Impacts of a multi-use pathway on American black bears in Grand Teton National Park, Wyoming

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ABSTRACT

In 2007, Grand Teton National Park authorized construction of several paved multi-use, non-motorized pathways, situated close to existing roads, and traversing various habitat types. Construction of the first 13-km section was completed during summer 2008. The pathway resulted in direct loss of wildlife habitat, a new form of human use on the landscape, and a wider zone of human influence. We examined how these changes affected black bear (*Ursus americanus*) movements, habitat use, activity, pathway/roadway crossings, and visibility to human park visitors. Twenty-nine (11F, 18M) bears, fitted with global positioning system (GPS) store-on-board radio-collars, were monitored during 1–3 distinct study periods: pre-pathway (2001–2007), construction (2008), and pathway (2009–2010). In addition, 6 trail counters were deployed to document variation in human use of the pathway during May–Nov 2009–2010. Counts of humans using the pathway ranged from 0 to 148 detections/counter/hour. Mean counts peaked during mid-summer months (15 Jun–30 Aug) and during mid-day (1100-1600 hrs). Evidence indicated bears did not shift their home ranges to avoid humans using the pathway, nor did they reduce their frequency of pathway/roadway crossings. Instead, bears altered the way they used the areas near the pathway. Across the study periods, bears showed greater selection for steep slopes and for areas further from the pathway. Bears were also increasingly likely to cross the pathway/roadway corridor in areas providing vegetative cover. Within 500m of the pathway, bears decreased their activity by approximately 30% during midday when human use of the pathway peaked, and increased their activity by about 10% during morning and evening when human use was lower. Proportion of roadway/pathway crossings occurring during nighttime hours also increased 17–40% during both the construction and pathway periods. These behavioral changes allowed bears to continue to utilize areas near the pathway, while simultaneously reducing their encounter rates with humans. But, the observed shift of activities toward morning, evening, and nighttime hours may potentially increase the likelihood that human-bear encounters would occur during the low light conditions of dawn and dusk; increase the potential for black bear-grizzly bear encounters near the pathway; and increase the odds of vehicle collisions.

INTRODUCTION

In 2007, Grand Teton National Park (GTNP) approved a long-term transportation plan that authorized construction of several paved multi-use, non-motorized pathways between the park's south boundary and Colter Bay. Situated close to existing roads, the proposed pathways traverse a variety of habitat types ranging from sage-grassland flats to undulating coniferous forests to incised riparian areas. A wide variety of mammals and birds live within the project area. Many wildlife species occur at high densities and are often visible to park visitors. There are few, if any, precedents for this type of new development in a national park with comparable abundance and diversity of wildlife resources. Potential impacts of the pathways on wildlife include direct loss of habitat, a new form of human use on the landscape, and a wider zone of human influence. Concerns exist that pathway development will introduce different and less predictable human activities and increase levels of human use, resulting in increased disturbance impacts to wildlife. These changes may increase the potential for negative human-wildlife interactions (i.e. sudden encounters or automobile collisions), while decreasing the potential for positive interactions (i.e. roadside viewing). In August 2006, under the draft transportation plan, the park conducted a workshop to identify the highest priority wildlife research needs associated with this development. Workshop representatives from the park, academia, private transportation firms, and non-profit research organizations selected 5 taxa for investigations of pathway impacts: elk (*Cervus elaphus*), pronghorn (*Antilocapra americana*), birds, small mammals, and black bears (*Ursus americanus*). The small mammal study was later dropped from the program due to funding constraints. Construction of the first pathway – a 13-km section between Moose and Jenny Lake - was scheduled for summer 2008. Research was initiated in 2007 and continued until 2010, allowing for data collection prior to, during, and after pathway construction. This report summarizes the findings of the black bear study.

Transportation corridors, including highways, roads, and trails, have been shown to have varying degrees of impact on bears. In most regions, roads and highways are associated with lower black bear survival, due to direct vehicle-caused mortality and facilitation of indirect human-caused mortality, such as hunting, poaching, and nuisance kill (Beringer et al. 1989, Brody and Pelton 1989, Hellgren and Maehr 1993, Kasworm and Their 1994). Roads were found to be a leading hazard to grizzly bear (*Ursus arctos*) survival in the greater Yellowstone ecosystem (Schwartz et al. 2010b). Many studies have shown that black bears avoid roads and highways, resulting in a net loss of effective habitat (Beringer et al. 1989, Brody and Pelton 1989, Gaines et al. 2005, Reynolds-Hogland and Mitchell 2007, Carter et al. 2010, and Obbard et al. 2010). In some national park settings, these survival impacts are reduced, and as bears habituate to human presence without anthropogenic food rewards, they are able to utilize roadside habitats with fewer negative consequences (Haroldson and Gunther 2011). Less is known about the impacts of trails on black bears. Kasworm and Manley (1990) found that black bears avoided both roads and trails, but avoidance of trails was less pronounced. Still, bears are known to utilize foot trails for travel (Pelton 1972), while timing their use to avoid humans (Brody and Pelton 1989, Onorato et al. 2003). In some circumstances, it is conceivable that the net impact of trails is negligible. Besides avoidance, bears also change their habitat use and activity in the vicinity of human transportation corridors. Martin et al. (2010) found that brown bears selected steeper slopes in response to spatial and temporal changes in human disturbance. Schwartz et al. (2010a) found that grizzly and black bears were more night-active and less day-active when <1 km from roads or developments in GTNP. In developed areas with the added attraction of anthropogenic foods, black bears were observed to become virtually nocturnal (Lyons 2005, Matthews et al. 2006). When crossing highways in northern Idaho, black bears were observed to select for forested sites away from human developments (Lewis et al. 2011).

We hypothesized that any or all of these effects might also be observed among black bears in GTNP as a response to human use of the multi-use pathway. However, we also presumed that impacts might be subtle and difficult to quantify, due to the fact that the pathway primarily traversed sagebrush shrublands–a habitat generally avoided by forest-dwelling black bears. Our objectives were to determine the impacts of the pathway on: (1) seasonal movement and distribution; (2) habitat use; (3) activity patterns; (4) location and frequency of road/pathway corridor crossings; and (5) visibility of bears from the road/pathway corridor. Finally, objective (6) was to determine the extent to which bears might acclimate to the new pathway over two years of pathway use by park visitors.

STUDY AREA

This study was conducted in the southern half of GTNP, centered on the pathway/road corridor between Moose and Jenny Lake (Fig. 1). Elevations ranged from approximately 2000m along the Snake River plain to 4200m at the highest peaks of the Teton Range. On the valley floor, dominant vegetative communities were sagebrush (*Artemesia* spp.) shrublands, cottonwood (*Populus* spp.) riparian forests, and grasslands (*Poa*, *Festuca*, and *Calamagrostis* spp.). At mid-elevations, forests of lodgepole pine (*Pinus contorta*), spruce-fir (*Abies lasiocarpa-Picea engelmannii*), and Douglas-fir (*Psuedotsuga menziesii*) were most common. Alpine communities of sedge (Carex spp.), American bistort (*Polygonum bistortoides*), *Sibbaldia procumbans*, *Senecio crassulus*, and *Trisetum spicatum* were interspersed among scree and talus slopes at the highest elevations. U.S. Highway 191 and various park roads traversed the eastern side of the study area, while a series of hiking trails traversed the western side.

The pathway was built along the same corridor as the Teton Park Road, generally about 50m from the edge of the roadway. In some areas, short lengths of the pathway were up to and exceeding 150m from the road. Areas adjacent to the pathway also included various road turnouts, parking areas, the Jenny Lake Campground, and the GTNP Moose administrative area. The pathway was situated on the western edge of a broad open plain in the valley center, just east of the contiguous forested habitat on the eastern slopes of the Tetons. This open plain was interspersed with stringers of riparian forest along the Snake River and Cottonwood Creek, as well as forested hills such as Timbered Island and Blacktail Butte. Roughly 80% of the pathway traversed sagebrush shrublands, while only about 8% of the pathway ran through conifer or riparian forest habitats. Limited data from 2007 and 2009 indicated non-motorized human use, particularly bicycle traffic, increased significantly along the pathway/roadway corridor following pathway construction (Patrick McGowan, Western Transportation Institute, personal communication), while vehicular traffic counts remained consistent during 2007–2010 (Sawyer et al. 2011).

METHODS

Field methods

Bear trapping began in Jun 2007 and was continued May–Oct in each successive year as needed to maintain a sample of 10–12 collared bears. Bears were trapped using culvert traps in vehicle-accessed areas (Fig. 1). Additional bears were captured during previous studies during 2001–2006. Adult and subadult bears (≥3 years old) were fitted with GPS (global positioning system) store-on-board radio-collars (Telonics, Mesa, AZ, USA). Most transmitters were programmed to collect a GPS location every 2.08 hours, but some earlier collars were programmed with 2.3-, 3.2-, or 3.4-hr fix intervals. Duty cycles were programmed to turn off

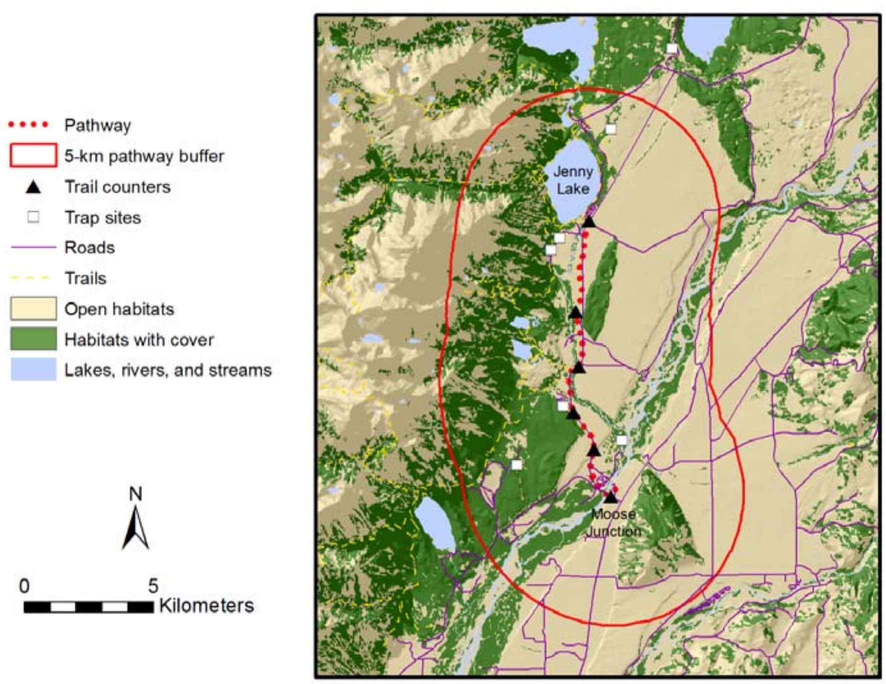

Figure 1. Study area in Grand Teton National Park, centered on the pathway. Habitats with cover were defined as those with vegetation ≥5 m in height and ≥25% horizontal density or vegetation 1-5m in height and ≥50% horizontal density.

between Oct–Nov and Mar–Apr while bears were in winter dens. Transmitters were also fitted with activity sensors. The activity sensor mechanism changed from a mercury switch in the Gen III units to an accelerometer in the Gen IVs. Collars were programmed for automatic timed release, which occurred during late Sep or mid Oct of the year following capture, except in 2010 when collars were timed to release during the same year as capture. Collared bears were monitored by fixed wing aircraft twice monthly during the non-denning season.

