Barren-Ground Grizzly Bears of the Western Arctic: Potential Influence of Oil and Gas Development and Climate Change

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Abstract

The Arctic is at the forefront of a profound period of industrial and climatic change. Exploration and extraction of hydrocarbon and mineral reserves will result in an increase in the human presence in this once remote landscape. In addition, climate change will likely result in an increase in temperature and precipitation levels and a decrease in seasonality. The Mackenzie Delta, located in Canada's north-western Arctic, is the starting point for the Mackenzie Gas Project pipeline that will transport oil and natural gas to southern markets. The Mackenzie Delta is also the northern edge of the North American barren-ground grizzly bear's range. Having a lower ecological resilience than other large carnivore species and a shorter active period than other North American grizzly bear populations will present a conservation challenge for wildlife managers to monitor and maintain sustainable population levels during this time of change. With the effects of climate warming expected to be severe in the Arctic and the additive stressors of increased anthropogenic disturbance related to development, the future of the grizzly bears that inhabit Canada's Arctic is uncertain.

Here, we outline some of the changes the Mackenzie Delta region may experience over the course of the next century and examine how these changes may affect grizzly bear ecology and population dynamics. We also introduce an assessment of the potential influence of future oil and gas development on grizzly bear habitat ecology in the Mackenzie Delta region. By considering the additive effects of climate change and human disturbance, wildlife managers and co-management boards will be able to design conservation initiatives to maintain sustainable grizzly bear populations in a changing North.

Keywords

Grizzly bear, *Ursus arctos*, oil and gas development, climate change, the Mackenzie Delta, Northwest Territories

Introduction

The Arctic is at the forefront of a profound period of industrial and climatic change (Houghton *et al.* 2001, Imperial Oil Resources Ventures Limited 2004, McDonald 2004). There is increasing pressure on the mineral resources of the North in both mining and hydrocarbon extraction (Hik and Boonstra 2004, McDonald 2004). For the Mackenzie Delta region, located in Canada's Western Arctic, industrial development means an increase in the level of anthropogenic activity related to the future construction of a pipeline and gathering system that will transport oil and natural gas resources to southern markets (Black and Fehr 2002, Imperial Oil Resources Ventures Limited 2004). In addition to oil and gas development, climate change is expected to be severe in the Arctic, and a driving force affecting northern ecosystems (Houghton *et al.* 2001). Higher temperatures and precipitation levels and a positive North-Atlantic Oscillation pattern are expected to influence the phenology or the timing of plant and animal activities (Hurrell 1995, Walther *et al.* 2002). Changes in phenology of interacting species may not occur at the same rate, which could cause the decoupling of ecosystem linkages (Penuelas and Filella 2001). As well, earlier snowmelt and a longer snow- or ice-free period could influence primary productivity levels and forage availability in northern terrestrial ecosystems (Molau 1996, Forchhammer *et al.* 1998). Bioenergetics of species and present-day biogeographical boundaries coupled with changes in forage availability can also be used to predict changes to these boundaries relative to climate change and community composition (Humphries *et al.* 2002, Walther *et al.* 2002). While warmer and wetter conditions may increase pathogen and insect development (Penuelas and Filella 2001, Harvell *et al.* 2002), non-native species across taxonomic groups are expected to move poleward within the limits of their dispersal ability, resource availability and metabolic tolerance (McCarty 2001). We presently lack the information necessary to fully anticipate how northern ecosystems will change with climate warming and how wildlife species, including grizzly bears (*Ursus arctos*), will adapt to the additive effects of anthropogenic disturbance and these ecosystem-level changes.

The relatively low resilience of the grizzly bear compared to other large carnivores (Weaver *et al.* 1996), and the harsh climatic conditions of the Arctic, make these bears especially vulnerable to increased industrial development and environmental change. There is relatively little information available on the barren-ground grizzly bears of the Mackenzie Delta region. To that end, research within the region is presently being conducted to collect the information required to develop the tools necessary for co-management boards and wildlife managers to integrate grizzly bear conservation strategies into land management protocols at the pre-development phase of hydrocarbon extraction and at the early stages of climate change. Here, we discuss the changes that the Mackenzie Delta region may experience over the course of the next century and we introduce a study entitled "*Ecology of grizzly bears in the Mackenzie Delta oil and gas development area*", which is being undertaken by

the Government of Northwest Territories (GNWT) – the Department of Environment and Natural Resources (DENR), and the University of Alberta (UA).

