Environment and Natural Resources Trust Fund

Research Addendum for Peer Review

Project Manager Name: Dr. Nicholas McCann

Project Manager Email address: mccan062@umn.edu

Project Title: Mapping habitat use and disease of urban carnivores

Project number:

Abstract

Wildlife is an important part of many urban landscapes, but urban wildlife studies remain only a small proportion of the wildlife literature. Coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), and gray foxes (*Urocyon cinereoargenteus*) occupy rural and urban landscapes. Although these species are well-studied in rural landscapes, urban research is relatively infrequent, and no study has occurred in the Minneapolis-Saint Paul Metropolitan Area (hereafter the Twin Cities Metro Area; TCMA) where managers lack information about resource requirements, disease, and human-conflict. In this study, we will investigate coyote, red fox, and gray fox space use, disease, diet, and demographics in the TCMA. We will capture and GPS collar individuals of each species across the TCMA's urban-rural gradient and examine biological samples (hair, blood, and scat) to assess diet and disease prevalence. We will develop resource selection functions (RSFs) using GPS locational data and use RSF results to map space use and the risk of conflict with people and disease transmission. Our results will provide much-needed information to TCMA wildlife managers and foundational infrastructure for future studies.

Background

Wildlife is an important part of many urban landscapes. Although urban wildlife studies have increased in frequency, they remain only a small proportion of the wildlife literature (Magle et al. 2012). A recent review summarizing the benefits and costs of urban wildlife for people found that wildlife provides important ecological services (e.g., as predators of pest species) and improve the wellbeing of city residents (Soulsbury and White 2016). Evidence suggests that viewing wildlife improves physical and mental health, and that the presence of wildlife may increase the value of green spaces (Soulsbury and White 2016). In addition to these benefits, urban wildlife also present challenges. Negative human-wildlife interactions can range in severity from damage to gardens to attacks on pets and people (White and Gehrt 2009). Whereas benefits of urban wildlife are difficult to quantify (Soulsbury and White 2016), costs are often more obvious and thus have garnered more attention. Severe human-wildlife conflicts draw media attention (White and Gehrt 2009) and may lead to negative misperceptions about wildlife (Gompper 2002). Perceptions of urban wildlife will likely be influential in how people prioritize conservation efforts as human populations grow and become more urbanized.

The presence of wildlife in urban areas has increased recently (Gompper 2002, Gehrt 2007, Gehrt et al. 2009) and research that elucidates how these growing wildlife populations interact with the urban landscape and the people that reside there is critical (Riley 2006). Studies have shown that the behavior and demographics of urban wildlife differ between urban and rural settings (Harrison 1997, Riley 2006) and have also shed light on why human-wildlife conflicts occur (Miller 2015, Poessel et al. 2017). Collectively, this provides managers with information about how to better manage urban wildlife and reduce conflicts (Breck et al. 2017).

Mapping animal space use provides important information to wildlife managers about resource selection (McCann and Moen 2011) and human-wildlife conflict (Miller 2015). It is possible to map space use multiple ways, including by collecting locational data using game cameras, scent stations, and Global Positioning System (GPS) collars (Gompper et al. 2006, Mueller et al. 2017). Tracking animals with GPS collars is a powerful way to assess animal space use (Cagnacci et al. 2010) because it allows researchers to consider variations caused by individual, age, and sex that are difficult or impossible to account for using other methods. Advancements in GPS collar battery life and location accuracy have expanded opportunities to track wildlife for long durations at fine temporal and spatial scales. These advancements will be particularly useful for understanding urban wildlife, because they will allow researchers to track how animals move among the patchy resources typical of urban landscapes (Gehrt et al. 2009).

Coyotes (*Canis latrans*), red foxes (*Vulpes vulpes*), and gray foxes (*Urocyon cinereoargenteus*) are mesocarnivores that occupy rural and urban landscapes. The three species can be important predators in some cities and their presence can improve the quality of life for human residents there (Gehrt and Riley 2010; Soulsbury et al. 2010). Although coyotes and foxes are relatively well-studied in rural landscapes, urban research is less common (Gehrt and Riley 2010). Urban gray fox research is especially rare and most urban red fox research is from Europe and Australia (Soulsbury et al. 2010). This is unfortunate as behavior of urban canids can differ from that of rural canids (Gehrt and Riley 2010), so extending results from rural research to urban landscapes is questionable.

Some urban canid populations have increased in recent decades, creating interest and concern for city residents (e.g., coyotes: Gompper 2002, Gehrt et al. 2007; red foxes: Reperant et al. 2007). Studies from multiple cities have improved our understanding of urban canid ecology, including in Chicago (Illinois; Gehrt et al. 2009), Madison (Wisconsin; Mueller et al. 2018), Denver (Colorado; Poessel et al. 2016), Geneva (Switzerland), and near San Francisco (California; Riley 2006), and elsewhere (reviewed by Gehrt and Riley 2010 and Soulsbury et al. 2010). These studies have revealed consistent patterns of how urban canids navigate urban landscapes. Coyote nocturnality and red fox density, for example, are positively correlated with urbanization, and vehicle strikes are the most important cause of mortality for both species in multiple urban areas (Gehrt and Riley 2010, Soulsbury et al. 2010). Such research has elucidated how canids use cities and interact with people, and how canid behavior changes across the urban-rural gradient.

