Neither could Stirling et al. (1999) find any clear evidence of delays in freeze-up dates[3] around the WH. The lack of consistency makes a simple explanation impossible and precludes any direct causal connection between climate change and polar bears.

Past correlation-based hypotheses about ecosystems have failed to survive subsequent empirical evidence (see Krebs and Berteaux, 2006; Berteaux et al., 2006; Botkin et al., 2007).

2. Evidence of the role of climate warming in affecting the western Hudson Bay polar bear population

First and foremost, it is worth reminding from Rosing-Asvid (2006: 359–360) (not available at the time when Dyck et al. (2007) was prepared and submitted for publication in December 2005) that different and alternative interpretations about the relationship between climate and polar bear population and condition are possible:

"The catch statistics presented here indicate a strong increase in the number of polar bears and a reduction in the number of ringed seals during mild climatic periods and vice-versa during cold periods. If these trends reflect population dynamics, they contradict the general belief that polar bears suffer during mild periods and that both ringed seal and polar bear populations fluctuate positively with productivity in the sea. If numbers of both species reflect productivity in the sea, one would expect a relatively close connection between the two, with ringed seals

leading the trend. Mild periods have, however, been linked to strong polar bear predation on ringed seal pups, and in the following I will argue that the data from [western] Hudson Bay indicate that strong spring survival of polar bear cubs during some years coincides with early ice breakup. This again seems to contradict the poorer body condition and reduced natality of adult female bears in Hudson Bay documented during mild years. Yet there are factors that in theory can explain these contradictions and trigger different responses to climate change.

Stirling et al. (1999) link lower polar bear reproduction and poorer body condition in fall in western Hudson Bay with increasingly earlier sea-ice breakup, but all major changes in body condition and birth rate took place from 1981 to 1985, when the population increased from ca. 500 to 1400 individuals (Stirling et al., 1999). During this period, both early fall freeze-ups and late spring breakups [NB: instead of late fall freeze-ups and early spring breakups] of the ice occurred, so the strong deterioration in various life-history traits during these years could not have been caused by shorter ice season, but is more likely density-dependent, and if these years are removed, the trends in the time series change significantly.

The trend towards increasingly earlier ice breakup began in 1993 (Fig. 3a in Stirling et al., 1999), and when this new trend occurred, cub survival (from spring to fall) increased from around 50% in 1988–1992 to more than 70% during the following 5 years with mild springs (Fig. 7 in Stirling et al., 1999)."

2.1. Increasing air temperatures in western Hudson Bay

The main points on this issue from our original paper are (1) a large inter-annual variability in the temperature data from the western Hudson Bay exists and (2) trend analyses are highly sensitive to the chosen time period. Nevertheless, Stirling et al.'s (2008) discussion regarding increasing air temperatures in WH raises significant questions. If polar bear populations are affected by an earlier spring ice melt in WH, why present annual mean temperatures and not temperatures from April and May—the key spring months according to Stirling et al. (1999)? In addition, the selection[4] of March, June, and July bypasses the cumulative heat loading which is more physically relevant to melting and accumulation of sea ice within Hudson Bay. Moreover, Stirling et al. (2008) suggest that the climatic impact on polar bears is nearly instantaneous and occurs in isolation from any additional factors and feedbacks. Such a suggestion is at odds with Rigor and Wallace (2004) who documented a delayed effect on Arctic ocean/sea ice of about 15 years from the atmospheric anomaly that occurred around 1989–1990.

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[3] See Fig. 3a of Gagnon and Gough (2005) where statistically significant later freeze-up tendencies can only be shown for limited spots around northern and northeastern Hudson Bay. In contrast to expectation, Gagnon and Gough (2005) found a tendency towards earlier freeze-up on the western side of James Bay.

[4] In their original submission, Stirling et al. (2008) included the following key claim: "They [Gagnon and Gough, 2005] also reported highly significant warming trends over the same periods for the months of March, June, and July at Churchill and Chesterfield Inlet, both of which are within the area occupied by the WH population" which has since been deleted – but the gap remains– upon seeing our earlier review.
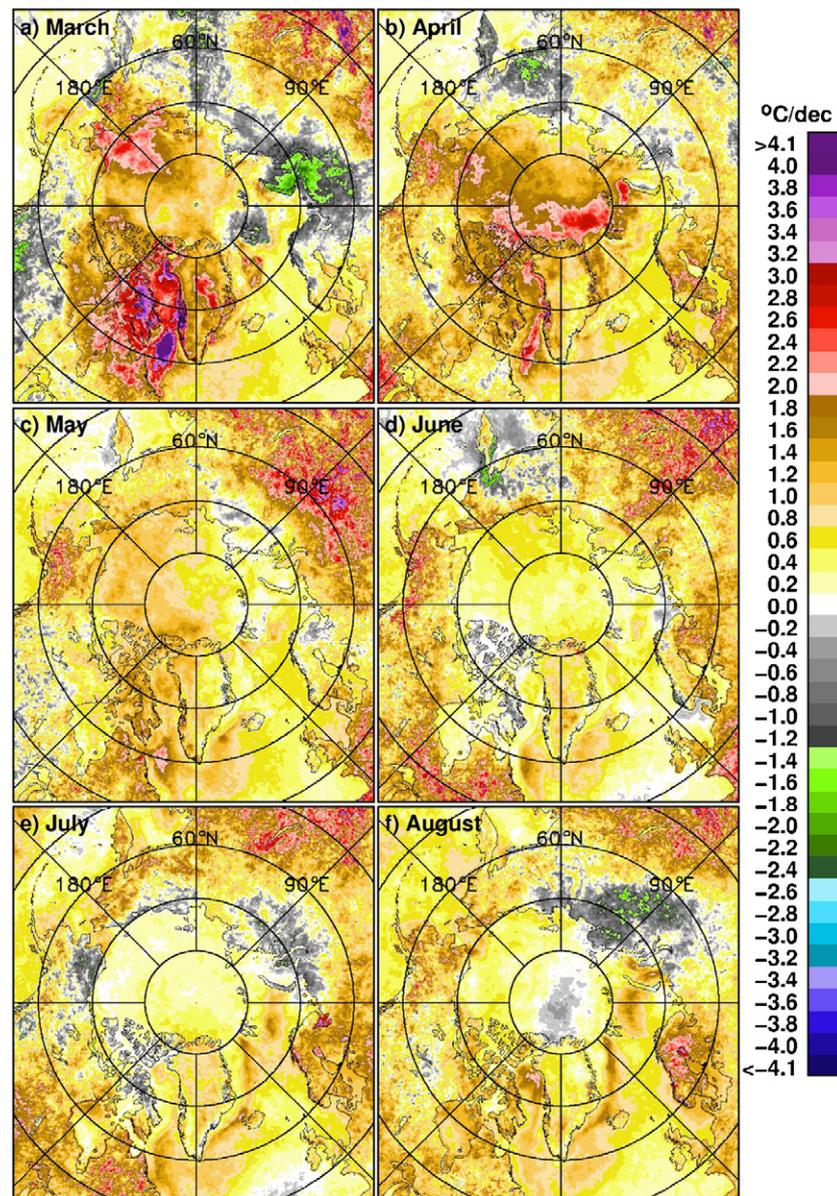
Fig. 2 – AVHRR clear-sky temperature trends [chart dated 12 July 2007, courtesy of Dr. Joey Comiso of NASA].

