The effects of roads on habitat selection and movement patterns of American badgers (Taxidea taxus jacksoni) in Ontario, Canada

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The effects of roads on habitat selection and movement patterns of American badgers

(*Taxidea taxus jacksoni*) in Ontario, Canada

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The effects of roads on habitat selection and movement patterns of American badgers

(*Taxidea taxus jacksoni*) in Ontario, Canada

Julia Sunga, Josh Sayers, Karl Cottenie, Christopher J. Kyle, Danielle M. Ethier.

**Abstract:** Road mortality is identified as a threat to American badger (*Taxidea taxus* Schreber, 1777) populations across Canada. Understanding habitat selection and movement in relation to roads is therefore vital to their conservation. Using telemetry data and road-kill locations of badgers in southwestern Ontario, we examined the relationship between habitat selection, movement patterns, and roads at three spatial scales. At the study area scale, we assessed the effects of habitat attributes on burrow site selection. Several individuals placed their burrows closer to primary highways than expected, suggesting badgers are not sensitive to human disturbances at this scale. Using straight-line movement trajectories between burrows, we analyzed individual movement patterns within home ranges. All badgers showed some degree of road avoidance, either crossing fewer roads or roads which posed lower mortality risk. At the road crossing scale, we compared landscape features surrounding road-kill locations to random locations along the same roadway. There was a positive relationship between road-kill locations and the number of water-based linear features and higher density of hedgerow cover. Our results provide evidence that badger movement is influenced by roads at multiple scales, which has important implications for managers interested in developing road-mitigation strategies for this endangered population.

**Key words:** American badger, *Taxidea taxus jacksoni*, conservation, movement, roads, species at risk, wildlife-vehicle collisions
Introduction

Roads bisect landscapes, putting wildlife populations at risk during regular daily movements (Kolowski and Nielsen 2008). Species with small effective population sizes and large home ranges, such as many wide-ranging carnivores, are particularly vulnerable to roads through both direct mortality and decreased crossing frequency, which can lead to inbreeding depression and ultimately the extinction of a population (Ernest et al. 2003; Jackson and Fahrig 2011).

Understanding how wide-ranging carnivores behave in relation to roads can therefore improve conservation planning for vulnerable populations through the implementation of targeted mitigation techniques, such as fencing, underpasses, overpasses, or seasonal reductions in speed limits (Beaudry et al. 2008; Garrah et al. 2015).

An individual’s response to roads may manifest at varying spatial scales (Thurfjell et al. 2014). For example, at relatively large scales, including habitat selection and daily movement patterns within the home range, Grizzly bears (Ursus arctos L., 1758) display den selection patterns favouring areas of low road densities, and avoid roads and trails during their daily movements (Kasworm and Manley 1990; Pigeon et al. 2014). At finer scales, such as at the road crossing location of an individual, landscape features can influence which roads, and where along a road, an animal will cross. Wolves (Canis lupus L., 1758), for example, are known to move along linear features, such as rivers and foot paths, which guide individuals to cross roads where these features intersect with roads (Latham et al. 2011). Road attributes can also influence an individual’s crossing behaviour and success. For example, road mortalities of porcupine (Erethizontidae dorsatum L., 1758), raccoon (Procyon lotor L., 1758), and skunk (Mephitis mephitis Schreber, 1776), are positively correlated with road width (Barthelmess 2014). To tailor road mitigation strategies to a particular species, it is therefore necessary to understand which
factors influence habitat selection and movement, and at what scales they operate (Beaudry et al. 2008; Garrah et al. 2015).