Results that differ between cities highlight the necessity for city-specific research. For example, coyotes consumed 18-times more anthropogenic food in Tucson (Arizona) than in Chicago (reviewed by Gehrt 2007) and gray fox home range sizes were >5-times larger in a residential area in New Mexico than near San Francisco (Harrison 1997, Riley 2006). Patterns of disease prevalence also differ among cities. Red foxes had 2.5-times more tapeworms (*Taenia* spp.) in Geneva than in Zurich (Switzerland; Hofer 2000, Reperant et al. 2007) and both positive (Soulsbury et al. 2010) and negative (Reperant et al. 2007) correlations of disease with urbanization have been reported. Different human population densities may explain why results differ between cities (Gehrt 2007). Different species assemblages, landscape compositions, and ecological interactions likely also influence study results.

Ours will be the first study of coyote and fox ecology in the Minneapolis-Saint Paul Metropolitan Area (hereafter the Twin Cities Metro Area; TCMA) and will provide foundational infrastructure for additional studies. Coyotes, red foxes, and gray foxes occur in the TCMA, but no published research exists to inform managers about TCMA coyote and fox resource requirements, disease, and demographics. Residents have reported human-coyote conflicts, which range from sightings to pet killings (M. Lunaris, Saint Paul Animal Control, Pers. Comm.). Sarcoptic mange

(*Sarcoptes scabiei*) has been found in coyotes (A. Shoemaker, Minnesota Trappers Association, Pers. Comm.) and rabies has been detected in a fox (species not reported; Minnesota Department of Health 2016), but these disease insights were based on opportunistic events and a baseline study of disease prevalence has not been conducted. Investigating space use, disease, diet, demographics, and human-wildlife conflict risk will provide information to improve management of coyotes and foxes in the TCMA.

Hypothesis

The overall objective of this study is to understand how coyotes, red foxes, and gray foxes use the TCMA, including their potential for interacting with people, and to provide a foundation for future investigations.

Our project will address 3 main research goals:

1) Resource selection

> H1: Coyotes, red foxes, and gray foxes select resources at multiple spatial scales (e.g., where to establish a territory and then how to use the resources within it; Johnson 1980's second and third orders of selection). We expect that coyotes and foxes will have smaller use areas in more urban landscapes, that they will select for large greenspaces with less use by people, and that foxes will use smaller green spaces that have more open areas due to competition with coyotes.

2) Disease

> H2.1: Diseases that are found in other coyote, red fox, and gray fox populations are present in the TCMA and will vary in prevalence across the urban-rural gradient. We expect that nematode infection rates will be greater in urban areas but that tapeworm infection rates will lower (Gehrt and Riley 2010, Soulsbury et al. 2010). Because we expect to find that patterns of space use and disease prevalence differ for coyotes, red foxes, and gray foxes, we expect that disease transmission risk—among wildlife species and to people and pets—will be also be heterogeneous across the landscape.

3) Diet

> H3: Diets for each species will differ across the urban-rural gradient, with a greater prevalence of anthropogenic foods found in areas with higher human densities.

Methodology

<u>Study area</u>

We will study coyotes, red foxes, and gray foxes in the TCMA, a 7,705 km^2 area in Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, and Washington counties (Figure 1). The mean temperature is -7 °C during winter (December to February) and 22 °C during summer (June to August; National Climate Data Center 2010). Annual liquid precipitation is 82 cm. Common tree species include green ash (*Fraxinus americana*), American elm (*Ulmus americana*), and boxelder (*Acer negundo*; Nowak et al. 2006). Human density varies widely across the study area. Urban centers of Minneapolis and Saint Paul are occupied by > 8,000 people / km^2. Outlying areas are typically occupied by < 1,000 people / km^2 (US Census Bureau 2010).