It also is puzzling that Stirling et al. (2008) do not explain that the "temperatures" deduced from the AVHRR instruments onboard NOAA satellites are strictly a measure of "clear-sky" conditions. The most obvious evidence for caution in reading these data is from the ever-changing trend maps produced in various publications [for example, Comiso (2003, 2006), Overland and Wang (2005), Serreze and Francis (2006)]. Indeed Fig. 3b of Serreze and Francis (2006), as cited by Stirling et al. (2008) to confirm the 1.2 °C/decade warming offshore to 0.4 °C/decade warming along-the-coast in spring, makes the case for our concern (see also Fig. 5b of Overland and Wang (2005)). A large area of cooling air temperatures (of magnitudes of −0.4° to −1.4 °C/decade for 1982–2005 in Serreze and Francis (2006) or roughly −0.6° to −2.4 °C/decade for 1982–2003 data presented in Overland and Wang (2005)) are situated west and southwest from Hudson Bay, which contradicts any robust

conclusion about a consistent pattern of surface air temperature warming trends over the region.

We now focus discussion around Fig. 2, updated from trend maps of the AVHRR clear-sky temperature as presented in Overland and Wang (2005) and Serreze and Francis (2006). These maps were produced courtesy of Dr. Joey Comiso of NASA – the expert responsible for the data (but certainly not our interpretation) – presented in various papers noted by Stirling et al. (2008). Trends for spring and summer months based on data from 1982 through 2006 are presented to help study the relationship between polar bears and sea ice.

Fig. 2 reaffirms our caution of relying too much on trend maps, deducing climatic information, and formulating scientific interpretation (either on climate or polar bears) from AVHRR, since the data interval is relatively short (covering a maximum of only 26 years). Patchy trends with both warming

and cooling areas, including relatively large warming trends over the Hudson Bay basin in March, are obvious while relatively weaker warming trends exist over Hudson Bay and cooling trends over nearby land areas.

Next, Stirling et al. (2008) accuse us of ignoring the most rapidly warming area near the Davis Strait (based on the same AVHRR record of ''clear-sky'' temperatures—see Fig. 2 for the ever-changing inconsistency in its trend amplitudes depending on what months are being highlighted). We referred to the parallel result from Stirling and Parkinson (2006) that failed to discern any significant earlier spring ice break-up trends, despite the very large spring warming trend around the Davis Strait region which exceeds ''4.1 °C/decade'' in March (see Fig. 2 here or Fig. 3b of Serreze and Francis, 2006, cited by Stirling et al., 2008).

Using limited data, Stirling and Parkinson (2006) suggested increases in populations of harp and hooded seals from the 1970s to the 1990s.[5] This is ''particularly relevant to the likely increase in the size of the polar bear population between the late 1970s and early 1990s'' (p. 270 of Stirling and Parkinson, 2006) although Taylor (2007), for example, suggested that the increase in the Davis Strait area is strongly linked to the ''recovery from historical over-hunting after quotas were introduced'' than nutrition. Thus, we reiterate that caution is required when extrapolating the situation from one region to another.

Stirling et al. (2008) also misunderstand our discussion of the Arctic Oscillation (AO) index and its impact on large-scale patterns of temperature change in Hudson Bay. They cite only Skinner et al. (1998) although the contributions of Ball (1995) and Catchpole (1995) cannot be ignored, particularly where large and rapid spring warming was observed in 1779, 1780, and 1782 (no data for 1781). The apparent dipolar see-saw pattern in air temperature trends resulting from the use of only two stations was only an illustrative discussion—the full pattern (Figs. 7 and 8 of Cohen and Barlow, 2005 and cited by Dyck et al., 2007) shows better the sense of a northeast-versus-southwest warming oscillation. Cooling anomalies were included only to caution about making broad statements of warming trends and base conclusions on WH regional results alone.

Our relevant discussion on the AO index and its impact on Hudson Bay shows why we believe the AO index could potentially be a useful climatic index in tracing the ''dynamic of trophic interactions under various settings of the arctic ecosystem''. It also is rather curious for Stirling et al. (2008) to cite Serreze et al. (2007) while concomitantly insisting that ''rising air temperatures'' drive Arctic sea ice changes. Serreze et al. (2007:1534) clearly note ''the recent cold-season

warming…is itself driven by the loss of ice (a positive feedback)…'' This positive feedback is exactly what we described in our paper. The complex interaction among atmospheric circulation, changes in atmospheric temperatures, oceanic heat transport, and advective exchanges among basins and sea ice is more realistic than the one-dimensional interpretation of Stirling et al. (2008) that warming air directly and solely leads to an earlier ice break-up. Furthermore, it is encouraging to find the discussion by Serreze et al. (2007) of the potential role that the advection of warm Pacific summer water through the Bering Strait plays in affecting sea ice in the central Arctic ocean, as first documented by Shimada et al. (2006).

