CANADIAN WILDLIFE BIOLOGY & MANAGEMENT

2012: Volume 1, Number 1 ISSN: 1929–3100

Review

Polar Bear-human conflicts: state of knowledge and research needs

Douglas A. CLARK [1], Floris M. van BEEST[2] and Ryan K. BROOK[3]

[1] School of Environment and Sustainability, University of Saskatchewan, 117 Science Place, Saskatoon, Saskatchewan, S7N 5C8 Canada. Email: d.clark@usask.ca

[2] College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan, S7N 5A8 Canada. Email: floris.vanbeest@usask.ca

[3] College of Agriculture and Bioresources, University of Saskatchewan, 51 Campus Drive, Saskatoon, Saskatchewan, S7N 5A8 Canada. Email: ryan.brook@usask.ca

Abstract

Knowledge of the biophysical and social factors influencing conflicts between people and Polar Bears (*Ursus maritimus*) across the circumpolar north is incomplete and insufficient to guide management. We reviewed the peer-reviewed literature and government reports on Polar Bear-human interactions to assess what is known about their environmental context, relevant bear behavior and life history attributes, and the human dimensions of these events. Polar Bear-human conflicts appear largely driven by the absence of sea ice, which is a normal seasonal occurrence but is increasing in duration due to a warming Arctic climate. Integrated multidisciplinary research is needed to inform Polar Bear conservation efforts and improve human safety. Research priorities should include monitoring spatial and temporal trends of conflicts, understanding variability in incident recording, evaluating mechanisms of climate change effects on Polar Bear-human conflicts, determining risk perception and stakeholder acceptance capacity, and assessing deterrent effectiveness.

Keywords: climate change, endangered species, food-conditioning, habituation, Polar Bear, *Ursus maritimus*, wildlife-human conflict.

INTRODUCTION

Scientific understanding of the factors influencing conflict between people and Polar Bears (*Ursus maritimus*) is substantially less developed than it is for other bear species (Osvyanikov 1996; Clark 2003) and yet it is important for the species' conservation, especially in a warming climate (Amstrup *et al.* 2010). Deaths of Polar Bears shot in defense of life and property are frequent outcomes during conflicts with humans, occurring in 61% (Fleck and Herrero 1988) and 92% of incidents (Gjertz and Persen 1987). In contrast, human injuries or fatalities are infrequent: together comprising only <1% and 6% of incidents for all

Correspondence: Douglas A. Clark, School of Environment and Sustainability, University of Saskatchewan, 117 Science Place, Saskatoon, Saskatchewan, S7N 5C8 Canada.
Email: d.clark@usask.ca

North American bear species analyzed by Middaugh (1987) and Herrero and Fleck (1990), respectively. Although rare, each human injury associated with Polar Bears is highly publicized and media coverage shapes public discourse about Polar Bear conservation (Foote *et al.* 2009).

Polar Bear-human conflicts are neither new nor common (Honderich 1991; Stirling *et al.* 1977). However, in the context of climate change these conflicts are becoming increasingly important for wildlife managers and circumpolar communities for several reasons (Obbard *et al.* 2010). Temporal trends in sea ice decline due to climate change suggest that we should expect longer periods of overlap and increased conflict with people throughout much of the species' range (Stirling and Derocher 1993; Stirling *et al.* 1999; Stirling and Parkinson 2006). Further, international expectations for Polar Bear conservation are high and likely to only increase (Vongraven and Peacock 2011), underscoring the need for development and dissemination of best management practices (Amstrup *et al.* 2010; Obbard *et al.* 2010).

Here, we summarize and assess the state of knowledge on Polar Bear-human conflicts using peer-reviewed literature and government reports, identifying where further research is needed. This review does not attempt to directly address the broader areas of Polar Bear ecology in general (e.g., Stirling 2011), changes in Arctic sea ice (e.g., Parkinson 2006; Stroeve *et al.* 2012), biological impacts of climate change on Polar Bears and Arctic ecosystems (e.g., Stirling and Parkinson 2006; Amstrup *et al.* 2007), or northern societies and economic development (e.g., AHDR 2004). Instead, our review is structured around Herrero *et al.*'s (2005) three-part model in which bear-human conflict outcomes are determined by situation-specific combinations of environmental context, bear behavior, and human responses/dimensions (Figure 1). We follow Hopkins *et al.*'s (2010) recommended terminology to describe the distinct types of interactions between people and Polar Bears (Table 1). This said, when we report published findings of others, we use their original terminology in order to not incorrectly categorize types of interactions.