Like other wide-ranging carnivores, American badgers (*Taxidea taxus*; Schreber 1777) encounter roads during their regular nightly movements as they travel large distances, up to 14 km (this study), in search of food and mates (Apps et al. 2002; Kinley and Newhouse 2008). Unlike their European counterparts, American badgers are solitary, digging and reusing large numbers of burrows within their partially overlapping home ranges. The agricultural lands in which badgers commonly reside are bisected by roads, increasing the potential influence of vehicle disturbance on badger movement patterns and mortality risk (Apps et al. 2002; Duquette et al. 2014). Of the three Canadian badger subspecies, two are listed as endangered: *T. t. jacksoni* in southern Ontario and *T. t. jeffersonii* in British Columbia (COSEWIC 2012). For both endangered populations, vehicle collisions are identified as an important, yet largely understudied source of mortality (but see Kinley and Newhouse 2008; Klafki 2013).

The objective of our study is therefore to investigate if roads affect badger habitat selection and movement patterns at three spatial scales: study area, within home ranges, and at road crossing locations. At the study area scale, we predict badgers will select burrow locations farther away from roads than expected by chance. If badgers associate risk with roads while moving within their home range, then we expect nightly movement trajectories will cross roads less frequently than expected by chance while moving between burrow locations. We also predict that if badgers can assess the varying risk associated with roads, they will preferentially cross roads with slower moving and fewer vehicles when moving within their home range. At the road crossing scale, we investigate which landscape features are correlated with individual road-
kill locations. We expect that road-kill locations will correlate with preferred habitat features, such as hedgerows, as well as more dangerous road attributes, such as higher speed limits.

To date, most multi-scale studies on American badgers look at different scales of habitat selection as described by Johnson (1980) (e.g., Apps et al. 2002; Duquette et al. 2014; Quinn 2008). Our study is therefore unique in that we investigate both broad-scale habitat selection (3rd order), and movement patterns at multiple spatial scales. By looking at multiple scales and types of badger-habitat relationships, our study aims to better resolve how badgers respond to roads to better inform targeted mitigation strategies.

Materials and methods

Study area

Our study was conducted in southwestern Ontario, Canada (Fig. 1, insert). This region of the province experiences cool winters and humid summers, with a mean annual temperature between 6°C and 9°C, and annual precipitation up to 1018 mm (Crins et al. 2009). The dominant land use types are agricultural (68% of land cover), including cropland (e.g., fruit, row, and forage crops) and livestock (e.g., poultry, hogs, beef, and dairy), forests (21%), and urban developments (2%) including an extensive road network (SOLRIS version 1.2: Ontario Ministry of Natural Resources 2008; Crins et al. 2009). The road network in the study area has an average density of 1.24 km of roads per km², and includes both urban and rural roads, which typically have low vehicle capacities and speed limits, and large arterial roads and freeways, which connect urban centres and have high vehicle capacities and speed limits (DMTI 2014). Our 2381 km² study area is defined by the minimum convex polygon enclosing all known badger burrows identified with radio-telemetry, plus a 5 km buffer (Basille et al. 2007) (Fig. 1).

Trapping and tracking
We trapped badgers using ‘soft-catch’ leg hold traps placed in pairs at the entrance of burrows with recent badger activity, as identified using motion-activated cameras, hair-snags, and/or distinct digging patterns at burrow entrances. We anesthetized trapped badgers with a solution of ketamine (10 mg/kg) and xylazine (2 mg/kg) based on the estimated mass of trapped individuals. Once anesthetized, badgers were transported to the Big Creek Veterinary Hospital in Delhi, Ontario, for implantation with an intraperitoneal transmitter (Model IMP400, Telonics, Mesa, AZ) using methods described by Crawshaw et al. (2007). We selected intraperitoneal transmitters because a badger’s neck and head morphology are not conducive to collars, and external transmitters may interfere with burrowing activity. We released badgers at the point of capture following recovery from surgery (Trent Animal Care Committee No. 23489; MNRF Animal Care Committee No. 14-281).

During the months of April to November from 2009 to 2015, we tracked badgers an average of 5 days a week during daylight hours, until loss or death of the individual. Badgers were located by driving in a grid pattern from the last known location outward, and scanning with an omni-directional whip antenna. Once a badger was found, we acquired permission from landowners to locate and record geographic coordinates of the badger’s daytime burrow within an accuracy of 5 m. When land access was not granted, we took at least 3 directional bearings from roads to estimate burrow locations through triangulation. Only triangulated locations that had an accuracy of 100 m or better were used in our nightly movement analysis.