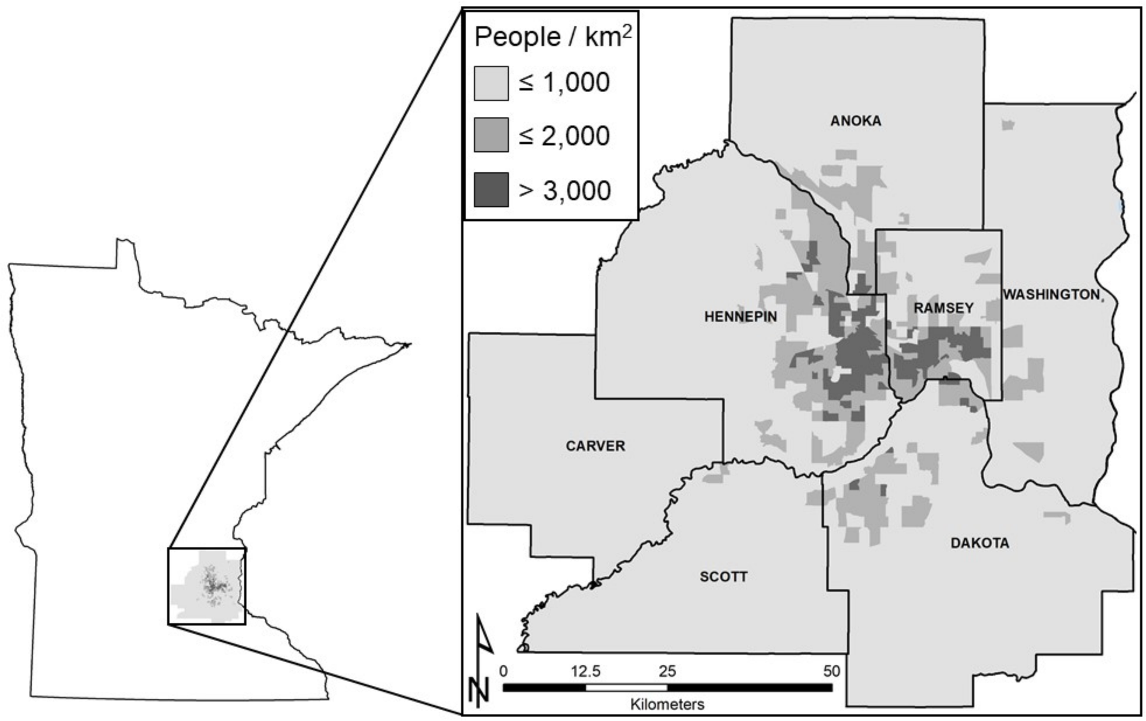

Figure 1. Area where we will study coyotes, red foxes, and gray foxes across a range of human densities. Darker gray shading corresponds with greater human density (people / km^2; US Census Bureau 2010). Inset depicts the Minnesota border.

<u>Capturing and handling coyotes and foxes</u>

We will focus on capturing coyotes and foxes across the range of human densities in the study area. Trapping efforts will focus on capturing study animals distributed evenly across 3 ranges of density: < 1,000 people / km^2, ≤3,000 people / km^2, and >3,000 people / km^2 (Figure 1). We will target male and female adult coyotes and foxes for capture opportunistically (based on reports from the public and wildlife managers), using assistance and reports from the Three Rivers Park District (project partners), Friends of the Mississippi River, the Minnesota Trappers Association, the National Park Service, and the Saint Paul Animal Control Center. These organizations have expressed interest in assisting our capture efforts by sharing information about coyote and fox locations.

We will capture coyotes, red foxes, and gray foxes using cable restraint livetraps that we will set between November 1, 2019 and February 28, 2020, and between November 1, 2020 and February 28, 2021. Cable restraint livetraps will include a "relaxing lock" that releases pressure on a captured animal's neck when the animal relaxes and "stops" that minimize the risk of capturing white-tailed deer. These traps have been safely deployed for canid research in another urban setting (Mueller et al. 2018). They are preferred over other livetraps that can reduce blood flow to a captured animal's toes (foothold traps) and which are more expensive and difficult to deploy (foothold traps and box traps).   We will chemically immobilize foxes and coyotes that we capture with ketamine (10 mg / kg for coyotes, 4 mg / kg for foxes) and xylazine (2 mg / kg; Mueller et al. 2018). For each coyote and fox we capture and immobilize, we will record mass and physical condition, collect biological samples (hair, blood, and feces), and equip a GPS collar that transmits locational data to us using satellites and includes a mortality sensor (Lotek Wireless Fish & Wildlife Monitoring, Newmarket, ON; LiteTrack Iridium 130 for foxes and LiteTrack Iridium 330 for coyotes). We will administer Yohimbine (0.1 mg / kg) to reverse immobilization chemicals before release. We will deploy collars on 15 individual adults from each species. To increase sample sizes, we will sanitize and re-deploy collars that we retrieve from study animals that die during the project. Capture and handling will follow guidelines from the American Society of Mammalogists (Sikes et al. 2016) and the University of Minnesota (Institutional Animal Care and Use Committee; approval pending).

GPS collar fixes

GPS collars will be programmed to record and relay location fixes for 1 year, prior to a scheduled drop off (battery life limits deployment duration). Fix rates will vary to collect locations at 2 scales. Most fixes will be scheduled at a relatively coarse scale (e.g., 7-hour intervals) to provide information about daily and seasonal space use. We will also program each GPS collar to record multiple sequential fixes at a higher rate (e.g., 1 fix every 3 minutes for 60 minutes) during multiple periods (distributed throughout the 24 h period) each week. These fine-scale data bursts will enable us to trace movement paths, including those that intersect parks, residential properties, and trails used by people for walking and biking. Collectively, coarse scale locations might result in approximately 24 locations each week, while bursts will result in an additional 20 locations during each of 3 days (totaling 84 locations per week and 4,368 per year).

Assessing causes of mortality

The GPS collars we use contain a mortality sensor and will send us a text message and email when a mortality of a study animal has occurred. By combining this mortality message with GPS location data transmitted by satellite, we will be able to find study animals shortly after mortalities occur, thereby increasing our ability to assign causes of mortality (Severud et al. 2015). Upon receiving a mortality text message or email, we will locate the study animal (using GPS locations), navigate to it in the field (using radio signals emitted by the collar's VHF transmitter, while respecting private property boundaries), and use evidence at the site (tracks and scat) and wounding patterns on the carcass to assign a cause of death.