Following completion of pathway construction, 6 infrared trail counters were placed at regular intervals along the pathway during 15 May–2 Dec 2009 and 8 May–3 Nov 2010 (Fig. 1). These collected counts of the number of people passing by on the trail by date and hour of day.

Data analysis

We compiled data into a bear location database, where we censored repetitive locations at den sites and locations occurring on the day of capture. We also excluded data from 3 bears that were monitored for <1 month. The only two bears originally captured and translocated for management issues were among these excluded bears, therefore the remaining sample included only research-captured bears. Less than 3% of the remaining successful locations were collected during Mar, Apr, or Nov, so these months were also excluded from all analyses. Several analyses were further confined to summer months, coinciding with peak human use of the pathway.

Our intent was to compare data between the pre-pathway and pathway study periods, but the construction phase presented an interesting challenge to the study design. Construction of the pathway began 9 Jun 2008 and continued until 31 Oct 2008, effectively consuming 1 of the 2 pre-pathway study years. To help detect potential effects of the construction on bear behavior, while maintaining our study design, we defined three study periods: pre-pathway (2001–2007), construction (2008), and pathway (2009–2010).

The area near the pathway represented only a small fraction of the home range for many of the bears; several individuals spent significant amounts of time as far as 40km from the pathway. For analyses of home range, we used all GPS collar locations, regardless of their proximity to the pathway. But for other analyses, we focused on spatial subsets of locations associated with areas closer to the pathway. We used a 2-km buffer around the pathway to represent the zone where bears potentially could be directly influenced by the pathway, based on the median daily home range span of bears (1760m). We used a 5-km buffer around the pathway to represent the larger area where bears were in the vicinity of the pathway, but had the option to enter or leave this zone of influence. We obtained this value by selecting those locations within the 2-km buffer, along with other fixes recorded on the same day, the day prior, and the day following. Among all of these locations, distance from the pathway ranged from 13m to 17.2

km, but 93% of locations were within 5 km of the pathway. These and all other geographic analyses were conducted using ArcGIS 9.3.1 (Esri, Redlands, CA, USA) and statistical analyses were conducted using SPSS 19.0.0 (IBM, Armonk, NY, USA), unless otherwise noted.

Objective 1: Determine the impacts of the pathway on seasonal movements and distribution – We assessed these potential impacts by examining second-order habitat selection, i.e. selection of a home range within a landscape (Johnson 1980). We hypothesized that black bears would react to increasing human activity associated with the pathway by avoiding the vicinity of the path and shifting their home away from the pathway. To test this hypothesis, we calculated 95% Brownian bridge home ranges (Bullard 1991, Horne et al. 2007) using the "brownian.bridge" routine in the "BBMM" package (Nielson et al. 2011) for R (R Development Core Team 2011). This method was most appropriate because it accounted for the sporadic missing locations and serial autocorrelation among the locations (Horne et al. 2007). Pre-screening of the location data indicated fix success was 76% among the entire sample. We estimated annual and summer home ranges for all bears monitored during the pathway period and one or both of the preceding study periods, with a minimum of 100 locations per period. We excluded bears with home ranges >2 km from the pathway from further analyses. Using all of the data, annual ranges for 3 bears were hugely inflated due to very long periods of missed fixes occurring either in early May or late October, probably associated with denning. To obtain more realistic ranges, we removed these lapses at the beginning or the end of the monitoring periods.

We used two characteristics to evaluate spatial shifts in home range locations: minimum distance between the home range edge and the pathway; and percent of the home range that overlapped the 2-km pathway buffer. We ran paired t-tests, with all year-to-year comparisons for each individual, to determine if the mean value differed from 0 ($\alpha = 0.05$).

Objective 2: Determine the impacts of the pathway on habitat use – We assessed this impact by examining third-order habitat selection, i.e. selection of habitat components within the home range (Johnson 1980). We hypothesized that black bears would respond to increasing human activity associated with the pathway by exhibiting greater selection of habitats that provide cover and distance from humans. Specifically, we predicted that:

(1) bears would increase use of areas with higher vegetative cover;
(2) bears would increase use of steeper, more rugged sites; and
(3) bears would decrease use of areas closer to the pathway.

To test this hypothesis, we used the resource selection function (RSF) for GPS fix success (Nielson et al. 2009), which combines a classic logistic discrete-choice model (McDonald et al. 2006) and a GPS fix success model. The discrete-choice model assumes each location of an animal represents a choice from a changing set of options over time. These options are in the form of discrete habitat units, each ascribed with values for the habitat covariates of interest. By incorporating distance from the previous location (i.e. speed of travel), this model limits the "available" habitat for each location to a specific choice-set of habitat units. Thus, resource availability can vary among individuals and over time for the same individual. The discrete-choice model estimates the probability that a unit will be selected from the choice-set on the next choice. The fix success portion of the model attempts to rectify the potential bias associated with habitat-induced signal loss by estimating probability of detection given selection. Use of a fix success model was necessary because previous research has demonstrated that GPS fix success can be highly influenced by the very habitat features identified in our predictions, namely canopy cover (Moen et al. 1996, Heard et al. 2008) and terrain (D'Eon et al. 2002). Using both models, all choices are evaluated simultaneously using maximum likelihood and the final model has coefficients for each of the habitat covariates.

We used a 400- x 400-m grid size for our habitat units, roughly equal to the median distance between two successive locations during mid-summer months. We defined the study area using the 5-km pathway buffer, in order to encompass areas inside and outside of the potential zone of influence. Within this study area, we overlaid the grid and assigned values to each grid cell for 5 covariates: percent cover; percent slope; distance to the pathway; distance to the nearest road; and distance to the nearest trail. Percent cover was calculated as the percent of the habitat unit with suitable vegetative cover, defined as vegetation ≥5 m in height with ≥25% horizontal density or vegetation 1–5 m in height with ≥50% horizontal density (GTNP vegetation map; USGS-NPS 2007). Percent slope was calculated as the mean value for the grid cell, based on a 30-m grid digital elevation map. Distance was measured from the midpoint of the grid cell. We used a binomial variable to distinguish habitat units with the potential for habitat-induced signal loss. We defined them as units with ≥25% north-facing slopes (293^o–68^o) and/or heavy timber (vegetation height ≥15m and horizontal density ≥50%; Schwartz et al. 2009). We entered slope as a quadratic to allow for an asymptote or decline, and we truncated the distance values to a maximum of 2 km. To facilitate computation of likelihoods, we standardized the values for all continuous variables.

For each individual with ≥100 locations/period within the 5-km buffer, we modeled habitat selection for each period during the summer months only. We selected this season because it coincided with peak human use of the pathway and it allowed us to avoid the confounding effects of annual variation in fall mast on habitat use (Lindzey and Meslow 1977, Garshelis and Pelton 1981, Samson and Huot 1998). We calculated a minimum convex polygon home range for each individual based on locations from all periods, and used the corresponding habitat units to model habitat selection for each individual within its own home range. We then averaged model coefficients among individuals for each period and calculated relative habitat selection for all habitat units within the study area. Averaging coefficients across individuals allowed us to develop population-level models (Millspaugh et al. 2006) while properly treating the individual animal as the primary sampling unit (Thomas and Taylor 2006). To map model predictions, habitat units were ranked in 5 quantiles according to their relative probability of selection.

Objective 3: Determine the impacts of the pathway on activity patterns – We hypothesized that black bears would respond to increasing human activity associated with the pathway by reducing their activity in the vicinity of the pathway, especially during hours of peak human use.

Due to the different activity sensors in the Gen III and Gen IV transmitters, data were not directly comparable. Values for activity were 0–0.99 for Gen III transmitters and 0–501 for Gen IV transmitters, and due to differences in distributions, no transformations of the data were successful in equalizing the variation between the two types. Therefore, we converted these continuous variables into a binomial variable signifying active versus inactive. We plotted histograms to help identify a maximum value for inactive locations. The two histograms were similarly shaped, although the Gen III distribution was substantially flatter. Both had two peaks – the larger peak centered on zero and the smaller peak centered over a mid-point value (Fig. 2). We defined the upper limits for inactive locations near the lowest point between these two peaks (0.135 for Gen III and 125 for Gen IV), making sure the proportion of locations falling below the limit were similar (52%) between the two collar types. Using these values, proportion of active locations was nearly identical between the two transmitter types as a function of hour of day (Fig. 3), suggesting the values were roughly equivalent. In addition, our value for the Gen III transmitters was close to the predicted breakpoint between active and resting locations calculated for black bears by Schwartz et al. (2010a) in GTNP.

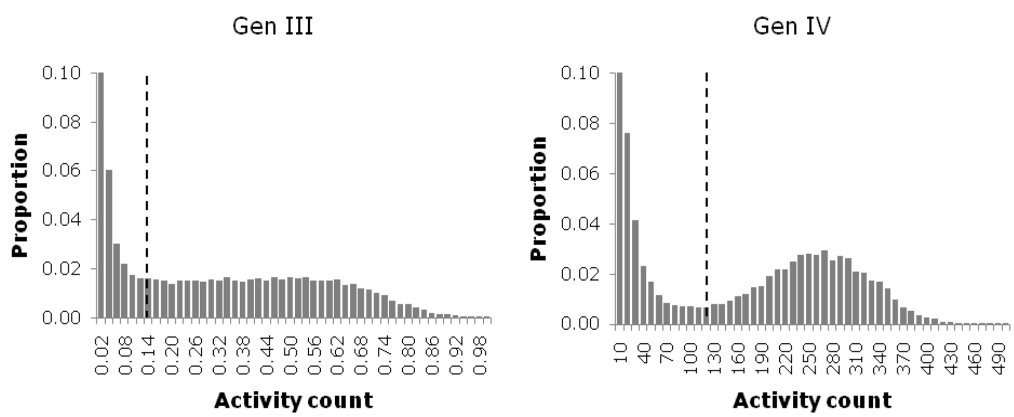

Figure 2. Histograms of activity counts for Gen III (left) and Gen IV (right) transmitters. Vertical dashed lines show designated cut-off between inactive and active locations. Values to the left of the line represented 52% of locations and were considered inactive, while values to the right were considered active.

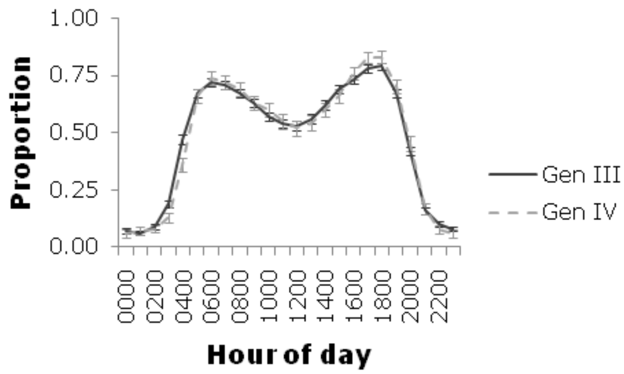

Figure 3. Proportion of locations designated as active (± 95% CI), by hour of day, for Gen III and Gen IV transmitters, after converting the continuous variable into a binomial variable.

