Title
Construction of a Highway Section Within a White-Tailed Deep Winter Yard Near Quebec City, Canada: Mitigation Measures, Monitoring, and Preliminary Results

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Construction of a Highway Section Within a White-Tailed Deer Winter Yard Near Near Québec City, Canada: Mitigation Measures, Monitoring, and Preliminary Results

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Abstract: The construction of a new 10.4 km (6.5 mi) section of HWY Robert-Cliche (73) south of Québec City, Canada, integrated an unprecedented number of mitigation measures to maintain connectivity between a bisected white-tailed deer winter yard and minimize apprehended deer-vehicle collisions. In this paper we present mitigation measures planned and complete as well as the monitoring approach to document deer use and movements in the winter yard before, during and after the construction. Some preliminary results regarding the impact of this project on the deer winter use of the project area also will be presented and briefly discussed.

We conducted 4 years (1999-2002) of winter track surveys along the projected centerline of the new highway section and aerial surveys done in mid-winter of 2003 and 2004 to document movements and to delineate boundaries of the Calway deeryard. Mitigation measures were then proposed and integrated in the project design for the bisected deer-yard. It included wildlife fencing for more than half (6.2 km or 3.9 mi) of the new highway section and combining it with 5 underpasses: one concrete box culvert, two open-span bridges over two major rivers and 2 open-span bridges over 2 rural roads. Before and during construction deer were captured each year in January and fitted with radio-collars. Yearly aerial surveys were also conducted to determine spatial use in relation with the construction phases. Around 20 deer were radio-collared each winter and telemetry data showed that about one-third of deer were long distance migrants (> 10 km) between their winter and summer home range, another one-third were short distance migrants (1 to 10 km), whereas the remaining were yearly residents of their winter range. All radio-collared deer monitored for more than a year consistently traveled between the same winter and summer home ranges. However some marked deer moved elsewhere to winter.

Two primary deer crossing structures were located at the Doyon Creek and Calway River and three secondary ones were available to deer. The design and specifications of three required underpasses were modified to facilitate use by deer. As of October 2006, four underpasses were completed, as well as 5.1 km (3.2 mi) of wildlife fencing and 21 jump-outs. An additional 6 escape ramps will be built before construction ends to allow trapped deer to escape from the fenced rights-of-way (ROW). Motorists were not yet allowed to use paved sections but they will be after project completion in fall 2007.

During the 2006 spring migration, about twenty deer were trapped within the 1.6 km (1.0 mi) fenced section and did not find the hole at the jump-outs. Adjustments were made on existing ramps to allow the deer to see the opening and not be reluctant to jump out to the adjacent forest. Also, new drawings and specifications were made to eliminate fence angles and reduce the height and slope of the ramp for the remaining one to build. Weekly visits from January to March 2007 showed that numerous deer were using both primary and secondary deer crossing structures to access both sides of the deeryard. Data from the aerial survey showed that the fenced highway section induced a light shift in the spatial use of the deeryard during the 2007 winter. Telemetry data provided evidence that deer with split winter home ranges continued to use both sides of the new section of highway despite a 5.1 km stretch of deer-proof fencing.

Introduction

Construction of new highways and public roads may reduce or alter both the quantity and quality of wildlife habitat. Construction activities, presence of construction workers and noise may also disrupt daily and seasonal movements of wildlife. Once constructed highways and public roads and their associated vehicular traffic can affect wildlife populations by traffic mortality, permanent habitat loss or resource inaccessibility (Jaeger et al. 2005, Forman and Alexander 1998).

Roads and highways can also be hazardous for people, particularly when large mammals such moose (*Alces alces*) or white-tailed deer (*Odocoileus virginianus*) inhabit the proximity of transportation corridors. Vehicle-ungulate collisions have recently increased in North America and Europe causing an increase numbers in human injuries and deaths, as well as considerable material damage (Forman et al. 2003). There were 204 reported human fatalities from animal-vehicle crashes in 2004 in the U.S. only (http://deercrash.com/states/national_data.htm).

In this paper we share information and preliminary results related to planning mitigation measures and monitoring use of deer crossing structures in a new build highway that bisected a northern deeryard. The main objectives are (1) to present mitigation measures planned and built to reduce impacts of the construction of a new highway section in a northern winter yard of white-tailed deer and human safety and (2) provide preliminary data obtained from monitoring underpasses and escape ramps.

Study Area

Our project took place in the Beauce region, located 60 km (37 mi) south-east of Quebec City near the Appalachians (fig. 1). The study area covered approximately 1,000 km^2 (386 mi^2) where rolling landscapes, numerous streams, and 4 rivers dominate the landscape. Altitude varies between 213 m (777') and 487 m (1598'). Snow cover appears in early

December and persists until mid-April. Annual precipitation averaged 1000 mm (39'') of which 25% fell as snow. The mean monthly temperatures vary between 18 °C (64 °F) and -12 °C (10.4 °F).

The landscape is mostly forested with some highly dispersed and patches of agricultural lands. The study area is located within the ecological region of the northern mesic hardwood forest. Intensive forest harvesting has a great effect on the actual forest structure and composition. Forests are mostly under private ownership and currently harvested for firewood, paper and lumber production. In 1995, only 25% were considered mature stands while the remaining ones were either young (36%) or regenerating (39%). The forest canopy is mainly composed of deciduous and mixed stands of sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), yellow birch (*Betula alleghaniensis*), balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), red spruce (*Picea rubens*) and white pine (*Pinus strobus*).

