ARCTIC
VOL. 62, NO. 4 (DECEMBER 2009)

InfoNorth

Polar Bear (*Ursus maritimus*) Life History and Population Dynamics in a Changing Climate

by Evan Richardson

INTRODUCTION

There is now an increasing body of scientific evidence that rapid changes in the earth's climate over the last half-century are influencing the physiology, phenology, distribution, and abundance of species (Hughes, 2000; McCarty, 2001; Stenseth et al., 2002; Root, 2003). As a result, understanding how climate change will affect the distribution and abundance of species has become a major concern in ecology. Among long-lived vertebrates, environmental variation is known to influence growth (Post et al., 1997), survival (Gaillard et al., 1997), reproductive success (Albon et al., 1983), and consequently the demography of populations. Although large-scale patterns of climatic variability such as the El Niño Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO) are known to influence the life history and population dynamics of both marine and terrestrial species (Stenseth et al., 2002), relatively little information exists on how rapidly occurring but persistent change in the earth's climate (i.e., global warming) will affect species life-history traits and population dynamics. The research I am conducting for my PhD will examine how environmental variation influences the life-history traits and population dynamics of a large carnivore species, the polar bear (*Ursus maritimus*), through climate-mediated shifts in the availability of essential prey resources.

Polar bear life history is intimately linked to the sea ice environment, with sea ice providing the platform from which bears hunt, travel, mate, and in some areas, den (Amstrup, 2003). Over the last 20 years, in association with climate warming, there have been significant declines in both the temporal and spatial extent of sea ice cover in the Arctic (Parkinson and Cavalieri, 1989; Parkinson et al., 1999; Comiso, 2002; Comiso and Parkinson, 2004; Stroeve et al., 2007). It has been suggested that spatial and temporal changes in the sea ice environment will result in reduced availability and abundance of the polar bears' primary prey, seals (Derocher et al., 2004). In turn, reduced prey availability has the potential to influence the life history of individuals (growth, reproduction, and survival) and thereby the population dynamics of polar bears. The effects of reduced prey availability are already evident in western Hudson Bay, where polar bears are forced ashore during an extensive ice-free period that can last for up to four months each summer. Higher air temperatures and earlier sea ice breakup in spring have extended this period and resulted in significant declines in the body mass of adult female polar bears (Stirling et al., 1999; Stirling and Parkinson, 2006). Sea ice–mediated changes in individual phenotypic quality have the potential to influence a number of individual life history traits (e.g., age at first reproduction, litter size, and longevity), all of which can influence the demography of polar bear populations. The purpose of my PhD research is to determine to what extent changes in the Arctic sea ice environment are influencing the growth, reproduction, and survival of polar bears and how changes in key life history traits and vital rates are influencing polar bear population dynamics.

STUDY POPULATION

In western Hudson Bay, polar bears come ashore during an extensive ice-free period that lasts from mid-July to mid-November (Stirling et al., 1977, 1999). Bears in this region arrive onshore shortly after sea ice breakup (Stirling et al., 1977, 1999) and remain relatively inactive while on land (Knudsen, 1978; Latour, 1981), subsisting on fat deposited during the spring and early summer while they were out on the sea ice (Nelson et al., 1983; Derocher and Stirling, 1990; Ramsay et al., 1991). In November, all polar bears except pregnant females return to the sea ice as it begins to reform (Derocher et al., 1993). Pregnant females remain on land fasting for up to eight months, relying on stored fat reserves to meet basic energetic demands, as well as the increased energetic demands of gestation and lactation (Watts and Hansen, 1987; Polischuk et al., 2001). Denning female polar bears in western Hudson Bay already endure one of the longest periods of food deprivation known for any mammal; thus, any significant further reduction in the availability of sea ice is likely to have profound effects on reproduction. Changes in sea ice conditions over the past two decades have already led to significant declines in physical condition of bears in the western Hudson Bay population (Stirling et al., 1999; Stirling and Parkinson, 2006). In addition, a recent study of this same population by Regehr et al. (2007) confirmed that from 1987 to 2004, its numbers declined from ~1200 to 950 individuals.