**Study area scale: Burrow selection analysis**

Animals move in search of preferred habitat attributes, food sources, and mates (Proulx et al. 2013). For this reason, we performed the burrow habitat selection analysis first, so that these results could be incorporated into the movement analysis within home ranges (Table 1).
assess habitat selection across the study area, we used presence-only modeling techniques: Mahalanobis distance factor analysis (MADIFA) and an ecological niche factor analysis (ENFA) (Hirzel et al. 2002; Brotons et al. 2004; Martinez et al. 2006). These modelling frameworks were selected over a generalized linear model (GLM; i.e., presence-absence modelling technique) since true absence data in elusive carnivores are frequently unknown, making 'pseudo-absences' largely unreliable (Brotons et al. 2004). In instances where reliable absence data are available, MADIFA and ENFA give comparable results to GLMs (Hirzel et al. 2006). The ENFA also has several advantages when compared to GLMs, including being robust to deviations from normality and accommodating highly correlated predictor variables (Glass and Hopkins 1984; Hirzel et al. 2002). We performed both MADIFA and ENFA for all badgers pooled across all years, as there were insufficient data to assess differences in habitat selection by individual or year.

MADIFA is a multivariate method for comparing used to available habitat to determine habitat selection in populations or individuals (Hirzel et al. 2002). MADIFA generates a global marginality score, which indicates the magnitude of the overall difference between used and available habitat space across all variables. A global marginality score >1 indicates significant habitat selection within the study area (Hirzel et al. 2002). The MADIFA can also be used to generate a habitat suitability map, by calculating the Mahalanobis distance between each cell’s value and the identified niche values, thus generating a relative suitability surface, where lower Mahalanobis scores correspond to higher habitat suitability.

While MADIFA describes overall habitat selection, ENFA quantifies the effects of individual variables on habitat selection through the generation of marginality and specialization scores. Variable marginality reflects the difference between values of each independent variable.
at known burrow locations and those available in the study area. The further the score is from 0, the greater the difference is between used and available habitat. Positive variable marginality indicates selection for larger values of the independent variable, whereas negative scores indicate selection for smaller values (Hirzel et al. 2002). The specialization axis measures the narrowness of the niche, which is the ratio of variance of the available habitat to the used habitat. Large, absolute values of variable specialization indicate greater variation in available habitat as compared to used, and a selection associated with that variable (Basille et al. 2007).

Based on a priori knowledge of American badger habitat selection, 13 independent variables were included in our analysis (Table 2). Specifically, to model the effects of human disturbance on badger burrow placement, we included distance to urban centers and distance to roads, which we modeled separately for the three different road classes present in our study area (Warner and Ver Steeg 1995). As a fossorial carnivore, we expected badger burrow placement to be influenced by soil texture and other terrain variables (percent rise and aspect), since these may affect the stability of the burrow (Apps et al. 2002). As a purportedly open habitat species (Apps et al. 2002), we modeled the proportion of agriculture – the most dominant open habitat type in our study area (67% of landcover) – within a 575m radius of a burrow, equaling half the average nightly distance moved by the badgers in this study. Further, we modeled distance to various vegetated habitat edges (woodlands, hedgerows, water course, and train tracks), since we expect badgers to use these linear features as travel corridors, foraging sites, and for concealment from predators, such as coyotes (Packham and Hoodicoff 2004; Quinn et al. 2008). Last, we modeled the proportion of wooded habitat edge within a 575m radius of a burrow to determine if edge density influences overall burrow placement.
Geospatial data on land use types was acquired from the Southern Ontario Land Resource Information Systems (SOLRIS) (Ontario Ministry of Natural Resources 2008), a raster-based landscape inventory with a 15 m² resolution, differentiating 23 land cover types. We extracted water courses, hedgerows, woodlands, and urban land use types and performed an Euclidean distance analysis to generate distance-to raster layers. Proportion of agriculture and wooded edge were also derived using SOLRIS, by calculating the density within a 575m radius of each burrow. Road and train track networks were obtained from Land Information Ontario, and the Euclidean distance function was used to generate distance to layers (DMTI Spatial Inc. 2014; Ontario Ministry of Natural Resources, 202). Soil was reclassified from its initial categorical format (i.e., loam, clay, sand) provided by the Canada Land Inventory (2003) to a numerical scale of grain size. Slope and aspect were obtained from the Digital Elevation Model layer (Ontario Ministry of Natural Resources 2006). Slope was reclassified to be expressed as percent rise (Apps et al. 2002). Square-root transformations were applied to several variables to reduce the positive skew, thus better meeting the assumptions of these analyses (see Table 2) (Calenge 2011). All raster datasets were processed at a 30 m² raster resolution in ArcGIS 10.3.1 (Environmental Systems Research Institute (ESRI) 2015).