The Mackenzie Delta Region, Western Arctic, Canada

Located in the Northwest Territories of western Canada, the Mackenzie Delta region is in the Inuvialuit Settlement Region (ISR), which covers 906,430 km^2 (DIAND 1984) (Figure 1). The Mackenzie Delta, located at the mouth of the river of the same name, empties into the Beaufort Sea and is the largest Arctic delta in North America (Black and Fehr 2002). Temperatures can range from -57°C - 32°C and the area can remain snow-covered from October to May, with snowfall occurring at any time during the year (Black and Fehr 2002). Within the Mackenzie Delta region, approximately 50% of the area is covered by lakes, rivers, and mud flats; marginal habitat for grizzly bears (Nagy *et al.* 1983). Pingos, which are used by bears for denning, are conspicuous features on the landscape (Shideler and Hechtel 2000). Mountains, flat alluvial plains, and rolling hills with broad habitat types including boreal forest, forest tundra-transition, and tundra characterize this landscape (Nagy *et al.* 1983, Black and Fehr 2002). A growing human population is centered in the villages of Tuktoyaktuk, Paulatuk, and Aklavik, the town of Inuvik, and in an increasing number of camps. In summer, access is limited to plane, helicopter, and boat or barge travel. However, in early spring and winter access to the land is facilitated by snow machine or by the Mackenzie River ice road to Tuktoyaktuk.

Recent changes in the level of human activity began with the construction of Inuvik and the Distant Early Warning (DEW) line that brought a new source of income in the form of government services and projects, as well as geophysical survey work, with the first exploratory test wells being drilled in 1962 (Fast *et al.* 2001). Local aboriginal communities recognized the potential economic opportunities that accompanied industrial development, but were wary of the impact this might have on their natural resource base and their culture (Berger 1977, Fast *et al.* 2001). In response to these concerns, the Department of Indian and Northern Affairs (DIAND) in 1974 initiated an inquiry on the potential for oil and gas extraction activities and pipeline development in the Mackenzie Delta region. The resulting Berger report called for a moratorium on oil and gas development until northern communities were more prepared, and existing land claims were settled (Berger 1977). By 1984, Inuvialuit land claims were settled, the Inuvialuit Final Agreement (IFA) was signed, and the Inuvialuit Settlement Region was created, which gave both surface and sub-surface rights to the Inuvialuit (Fast *et al.* 2001). Onshore oil and gas development in the Mackenzie Delta region has resulted in 21,041 km of seismic activity and the drilling of 119 wells (Holroyd and Retzer 2005). Approximately 210 billion m^3 of proven onshore natural gas reserves have been discovered through drilling activity and sub-surface geology suggests there is an additional 198 billion m^3 of unproven gas reserves (Holroyd and Retzer 2005). Deposits of iron, coal, copper, lead, and zinc are present in the Inuvialuit

Settlement Region but their economic potential remains unknown (Fast *et al.* 2001). The Inuvialuit Final Agreement gave constitutional protection to Aboriginal and treaty rights with the goal "to protect and preserve the arctic wildlife, environment and biological productivity through the application of conservation principles and practices" (DIAND 1984).