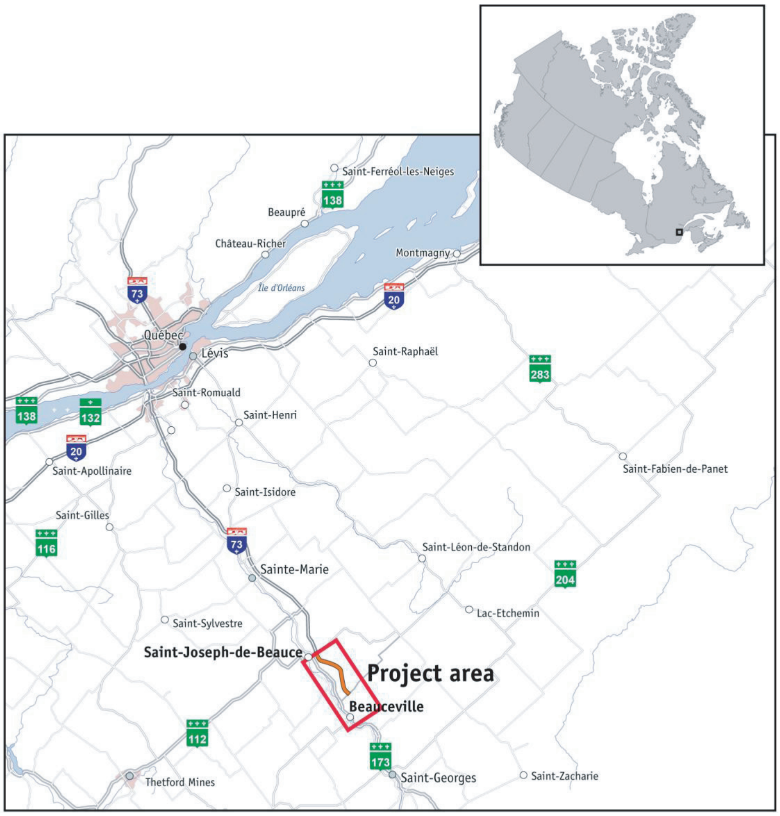

Figure 1. Location of the study area and HWY 73 in the Beauce Region, Province of Québec, Canada.

White-tailed deer is the most abundant large mammal species in the area. Deer density has been estimated at 6.7 deer per km of habitat in 2001 (Desjardins et al. 2001). Moose and black bear are also present but only occur in limited numbers. As it is the case in most of its northern range, yarding behaviour is much prevalent among this population. It induces well-known migrations in the area from summer to wintering areas although some deer do not and others do only during severe winters but not in mild winters (Messier and Barrette 1985, Van Deelen et al. 1998). Deer have established a winter yard in the area in 1989 along the Calway River. It size has grown from 4 km^2 (1.54 mi^2) in 1989 to near 15 km^2 (5.8 mi^2) in 1998 (Hébert, 2003). It is worthwhile to note than the Chaudière River, the Road 173 and agricultural land act in some ways as a barrier or a filter to westward movement by terrestrial fauna.

Highway Project Description

Construction of HWY 73 began in 1973 and aimed at connecting the City of St-Georges to the urban population of Québec City. The uninterrupted movement of people, freight and business is deemed essential to the economic vitality of the Beauce region. It is an important link connecting Central Quebec to the State of Maine, USA. A total of 62 km (38.5 mi) has been built and is currently open to vehicular traffic. This project will add a 10.4 km (6.5 mi) section of HWY 73 from St-Joseph-de-Beauce to Beauceville. The annual average traffic volume was estimated at 7 300 vehicles per day in 2003 at the southern end of HWY 73 (QMOT, unpublished data).

Construction of the new section has been split in three phases started from the northern to the southern end. The first phase started during summer 2004 and the completion of the third phase is scheduled for fall 2007. The first 6.0 km (3.7 mi) section of HWY 73 is a two-lane infrastructure. The remaining part is a four-lane divided section. The project includes one concrete box culvert, 4 bridges (2 over major rivers and 2 over low volume rural roads) and several small concrete boxes or creek crossing structures. The cross section of the two-lane part consists of two 3.7-m lanes, two 3-m outside shoulders and around 15 m of adjacent rights-of-way (*sensu* roadsides). Road characteristics for the four-lane divided section are identical to the two-lane highway section except that inside shoulders will be separated by a grass median of 20 m (66') and a total right-of-way width of about 105 m (344').

Methods

Planning and Implementing Mitigation Measures

From the early stage of planning and environmental assessment of this project, the presence of a traditional wintering area for deer bisecting the corridor became an important issue. To circumvent this area it would have required substantial project concept modifications, increased travelling distance, and reduced traffic flow for motorists and truckers due to major slope constraints. In addition, the estimated cost of such design modification would have been very expensive. Given this situation, the need for mitigation measures for deer arose early during the engineering studies and project design activities by the proponent. Deer fencing and wildlife crossing structures were readily considered and planned to reduce risks of deer-vehicle collision and allow deer to access to the entire deeryard during winter.

In order to determine the placement of mitigation measures, we conducted yearly winter tracks and trails surveys in mid March 1999, 2000 and 2001 and every 3 weeks between December 19, 2001 and April 2002 along the projected centerline before forest clearing of rights-of-way started. Surveys only occurred ≥2 days after snowfall to ensure a minimum of detectable tracks and trails. Tracks and trails counts were conducted on snowshoes. Snow and sinking depths were also recorded every 200 m (656') along transects. Each track or trail was either considered to have crossed or to have paralleled the projected centerline. We used a GPS with a 6-10 m accuracy to obtain track and trail locations.

An aerial inventory of deer was also conducted on February 14, 2002 to estimate the number of deer wintering in the Calway deeryard. The double-count technique was used (Potvin et al. 2004). Two other aerial surveys were conducted on February 17, 2003 and March 13, 2003 to delineate the spatial extent of the deeryard and to determine spatial use during pre-construction phase. To illustrate spatial distribution of deer used from these aerial inventories, we used the Density (Kernel) function of the Spatial Analyst program extension in ArcView. Search radius was set to 1000 m (3281') and the following weights were attributed: 1 for a single track, 2 for a single trail, 3 for a network of tracks and 3 for seen deer.

With this information in hand, the Quebec Ministry of Transportation (QMOT) environmental specialists and independent wildlife biologists reviewed the project and discussed with project engineers. Deer fencing recommendations were put forward as a safety and a wildlife mitigation measure. This planning process led to adjustments in bridge and creek crossing structures designs to provide adequate sites for safe deer crossing along the bisecting highway. We identified and prioritized the location of deer fencing and mitigation passages for deer based upon our tracks and trails surveys as well as aerial inventories. We located two primary and three secondary deer crossing structures. Design guidelines were based on available literature, personal contact with other deer specialists and our knowledge of deer movements and ecology in the area.

Monitoring Program

Once the mitigation measures accepted and integrated in the project, the QMOT and the Québec Ministry of Natural Resources and Wildlife (QMNRW) set up a 6-years monitoring program (1) to determine if the new highway and its fenced section change patterns of space use and migratory movements toward and out of the Calway deeryard, (2) to determine use and identify factors facilitating deer passage through available crossing structures and (3) to estimate the proportion of migratory and non-migratory deer using the Calway deeryard.