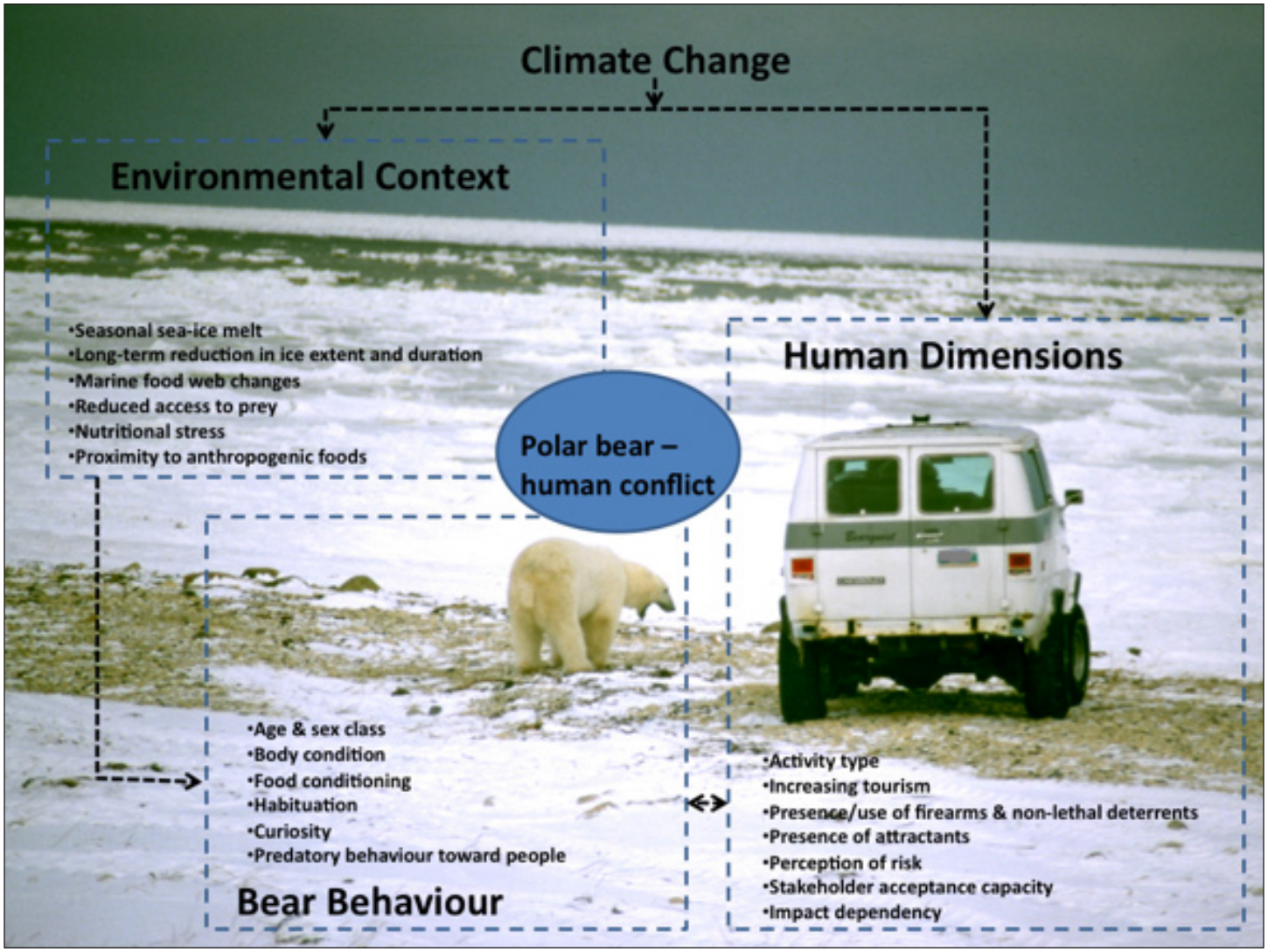

Figure 1: Interactions between climate change and the dimensions of Polar Bear-human conflicts. Arrows indicate directionality of effect. Photo: D.A. Clark.

Table 1. Terminology used in bear-human conflict management as recommended by Hopkins *et al.* (2010).

Scientific term	*Definition*
Human-bear interaction	An occurence when a person and bear are mutually aware of each other.
Incident	An occurence that involved a human-bear conflict or episodes where bears caused property damage, obtained anthropogenic food, killed or attmpted to kill livestock or pets, or were involved in vehicle collisions.
Human-bear conflict	When a bear exhibited stress-related or curious behaviour, causing a person to take extreme evasive action, made physical contact with a person or exhibited clear predatory behavior, or was intentionally harmed or killed (not including legal harvests) by a person.

ENVIRONMENTAL CONTEXT

Here we define environmental context as the suite of biophysical conditions and trends across multiple temporal and spatial scales that influence the distribution, reproduction, ecology, and foraging patterns of Polar Bears and people who inhabit Arctic and sub-Arctic marine and coastal ecosystems. Most Polar Bear-human conflicts occur when bears are forced ashore by seasonally melting sea ice (Gjertz and Persen 1987; Fleck and Herrero 1988; Stenhouse *et al.* 1988; Gjertz *et al.* 1993; Gjertz and Schie 1998; Dyck 2006). Such seasonal melt is not a new phenomenon but the extent and duration of seasonal melt is increasing rapidly in some regions of the Arctic (Parkinson 2006; Stroeve *et al.* 2012) and results in Polar Bears being on shore longer (Stirling *et al.* 1999). The number and frequency of Polar Bear-human conflicts will likely increase in the future because the warming Arctic climate restricts bears' access to sea ice, forces them to spend more time on land, reduces their feeding opportunities, and thus causes nutritional stress (Stirling *et al.* 1999; Regehr *et al.* 2007, 2009; Peacock *et al.* 2010). Indirect effects of sea-ice decline on Arctic marine food webs likely compound this problem by ultimately reducing the abundance of their preferred prey species, Ringed Seals (*Pusa hispida*) (Ferguson *et al.* 2006). Polar Bears on shore for longer periods are not only more likely to be nutritionally stressed but may also simply be in greater proximity to people and anthropogenic food sources such as garbage dumps and harvested wildlife (Stirling and Derocher 1993; Stirling and Parkinson 2006; Towns *et al.* 2009; Peacock *et al.* 2010). Individual human-bear incidents cannot be directly attributed to climate change (Hulme 2009), but the causal chain of reduced ice/nutritionally-stressed Polar Bears/more conflicts with people is supported by considerable empirical evidence from studies in diverse locations. The nature of this relationship is also something on which scientists and northern indigenous people largely agree (Lemelin *et al.* 2010). This congruence is important because effective management of Polar Bears requires cooperation between those groups, and, to date, such agreement has been scarce (Dowsley and Wenzel 2008; Tyrrell 2007, 2009; Henri *et al.* 2010; Peacock *et al.* 2011).