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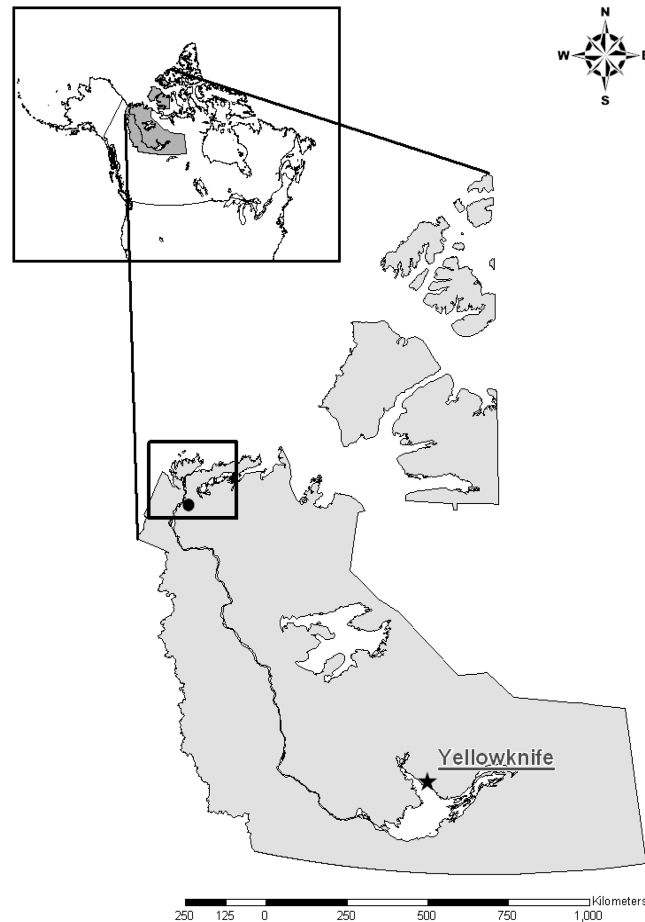

***Figure 1**: Location of the Mackenzie Delta region, Northwest Territories, Canada.*

In Canada, management of non-migratory wildlife is under the direction of provincial and territorial governments (Servheen *et al.* 1999). Grizzly bears in the Inuvialuit Settlement Region are co-managed under the Inuvialuit Final Agreement by the following agencies and land claim organizations (DIAND 1984, Nagy and Branigan 1998): the Government of the

Northwest Territories-Department of Environment and Natural Resources; the Inuvik, Paulatuk, and Tuktoyaktuk Hunters and Trappers Committees; the Inuvialuit Game Council; Wildlife Management Advisory Council; and Heritage Canada/ Parks Canada. The objective is to ensure that grizzly bears and important bear habitat are protected and that harvesting rights are preserved. The Co-Management Plan outlines objectives for management of the grizzly bear population and identifies objectives for managing people (Nagy and Branigan 1998).

Barren-Ground Grizzly Bears of the Western Arctic

Barren-ground grizzly bear population levels in the Northwest Territories are believed to have remained stable since 1991 (COSEWIC 2002). However, northern populations are considered to be vulnerable because of their low population densities and the rapid advance of resource extraction activities (COSEWIC 2002). With little human access to northern landscapes, impacts occur primarily within the vicinity of human settlements and where petroleum exploration and development have had a significant impact on the land (Servheen *et al.* 1999). Grizzly bears in the North have a shorter active period in which to accumulate the energy reserves necessary for successful denning, reproduction and survival (Rogers 1987, Ferguson and McLoughlin 2000). When food resources become scarce, bears increase their search area to find quality foods (Mattson *et al.* 1992). However, increased movement also increases the likelihood of potentially fatal human-bear interactions (Blanchard and Knight 1991). Mattson *et al*. (1992) reported an inverse relationship for the abundance of naturally occurring bear foods and the incidents of human-bear conflict and bear use of areas of human occupation. Once a bear has obtained human food it is more likely to return and become a habituated problem bear. Bears habituated to areas of anthropogenic activity have an increased likelihood of mortality. To maximize energy intake, grizzly bears require secure habitats to forage undisturbed (Eberhardt 1990, Gibeau *et al.* 2001). With increasing levels of development and increasing human access to once remote areas of the Mackenzie Delta region, secure habitats may be reduced (McLoughlin *et al.* 2003).