With regards to the statistical analyses offered by Gough et al. (2004b), we simply disagree with Stirling et al. (2008). Our primary objective in introducing this was to document the analyses by Gough et al. (2004b) that covered sea ice records from 1971 to 2003. We are at a loss to understand how ''climatic noise'', data trends and ''multi-decadal oscillations'' can be distinguished with data records of only 33 years using statistical techniques and algorithms, however sophisticated. Our initial point that large and significant variability exists as documented from instrumental, historical and proxy records of climatic variables on a multi-decadal timescale is still well-taken.

Our citation of Saucier et al. (2004) was solely to illustrate that ''Detailed high-resolution modeling efforts…that considers tides, river runoff and daily meteorological forcing, found tidal mixing to be critically important for ice-ocean circulation within, and hence the regional climate of the Hudson Bay basin.'' There was no intention to mislead anyone about the content of Saucier et al. (2004).

Our original paper did not infer any uni-dimensional relationship among snowfall, sea-ice thickness, or the length of seasonal sea ice season. We reference Gough et al. (2004a) and state they ''recently identified snow depth as the primary governing parameter for the inter-annual variability of winter sea-ice thickness in Hudson Bay because of its direct insulating effect on ice surfaces. By contrast, the concurrent winter or previous summer air temperatures yield only weak statistical correlations with ice thickness.'' We properly quoted their article and referenced it to illustrate the multi-dimensionality of factors that affect climate and polar bear populations in WH; again, the hypothesis of Stirling et al. (1999) is an extreme oversimplification of a complex reality.

2.2. Timing of sea ice breakup and effects on polar bears in WH

Stirling et al. (2008) react to footnote 4 in our original paper regarding statistical significance in the detection of an earlier spring ice break-up, but we believe that they took our note out of context. Throughout our paper, the consistent message was to establish a defensible hypothesis and examine physical links and connections rather than to accept blindly the convenient results of statistical arguments. We simply defer to our previous replies in Section 2.1 above on both the difficulty and subjectivity in attempting to interpret sea ice and temperature effects around the Hudson Bay region from the references cited by Stirling et al. (2008).

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[5] Dr. Martina Tyrrell commented that ''This time frame coincides with the Greenpeace campaign to boycott seal skin products, leading to a dramatic decline in the European market for seal skins and the eventual EC seal skin ban in 1989. With regard to ringed seals, the annual sale of skins to the Hudson Bay Company in one east Baffin community (Clyde River) declined from 2504 pelts in 1979–1980 to 532 pelts in 1984–85 (Wenzel, George. 1991. Animal rights, human rights: Ecology, economy and ideology in an Arctic community. Toronto: University of Toronto Press. p. 124). I don't know how significant this is, or if the impact of a seal skin ban would be so quickly reflected in an increase in polar bear numbers [i.e., between the late 1970s and early 1990s according to Stirling and Parkinson (2006)].'' (email communication April 8th, 2008).

Readers may also be surprised to find the puzzling result about sea and lake ice thickening around WH as described in Gagnon and Gough (2006) but not reported by Stirling et al. (2008) even though Gough is a co-author of Stirling et al. (2008). Gagnon and Gough (2006:177) state, the ''Freeze-up (of ice-cover in the Hudson Bay Region, HBR) typically occurs in October and November, ice cover reaches its peak thickness from late March to May, and water bodies in the HBR are usually ice-free beginning in early August. …[S]tatistically significant thickening of the ice cover over time was observed on the western side of the Hudson Bay, while a slight thinning lacking statistical significance was observed on the eastern side. … Increasing maximum ice thickness at a number of stations is correlated to earlier freeze-up due to negative temperature trends (i.e., cooling trends) in autumn. … These results are in contrast to the projections from general circulation models (GCMs), and to the reduction in sea-ice extent and thickness observed in other regions of the Arctic. This contradiction must be addressed in regional climate change impact assessments.'' We agree with Gagnon and Gough (2006).

We are not convinced that the existing records for air temperatures, sea ice and polar bear numbers are of sufficient quality and appropriate duration to establish robust trends and tendencies. We stand by our call for caution in over-interpreting and extrapolating these inadequate datasets.

2.3. Population trend in WH and density dependence

To examine population trends, the entire area that the individuals of a population occupy must be surveyed. The area most commonly surveyed for the WH polar bear population ranged from about latitude 57°00′ to 58°50′N and longitude 92°25′ to 94°10′W (e.g., Derocher and Stirling, 1995a), with an extension to the east towards Cape Tatnam (Lunn et al., 1997). However, the established and recognized WH polar bear population boundary extends beyond Manitoba into Nunavut up to around Chesterfield Inlet (63°20′N, 90°43′W; Aars et al., 2006). Nunavut communities in recent years have raised the issue that more bears are seen in these areas (Stirling and Parkinson, 2006; Tyrrell, 2006). To obtain a better picture of the complete population estimate of WH polar bears and to confirm whether and by how much the population has declined, the Nunavut portion of the WH population must be included in a complete population survey and further discussion should await the conclusion of such a study.

Mitchell Taylor, a scientist with expertise in the estimate of polar bear population, commented and explained that (Taylor, 2007):

''The WH [Western Hudson Bay] mark-recapture [M-R] study has some problems. The capture work for the 1978–1992 interval described in [Derocher and Stirling, 1995a]Derocher and Stirling (1995) [1995a] did not cover the area from the Ontario border to the core area around Churchill in most years, and did not extend north of the Seal River, Manitoba. The estimate was only about 1000, but this was ''expert corrected'' up to 1200 by the Federal/Provincial Polar Bear Technical committee to account for the areas missed. The estimate of 1200 was approximately the number needed to sustain the current quotas of the day, and the population was believed to be sustaining the harvest (i.e., stationary or increasing).

The M-R analysis (Model 2 Jolly-Seber) was repeated in 1994–1995 and this time the area to the Ontario border was covered. The new estimate increased to 1200, which the authors suggested served to validate the correction identified for the first study. The M-R analysis was done independently on males and females older than cubs. Then the cubs were estimated based on the adult to cub ratio observed. For the time, this was a good analysis. However, simulation models indicated that the adult survival estimate from both first and second M-R analyses was too low for the population to sustain itself, even with no harvest.

