The Effects Of Ecotourism On Polar Bear Behavior

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THE EFFECTS OF ECOTOURISM ON POLAR BEAR BEHAVIOR

by

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ABSTRACT

Polar bears spend the majority of their lives on the sea ice, where they gain access to seals and mates. In western Hudson Bay, the sea ice melts for three to four months in the summer, and polar bears there are forced onto land. These bears live on their fat reserves for the duration of the iceless period, until temperatures get colder in the fall and freeze up begins. The aggregation of polar bears near Churchill, Manitoba during the ice free period has led to a thriving tourist industry, with a large influx of tourists visiting Churchill in the fall in a six to eight week period, yet little is known about the impacts of this industry on the biology of the bears. This study investigated the effect of tourist vehicles and human presence on the behavior of polar bears over the fall of 2003 and 2004. Overall time budgets were estimated for bears, and the behavior of males and females was compared. Females spent significantly less time lying and more time in locomotion than males. Time budgets were also estimated for bears in the presence and absence of tourist vehicles. Bears spent less time lying and more time in a sit/stand position in the presence of vehicles. Air temperature had no significant effect on the time budgets of polar bears. Tundra vehicle approaches were manipulated to determine effects on polar bear behavior, and to investigate any variables that significantly affected response, including habituation. A response was defined as any sudden whole body movement or change in position or behavior at the time of approach. A total of 25% of all bears responded to the experimental vehicle approach. For bears that responded to approach, the average distance at response was 43 m. The average speed of the vehicle was 0.66 ± 0.02 m/s (range 0.23 to 1.15 m/s). Approach variables that significantly influenced the likelihood of response of a bear to an approaching vehicle included angle of approach and vehicle speed. Direct approaches, in which the bear was in the path of the moving vehicle, had a higher probability of eliciting a response than indirect approaches, in which the vehicle stayed to one side of the bear at all times. Higher speeds of the vehicle increased the probability of a response by a bear. Behaviors of the bear that significantly predicted a response were shifting of the body and smacking of the lips. A playback study was conducted to determine the effects of human induced sound on polar bears. There was no significant effect of human sound on polar bears. Results presented here provide the first experimental evidence of variables in the tourist industry that affect polar bear behavior, and the first evidence of behavioral cues predicting a response to vehicle approach.

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INTRODUCTION

‘Ecotourism’ is nature-based tourism, differing from other types of tourism by involving education and conservation. Ecotourism operations differ from other wildlife recreation operations because they promote management in order for the wildlife to remain ecologically sustainable. The term ecotourism implies little impact, but the reality of whether or not any tourism has long-term impacts on wildlife requires investigation (Szaniszlo 2001). In order for responsible management practices to be developed, rigorous scientific data on potential impacts of tourism on wildlife is required.

Human impacts on wildlife in a tourism arena can manifest themselves in changes in behavior (Duchensne et al. 2000; Kinnaird & O’Brien 1996; Acevedo 1991). All human-caused changes in behavior can be potentially harmful to wildlife, but behavioral changes that lead to long-term effects on survival and reproductive success can be critical for individuals. Changes in time budgets can occur, as well as habituation (Olson et al. 1997; Fowler 1999). Habituation can be defined as the acceptance by wild animals of a human observer as a neutral element in their environment. Current research into habituation and human disturbances due to tourism has focused mainly on prey species. Negative effects of tourism on wildlife were reported most commonly in a review conducted on wildlife tourism (Boyle & Samson 1985). Approximately half of the published data in the literature involved avian species, with little data available on the effect of tourism on other taxa (Green & Higginbottom 2000). Specifically, there seems to be a lack of research on the effects of ecotourism on top predators, although tourists tend to seek out these large animals.

Densities of polar bears (*Ursus maritimus*) in the Hudson Bay area have been referred to as one of the most concentrated along any shore (Latour 1981), with the western Hudson Bay population estimated at around 1200 bears (Lunn et al. 1997). During the summer and fall months when there is no sea ice, bears are forced onto land (Stirling et al. 1977), living on their fat reserves due to lack of access to seals, which is their primary food source (Stirling & Archibald 1977). This waiting period is approximately four months, usually from July to November when the pack ice re-forms (Stirling et al. 1977). During this ice-free period, polar bears aggregate along the coast (Derocher & Stirling 1990). This aggregation has resulted in a thriving ecotourism industry in Churchill, Manitoba, with an influx of tourists visiting town in the fall in an eight-week period. Tourists have several ways of viewing free-ranging polar bears, including day trips in vehicles modified to travel on the tundra, overnight stays in seasonal lodges that are located on the tundra, as well as helicopters that provide an aerial view of the arctic landscape and the bears. The vehicles are large, with the bottom of the viewing windows reaching approximately 3.5 meters off of the ground, and the lodges are modifications of these vehicles, with seven vehicles linked together for a total length of approximately 60 meters.

Reports on the effects of ecotourism have varied, with some stating that there seems to be a low impact or short-term impact on species (Duchesne et al. 2000; Henry & Hammill 2001; Kovacs & Innes 1990). Factors that may affect wildlife vary between individual viewing arrangements, but some remain consistent. Distance between tourists and individual animals is a factor that has been found to be significant across a wide variety of taxa. Cassini (2000) found that South American fur seals showed strong behavioral responses when tourists crossed a threshold of 10 m. Research on buffer-zone distances for a variety of water birds from boats and personal watercrafts recommended different distances for individual groups as responses varied

(Rodgers et al. 2002). Coburn-Isaacs (2000) reported that, in Canada, polar bears are allegedly harassed by tourists approaching too closely, but this statement remains unsupported. Dyck & Baydack (2004) reported tourist vehicles affecting polar bear behavior, but recommended further research to substantiate this conclusion.

Human-induced noises may have a negative impact on wildlife, possibly affecting communication between conspecifics or eliciting physiological signs of stress (Green & Higginbottom 2000). Tourist behavior significantly affected the behavior of South American fur seals, with responses by seals increasing with intensity of tourist behavior (Cassini 2000). Kinnaird & O'Brien (1996) reported a negative effect of loud and aggressive behavior of tourists on primates, with monkeys fleeing from loud parties pursuing the animals. Windows on the tundra vehicles can be lowered, and sound can travel to nearby bears, exposing the bears to sounds within the vehicles.

Habituation of polar bears to humans could have serious repercussions. If bears become used to human-induced noises and voices, and the sight of people, bears may be more likely to stay in areas of human habitation, possibly evoking more human-bear confrontations. Herrero & Herrero (1997) reported that polar bears near Churchill have become habituated and that occasional drinking of kitchen drainage water in tundra camps has contributed to the food conditioning of some bears, but this statement remains unsupported. Watts & Ratson (1989) also suggested bears were becoming habituated to tourist vehicles including increased approaches of vehicles over time.

Bears are potentially at their lowest body condition at the time of year when tourists are present, as they have primarily been using fat storage to survive (Stirling 1998). Possible effects on the behavior, activity and energy expenditure of the bears resulting from tourism could impact the survival of an individual. Any wildlife fleeing from observers could reduce survival if it occurs at a critical time for the species or a critical location (Green & Higginbottom 2000). Polar bears are inefficient walkers, requiring high-energy output to initiate walking (Best et al. 1981; Hurst et al. 1982b;Watts et al. 1991). Polar bears could potentially flee from ground tourist vehicles. Human-induced locomotion could have a high energetic cost for the individual polar bear (Watts et al. 1991), possibly using up much-needed fat storage at a time of year when preserving those reserves may be critical.

Age, size and body condition could possibly affect the probability of response to tourists for bears. Beale and Monaghan (2004) found that turnstones, *Arenaria interpres*, with lower body condition showed the least behavioral response to human disturbance, while individuals with artificially enhanced condition showed greater responsiveness. Thus, bears with low fat reserves may not respond to vehicles regardless of the intensity of the disturbance. Age may be a significant factor to investigate, as polar bear subadults may be subject to elevated metabolic rates (Watts et al. 1991), resulting in a potentially higher cost of human induced locomotion.

In this study I investigated the effects of ecotourism on the behavior of polar bears, including the effects of tourist vehicles/tourist behavior and tourist camps. I investigated time budgets of bears in the presence and absence of tourist vehicles, expecting to see a change in behavior. I examined the effect of temperature on behavior, anticipating that there would be less activity in warmer temperatures. I explored the effect of vehicle approaches using experimental procedures, predicting a higher proportion of bears would respond to direct approaches than indirect, and that bears would become habituated to vehicle approach over a short period of time. I looked at subtle behaviors of polar bears during the vehicle approach, expecting that there would be significant behavioral cues to predict a response to vehicles by an individual. I investigated the effect of size and body condition of the proportion of responses to vehicles, anticipating that smaller (younger) bears would have a higher proportion of responses, and that bears in below average body condition would have a lower proportion of responses. I predicted that bears in lower body condition would have a significantly smaller average distance at response than bears in good condition. I investigated the effect of human sound on polar bears, predicting that bears would respond to loud noises, but would habituate over a short time to the human induced sounds.