In the Inuvialuit Settlement Region, the grizzly bear harvest is managed using tags allocated to Grizzly Bear Management Areas, where there is an allowable sustainable harvest of 3% of an area's estimated population of bears greater than 2 years of age (Nagy and Branigan 1998). No more than 33% of the harvested bears can be female. However, there is no current population estimate for grizzly bears in the Inuvialuit Settlement Region and additional mortalities will likely be additive as there is little evidence of compensatory mortality in bears (Miller 1990). Weaver *et al*. (1996) suggested that grizzly bears have a relatively lower ecological resilience than other large carnivores, characterized by low population density, low fecundity, and low dispersal ability through developed habitats. Due to the reduced amount of cover available, grizzly bears inhabiting the tundra are more likely to be displaced by

anthropogenic disturbance than bears in forested habitats (McLellan 1990). Displacement from important habitats can result in increased physiological and energetic costs, reduced net energy intake and reproductive output (Weaver *et al.* 1996, Ferguson and McLoughlin 2000). Lower ecological resilience suggests that the grizzly bears of the Mackenzie Delta region, which live at the species' northern geographical limit, may be especially sensitive to the effects of environmental change (Weaver *et al.* 1996).

Globally, grizzly bears or brown bears in Europe and Asia show high diversity in life-history traits, which may be an adaptation to the great variety of environments they inhabit, from Arctic to desert ecosystems (Pasitschniak-Arts 1993). Two important drivers for differences in life-history traits along species' geographical gradient are available energy and environmental variation (Stevens 1989). Canadian Arctic grizzly bear populations are characterized by lower average population densities, large home range size, a shorter active period, lower adult female body mass, a higher age of first parturition, and more litters (Nagy and Haroldson 1990, Ferguson and McLoughlin 2000). Ferguson and McLoughlin (2000) suggest that at high latitudes (> 65°N) with extreme conditions, low primary productivity, high seasonality, and less climatic predictability, grizzly bears may have adopted a risk-spreading strategy that distributes the risk of reproductive failure (Ferguson and Messier 1996). In extreme environments where resource availability is seasonally and annually stochastic, bet-hedging theory predicts that grizzly bears should reduce reproductive effort in favour of longer life expectancy so that they have more opportunity to reproduce over the course of their lifetime (Murphy 1968, Stearns 1976, Philippi and Seger 1989). Bet-hedging allows reproductively active female grizzly bears to sample a greater variety of environmental conditions and increase the number of offspring born into beneficial conditions (Yoshimura and Jansen 1996, Philippi and Seger 1989, Ferguson and McLoughlin 2000). Although highly adaptable to a diversity of environmental conditions, low ecological resilience and the projected rapidity of climate change may be too great for the species to adapt (McCarty 2001, Stockwell *et al.* 2003).

Potential Impacts of Oil and Gas Development on Barren-Ground Grizzly Bears

Pipeline-related environmental impact assessment results are under review and plans are already being considered for further expansion subsequent to the establishment of the initial pipeline infrastructure (Cizek and Montgomery 2005). In Prudhoe Bay, where oil development began in the 1970s, Truett and Johnson (2000) reported on the variable responses of wildlife populations to anthropogenic-related changes to the landscape. The Prudhoe Bay study can provide a starting point for understanding the anticipated influences that future oil- and gas-related development could have on northern wildlife species, including the barren-ground grizzly bear that inhabit the Mackenzie Delta oil and gas development area.

Habitat disturbance or loss from oil and gas development in the Mackenzie Delta region will result from increased seismic activity and the construction of trunk and feeder pipelines, access roads and airfields, well sites and borrow pits, camps, stockpiles and staging areas, and compression facilities (Cizek and Montgomery 2005, Holroyd and Retzer 2005). Following habitat disturbance from industrial development, many plants have the ability to recover and re-colonize these areas (McKendrick 2000). How rapidly a disturbed site recovers depends on how fast seeds and/or vegetable propagules become available, as well as the characteristics of the substrate and the level of moisture. Moist and intact soil will recover faster and dryer soil will recover slower. Wildlife response to a disturbed site is variable (McKendrick 2000). The use of a previously disturbed site by wildlife is influenced by forage availability and vigor, the acceleration of spring snowmelt, and delayed autumn senescence (McKendrick 2000). In the Prudhoe Bay oil field, McKendrick (2000) found that disturbed sites on the tundra produced plants that were more robust and succulent than plants on adjacent undisturbed sites. In addition, these plants usually senesced later in the growing season providing additional forage availability. These sites attracted grazers like caribou (*Rangifer tarandus*), Arctic ground squirrels (*Spermophilus parryii*), and grizzly bears that accelerated plant re-colonization and mineral cycling through feces and urine. Although animals generally avoided areas with dense clusters of infrastructure they did not completely avoid disturbed sites suggesting that these areas provided access to otherwise rare resources and foraging opportunities (McKendrick 2000).