Visiting coyote location clusters

During spring and summer we will visit field sites where coyote GPS locations (downloaded via satellite periodically) are clustered within parks and near walking and biking trails. We will also visit 1 or more random sites nearby (75 m away, within the park or along the same trail). At each site we will measure factors that we expect to influence resource selection, including vegetation and anthropogenic structures (Murray and St. Clair 2017). We will focus this data collection only on coyotes during spring and summer because coyotes cause the greatest concern for TCMA residents and human-coyote interactions are most frequent during spring and summer in the TCMA (M. Lunaris, Saint Paul Animal Control, Pers. Comm.).

Data analysis

Survival

We will estimate survival for each species using the Kaplan-Meier Method. This method allows for staggered entry and censoring of missing study animals (Pollock et al. 1989). It also allows for quantifying cause-specific estimates of mortality (McCann et al. 2010).

Diet

We will assess diet for each species separately using 2 methods: stable isotope analysis of hair and examination of scats. We will send hair samples collected directly from each captured study animal (sectioned to acquire information from multiple periods; Murray et al. 2015) to an analytical laboratory for processing. Resulting $\delta^{13}C$ stable isotope data from these 45 individual coyotes and foxes will enable us to assess the frequency of corn-rich foods in coyote and fox diets (Murray et al. 2015). Corn is present in nearly all processed foods and is commonly used for livestock feed. We will also dissect scats collected near capture sites to quantify prevalence of prey species and other forage groups using standard methods (Murray et al. 2015, Poessel et al. 2017). We plan to collect scats from each fox and coyote that we capture (when scats are available at capture locations). This includes each of the 45 study animals that we collar and additional animals that we capture but do not collar before release (e.g., juveniles). It is impossible to know how many scats we will collect, but expect to collect > 50 scats.

Disease prevalence

We will examine captured study animals for presence of ectoparasites (ticks and fleas) and physical signs of sarcoptic mange. We will test fecal samples (collected directly from the rectum) for the presence and intensity of *Echinococcus* spp., *Taenia* spp., and other parasites using fecal floatation techniques. We will send blood serum samples (collected from study animals during processing) to the University of Minnesota Veterinary Diagnostic Laboratory to test for antibodies for the following diseases: rabies, canine distemper virus, canine parvovirus, *Toxoplasma gondii*, *Leptospira* spp., and *Borrelia burgdorferi*. This lab will also test blood serum samples for infection by *Dirofilaria immitis*, the causative agent for canine heartworm.

Home range analysis

We will estimate coyote, red fox, and gray fox home ranges by plotting coarse-temporal-scale locations (7-hour fix interval) from GPS collars in a Geographic Information System (GIS) and calculating kernel density estimates and other home range models (Gehrt et al. 2009, Mueller et al. 2017). We will then develop second-order (Johnson 1980) resource selection functions (RSFs; Manly et al. 2007). Cover type will be the explanatory variable of interest, but we will model interactions with sex, season, and human density. Cover type data and human density will be from GIS layers that are publicly available (e.g., University of Minnesota Department of Forest Resources, NASA; US Census Bureau 2010; Homer et al. 2015).

We will assess actual and potential overlap in space use by coyotes and red foxes. First, we will assess spatial overlap of home ranges where we have data from coyotes and red foxes. As it is likely that most home ranges in our study will not overlap, we will also quantify overlap in use of cover types to assess potential resource partitioning following methods of Mueller et al. (2017).

Distribution and abundance

We will estimate potential coyote, red fox, and gray fox distribution and abundance using methods that are similar to those used by the Minnesota Department of Natural Resources for estimating wolf distribution and abundance (Erb et al. 2017). After identifying selected resources for each species at the home range scale (using MCPs), we will estimate the total area with resources suitable for home-range establishment in the study area. We will calculate abundance estimates by dividing this area by the mean MCP size and then multiplying by mean pack size estimates (adjusting for solitary individuals) using data from our study and other urban canid studies. Results will reflect coarse estimates of potential distribution and abundance.

Selection of parks, residences, and trails

We will develop RSFs across the entire TCMA for all three species. This will allow us to assess the relative probability of animals using specific parks, residences, and walking and biking trails (where human-wildlife conflict is most likely to occur; White and Gehrt 2009; Breck et al. 2017).

For each species, we will develop two third order (within the home range; Johnson 1980) RSFs by comparing characteristics of used locations to those of locations that are available, but unused, within the animal's territory (Manly et al. 2007). The first will describe selection of features (parks, residences, or trails) and the second will describe selection for characteristics within or near features (within-feature-scale; i.e., given that an animal is in a park, how does it use the resources there?). We will fit models to individual animals and then combine them using a lasso regression approach (Street et al. 2016)

The second set of RSFs will quantify selection of attributes within and near features. In a GIS, we will convert sequences of fine-temporal-scale GPS point locations (3-minute fix rate) to lines (hereafter, movement paths). We will overlay movement paths on maps of parks, residences, and trails. We will then model the selection of each feature type by developing step selection functions (SSFs; Thurfjell et al. 2014).

For coyotes only, we will develop a third set of within-feature-scale RSFs with data collected at GPS point clusters (and nearby points without point clusters) at and near features (parks and trails) that we visit in the field. This analysis will provide fine-scale information about space use. Attributes of vegetation and anthropogenic structures will be explanatory variables (Murray and St. Clair 2017) in case-control logistic regression models.