METHODS

Study Site

Data were collected near Churchill, Manitoba, Canada (58°45'N, 94°00'W). Gordon Point, located approximately 30 km east of Churchill on the coast of Hudson Bay, has been used for wildlife viewing since 1979, when the first vehicles started taking passengers to view polar bears in the wild. The tourist season at Gordon Point typically begins early in October, when tourist vehicles use old military roads and trails in this area for viewing wildlife. There are a total of 18 permitted tourist vehicles every year. The area that tourist vehicles travel in is approximately 7.5km^2, whereas the coastline used by this population in the fall is approximately 250 km in length, from the town of Churchill east to Cape Churchill, and south to Nelson River (Stirling et al. 1977). Thus the majority of the coastline is vehicle-free, and bears can leave the tourist area at any time. The tourist vehicles, two wooden observation towers, and two temporary tourist hotels are the major man-made structures in this area. The temporary hotels serve meals to guests staying on board.

Polar bears were also observed at Cape Churchill, approximately 50 km east of Churchill along the coast. Cape Churchill remains tourist-free for the beginning of the tourist season, and only after the ground is frozen in mid-November do tourist vehicles and one camp move out to that location. This area is thought to be a vantage point to wait for ice formation in the fall, thus late in the season before ice formation there is an aggregation of bears for viewing.

Bear Identification

Individual bears were identified and distinguished from other bears by recording facial images using a Nikon D100 with a zoom lens. Photo-identification images concentrated on the muzzle of each side of the bear, as well as any visible natural markings such as scars. In addition to digital images, a sketch of the face was drawn as a reference guide to identify bears in the field, and other characteristics were recorded such as body condition and body scars.

Bear Size and Body Condition

Photogrammetric techniques were used to determine bear size and bear condition. Invasive methods of obtaining body size of animals have been used historically, including immobilization coupled with physical measurements (Stirling et al. 1977; Derocher & Stirling 1995; Durner & Amstrup 1996). Previous indices developed for body condition also involve invasive techniques, and in some cases require the destruction of animals for the building of the models (Cattet et. al. 2002).

I used a Nikon D100 with a 70-300mm lens to take body images of each bear, with the lens extension at 70mm or 300mm. The distance from the camera to the bear was measured with a laser rangefinder. Side profiles, consisting of a bear standing perpendicular to the camera with the bottom of the feet visible, and rump images were recorded. Using Adobe Photoshop 7.0, measurements (in pixels) of shoulder height, length from shoulder to tail, belly height, rump height and width were taken of each image. Bear size (in meters) was then determined for each bear using a pre-determined calibration equation relating distance to size. Size differs for bears of different ages (Stirling et al. 1977), thus size was the only non-invasive method of investigating potential effects on different age categories of polar bears. A body condition index was developed for each bear using a shoulder height/belly height ratio (Packer & West 2002).

Behavioral Data Collection

During the tourist season, from mid-October to mid-November, observations were made from tundra vehicles. Tundra vehicles typically travel in the tourist area between 9am and 4pm, although occasionally night tours take place. Sampling of bear behavior was also conducted from the temporary tourist camp for daylight hours (8am to 6pm), both in the presence and absence of vehicles. The behaviors of all bears in the vicinity were recorded every 30 minutes using scan sampling (Altmann 1974). Time budgets estimated from these data were used to determine any change in bear behavior in the presence/absence of tourist vehicles. Behaviors were categorized into lying, sitting or standing, locomotion (walking and running) and play (interaction between 2 or more bears involving body contact). Locations of each bear (distance and angle) relative to my location were taken using a laser rangefinder and compass, and my location was recorded using a Global Positioning System (UTM coordinates). These data were used to determine the effects of conspecifics (within 100 m) on the behavior of polar bears. All-occurrence sampling (Altmann 1974) was used to record apparent responses to either vehicles or human sound. I recorded every time a bear responded to a vehicle approach, as well as every time a bear responded to human sound, for any observed vehicle. Response to vehicles was recorded only if a moving vehicle was within 100m of the bear, and the bear walked or ran away from the approaching vehicle. Response to human sound, also called human induced relocation

(Watts & Ratson 1989), was recorded only if an audible noise preceded a bear walking or running away from a tourist vehicle.

Temperature Effects

For every day of observation, air temperature was recorded every half hour on a Hobo data logger. Using these data I investigated any differences in behavior or activity levels due to temperature.

Approach and Sound Experiments

I conducted a series of experiments to determine the effects of vehicle approach and human sound on bears. Three different types of vehicle approach were made toward a bear: (1) direct, (2) indirect, and (3) indirect with sound. Direct approaches by tourist vehicles are not as common as indirect, but occur in situations where the bear is positioned in the vehicle path. An indirect approach, where the vehicle approaches the bear indirectly (the bear is kept to one side of the vehicle at all times), is more commonly used by tour operators. The type of approach was usually dictated by the bear's position.

In the experiment, a bear in a stationary position (lying, sitting or standing) was approached by the vehicle. Once the approach began, the vehicle continued at a constant speed without stopping and the bear behavior was taped with a Sony digital camcorder. The approach experiment terminated when the bear responded or when we were no closer than 17m, the closest distance recorded by the laser rangefinder. A response was defined as any sudden movement or change in whole body position or behavior at the time of approach (i.e. from lying down to standing, walk away, or run away). For both the approach and sound experiments I recorded bear identity, sex, angle of approach, minimum number of days each approached bear was in the tourist area, approach number, number of conspecifics and number of vehicles within 100m of the experimental bear, start distance of the vehicle to the bear, end distance of the vehicle to the bear and distance from the vehicle to the tourist lodge. Using the length of time for the approach and the distance covered, I calculated the average speed of the vehicle. Approach trials were repeated for the same individual to determine if bears habituate to the approach of a vehicle.

Indirect with sound was only performed if the bear did not respond to the indirect approach. All sound experiments were performed within 35m of a bear. The indirect approach with sound experiments were designed to determine the effects of human-induced noise on the behavior of polar bears. Prior to the onset of the sound experiments, I rode in vehicles with tourists traveling on the tundra for the first time. I measured noise levels produced by people at the first close encounter with a bear (using a decibel meter), and at several other points during the day, to determine the appropriate level of sound to use during the sound experiments. In the experiment, the bear was approached at an indirect angle, so that the vehicle was broadside to the bear. Once the vehicle was stationary, the engine was turned off, a window on the side facing the bear was lowered, and speakers were used to play one of four recordings. Three of these recordings were voices of humans in groups (at predetermined decibel levels) and no sound was played for the fourth as a control. Each recording was 8 seconds in length, including the control, and the order of the recordings played was determined randomly. All experiments were recorded using a video camera. From these data I determined whether bears responded to human noises, and if the response changed over time. These experiments were run on consecutive days on the same individuals to investigate whether bears habituate to human-induced noise. These experiments terminated after the recording finished, whether the bear responded or not, and only took place when there were no other vehicles within 100m of our vehicle. Additional variables measured included playback number, distance and direction to bear, wind speed and direction, and decibel level.

Data analysis

Recorded video footage of all experiments was captured using Adobe Premiere 6.0, compressed using Cinema Craft Encoder Lite and burned onto DVDs. The Observer 5.0 was used to analyze the video footage for any subtle behavioral cues that might predict reaction responses from individuals (Eckhardt & Waterman 2004). An ethogram of body positions (lying, sitting, standing), and positioning of head, ears, eyes and lips was constructed for this analysis based on previous observations of reactions by bears to both other bears and tours. Frequency and duration of these behaviors were measured for further analysis.

I compared bear behavior in the presence and absence of tourist vehicles at Gordon Point using Mann-Whitney U and Wilcoxon signed rank tests (Zar 1999), and used binary logistic regression to compare behavioral responses to vehicle approach and to look for behavioral predictors to response (Dytham 1999). Time budgets were calculated separately for each individual with at least 8 observations and then averaged over all individuals. All p values reported are significant at the 0.05 level. All errors reported are standard errors.

RESULTS

Behavioral Observations

Scan and all-occurrence behaviors were recorded for a total of 22 days in 2003 and 30 days in 2004. At least one vehicle was found to be within 100 m of an individual 68% of the time during the time of day when vehicles could be present (Fig. 1), and the average number of vehicles per bear was 1.3. I observed 1.7 responses per day by bears to other vehicles and 0.6 responses per day by bears to human sound over 52 days of observation in 2003 and 2004. I observed tourist vehicle movement over an hour period, specifically looking at angle of approach. I recorded six direct approaches and seven indirect approaches. Three of these direct approaches resulted in a response from the bear, with all three bears changing from a stationary position to walking away. One indirect approach resulted in a response, with the bear walking away.