Shifts in terrestrial distribution during the on-shore period could alter the spatial overlap of Polar Bears and people, making conflicts more likely, although such an effect has not been demonstrated. Several authors hypothesized this was the case with Polar Bears moving northward along the western coast of Hudson Bay, increasing conflicts in communities there (Peacock *et al.* 2010; Towns *et al.* 2010). However, Atkinson *et al.* (2012) document a southward shift in bears observed on shore there over the same period, so this situation and its causes remain unclear.

There is no published long-term documentation of spatial or temporal trends in Polar Bear-human conflicts beyond individual jurisdictions, usually over relatively short time periods: e.g., Svalbard, Norway (Gjertz and Persen 1987; Gjertz *et al.* 1993; Gjertz and Schie 1998; Peacock *et al.* 2010), the Town of Churchill in Manitoba (Kearney 1989; Towns *et al.* 2009), and Canadian national parks (Fleck and Herrero 1988; Leonard 1989; Clark 2003). An exception is Middaugh's (1987) 86-year review of Alaska, which contained only one Polar Bear-human conflict. Low numbers of reported incidents in those papers and limited spatial coverage preclude detailed statistical analysis, making it difficult to test hypotheses.

BEAR BEHAVIOR AND LIFE HISTORY ATTRIBUTES

Polar Bears are vulnerable to conflicts with humans because they are large-bodied wide-ranging carnivores with high energetic needs, able to challenge (or stalk) people for food. They often exhibit little or no fear of people, and at an individual level display complex behaviors that can increase their likelihood of approaching people or seeking anthropogenic foods. Most Polar Bears killed during conflicts with people are sub-adult males (Lunn *et al.* 1985; Gjertz and Persen 1987; Fleck and Herrero 1988; Stenhouse *et al.* 1988; Gjertz *et al.* 1993; Gjertz and Schie 1998; Dyck 2006). Consistent with other bear species, these outcomes are thought to result from those bears' inexperience as hunters plus their competitive disadvantage against other bears when seeking and defending food (Herrero and Fleck 1990). The apparent boldness and curiosity of Polar Bears of all age and sex classes towards humans has long been noted, but this behavior is not well understood from a scientific perspective (Amstrup *et*

al. 1986; Clark 2003). It is rarely clear to an observer when a bear's curiosity becomes dangerous (Osvyanikov 1996).

Habituation and food conditioning both appear to be important behavioral factors leading individual Polar Bears into conflicts with people, as they are for other bear species (Herrero *et al.* 2002, 2005; Hopkins *et al.* 2010). Evidence for this comes largely from Churchill, Manitoba, Canada, where for decades Polar Bears have had access to anthropogenic food sources such as garbage dumps, deliberately-placed baits, and community refuse (Watts and Ratson 1989; Herrero and Herrero 1997). Lunn and Stirling (1985) found that tagged Polar Bears that had fed in the Churchill garbage dump were significantly more likely to be destroyed as problem bears than tagged bears which had not fed there. They also found that tagged bears that had fed in that dump were twice as likely to be harvested by Inuit hunters from communities north of Churchill. However, the overall prevalence of food conditioning and habituation in that western Hudson Bay sub-population or others is unknown, and further investigation may yet reveal differences in how these behaviors manifest in Polar Bears compared to other species. Recently, Inuit and Cree communities have reported increases in Polar Bear-human interactions and conflicts around Baffin Bay and Hudson Bay, as well as bears being more aggressive and less afraid of people (Dowsley and Wenzel 2008; Nirlungayuk and Lee 2009; Tyrrell 2009; Lemelin *et al.* 2010). In western Hudson Bay, Inuit community members attribute these observed behavioral changes to long exposure of Polar Bears to people and anthropogenic foods in the Churchill region (Nirlungayuk and Lee 2009; Tyrrell 2009).

Control of Polar Bear attractants is important since, like other bear species, they are attracted to odors indicating potential food (Cushing 1983; Herrero and Fleck 1990; Herrero 2002). However, because Polar Bears do at times attempt to prey on people, attractant control alone is insufficient for human safety. Deterrents, including firearms carried by trained and/or experienced people, are also necessary to safeguard human life in certain situations (Herrero and Fleck 1990). Firearms are not completely reliable deterrents though. Smith *et al.* (2012) found that firearms were successfully used for deterring Polar Bears in only 50% of close range encounters with polar bears. Importantly for conservation, common non-lethal precautions appear to be effective on Polar Bears; notably capsicum deterrent spray (Smith *et al.* 2008), and electric fencing and acoustical deterrents – including snowmobiles (Woolridge 1983; Miller 1986;, Andersen and Aars 2008).