Feature-scale RSFs and within-feature-scale SSFs will incorporate explanatory variables that we can map over the extent of the TCMA, including attributes of parks, trails, and residences. Park size, cover type composition, and usage rates by people will be explanatory variables for selection of parks. Trail type (on-street or off-street, pedestrian or biking), cover type composition in the surrounding area, and usage rates by people will be explanatory variables for selection of trails. Property parcel size, and housing density and cover type composition in the surrounding area will be explanatory variables for selection of residences. Data for park location, park size, park usage, trail location, trail type, trail usage, and parcel size are publicly available (Metropolitan Council 2016, Metro Park and Trail Data Collaborative 2017). Cover type (Homer et al. 2015), human density (US Census Bureau 2010), sex, season, and time of day will be additional explanatory variables.

Mapping risk

We will use results from feature-scale RSFs and within-feature-scale step selection functions to map the relative probability of encountering each study species at parks, residences, and when using trails. We will develop maps in a GIS that depict the probability of encountering a coyote, red fox, and gray fox at each feature (or within a feature, for SSFs) using the best-fitting, most parsimonious models from candidate sets for each species. After testing for spatial clustering of disease positive animals, we will create a disease risk map (Ostfeld et al. 2005) based on the product of the relative probability of use by an animal and the probability that an animal is carrying a specific disease (as determined from testing of fecal samples and blood serum). All maps will be species- and disease-specific.

Results and Deliverables

For coyotes, red foxes, and gray foxes separately, we will estimate space use, distribution, demographics, diet, and disease prevalence. We will also map the risk of encountering each species in the TCMA (for diseased and apparently healthy individuals separately).

The following list summarizes deliverables from this project; the first study of coyotes, red foxes, and gray foxes from the TCMA:

1. *Home range estimates.* These estimates will provide information about resource quality for coyotes and foxes, as home range size correlates negatively with resource quality.
2. *Resource selection functions.* These results will provide information about resource needs for coyotes and foxes, which will in-turn inform greening initiatives.
3. *Distribution maps.* These maps will show where coyotes and foxes are likely to be located.
4. *Abundance estimates.* These coarse estimates will provide information about how many coyotes and foxes are in the TCMA, which is a question that is often posed by the public.
5. *Survival estimates.* These estimates will provide a better understanding about the health of coyote and fox populations, including what causes mortality and whether urban populations are sinks.
6. *Diet information.* These results will describe the role of anthropogenic food sources maintaining populations of wild canids.
7. *Disease prevalence estimates.* These estimates will provide information about the health of coyotes and foxes, with potential inferences for the health of people and pets.
8. *Maps of conflict and disease transmission risk.* These maps will depict the relative probability of human-wildlife interactions in the TCMA, including an index of risk of encounter with animals carrying pathogens or parasites.
9. *Recommendations.* We will make management recommendations for urban coyotes and foxes, especially as they relate to human-conflict, disease management, and resource requirements.

Timetable

Outcome	**Completion Date**
1. Identify study sites, acquire equipment, and train staff	September 30, 2019
2. Capture and process foxes and coyotes – season 1	February 28, 2020
3. Capture and process foxes and coyotes – season 2	February 28, 2021
4. Submit hair samples for stable isotope analysis and submit other biological samples for disease analysis	March 31, 2021
5. Submit final report and results; including risk maps and estimates of space use, distribution, demographics, diet, and disease prevalence	June 30, 2022

Budget

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Budget	Amount Spent	Balance
BUDGET ITEM			
Personnel (Wages and Benefits)	$ -	$ -	$ -
University of Minnesota Graduate Research Assistant, $44,970 (58% salary, 42% benefits) 50% FTE for 1 year	$ 44,970	$ -	$ 44,970
University of Minnesota Graduate Research Assistant, $96,108 (56% salary, 44% benefits) 50% FTE for each of 2 years	$ 96,108	$ -	$ 96,108
University of Minnesota Undergraduate Intern, $5,880 (100% salary, 0% benefits) 4% FTE for each of 2 years	$ 5,880	$ -	$ 5,880
University of Minnesota Postdoctoral Research Assistant, $205,298 (81% salary, 19% benefits) 100% FTE for each of 3 years	$ 205,298	$ -	$ 205,298
University of Minnesota Faculty Member, $12,908 (75% salary, 25% benefits) 8% FTE for 1 year	$ 12,908	$ -	$ 12,908
University of Minnesota Faculty Member, $12,130 (75% salary, 25% benefits) 8% FTE for 1 year	$ 12,130	$ -	$ 12,130
Professional/Technical/Service Contracts			
Service contract for testing 45 biological samples for 8 diseases at University of Minnesota diagnostic laboratories ($13,095)	$ 13,095	$ -	$ 13,095
Service contract for analysis of diet composition at stable isotope laboratory; competitive process will be used to identify a laboratory ($1,350)	$ 1,350	$ -	$ 1,350
Service contract for GPS collar data downloads; competitive process will be used to identify a provider ($21,600)	$ 21,600	$ -	$ 21,600
Professional contract for locating foxes and coyotes and accessing private properties in the Metro area; contract to be with Friends of the Mississippi River ($5,630).	$ 5,630	$ -	$ 5,630
Equipment/Tools/Supplies			
Equipment for fieldwork and managing biological samples, including pharmaceuticals and traps ($5,490)	$ 5,490	$ -	$ 5,490
Capital Expenditures Over $5,000			
GPS collars for red and gray foxes (30 collars @ $1,512 per collar = $45,360)	$ 45,360	$ -	$ 45,360
GPS collars for coyotes (15 collars @ $1,470 per collar = $22,050)	$ 22,050	$ -	$ 22,050
Fee Title Acquisition			
	$ -	$ -	$ -
Easement Acquisition			
	$ -	$ -	$ -
Professional Services for Acquisition			
	$ -	$ -	$ -
Printing			
	$ -	$ -	$ -
Travel expenses in Minnesota			
Vehicle mileage for locating, capturing, and monitoring study animals, delivering presentations, and meeting with collaborators in Minnesota (14,920 miles @ $0.545 per mile = $8,131)	$ 8,131	$ -	$ 8,131
Other			
	$ -	$ -	$ -
COLUMN TOTAL	$ 500,000	$ -	$ 500,000