Starting in 2003, deer were captured in January using Stephenson box traps placed along known trails and on each side of the proposed highway corridor (2003 and 2004) or of the newly cleared rights-of-way sections (2005, 2006, and 2007). Traps were baited with white cedar foliage and commercial feeds. All deer were immobilised in a net, sexed and fitted with an ear tag and a radio collar. Between 20 and 22 deer were radiocollared each winter because not all of them survived or returned to the Calway deeryard to the next winter. The number of marked deer available for telemetry monitoring each winter is given in table 1. Deer were located from the ground twice a week by triangulation between January 1 and March 31 and from the air once or twice during summer and fall. We used the minimum convex polygon (MCP; 100% confidence area) to estimate winter home range of each deer. We only used deer that had 15 or more locations.

Aerial surveys were conducted once or twice during winter depending upon prevailing snow conditions on the ground to locate and determine the spatial use of the Calway deeryard. Two surveys were conducted in 2003, and one per year in 2004, 2005, 2006, and 2007 using an Highlander plane, a Bell 206, or a R44 helicopter.

We started monitoring every week four completed deer crossing structures using tracks surveys and wildlife infrared sensor cameras from January 2007 to April 2007 following the near completion of deer-proof fencing in fall 2006. Escape ramps and a strip of 150 m (492') at the northern ends of the fence section were also checked weekly for tracks and movement toward the fenced rights-of-way.

Table 1: Number, sex and age of usable radio-collared deer per year

Winter	Adult deer		Immature deer		Total
	Male	**Female**	**Male**	**Female**	
2003	3	3	4	2	**12**
2004	6	8	9	5	**28**
2005	5	15	1	8	**29**
2006	3	16	3	9	**31**
2007	3	17	6	9	**35**

Results

Chronology of the highway construction project

Summer 2004

A total of 6-km (3.7 mi), 55 (180') to 65 m (213') wide strip of forests were cleared within the rights-of-way to accommodate the new section of highway north of the Calway Road. Preliminary grading work started but stopped in late fall. Most of this section was located outside of the Calway deeryard and the forest clearing operations barely affected the northwest edge of the deeryard.

Summer 2005

The construction of one of the two primary deer crossing structures started at the Doyon Creek (fig. 2). Part of the deer-proof fence (2.4 m or 8' high and constructed of woven wire) was installed at the northern end of the deeryard and on each side of this structure for a total length of 1.8 km (1.1 mi). Eight escape ramps were also built within the fenced section for deer. Construction of the Calway River Bridge started but stopped in late fall. This open-span bridge is considered at the heart of deeryard and is the second primary deer crossing structure. The construction of the Calway road bridge also started during the summer. This structure is considered a secondary deer crossing underpass because deer often use this very low-used gravel road during winter to travel within the deer yard. In early fall, the completed section of the highway was paved and roadsides seeded for a length of 5 km. No vehicular traffic was allowed except for construction workers.

Summer 2006

The Calway River Bridge was completed (fig. 3) and deer-proof fences were tied into the bridge abutments. Another section was cleared, graded and paved with an average right-of-way width of about 100 m. Deer-proof fences were installed on another 3.3 km (2.1 mi) section adjacent to the previous fenced section. A total of 13 escape ramps were also put up. Construction of the Carrière road bridge started and was completed by fall 2006. This underpass is considered a secondary deer crossing structure. The Carrière Road is a privately-owned gravel road and is seldom used during winter when deer are using the Calway deeryard. Clearing and grading started for the third and last section of highway. Construction of the open-span Des Plantes River bridges also started and some drilling operations lasted until early March 2007. Adjustments were made on previously built escape ramps during spring and summer 2006. Again, no vehicular traffic was allowed on paved surfaces except for construction. Two primary and two secondary crossing structures combined with deer-proof fencing funnelling deer toward the underpasses were therefore available at the onset of fall migration into the deeryard for winter 2007.

Summer 2007

Construction of the Des Plantes River Bridges will be completed and will represent the fifth and last deer crossing structure available to deer. Deer-proof fencing will be completed and tied into the bridges abutments. Six additional escape ramps will also be constructed to allow trapped deer in right of way to return to forested areas. The remaining section will be graded and paved for public opening of the highway section during fall 2007.

Dimensions and description of deer crossing structures

Table 2 provides technical information on crossing structures available in this new section of HWY 73. Deer-proof fencing will be put up between kilometre markers 3+400 and 9+600.

Table 2: Location and description of crossing structures on the new section of HWY 73

Kilometer marker	Structure	Type	**Year completed**	**Span (m)**	**Rise (m)**	**Length (m)**	**Openness ratio**
3+920	Doyon Creek	Concrete box culvert	Fall 2005	10 (32.8')	5.0 (16.4')	13.4 (44.0')	3.7
5+300	Calway River	Open-span bridge	Summer 2006	120 (394')	10.9 (35.8')	14.3 (46.9')	91.5
5+600	Calway road	Open-span bridge	Summer 2006	27.5 (90,2')	5.0 (16.4')	14.3 (46.9')	9.6
7+340	Carrière road	2 open-span bridges	Fall 2006	12.6 (41.3')	5.1 (16.7')	12.6 (41.3') each	5.1
8+800	Des Plantes River	2 open-span bridges	Fall 2007	177 (581')	14 (45.9')	12.6 (41.3') each	196.7

Figure 2. Doyon Creek concrete box culvert before tree and shrub planting.

Salient Features on the Spatial Use of the Calway Deeryard

Pre-construction Phase

Spatial use of the Calway deeryard was variable from one year to another depending on snow depth and timing of storm events. Table 3 provides the results of the tracks and trails survey of mid-March conducted along the projected center line between 1999 and 2002 before construction. Abundant snow precipitation in winter 1999 and 2001 limited deer movement outside well used trails. However, traveling conditions for deer were much better in 2002 when snow cover was light and contained a hard crust formed after heavy rains in February. Combined data surveys in the winter 2001-2002 showed that deer trails were most abundant on both sides of the Calway River, between kilometre markers 4+300 and 5+800 (fig. 4). Tracks were more widely distributed that trails and high numbers were observed between kilometre markers 3+800 and 5+800 (fig. 5). Unlike previous years, a group of deer used a section located between markers 1+200 and 1+800. We suspected that deer stayed around this area because of intense forest harvesting operations.

Figure 3. Calway River open-span Bridge before tree and shrub planting.