Experimental testing of a variety of deterrents (38mm and 12-gauge projectiles, electric fences, noisemakers, cracker shells) at a baited site at Cape Churchill, Manitoba over several years yielded variable results (Clarkson 1987). Because of the experimental constraints and potential confounding influences of unknown individual bears' histories on those tests, questions remain about the effectiveness of most of those deterrents. However, experience with electric and non-electric fencing at research camps since then has shown it can be reliable (Davies and Rockwell 1986; Clark 2003). Variations in 12-gauge projectile quality (Clarkson 1987) and possible habituation of bears to cracker shells (Matt 2010) remain potential limitations of these specific deterrents.

HUMAN DIMENSIONS

Here we define the human dimensions of Polar Bear-human conflicts as the diverse human activities, attitudes, values, knowledge, and institutions influencing the probability and consequences of interactions between Polar Bears and people. Little has been written about human dimensions of Polar Bear-human conflicts. As with other bear species, attractants make Polar Bear-human conflicts more likely to occur. Fleck and Herrero (1988) found that attractants were present in 92% of all incidents and 40% of injurious attacks by Polar Bears. Indigenous peoples' activities in the Arctic and sub-Arctic often involve storing harvested wildlife, which can attract Polar Bears. Consequently, they face qualitatively different interaction risks than other groups (Stenhouse *et al.* 1988; Fleck and Herrero 1988; Dyck 2006). Scientists and tourists in remote areas were involved in the majority of polar bear incidents where human activities were analyzed across groups (Gjertz and Persen 1987; Gjertz *et al.* 1993; Gjertz and Schie 1998; Clark 2003). However, those analyses were of situations where Aboriginal people were absent (Svalbard) or typically engaged in very little harvesting activity (Canadian national parks). As such, direct comparisons of the situations and risks faced by these different groups are not appropriate.

Lethality of people to Polar Bears can be high but is not uniformly so: Polar Bears were killed in only 4% of interactions between people and Polar Bears in Canadian national parks (Clark 2003). Most of those situations involved researchers working from fenced camps with established communication and safety protocols, suggesting that preparation and careful risk mitigation can reduce the likelihood of Polar Bears being killed during conflicts. Indeed, in the recently-established Torngat Mountains National Park in Labrador, Canada, tourism is increasing but to date Polar Bear-human conflicts are few; largely because that park employs effective mitigation strategies which were developed in Wapusk National Park (Lemelin and Maher 2009). Unlike other bear species, the probability of Polar Bear-human interactions in Canadian national parks is independent of the number of visitors (Clark 2003). However, it is not clear whether this relationship will hold for northern parks with more infrastructure development and tourism than was the case at the time of that study. Similarly, increased resource development activity could conceivably increase Polar Bear-human conflicts by simply exposing more people and Polar Bears to each other, but this has not yet been shown. Fortunately, management lessons from national parks suggest that conflicts arising from Polar Bear-human interactions can be minimized, even in areas of high seasonal bear density.

RESEARCH NEEDS

Polar Bear-human conflicts are likely to become more common due to climate change, so specific research is needed to improve conservation efforts and increase human safety. Current knowledge about the basic relationship between reduced sea ice, nutritional stress, and Polar Bear-human conflicts is sufficient to generate hypotheses and predictions that give a general sense of what to expect under future scenarios of regional climatic change. However it is insufficiently precise to guide management actions. This is especially true at the restricted temporal and spatial scales that are most relevant to wildlife management agencies' decision processes. Furthermore, there are important regional differences in environmental conditions, land use patterns, and human activities, suggesting that Polar Bear-human conflicts may vary spatially. Mechanistic understanding of the nature and extent of the effects from reduced access to sea ice on Polar Bears and consequent nutritional stress remains incomplete (Molnár *et al.* 2010, 2011). How that affects the frequency, timing, spatial distribution, or outcomes of Polar Bear-human conflicts is still only known in generalities but if the ice/nutrition relationship is nonlinear, as suggested by Molnár *et al.* (2010), abrupt rises in bear-human conflicts are likely. At a recent workshop, Polar Bear managers identified conservation and public safety contingency planning as priorities (Matt 2010). We endorse that recommendation, particularly because of the potential for nonlinear changes in the ice/nutrition relationship. We further suggest that such planning would be most practical at local and sub-population scales. Developing predictive capability about Polar Bear-human conflict probabilities based on environmental signals or other relevant indicators identified by local and traditional ecological knowledge would be an obvious benefit to those planning processes.