Using this binomial variable (active vs. inactive) as a response, we ran logistic regression models with study period as a covariate. Models also included time of day treated as a circular variable (transformed to radians) and then transformed using sin, cosine, and $cosin^2$ to fit the curvilinear shape of the known diel pattern of activity to a linear model (Schwartz et al. 2010a). We included all locations within the 5-km buffer, with corresponding activity data. We ran models on subsets of locations ≤500m, 0.5–2.0 km, and ≥2.0 km from the pathway to examine how behavior differed by distance from the pathway. These analyses were confined to the summer months coinciding with peak human use of the pathway.

<u>Objective 4: Determine the impacts of the pathway on location and frequency of road/pathway corridor crossings</u> – We hypothesized that black bears would respond to increasing human activity associated with the pathway by changing their behavior when crossing the pathway corridor to avoid humans. Specifically, we predicted that:

(1) bears would reduce the frequency of pathway crossings;
(2) bears would change the timing of crossings to coincide with hours of low human use of the pathway; and
(3) bears would exhibit greater selection for habitats providing cover when crossing the pathway.

Using data within the 5-km pathway buffer, we converted the location-point file to a line file, and selected those line segments that intersected the pathway. Using only individuals that were known to cross the pathway, we compared the frequency of crossings/day among periods. For analyses of timing, we selected pathway crossings that had a fix interval of <4 hrs. Assuming a constant rate of speed, we determined the approximate time of pathway crossing, using the distance of the start and end points from the pathway. We compared the proportion of crossings that occurred during hours with different rates of human use, based on the mean number of trail counts by hour of the day. Finally, we divided the pathway into thirty-two 400-m segments and generated a 200-m buffer on each side of the segment using the

"LineSquareBuffer" script for use with ArcView 3.1 (Esri, Redlands, CA, USA). We assigned each cell a value, based on the presence of vegetative cover: 0 = none present, 1 = present on one side of the pathway, and 2 = present on both sides of the pathway. As above, cover was defined as vegetation ≥5 m in height with ≥25% horizontal density or vegetation 1-5m in height with ≥50% horizontal density. We compared frequency of crossings among these cover classes by study period.

Objective 5: Determine the impacts of the pathway on visibility of bears from the road/pathway corridor – We hypothesized that the combined responses of black bears to increasing human activity associated with the pathway would reduce their visibility to human visitors. Specifically, we predicted that:

(1) bears would reduce use of areas within the view shed; and
(2) bears would change the timing of use of areas within the view shed to coincide with hours of lower human use of the pathway.

We constructed a viewshed from the pathway by initially selecting 82 points along the pathway based on changes in slope, direction, and vegetation type to serve as representative views. Viewsheds were then calculated from each point using ArcGIS 3D Analyst and a 10m resolution digital elevation model corrected for 4 height classes of vegetation. Individual viewsheds were calculated out to 3km from the pathway and then merged to form a single viewshed. Finally, we masked some forested polygons on steep slopes where the viewshed function included continuous surfaces of tree tops, where animals would not be visible.

Haroldson and Gunther (2011) documented characteristics of "bear-jams" – roadside viewing opportunities that caused traffic congestion – in Yellowstone National Park during 1990–2004. Median distance between sighted bear(s) and the road was 62m for both black and grizzly bears (n = 3,863), and ≥95% of black bear-jams involved bear(s) <500m from the roadway (n = 2,496). Maximum distance was 1,792m for black bears. Ninety-seven percent of jams occurred between 0700 and 2000 hours. Based on these findings and data on human use of the pathway, we restricted our analyses to daylight hours (0700–2000 hrs), and ran separate analyses for bear locations ≤500m from the roadway and bear locations 0.5–2.0 km from the pathway. Using Chi-square tests, we compared the proportion of bear locations potentially visible to humans by period, and compared the proportion of visible locations occurring during peak and off-peak hours of human use.

Objective 6: Determine the extent to which bears might acclimate to the new pathway over two years of pathway use – When pathway effects were detected in any of the analyses above, we examined data from 2009 and 2010 separately, when possible, to determine if the effects were more pronounced during 2009.

RESULTS

During 2007–2010, 26 bears were captured a total of 40 times. Data from two of these bears and an additional 6 bears were also available from previous capture efforts during 2001-2006. Data from 29 (11F, 18M) bears were used in analyses; 17 bears monitored during one study period, 9 bears monitored during 2 study periods, and 3 bears monitored during all 3 study periods (Fig. 4). Varying numbers of bears were dropped from particular analyses due to missing activity data, too few locations for the season or location of interest, or other considerations. A total of 62,215 successful fixes were obtained, with 51% occurring within the 5-km pathway buffer, 17% occurring within the 2-km pathway buffer, and 2% occurring within the 500-m pathway buffer.

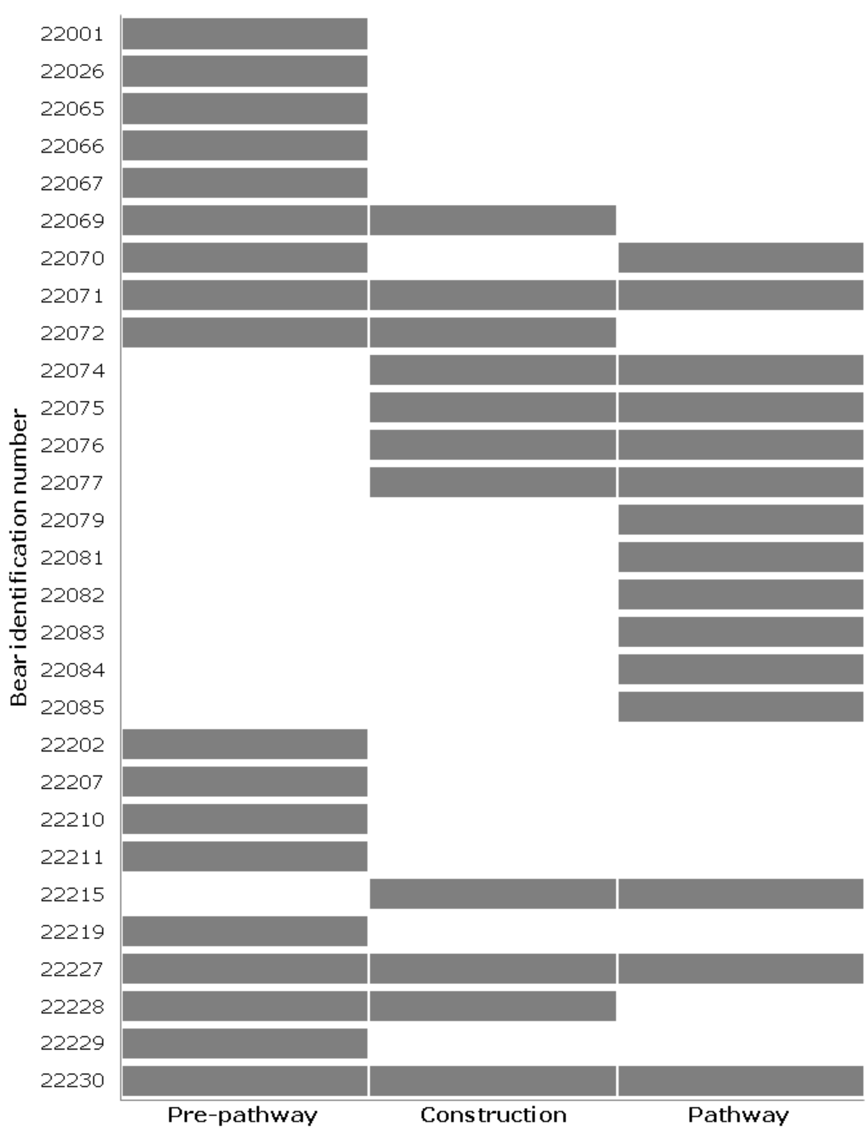

Figure 4. Duration of GPS monitoring for individual black bears, relative to study periods: pre-pathway (2001–2007); construction (2008), and pathway (2009–2010).

Human use of the pathway

Although construction work often involved heavy equipment and vehicles, the overall presence was more spatially and temporally restricted than subsequent visitor use. Comparing 6 sections of the pathway associated with the trail counters, visitors used all sections of the pathway during 96% of days, but construction work occurred on ≥1 section during only 70% of days and on all sections during only 6% of days. On active days, 1 to 7 sites were under construction, each ranging from 50m to 7.4 km in length. A typical day involved a mean of 3.7 sites under construction, with a median length of only 250m.

Counts of humans using the pathway ranged from 0 to 148 detections/counter/hour, and mean values varied across months and hours of the day (Fig. 5). Mean number of detections peaked during Jul and Aug on a semimonthly basis. We defined the peak summer period of human use as 15 Jun–30 Aug, when mean trail counts were ≥5 detections/hr. Mean number of detections peaked during mid-day on an hourly basis. We defined peak hours of human use as 1100-1600 hrs, when mean trail counts were >10 detections/hr. Mean trail counts were 1–10/hr during morning (0700-1000 hrs) and evening (1700-2000 hrs) hours, and <1/hr during nighttime hours (2100–0600 hrs).

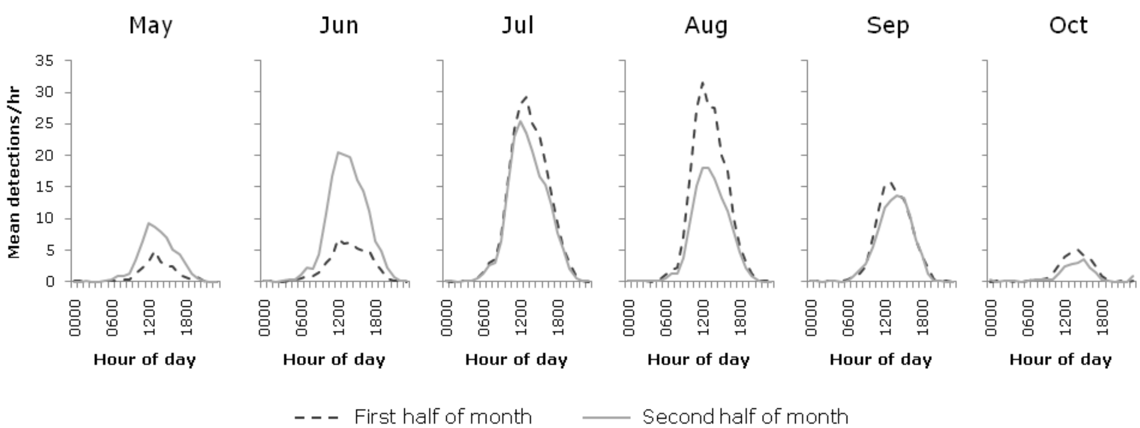

Figure 5. Mean counts of human pathway users from infrared trail counters, by hour and half month, 2009–2010.

Impacts on black bears

<u>Objective 1: Determine the impacts of the pathway on seasonal movements and distribution</u> – We estimated a total of 27 annual (May–Oct) home ranges for 9 (4F, 5M) individuals: 2 bears monitored during the pre-pathway and pathway periods, 4 bears monitored during the construction and pathway periods, and 3 bears monitored during all three periods. We estimated a total of 25 summer (15 Jun-30 Aug) home ranges for 8 (4F, 4M) individuals: 2 bears

monitored during the pre-pathway and pathway periods, 3 bears monitored during the construction and pathway periods, and 3 bears monitored during all three periods. Minimum distance from the outer 95% home range contour to the pathway ranged from 0 to 7.0 km for annual ranges and from 0 to 6.8 km for summer ranges. Percent overlap with the 2.0-km pathway buffer ranged from 0 to 49% for annual ranges and 0 to 55% for summer ranges.