Bears (n =18 individuals; 6 females, 12 males) in the tourist area spent the majority of their time lying down (64 ± 5%), with smaller amounts of time allotted to sitting or standing (15 ± 3%), locomotion (16 ± 3%) and social interactions (5 ± 2%). Females spent less time lying (Mann-Whitney U test: U=14.5, n_1=6, n_2=12, p=0.04) and more time in a sit or stand position (Mann-Whitney U test: U=8.0, n_1=6, n_2=12, p=0.01) than males (Fig. 2). Bear behaviors differed in the presence and absence of tourist vehicles. Less time was spent lying down in the presence of vehicles (Wilcoxon signed-ranks test: Z=-2.25, n=18, p =0.024), and more time was spent in an upright sit or stand position (Wilcoxon signed-ranks test: Z=-2.121, n =18, p =0.034). Within the sexes, there was no difference in behavior for males in the presence and absence of vehicles (Fig. 3 top), but there was a difference for females (Fig. 3 bottom). In the presence of tourist vehicles, females spent significantly less time lying (Wilcoxon signed-ranks test: Z=0, n =6, p =0.043), and more time in a sit/stand position (Wilcoxon signed-ranks test: Z=-2.032, n =6, p =0.042). Between the sexes, there was a significant difference in behavior in the presence of vehicles, but no difference when vehicles were absent (Mann-Whitney U test: U $\geq$28.0, n_1=6, n_2=12, $p \geq$0.48). Females spent significantly less time lying than males (Mann-Whitney U test: U=14.0, n_1=6, n_2=12, p=0.044) and more time in locomotion (Mann-Whitney U test: U=4.0, n_1=6, n_2=12, p=0.003). Since the behavioral category of lying was normally distributed, I compared the effect of sex and vehicle presence on time spent lying using a two-way analysis of variance (ANOVA). Polar bears spent less time lying when vehicles were present ($F_{1,32}$=5.314, p=0.028), and males spent more time lying than females ($F_{1,32}$=4.480, p=0.042). The interaction between sex and vehicle presence was not significant ($F_{1,32}$=2.771, p=0.106). Time spent in the absence and presence (1, 2, and $\geq$3) of vehicles did not differ for males and females (Mann-Whitney U test: U=31.0, n_1=6, n_2=12, p=0.67).

<u>Temperature Effects</u>

Air temperatures were recorded to determine temperature effects on time budgets. As vehicles are around during daylight hours, corresponding with warmer temperatures, differences in time budgets in the presence and absence of vehicles could be masking temperature effects. Temperatures were categorized as greater than or equal to 0°C or less than 0°C. Time budgets were calculated for individuals (n =7) that had sufficient numbers of observations in the two temperature categories (minimum of 4 observations in each category). All individuals (n =11) not included in the temperature analysis did not have sufficient numbers in both temperature categories. Temperature had no effect on the time budgets of bears (Wilcoxon signed-ranks test: $Z \geq -1.363$, $n = 7$, $p \geq 0.17$) (Fig. 4), thus temperature is not a confounding variable for vehicle effects on time budgets of polar bears.

Conspecific Effects

For the individuals included in the time budget analysis ($n = 18$), the presence or absence of conspecifics (within 100m) at the time of each observation was determined to investigate conspecific effects on time budgets of bears. Time budgets were calculated for individuals ($n = 5$) that had sufficient numbers of observations in the two categories (minimum of 4 observations in each category). The presence of conspecifics had no effect on the time budget of bears (Wilcoxon signed-ranks test: $Z \geq -1.342$, $n = 7$, $p \geq 0.07$) (Fig. 5).

Vehicle Approach Experiments

A total of 186 approach experiments were completed, 68 from 2003 and 118 from 2004. Multiple approaches were completed for some individuals, with a range of one to six approaches for any given bear. The average number of days any individual bear spent in the tourist area was 1.6 ± 0.2 days (range: 1-16 days). A total of 117 approaches to 78 individuals were videotaped for detailed behavioral analyses to identify subtle behavioral cues predicting a response. Of the videotaped experiments, I was able to calculate velocity of the vehicle for 95 approaches. The average speed of the vehicle was 0.66 ± 0.02 m/s, ranging from 0.23 to 1.15 m/s. Results for variables on proportion of response and response versus no response are summarized in Tables 1 and 2.

Head up frequency and duration were examined to determine if there was a difference in either parameter in relation to response (32 approaches) versus no response (63 approaches) during the vehicle experiments. There was no significant difference in the average frequency of head up behaviors for bears that responded and did not respond to experiments (Mann-Whitney U test: U=938.5, n_1=32, n_2=63, p=0.76). The proportion of responses for bears that had no head up behavior (response=2/18) differed significantly from bears with one or more head up behavior (response=30/77) (Fisher's exact test, p=0.028). Thus it appears that at least one head up behaviors may be related to response in bears. Head up duration was significantly higher for bears that ended the experiment with a response (Mann-Whitney U test: U=629, n_1=32, n_2=63, p=0.005). I did not include head up as a response for the remainder of the analyses, allowing a more conservative analysis due to large, more energetically costly reactions only being counted as responses.

Of all approach experiments, 25% (47/186 approaches) resulted in a response by an individual bear, and 30% of first approaches resulted in a response (40/134 approaches). Of the approaches that resulted in a response, at the end of the trial 39% of individuals were in a sit/stand position, 57% walked away from the vehicle, and 4% ran away from the vehicle. A significantly higher proportion of bears responded to direct approaches (41%) than indirect approaches (21%) (Chi-square test, χ^2=6.64, df =1, p=0.009) (Fig. 6). Of the bears that responded to approach, the average distance at response was 42.8 ± 3.2 m (47 approaches). There was no significant difference in distance at response for direct 41.6 ± 6.2 m (17 approaches) and indirect 43.5 ± 3.6 m (30 approaches) approaches (Mann-Whitney U test:

U=217.5, n_1=17, n_2=30, p=0.41). Approach number did not affect the proportion of responses (n=17 individuals) (Chi-square test, χ^2=2.11, df =1, p=0.14). Of bears that were approached, the average minimum number of days spent in the tourist area had no affect on response for both males (Mann-Whitney U test: U=217.5, n_1=20, n_2=28, p=0.41) and females (Mann-Whitney U test: U=217.5, n_1=8, n_2=18, p=0.41) (Fig. 7). There was no significant difference in the average minimum number of days spent in the tourist area for bears that responded (1.8 ± 0.4 days) and did not respond (1.9 ± 0.2 days) (Mann-Whitney U test: U=3246, n_1=47, n_2=139, p=0.95). Sex had no affect for bears that responded to approach (Chi-square test, χ^2=0.79, df =1, p=0.37). There was no significant difference in the proportion of bears that responded to vehicle approach in the presence and absence of conspecifics within 100 m of the test subject (Chi-square test, χ^2=1.33, df=1, p=0.25).

The number of bears responding to approach increased as the distance from the vehicle to the bear decreased (Spearman rank correlation: r_s=-0.742, n =40, p=0.014) (Fig. 8).

Body Size and Body Condition

Bear shoulder height and shoulder to tail length were correlated (Spearman rank correlation: r_s=0.893, n =43, p<0.001). Due to the correlation, bear shoulder height was used in analyses representing size for all individuals.

The average height of bears was 0.98 ± 0.02 m (n =44) (range 0.55-1.21 m), and average belly/shoulder body condition was 0.63 ± 0.01 m (n =53) (range 0.55-0.74 m). On average, males were significantly taller than females (males 1.04 ± 0.02 m, n =21; females 0.92 ± 0.01 m, n =9; Mann-Whitney U test: U=33, p=0.006). The body condition of males was lower than that of females (males 0.62 ± 0.01, n =24; females 0.64 ± 0.01, n =12; Mann-Whitney U test: U=80, p=0.03). There was no significance difference in body condition between years for males (Mann-Whitney U test; U=24.0, n_1=4, n_2=20, p=0.23) or females (Mann-Whitney U test; U=7.0 n_1=2, n_2=10, p=0.59). Males and females were analyzed separately for further analysis, and sorted into categories (below average and above average) for both measurements of size and condition.

There was no significant difference in the proportion of responses to vehicle approach for bears that were above and below average condition (males: Fisher's exact test, p=1.0; females: Fisher's exact test, p=0.52) or size (males: Fisher's exact test, p=0.40; females: Fisher's exact test, p=1.0). The average response distance did not differ significantly for bears that were above average and below average condition (Mann-Whitney U test: U=15, n_1=7, n_2=8, p=0.15) or size (Mann-Whitney U test: U=14, n_1=5, n_2=8, p=0.42).

Approach Variables Predicting Response

Using univariate binary logistic regression, I tested approach variables that were potential predictors of response (Table 3) with a value of p=0.25 for variables to remain in the model. Sex (p=0.376), minimum number of days (p=0.717) and distance to camp (p=0.986) were not significant predictors of response. Both condition (belly index) and size (shoulder height) were investigated by univariate logistic regression, then each entered separately into the logistic regression model with approach variables, and in both cases neither size (p=0.679) nor condition (p=0.614) were significant predictors of response.

Using multivariate binary logistic regression, and both forward and backward selection models, I produced four models for variables with potential significance. Each model included different blocks of independent variables. The final model (Table 4) included angle of approach and speed as significant variables that predict response to approach, using a p entry value into the model of 0.05 and a removal value of 0.10. The final model had a good fit indicated by Hosmer and Lemeshow goodness of fit (χ^2=4.737, df=8, p=0.785), and had a significant test of model coefficients (χ^2=9.330, df=2, p=0.009), indicating the model is statistically significant.