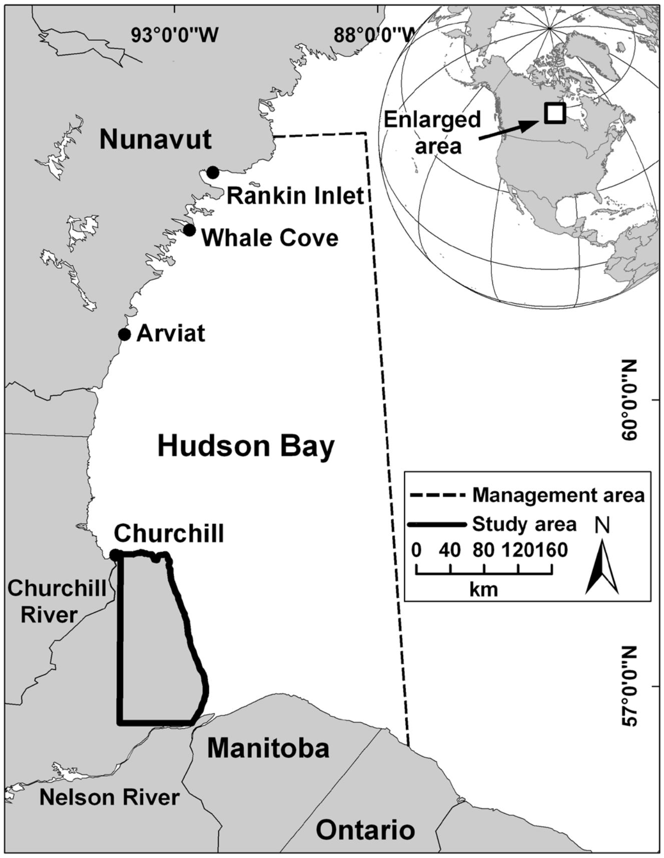

FIG. 1. Western Hudson Bay, showing the study area where the Western Hudson Bay polar bear population has been continuously monitored from 1980 to the present.

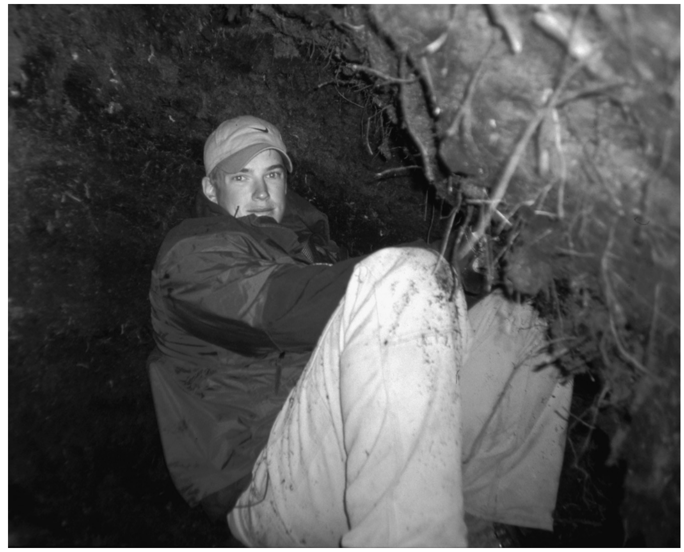

FIG. 2. Evan Richardson inside a polar bear den in the western Hudson Bay study area (Photo: J. Henderson).

METHODS

For my dissertation, I will make use of 28 years of capture-recapture data, consisting of over 3000 uniquely marked individuals of known age from the western Hudson Bay polar bear population located near Churchill, Manitoba (Fig. 1). My field research will involve collecting an additional three years of data as part of the western Hudson Bay polar bear project (Fig. 2). Each year from late August to early October, scientists from Environment Canada immobilize a random sample of bears from the western Hudson Bay polar bear population using standardized capture techniques (Stirling et al., 1989). At the time of initial capture, each animal is assigned a unique identification number that is applied as a permanent tattoo on the inside of its upper lip and on plastic tags placed in both ears. All individual bears that are not caught as cubs are aged by counting the growth-layer groups in the cementum of a vestigial premolar tooth (Calvert and Ramsay, 1998). Morphometric measurements are taken on the immobilized bear, including body mass (kg), body length (cm), axillary girth (cm), zygomatic breadth (mm) and skull length (mm) (Derocher et al., 2005).