Comparing pathway-period ranges to pre-pathway ranges, approximately half of bears shifted their home ranges 0.05–7.0 km closer to the pathway, while a smaller proportion shifted their home ranges 0.2–6.8 km further away from the pathway. One bear had home ranges that directly overlapped the pathway during both periods (Appendix 1). Mean pair-wise differences in distance did not differ from 0 among all valid year-to-year comparisons for annual or summer ranges (Table 1). Comparing the same periods, most bears increased the proportion of their home range that overlapped the 2-km pathway buffer by 2–28%, while 1 bear decreased overlap by 1–4% (Appendix 2). On average, overlap of the buffer area during the pathway period was 8% higher for annual ranges and 13% higher for summer ranges (Table 1, Fig. 6).

Comparing pathway-period ranges to construction-period ranges, some bears shifted their home ranges 0.5–2.2 km closer to the pathway, others shifted their home ranges 0.1–1.7 km further from the pathway, and 1 bear shifted its home ranges 0.2–0.5 km further from the pathway during 2009 and 0.8–1.0 km closer to the pathway during 2010. Still other bears had home ranges that directly overlapped the pathway during both periods (Appendix 1). Mean

Table 1. Mean pair-wise differences in home range characteristics between the pathway period and the pre-pathway period, and between the pathway period and the construction period, for bears monitored during both periods. Distance to the pathway was the minimum distance between the outer contour of a 95% Brownian bridge home range and the pathway. Percent overlap was the percent of the home range that overlapped the 2-km pathway buffer. Number of bears represents the sample size of individuals, while the degrees of freedom (df) reflect the number of valid year-to-year comparisons among these individuals.

Characteristic	Season	Period compared to pathway period	No. bears	Mean	SE	*t*	df	*P*
Distance (m)	May-Oct	Pre-pathway	5	1342.7	3101.9	1.2	7	0.26
		Construction	7	-320.2	716.2	-1.5	11	0.15
	15 Jun-30 Aug	Pre-pathway	5	1093.6	1135.4	1.0	7	0.37
		Construction	6	-416.7	219.8	-1.9	10	0.09
Percent overlap	May-Oct	Pre-pathway	7	0.08	0.10	2.2	7	0.07
		Construction	7	-0.002	0.10	-0.1	11	0.95
	15 Jun-30 Aug	Pre-pathway	5	0.13	0.04	2.8	7	0.03
		Construction	6	0.02	0.03	0.7	10	0.53

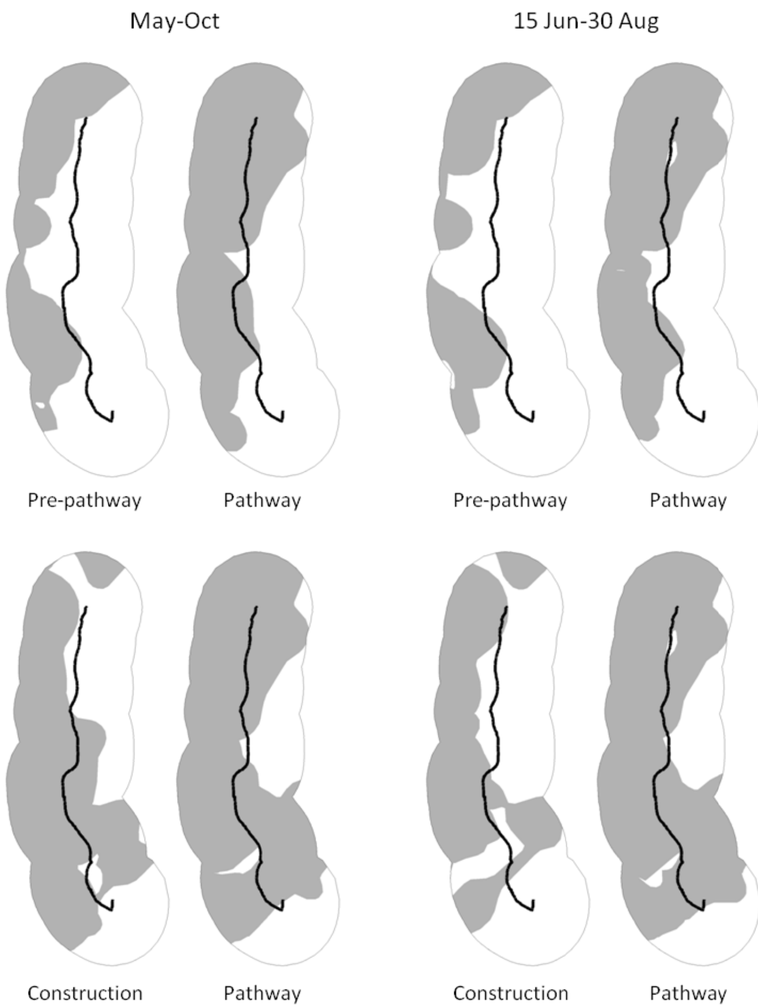

Figure. 6. Pair-wise comparison of overlap of the 2-km pathway buffer by composite 95% Brownian bridge home ranges. Pairs depict composites of home ranges for the same individuals monitored during the pre-pathway and pathway periods (top) or the same individuals monitored during the construction and pathway periods (bottom). The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

pair-wise difference in distance did not differ from 0 for annual ranges (Table 1). For summer ranges, the mean pair-wise difference in distance was -416.7 m, indicating, on average, bears moved closer to the pathway during the pathway period. Comparing the same periods, most bears increased overlap of the pathway buffer by 1-15%, while a few bears decreased overlap by 3–21% (Appendix 2). On average, mean pair-wise difference in overlap did not differ from 0 for annual or summer ranges (Table 1, Fig. 6).

Objective 2: Determine the impacts of the pathway on habitat use – Individual models of habitat selection were estimated for 10 (7F, 3M) bears during the pre-pathway period (Appendix 3). Nine (90%) bears had positive coefficients for percent cover and 8 (80%) bears had positive coefficients for slope, indicating most bears selected for higher cover and higher slopes. Six (60%) bears had positive coefficients for distance to the pathway, indicating selection both for and against areas near the pathway. Only 4 (40%) and 1 (10%) bear(s) had positive coefficients for distance to roads and trails, respectively, indicating most bears selected for areas closer to these human travel corridors. Six (60%) of bears had positive coefficients for the signal block covariate, indicating the fix-success model was helpful for estimating habitat selection.

Individual models were estimated for 9 (6F, 3M) bears during the construction period (Appendix 3). All 9 (100%) bears had positive coefficients for percent cover and slope, indicating selection for higher cover and higher slopes. Five (56%) bears had positive coefficients for distance to pathway and distance to roads, indicating selection both for and against areas closer to the pathway and roads. Only 2 (22%) bears had positive coefficients for distance to trails, indicating most bears selected for areas closer to trails. Only 2 (22%) of bears had positive coefficients for signal block, indicating fix-success was not very important for estimating habitat selection.

Individual models were estimated for 8 (5F, 3 M) bears during the pathway period (Appendix 3). Seven (88%) bears had positive coefficients for percent cover and 8 (100%) had positive coefficients for slope, indicating most bears selected for higher cover and higher slopes. Seven (88%) bears had positive coefficients for distance to pathway, indicating most bears selected for areas further from the pathway. Four (50%) bears had positive coefficients for distance to road, indicating selection both for and against areas near roads. Again, only 2 (25%) had positive coefficients for distance to trails and signal block, indicating most bears selected for areas closer to trails and fix-success was not very important for estimating habitat selection.

Table 2. Coefficients for population-level models of habitat selection for black bears located within 5 km of the pathway, during the pre-pathway (2002–2007), construction (2008), and pathway (2009–2010) periods. Analyses were restricted to mid-summer months (15 Jun–30 Aug), coinciding with peak human use of the pathway. Population-level models represent averaged coefficients from 10, 9, and 8 individual models for each period, respectively.

		Pre-pathway		Construction		Pathway	
Model	Covariate	β	SE	β	SE	β	SE
Discrete-choice	Distance from last	-3.30	0.13	-3.32	0.12	-3.57	0.10
	Percent cover	0.55	0.10	0.44	0.10	0.34	0.07
	Distance to pathway	-0.01	0.24	0.17	0.20	0.18	0.22
	Distance to road	0.09	0.17	0.03	0.15	-0.10	0.16
	Distance to trail	-0.37	0.16	-0.23	0.13	-0.21	0.12
	Slope	0.88	0.41	0.92	0.40	0.92	0.33
	$Slope^2$	-1.26	0.46	-0.90	0.44	-0.93	0.34
Fix-success	Intercept	1.73	0.26	1.52	0.24	1.43	0.16
	Signal block	-0.30	0.43	0.40	0.43	0.39	0.37

Averaged population-level models (Table 2) indicated that bears tended to select for areas with higher cover, with higher slopes, and closer to trails during all study periods. Selection for areas further from the pathway was more apparent during the construction and pathway periods compared to the pre-pathway period. Mapped predictions from these averaged models showed only minor differences in the spatial distribution of habitat units ranked according to their relative probability of selection (Fig. 7)