OTHER FUNDS CONTRIBUTED TO THE PROJECT	Status (secured or pending)	Budget	Spent	Balance
Non-State:		$ -	$ -	$ -
State:		$ -	$ -	$ -
In kind:		$ -	$ -	$ -

PAST AND CURRENT ENRTF APPROPRIATIONS	Amount legally obligated but not yet spent	Budget	Spent	Balance
Current appropriation: M.L. 2016, Chp. 186, Sec. 2, Subd. 03l; Restoration of Elk to Northeastern Minnesota; Dr. Nicholas McCann is the Postdoctoral Associate for this project		$ 300,000	$ 118,006	$ 181,994
Past appropriations:		$ -	$ -	$ -

Credentials

Nicholas P. McCann (Project manager)

Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota

Education

Ph.D., Wildlife Sciences. Purdue University. 2011.
M.S., Biology and Minor in Applied and Computational Mathematics. University of Minnesota–Duluth. 2006.
B.S., Biological Aspects of Conservation. University of Wisconsin–Madison. 2000.

Professional positions

University of Minnesota–Twin Cities. Postdoctoral Associate. 2017 to present.
Great Lakes Indian Fish and Wildlife Commission. Wildlife Biologist. 2014 to 2017.
Minnesota Zoo. Postdoctoral Researcher/Conservation Biologist. 2012 to 2014.
Iowa State University. Bobcat Field Technician. 2003 to 2004.
United States Forest Service. Canada Lynx Field Intern. 2001.

Selected publications

Day, C.C., **N.P. McCann**, P.A. Zollner, J.H. Gilbert, and D.M. MacFarland. Re-submitted. Plasticity in habitat selectivity explains patterns of dispersal and home range establishment in a solitary carnivore. Animal Behaviour.

McCann, N.P., P.A. Zollner, and J.H. Gilbert. 2017. Temporal scaling in analysis of animal activity. Ecography. doi:10.1111/ecog.02742.

McCann, N.P., P.A. Zollner, and J.H. Gilbert. 2017. Classifying carnivore tracks using dimensions that control for snow conditions. Wildlife Society Bulletin 41:278–285. doi:10.1002/wsb.760.

McCann, N.P., R.A. Moen, S.K. Windels, and T.R. Harris. 2016. Bed sites as thermal refuges for a cold-adapted ungulate in summer. Wildlife Biology 22:228-237. doi:10.2981/wlb.00216.

McCann, N.P., P.A. Zollner, and J.H. Gilbert. 2014. Bias in the use of broad-scale vegetation data in the analysis of habitat selection: an example with mammalian predators. Journal of Mammalogy 95:369-381. doi:10.1644/13-MAMM-A-110.

Pauli, B., **N.P. McCann**, P.A. Zollner, R. Cummings, J.H. Gilbert, and E. Gustafson. 2013. SEARCH: Spatially explicit animal response to composition of habitat. PloS One 8:e64656. doi:10.1371/journal.pone.0064656.

McCann, N.P., and R.A. Moen. 2011. Mapping potential core areas for lynx (*Lynx canadensis*) using pellet counts from snowshoe hares (*Lepus americanus*) and satellite imagery. Canadian Journal of Zoology 89:509-516. doi:10.1139/z11-016.

McCann, N.P., P.A. Zollner, and J.H. Gilbert. 2010. Survival of adult martens in Wisconsin. Journal of Wildlife Management 74:1502-1507. doi:10.1111/j.1937-2817.2010.tb01277.x.

Selected awards

Great Lakes Indian Fish and Wildlife Commission ($21,700 over 3 yrs.). 2014, 2015, and 2016.
Bilsland Dissertation Fellowship for outstanding Ph.D. Candidates ($18,727). 2011.
Charles M. Kirkpatrick Memorial Graduate Student Award ($750). 2011.

Selected certifications

Furbearer Trapping Certification from the State of Wisconsin. 2016.
Chemical Immobilization of Animals Certification from Safe-Capture International. 2015.
Furbearer Trapping Certification from State of Indiana. 2010.