During pipeline development, human activity on the landscape peaks during the construction phase and is concentrated at infrastructures (Truett and Johnson 2000). Following the construction phase, human activity may diminish, but the volume of aircraft overflights escalates with the increase in industry-related activity (Truett and Johnson 2000). Once abandoned, drill pads and airfields provide landing areas for small aircraft, which facilitates increased access for recreational sport hunters and guiding outfitter services (Truett and Johnson 2000). A growing human population in the Mackenzie Delta region and increased access to more remote areas of the tundra and along waterways may increase further, and improper disposal of refuse can become an attractant leading to more incidences of human-grizzly bear conflict, habituation, and mortality (Bromley 1985, Follmann and Hechtel 1990).

Long term population viability of grizzly bears requires maintenance of extensive habitat with a variety of landforms and vegetation types with different phenologies to provide secure cover and adequate high quality foods (Craighead *et al.* 1995, Weaver *et al.* 1996). Population size and growth rate are a function of both the quality and availability of habitats, which are affected by both natural and anthropogenic factors (Pulliam and Danielson 1991). When resource-extraction and recreational activities increase in once remote areas, grizzly bear habitats and populations are often compromised (Weaver *et al.* 1996). Doak (1995) suggested that in multi-use landscapes source (good)

habitats can become sink (bad) habitats through habitat destruction and the less quantifiable effects of habitat degradation. In sink habitats, mortality exceeds recruitment and animals should learn to avoid these areas, assuming that animals are able to identify these habitats as sinks (Pulliam and Danielson 1991). Grizzly bears may be forced to use sink habitats to meet resource needs because of limited resource availability and distribution as well as social structure and the avoidance of more dominant bears (Mattson *et al.* 1987, Wielgus *et al.* 2002). However, the use of these marginalized habitats, associated with human activities, may also increase the risk of habituation and mortality (Mattson *et al.* 1992).

Climate Change and Northern Ecosystems

The Arctic is one of the coldest and least productive environments in the world, and is presently undergoing a major period of warming that is greater than any other in the last 1000 years (Houghton *et al.* 2001, Walther *et al.* 2002). The Earth's mean temperature has increased by 0.6°C in the past 100 years (Hassol 2004). Climate change models predict that average temperatures in North America will increase 6°C - 8°C during the next century (Johns *et al.* 1997, Humphries *et al.* 2002). In the western Arctic, some regions have already experienced a 2°C - 4°C increase in the last 50 years (Hassol 2004). Mean annual sea level pressure is decreasing (Walsh *et al.* 1996), the Artic Oscillation pattern has changed (Thompson and Wallace 1998), sea-ice coverage is decreasing (Serreze *et al.* 2003), snow accumulation has changed, permafrost temperatures have increased, and tundra areas are receding with the advancement of shrubs and changes to the tree line (Sturm *et al.* 2001, Wang and Overland 2004). Our ability to predict how well northern species will be able to adapt to climate change is limited. Although, much of the Arctic has experienced climatic fluctuations in the past and many species have the genetic variability to quickly adapt to climate change (Berteaux *et al.* 2004), intense selective pressure generated by harsh conditions may reduce the ability of some species to change (Post and Stenseth 1999). How climate change is affecting grizzly bears and how the bears are adapting is unknown.