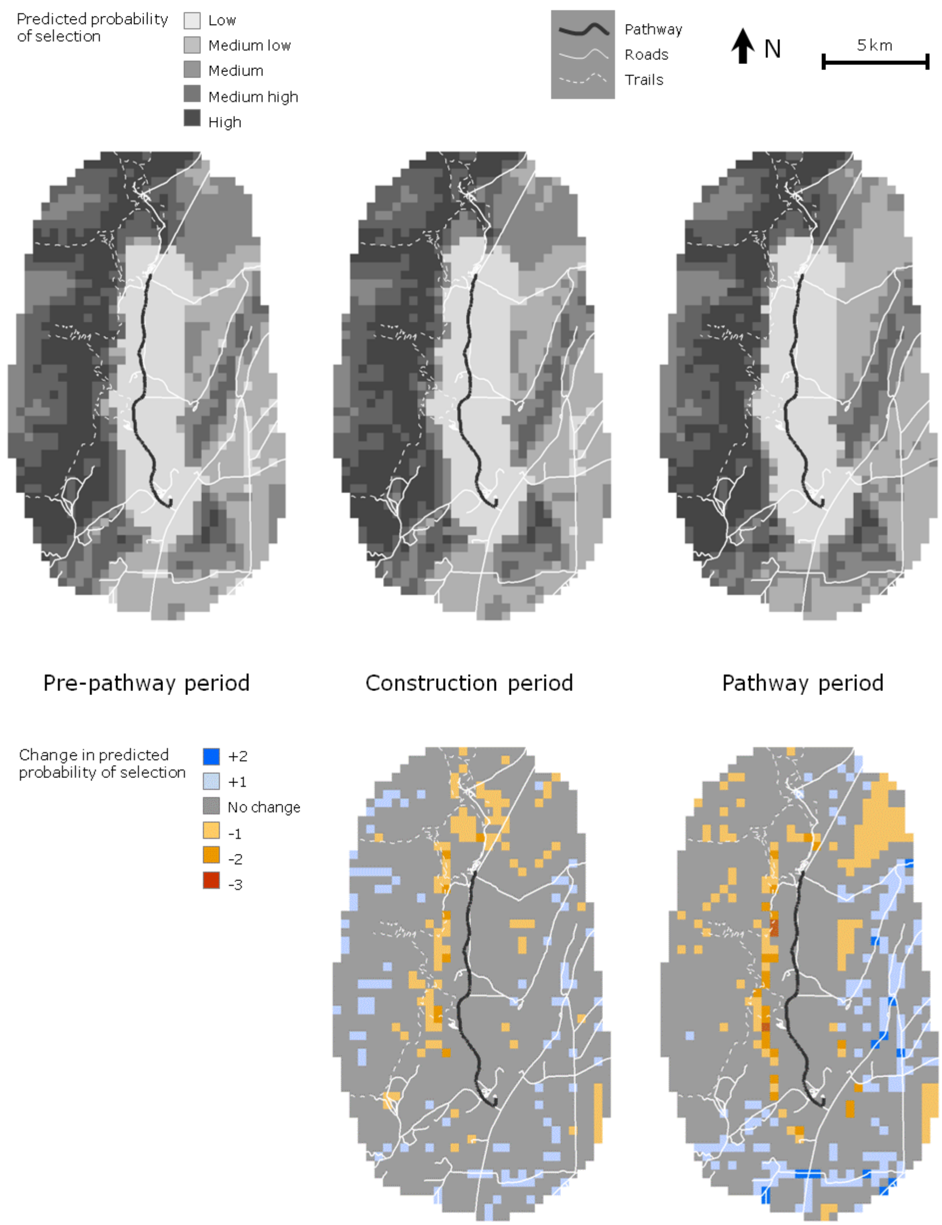

Figure 7. Relative predicted probability of selection (top) for habitat units within 5-km of the pathway, during the pre-pathway, construction, and pathway periods; and predicted change in relative probability of selection as compared to the pre-pathway period (bottom).

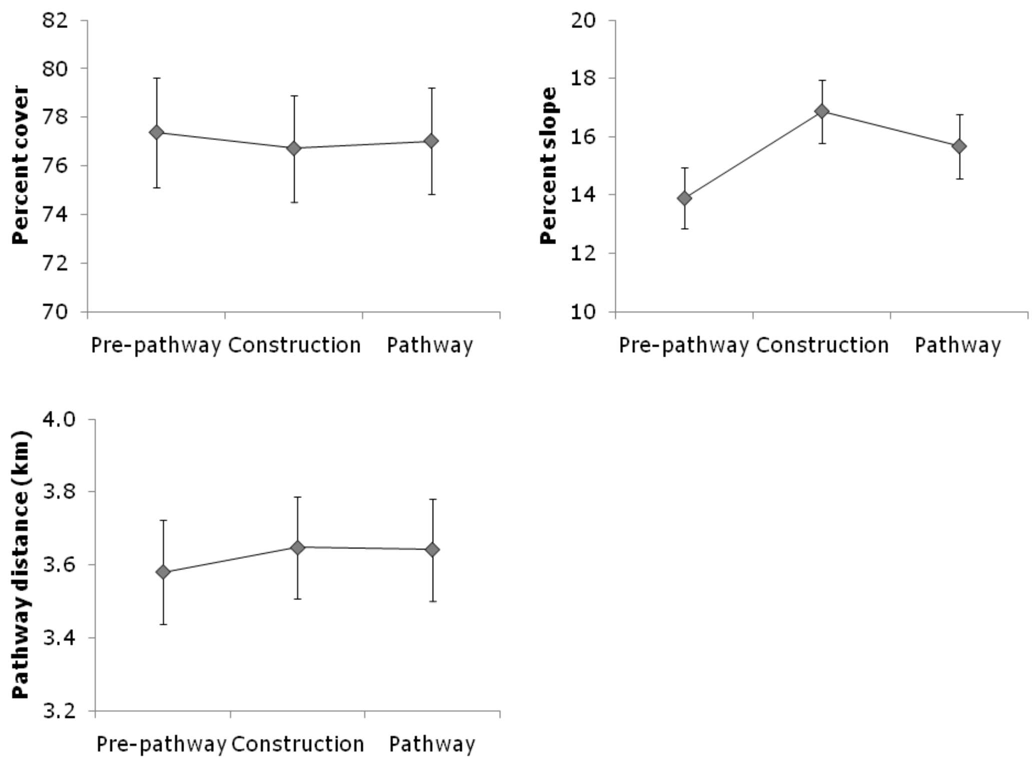

Figure 8. Mean (± 95% CI) percent cover, percent slope, and distance from pathway for habitat units ranked in the quantile with the highest estimated relative probability of selection from population-level models during the pre-pathway, construction, and pathway periods.

Within 500m of the pathway, 100% of habitat units had the lowest probability of selection during all three periods. Within 0.5–2 km of the pathway, 62% of units had the lowest probability of selection during the pre-pathway period, compared to 68% during the construction period and 73% during the pathway period (X^2_8 = 17.0, *P* = 0.03). At distances >2 km from the pathway, <3% of units had the lowest probability of selection during all periods, and frequencies of units with higher probabilities did not differ among periods (X^2_6 = 1.2, *P* = 0.98).

Among the quantile of habitat units with the highest probability of selection, neither mean distance from the pathway nor mean percent cover differed among periods (P ≥ 0.76; Fig. 8). Mean slope was higher during the construction and pathway periods, compared to the pre-pathway period ($F_{2,882}$ = 7.3, *P* = 0.001).

<u>Objective 3: Determine the impacts of the pathway on activity patterns</u> – Among locations within 5 km of the pathway corridor, we had valid activity data for 20 (9F, 11M) bears. Pooling all periods, bears were most active when located 0.5–2.0 km from the pathway (60%), least

active within 500m of the pathway (54%), and active at an intermediate level when >2.0 km from the pathway (58%; X^2_2 = 10.4, *P* = 0.005). Bears were also less active during the pre-pathway period (54%), compared to the construction (59%) and pathway (60%) periods (X^2_2 = 37.9, *P* <0.001). These differences did not appear correlated to differences in sex ratio or transmitter type.

Using logistic regression to examine diel patterns of activity, we examined the interaction term period*sin(radian[hr])^2 to determine if bears responded to daily variation in human use of the pathway. This quadratic term estimates the inflection point and depth of the midday decline in activity. Within 500m of the pathway, bears were less likely to be active during midday hours and more likely to be active at dawn and dusk during the pathway period, when compared to the pre-pathway period ($Wald_{1,489}$ = 9.3, *P* = 0.002) and the construction period ($Wald_{1,489}$ = 8.1, *P* = 0.004; Fig. 9). When bears were 0.5–2.0 km from the pathway, no difference in the diel

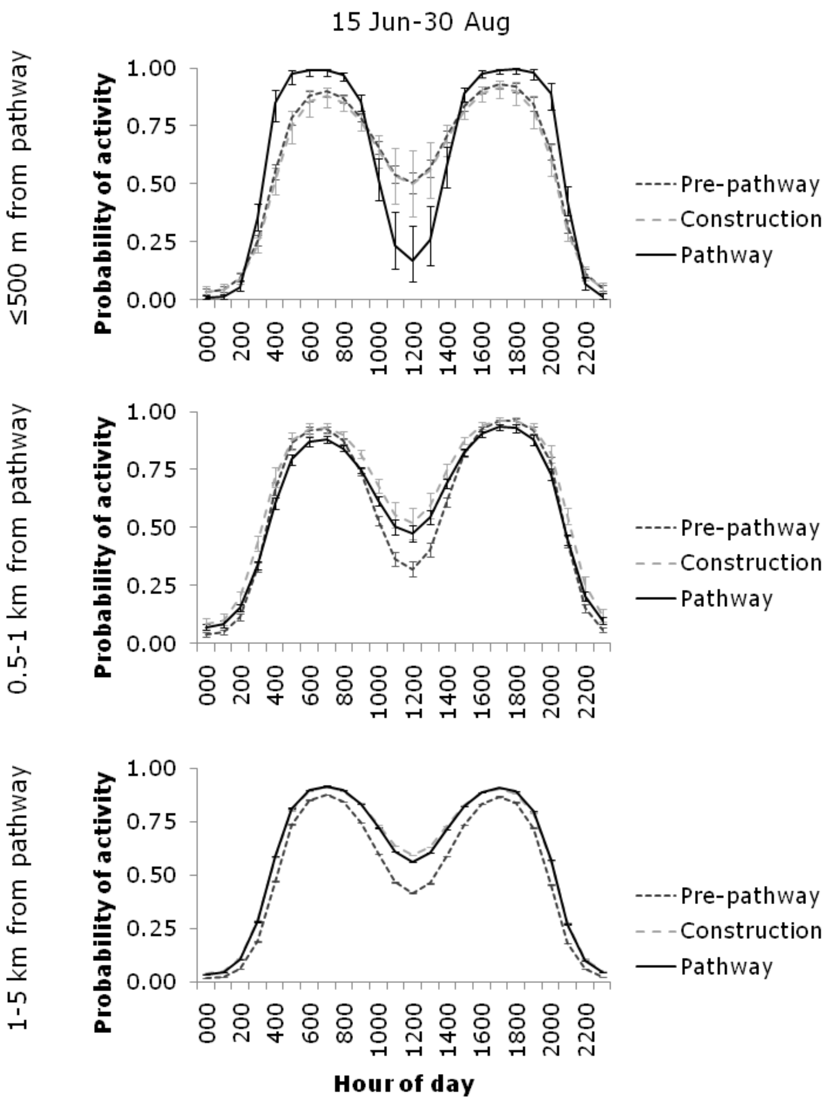

Figure 9. Predicted probability of activity (± 95% CI), by hour of day and study period, within three distances from the pathway: ≤500 m (top), 0.5-2 km (center), and 2–5 km (bottom). The dates 15 Jun–30 Aug coincide with peak human use of the pathway.

pattern was detected comparing the pathway period to the construction period ($Wald_{1,3617}$ = 1.0, P = 0.33), but bears were less active at midday during the pre-pathway period ($Wald_{1,3617}$ = 6.9, *P* = 0.009). When bears were >2.0 km from the pathway, no difference in the diel pattern was detected comparing the pathway period to the pre-pathway period ($Wald_{1,10907}$ = 0.007, P = 0.93), although bears were less active overall during the pre-pathway period. Bears were slightly more active at midday during the construction period ($Wald_{1,10907}$ = 3.5, *P* = 0.06).

<u>Objective 4: Determine the impacts of the pathway on location and frequency of road/pathway corridor crossings</u> – Crossings of the pathway/road corridor were extremely rare. Among the subsample of locations within 5 km of the pathway, only 121 crossings were observed among >29,000 locations. For our sample of 28 (10F, 18M) bears, this equated to 0.1 crossing per day, with a range of 0–3. Crossings occurred on approximately 11% of days during May–Oct. Crossings were most frequent during Jun and least frequent during May and Oct. Nine (3F, 6M) individuals were observed to cross the pathway corridor, but 79% of crossings involved just two individuals (2F). Eighty-eight percent of crossings had a fix interval of 1 and median time between start and end points was 2.08 hrs.

Among bears known to cross the pathway corridor, number of crossings ranged from 0 to 3 per day during May–Oct and 0 to 2 per day during 15 Jun–30 Aug. Mean number of crossings/day did not differ between the pre-pathway and pathway periods, but a decrease was detected during the construction period during May–Oct ($F_{2,\,875}$ = 4.5, *P* = 0.01) and during 15 Jun-30 Aug ($F_{2,\,493}$ = 2.8, *P* = 0.06; Fig. 10).