The current analysis pools the CWS [Canadian Wildlife Service] captures with the Manitoba deterrent captures, probably because the CWS ''research'' captures did not contain enough sub-adults and many of the Manitoba deterrent program captures in the vicinity of Churchill were sub-adults. The new analysis increased the estimates for the mid 1980s to 1200, reduced the mid-1990 estimate to something less than 1100, and we are down to 935 in 2004. They also provide age-specific survival and recruitment estimates, and we know the harvest, so the decline can be checked for consistency using a demographic simulation model. The simulation model suggests a more rapid rate of decline, indicating their survival rates could be under-estimated, which is typical of M-R studies with sampling problems (unexplained capture heterogeneity). If you increase their adult survival rates by 1.5% you recover the decline identified by the M-R estimates.

This could be important because one explanation for the decline is that some of the population has shifted its range north of the Seal River, and the recent study has mistaken emigration for mortality. Perhaps the population decline is not as great as their estimates suggest. Perhaps there had been no decline. We will do some capture work in the areas not covered by CWS in the fall of 2007 to check this out. Clearly the natality rate in the WH polar bears has declined, with a concurrent reduction in the sustainable harvest from this population. Both population numbers and vital rates determine the sustainable harvest and the time trajectory of populations. We are attempting to resolve this uncertainty with additional sampling.'' (Taylor, 2007)

The Hudson Bay sea ice is shared extensively during winter and spring by bears of WH, southern Hudson Bay (SH), and Foxe Basin (FB) (Aars et al., 2006). The limited aerial surveys of SH population showed an increasing trend, at least from 1963 to 1996 (Stirling et al., 2004). The FB population estimate is dated (Aars et al., 2006; Taylor and Lee, 1994) and both the amount of bears and the rate of increase is unknown since only one biomarker mark-recapture study was conducted. The latest population estimate was set at 2300 based on Inuit Knowledge. It is likely, if SH and FB populations were/are increasing, that food competition occurs on the ice. To better

assess this hypothesis, we must await a new population estimate of FB bears that will also produce information on the rate of increase of this particular regional population.

Although Regehr et al. (2007) was not published by the time our original manuscript was submitted in December 2005, it is certainly important and relevant. But three serious problems are raised:

(1) on density dependence and ruling out this factor for the observed WH polar bear conditions.

Stirling et al. (2008) appear to have ignored what we presented in our original paper:

"Given these long-term data on population estimates and responses, it is possible that density-dependent processes have been imprinted in the observed records of polar bears at [WH]. It is important, however, to recognize the great difficulties in demonstrating density dependence in the population studies (e.g., Ray and Hastings, 1996; Mayor and Schaefer, 2005) among which is the sensitivity of the phenomenon on spatial scale covered by the population sampling techniques (e.g., Taylor et al., 2001)."

Although the issue is still far from settled, we note that Stirling and Derocher (1993:243) argue that "This result is consistent with the hypothesis that density-dependent responses were being shown by the polar bear population in WH (Derocher and Stirling, 1992) and suggests the polar bear population might already be the maximum size that can be supported by the existing ringed seal population. If an additional 3 weeks spent hunting does not enable the bears to significantly increase the amount of body fat stored[6] then it is possible a trend toward earlier break-up and a shortening of the time spent hunting will be reflected fairly quickly in the lower rates of reproduction and cub survival."

(2) on the latest WH polar bear population estimates by Regehr et al. (2007).

Stirling et al. (2008) quote the WH polar bear population estimates from Regehr et al. (2007) to be "from about 1200 in 1987 to 935 in 2004" while failing to indicate that the 95% confidence intervals for the two estimates are between

1020–1368 and 793–1076, respectively. Stirling et al. (2008) apparently ignored estimates from other studies such as Lunn et al. (1997), with Stirling as a co-author, that we cited in our original paper. Lunn et al. (1997) give "a 1995 WH polar bear population of 1233 with a 95% confidence interval that ranges from 823 to 1643 bears, so the actual confidence in the "decline" of the WH polar bear population in 2004, relative to the 1995 values, is difficult to confirm." If Stirling et al. (2008) are prepared to defend their confidence in the estimates by Regehr et al. (2007), they must explain how truly sensitive those estimates are depending on data bases and sampling errors and techniques. These are problems and questions that require scientific and objective resolutions rather than subjective selection of population surveys that may not be compatible.

The relevant paper by Tyrrell (2006) shows another aspect in the current debate on polar bear numbers around WH that are dismissed by Stirling et al. (2008) but recognized by Stirling and Parkinson (2006)—the suggestion of an increased population of polar bears in the area, according to Inuit knowledge. We are not arguing for an absolute answer one way or another but note that at least the possibility of an increased polar bear population around the WH should be discussed.

This is why we must question Stirling et al. (2008) on their unjustified assumption of any serious polar bear population decline in WH, including the incorrect insistence that the "decline" of the WH polar bear population "accelerated", which was refuted by the actual results from Regehr et al. (2007).

(3) on WH polar bear population "is now well below historic levels".

This exaggerated statement undermines the statistical nature of the population estimates and model results, such as those produced by Regehr et al. (2007). What is the basis for claiming the current (2004) WH regional polar bear population is now at a historic low level? Stirling et al. (2008) failed to define the term "historic" which we take to imply a longer-term average level rather than any recent point estimate like the population estimate for 2004. Some direct quotes illustrate the contradictory claims made by Stirling. Derocher and Stirling (1995a) (as cited in Stirling et al., 2008) recognized that past polar bear populations in the WH region were significantly overharvested before the establishment of the hunting quota in 1968. This implies knowledge of polar bear populations at a previous time:

"Throughout the 1950s, 50–100 polar bears were harvested annually within the study area [Churchill, WH] (Stirling et al., 1977). Adult females and their cubs leaving the denning area were harvested during spring for hides and dog food. Closure of York Factory (a fur trading post at the south edge of the study area) in 1957 reduced the harvest. Unrecorded harvest by military personnel stationed at Churchill ended in 1964. Except the removal of problem bears, harvest in the Churchill area ended by the mid-1960s. Harvest continued north of the study area in the Northwest Territories, where quotas were introduced in

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[6] We note that this direct observation by itself, notably with low numbers of polar bears studied, can be also simply interpreted as the lack of sensitivity of polar bear body weights to extended sea ice condition. The limited data with a small sample size certainly does not symmetrically extend to imply much lower body weights with less spring ice or earlier spring ice break-up, but we included this quote in full to avoid being accused of changing the meaning and context from the original paper. Hunting for food must surely involve not only age and skill of the predator but also the elements of circumstance, including the availability of prey. To insist that simply having more or less ice cover in spring will determine whether the polar bears are more or less well fed, to the extent of having more or less body fat stored is an arguable assumption that ignores complex ecological realities.