Documenting spatial and temporal trends of these conflicts is critical information for understanding and resolving carnivore-human conflicts (Packer 2005), but knowledge of these trends for Polar Bears remains incomplete. The US Fish and Wildlife Service is establishing a coordinated international database for recording such incidents (Vongraven and Peacock 2011). Along with such developments, reporting and recording practices need to be examined since different groups of people are likely to report at different rates. Recent works that ascribe apparent increases in Polar Bear-human interaction frequency to climate change did not test whether other factors they identified might have confounded those results, such as changes in management practices (Stirling and Parkinson 2006; Towns *et al.* 2009; Peacock *et al.* 2010). Consistency in incident recording practices over time is critical but cannot be assumed in government agencies as both personnel and recording policies change for many reasons (Burrows *et al.* 2000; Boivin and Cordeau 2011). Further, inconsistent terminology for describing incidents hinders comparison and analysis between and even within agencies (Hopkins *et al.* 2010; Vongraven and Peacock 2011).

Deeper insights into the human dimensions of Polar Bear-human conflicts are necessary (Vongraven and Peacock 2011). How northern inhabitants perceive and respond to the risk of Polar Bear-human conflicts or how they are adapting to long-term changes has not been studied, but such knowledge would ultimately allow managers and other communities to respond more effectively. A participatory, community-based research approach (e.g., Wolfe *et al.* 2011) would be the most appropriate model and should focus on: i) interpreting local observations of Polar Bear-human conflicts; ii) documenting perceptions of risk from bears (e.g., Gore *et al.* 2007); iii) determining stakeholder acceptance capacity –a measure of stakeholders' tolerance for Polar Bears (Carpenter *et al.* 2000); iv) evaluating the impact dependency of such tolerances – i.e., how the range of observed and perceived impacts by polar bears on those stakeholders affects their attitudes about management actions (Decker *et al.* 2006); and v) comprehensively understanding the social-ecological context that stakeholders consider relevant to Polar Bear-human conflicts (Clark 2011).

Further research into Polar Bear deterrents is needed too, especially addressing outstanding concerns about Polar Bear habituation to deterrents. Notably, Smith *et al.* (2008) recommended continued research on capsicum spray's efficacy and we concur. Questions remain about the effectiveness of other deterrents, techniques for safely storing food in Polar Bear country, and indeed the social acceptance and utility of different approaches in Arctic indigenous communities (Matt 2010). Better understanding these issues could reduce conflicts and bear mortalities. Appraisal of emergent local strategies for preventing, responding, and adapting to Polar Bear-human conflicts, such as community patrols in Russia, Canada, and Alaska, is also needed (Matt 2010).

Given the prominence of attractants and the apparent insensitivity of interaction rates to regional human densities (as indicated by national park visitation), we hypothesize that unfavorable environmental conditions and resulting nutritional stress on Polar Bears may ultimately be the most important determinant of the frequency of Polar Bear-human conflicts. This hypothesis requires testing, which ought to be feasible in situations where accurate records of Polar Bear-human interactions, a series of estimates or indices of Polar Bear populations, and information on human population and activities are all available over time. Even if such a relationship were established though, such a finding would not detract from the importance of human dimensions in determining the outcomes of Polar Bear-human interactions, or even their likelihood under circumstances that are shaped by proximate human behavior (e.g., where anthropogenic foods remain available to bears).

There is unlikely to be a single solution to Polar Bear-human conflicts given their complexity and contingency. Integrated multidisciplinary research can describe and inform strategies and tactics for both preventing and mitigating Polar Bear-human conflicts. Such responses may be based on scientific understanding or local

and traditional knowledge (or both since these approaches are often complementary), and will have to be applied flexibly across a range of diverse and changing ecological and social situations. Documenting, evaluating, and widespread sharing of reliable knowledge about 'what works' will be critical to ameliorating Polar Bear-human conflicts, and assisting with the species' conservation.

ACKNOWLEDGMENTS

We are grateful for support from the Social Sciences and Humanities Research Council of Canada, PrioNet, the University of Saskatchewan, Wapusk National Park, and the Churchill Northern Studies Centre. We also thank many colleagues and mentors in the field for sharing their hard-earned knowledge with us, including Dennis Andriashek, Jack Batstone, Kevin Burke, Murray Gillespie, Daryll Hedman, Jack Herrero, John Henderson, Kavavow Kiguktak, David Koonelusie, Greg Lundie, Steve Miller, Brendan McEwan, Allan Oman, Malcolm Ramsay, Wayde Roberts, Michael Spence, Morris Spence, and Ian Stirling.

Main Points

• The majority of Polar Bear-human conflicts occur when bears are forced ashore by seasonally melting sea ice.

• Polar Bear-human conflicts are neither new nor common but will likely increase as the warming Arctic climate restricts bears' access to sea ice.

• Sub-adult male Polar Bears are involved in most conflicts, and attractants make Polar Bear-human conflicts more likely to occur.

• Lethality of people to Polar Bears can be high but can be reduced through deliberate, situation-specific practices.

• There is a need to accurately and comprehensively document spatial and temporal trends in Polar Bear-human conflicts, and to understand variability in incident recording.

• Further research is needed on human dimensions of Polar Bear-human conflicts and deterrent effectiveness.

• A community-based research approach is needed to more fully understand what works to prevent and mitigate conflicts.

LITERATURE CITED

AHDR. 2004. Arctic human development report. Stefansson Arctic Institute, Akureyri, Iceland. http://www.svs.is/AHDR/. Accessed June 25, 2012.

Andersen, M., and J. Aars. 2008. Short-term behavioral response of polar bears (*Ursus maritimus*) to snowmobile disturbance. Polar Biology 31: 501-507.