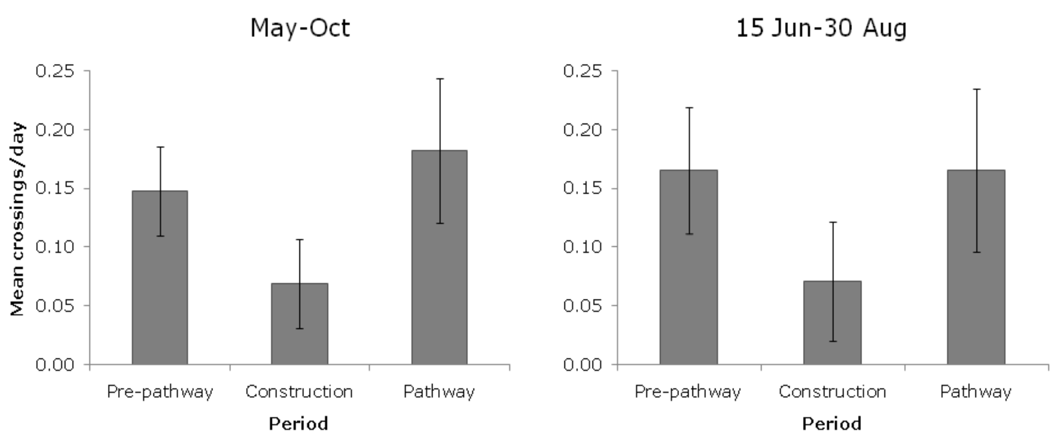

Figure 10. Mean number of pathway crossings/day (± 95% CI), by study period, for bears known to have crossed the pathway. This study sample included bear-days when bears were located within 2 km of the pathway. The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

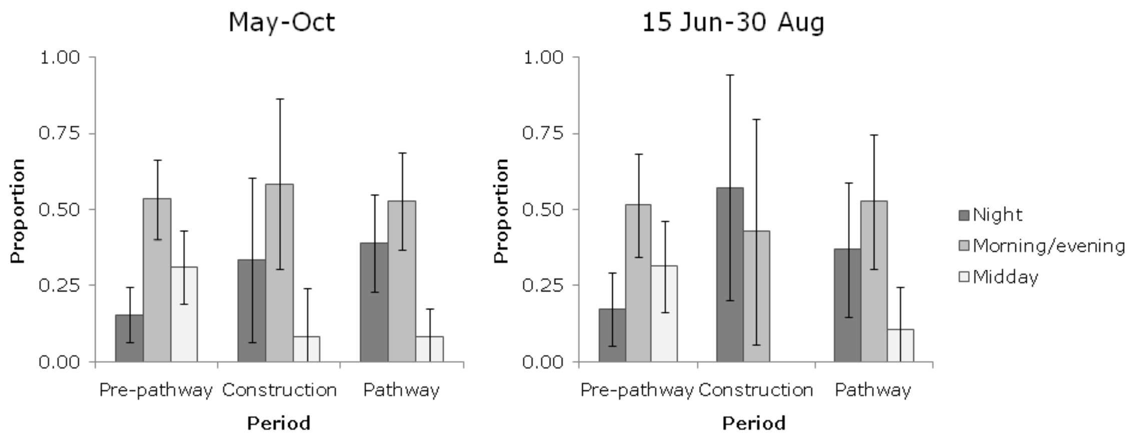

Figure 11. Proportions of pathway crossings (± 95% CI), by study period, that occurred during night (2100–0600 hrs), morning/evening (0700–1000 and 1700–2000 hrs), and midday (1100–1600 hrs). Midday hours coincide with peak human use of the pathway, while night hours coincide with minimal use. The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

Crossings occurred throughout the hours of the day, with a peak at approximately 1800 hours. We detected changes in the proportion of crossings that occurred within different diel periods during May–Oct ($X^2_4 = 11.7$, $n = 106$, $P = 0.02$) and 15 Jun-30 Aug ($X^2_4 = 8.5$, $n = 61$, $P = 0.08$; Fig. 11). Frequency of morning/evening crossings was similar among periods, but frequency of night crossing increased and frequency of midday crossings decreased during the construction and pathway periods compared to the pre-pathway period.

Of the 32 sample units along the pathway corridor, 25% had no vegetative cover, 38% had cover on one side of the pathway, and 38% had cover on both sides of the pathway. Overall, 57% of crossings occurred in the units with vegetation on both sides of the pathway. Proportion of crossings within these units increased during the construction and pathway period, when compared to the pre-pathway period, during May–Oct ($X^2_4 = 21.9$, $P < 0.001$) and during 15 Jun–30 Aug ($X^2_4 = 9.4$, $P = 0.05$; Fig. 12).

<u>Objective 5: Determine the impacts of the pathway on visibility of bears from the road/pathway corridor</u> – Location data from 16 (8F, 8M) bears were available for view shed analyses within 500m of the pathway. Fifty-eight percent of this area was visible to humans on the roadway, offering good opportunities to view wildlife with the naked eye. Pooling all periods, only 8% of bear locations within this range were potentially visible to humans. For our sample of 16 bears, this equated to 0.2 potential sightings per day, with a range of 0–2. Potential sightings occurred on approximately 18% of days during May–Oct. Proportion of visible locations was highest during Aug.

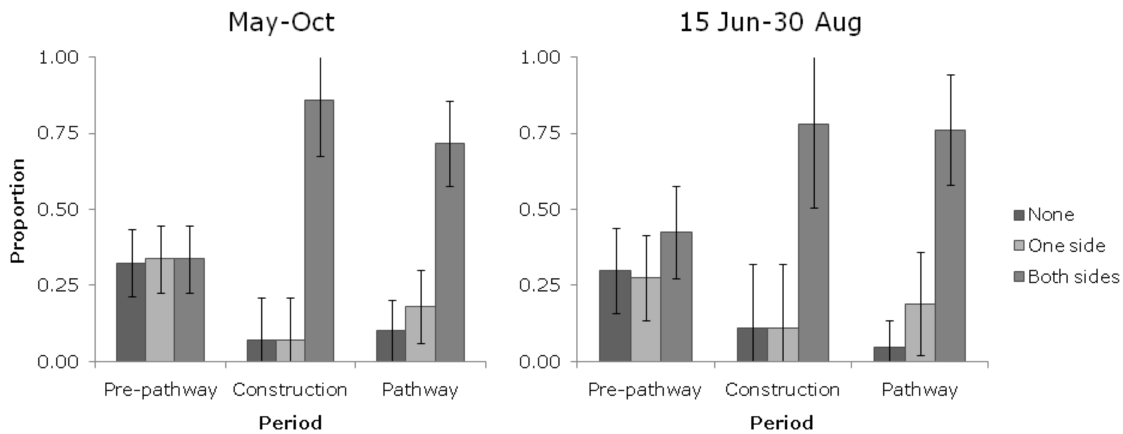

Figure 12. Proportion of pathway crossings (± 95% CI), by study period, that occurred within sample units with no vegetative cover, vegetative cover on one side of the pathway, and vegetative cover on both sides of the pathway. Cover was defined as vegetation ≥5 m in height with ≥25% horizontal density or vegetation 1-5m in height with ≥50% horizontal density. The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

Location data from 28 (10F, 18M) bears were available for view shed analyses 0.5–2.0 km from the pathway. Twenty-four percent of this area was visible to humans on the roadway, offering opportunities to view wildlife primarily with the aid of binoculars or spotting scopes. Pooling all periods, only 5% of bear locations within this range were potentially visible to humans. For our sample of 28 bears, this equated to 0.3 potential sightings per day, with a range of 0–7. Potential sightings occurred on approximately 20% of days during May–Oct. Proportion of visible locations was highest during May, Jun, and Oct.

Within 500m of the pathway, we detected no difference in the proportion of bear locations potentially visible to humans among periods during May–Oct (X^2_2 = 0.4, n = 567, P =0.98) or during 15 Jun–30 Aug (X^2_2 = 0.4, n = 285, P =0.81; Fig. 13). Within 0.5–2.0 km of the pathway, the proportion of bear locations visible to humans was higher during the pre-pathway period than during the construction or pathway periods during May–Oct (X^2_2 = 27.1, n = 5799, P < 0.001), but the proportions did not differ among periods during 15 Jun–30 Aug (X^2_2 = 3.1, n = 2776, P =0.22).

Potentially visible bear locations were observed during all daylight hours and no diel pattern was evident. Thirty-seven percent of these bear locations occurred during the mid-day hours (1100–1600 hrs) coinciding with peak human use of the pathway, while 63% occurred during the morning and evening hours (0700-1000 and 1700-2000 hrs). We detected no difference in these proportions among periods, during May–Oct (X^2_2 = 1.0, n = 325, P = 0.62) or during 15 Jun–30 Aug (X^2_2 = 0.4, n = 130, P = 0.83; Fig. 14).

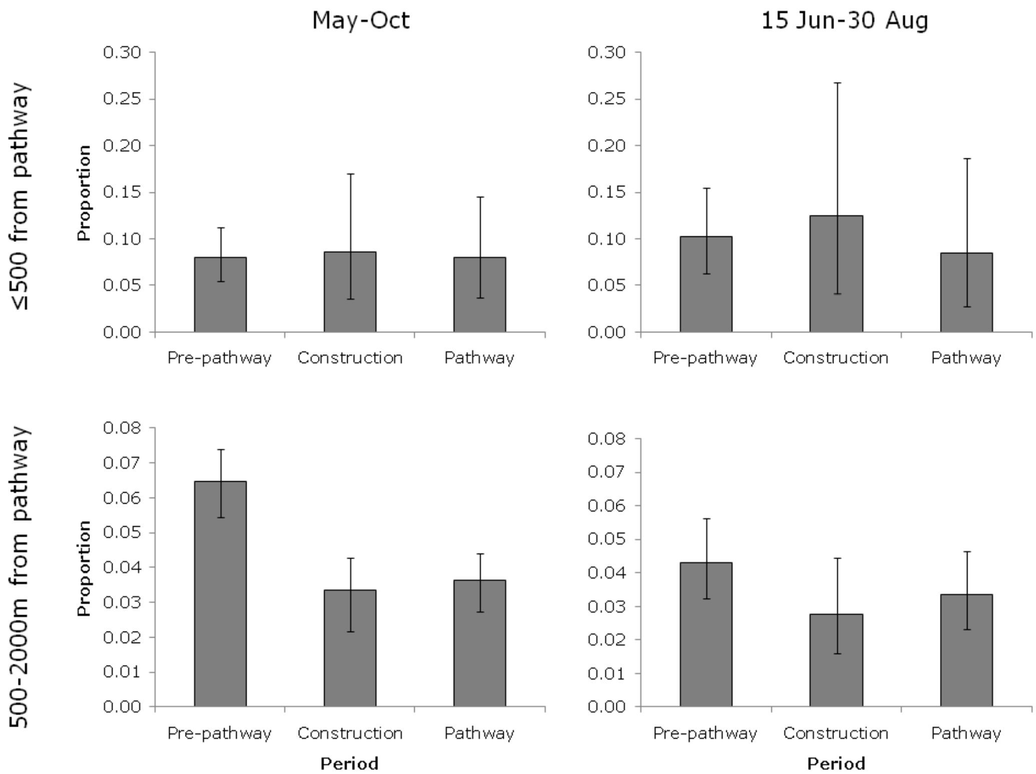

Figure 13. Proportions of bear locations (± 95% CI), by period, that were potentially visible to humans on the roadway. Bears within 500m of the pathway (top) were likely visible to humans with the naked eye, while bears 0.5–2.0 km (bottom) were likely visible with the aid of binoculars or spotting scopes. The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