1968. We suggest the population was lower during the 1960s than after this period." (p. 220)

In his open exchange with Douglas Clark, the senior author and his collaborator, Nick Lunn, noted[7] that:

"Prior to the establishment of quotas on polar bears in 1968, and the elimination of several sources of substantial but undocumented harvesting, it appears the [WH] population was significantly over-harvested. Thus, although not well documented, it is likely true, as has been suggested by Derocher and Stirling (1995) [1995a] and more recently by Scott and Stirling (2002) that the population increased in size in the latter half of the 1960s and possibly well into the mid-1970s or so."

We conclude that it is difficult to find support for Stirling et al.'s (2008) claim that the 2004 polar bear population of 935 (with a prescribed 95% statistical confidence range of 794–1076) is "well below historic levels." We refer the interested reader to Calvert et al. (1991) where a WH polar bear population estimate by A.E. Derocher (also a co-author of Stirling et al., 2008) for 1985 was either 685 or 773 bears, depending on the index applied.

2.4. Timing of sea-ice breakup and trends in SH

It is puzzling to see this renewed attempt by Stirling et al. (2008) to argue for a general (if not universal) extension of their spring temperature-earlier ice break-up and polar bear relation from WH using the limited data available from southern Hudson Bay as discussed in the research note by Obbard et al. (2006). We notice that Stirling et al. (2008) added the previously ignored reference of Stirling and Parkinson (2006) in their final version. But Stirling and Parkinson (2006) were unable to show or confirm any statistically significant earlier spring melt dates for the ice around SH. We are again surprised that this observed fact is not openly stated by Stirling et al. (2008).

Here we offer no additional comments other than the caution already expressed in our paper, but a more complete quote from Obbard et al. (2006) may better explain the nature of the data and connection than the re-framing by Stirling et al. (2008):

"For the periods 1984–86 and 2000–2003, we examined inter-annual variability in BCI [Body Condition Index] 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 variations in BCI among years. This was so despite the

fact there is strong evidence of a significant trend towards both later freeze-up and earlier break-up (Gough et al., 2004b), 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 a later freeze-up and an 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 conditions 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 during these same conditions. 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).

We note that the multi-variable discussion by Obbard et al. (2006) is, in fact, consistent with our call for a total avoidance in making one-dimensional predictions of how warming spring air temperatures, as Stirling et al. (2008) insist, to solely decide the fate of polar bears. Although Obbard et al. (2006) was not available at the time of the initial submission of our manuscript; nevertheless, their study found that body condition for all age and reproductive classes of polar bears has declined considerably since the mid-1980s, although no reference to the SH population size and status was presented to assess possible food competition. However, they also suggest that variation in sea ice break-up or duration of ice cover in the previous winters do not fully explain the bear condition among years. We urge interested readers to consult and study Table 3 of Obbard et al. (2006) to fully verify this fact. Obbard et al. (2006) explain that other meteorological and climate-change factors (i.e., depth of snow accumulation, roughness of sea ice) could also be important. Although parallels regarding polar bear body condition exist, it is difficult to compare results from WH and SH studies due to the different applications of the term "condition" (i.e., body mass versus Quetelet Index versus body condition index; Obbard et al., 2006; Derocher and Stirling, 1995b; Stirling et al., 1999). For future monitoring and ease of comparison among polar bear populations, we encourage investigators to use a standard approach in calculating body condition.

3. Responses to suggested importance of human–polar bear interactions

3.1. Research handling of polar bears

Stirling et al. (2008) are incorrect in suggesting that Dyck et al. (2007) proposed that extensive handling of polar bears in WH

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[7] Available at http://forum.polarcom.gc.ca/30/Posting/Posting.cfm?2B07183C303E151A01097F5F595C6B7E.

may be responsible for declines in body condition and reproduction. What Dyck et al. (2007) suggested was, as we pointed out numerous times previously, that ''global warming may indeed have an effect on the polar bears of WH but it must be assessed in a more realistic framework that considers all the likely stress factors and their cumulative impacts'' (Dyck et al., 2007: p. 74). In that context, we examined the extensive handling of WH polar bears. Stirling et al. (2008) are correct that the sampling was spread out over a wide area within the WH population boundary, but a survey encompassing all of the area was never conducted until recently (see discussions above in Section 2.3 and below). It is therefore erroneous of Stirling et al. (2008) to oversimplify the calculation of how many bears as proportion of the WH population were captured or handled. One cannot use the 1200 individuals as a base to proceed with such a calculation. Because the complete population area was never surveyed and assuming conservatively that approximately 100 bears are occupying the area north of the usual study areas, one is left with 1100 individuals. Second, catching all individuals during an inventory is virtually impossible (Lancia et al., 1994). If one assumes that about 40% of a population is actually captured during a mark-recapture study, one would end up with about 440 bears that could be captured ideally. Therefore, probability of a bear being caught each year is now 42.5% (187/440), as compared to Stirling et al.'s (2008) 15.6% (i.e., 187/1200). We also would like to refer the interested reader to Calvert et al. (1995) where, for example, recapture rates for WH bears greater than 1 year of age were found to be up to 88% for a capture sample of 179 bears caught during 1990. This would indicate that bears are recaptured repeatedly over many years, but detailed information on that topic for WH bears is not readily available.