Throughout northern Canada, increasing temperatures and precipitation levels, and a positive North Atlantic Oscillation pattern are producing warmer, wetter winters with earlier snowmelt, spring onset, leaf unfurling, and flowering (Hurrell 1995, Beaubien and Freeland 2000). Increasing temperature and precipitation have direct and indirect impacts on species and ecosystems (Easterling *et al.* 1997, Hassol 2004). The phenology of plant and animal activities is changing with the earlier end of winter and start of spring (McCarty 2001). Beaubien and Freeland (2000) documented a 26-day advance in spring flowering of aspen polar (*Populus tremuloides*) in north-western Canada during the last century. A decadal trend in earlier breeding and egg-laying of birds and amphibians, and the earlier appearance of butterflies has been observed and attributed to the advanced growing season and the increase in forage availability (Beebee 1995, Crick *et al.* 1997,

Forchhammer *et al.* 1998, Roy and Sparks 2000). Macinnes *et al.* (1990) reported that breeding in snow geese (*Chen caerulescens*) and Canada geese (*Branta canadensis*) had advanced by 30 days between 1951 and 1986.

For bears, denning and a state of winter torpor is the physiological adaptation during periods of food scarcity and energy constraints (Watts and Jonkel 1988). Denning allows bears to escape the severity of winter storms, maintain homeothermy, evade predators, and allows females refuge where they can safely have their cubs. Early spring and snowmelt may reduce denning time, increase energy expenditure, and expose cubs to predation and infanticide (Dahle and Swenson 2003). The level of insect predation or harassment is also expected to increase with climate warming with faster development from the larval to the adult stage (Penuelas and Filella 2001). The indirect effects of insect harassment of animals include negative energy balance through avoidance behaviour, loss of blood, and lowered body condition (Grayson and Delpech 2005).

With changing phenologies, climate change can produce asynchrony of species interactions at the same or adjacent trophic levels (Walther *et al.* 2002, Penuelas and Filella 2001). Some species may have a better ability to respond to change by altering life-history events and the rate of change between groups may be different (Forchhammer *et al.* 1998, Ahas *et al.* 2002). For instance, global climate pattern shifts are influencing migratory birds (Penuelas and Filella 2001). When the environmental cues to begin migration are not synchronous with the conditions in the breeding area, birds may arrive at an inappropriate time to exploit resources and increase interspecific competition for limited resources. Climate warming may initiate a decoupling of species interactions between plants and pollinators, and animals and their food sources (Penuelas and Filella 2001). Species with long generation times like the grizzly bear, may be slower to change the timing of life-history events (Gomulkiewicz and Holt 1995). The loss of synchrony with other important ecological factors, such as the appearance of specific foods at critical times, could be detrimental to population viability (McCarty 2001, Stockwell *et al.* 2003)

The timing and duration of the growing season are sensitive to changes in snow accumulation and persistence and are important factors limiting productivity and nutritional value of northern plants and the foraging ecology, reproduction and population growth or herbivores (Post and Stenseth 1999). Grizzly bears in the North have a shorter active season and reduced availability of resources in which to accumulate the energy necessary for successful denning and reproduction (Ferguson and McLoughlin 2000). Early springs and an earlier onset and rapid progression of plant phenology may lengthen the growing season and increase primary productivity (Post *et al.* 1997). A later autumnal trend is less evident but may also be contributing to a longer growing season (Walther *et al.* 2002). For instance, different proportions of bird species have advanced, delayed, or maintained autumn migration dates, and patterns of leaf senescence are variable (Gatter 1992, Menzel *et al.* 2001). Further, the longer growing season correlates with an observed increase in the amplitude of

the annual CO_2 cycle and satellite data of green biomass over the past 50 years (Keeling *et al.* 1996, Myneni *et al.* 1997). A longer growing season can increase the number of flowers, the number and size of seeds, the survival of seedlings, and the overall primary productivity, increasing the forage availability and duration of herbaceous food sources for grizzly bears (Schmitt 1983, Post and Stenseth 1999). However, early leaf unfolding may also increase exposure to episodes of late frost, resulting in seed production loss, and reduced reproductive potential (Beaubien and Freeland 2000, Walther *et al.* 2002).