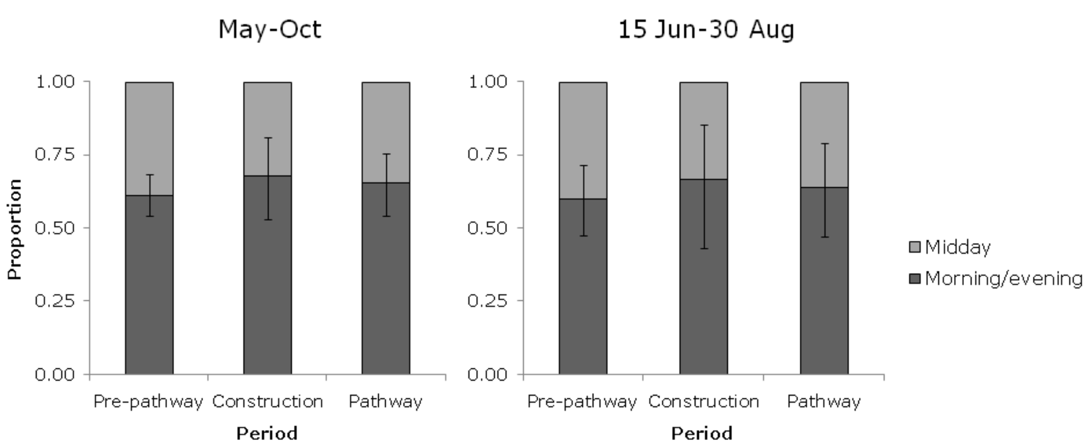

Figure 14. Proportions of roadway-visible bear locations (± 95% CI), by study period, that occurred during midday (1100–1600 hrs) and morning/evening (0700–1000 and 1700–2000 hrs). Potentially visible locations were ≤2 km from the pathway, fell within a calculated view shed, and occurred during daylight hours. Midday hours coincided with peak human use of the pathway. The months May–Oct (left) represent the full period of monitoring, while the dates 15 Jun–30 Aug (right) coincide with peak human use of the pathway.

Objective 6: Determine the extent to which bears might acclimate to the new pathway over two years of pathway use – There was a marginal difference in the diel pattern of activity between 2009 and 2010, within 500m of the pathway. Predicted levels of activity were lower during midday hours and higher at dawn and dusk during 2009 than during 2010 ($Wald_{1,125}$ = 3.0, *P* = 0.08), however confidence intervals overlapped. Comparing pathway/roadway crossings during 2009 versus 2010, we detected no changes in the proportion that occurred within different diel periods during May–Oct (X^2_2 = 0.7, *n* = 39, *P* = 0.72) or 15 Jun-30 Aug (X^2_2 = 0.3, *n* = 21, *P* = 0.86). Neither did we detect any changes in the proportion that occurred within units with different degrees of vegetative cover during May–Oct (X^2_2 = 2.9, *n* = 39, *P* = 0.24) or during 15 Jun–30 Aug (X^2_2 = 3.0, *n* = 21, *P* = 0.22).

DISCUSSION

We were able to reject our first hypothesis, as evidence did not indicate that bears shifted their home ranges to avoid humans using the pathway. Given that many home range boundaries, even before pathway construction, coincided with the conifer edge located 100–1000m west of the pathway, this result was not surprising. This timbered edge likely would have represented the edge of typical bear activity, with or without the presence of the pathway, or possibly even the road. Our habitat selection results also support this idea, in that all of the habitat units within 500m of the pathway had the lowest relative probability of use, even during the pre-pathway period. In addition, evidence failed to support our prediction that the frequency of pathway/roadway crossings would decrease in response to human use of the pathway. Frequency did not differ between the pre-pathway and pathway periods, although a drop in crossings was observed during the construction period. Adult black bears are known to exhibit great fidelity to their home ranges, especially during spring and summer (Costello 2010). As bears living in this area would have already been accustomed to some human activities, it does not appear that the increased human presence associated with the pathway was enough to cause them to abandon a portion of their home range, even if it meant crossing the pathway/roadway corridor.

Instead, bears altered the way they used the areas near the pathway. Although general patterns of habitat use were very similar during all three study periods, there were some subtle changes over time that marginally supported our second hypothesis, and two of the three predictions. Across the three study periods, an increasing proportion of individuals displayed a positive coefficient for distance to pathway, indicating greater selection for areas further from the pathway. A higher proportion of individuals also selected for steeper slopes during the construction and pathway periods, and mean slope of highly selected habitat units was significantly higher during these periods than during the pre-pathway period. An increasing trend in selection for vegetative cover was not observed, but it should be noted that a majority of bears selected for higher vegetative cover during all three periods, perhaps leaving little room for increase. Similarly, as predicted, bears were increasingly likely, over the three periods, to cross the pathway/roadway corridor in areas providing vegetative cover.

Evidence in support of our third hypothesis was strong and indicated bears also altered their activity due to human use of the pathway. The estimated effect size was large, but the zone of influence was limited. Within 500m of the pathway, the already crepuscular pattern of activity was further exaggerated during the pathway period, whereby bears decreased their activity by approximately 30% during midday when human use of the pathway peaked, and increased their activity by about 10% during morning and evening when human use was much lower. Bears were nearly 100% active during these dawn and dusk hours. Outside of this distance band, this effect was not apparent. In fact, at intermediate distances, bears were about 12% less active midday during the pre-pathway period. As predicted, timing of roadway/pathway crossings also shifted toward times when fewer people were utilizing the pathway. Proportion of crossings that occurred during nighttime hours increased 17–40% during the construction and pathway periods.

Comparing the most salient altered behaviors across the two years of the pathway period, we found little evidence to suggest that bears had acclimated to human use of the pathway over time. The changes we observed in the timing and habitat selection of pathway/roadway crossings were virtually identical during 2009 and 2010. The observed shift toward lower activity during peak midday hours of human use was more extreme during 2009 than during 2010, however confidence intervals overlapped, and a return to the pre-pathway pattern of activity was not observed during 2010. Perhaps this hints at a trend toward acclimation, but more study over a longer period would be needed to verify this result.

Due to the hazardous and difficult winter conditions in GTNP, and the high potential for failure to access den sites, we chose to utilize radio-collars with timed release, rather than retrieve and replace collars in dens. As this meant continuous monitoring of individuals was contingent on their recapture, our resulting sample varied across years and study periods. Since we were unable to maintain the identical sample of bears during all study periods, we cannot discount the role of individual variation in explaining some of the differences we observed among the study periods, therefore our results must be viewed with some caution. Nonetheless, the weight of evidence, and the similarity of results among various tests, indicate that the effects we observed were likely real.

The behavioral changes of bears in close proximity to the pathway allow them to continue to make use of these areas, for foraging or traveling, while simultaneously reducing their encounter rates with humans. Given that the pathway area represents a peripheral portion of most bear home ranges, these tactics to accommodate humans likely have little overall impact on bear fitness. However, this may not be the case if future proposed pathways traverse quality timbered habitat at the core of bear home ranges. If the same behavioral changes occurred, the compounded effects might reduce the ability of bears to utilize habitats adjacent to the pathway and potentially reduce bear fitness.

Consistent with the bear's continued, albeit altered use of areas near the pathway/roadway corridor, their potential visibility park visitors did not change over time. Thus, at this location, it appears the Park was successful at introducing a new human activity, without compromising existing levels of positive human-black bear interactions (i.e. viewing). But, the shift of bear activity toward morning, evening, and nighttime hours, when close to the pathway, may have consequences for negative human-bear interactions (i.e. encounters and vehicle collisions) and bear survival. These behavioral changes likely help minimize overall human-black bear encounter rates on the pathway, but they may also increase the likelihood that the infrequent encounters would occur predominantly during the low light conditions of dawn and dusk. The shift toward more pathway/roadway crossings occurring during dark nighttime hours may also increase the odds of vehicle collisions. The observed low frequency of pathway crossings at this location suggests that vehicle collisions would still be a rare event. However, crossings of proposed future pathways, traversing quality bear habitat, would likely be more frequent, and the potential increased risk to bears in those areas might affect population survival rates.

To a lesser degree, black bear encounters with grizzly bears might also increase due to temporal shifts in activity near the pathway. Schwartz et al. (2010a) showed that black bears sympatric with grizzly bears in GTNP were more day-active than allopatric black bears. They hypothesized this was a behavioral strategy for avoiding grizzly bears, which occasionally killed black bears in their study. As grizzly bears continue to re-colonize the southern reaches of the park, black bear behavioral changes in response to the pathway could put them at higher risk of predation by grizzly bears, but only if grizzlies also frequent areas near the pathway.

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APPENDICES

Appendix 1. Year-to-year differences in minimum distance (km) of 95% Brownian bride home range contours to the pathway, for individual bears monitored during the pre-pathway and pathway periods, and/or during the construction and pathway periods.

					May-Oct			15 Jun-30 Aug		
Bear	Period (a)	Period (b)	Year (a)	Year (b)	Distance (a)	Distance (b)	Difference (b-a)	Distance (a)	Distance (b)	Difference (b-a)
22070	Pre-pathway	Pathway	2007	2009	0	0.01	0.01	0.65	0	-0.65
22071	Pre-pathway	Pathway	2007	2009	0	0	0	0	0	0
22071	Pre-pathway	Pathway	2007	2010	0	0	0	0	0	0
22071	Construction	Pathway	2008	2009	0	0	0	0	0	0
22071	Construction	Pathway	2008	2010	0	0	0	0	0	0
22075	Construction	Pathway	2008	2009	2.06	0.95	-1.11	2.37	1.69	-0.67
22075	Construction	Pathway	2008	2010	2.06	0.19	-1.87	2.37	0.18	-2.19
22076	Construction	Pathway	2008	2009	0	0	0	0	0	0
22076	Construction	Pathway	2008	2010	0	0	0	0	0	0
22077	Construction	Pathway	2008	2009	0	0	0	0	0	0
22215	Construction	Pathway	2008	2009	0.29	1.25	0.96	0.87	1.40	0.54
22215	Construction	Pathway	2008	2010	0.29	0.12	-0.17	0.87	0.10	-0.77
22227	Pre-pathway	Pathway	2007	2009	0.84	0	-0.84	1.40	0	-1.40
22227	Pre-pathway	Pathway	2007	2010	0.84	0	-0.84	1.40	0	-1.40
22227	Construction	Pathway	2008	2009	0.78	0	-0.78	0.75	0	-0.75
22227	Construction	Pathway	2008	2010	0.78	0	-0.78	0.75	0	-0.75
22229	Pre-pathway	Pathway	2006	2009	1.36	7.00	5.64	1.19	6.79	5.60
22229	Pre-pathway	Pathway	2007	2009	0.04	7.00	6.96	0.00	6.79	6.79
22230	Pre-pathway	Pathway	2007	2009	0.18	0	-0.18	0.20	0	-0.20
22230	Construction	Pathway	2008	2009	0.11	0	-0.11	0	0	0

Appendix 2. Year-to-year differences in percent overlap of 95% Brownian bridge home ranges with the 2-km pathway buffer, for individual bears monitored during the pre-pathway and pathway periods, and/or during the construction and pathway periods.