Stirling et al. (2008) are correct in their elaborate recitation of the number of statistical analyses that were performed by Messier (2000) in his study on the effects of polar bear handling. What they fail to mention is that these 3237 bears, captured between 1989 and 1997, came from 7 different polar bear populations (i.e., Northern Beaufort, Kane Basin, Baffin Bay, Davis Strait, Viscount Melville Sound, Lancaster Sound, and Norwegian Bay) and data were lumped together in the subsequent analyses (NB: in contrast, 3300 bears were handled during the same time frame for WH alone; Table 3 in Messier (2000)). Also not explained by Stirling et al. (2008) was the definition of ''long-term'', used by Messier (2000). The author defined long-term as ''effects defined as changes due to handling during the first year following tagging''; Messier (2000: p.18). Most importantly though, polar bear research activities in the Northwest Territories (or what is now Nunavut) occur in about 15-year rotational cycles where individuals of a polar bear population are marked and re-captured for up to 3 years and then left alone until the next inventory of the same population occurs—that simply is not comparable to the annual research efforts to which WH polar bears are exposed. Although we recognize that polar bears are probably affected by short-term handling during these 15-year inventory cycles, **true long-term** (emphasis added) effects (>1 years; resulting from injuries, for example; (Cattet et al., 2006)) are poorly understood, and rarely investigated. Some of the studies that examine the effects of capture of polar bears do not provide a sufficiently detailed description on how multiple

captures of the same individuals over a long-term (e.g., individual X captured in year y, recaptured in year y + t, etc.) are incorporated into the analyses (e.g., Derocher and Stirling, 1995b).

We commend the authors of Rode et al. (2007) for their detailed description and analyses of the handling effect on polar bears for the Southern Beaufort population and encourage them to examine data for WH in the same fashion. We assume that if an examination of these handling effects on all WH polar bears over the long-term are conducted now and if one would find some effects, the results are most likely confounded and a cause and effect could not be established.

A study that examined disturbance of pregnant polar bears (co-authored also by the senior author of Stirling et al., 2008) found that the movement of pregnant females (as examined in Ramsay and Stirling, 1986; Amstrup, 1993) ''probably was as a direct consequence of being handled and not for other reasons'' (Lunn et al., 2004: p. 354). Stirling et al. (2008) selectively neglect to mention that female cubs of handled autumn pregnant females had significantly lighter weights for the same reason. The same study also concludes that ''it is not known what the effects of disturbance of the capture of pregnant females might be in late October or early November, closer to the time when cubs are born'' (Lunn et al., 2004: p. 355).

Stirling et al. (2008) insinuate that Dyck et al. (2007) proposed that females may suffer from handling by being displaced from feeding sites. We find it astonishing that Stirling et al. (2008) seem to refute this thought, although the senior author also co-authored the original paper that suggested this. This was proposed by Ramsay and Stirling (1986) in their study on handling effects of polar bears from WH, which Dyck et al. (2007) cited and explained.

Stirling et al. (2008) provide a description about lactation and how it is part of the female polar bear's life history. However, they appear to miss the point of Dyck et al. (2007) that emphasized that capture work is done either on animals during spring that are emerging from their dens (i.e., family groups), or during the ice-free period while bears are distributed along the southwestern shore of Hudson Bay—times when bears are either stressed due to lactation (Arnould, 1990) or are undergoing a fasting period while living off their stored fat reserves. However, since historical body masses are no longer attained by WH polar bears (i.e., they have less body mass; Stirling et al., 1999), lactation and fasting, although a result of evolutionary adaptation, has likely become more energetically challenging (or stressful) for polar bears. Stirling and Derocher (1993) and Derocher et al. (2004) provide data for body mass losses, for example, for females as they come off the ice earlier and return later or body mass thresholds for reproduction, respectively, that indicate that these bears will be energetically challenged.

3.2. Tourism

The section on tourism in Dyck et al. (2007) describes one additional factor to climatic effects that could possibly contribute to the negative energy balance of bears while on land. Stirling et al. (2008) claim that the description of tourism activities at Churchill, as described in Dyck et al. (2007), is

"inaccurate" and that the conclusion is based on an "incomplete review of available literature" on this topic. They go on by saying that the summary in Dyck et al. (2007) on page 3 (actually p. 75 of Dyck et al., 2007) implies that all bears congregate east of Churchill where tourism activities occur. If Stirling et al. (2008) would have read the previous sentence to their selection, it would have been clear that Dyck et al. (2007) mentioned that *some* bears are exposed to these tourism activities and not the complete population. It is unclear how Stirling et al. (2008) derive the 40% of time that bears would spend around tourism activities.

Stirling et al. (2008) go on by describing tourism activities at Gordon Point, which were mentioned in Dyck (2001) (as cited in Dyck and Baydack, 2004, 2006). The estimated number of tourists (i.e., 6000) in the polar bear viewing area as described by Dyck et al. (2007) are, in fact, in line with what Lemelin and Wiersma (2007) reported (i.e., – the only difference between the two studies is the definition of a "tourist" and a "visitation"). Stirling et al. (2008) fail to mention the true scope of Lemelin and Wiersma (2007) – the perceptions of polar bear tourists. In their paper, Lemelin and Wiersma (2007) describe that some polar bear viewing tourists were distracted by the vehicular impacts and "un-natural" behaviors of polar bears, and that "the negative aesthetics from tundra vehicle tracks and grey water discharge from the tundra vehicle lodges" influenced visitor experience and enjoyment (Lemelin and Wiersma, 2007: p. 49). Stirling et al. (2008) are correct in their claim that baiting has been illegal and that vehicles are only allowed on designated routes, etc. However, at times there is a difference between what "should" happen and what actually happens. During research activities, M. Dyck has personally observed (a) tundra vehicles driving off trails, (b) tundra vehicles approaching lying polar bears, and (c) food rewards being given to polar bears. Such an uncontrolled problem can be confirmed by other independent observers and scientists. The claim by Stirling et al. (2008) that such behavior is restricted by enforcement may be true, but it still occurred occasionally during Dyck's (2001) study period and has continued to occur thereafter.

Stirling et al. (2008) provide data regarding which possible proportion of the WH polar bear population would be exposed to tourism activities and for how long. We feel that these comments and value judgements can be interpreted as a justification for tourism activities to occur, even if they may have negative effects on animals. To our knowledge, there is no published material that indicates that nature or wildlife tourism is adversely affecting, or must be adversely affecting, a vertebrate population as a whole. However, the estimated 5% of polar bears that are in contact with tourists, according to Stirling et al. (2008), could be used as a bench mark and safeguard to protect wildlife species from potential harmful tourism operations elsewhere. Stirling et al. (2008) fail to mention, however, that concern about tourism operations at Churchill were expressed during the 12th Working Meeting of the IUCN/SSC Polar Bear Specialist Group Meeting (Calvert et al., 1998 as cited in Dyck et al., 2007).