Table 3: Number of tracks and trails recorded during yearly surveys along the projected centreline of the new section of HWY 73 before construction

Variable	1999	2000	2001	2002
Transect length (m)	6296	6897	6909	9502
Total number of tracks	200	789	238	2117
Total number of tracks/ 100m	3.18	11.59	3.44	22.24
Total number of trails	27	72	117	70
Total number of trails/100m	0.43	1.06	1.69	0.74
Average snow depth (cm)	69	44	76	40
Sinking depth of deer (cm)	23	10	42	4
Presence of a crust	Yes	Yes	No	Yes

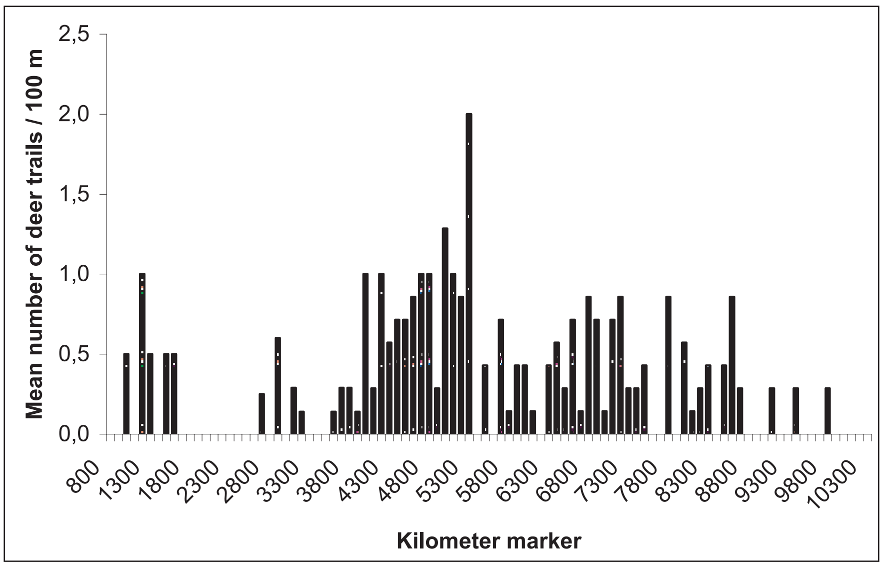

Figure 4. Mean number of trails per 100 m recorded over 7 surveys from mid-December 2001 to early April 2002 along the projected centreline of the new section of HWY 73 before construction.

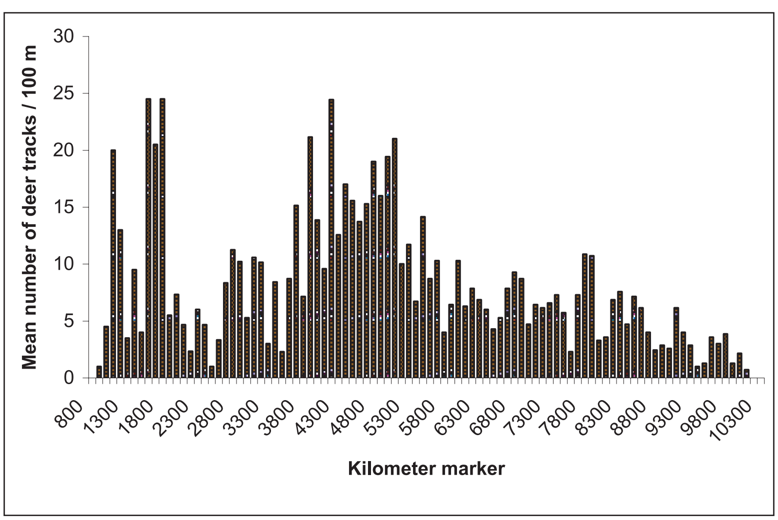

Figure 5. Mean number of tracks per 100 m recorded over 7 surveys from mid-December 2001 to early April 2002 along the projected centreline of the new section of HWY 73 before construction.

The aerial survey using the double-count technique conducted on February 14, 2002 provided an estimation of 315 deer in a delineated area of 36 km^2 (13.9 mi^2).The winter density averaged 8,8 deer/km^2 ± 44% and was considered a low-density population compared to nearby deeryards of density above 25 deer/km^2. Data from aerial surveys conducted on 17 February and 13 March, 2003 showed that deer occupied an area of 30.3 (11.7 mi^2) and 22.1 km^2 (8.5 mi^2) respectively. In February, large concentration of deer, tracks and track networks were located between kilometre marker 3+000 and 7+600. Snow and sinking depth were 50 and 46 cm respectively. Later in March, most deer had reduced their spatial use of the deeryard and they were particularly abundant in an area of 4 km^2 (1.5 mi^2) between Calway Road (5+620) and Doyon Creek (3+750) on each side of the projected centerline. The survey conducted on 12 February, 2004 provided different results. Deer and deer signs were much more concentrated and distributed toward the west side of the projected centreline. The deeryard occupied an area of 23.7 km^2 (9.2 mi^2), a 7 km^2 (2.7 mi^2) difference from the year before. Snow and sinking depth were very similar to that of the previous year with respective values of 55 and 44 cm. However, winter arrived earlier in 2004 and deer started to congregate much earlier to the center of the deeryard.

We located 36 deer 807 times from the ground between 1 January and 31 March in 2003 and 2004 to estimate mean winter home range of deer in the Calway deeryard. Average winter home ranges for marked deer were 269 ha in 2003 and 150 ha in 2004. These two years of telemetry have also shown that almost all deer using the Calway deeryard move to the east or the northeast for the summer. About one third remained within 1 km (0.62 mi) of their winter range. One third moved from 1 to 10 km (6.2 mi) away from the known winter home ranges. Finally, the remaining deer migrated a distance longer than 10 km (6.2 mi) to reach their summer range. Average distances between the summer location and the centroïd of the winter home range were 15.3 km (9.5 mi) and 13.7 km (8.5 mi) for males (N= 21) and females (N = 16) respectively. No differences were found between males and females.

Construction Phases

Use of the deeryard in winter 2005 was very similar to that of preconstruction phase despite a cleared right-of-way of more than 6.0 km long and 55 to 65 m wide at the northwest end of the project. Deer moved to the winter yard in December as usual. The average home range of radio-collared deer was 167 ha (N = 29) which was very similar to that of 2004. Deer used the entire deeryard (fig. 6) and were not impeded by the presence of a cleared strip. Deer and deer signs were again more abundant on the west side of the projected centerline. The deeryard occupied an area of 22.7 km^2 (8.8 mi^2). Snow and sinking depth were much lower than that observed in previous years, with respective values of 35 and 20 cm.