From the positive signs of the coefficients for angle and speed in the model, the probability of response increases for direct approach, and increases as speed increases. No other variables were significant predictors of response.

Frequency Behaviors Predicting Response

I used univariate logistic regression to determine possible significant behavioral predictors of response in polar bears, using p=0.25 as a minimum indicator of significance. Only one potential behavior was excluded from the analysis, head up frequency, as it was not significant as a predictor of response (p=0.994). Using multivariate binary logistic regression, I investigated several behaviors as potential predictors of a response from individual bears. This analysis included behaviors measured in frequency during the approach experiments (Table 5). I analyzed 117 approaches for 78 individuals. Individuals could only appear twice if they had both responded not responded to an approach, resulting in the final analysis of 95 approaches. Using both forward and backward selection models, I produced five fitted models. Each model includes different blocks of independent variables. The final model (Table 3) included the behaviors body shift and lip smack as significant variables that predict response to approach, using a p entry value into the model of 0.05 and a removal value of 0.10. The final model had a good fit indicated by Hosmer and Lemeshow goodness of fit (χ^2=0.887, df=3, p=0.829), and a significant test of model coefficients (χ^2=64.908, df=2, p<0.001), indicating the model is statistically significant.

From the positive signs of the coefficients for body shift and lip smack in the model, the probability of response increases as body shift and lip smacking behavior increases. No other variables were significant predictors of response.

Duration Behaviors Predicting Response

Using univariate binary logistic regression, I investigated the duration of head up behavior as a predictor to response in individual bears. The summary of the model can be seen in Table 3. This model had a good fit indicated by Hosmer and Lemeshow goodness of fit (χ^2=8.084, df=7, p=0.325), indicating a fit model, and a significant test of model coefficients (χ^2=6.991, df=1, p=0.008), indicating a statistically significant model. From the positive sign of the coefficient for head up duration, the probability of response increases as head up duration increases.

Human Sound Experiments

The average decibel level of human noise during close encounters with polar bears was 94.1 ± 2.2 dB (range 73.2-105.6 dB) over 4 groups of tourists and a total of 21 readings.

A total of 66 sound experiments were performed on 49 individuals with the distribution of the four playback sounds: (1) 19, (2) 17, (3) 15 and (4) 15. The first three playback numbers were human group sounds and number four was a silent control. Only 6.1% of all bears responded to the playback trials experimental sounds. All responses were to sound playback, there were no responses to the control trials. The average decibel level of the playback sounds was 106.1 ± 0.6 dB (range 103-117 dB), which compared closely to the high range measured on tourist vehicles in the field, 105.6 dB, and the average for the control was 73.2 ± 3.7 dB (range 58-107 dB).

DISCUSSION

Bears in the tourist area near Churchill spent most of their time in the fall lying down waiting for the sea ice to form. However, females spent significantly less time lying and more time in a sitting or standing position and in locomotion when vehicles were present. An upright position may allow for faster escape if required. This change in behavior in the presence of tourist vehicles was not temperature related. There could be an effect of both vehicle and conspecific movement, resulting in a higher proportion of watchful behavior, as there were insufficient numbers of observations to test presence of conspecifics for females only. Previous studies have found that females have been found to spend more time in activity than males (Latour 1980), which could be because females tend to avoid males and remain spatially segregated (Latour 1980). Females and family groups could be avoiding tourist camps because of the presence of adult males, which have been observed to injure or even kill females and cubs (Derocher & Wiig 1999; Dyck & Daley 2002).

Dyck and Baydack (2004) found an increase in frequency of head up behavior of polar bears in the presence of tourist vehicles. In this study, however, the frequency of head up behavior did not predict the response of bears to vehicle approach. Whole body behavioral changes, including locomotion, would be more energetically costly than head raising behavior and thus more likely to affect energy budgets of bears (Watts et al. 1991).

A study on interactions between boats and whales found that more than 80% of interactions between tourist boats and whales involved a maneuver by the boat that affected whale behavior (Rivarola et al. 2001). Similarly, angle of approach has been suggested as an important variable affecting the response of polar bears to tundra vehicles (Watts & Ratson 1989), and in my experiments, direct approaches were more likely to cause a response than indirect approaches, probably because the bear was in the path of the vehicle. The vehicle operators can control the approach angle and speed, and planning approaches in advance can minimize responses.

Identifying recognizable behavioral indicators for responses to vehicle approach may allow operators of tourist vehicles to use these subtle cues to gauge how distance and speed of approach is affecting an individual. From the model, the two behaviors that can predict a response were body shift and lip smack. Thus, an increase in frequency of these behaviors increases the probability of response by a bear. An increase in the duration of head up behavior also indicates a higher probability of response, but head up frequency was not a significant predictor of response.

Good photo opportunities may require close distances to wildlife, which can affect the behavior of the individual approached (Acevedo 1991). This distance was influenced by speed of the vehicle and angle of approach. The size of the vehicle and position of other bears and/or vehicles could also influence the likelihood of response. The distance at which a bear responds may also be related to age, the speed at which a given bear can move, and the immediate environment and state of the individual (Beale & Monaghan 2004).

Age, size and condition may affect the probability of response in some species. Beale and Monaghan (2004) found that birds with lower body condition showed the least behavioral response to human disturbance, while individuals with artificially enhanced condition showed greater responsiveness. One could predict that bears with low fat reserves may show slower responsiveness regardless of the intensity of the disturbance. However, I found no effect of size and condition of polar bears on the likelihood of response to vehicle approach or on the average response distance. The lack of significance of condition could be due to previous habituation to vehicles. Bears in very low condition may avoid the tourist area completely. There was also no significance of age using size as an indicator. Subadults may be subject to elevated metabolic rates (Watts et al. 1991), resulting in a potentially higher cost of human induced locomotion, but the ratio of adults to subadults in the tourist area has not been examined.

Of the 25% of bears that responded to vehicle approach, 57% walked away and 4% ran away from the vehicle. Vehicle disturbances that result in polar bears sustaining locomotion have been shown to have significant metabolic costs, especially disturbances resulting in running have high metabolic costs (Watts et al. 1991). The cost of locomotion for polar bears is high (Hurst et al. 1982b; Best 1982) and any changes in the time spent in locomotion could have implications for survival. Increased movement uses up potentially crucial energy reserves (Watts et al. 1991), and bears may be unable to dissipate heat at fast walking speeds (Hurst et al. 1982a). Moving away from tourists could reduce survival if it occurs at a critical time for the species or a critical location (Green & Higginbottom 2000).

The area that tourist vehicles can travel in is small relative to the coastline available to the polar bears, and bears that respond to vehicles may leave the area immediately, leaving already habituated bears in the tourist area. Thus, the bears that did not respond to vehicles may already be habituated. Five individual males observed in this study had been identified in the tourist area in previous years, non of which respond to vehicle approach, suggesting that some bears are repeat visitors to the tourist area and are habituated to the tourist camps and vehicles. Although there was no significant difference between responses for first approach versus consecutive approaches, there was a trend for response rate to decrease. Habituation of animals to humans is usually viewed as negative in the literature, but in the case of the polar bears near Churchill, there are different aspects that need to be addressed. Polar bears appear to habituate quickly to vehicle approach, with a trend of decreases in response occurring over a single day. Thus it can be argued that there are only short-term effects on polar bear behavior due to vehicle approach. However, habituation to vehicles and habituation to humans are different factors with different consequences. There was no effect of the playback human sound experiments on bears within the tourist area. Thus, these bears could be habituated to humans and/or human sound. If bears are habituating to humans in the tourist area quickly, that habituation may affect reactions of bears to humans in the community (Watts & Ratson 1989), and there may be an increase in human-bear conflicts and interactions due to bears traveling to town. Thus, implications of habituating polar bears are widespread and need further investigation.

CONCLUSIONS

Wildlife can avoid tourist areas in which disturbances can occur if they have alternative sites to go to (Gill et al. 2001). Although bears can leave the relatively small tourist area near Churchill if they choose, other factors may encourage them to stay. Bears are potentially drawn to the smells of cooking food distributed through the air at the tourist temporary hotels. Thus bears may stay in the tourist area due to the potential payoff of being near food sources and smells, and near kitchen runoff water (Herrero & Herrero 1997).

The polar bears of Churchill are near the southern edge of the species distribution, and will be one of the first potentially affected by climate change. Early impacts could include a decrease in body condition and increase in human-bear interactions (Stirling & Derocher 1993). It will become crucial that bears have sufficient fat storage if the ice-free period increases, and any change induced by humans in the activity and locomotion of bears could impact their condition and fat reserves. Thus, any effect that people have on locomotion or energy expenditure of bears needs to be minimized. My data suggest changes in bear behavior in the presence of tourist vehicles. Bears that responded to vehicle approach did so at an average of 43 m, and there was an increase in the number of bears that responded to vehicle approach closer than 50 m, indicating a possible buffer zone distance, which is the distance between wildlife and tourists recommended to minimize response. This distance from bears to tourist vehicles could minimize responses to vehicles and reduce behavioral changes in the presence of vehicles.