To investigate the influence of changing sea ice conditions on individual phenotypic quality, life history traits, and population dynamics of polar bears in western Hudson Bay, I will be using multichannel passive-microwave satellite data to determine daily changes in sea ice extent from 1980 to 2008 (Parkinson et al., 1999). From these data, I will calculate three different sea ice measurements: (1) breakup date (Julian date of 50% sea ice cover in the spring), (2) freeze-up date (Julian date of 50% sea ice cover in the fall), and (3) fasting period (number of days between sea ice breakup and freeze-up). Using detailed information on growth, reproduction, and survival of individuals in the population, I will test several hypotheses regarding the long-term impacts of changing sea ice conditions at both individual and population levels. At the individual level, I will use mixed-effects modeling (Pinheiro and Bates, 2000) to test whether sea ice conditions experienced during early development influence adult body size, body mass, and body condition. Using the same modeling approach, I will use measurements of litter size and cub body mass to examine how changes in individual phenotypic quality (e.g., body mass and body condition) influence female reproductive effort. To examine the potential effects of changing sea ice dynamics on individual survival, I will use open population capture-recapture models (Lebreton et al., 1992) and model selection (Burnham and Anderson, 2002) to evaluate a suite of survival models based on biological hypotheses. For example, one hypothesis is that the length of the fasting period has a negative influence on survival of juvenile polar bears because of their limited body reserves and fasting endurance (Fig. 3).

SIGNIFICANCE OF RESEARCH

Currently, the western Hudson Bay population is the only polar bear population in the world for which we have the detailed long-term demographic data needed to examine

FIG. 3. Polar bear on land during the summer fasting period in western Hudson Bay (Photo: M. Gillespie).

the complex relationships between sea ice extent and the life history traits and population dynamics of polar bears. The results of this study are expected to provide critical insight into the individual and population-level response of polar bears to rapidly changing sea ice conditions in the Canadian Arctic. Furthermore, because the western Hudson Bay polar bear population is located at the southern limit of the species' range, this study will serve as a litmus test for how other polar bear populations are likely to respond to changing sea ice conditions throughout the Arctic. Finally, it is expected that the results from this study will provide a unique look into how long-term variation in the availability of essential prey resources can influence the life history and persistence of a long-lived carnivore species.

ACKNOWLEDGEMENTS

I am very proud to be the recipient of the 2009 Jennifer Robinson Memorial Scholarship sponsored by the Arctic Institute of North America. My PhD research has also been supported by the Steve and Elaine Antoniuk Graduate Scholarship in Northern Research and the Ashley and Janet Cameron Graduate Scholarship in Northern Studies and Scientific Research. Long-term research and monitoring of the western Hudson Bay polar bear population has been supported by the Busch Entertainment Corporation/Sea World, the Canadian Wildlife Service, the Churchill Northern Studies Centre, the Manitoba Department of Conservation, the National Fish and Wildlife Foundation, the Natural Sciences and Engineering Research Council (NSERC), the Nunavut Wildlife Management Board, the Ontario Ministry of Natural Resources, Parks Canada Agency, the Polar Continental Shelf Project, and the World Wildlife Fund (Canada and International).

REFERENCES

Albon, S.D., Mitchell, B., and Staines, B.W. 1983. Fertility and body weight in female red deer: A density-dependent relationship. Journal of Animal Ecology 52:969–980.

Amstrup, S.C. 2003. Polar bear (*Ursus maritimus*). In: Feldhamer, G.A., Thompson, B.C., and Chapman, J.A., eds. Wild mammals of North America: Biology, management and conservation. 587–610.

Burnham, K.P., and Anderson, D.R. 2002. Model selection and multimodel inference, 2nd ed. New York: Springer-Verlag.

Calvert, W., and Ramsay, M.A. 1998. Evaluation of age determination of polar bears by counts of cementum growth layer groups. Ursus 10:449–453.

Comiso, J.C. 2002. A rapidly declining perennial sea ice cover in the Arctic. Geophysical Research Letters 29:1956.

Comiso, J.C., and Parkinson, C.L. 2004. Satellite-observed changes in the Arctic. Physics Today 57:38–44.

Derocher, A.E., and Stirling, I. 1990. Distribution of polar bears (*Ursus maritimus*) during the ice-free period in western Hudson Bay. Canadian Journal of Zoology 68:1395–1403.

Derocher, A.E., Andriashek, D., and Stirling, I. 1993. Terrestrial foraging by polar bears during the ice-free period in western Hudson Bay. Arctic 46:251–254.

Derocher, A.E., Lunn, N.J., and Stirling I. 2004. Polar bears in a warming climate. Integrative and Comparative Biology 44:163–176.

Derocher, A.E., Anderson, M., and Wiig, O. 2005. Sexual dimorphism of polar bears. Journal of Mammalogy 86:895–901.