In 2006, we obtained similar results despite a 6-km completed section and 2-km of deer-proof fencing. The Doyon Creek concrete box was available for deer to go across the fenced portion. Although no monitoring was conducted on the use of this primary deer crossing structure, numerous tracks were detected during occasional visits to the site by QMTQ and MRNQ wildlife technicians and biologists. Pictures of deer using the passage were also taken from wildlife cameras installed on the inside walls of the underpass. The average home range of radio-collared deer was 152 ha (N = 31) which very similar to that observed during the previous winter. Deer used the entire deeryard but they seemed to be less present near the northeast side of the fenced portion and near the Calway River. They were still using the northwest part of the range like other years. The deeryard occupied an area of 18.1 km^2 (7.0 mi^2), which was slightly smaller than in 2005 and 2004. However, snow conditions were more severe with an average snow depth of 54 cm and a sinking depth of 30 cm.

However, during the week of 9 April 2006, when deer were presumably moving to their summer range, about 20 of them penetrated inside the fenced section from the southern end at the Calway River Bridge construction site. They spend an unknown amount of time walking along the fences and some of them succeeded in escaping through the escape ramps or jumps-out. However, a number of them did not find the openings and kept dashing into the wildlife fence at the edge of escape ramps, and specifically where there was a change of alignment in the wildlife fence. Use of the highway paved section by some construction workers probably induced panicking among deer that felt trapped in someway. Snow fences were quickly put up on the metallic fences on critical spots of escape ramps so that the deer will perceive it as a wall and keep walking toward the opening instead of trying to get across the fence that had suddenly and probably appeared as brushes. This event initiated a number of design modifications on specifications of escape ramps (height, slopes steepness, links with fences) and their positioning along the wildlife fencing.

In winter 2007, as most of the deer-proof fences were put up, deer occupied the same area of the yard, besides minor differences (fig. 7). Among them, there were less deer using the southwest part of the deer yard, probably owing to many factors such as the fact that construction activities took place until March 2007 at the Des Plantes River bridges construction site, the presence of newly cleared right-of-way and deer-proof fences, and large clear-cut areas in the vicinity. Distribution of deer was also more extended in 2007 than in previous year, especially toward the northeast. We believed that unusual light snow cover that last up to mid-February did not incite all deer to move to the core of the deeryard as in normal years. An area of heavy use by deer was also detected to the northwest part of the yard, but this phenomenon appeared related to forest harvesting activities that provided plentiful of browse from felled trees, at least during January and February 2007. The area occupied by deer covered 25.5 km^2 (9.8 mi^2) and snow depth tallied to 47 cm with a sinking depth of 43 cm.

Home range analyses were not completed for winter 2007, except for few deer followed since 2003 and 2004. Two examples are provided in figures 8 and 9 of two adult females that had their winter home range split by the new highway section. After construction of the deer-proof fences in fall 2006, deer #47 maintained its winter home range on each side of the new highway section. However this adult female has more than doubled its winter home range and moved slightly to the northwest in 2007. Deer #81 reacted similarly, but moved slightly its home range to the north in 2007. This deer was photographed crossing the Calway River underpass in both ways in many occasions. Table 4 shows yearly estimates of winter home range of these two radio-collared deer potentially and directly affected by this project. Greater winter home ranges in 2007 may partly be attributed to very light snow cover enabling deer to move easily throughout the area.

During the 2007 winter, starting 6 December 2006 and ending 29 March 2007, we monitored the four completed deer crossing structures once a week using snow track surveys and still cameras triggered by active infrared sensor. Table 5 shows preliminary results of the track surveys for all underpasses. These numbers must be considered as minimum values because snow precipitations erased tracks between days of data collection. Consequently, deer tracks could be recorded during 64 days only, over a period of 149 days. In addition, number of tracks observed underneath for the Calway Road and the Carrière Road bridges (fig. 10) must be considered minimum values because deer used snowmobile tracks or ATV trails to cross these structures, where they became undetectable following use of the trails by these vehicles. Nevertheless we believe the Calway River Bridge received the heaviest use by far. Peak use in this underpass occurred in December 2006 (2.5 deer/day) and the last week March 2007 (7.0 deer/day). The same pattern was observed in December at the Doyon underpass. Deer movement was linked to the fall migration to winter range. Newly designed and built escape ramps seem to work better as a total of 12 deer jumped over out of 21 that walked on the ramps during the 2007 winter track surveys each week.

Table 4: Estimates of annual winter home ranges of two radio-collared deer with home ranges split by the new highway between 2003 and 2007 in the Calway deeryard

Winter	Winter home range of deer # 47 (km^2)	Distance of centroids between consecutive winters (m)	Winter home range of deer #81 (km^2)	Distance of centroids between consecutive winters (m)
2003	---	---	0.93	---
2004	1.98	---	0.51	320
2005	4.29	385	0.51	162
2006[1]	2.65	473	1.15	407
2007[2]	3.61	1919	1.89	664

[1] deer-proof fencing partially completed (34%) and one deer crossing structure available

[2] deer-proof fencing almost completed (87%) and four deer crossing structure available

Table 5: Total number and direction of deer passing through each underpass for the 2007 winter (6 December 2006 to 29 March 2007)

Deer crossing structure	East	West	Undetermined	Total	Number of deer crossings per day (n = 64)
Doyon Creek	21	23	0	44	0.69
Calway River	67	42	11	120	1.88
Calway road	18	12	0	30	0.47
Carrière road	15	18	0	33	0.52