Further study should involve rigorous investigation on the effects of vehicle and human presence on family groups, i.e., females with cubs, including different age groups such as cub of the year versus yearling cubs. These family groups are highly sought after for photo opportunities, and since females with cubs are lactating in addition to living off of fat reserves, they may be the most sensitive energetically to human induced locomotion. Polar bears are viewed from vehicles of varying sizes, ranging from small bus-like vehicles with a capacity of less than ten people, to very large tundra vehicles that can carry close to 50 tourists. Since bears are subject to different tourist group sizes and vehicle sizes, vehicle and group size may affect the likelihood of response by bears. Tourist group size affects behavioral responses in other species (Kinnaird & O'Brien 1996; but see Grieser Johns 1996), although data on this subject seems scant. The surrounding habitat of the bear may also affect the likelihood of response (Watts et al. 1991). Bears with a higher degree of cover from willows may respond differently than bears open to approach from all sides.

Data presented here provide the first experimental evidence of variables in the tourist industry that affect polar bear behavior, and the first evidence of behavioral cues predicting a response to vehicle approach. The experimental vehicle approach methodology can be used in future studies to help determine wildlife response to vehicles and potential buffer zones to animals subject to wildlife viewing worldwide.

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Table 1
Proportion of responses by polar bears to experimental vehicle approaches in the tourism area near Churchill, Manitoba.

Variable		Proportion of Response	*n*
Angle	Direct	0.41	42
	Indirect	0.21	144
Approach #	First	0.24	17
	Second	0.06	17
Conspecifics	Absent	0.35	43
	Present	0.24	50
Sex	Females	0.29	24
	Males	0.44	43
Head Up	Absent	0.11	18
	Present	0.39	77
Size	Below Ave. Females	0.25	4
	Above Ave. Females	0.50	4
	Below Ave. Males	0.36	11
	Above Ave. Males	0.60	10
Condition	Below Ave. Females	0.25	4
	Above Ave. Females	0.60	5
	Below Ave. Males	0.50	14
	Above Ave. Males	0.44	9

Table 2
Comparison of polar bears that responded and did not respond to vehicle approach experiments in the tourism area near Churchill, Manitoba (mean ± SE, sample size in parentheses).

Variable	Response	No Response
Head Up Frequency	1.8 ± 0.2 (32)	1.9 ± 0.2 (63)
Head Up Duration (seconds)	43 ± 6 (32)	27 ± 4 (63)
Minimum Number of Days in area	1.8 ± 0.4 (47)	1.9 ± 0.2 (139)

Table 3
Approach variables measured during vehicle approach experiments to polar bears in the tourist area near Churchill, Manitoba.

Variable	Description
Angle	The angle of vehicle approach; direct (N=14) or indirect (N=81)
Speed	The average speed of the vehicle over the approach, ranging from 0.23 to 1.15 m/s
Vehicle#	The number of vehicles within 100m of the test subject, including the test vehicle, ranging from 1-5
Bear#	The number of other bears within 100m of the test subject, ranging from 0-10
Sex	The confirmed sex of the bear being approached
Approach#	The minimum number of times a bear was approached by the test vehicle, ranging from 1-6
Minimum Days	The minimum number of days that the bear has been identified in the tourist area
Distance to Camp	The distance from the bear to the tourist hotel

Table 4
Summary of the final models from logistic regression results for approach variables (multivariate: angle of approach, approach number, speed, number of bears within 100m, and number of vehicles within 100m), behaviors (multivariate: body shift, eye contact, lip jut, lip smack, yawn and tongue flick) and head up duration (univariate) of polar bears near Churchill, Manitoba.

		β	S.E.	Wald	df	Sig.	Exp(β)	95.0% C.I.for EXP(β)	
								Lower	Upper
Approach Variables	Angle(direct)	1.437	0.659	4.750	1	0.029	4.207	1.156	15.313
	Speed	3.224	1.349	5.714	1	0.017	25.122	1.787	353.207
	Constant	-3.665	1.028	12.713	1	0.000	0.026		
Behaviors	Body shift	4.117	0.903	20.762	1	0.000	61.356	10.443	360.496
	Lip smack	2.793	1.206	5.361	1	0.021	16.332	1.535	173.753
	Constant	-3.370	0.750	20.206	1	0.000	0.034		
Head Up Duration	HUD	.018	.007	6.371	1	.012	1.019	1.004	1.033
	Constant	-1.285	.334	14.817	1	.000	.277		

Table 5
Behaviors scored during vehicle approach experiments to polar bears in the tourist area near Churchill, Manitoba.

Behavior	Description
Body shift	Bear shifts weight and body moves visibly, but overall position does not change
Eye contact	Bear orients head position towards approaching vehicle and maintains eye contact with the vehicle
Lip jut	Bear sticks out upper lip; very prominent over lower lip
Lip smack	Bear open and closes mouth repeatedly
Yawn	Bear opens mouth wide
Tongue flick	Bear's tongue comes out of mouth repeatedly, showing long length

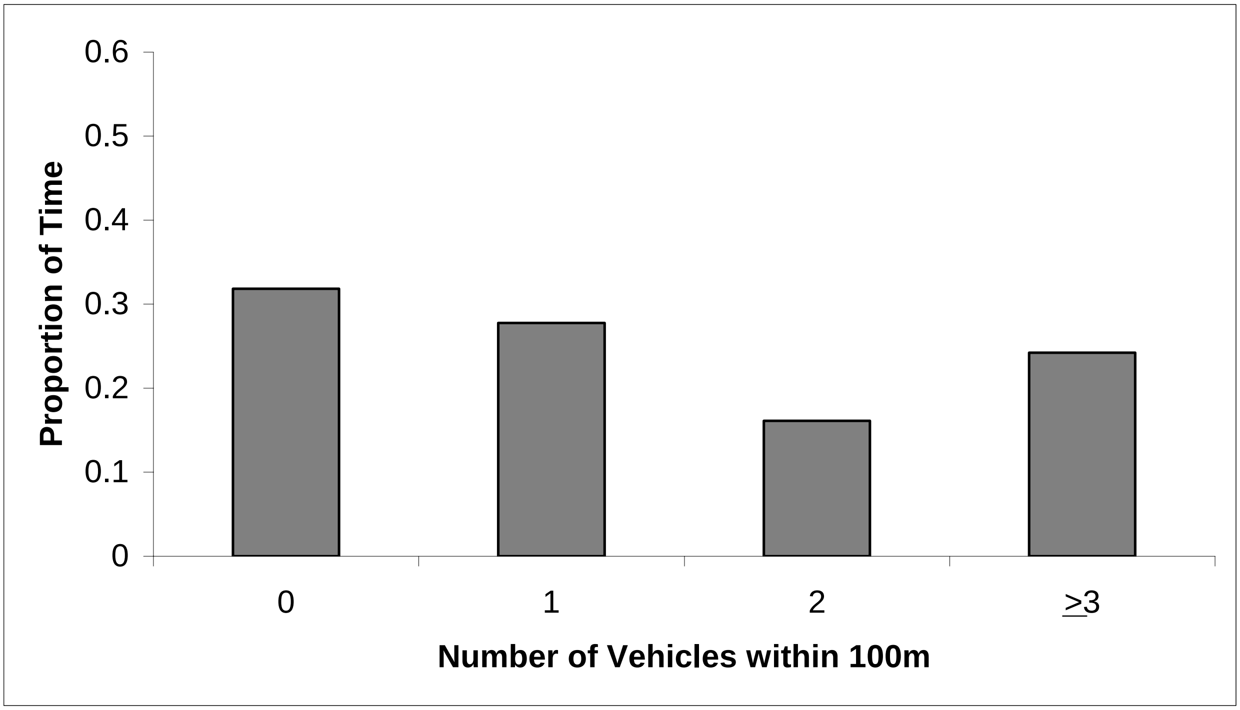


Figure 1: The proportion of time spent by polar bears in the presence of 0, 1, 2, and 3 or more tourist vehicles within 100 m near Churchill, Manitoba.