**Within home range: Nightly movement analysis**

We used burrow locations as well as triangulated locations with <100m accuracy on consecutive days to generate simplified straight-line movement trajectories (i.e., actual trajectories) by connecting start and end burrow locations in ArcGIS (ESRI 2015). Using Geospatial Modelling Environment (Beyer 2015) we generated 10 random end points within an individual’s home range for each known start point, where the home range was defined as the minimum convex polygon encompassing all known burrow locations. We constrained random end points such that
their distance from the start point was between the first and third quartile of the average nightly
distance travelled, reflecting a distance that an individual would realistically reach within an
average night. Random end points were also constrained such that their locations were in habitats
with suitability scores less than the third quartile, excluding the most unsuitable habitat from the
random point generation. We then drew straight lines between start points and all randomly
generated end points (i.e., random trajectories). Random trajectories were associated with their
corresponding actual movement trajectory.

Actual and random trajectories were overlaid on the CanMap® RouteLogistics local road
network layer (DMTI 2014). We extracted the number of roads crossed for each trajectory, and
information on the road attributes at each intersection between the trajectories and roads. These
attributes included road class (a reflection of traffic volume and road surface) and speed limit in
kilometers per hour. We reclassified road class values such that higher values represented
highways and lower values denoted smaller, local roads. Specifically, of the five road classes in
Ontario, three were found in our study area: 4 = primary highways, 2 = major paved roads, and 1
= local gravel roads. The number of road crossings per night was standardized by meter
travelled.

The standardized number of road crossings was compared between actual and random
trajectories sharing a common start point using a conditional logistic regression (Thurfjell et al.
2014). We also used a conditional logistic regression to determine if road class or speed limit
affected road crossing, where road attributes were treated as the independent variables. Since
most movement trajectories had multiple road intersection points, it was necessary to summarize
road attributes for each movement trajectory into a single value. We selected the maximum road
class and maximum speed limit, under the assumption that roads with the highest perceived risk will have the greatest influence on movement behavior within the home range.

Road crossing scale: Road mortality analysis

Geographic positions of road-killed badgers with <100 m accuracy were compiled from public sighting reports collected from August 1987 to October 2015. To assess landscape features influencing individual road crossings, we compared features at road-kill locations to a set of 10 non-overlapping, random locations along the same roadway within 2.3 km in either direction, which corresponded to the average nightly displacement by radio-tracked badgers in this study. For actual and random locations, speed limit was recorded because this attribute varies along the length of a road. Road class was not included as there was no variation in this attribute along roadways. Within a 100 m buffer of each actual and random point, we recorded the percent cover of agriculture (e.g., pasture and cropland), forest, and hedgerows as well as the number of wooded and linear water features (e.g., rivers, streams, drainage ditches) approaching the roadway. We compared attributes of road-kill locations to random locations using a conditional logistic regression. All statistical analyses were performed using R version 3.2.2 (R Development Core Team 2013).