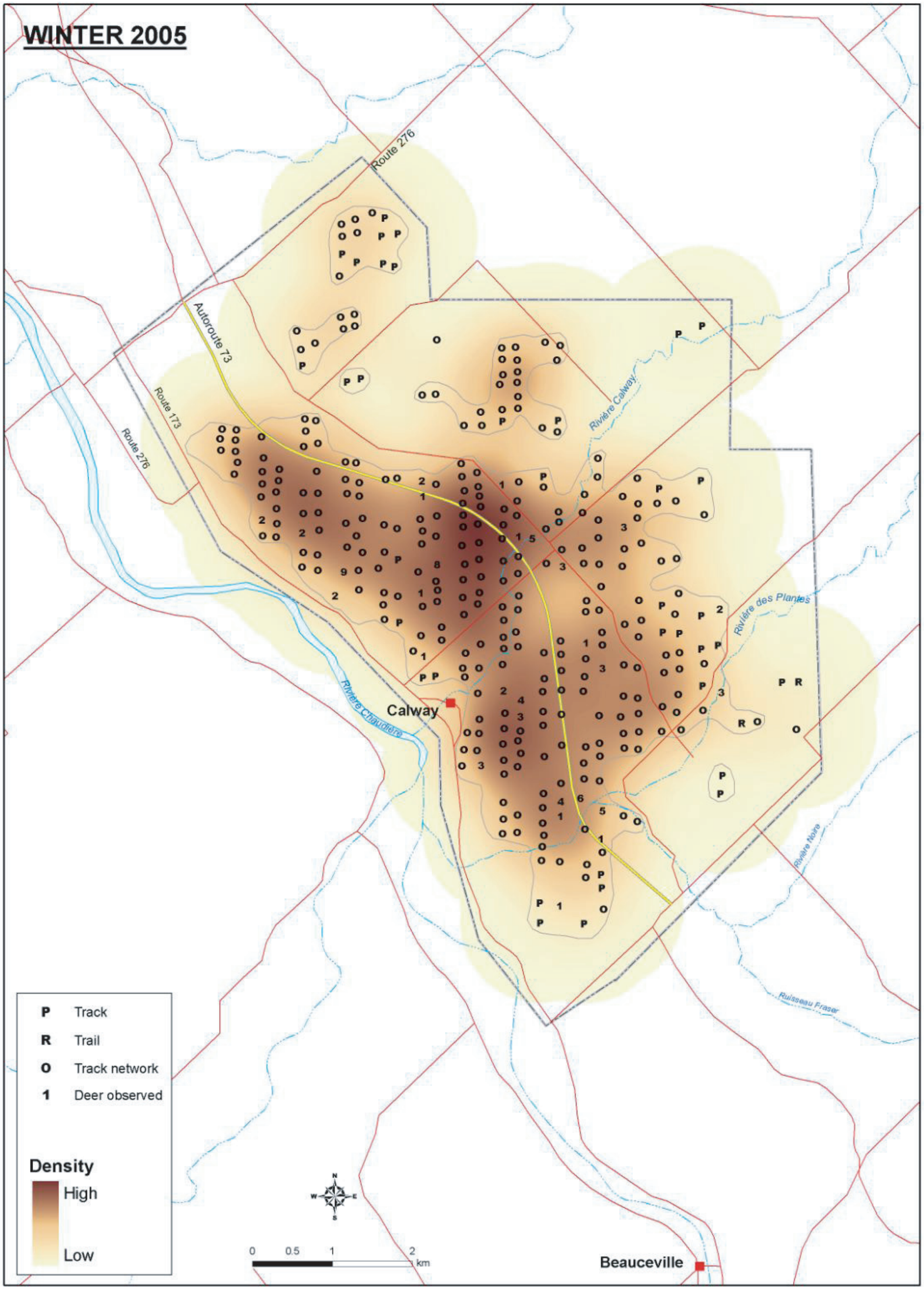

Figure 6. Spatial use of the Calway deeryard determined from an aerial inventory of deer signs on 25 February 2005 (darker areas show stronger use by deer, see methods).

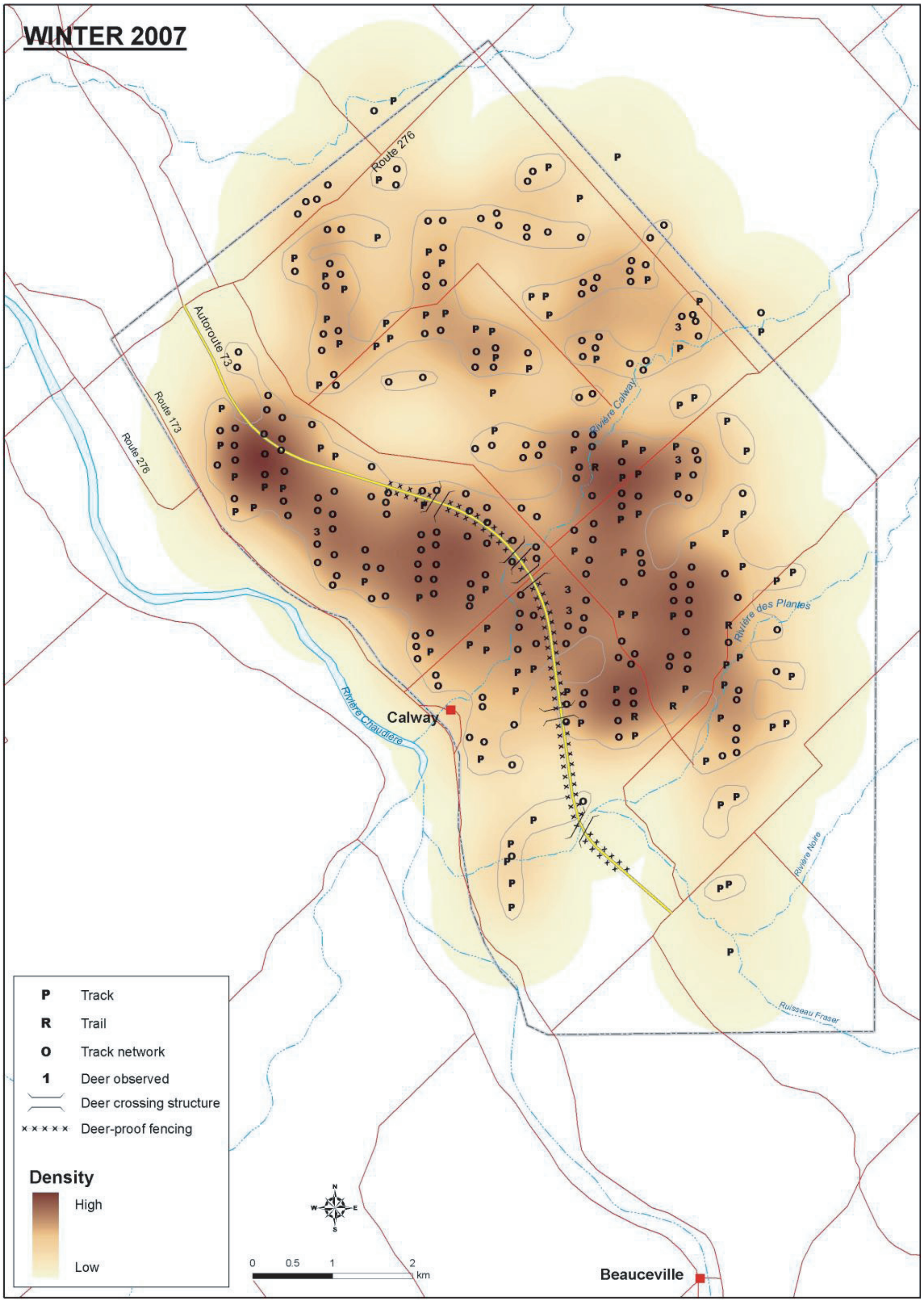

Figure 7. Spatial use of the Calway deeryard determined from an aerial inventory of deer signs on 28 February 2007 (darker areas show stronger use by deer, see methods).