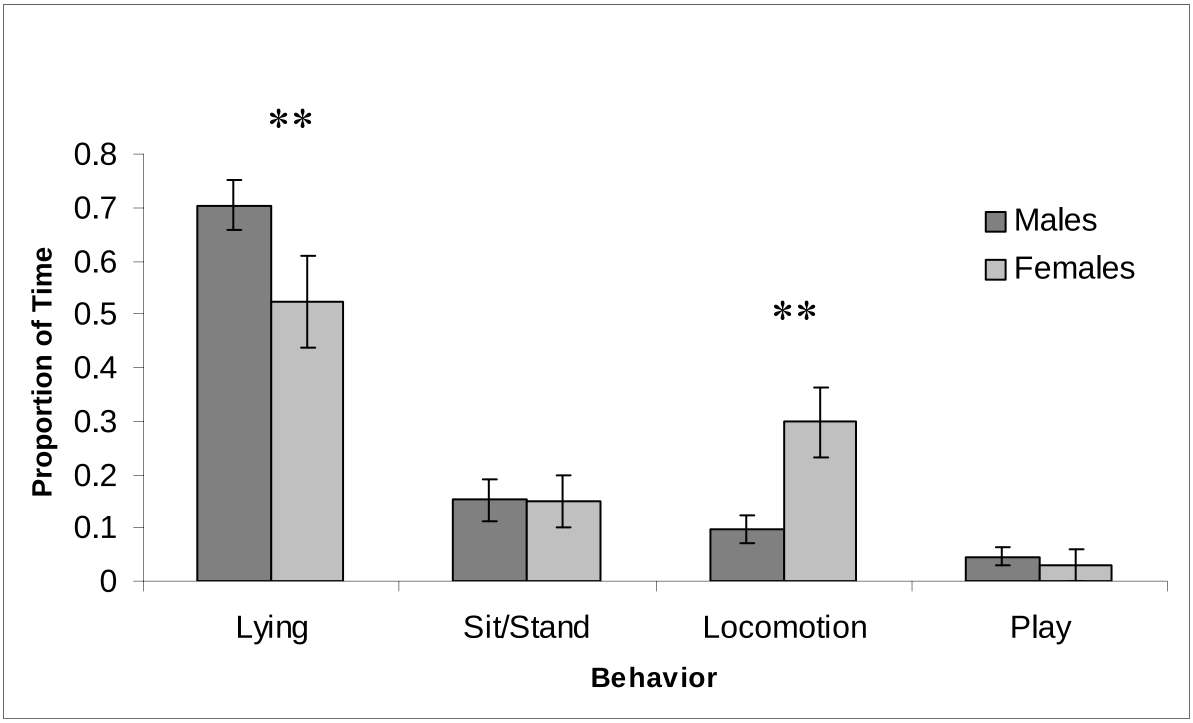
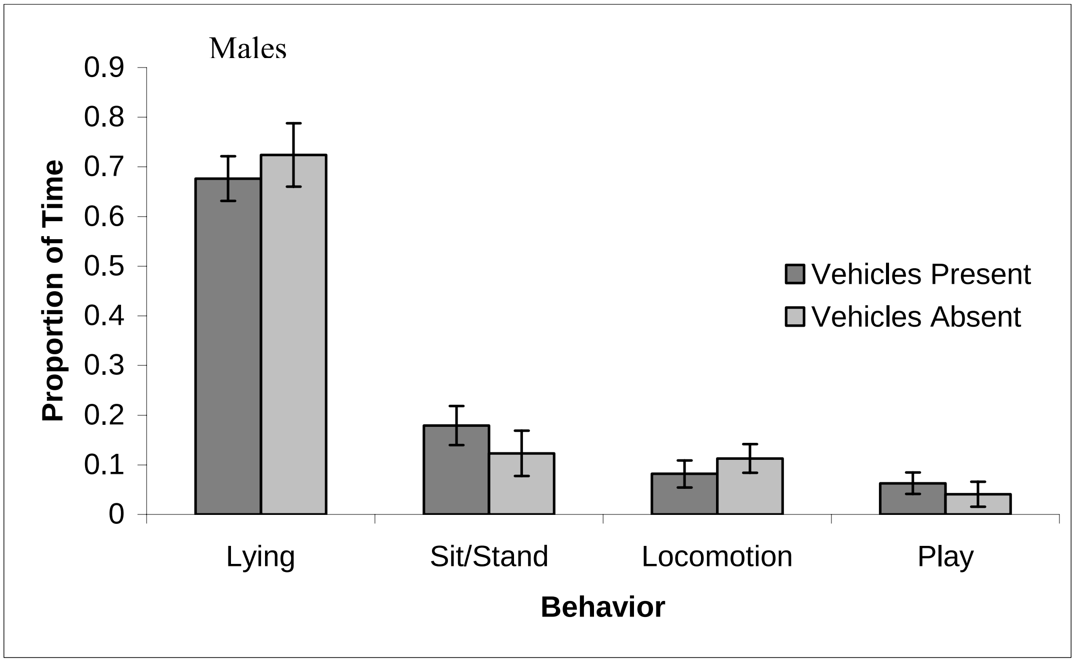


Figure 2: Mean proportion of time (± SE) spent by polar bears during the day for males (n =12) and females (n =6) in each behavioral category in the tourist area near Churchill, Manitoba (** $p \leq 0.01$).



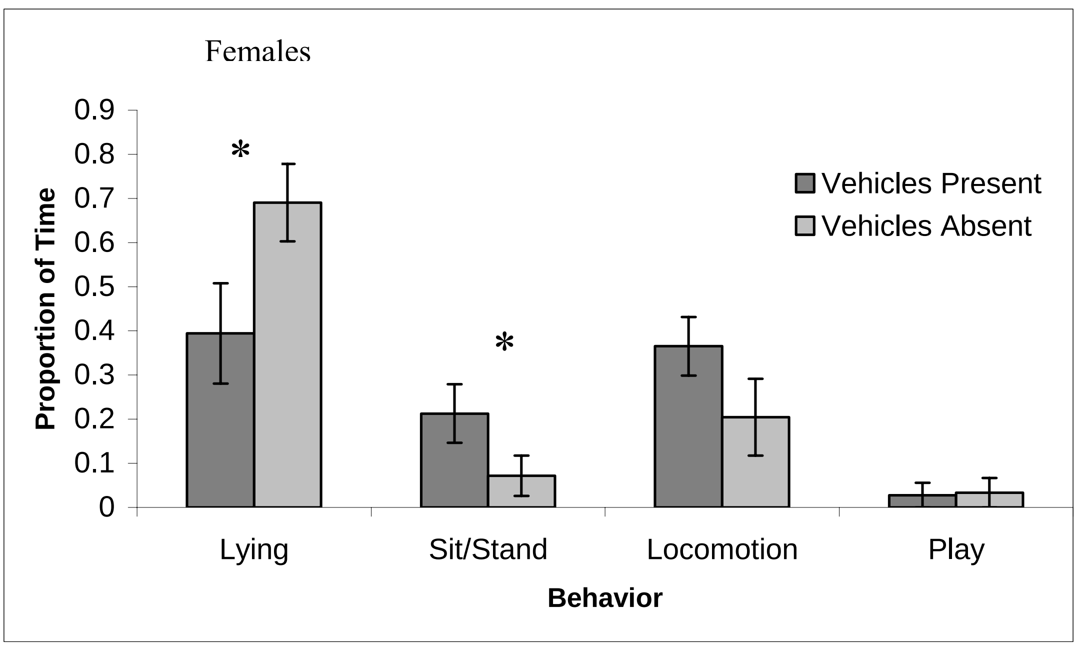


Figure 3: Mean proportion of time (± SE) spent by male (top, *n* =12) and female (bottom, *n* =6) polar bears in each behavioral category in the presence and absence of tourist vehicles near Churchill, Manitoba (**p* <0.05).

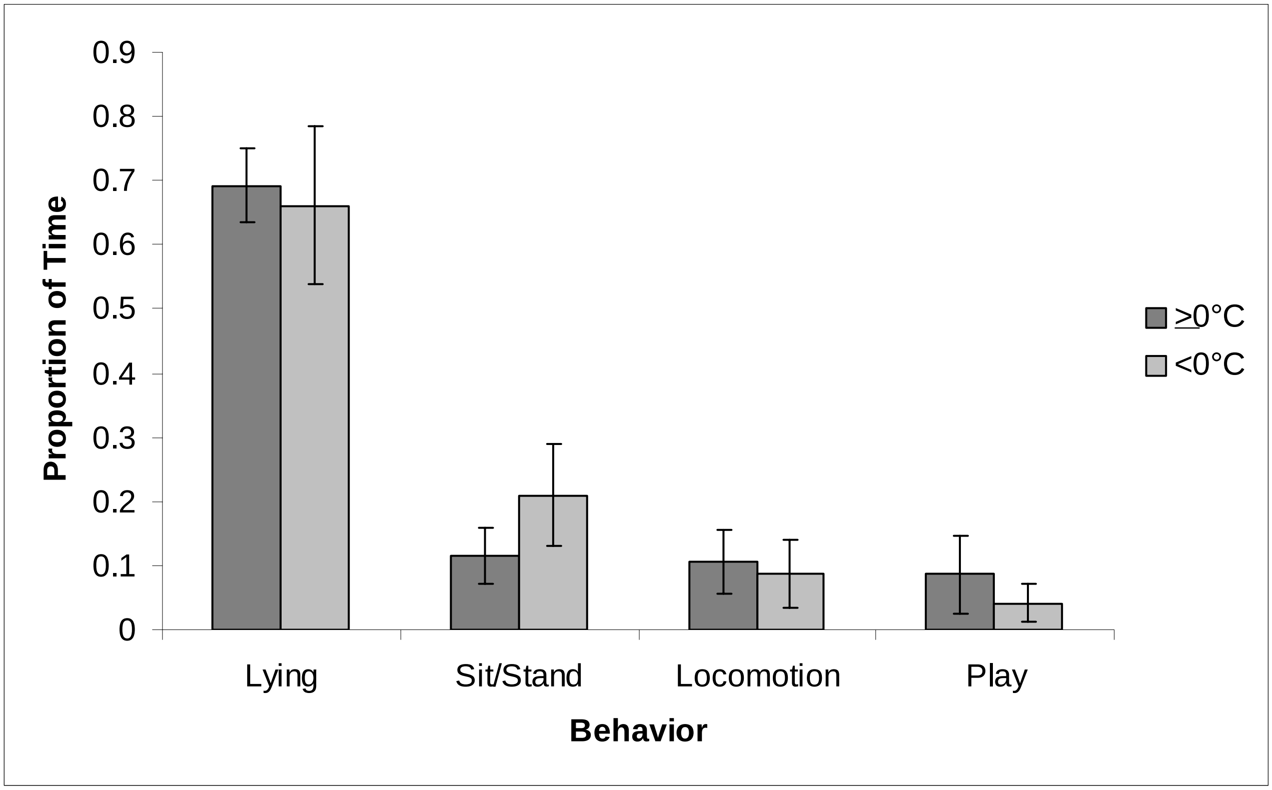


Figure 4: Mean proportion of time (± SE) spent by polar bears (5 males, 2 females) in each behavioral category in warm (≥0°C) and cool (<0°C) temperatures near Churchill, Manitoba; no significant differences.