					May-Oct			15 Jun-30 Aug		
Bear	Period (a)	Period (b)	Year (a)	Year (b)	Overlap (a)	Overlap (b)	Difference (b-a)	Overlap (a)	Overlap (b)	Difference (b-a)
22070	Pre-pathway	Pathway	2007	2009	0.06	0.08	0.02	0.04	0.08	0.04
22071	Pre-pathway	Pathway	2007	2009	0.24	0.41	0.17	0.21	0.49	0.28
22071	Pre-pathway	Pathway	2007	2010	0.24	0.49	0.25	0.21	0.49	0.28
22071	Construction	Pathway	2008	2009	0.38	0.41	0.03	0.43	0.49	0.06
22071	Construction	Pathway	2008	2010	0.38	0.49	0.11	0.43	0.49	0.06
22075	Construction	Pathway	2008	2009	0	0.01	0.01	0	0	0
22075	Construction	Pathway	2008	2010	0	0.07	0.07	0	0.07	0.07
22076	Construction	Pathway	2008	2009	0.46	0.25	-0.21	0.55	0.42	-0.13
22076	Construction	Pathway	2008	2010	0.46	0.43	-0.03	0.55	0.46	-0.09
22077	Construction	Pathway	2008	2009	0.12	0.15	0.03			
22215	Construction	Pathway	2008	2009	0.19	0.05	-0.14	0.15	0.06	-0.09
22215	Construction	Pathway	2008	2010	0.19	0.13	-0.06	0.15	0.16	0.01
22227	Pre-pathway	Pathway	2007	2009	0.02	0.07	0.05	0.01	0.10	0.09
22227	Pre-pathway	Pathway	2007	2010	0.02	0.16	0.14	0.01	0.19	0.18
22227	Construction	Pathway	2008	2009	0.03	0.07	0.04	0.04	0.10	0.06
22227	Construction	Pathway	2008	2010	0.03	0.16	0.13	0.04	0.19	0.15
22229	Pre-pathway	Pathway	2006	2009	0.01	0	-0.01	0.01	0	-0.01
22229	Pre-pathway	Pathway	2007	2009	0.04	0	-0.04	0.04	0	-0.04
22230	Pre-pathway	Pathway	2007	2009	0.08	0.11	0.03	0.05	0.23	0.18
22230	Construction	Pathway	2008	2009	0.11	0.11	0	0.14	0.23	0.09

Appendix 3. Coefficients and SEs for individual models of habitat selection for black bears located within 5 km of the pathway, during the pre-pathway (2002–2007), construction (2008), and pathway (2009–2010) periods. Analyses were restricted to mid-summer months (15 Jun–30 Aug), coinciding with peak human use of the pathway.

		Discrete-choice model covariates							Fix-success model covariates	
Period	Bear	Distance from last	Percent cover	Distance to pathway	Distance to road	Distance to trail	Slope	$Slope^2$	Intercept	Signal block
Pre-pathway	22001	-3.43 ± 0.16	0.68 ± 0.11	0.05 ± 0.29	0.29 ± 0.18	-0.29 ± 0.20	0.94 ± 0.45	-1.62 ± 0.46	1.41 ± 0.17	-0.77 ± 0.34
	22069	-2.74 ± 0.09	0.55 ± 0.07	0.13 ± 0.12	-0.20 ± 0.10	-0.83 ± 0.16	0.27 ± 0.24	-0.29 ± 0.25	2.19 ± 0.27	-1.09 ± 0.39
	22071	-3.10 ± 0.15	0.33 ± 0.11	-0.13 ± 0.17	0.11 ± 0.22	-0.25 ± 0.15	-0.03 ± 0.46	0.56 ± 0.36	2.25 ± 0.39	-0.72 ± 0.56
	22072	-3.76 ± 0.16	-0.01 ± 0.12	-0.17 ± 0.27	0.85 ± 0.30	-0.73 ± 0.19	1.67 ± 0.48	-2.17 ± 0.53	2.21 ± 0.40	-0.73 ± 0.51
	22202	-3.65 ± 0.11	0.87 ± 0.09	-0.18 ± 0.10	-0.01 ± 0.14	-0.40 ± 0.12	3.60 ± 0.46	-6.22 ± 0.83	1.67 ± 0.17	-0.75 ± 0.24
	22207	-3.58 ± 0.05	0.60 ± 0.04	-0.26 ± 0.05	-0.21 ± 0.06	-0.02 ± 0.06	0.60 ± 0.19	-0.58 ± 0.21	2.03 ± 0.09	-0.31 ± 0.16
	22219	-2.16 ± 0.19	0.49 ± 0.19	0.07 ± 0.22	0.39 ± 0.23	-0.08 ± 0.20	1.06 ± 0.81	-2.01 ± 1.03	1.24 ± 0.57	0.44 ± 0.80
	22227	-3.24 ± 0.13	0.84 ± 0.09	0.29 ± 0.51	-0.13 ± 0.16	0.02 ± 0.14	-0.99 ± 0.39	1.10 ± 0.32	1.80 ± 0.27	0.17 ± 0.45
	22229	-4.04 ± 0.12	0.18 ± 0.07	0.16 ± 0.42	-0.08 ± 0.12	-0.18 ± 0.14	0.69 ± 0.21	-0.46 ± 0.20	0.99 ± 0.11	0.45 ± 0.30
	22230	-3.34 ± 0.16	0.94 ± 0.12	0.00 ± 0.22	-0.10 ± 0.16	-0.95 ± 0.26	0.99 ± 0.44	-0.90 ± 0.45	1.46 ± 0.15	0.29 ± 0.52
	Mean	-3.30 ± 0.13	0.55 ± 0.10	-0.01 ± 0.24	0.09 ± 0.17	-0.37 ± 0.16	0.88 ± 0.41	-1.26 ± 0.46	1.73 ± 0.26	-0.30 ± 0.43
Construction	22069	-3.02 ± 0.09	0.46 ± 0.06	-0.22 ± 0.12	-0.3 ± 0.09	-0.28 ± 0.14	1.18 ± 0.27	-0.96 ± 0.31	1.74 ± 0.14	-0.16 ± 0.34
	22071	-3.77 ± 0.09	0.65 ± 0.07	-0.31 ± 0.13	0.26 ± 0.18	-0.31 ± 0.10	0.52 ± 0.27	-0.39 ± 0.28	1.43 ± 0.21	0.32 ± 0.31
	22072	-3.76 ± 0.09	0.03 ± 0.08	-0.21 ± 0.11	0.23 ± 0.12	-0.71 ± 0.12	2.01 ± 0.30	-1.94 ± 0.32	1.60 ± 0.15	0.62 ± 0.36
	22076	-3.98 ± 0.13	0.30 ± 0.10	-0.06 ± 0.13	0.51 ± 0.19	0.22 ± 0.16	0.73 ± 0.35	-1.19 ± 0.31	1.83 ± 0.22	0.16 ± 0.37
	22077	-2.61 ± 0.12	0.42 ± 0.11	0.07 ± 0.13	-0.53 ± 0.15	-0.52 ± 0.14	2.11 ± 0.49	-2.47 ± 0.62	2.03 ± 0.42	-0.14 ± 0.66
	22215	-2.71 ± 0.12	0.94 ± 0.15	1.12 ± 0.42	0.13 ± 0.15	-0.24 ± 0.13	0.19 ± 0.38	0.06 ± 0.34	0.84 ± 0.29	1.46 ± 0.51
	22227	-4.09 ± 0.14	0.57 ± 0.08	0.43 ± 0.33	0.34 ± 0.18	0.10 ± 0.14	0.38 ± 0.73	-0.33 ± 0.91	1.88 ± 0.20	0.43 ± 0.41
	22228	-2.29 ± 0.14	0.33 ± 0.13	0.45 ± 0.22	-0.09 ± 0.17	-0.20 ± 0.13	0.16 ± 0.47	-0.10 ± 0.55	0.89 ± 0.37	0.34 ± 0.54
	22230	-3.62 ± 0.11	0.29 ± 0.08	0.31 ± 0.17	-0.26 ± 0.12	-0.14 ± 0.12	1.03 ± 0.36	-0.82 ± 0.35	1.42 ± 0.16	0.58 ± 0.34
	Mean	-3.32 ± 0.12	0.44 ± 0.10	0.17 ± 0.20	0.03 ± 0.15	-0.23 ± 0.13	0.92 ± 0.40	-0.90 ± 0.44	1.52 ± 0.24	0.40 ± 0.43

Appendix 3 (continued).

Period	Bear	Discrete-choice model covariates							Fix-success model covariates	
		Distance from last	Percent cover	Distance to pathway	Distance to road	Distance to trail	Slope	$Slope^2$	Intercept	Signal block
Pathway	22071	-4.24 ± 0.08	0.75 ± 0.07	-0.14 ± 0.09	0.23 ± 0.12	-0.22 ± 0.08	0.02 ± 0.22	-0.06 ± 0.21	1.76 ± 0.16	-0.30 ± 0.20
	22075	-3.55 ± 0.11	0.14 ± 0.07	0.16 ± 0.16	-0.29 ± 0.12	-0.48 ± 0.13	1.16 ± 0.26	-0.79 ± 0.24	0.95 ± 0.10	0.25 ± 0.30
	22076	-3.91 ± 0.06	0.28 ± 0.04	0.01 ± 0.06	0.15 ± 0.09	0.24 ± 0.07	0.31 ± 0.16	-0.87 ± 0.14	2.34 ± 0.11	-0.67 ± 0.17
	22079	-3.65 ± 0.07	0.19 ± 0.05	0.08 ± 0.37	-0.63 ± 0.09	-0.08 ± 0.07	1.47 ± 0.20	-1.02 ± 0.16	1.05 ± 0.12	0.10 ± 0.17
	22085	-3.28 ± 0.19	-0.19 ± 0.13	0.71 ± 0.67	0.41 ± 0.45	0.42 ± 0.19	0.96 ± 0.56	-1.26 ± 0.51	1.42 ± 0.27	1.77 ± 1.10
	22215	-4.25 ± 0.06	0.16 ± 0.04	0.49 ± 0.19	0.16 ± 0.09	-0.32 ± 0.07	1.48 ± 0.24	-1.17 ± 0.24	2.16 ± 0.15	0.32 ± 0.23
	22227	-3.26 ± 0.08	0.52 ± 0.05	0.01 ± 0.10	-0.17 ± 0.09	-0.39 ± 0.11	0.86 ± 0.25	-0.90 ± 0.30	1.12 ± 0.12	0.91 ± 0.27
	22230	-2.42 ± 0.15	0.86 ± 0.13	0.15 ± 0.14	-0.65 ± 0.20	-0.85 ± 0.24	1.14 ± 0.72	-1.40 ± 0.91	0.67 ± 0.28	0.73 ± 0.48
	Mean	-3.57 ± 0.10	0.34 ± 0.07	0.18 ± 0.22	-0.10 ± 0.16	-0.21 ± 0.12	0.92 ± 0.33	-0.93 ± 0.34	1.43 ± 0.16	0.39 ± 0.37