Amstrup, S. C., B. G. Marcot, and D. C. Douglas. 2007. Forecasting the range-wide status of polar bears at selected times in the 21st century. USGS Administrative Report, US Geological Survey, Reston, Virginia, USA. http://www.usgs.gov/newsroom/special/polar_bears/docs/USGS_PolarBear_Amstrup_Forecast_lowres.pdf Accessed June 25, 2012.

Amstrup, S. C., I. Stirling, and J. W. Lentfer. 1986. Past and present status of polar bears in Alaska. Wildlife Society Bulletin 14: 241-254.

Amstrup, S. C., E. T. DeWeaver, D. C. Douglas, B. G. Marcot, G. M. Durner, C. M. Bitz, and D. A. Bailey. 2010. Greenhouse gas mitigation can reduce sea-ice loss and increase polar bear persistence. Nature 468: 955-958.

Atkinson, S., D. Hedman, D. Garshelis, and S. Stapleton. 2012. Western Hudson Bay polar bear survey 2011, final report. Government of Nunavut, Iqaluit, Nunavut, Canada.

Boivin, R., and G. Cordeau. 2011. Measuring the impact of police discretion on official crime statistics: a research note. Police Quarterly 14:186-203.

Burrows, J., R. Tarling, A. Mackie, R. Lewis, and G. Taylor. 2000. Review of police forces' crime recording practices. Home Office Research Study 204. Home Office, London, UK.

Carpenter, L. H., D. J. Decker, and J. F. Lipscomb. 2000. Stakeholder acceptance capacity in wildlife management. Human Dimensions of Wildlife 5: 5-19.

Clark, D. A. 2003. Polar bear-human interactions in Canadian national parks, 1986-2000. Ursus 14: 65-71.

Clark, S. G. 2011. The natural resource policy process: a guide for professionals. Yale University Press, New Haven, Connecticut, USA.

Clarkson, P. 1987. Bear deterrent study, Cape Churchill, Manitoba. 1985. Government of the Northwest Territories, Yellowknife, Northwest Territories, Canada.

Cushing, B. S. 1983. Responses of polar bears to human menstrual odors. International Conference on Bear Research & Management 5: 270-274.

Davies, J.C. and R.F. Rockwell. 1986. An electric fence to deter polar bears. Wildlife Society Bulletin 14: 406-409.

Decker, D. J., D. A. Dobson, and T. L. Brown. 2006. Situation-specific "Impact Dependency" as a determinant of management acceptability: Insights from wolf and grizzly bear management in Alaska. Wildlife Society Bulletin 34: 426-432.

Dowsley, M., and G. W. Wenzel. 2008. "The time of the most polar bears": a co-management conflict in Nunavut. Arctic 61: 177-189.

Dyck, M. 2006. Characteristics of polar bears killed in defense of life and property in Nunavut, Canada, 1970-2000. Ursus 17: 2-62.

Ferguson, S. H., I. Stirling, and P. McLaughlin. 2006. Climate change and ringed seal (Phoca hispida) recruitment in western Hudson Bay. Marine Mammal Science 21: 131-135.

Fleck, S., and S. Herrero. 1988. Polar bear-human conflicts. Contract (no. 502/85/23) report for Parks Canada and Government of Northwest Territories, Canada.

Foote, A. L., N. Krogman, L. Johnston, and D. Clark. 2009. Polar

bears in the media: the ways in which we know the icon. Pages 187-196 in M. Freeman and A.L. Foote, editors. Inuit, Polar bears, and sustainable use. Canadian Circumpolar Institute Press, Edmonton, Alberta, Canada.

Gjertz, I., and E. Persen. 1987. Confrontations between humans and polar bears in Svalbard. Polar Research 5: 253-256.

Gjertz, I., and J. O. Schie. 1998. Human casualties and polar bears killed in Svalbard, 1993-1997. Polar Record 34: 337-340.

Gjertz, I., S. Aarvik, and R. Hindrum. 1993. Polar bears killed in Svalbard 1987-1992. Polar Research 12: 107-109.

Gore, M. L., B. A. Knuth, P. D. Curtis, and J. E. Shanahan. 2007. Factors influencing risk perception associated with human-bear conflict. Human Dimensions of Wildlife 12: 133-136.

Henri, D., H. G. Gilchrist, and E. Peacock. 2010. Understanding and managing wildlife in Hudson Bay under a changing climate: some recent contributions from Inuit and Cree ecological knowledge. Pages 267-289 *in* S.H. Ferguson, L.L. Loseto, and M.L. Mallory, editors. A little less Arctic: Top predators in the world's largest Northern Inland Sea, Hudson Bay. Springer, New York, New York, USA.

Herrero, J., and S. Herrero. 1997. Visitor safety in polar bear viewing activities in the Churchill region of Manitoba, Canada. Bios Environmental Research and Planning Associates Ltd., Calgary Alberta, for Manitoba Natural Resources and Parks Canada.

Herrero, J., and S. Herrero. 1999. Visitors and polar bears in Wapusk National Park: planning for safety. Bios Environmental Research and Planning Associates Ltd., Calgary Alberta, for Parks Canada.

Herrero, S., and S. Fleck. 1990. Injury to people inflicted by black, grizzly or polar bears: recent trends and new insights. International Conference on Bear Research and Management 8: 25-32.