In their overview of the tourism operations at Churchill, Stirling et al. (2008) also fail to mention the helicopter viewing activities that occur during fall concurrently with the tundra vehicle activities (Dyck, 2001). Up to 36 helicopter over-flights per day occurred during the 2000 polar bear viewing season, where helicopters passed over the viewing area on average every 30 min. These helicopter tours offer visitors a birds-eye perspective of the area and polar bears. Also taking spring viewing of polar bear dens into account, the 5% of bears being in contact with tourism, as estimated by Stirling et al. (2008), seems to be an underestimate.

Stirling et al. (2008) discuss the polar bear viewing area size in relation to the area used by WH bears during summer and fall. Their argument seemingly provides another justification for tourism activities because "only about 1.4% of the approximately 2200 km^2 land area" is used by bears and "therefore only a small proportion of polar bear habitat is affected by tourism activities and bears could easily avoid these areas if they chose; in fact more than 95% of the bears do avoid the area". In part, it is intuitive that not every individual of the WH polar bear population will be in the small viewing area and natural avoidance might be the case. However, it is also very likely that many bears avoid the area because of human disturbances that occur. Examples of such behavior are listed by Gill et al. (2001), as well as an elaboration of the concept of avoidance versus non-avoidance of disturbance and that species that do not avoid disturbance could be falsely assumed to not be vulnerable. Even if bears do not avoid tourism activities and they appear "calm", significant internal physiological changes can still occur (e.g., Wilson et al., 1991). The scientific work on the effects of wildlife tourism and human disturbance on wildlife species has grown during the past 15+ years and several studies demonstrated indirect and direct disturbance effects on populations and individuals (e.g., Yarmoloy et al., 1988; Harrington and Veitch, 1992; Phillips and Alldredge, 2000; Knight and Gutzwiller, 1995; Amo et al., 2006).

When faced with a stimulus in the form of a human-caused disturbance, animals make decisions similar to predation avoidance (Frid and Dill, 2002). Bears that are faced with tourism have the option to avoid or tolerate the stimulus and need to make a decision based on costs (Gill et al., 2001). From an individual level, bears that tolerate the stimulus may incur higher costs when avoiding the stimulus than when staying in the area. In other words, bears that tolerate tundra vehicular stimuli (and helicopter activity; see Dyck, 2001) may be in a different state (e.g., body condition) as compared to bears that have excess energy to move to another location to avoid these activities. Polar bears are very individualistic and displacement can easily occur by any stimulus—and as a result a preferred resting area is abandoned. Currently there is no scientific data to support this hypothesis, but studies on other species have found similar results (e.g., Amo et al., 2006) and we therefore encourage a study that would compare body mass and condition of bears in and outside the bear viewing area. In addition, Inuit living in Nunavut and outside the usual study area for WH polar bears have commented in recent years that they see more bears on the land during the season when, in the past, few bears were seen, proposing that some WH polar bears have moved north, or the WH population is even increasing (Tyrrell, 2006).

Stirling et al. (2008), in their brief elaboration on the study by Dyck and Baydack (2004), note that nothing about female polar bear vigilance behavior was mentioned in Dyck et al. (2007). Dyck and Baydack felt that the data collected from

females were too small, and any inference from that would be too speculative (as was pointed out in Dyck and Baydack, 2004: p. 348). We completely agree with Stirling et al. (2008) that bears have the potential to habituate or adapt to human activity, particularly in circumstances of repeated and predictable human activity (Aumiller and Matt, 1994; Herrero et al., 2005; Smith et al., 2005). During their study, Dyck and Baydack (2004, 2006) found that some tundra vehicles would approach and leave the immediate vicinity of viewed bears about every 10 min, creating an environment that would unlikely allow for easy habituation (NB: if vehicles remain stationary it would allow for better habituation, which was pointed out in Dyck and Baydack (2004)). It was therefore recommended "that the responsible wildlife management agency take a lead role in developing a visitor and tour operator system that makes tundra vehicle conduct more predictable and consistent for polar bears in the Churchill area" (Dyck and Baydack, 2006: p. 144), which Stirling et al. (2008) neglected to mention, as well in their comments about their "complete" review of the Churchill tourism industry.

Although the study results by Rode et al. (2006) are intriguing and very likely beneficial to manage visitors in bear viewing areas, comparing visitors on foot in a group of 6 visitors/group on average to 15–18 multi-ton motorized tundra vehicles carrying ~40 passengers each per day through the viewing area in Churchill seems somewhat unwarranted.

Dyck and Baydack (2004) used a novel, non-invasive tool in the form of vigilance to examine how *resting* polar bears respond to a human disturbance and how management agencies could examine possible effects of tourism activities on resting polar bears. Some studies on wildlife disturbance documented various physiological and behavioral responses (see Dyck and Baydack, 2004 for some detailed references). Another study examined polar bear physiology, in particular, their heart rate and metabolism (e.g., Øritsland et al., 1977). These studies found that heart rate increases when an animal is presented with a stimulus and that the heart rate in polar bears in particular increases from a resting to a lying and to a standing position. If heart rate is indicative of metabolic activity (Øritsland et al., 1977), then it follows that increases in heart rate would mean increases in metabolic activity. Since Dyck and Baydack (2004, 2006) did not perform surgical procedures to implant data-logging systems in the polar bear viewing area at Churchill to measure heart rates and metabolic activity of polar bears, they used deductive reasoning to come to their conclusions given the published facts on polar bear physiology and animal responses to human disturbances. We are not as confident as Stirling et al. (2008) that the current body of literature is as conclusive on the physiological effects of tourism on large carnivores.

3.3. Polar bear alert program

We agree with Stirling et al. (2008) that the Polar Bear Alert Program (PBAP) is important for the safety of Churchill residents (and bears). It is however surprising to see that Stirling et al. (2008) were rather uncritical towards the handling deaths or control kills by the PBAP officers.