Results

We tracked 9 adult badgers with radio-transmitters (5 males, 4 females). Males had an average home range size of 223 km$^2$ and females 52 km$^2$ (Table 3). In total, 817 unique burrows were identified (range 27 - 140 per individual; Table 3), most of which were found in forests (46%, with 61% of those burrows occurring less than 10 from the forest edge), followed by agricultural lands (38%) and hedgerows (5%). Badgers were located on 1521 consecutive nights (range 49 - 315; Table 3) and on average moved 2.3 km from their previous locations based on straight-line
distances (maximum 13.7 km). Road density ranged from 0.48 – 3.52 km/km² within home
ranges. On average, 1.6 roads were crossed in a night based on minimum estimates (±1 SD =
2.22). Excluding trajectories that did not cross any roads, the average speed limit of roads
crossed by actual trajectories was 66.2 km/h (±1 SD = 13.2) and the average road class was 1.35
(±1 SD = 0.73), which generally corresponds to gravel roads in rural areas. Of the 9 badgers
tracked with radio telemetry, 3 died by collisions with vehicles, the locations for which were
included in the road mortality analysis.

The significant global marginality score of the MADIFA indicates badgers in our study
select for at least one of the included habitat variables (1.86, p = 0.001, Fig. 1). Based on the
results of the ENFA (Table 2, Fig. 2), the independent variables which have the greatest effect on
badger burrow placement (> 0.20; Hirzel et al. 2002) are percent rise, soil texture, edge density,
and distances to train tracks, woodlands, and hedgerows. Specifically, badger burrows are placed
in areas with steeper slopes, sandier soils, and closer to vegetated habitat edges. High edge
density has the greatest influence on burrow placement. The first axis of specialization suggests
badger burrow placement is most restricted by distance to roads of higher class (i.e., primary
highways) and distance to train tracks.

At the home range scale, five badgers crossed significantly fewer roads than expected by
chance, whereas one badger crossed roads significantly more frequently than the associated
random trajectories (AB29; Table 4). Three badgers significantly avoided roads of higher speed
limits and six avoided roads of higher road class (Table 4).

Of the 21 road-killed badgers analyzed at the road crossing scale, the number of water-
based linear features and percent cover of hedgerows showed a positive correlation with actual
road-kill locations (p < 0.05).
Discussion

Findings from our study suggest Ontario badgers are affected by roads at multiple spatial scales, including burrow site selection (Table 2, Fig. 2) and movement within the home range (Table 4). These results have important implications for managers interested in developing road-mitigation strategies for this endangered population.