James D. Forester — Biographical Sketch

Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, Saint Paul, MN

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(a) Professional Preparation

Frostburg State University, MD	Wildlife/Fisheries, Biology	**B.Sc.,1997**
Univ. of Wisconsin – Madison, WI	Zoology	M.Sc., 2002
Univ. of Wisconsin – Madison, WI	Zoology	Ph.D., 2005
University of Chicago, IL	Ecology & Evolution, Statistics	Post-doc 2005-2008
Harvard University, MA	Organismic & Evolutionary Biology	Post-doc 2008-2010

(b) Professional Appointments

July 2010 – June 2018 Asst. Prof., Dept. Fisheries, Wildlife & Cons. Biol., Univ. of Minnesota
July 2018 – present Assoc. Prof., Dept. Fisheries, Wildlife & Cons. Biol., Univ. of Minnesota

(c) Products

(i) Products Most Closely Related to the Proposed Project.

1. White, L. A., **J. D. Forester**, and M. E. Craft. 2018. Disease outbreak thresholds emerge from interactions between movement behavior, landscape structure, and epidemiology. PNAS https://doi.org/10.1073/pnas.1801383115.
2. Swanson, A., T. Arnold, M. Kosmala, **J. D. Forester**, and C. Packer. 2016. In the absence of a "landscape of fear": How lions, hyenas, and cheetahs coexist. Ecology and Evolution 6:8534-8545 doi:10.1002/ece3.2569.
3. **Forester, J. D.**, H. K. Im, and P. J. Rathouz. 2009. Accounting for animal movement in estimation of Resource Selection Functions: Sampling and data analysis. *Ecology* 90(12):3554–3565.
4. **Forester, J. D.**, D. P. Anderson, and M. G. Turner. 2007. Do high-density patches of coarse wood and regenerating saplings create browsing refugia for aspen (*Populus tremuloides* Michx.) in Yellowstone National Park (USA)? *Forest Ecology and Management* 253:211-219.
5. **Forester, J. D.**, A. R. Ives, M. G. Turner, D. P. Anderson, D. Fortin, H. L. Beyer, D. W. Smith, and M. S. Boyce. 2007. State-space models link elk movement patterns to landscape characteristics in Yellowstone National Park. *Ecological Monographs* 77(2):285-299.

(ii) Other Significant Products.

1. Kohl, M. T., D. R. MacNulty, D. R. Stahler, M. C. Metz, **J. D. Forester**, M. J. Kauffman, N. Varley, P. J. White, D. W. Smith. 2018. Wolf downtime flattens the landscape of fear in Yellowstone National Park. Ecological Monographs (in press).
2. Berg, S. S., J. D. Erb, J. R. Fieberg**, J. D. Forester**. 2017. Utility of radio-telemetry data for improving statistical population reconstruction. *Journal of Wildlife Management* 81(3):535-544.
3. Street, G. M., J. Fieberg, A. R. Rodgers, M. Carstensen, R. Moen, S. A. Moore, S. K. Windels, and **J. D. Forester**. 2016. Habitat functional response mitigates reduced foraging opportunity across bioclimatic gradients: implications for animal fitness and space use. *Landscape Ecology* 31:11939-1953.
4. Oliveira-Santos, L. G. R.*, **J. D. Forester**, U. Piovezan, W. M. Tomás, and F. A. S. Fernandez. 2016. Incorporating animal spatial memory in step selection functions. *Jounal of Animal Ecology* 85(2):516-24.
5. **Forester, J. D**., D. P. Anderson, and M. G. Turner. 2008. Landscape and local factors affecting northern white cedar (*Thuja occidentalis*) recruitment in the Chequamegon-Nicolet National Forest, Wisconsin (USA). *American Midland Naturalist* 160:438-453.

(d) SYNERGISTIC ACTIVITIES

- Institute on the Environment Fellow at the University of Minnesota working to develop collaborations between the College of Food, Agriculture, and Natural Resource Sciences, the College of Veterinary Medicine, and the Minnesota Department of Natural Resources (2011–present).
- Development of a graduate course that teaches students to design statistical modeling frameworks from scratch. This course will start with simple concepts such as linear regression progress to generalized linear models and conclude with non-linear, hierarchical Bayesian models (2012).
- Development of an undergraduate course that focuses on training students to design and carry out independent research projects related to wildlife-habitat interactions (2010).
- Development of an undergraduate online course to teach basic field skills, wildlife species identification, and data analysis (2018)
- Development of an undergraduate field-methods, experiential learning course (2012)
- Participation in the Colorado State University Bayesian Modeling for Practicing Ecologists workshop (2015).

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My research program aims to understand the spread and control of infectious diseases within and between animal species. To achieve this aim, I test hypotheses regarding infectious disease dynamics by using real-world data in models. My professional training has equipped me with a rare combination of skills: I conduct both field-based data collection and theoretical modeling. My research has focused on the spread and control of pathogens in wild and domestic animals.