Stirling et al. (2008) indicate that there was an increase in the handling from 48 bears per year between 1969 and 2000

(which Dyck et al., 2007 used for their analyses) up to 135 bears per year between 2001 and 2004. This indicates more bears are coming in contact with humans and are being handled, either because more bears move to the surroundings of Churchill or increased efforts by the PBAP, or possibly both.

It is likely that several social, rather than strict ecological (i.e., hungrier bears noted below), factors could have been responsible for the increased handlings but it is surprising to find Stirling and Parkinson (2006) [p. 266] suggest that "the more likely reason for increasing numbers of polar bears coming into coastal settlements in WH (and hence increased handling by PBAP) is that they are hungry..." There were observations in the late 1990s that nearly 50% of the bears handled were captured at the Churchill dump—the PBAP officers were using the dump as a giant interceptor bait site so that by trapping the bears there less bears would be coming into town.

4. Limitations on polar bear adaptation to projected climate change

4.1. Hunting of species other than ringed seals

As discussed in Dyck et al. (2007), although some climate models predict a complete disappearance of sea ice over the central Arctic ocean for the month of September, while in contrast, the whole of Hudson Bay is always ice-free during this time, regardless of forcing by anthropogenic greenhouse gases (see for example Figs. 8 and 9 in Johannessen et al., 2004). Moreover, sea ice for Hudson Bay was never predicted to completely disappear for late winter or early spring (i.e., March). Therefore, polar bears of WH still have sea ice left to hunt seals, even in the highly unlikely event the extreme conditions of climatic warming come true. Contrary to what Stirling et al. (2008) indicated, however, Dyck et al. (2007) proposed that bears may resort more to eating berries and vegetation to overcome some food deficits (i.e., when not enough seals were caught or from a shorter hunting season), but did not suggest bears would depend entirely upon vegetation for food. It has been estimated by Clark (1997) that the highest productivity site of berries in the WH Lowlands was about 0.48 kg/ha, which is one to two orders of magnitude lower than for other northern areas where bears are known to feed on berries. There are other food sources like migratory birds and their eggs and caribou (*Rangifer* spp.) that would be necessary to include in a more comprehensive study of potential adaptation strategies.

Polar bears are intelligent animals that learn from observing conspecifics (Stirling, 1974). This is perhaps how they learned to catch seals during the ice-free season (Furnell and Oolooyuk, 1980) and to capture fish by diving (Dyck and Romberg, 2007). It is very likely that berries and vegetation alone will not be sufficient to "bridge" energetically any extended ice-free season. However, as long as polar bears have a hunting platform throughout the year to hunt seals, a combination of these together with the occasional seal and fishes may provide as much energy as is lost per day, or possibly more (Dyck, unpublished data), although our view is not shared by all authorities on polar bears since it would

probably require more data and analyses. Given this potential for learning and acquiring new skills, we believe that individuals of a population can therefore gain sufficient energy throughout the ice-free period to at least maintain body mass.

4.2. Dependence on significant amounts of terrestrial vegetation

We also agree with Stirling et al. (2008) that terrestrial feeding of polar bears occurred at levels that were negligible. However, the cited studies used polar bear samples collected between 1986 and 1991 (Ramsay and Hobson, 1991; Hobson and Stirling, 1997), which was more or less at the onset when decreases in body masses were detected. It would be useful to re-examine this topic with samples from the early 1980 and early 2000s (see Fig. 3 in Stirling and Parkinson, 2006). One could then test whether terrestrial feeding increased over the entire time frame where decreases in body masses were detected.

It should also be pointed out that Stirling and Øritsland (1995) (as cited in Stirling et al., 2008) calculated that polar bears need 43 ringed seals per year to survive. We find this a good approach, but somewhat speculative. The study was based on energetic research done on tread mills in a Churchill facility and therefore not based directly on any ecological field data. It is likely that polar bears are much more efficient than the lab studies suggest (Taylor, 2007).

We fully agree with Stirling et al. (2008) that polar bears need meat and protein, aside from berries and vegetation, to maintain body size and population densities. Nunavut, where most of the world's polar bears occur (Aars et al., 2006), is also rich in other marine mammals that are hunted. Many communities harvest Beluga whale (*Delphinapterus leucas*), narwhal (*Monodon monoceros*), and walrus (*Odobenus rosmarus*). For example, Nunavut hunters harvested approximately 8000 narwhals and 7500 Beluga whales (excluding wounded and lost whales) between 1977 through 2000 (Dyck, 2006). Not all of that meat and fat is utilized by the Inuit, and bears can gain easy access to these carcasses during the ice-free period along shorelines. It is not rare to find eight to ten bears of different sex and age classes feeding on a dead walrus (M. Dyck, personal observation from Davis Strait 2006), consuming fat and protein that aid in maintaining their body mass.

4.3. Evolution of ''a true hibernation state''

We accept the criticism by Stirling et al. (2008) concerning our previous statement on extended hibernation as a means for polar bear to adapt to climate change but we wish to note that no comprehensive study has yet been conducted on potential adaptations of polar bears to either gradual or abrupt climate and environmental changes.

5. Conclusions

The paper by Dyck et al. (2007) provides a more realistic or holistic (i.e., less reductionistic) view of possible interacting factors (i.e., humans and the environment) that, in an additive fashion, could produce the results that are currently observed in WH polar bears. We emphasize that it would be difficult to single-out climate change as the only factor (e.g., see Krebs and Berteaux, 2006). Contrary to the arguments of Stirling et al. (2008), Dyck et al. (2007) did not provide ''alternative explanations'' for the observed changes. Rather, Dyck et al. (2007) provided brief summaries of possible factors (i.e., human–bear interactions in the form of research, the polar bear alert program, and tourism; food availability and competition) that could, together with the effects of climate change, result in what has been observed in the ecology of polar bears of WH—namely decreased reproduction, decreased body condition of adult male and female polar bears accompanied by dependent young, and a decreased proportion of independent yearling offspring captured during the open water season in summer and autumn (Stirling et al., 1999). Global warming (or climate change) was not the focus of our paper, but rather Dyck et al. (2007) questioned whether air temperature at Hudson Bay was actually the ultimate factor causing earlier ice break-up, as was suggested by Stirling et al. (1999).

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