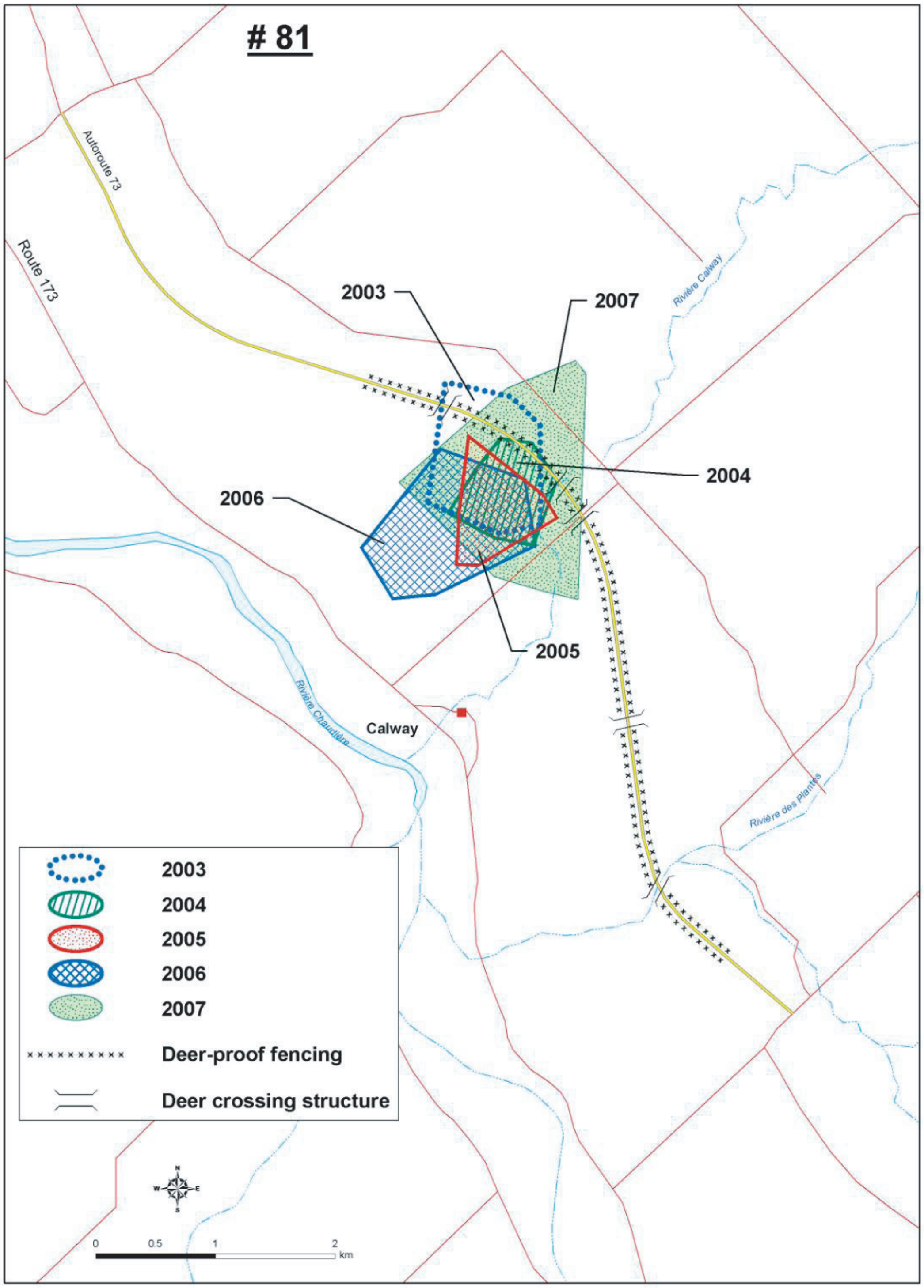

Figure 8. Location of winter home ranges of deer #81 between 2003 and 2007 in the Calway deeryard.

