Comparing Carnivore Survey Station Data in Carlton County, Minnesota

(Inquiry Action Project 1)

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Abstract:

Carnivore survey station camera trap data from Carlton County, MN was analyzed in this project. Camera trap data was collected in Carlton County by the Tax forfeited land department staff and summarized by the Natural Resources Research Institute (NRRI). Wildlife species relative abundance, richness and Shannon Diversity Index was analyzed for each site and compared. Differences in relative abundance, species richness and diversity may be explained by a variety of factors. General inferences from this investigation should be seen as an example of a way to analyze this data and as a starting point for future research. Further investigations taking into account detailed forest inventory data as well as seasonality and survey lengths will make inferences from this Inquiry Action Project (IAP) investigation stronger.

Introduction:

Land management goals often rely on information about the structure of wildlife populations including abundance, species richness, and diversity (Jiménez et al., 2017). Mammalian carnivores are particularly important to land managers because of their ability to regulate prey populations and to provide ecosystem services (such as seed dispersal). According to Jiménez et al. (2017) carnivores can heavily influence ecosystem function evidential in the dynamics of a top-down trophic control system. It is important to track the presence of carnivore species that are endangered/threatened, valued as furbearers, or those targeted as nuisance animals, because removal by humans can have a significant influence on their populations and others (Moruzzi et al., 2002). Although not all carnivores are sought after as a furbearer species, those that are subject to managed harvests must be monitored to ensure those populations remain viable. The American marten (*Martes americana*) is an example of a carnivore that nearly disappeared in Minnesota by 1920 due to habitat loss as a result of logging practices (MNDNR, 2019). Another example is the Gray wolf (Canis lupus), which was nearly extirpated from Minnesota due to habitat deterioration, reduction of

prey populations and direct persecution by humans (MNDNR, 2019). Motion-triggered cameras are an effective survey technique because they can be used to estimate distribution, behavior, corridor use, and population size, among other metrics of wildlife population dynamics (Moruzzi et al., 2002). Additionally, remotely triggered cameras are preferred to detect species like forest carnivores that are nocturnal, have secretive habits, may be difficult to physically trap/handle, or that occur at low densities (Iannarilli et al., 2018). Data from camera trap survey stations can be used as point-based sampling devices and the time stamp feature can be used to analyze activity patterns and interspecies temporal interactions (Sollmann, 2018).

The Carlton County Land Department will benefit from resulting insights of the investigation into the comparative question of this project (next section). Because no formal carnivore surveys have been analyzed by county entities in Minnesota it will help to establish best monitoring practices. Monitoring data provides baseline carnivore data for the local land base. Knowing about the carnivore diversities, densities, and activity patterns of carnivores on County managed lands may influence future forest management activities. The Carlton County Land Department is dually certified in the Forest Stewardship Council (FSC) and the Sustainable Forests Initiative (SFI). Both forest certification bodies value wildlife considerations by their members and take them into account when awarding their stamp of approval. Furthermore, findings from this study will be cataloged and can be produced for forest certification auditors when asked about wildlife considerations. Principle 6 from the FSC certification criteria states that “the organization shall maintain, conserve, and/or restore ecosystem services and environmental values of the management unit, and shall avoid, repair, or mitigate negative environmental impacts” (FSC, 2019). Monitoring wildlife by a certified organization will allow insights of how those species, a key part of the ecosystem services mentioned, are being affected by forest management practices.

Comparative Question:

What is the relative abundance, species richness, and diversity of wildlife species at camera-trap carnivore stations in Carlton County, MN?

Methods for collecting data:

Trail camera data on carnivores (and all other species that were detected) was collected from stations on Carlton County managed lands for over 2 years; in the winters of 2017-2018 and 2018-2019. At each survey site GPS coordinates were recorded and a trail camera was affixed 0.5-1m above the ground and locked to a robust tree (to prevent false triggering from wind). A deer leg (bait) was fastened to another tree, within 10m of the camera in its field of view (**see Image 1**). Luring wild animals to a sampling site has been a common practice in wildlife research for decades (Stewart et al., 2019 & Schlexer, 2008). The use of bait (lures or attractants) is an invaluable tool to optimize detection of wildlife (carnivores in particular), especially those such as a fisher (*Pekania pennanti*) which occur at low densities. Stewart et al. (2019) contend that local-scale landscape variability is more important in determining probability of detection than the effect of bait (potential bias of animal movement and space-use).