Herrero, S. 2002. Bear attacks: Their causes and avoidance. Second edition. Winchester Press, Piscataway, New Jersey, USA.

Herrero, S., T. Smith, T. D. Debruyn, K. Gunther, and C. A. Matt. 2005. Brown bear habituation to people- safety, risks, and benefits. Wildlife Society Bulletin 33: 362-373.

Honderich, J. E. 1991. Wildlife as a hazardous resource: an analysis of the historical interaction of humans and polar bears in the Canadian Arctic 2,000 BC to AD 1935. M.A. Thesis, Department of Geography, University of Waterloo, Waterloo, Ontario, Canada.

Hopkins, J. B., S. Herrero, R. T. Shideler, K. A. Gunther, C. C. Schwartz, and S. T. Kalinowski. 2010. A proposed lexicon of terms and concepts for human-bear management in North America. Ursus 21:154-168.

Hulme, M. 2009. Why we disagree about climate change. Cambridge University Press, New York, New York, USA.

Kearney, S. 1989. The polar bear alert program at Churchill, Manitoba. Pages 83-92 *in* M. Bromley, editor. Bear-people conflicts: Proceedings of a symposium on management strategies. Northwest Territories Department. of Renewable Resources, Yellowknife, Northwest Territories, Canada.

Lemelin, R. H., and P. Maher. 2009. Nanuk of the Torngats: human-polar bear interactions in the Torngat Mountains National Park, Newfoundland and Labrador, Canada. Human Dimensions of Wildlife 14: 152-155.

Lemelin, R. H., M. Dowsley, B. Walmark, F. Siebel, L. Bird, G. Hunter, T. Myles, M. Mack, M. Gull, M. Kakkekaspan, the Washaho First Nation at Fort Severn, and the Weenusk First Nation at Peawanuck. 2010. Wabusk of the Omushkegouk: Cree-polar bear (*Ursus maritimus*) interactions in northern Ontario. Human Ecology 38: 803-815.

Leonard, R. 1989. Polar bear-human conflict on the national historic park and sites in the Churchill area. Pages 75-82 *in* M. Bromley, editor. 1989. Bear-people conflicts: Proceedings of a symposium on management strategies. Northwest Territories Department of Renewable Resources, Yellowknife, Northwest Territories, Canada.

Lunn, N. J., and I. Stirling. 1985. The significance of supplemental food to polar bears during the ice-free period of Hudson Bay. Canadian Journal of Zoology 63: 2291-2297.

Matt, C. 2010. Third International bear-people conflicts workshop: Polar bear focus day summary. November 18, 2009, Canmore, Red Deer College, Alberta, Canada. http://www.rdscience.ca/bear/bear.html. Accessed February 28, 2012.

Middaugh, J. P. 1987. Human injury from bear attacks in Alaska, 1900-1985. Alaska Medicine 29: 121-126.

Miller, G. D. 1986. Field tests of potential polar bear repellents. International Conference on Bear Research and Management 7: 383-390.

Molnár, P., A. E. Derocher, G. W. Thiemann, and M. A. Lewis. 2010. Predicting survival, reproduction and abundance of polar bears under climate change. Biological Conservation 143: 1612-1622.

Molnár, P. K., A. E. Derocher, T. Klanjscek, and M. A. Lewis. 2011. Predicting climate change impacts on polar bear litter size. Nature Communications 2:186.

Nirlungayuk, G., and D. S. Lee. 2009. A Nunavut Inuit perspective on western Hudson Bay polar bear management and the consequences for conservation hunting. Pages 135-142 *in* M. Freeman and A.L. Foote, editors. Inuit, polar bears, and sustainable use. Canadian Circumpolar Institute Press, Edmonton, Alberta, Canada.

Obbard, M. E., G. W. Thiemann, E. Peacock, and T. DeBruyn, editors. 2010. Polar bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, Copenhagen, Denmark, 29 June-3 July 2009. Gland, Switzerland and Cambridge, UK.

Osvyanikov, N. 1996. Interactions of polar bears with other large mammals, including man. Journal of Wildlife Research 1: 254-259.

Packer, C. 2005. Lion attacks on humans in Tanzania. Nature 436:927-928.

Parkinson, C. 2006. Earth's cryosphere: current state and recent changes. Annual Review of Environment and Resources 31: 33-60.

Peacock, E., A. E. Derocher, N. J. Liunn, and M. E. Obbard. 2010. Polar bear ecology and management in Hudson Bay in the face of climate change Pages 93-115 *in* S.H. Ferguson, L.L. Loseto, and M.L. Mallory, editors. A little less Arctic: Top predators in the world's largest Northern Inland Sea, Hudson Bay. Springer, New York, New York, USA.

Peacock, E., A.E. Derocher, G.W., Thiemann, and I. Stirling. 2011.

Conservation and management of Canada's polar bears (*Ursus maritimus*) in a changing Arctic. Canadian Journal of Zoology 89: 371-385

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

Regehr, E., C. M. Hunter, H. Caswell, S. C. Amstrup, and I. Stirling. 2009. Survival and breeding of polar bears in the south Beaufort Sea in relation to sea ice. Journal of Animal Ecology 79: 117-127.