Primary highways contributed most to the specialization axis of the ENFA, suggesting badgers are restricted to a limited range of this variable (i.e., there is greater variation in available habitat as compared to used), with a mean shift toward lower distances. Specifically, the burrows of four badgers (AB24, AB33, AB34, AB35) were clustered around two primary highways (Highway 3 and 19), which bisect the city of Tillsonburg (population ~16,000). Similar patterns in badger habitat selection have been observed in British Columbia (Apps et al. 2002) and Ohio (Duquette et al. 2014), where burrows were found closer to roads than would be expected by chance. In these instances, selection for areas close to roads, and other areas of human disturbance (e.g., urban centers) (Hoodicoff 2003), is thought to be related to the presence of preferred prey resources (Apps et al. 2002). Sampling bias may also play an important role in the observed pattern of burrow site selection, whereby badgers whose territories are closer to primary highways have burrows which are more easily seen and are subsequently more likely to be trapped and radio-tracked. Clustering of badger activity in areas where other badgers are also present, particularly during the breeding season, increases spatial overlap in home ranges (Minta 1993), and may amplify the effect of sampling bias near roads. Regardless of what mechanism is responsible for the observed pattern in burrow site selection, our results suggest that badgers are relatively tolerant of human disturbance at this spatial scale.
Over half the badgers in our study crossed significantly fewer roads than expected by chance, suggesting badgers avoid roads during regular nightly movements within their home range. When badgers did make road crossings, some individuals avoided crossing more risky roads (i.e., primary highways with higher speed limits). Most notably, badgers whose burrows were located closer to primary highways (AB24, AB33, AB34, AB35), were less likely to cross those highways than expected by chance (Table 4). Thus, while the presence of preferred habitat attributes may attract badgers to place burrows near roads, this will not necessarily result in more frequent crossing attempts. This result suggests badgers can detect differences in road risk, and make movement decisions accordingly. Similar movement patterns are seen in hedgehogs (Erinaceus europaeus L., 1758), which cross fewer large roads (> 4 m wide) than expected based on random movement trajectories. Wolves have also been shown to differentiate between high and low traffic roads during crossing events (Thurber et al. 1994; Rondinini and Doncaster 2002; Dellinger et al. 2013). Many hypotheses are proposed to explain road avoidance behavior by wildlife (reviewed by Forman and Alexander 1998), yet relatively few studies resolve mechanism. Perhaps the most likely mechanism is that badgers perceive oncoming vehicles as they would predators, and avoid crossing roads when vehicles are present (Frid and Dill 2002). This is supported by observations of an American badger in British Columbia, which was observed walking along a roadside and hiding in the roadside vegetation as cars approached (Klafki, pers. comm.). Factors such as traffic-associated noise or vibrations could also result in a behavioural shift away from roads of higher traffic volumes, as is seen in Gray wolves (Whittington et al. 2005), cougars (Puma concolor L., 1771; Dickson et al. 2005), and Grizzly bears (Pigeon et al. 2014). In order for the mechanism of road avoidance to be elucidated, shorter telemetry time-steps would be necessary, as our straight-line 12-24 hour movement trajectories...
greatly oversimplify the actual movement profiles of individual badgers. While trajectories based
on daily telemetry allow us to estimate the minimum number of roads crossed, and provide
limited detail about crossing conditions (i.e., road class and speed limit), shorter time steps and
more detailed information on road attributes (i.e., nightly traffic volume) and resource
distribution (i.e., prey availability) would allow a more refined analysis of factors affecting
badger movement patterns, provide a more accurate estimate of the number of roads crossed, and
better resolve the mechanisms responsible for the road avoidance apparent at this spatial scale.

Percent cover of hedgerows and number of water-based linear features intersecting roads
were positively associated with road-kill locations. This relationship between mortality locations
and water-based linear features is consistent with the findings for Gray wolves, which tend to
cross roads in areas where roads intersected with rivers (Latham et al. 2011). Riparian areas are
also important movement corridors for other species including genets (*Genetta genetta* L., 1758)
and cougars (Dickson et al. 2005; Carvalho et al. 2016). The cause for this association may not
be due to the presence of the water feature itself, but rather the presence of vegetated habitat
buffers and steeper slopes that can accompany rivers, streams and ditches. This assertion is
supported by the results of the ENFA, which indicate that badgers place burrows closer to
vegetated linear features (e.g., hedgerows, woodlands, and train tracks), as well as in areas with
steeper slopes, such as along ravines. Both burrow site selection and road crossing attempts near
these vegetated linear features may be due to increased cover, prey abundance, or a combination
thereof, as hypothesized for other carnivores in which selection for edge habitat is observed
(Bider 1968; Larivière 2003; Šálek et al. 2010; Svobodová et al. 2011).

A commonly proposed solution to reduce road-kill incidence of American badgers is
culverts (Clevenger and Waltho 2000; Kinley and Newhouse 2009; Klafki 2013). For example,
in British Columbia, Kinley and Newhouse (2009) found a negative relationship between the number of culverts and road-mortality instances. It was concluded that wildlife culverts should reduce badger mortality and aid recovery. Our findings, on the other hand, indicate that road mortalities are more likely to occur near features that may already have culverts or underpasses in place (i.e., near linear water features), which suggests that, while culverts and underpasses may be present, they are not necessarily being used to facilitate badger road crossings. Presumably, this is because culverts are obstructed with vegetation, inundated with water (Kinley and Newhouse 2009), or are not preferred road crossing structures for badgers. Preserving vegetated edge habitat types away from roads may therefore be a more efficient use of resources to protect the Ontario badger population, since these areas are selected for at multiple spatial scales, and may be crucial for providing suitable burrow sites and prey resources in less disturbed areas (Carvalho et al. 2016).