Gaillard J.-M., Boutin, J.-M., Delorme, D., Van Laere, G., Duncan, P., and Lebreton, J.-D. 1997. Early survival in roe deer: Causes and consequences of cohort variation in two contrasted populations. Oecologia 112:502–513.

Hughes, L. 2000. Biological consequences of global warming: Is the sign already apparent? Trend in Ecology and Evolution 15:56–61.

Knudsen, B. 1978. Time budgets of polar bears (*Ursus maritimus*) on North Twin Island, James Bay, during summer. Canadian Journal of Zoology 56:1627–1628.

Latour, P.B. 1981. Spatial relationships and behavior of polar bears (*Ursus maritimus* Phipps) concentrated on land during the ice-free season of Hudson Bay. Canadian Journal of Zoology 59:1763–1774.

Lebreton, J.-D., Burnham, K.P., Clobert, J., and Anderson, D.R. 1992. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monographs 62:67–118.

McCarty, J.P. 2001. Ecological consequences of climate change. Conservation Biology 15:320–331.

Nelson, R.A., Folk, G.E., Jr., Pfeoffer, E.W., Craighead, J.J., Jonkel, C.J., and Steiger, D.L. 1983. Behavior, biochemistry, and hibernation in black, grizzly, and polar bears. International Conference on Bear Research and Management 5:284–290.

Parkinson, C.L., and Cavalieri, D.J. 1989. Arctic sea ice 1973–1987: Seasonal, regional, and interannual variability. Journal of Geophysical Research 94:14499–14523.

Parkinson, C.L., Cavalieri, D.J., Gloersen, P., Zwally, H.J., and Comiso, J.C. 1999. Arctic sea ice extents, areas, and trends, 1978–1996. Journal of Geophysical Research 104:20837–20856.

Pinheiro, J.C., and Bates, D.M. 2000. Mixed-effects models in S and S-PLUS. New York: Springer-Verlag.

Polischuk, S.C., Hobson, K.A., and Ramsay, M.A. 2001. Use of stable-carbon and -nitrogen isotopes to assess weaning and fasting in female polar bears and their cubs. Canadian Journal of Zoology 79:499–511.

Post, E., Stenseth, N.C., Langvatn, R., and Fromentin, J. 1997. Global climate change and phenotypic variation among red deer cohorts. Proceedings of the Royal Society of London Biological Series B 269:747–753.

Ramsay, M.A., Nelson, R.A., and Stirling, I. 1991. Seasonal-changes in the ratio of serum urea to creatinine in feeding and fasting polar bears. Canadian Journal of Zoology 69:298–302.

Regehr, E.V., Lunn, N.J., Amstrup, S.C., and Stirling, I. 2007. Effects of earlier sea ice breakup on survival and population size of polar bears in western Hudson Bay. Journal of Wildlife Management 71:2673–2683.

Root, T.L., Price, J.T., Hall, K.R., Schneider, S.H., Rosenzweig, C., and Pounds, J.A. 2003. Fingerprints of global warming on wild animals and plants. Nature 421:57–60.

Stenseth, N.C., Mysterud, A., Ottersen, G., Hurrell, J.W., Chan, K.S., and Lima, M. 2002. Ecological effects of climate fluctuations. Science 297:1292–1295.

Stirling, I., and Parkinson, C.L. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. Arctic 59:261–275.

Stirling, I., Jonkel, C., Smith, P., Robertson, R., and Cross, D. 1977. The ecology of the polar bear (*Ursus maritimus*) along the western coast of Hudson Bay. Canadian Wildlife Service Occasional Paper 33. 62 p.

Stirling, I., Spencer, C., and Andriashek, D. 1989. Immobilization of polar bears (*Ursus maritimus*) with Telazol® in the Canadian Arctic. Journal of Wildlife Diseases 25:159–168.

Stirling, I., Lunn, N.J., and Iacozza, J. 1999. Long-term trends in the population ecology of polar bears in western Hudson Bay in relation to climatic change. Arctic 52:294–306.

Stroeve, J., Holland, M.M., Meier, W., Scambos, T., and Serreze, M. 2007. Arctic sea ice decline: Faster than forecast. Geophysical Research Letters 34:5.

Watts, P.D., and Hansen, S.E. 1987. Cyclic starvation as a reproductive strategy in the polar bear. Symposium of the Zoological Society of London 57:305–318.

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