Other important food sources for northern bears are moose (*Alces alces*), reindeer and barren-ground caribou, and ground squirrels (Nagy *et al.* 1983, Gau *et al.* 2002). Changes in climate influence the abundance of some prey species. For example, some Northern European ungulate populations have declined with warmer winters (Post and Stenseth 1999). Populations inhabiting interior mainland regions experienced greater snow accumulation, which resulted in increased energy expenditure, low body mass, and increased vulnerability to predation. For bears, predation and carrion from the reduced body condition of ungulate species and overwinter mortality could provide an important food source following den emergence (Mattson 1997). Coastal areas experienced less snow accumulation during warm winters, which resulted in increased ungulate survival, low body mass, and increased competition for resources (Post and Stenseth 1999). Grizzly bears inhabiting coastal regions may be able to exploit the reduced condition of these ungulate populations. For northern bear populations, ground squirrels are an important source of food during the hyperphagic period prior to denning (Nagy *et al.* 1983). Although, the longer growing season may also increase forage availability of ground squirrels, changing habitat conditions resulting from advances in treeline and shrub abundance suggest variable impacts on population dynamics surrounding the stability of this food source for grizzly bears (Hubbs and Boonstra 1998, Sturm *et al.* 2001).

Climate change may also result in range expansion and community shifts, with some population numbers increasing and others decreasing (McCarty 2001, Walther *et al.* 2002). Geographical range expansion has been documented across taxonomic groups of plants and animals (Walther *et al.* 2002). Environmental conditions and metabolic tolerance are important determinants of the biogeographical range of a species (Andrewartha and Birch 1954, Root *et al.* 2003). An examination of energy constraints and negative energy balance that characterise a particular species will dictate what environments the population may and may not occupy or move to in response to climate change (Humphries *et al.* 2002, Hansell *et al.* 1998). During the past 50 years shrub and tree species have increased in their abundance and distribution in traditionally tundra habitats (Sturm *et al.* 2001). However, the poleward advance of tree and shrub species may be hindered by early leaf and flowering exposure, resulting from early spring onset, to episodes of late frost that reduce seed productivity (Beaubien and Freeland 2000, Harvell *et al.* 2002). The bioenergetics of a species, resource availability and the present-day

boundaries can be used to predict the sensitivity of these boundaries to climate changes. For instance, the appearance of grizzly bears on Victoria Island and Melville Island has recently been documented (Wolkow 2005). However, the distribution of ground squirrels, a staple food source for northern bear populations, does not extend to these Arctic islands and more research is needed to determine if the bears will be able to meet the energy requirements to sustain a resident population (Banfield 1974, Nagy *et al.* 1983). In addition to these examples of range expansion, the invasion of unwanted infectious disease pathogens may also occur (Harvell *et al.* 2002). Increasing annual temperatures has resulted in the expansion of mosquito, tick, and midge vector-borne diseases (Harvell *et al.* 2002). With climate warming most host-parasite interactions are predicted to become more frequent and severe, which could result in a loss of biodiversity through rapid population decline and species extinctions (Harvell *et al.* 2002).

The current global patterns of energy availability, productivity, biodiversity, and species richness suggest that the change in temperature may increase species diversity with new species emerging in greater or equal abundance compared to the number of current species that may disappear (Currie 1991, Gaston 2000, Humphries *et al.* 2004). The processes of speciation, adaptive radiation, differential movement, and poleward range expansion of temperate zone species will be the mechanisms of change for both plant and animal populations (Root *et al.* 2003, Humphries *et al.* 2004). A change in community composition may occur as non-native species invade non-traditional areas and add new elements to the community and increase species richness (Walther *et al.* 2002). Lower latitude species may be able to move more easily than higher latitude species and the variability in rates of range shift will increase the species richness of the community as some species are lost and previously rare species increase (Walther *et al.* 2002). Recent reports have documented the northern advancement of mammals including red fox (*Vulpes vulpes*) moving into arctic fox (*Alopex lagopus*) ranges (Hersteinsson and Macdonald 1992). With tree line advance, black bears (*Ursus americanus*) that require forested habitats for predator avoidance may expand into once tundra areas and compete with grizzly bears for limited resources (Aune 1994).