Smith, T., S. Herrero, T. DeBruyn, and J. Wilder. 2008. Efficacy of bear deterrent spray in Alaska. Journal of Wildlife Management 72: 640-645.

Smith, T., S. Herrero, C. S. Layton, R. S. Larsen, and K. R. Johnson. 2012. Efficacy of firearms for bear deterrence in Alaska. Journal of Wildlife Management 76: 1021-1027.

Stenhouse, G. B., L. J. Lee, and K. G. Poole. 1988. Some characteristics of polar bears killed during conflicts with humans in the Northwest Territories, 1976-86. Arctic 41: 275-278.

Stirling, I. 2011. Polar bears: a natural history of a threatened species. Fitzhenry and Whiteside, Markham, Ontario, Canada.

Stirling, I., and A. E. Derocher. 1993. Possible impacts of climate warming on polar bears. Arctic 46: 240-245.

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

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

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

Stroeve, J. C., M. C. Serreze, M. M. Holland, J. E. Kay, J. Maslanik, and A. P. Barrett. 2012. The Arctic's rapidly shrinking sea ice cover: a research synthesis. Climatic Change 110: 1005-1027.

Towns, L., A. E. Derocher, I. Stirling, N. Lunn, and D. Hedman. 2009. Spatial and temporal patterns of problem polar bears in Churchill, Manitoba. Polar Biology 32:1529-1537.

Towns, L., A. E. Derocher, I. Stirling, and N. Lunn. 2010. Changes in land distribution of polar bears in western Hudson Bay. Arctic 63: 206-212.

Tyrrell, M. 2007. More bears, less bears: Inuit and scientific perceptions of polar bear populations on the west coast of Hudson Bay. Études Inuit Studies 30: 191-208.

Tyrrell, M. 2009. West Hudson Bay polar bears: the Inuit perspective. Pages 95-110 *in* M. Freeman and A.L. Foote, editors. Inuit, polar bears, and sustainable use. Canadian Circumpolar Institute Press, Edmonton, Alberta, Canada.

Vongraven, D., and E. Peacock. 2011. Development of a pan-Arctic monitoring plan for polar bears. CAFF Monitoring Series Report No. 1. CAFF International Secretariat, Akureyri, Iceland.

Watts, P.D., and P.S. Rattson. 1989. Tour operator avoidance of deterrent use and harassment of polar bears. Pages 189-195 *in* M. Bromley, editor. 1989. Bear-people conflicts: Proceedings of a symposium on management strategies. Northwest Territories Dept. of Renewable Resources, Yellowknife, Northwest Territories, Canada.

Wolfe, B. B., M. M. Humphries, M. F. J Pisaric, A. M. Balasubramanian, C. R. Burn, L. Chan, D. Cooley, D. G. Froese, S. Graupe, R. I. Hall, T. Lantz, T. J. Prter, P. Roy-Léveillée, K. W. Turner, S. D. Wesche, and M. Williams. 2011. Environmental change and traditional use of the Old Crow Flats in northern Canada: An IPY opportunity to meet the challenges of the new northern research paradigm. Arctic 64:127-135.

Woolridge, D. R. 1983. Polar bear electronic deterrent and detection systems. International Conference Bear Research and Management 5: 264-269.

Received 5 March 2012 – Accepted 13 August 2012.

ABOUT THE AUTHORS

Douglas A. Clark is the Centennial Chair in Human Dimensions of Environment and Sustainability and an Assistant Professor with the School of Environment and Sustainability at the University of Saskatchewan. He is also an Associate Member of the Johnson-Shoyama Graduate School of Public Policy and the International Centre for Northern Governance and Development, as well as a Research Affiliate with the Northern Rockies Conservation Cooperative in Jackson, Wyoming, USA. Doug worked for 11 years in natural resource conservation with Parks Canada, and was twice awarded that Agency's Award of Excellence for training program design and mountain rescue. He earned a Bachelor Degree in biology from the University of Victoria, a Master's in zoology from the University of Alberta, and a Ph.D. in geography and environmental studies from Wilfrid Laurier University. His research interests include governance and policy processes for wildlife and ecosystem management, solving resource management conflicts, and improving professional practice in natural resource management.

Floris M. van Beest is a Post-doctoral Fellow. His research mostly

deals with the effect of various environmental conditions on the spatial and temporal distribution of wildlife. Specifically, the interactions of factors such as forage variability, climatic stochasticity, population density, and predation risk on scale-dependent habitat selection strategies, movement patterns, and home range size. How individual behavior influences (or is influenced by) population dynamics is a key question in Floris' work. In his research, Floris makes use of spatial and statistical modeling including resource selection functions, cox-proportional hazards survival analyses, and landscape simulation models using GIS.

Ryan Brook is an Assistant Professor in the Indigenous Land Management Institute, Department of Animal and Poultry Science, and the School of Environment and Sustainability at the University of Saskatchewan. His focus is on wildlife ecology and community sustainability issues that intersect with indigenous and rural communities in Canada including caribou health, deer, elk, and carnivores. His research uses local and traditional knowledge with ecological and social research to answer theoretical and applied questions about wildlife movements, disease, and evaluating management options based on a collaborative stakeholder approach. This transdisciplinary work utilizes both ecological and social research.