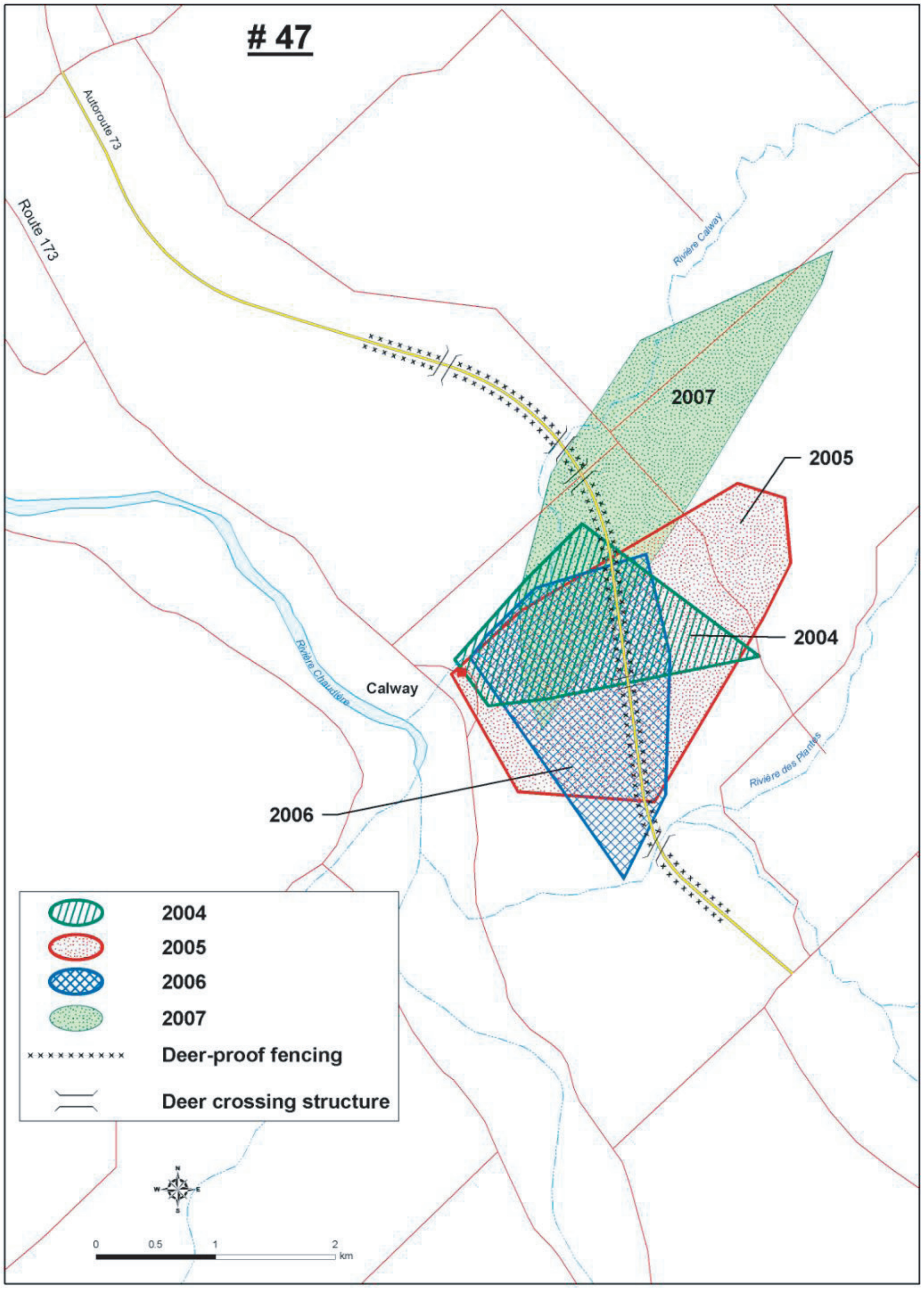

Figure 9. Location of winter home ranges of deer #47 between 2004 and 2007 in the Calway deeryard.

Figure 10. Six deer passing under the Carrière Road bridges, a secondary deer crossing underpass on 10 April 2007.

Discussion

Our study demonstrates that valuable information can be gathered during planning and before construction to locate the most suitable sites for wildlife crossing structures. Site-specific examples such as this project show the value of obtaining field data and the possibility of adjusting designs before final drawings and specifications to develop solutions to maintain habitat connectivity for wildlife.

In this particular case of a bisected northern deer winter yard, track surveys showed that a great proportion of movements occurred near the valley of the Calway River and to the north of it. Some other corridors like the Calway and the Carrière Roads also proved to be fairly well used by deer moving within the winter yard, probably due to low levels of human activity on these roads. The track and aerial surveys also helped us to determine where we had to make the greatest efforts to provide suitable crossing structures for deer while maintaining highway safety.

A number of decisions were therefore taken early at the planning and designing stages of these structures and their surrounding landscape to facilitate deer use of these underpasses even if some were classified as secondary crossing structures. Aerial surveys also showed that the size and the area used each year by deer in the Calway deeryard vary according to snow cover conditions, the timing of winter storm events, and forest harvesting activities. We therefore dealt with a deer population that already had and demonstrated flexibility on their use of the winter range.

Our preliminary results on weekly snow tracks inventories gathered in the 2007 winter when most fencing and crossing structures were completed clearly indicated that all available deer crossing structures have been used by deer to varying degrees. Given the number of recorded deer crossings in only three months (n = 227), the design of crossing structures met the species requirements (openness ratio) and they were adequately located. Observed crossing frequency obtained for the Calway River underpass during winter was very similar to the annual value reported by Donaldson (2006; 1.34 crossings/day at Site 2) for a similar bridge in Virginia, USA.

However, our crossing structures were used but their effectiveness (percentage of repels) is unknown as we did not gather data on repel rates using video monitoring. However, we believe that a significant portion of this population has been using the crossing structures, as we captured images of different radio-collared deer. The 2007 telemetry data have not been yet analysed, and therefore, the number of marked deer getting across the fenced portion of highway remains unknown. Also we do not know yet if some deer have altered their movement patterns to cross the fenced portion through completed underpasses.

The similar spatial distribution of deer north of the Calway River before and during construction indicated that deer were successful into crossing structures. If the deer would have not been able to reach this portion of the deeryard, we would have recorded low density of deer signs and this was not the case. There was also repeated use of the Calway River underpass by deer during the 2007 winter. This crossing structure seems to be very effective in terms of facilitating deer passage, probably because 1) deer knew this area well and had used it heavily before construction and 2) the structural features of this underpass resulted into a very high openness index. Both location and landscape features (Beier and Loe 1992) and structural features (Clevenger and Waltho 2005) have contributed in determining the Calway River underpass's success.

The 2007 winter use of the area south of the Calway River has been somehow lighter than in pre-construction years. It's however hard to tell which factors contributed the most to this lesser use of this area. Construction and human activities that took place until March 2007 at the Des Plantes River bridges construction site may have repelled some deer to use this area. Also, the presence of new large clear-cuts may not have provided enough suitable cover and food for and may have forced deer to spend the winter elsewhere in the deeryard. The very late arrival of winter may also have altered the usual distribution pattern of deer. Finally, the presence of the deer-proof fence may also have had an impact on the use of the area of the deeryard. Further monitoring of the spatial distribution of deer in subsequent years is necessary to help us to better understand the effect of these yearly changes in spatial use of the Calway deeryard.

Lack of vehicle traffic, noises and disturbances on the ready-to-use completed section of HWY 73 may have contributed to facilitate use and familiarization of the crossing structures by deer. Monitoring during winter 2008 will give us the opportunity to determine if this factor can have a significant effect of the use of crossing structures. However, its effects might be confounded with the fact that deer had up to two years to learn the structures' locations and to become accustomed to it.

We also learned from this project that successful management actions implemented at one site may not give the same result in another area. Also, small detail in designing structures can make a difference to improve the efficiency of a given mitigation measure. This was particularly the case with escape ramps in which fence angles at the approach were eliminated and the height of the platform lowered by about 25 cm (10'').

In conclusion, the four completed crossing structures combined with deer-proof fencing have been readily and successfully used by deer and have so far contributed to maintaining access to the bisected deeryard. Further analyses and monitoring will provide detailed data regarding individual and population responses, expected increase of deer use of crossing structures (Clevenger and Waltho, 2006) and the effectiveness of escape ramps.

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