Like other northern species, the barren-ground grizzly bear of the Mackenzie Delta region has adapted to a harsh and unpredictable environment. In past episodes of rapid climate change, wildlife species have responded by moving to metabolically tolerable areas, changing the timing of life-history events, or changing their morphology (Root *et al.* 2003). With the ability to tolerate a variety of environmental conditions, the grizzly bear has adapted to the harsh conditions of the Arctic (Pasitschniak-Arts 1993). However, when we consider the effects of climate change plus other potential stressors such as human encroachment, habitat fragmentation and loss, it is conceivable that the ability of grizzly bears to adapt quickly enough or to move to more favourable areas may be limited (McCarty 2001). These landscape level changes present

challenges for wildlife managers and land-use planners to maintain habitat connectivity and community composition (Hansell *et al.* 1998, Root *et al.* 2003).

Increasing our Understanding

To anticipate the influence of environmental changes on grizzly bears in the Mackenzie Delta region, a study entitled "*Ecology of grizzly bears in the Mackenzie Delta oil and gas development area*" was initiated in 2003 by the Government of the Northwest Territories-Department of Environment and Natural Resources, and the University of Alberta. The primary goals of this research are to collect baseline ecological information, to describe seasonal home range sizes and distribution, to examine fine-scale movement patterns of grizzly bears and to identify important habitats. The results of this study will provide tools required to assess the potential influence of hydrocarbon-extraction activities and increased anthropogenic disturbance on grizzly bears and assist co-management boards in developing protocols for improving grizzly bear conservation under changing environmental conditions.

To date 35 grizzly bears have been fitted with GPS collars that record location information 6 times daily, at 4-hour intervals, over a 24 hour period at a finer scale than has ever been documented for this population. We anticipate that 53 to 63 bear-years of information will be available for analysis. To augment our understanding of the ecology of this north-coastal population, the carbon and nitrogen stable isotopes in hair and claw samples are being analysed to determine the proportional contribution of marine and terrestrial protein and vegetation to their diet, seasonal changes in diet, and north-coastal grizzly bear trophic position (Jacoby *et al.* 1999, Hobson *et al.* 2000).

We are also developing Resource Selection Function (RSF) models to quantify resource selection and assess the potential influence of oil and gas development on grizzly bears in the Mackenzie Delta (Manly *et al.* 1993). RSF models are proportional to the probability of a resource being used by an organism, and assumes animals should avoid areas that are detrimental and favour habitats that are beneficial to their fitness. RSF models are being developed to identify seasonally important habitat resources at the regional and home range scale. These models will be combined with GIS mapping techniques to produce maps delineating the probability of a grizzly bear using habitats across the Mackenzie Delta development area , which represents a powerful management and conservation tool (Boyce and McDonald 1999, Boyce *et al.* 2002, Nielsen *et al.* 2003). A factorial-simulation approach, where different development scenarios can be investigated as they emerge, will be used to provide an index of potential responses to pipeline development. An initial step is the development of a vegetation classification model for the region. In July 2003 and 2005, we conducted air calls of training sites to build the vegetation classification model, which is scheduled for completion in autumn 2005.

Conclusion

The face of the Western Arctic is changing, and over the course of the next century, the magnitude of this change will be unprecedented. Change will come from increased mineral and hydrocarbon exploration and extraction and associated anthropogenic activities, and from warming temperature and changing precipitation levels resulting from climate change (Watson *et al.* 1997, Hassol 2004). The construction of a pipeline to transport oil and natural gas from the north to southern markets and the associated infrastructure will mean an increased anthropogenic presence in once remote landscapes of the Mackenzie Delta region (Truett and Johnson 2000, Cizek and Montgomery 2005). The response of grizzly bears to climate change has not been thoroughly investigated. Although a causal link between climate change and the decline or extinction of species is not possible, in multi-use northern landscapes climate change must be considered along with the additive influence of other stressors such as human encroachment, habitat degradation and fragmentation (McCarty 2001). With greater initiative and foresight in the pre-planning stages of development, grizzly bear extirpations and population declines that have been observed in other regions can be avoided (Mattson and Reid 1991, Mace and Waller 1998, McLellan *et al.* 1999, Mattson and Merrill 2002). With the additive influence of development and climate change expected to culminate over the next century, more research is needed to provide the information necessary to implement conservation initiatives now, in order to mitigate these effects and maintain sustainable grizzly bear populations in today's changing North.

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