Academic Rank

Associate Professor in Veterinary Population Medicine
Graduate Faculty in Veterinary Medicine
Graduate Faculty in Ecology, Evolution, and Behavior
Graduate Faculty in Conservation Sciences

Education

B.A.	Brown University (Biology Major)	1997
Ph.D.	Ecology, Evolution, and Behavior, University of Minnesota	2008

Positions/Employment

Associate Professor, Department of Veterinary Population Medicine, UMN	2018-present
Assistant Professor, Department of Veterinary Population Medicine, UMN	2011-2018
Global Environmental Leadership Fellow, UMN	2011
Fellow, Boyd Orr Centre for Populat. & Ecosystem Health, U. of Glasgow	2009-2011
Postdoctoral Fellow, Section of Integrative Biology, U of Texas, Austin	2008-2009
Ph.D. student, Ecology, Evolution, and Behavior, UMN	2003-2008

Honors and Awards

McKnight Land-Grant Professorship, UMN (2016-2018)
Institute on the Environment Fellow, UMN (2016-present)
Institute on the Environment Resident Fellow, UMN (2011-2016)
National Science Foundation—International Research Fellowship (2009-2011)
Young Author of the Year Award (Elton Prize)—British Ecological Society (2008)
National Science Foundation—Doctoral Dissertation Improvement Grant (2007)
Elected to Sigma Xi (Scientific Research Honor Society,1997)
Magna Cum Laude (Brown University, top 10% of graduating class, 1997)

Current Funding from External Sources

- Natural Environment Research Council (NERC), UK; *The impact of resource availability on parasite transmission: insights from a natural multi-parasite community* (2018-2021) £631,347; Role: Project Partner, PI: A. Pedersen.
- National Science Foundation; *Parasitism as a selective pressure on seasonal migration* (2017-2021) $149,248; Role: Co-PI, PI: A. Shaw
- Environment and Natural Resources Trust Fund; *Eco-epidemiological model to assess Aquatic Invasive Species management* (2016-2018) $215,000; Role: Co-investigator, PI: N. Phelps
- National Science Foundation, Ecology and Evolution of Infectious Disease; Title: *Impacts of landscape structure, host demography and management interventions on disease dynamics* (2014-2019) $2,140,013; Role: PI of the subcontract (Co-PI), PI: Susan VandeWoude, Colorado State

Publication Summary Metrics

h-index: 18
i10-index: 26
Total citations: 1047

Selected peer-reviewed publications out of 52 ([g]*graduate advisee*):

1. [g]White, L.A., J.D. Forester & **M.E. Craft**. Disease outbreak thresholds emerge from interactions between movement behavior, landscape structure, and epidemiology. (Provisionally accepted—*Proceedings of the National Academy of Sciences*).
2. [g]White, L.A., J.D. Forester & **M.E. Craft**. (2017) Using contact networks to explore mechanisms of parasite transmission in wildlife. *Biological Reviews*, 92: 389-409. doi: 10.1111/brv.12236
3. **Craft, M.E.** (2015) Infectious disease transmission and contact networks in wildlife and livestock. *Philosophical Transactions of the Royal Society B- Biological Sciences*, 370: 20140107. doi: 10.1098/rstb.2014.0107
4. **Craft, M.E.**, E. Volz, C. Packer & L.A. Meyers. (2011) Disease transmission in territorial populations: the small-world network of Serengeti lions. *Journal of the Royal Society Interface*, 8: 776-786. doi: 10.1098/rsif.2010.0511
   - Recommended by Lloyd-Smith and Pulliam: In F1000Prime, 19 Jan 2011; doi: 10.3410/f.7706956.8032054. http://f1000.com/prime/7706956#eval8032054
5. **Craft, M.E.**, E. Volz, C. Packer & L.A. Meyers. (2009) Distinguishing epidemic waves from disease spillover in a wildlife population. *Proceedings of the Royal Society B: Biological Sciences*, 276: 1777-1785. doi: 10.1098/rspb.2008.1636

Locations of Recent Invited Seminars

Linkoping University, Sweden; The Ohio State University, USA; Penn State; University of Illinois; Colorado State University; University of Bath, UK; University of Liverpool, UK; University of York, UK; Bristol University, UK.

Teaching

Curriculum Development: Health and Biodiversity (VPM 3850W; One Health and Infectious Diseases of Wildlife (VMED 5492)

Instructor: Mechanisms of Animal Health and Disease (CMB 8202); Veterinary Public Health and Preventative Medicine Seminar (VMED 8550, sec 2); Topics in Infectious Disease: Rabies (PubH 7230); Epidemiology of Zoonoses (VMED 8090); Ecology of Infectious Diseases (PubH 5180 & PubH 6380); Agents of Disease II (CVM 6917); Veterinary Clinical Epidemiology (CVM 6922 & 6220); Virology (CVM 6204)

Advising and mentoring

I am currently supervising 4 PhD students, and have supervised 8 undergraduate students, 6 Doctor of Veterinary Medicine students, 5 postdoctoral scholars, and have served/serve on 9 graduate committees.

Service to the Discipline

- Selected panelist or referee activities: Einstein Foundation Berlin, Germany; FRIAS-USIAS; Marsden Fund, New Zealand; National Geographic, Committee for Research and Exploration; National Science Foundation- Ecology and Evolution of Infectious Disease panelist; United States Department of Agriculture-NIFA- Animal Health panelist
- Ad hoc reviewer for over 31 journals

Dissemination and Use

We will present results at state and national scientific conferences (e.g., annual meetings of The Wildlife Society). We will make scientific publications that result from this project available through University of Minnesota websites, Open Access journal websites, and upon a request. Outreach will include speaking engagements at nature centers (e.g., the Eastman Nature Center operated by the Three Rivers Park District) and at meetings held by organizations that are interested in conservation and management of wildlife (e.g., the Minnesota Trappers Association). We expect that this research will draw media attention, which will provide additional opportunities to inform the public about findings from this project.

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