Road mortality was the leading known cause of death of radio-tracked badgers in this study (3 of 9), and of collected carcasses in Ontario (~1.3 individuals / year since 1972; Natural Heritage Information Centre 2016, J. Sayers, Ontario Badger Project, personal observation). However, to some extent, the latter is likely a result of sampling bias, whereby badgers killed on roadsides are more likely to be seen and collected than those that have died of other causes (e.g., disease; Ethier et al. 2017). Despite some unsuccessful crossing attempts, our results demonstrate that badgers make many successful road crossings during movements. Further, the majority of badger movements occur at night, when roads see greatly reduced traffic volume. Consequently, it is difficult to ascertain the population level effects of road mortality on badger population persistence, particularly because population size in Ontario is itself poorly understood (estimated < 200 breeding individuals, COSEWIC 2012), and other sources of mortality remain largely
unquantified (e.g., kit survival; Ethier et al. 2017). Although our study could not resolve the mechanism of badger burrow selection or road avoidance during nightly movements, the basic understanding of habitat selection and movement in relation to roads at multiple spatial scales provides useful direction for implementing effective and efficient conservation strategies to protect this endangered population.

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Fig. 1. Habitat suitability map for American badgers (*Taxidea taxus jacksoni*) in southern Ontario, Canada (insert). Suitability was calculated with a Mahalanobis distance factor analysis of all known badger burrow locations in the study area (large polygon), mapped at a 30 x 30m resolution. High suitability scores are shown in black (i.e., lower Mahalanobis scores correspond to higher habitat suitability) and low suitability in white. Individual badger home ranges are denoted with white polygons.

Fig. 2. Biplot of the ecological niche factor analysis for American badger (*Taxidea taxus jacksoni*) habitat selection in southern Ontario, Canada. The x-axis corresponds with the variable marginality score and the y-axis corresponds with specialization. The dark grey polygon represents the used habitat, with the white dot denoting its center. The light grey polygon represents the available habitat. Arrows demonstrate the relative influence of marginality and specialization scores of the environmental variables. Abbreviated names of variable are described in Table 2.
**Table 1.** The relationships between spatial scale, analysis performed, date type and statistical test used to assess American badger (*Taxidea taxus jacksoni*) habitat selection and movement behavior in Ontario, Canada.

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</tr>
</tbody>
</table>
Table 2: Marginality and specialization scores for independent variables included in the ecological niche factor analysis (ENFA) for burrow selection by American badger (*Taxidea taxus jacksoni*) in southern Ontario, Canada.

<table>
<thead>
<tr>
<th>Name</th>
<th>Variable description</th>
<th>Marginality</th>
<th>Specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>aspect</td>
<td>Aspect</td>
<td>-0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>rise</td>
<td>Percent rise*</td>
<td>0.29</td>
<td>-0.08</td>
</tr>
<tr>
<td>soil</td>
<td>Soil texture based on grain size</td>
<td>0.38</td>
<td>-0.04</td>
</tr>
<tr>
<td>agri</td>
<td>Proportion of agriculture within a radius of 575m</td>
<td>-0.19</td>
<td>-0.15</td>
</tr>
<tr>
<td>edge</td>
<td>Wooded edge density within a radius of 575m</td>
<td>0.52</td>
<td>0.05</td>
</tr>
<tr>
<td>track</td>
<td>Distance to train tracks</td>
<td>-0.26</td>
<td>0.65</td>
</tr>
<tr>
<td>water</td>
<td>Distance to water*</td>
<td>-0.21</td>
<td>-0.09</td>
</tr>
<tr>
<td>wood</td>
<td>Distance to woodlands*</td>
<td>-0.45</td>
<td>-0.08</td>
</tr>
<tr>
<td>hedge</td>
<td>Distance to hedgerows*</td>
<td>-0.34</td>
<td>0.01</td>
</tr>
<tr>
<td>urban</td>
<td>Distance to urban center*</td>
<td>-0.08</td>
<td>0.09</td>
</tr>
<tr>
<td>road1</td>
<td>Distance to local grave road*</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>road2</td>
<td>Distance to major paved road*</td>
<td>-0.03</td>
<td>0.13</td>
</tr>
<tr>
<td>road4</td>
<td>Distance to primary highway*</td>
<td>-0.15</td>
<td>-0.71</td>
</tr>
</tbody>
</table>