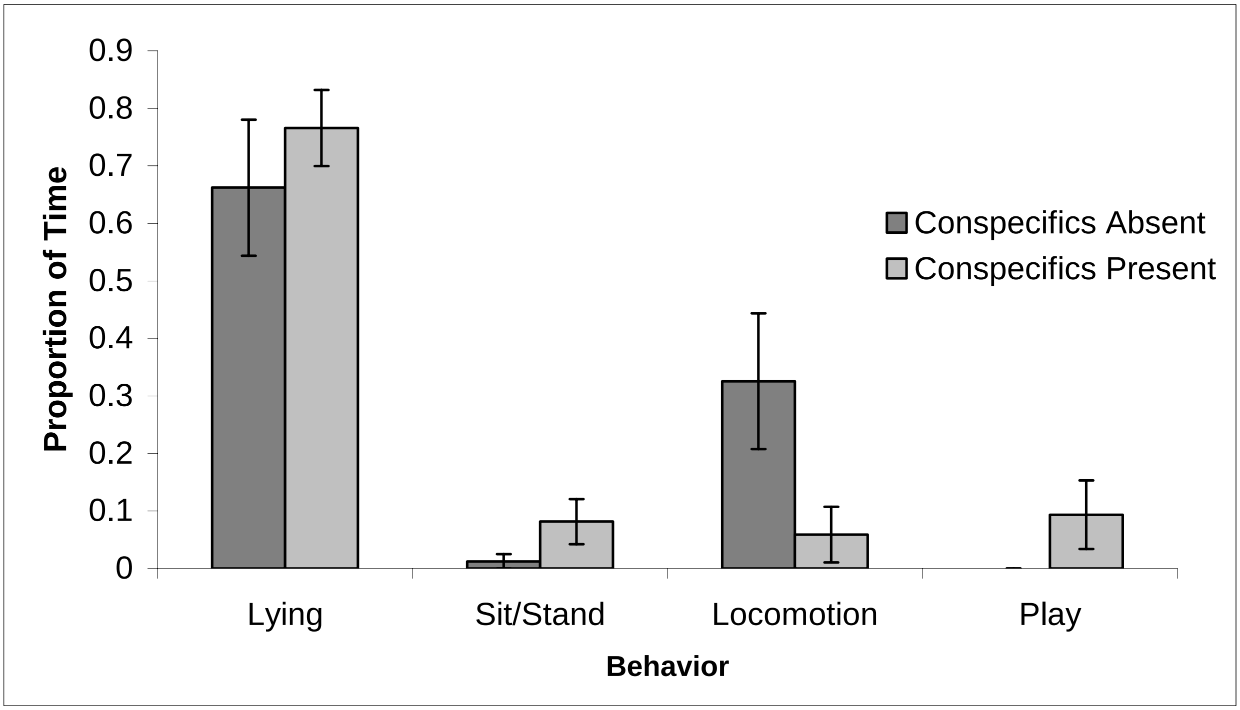


Figure 5: Mean proportion of time (± SE) spent by polar bears (*n* =5) in each behavioral category in the presence and absence of conspecifics near Churchill, Manitoba; no significant differences.

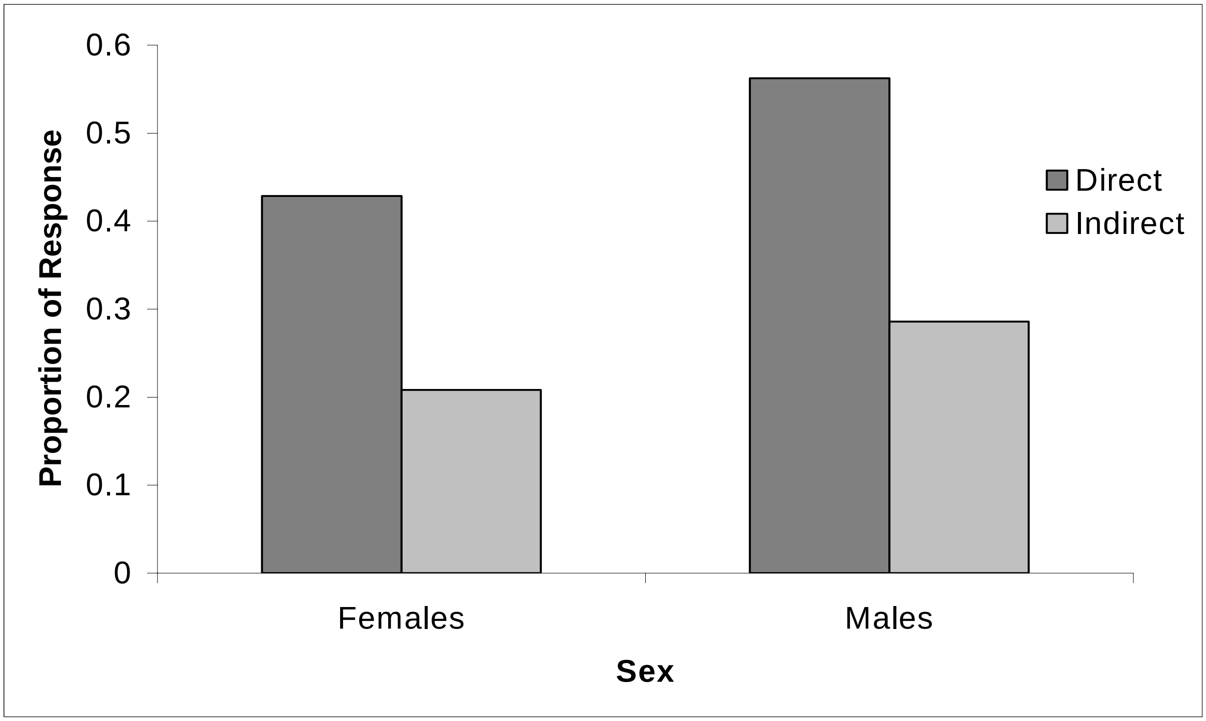


Figure 6: Proportion of responses by polar bears to direct tourist vehicle approaches (females, *n* =7; males, *n* =16) and indirect tourist vehicle approaches (females, *n* =24; males, *n* =56) in the tourist area near Churchill, Manitoba ($p<0.01$). Direct – the bear is in the path of the vehicle; Indirect – the bear is to one side of the vehicle.

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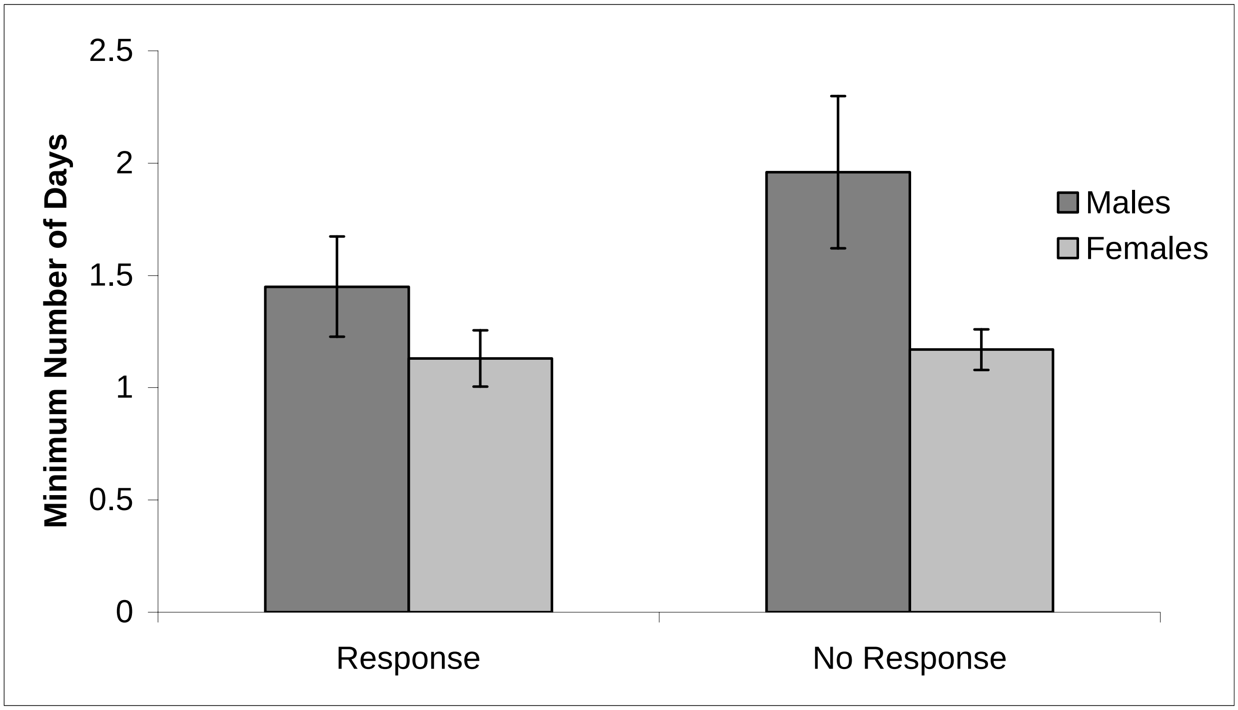