Image 1: Pictured left is a typical carnivore survey station setup. Note the trail camera in the foreground strapped and locked to a robust tree. A deer leg (bait) is fastened to a tree in the background, approximately 10ft from the camera.

Each carnivore survey site was selected based largely following protocol set by the NRRI (so that this data could contribute to a larger, region-wide study in the future). Sites were chosen

based on a variety of factors including: Carlton County ownership, relative accessibility (proximity to a forest road/trail), cover type (mature hardwoods and/or conifer presence), relatively continuous canopy (forest interior animal focus), and an average diameter of trees at breast height (DBH) greater than 10”. Scouting for survey station locations was done using ArcMap 10.5, aerial imagery, LiDAR imagery, and by scouting on foot. There were a total of 10 survey locations distributed relatively evenly across Carlton County managed lands (**see Figure 1**). Minimum survey length was 6-8 weeks between re-baiting, although total survey periods varied (**see Table 3**). During each camera check (at 6-8 weeks from start) batteries and memory cards were replaced if needed. NRRI compiled the data in summary form which included an excel spreadsheet organized by location, species detected, and time/date stamp.

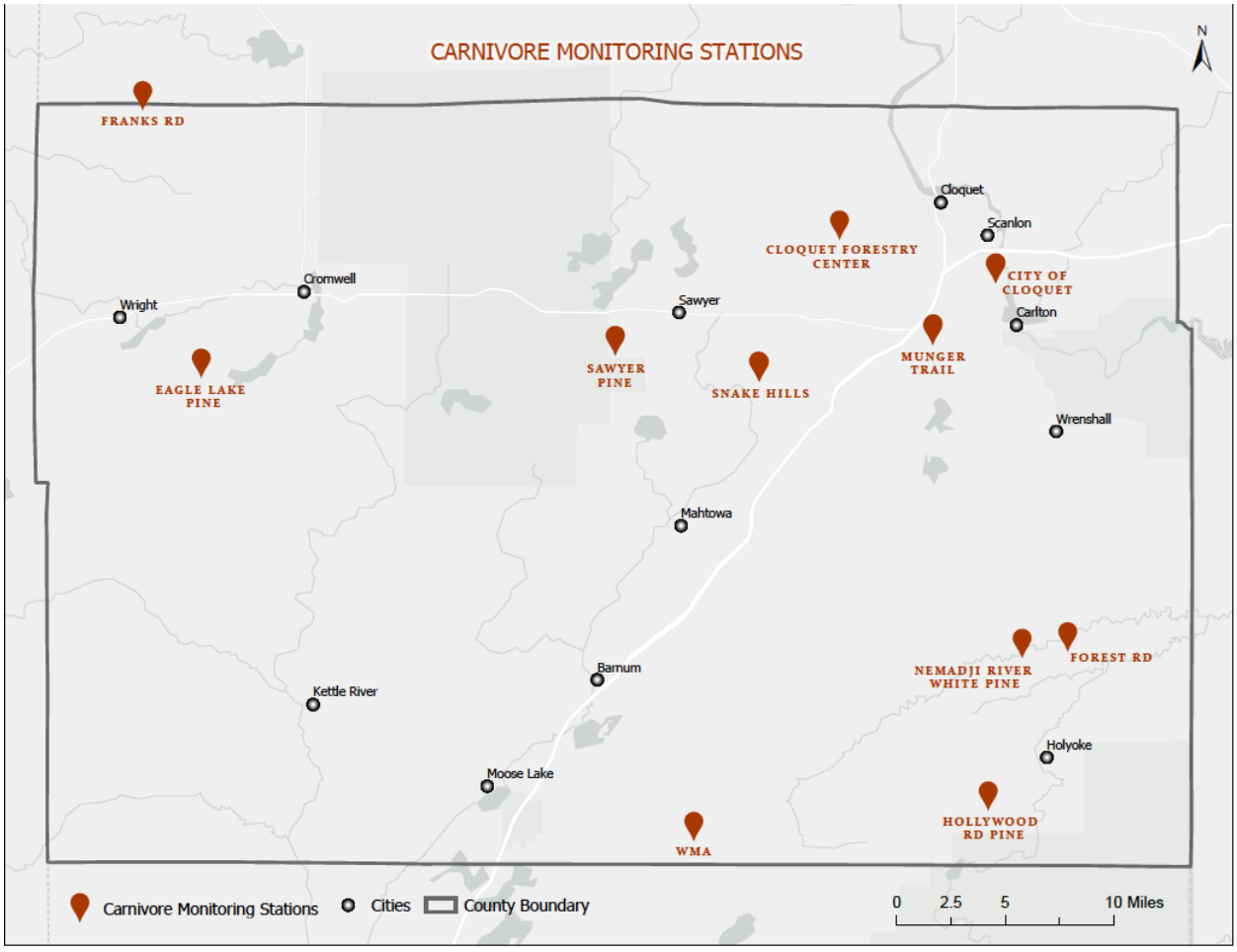

Figure 1: A map of Carlton County, MN with the 10 carnivore survey station locations overlayed. Generated in ArcGis-Online (Courtesy of the Carlton County Land Department).

Methods for analysis:

Relative Abundance will be defined as the total number of organisms detected at each camera trap survey site, regardless of what species they are. This will be calculated by adding up the total number of detection events for each species identified at the site. Species Richness will be defined as the number of different species at each camera trap survey site. Richness will be calculated by adding up the total number of unique species detected at each location. By just looking at relative abundance and/or species richness, it does not give a holistic view of the wildlife populations of those areas. Diversity incorporates both the number of species in an area and the evenness of their abundances.