* square-root transformation applied to reduce positive skew
Table 3: Summary statistics of telemetry data collected on American badgers (*Taxidea taxus jacksoni*) in southern Ontario, Canada, and associated home range attributes.

<table>
<thead>
<tr>
<th>Badger ID</th>
<th>Sex</th>
<th>Average distance travelled/night (m)(^1)</th>
<th>Number of consecutive days</th>
<th>Number of unique burrows</th>
<th>MCP(^2) home range size (km(^2))</th>
<th>Home range road density (km/km(^2))</th>
<th>Cause and date of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB27</td>
<td>Male</td>
<td>1962</td>
<td>136</td>
<td>121</td>
<td>199.1</td>
<td>1.19</td>
<td>Canine distemper</td>
</tr>
<tr>
<td>AB34</td>
<td>Female</td>
<td>1171</td>
<td>181</td>
<td>124</td>
<td>81.6</td>
<td>1.57</td>
<td>Status Unknown</td>
</tr>
<tr>
<td>AB36</td>
<td>Female</td>
<td>873</td>
<td>51</td>
<td>52</td>
<td>53.8</td>
<td>1.04</td>
<td>Status Unknown</td>
</tr>
<tr>
<td>AB30</td>
<td>Male</td>
<td>1272</td>
<td>141</td>
<td>111</td>
<td>170.4</td>
<td>1.17</td>
<td>Vehicle Collision</td>
</tr>
<tr>
<td>AB35</td>
<td>Female</td>
<td>940</td>
<td>114</td>
<td>103</td>
<td>54.2</td>
<td>3.52</td>
<td>Cause of death unknown</td>
</tr>
<tr>
<td>AB23</td>
<td>Female</td>
<td>627</td>
<td>27</td>
<td>27</td>
<td>52.3</td>
<td>0.48</td>
<td>Vehicle Collision</td>
</tr>
<tr>
<td>AB24</td>
<td>Male</td>
<td>1403</td>
<td>77</td>
<td>54</td>
<td>174.7</td>
<td>1.80</td>
<td>Vehicle collision</td>
</tr>
<tr>
<td>AB33</td>
<td>Male</td>
<td>2187</td>
<td>171</td>
<td>140</td>
<td>237</td>
<td>1.80</td>
<td>Status Unknown</td>
</tr>
<tr>
<td>AB29</td>
<td>Male</td>
<td>1554</td>
<td>104</td>
<td>98</td>
<td>336.2</td>
<td>1.39</td>
<td>Cause of death unknown</td>
</tr>
</tbody>
</table>

\(^1\) average distance calculated using all consecutive nights (includes nights where no movement occurred)

\(^2\) MCP = Minimum convex polygon
Table 4: Results of the conditional logistic regression of road crossing frequency (number of crossings per meter travelled) and road attributes for each American badger (*Taxidea taxus jacksoni*), tracked with radio-telemetry in Ontario, Canada, where symbols indicate the direction of significance ($p<0.05$) and blanks indicate non-significant results.

<table>
<thead>
<tr>
<th>Badger ID</th>
<th>Difference in crossing frequency</th>
<th>Maximum road class</th>
<th>Maximum speed limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB27</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB34</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB36</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB30</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB35</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB23</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB24</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB33</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>AB29</td>
<td>+</td>
<td>−</td>
<td>−</td>
</tr>
</tbody>
</table>