Figure 7: Mean minimum number of days (± SE) spent in the tourist area by male and female polar bears that responded (males, *n* =20; females, *n* =8) and did not respond (males, *n*=28; females, *n* =18) to vehicle approach near Churchill, Manitoba; no significant differences.

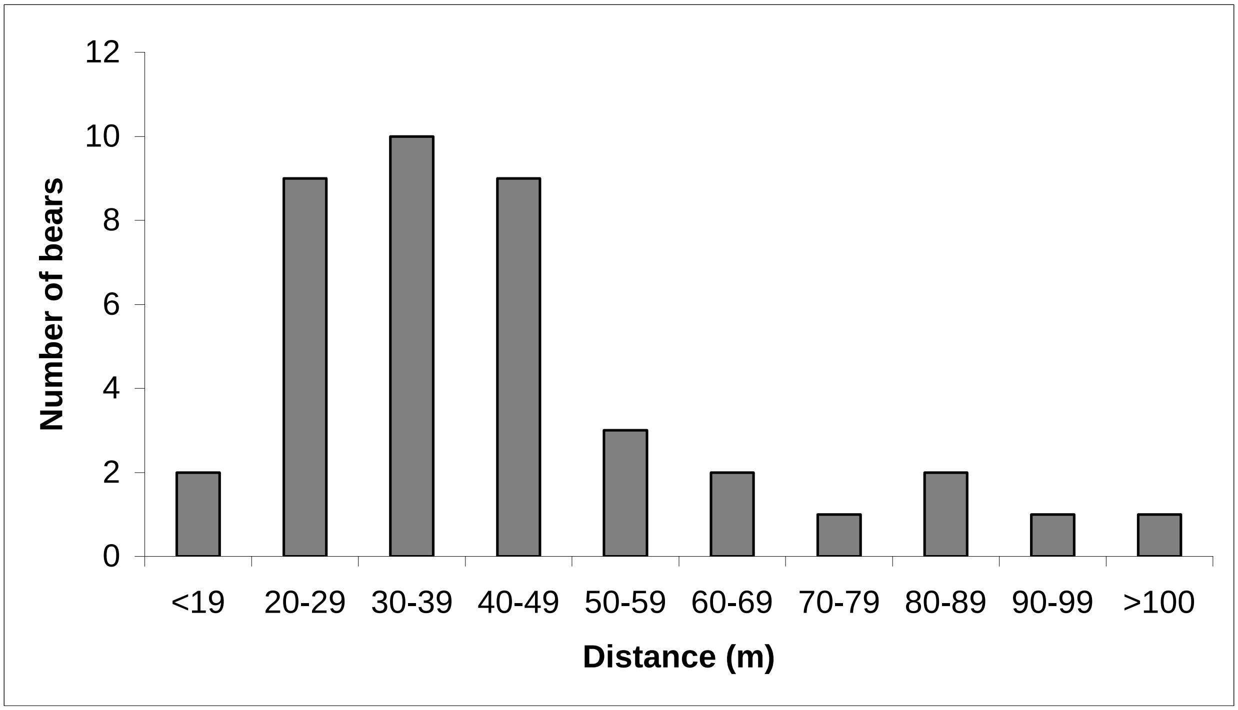

Figure 8: The distance at which polar bears responded to tourist vehicle approach (*n* =40 individuals) in the tourist area near Churchill, Manitoba.

APPENDIX: MODELS GENERATED USING LOGISTIC REGRESSION

Appendix Table A1
Logistic regression results for approach variables (angle of approach, approach number, speed, number of bears within 100m, and number of vehicles within 100m) to polar bears near Churchill, Manitoba.

		β	S.E.	Wald	df	Sig.	Exp(β)	95.0% C.I.for EXP(β)	
								Lower	Upper
Model 1	Angle(direct)	1.807	0.734	6.060	1	0.014	6.094	1.445	25.689
	Approach	-0.161	0.318	0.257	1	0.612	0.851	0.456	1.588
	Speed	3.058	1.353	5.108	1	0.024	21.278	1.501	301.672
	Bears	0.157	0.166	0.890	1	0.345	1.169	0.845	1.619
	Vehicle#	-1.160	0.727	2.542	1	0.111	0.314	0.075	1.305
	Constant	-2.204	1.387	2.524	1	0.112	0.110		
Model 2	Angle(direct)	1.837	0.730	6.328	1	0.012	6.279	1.501	26.278
	Speed	3.116	1.354	5.295	1	0.021	22.546	1.587	320.332
	Bears	0.160	0.166	0.930	1	0.335	1.173	0.848	1.624
	Vehicle#	-1.183	0.736	2.583	1	0.108	0.306	0.072	1.297
	Constant	-2.449	1.317	3.459	1	0.063	0.086		
Model 3	Angle(direct)	1.677	0.699	5.756	1	0.016	5.352	1.359	21.069
	Speed	3.018	1.337	5.098	1	0.024	20.459	1.489	281.086
	Vehicle#	-1.089	0.738	2.178	1	0.140	0.337	0.079	1.429
	Constant	-2.284	1.295	3.113	1	0.078	0.102		
Model 4	Angle(direct)	1.437	0.659	4.750	1	0.029	4.207	1.156	15.313
	Speed	3.224	1.349	5.714	1	0.017	25.122	1.787	353.207
	Constant	-3.665	1.028	12.713	1	0.000	0.026		

Appendix Table A2
Logistic regression results for behavioral variables scored during vehicle approach experiments to polar bears in the tourist region of Churchill, Manitoba.

		β	S.E.	Wald	df	Sig.	Exp(β)	95.0% C.I.for EXP(β)	
								Lower	Upper
Model 1	Body shift	3.846	1.051	13.392	1	0.000	46.796	5.966	367.057
	Eye Contact	0.337	0.272	1.534	1	0.216	1.401	0.822	2.390
	Lip jut	-0.142	0.684	0.043	1	0.835	0.867	0.227	3.317
	Lip smack	3.080	1.528	4.065	1	0.044	21.768	1.090	434.872
	Yawn	1.675	1.160	2.087	1	0.149	5.341	0.550	51.860
	Tongue flick	-0.672	0.666	1.017	1	0.313	0.511	0.138	1.885
	Constant	-4.439	1.208	13.512	1	0.000	0.012		
Model 2	Body shift	3.772	0.981	14.773	1	0.000	43.478	6.351	297.636
	Eye Contact	0.338	0.271	1.551	1	0.213	1.402	0.824	2.384
	Lip smack	3.020	1.496	4.079	1	0.043	20.501	1.093	384.383
	Yawn	1.676	1.159	2.090	1	0.148	5.343	0.551	51.829
	Tongue flick	-0.715	0.641	1.242	1	0.265	0.489	0.139	1.720
	Constant	-4.431	1.202	13.592	1	0.000	0.012		
Model 3	Body shift	3.608	0.953	14.331	1	0.000	36.888	5.697	238.848
	Eye Contact	0.351	0.260	1.821	1	0.177	1.421	0.853	2.367
	Lip smack	2.578	1.273	4.097	1	0.043	13.165	1.085	159.723
	Yawn	1.368	1.054	1.687	1	0.194	3.929	0.498	30.980
	Constant	-4.379	1.163	14.176	1	0.000	0.013		
Model 4	Body shift	4.078	0.918	19.745	1	0.000	59.005	9.768	356.445
	Eye Contact	0.269	0.245	1.205	1	0.272	1.308	0.810	2.114
	Lip smack	2.593	1.245	4.340	1	0.037	13.375	1.166	153.452
	Constant	-4.048	1.056	14.695	1	0.000	0.017		
Model 5	Body shift	4.117	0.903	20.762	1	0.000	61.356	10.443	360.496
	Lip smack	2.793	1.206	5.361	1	0.021	16.332	1.535	173.753
	Constant	-3.370	0.750	20.206	1	0.000	0.034		