I will use the Shannon Diversity Index to compare the diversity of sites. A camera trap study by Zlatanova (2018) used a survey period of 138 days and analyzed the diversity of sites using the Shannon Diversity Index. The Shannon Diversity Index (H), uses the following formula: $H = -\sum (P_i) \times \text{Ln} (P_i)$, where *Pi* = the proportion of individuals of each species (**see Table 1**). Microsoft Excel was used to calculate abundance and Shannon Diversity Indices. Graphs and tables were generated to spatially represent results through Microsoft Excel. In order to test whether trapping effort was correlated with abundance, richness, or diversity I used excel to calculate the correlation coefficient (**see Table 2**). “Trapping effort” will be referred to as the total number of days that cameras were operational during each monitoring period. For stations that included multiple years of data, the survey data was combined. The criteria for a detection “event” to count is that an animal is clearly and accurately identified in at least one picture from the site. An event is defined as each single or series of picture(s) depicting the same species/individual with no gaps greater than 30 minutes. This means that an event would only count as one detection even if there are hundreds of pictures of the individual over several continuous hours (as long as there are no lapses in activity for greater than 30 minutes).

Results:

For each of the 10 sites surveyed by baited camera stations in Carlton County a Shannon Diversity Index table was generated for each (**see table 1**). For all sites there were variations in all three wildlife population metrics (**see Table 3**). Franks Rd had the highest

relative abundance with 211 total wildlife detections. Forest Rd had the lowest relative abundance with only 11 total wildlife detections. The Snake Hills site had the highest richness with 10 unique species detected. Forest Rd site had the lowest richness with only 2 unique species detected. The Snake Hills survey station had the highest diversity of wildlife detected on the camera with an (H) value of 1.68. Forest Rd site once again had the lowest value, this time an (H) value of only 0.24.

Table 1: Snake Hills Shannon Diversity Index (H) table

Station Name: Snake Hills
Monitoring Year(s): 2017-2018 and 2018-2019
Survey Dates: 3/19/18--5/15/18 and 1/17/19--4/24/2019
Survey Length: 155 days
County: Carlton

Species	**R. Abundance**	***Pi***	***Ln(Pi)***	***Pi x Ln(Pi)***
Bobcat	4	0.02	-3.91	-0.10
Coyote	2	0.01	-4.61	-0.05
White tail deer	3	0.02	-3.91	-0.10
Fisher	9	0.05	-3.91	-0.20
Flying squirrel	32	0.17	-1.80	-0.31
Peromyscus	15	0.08	-2.53	-0.20
Red fox	3	0.02	-3.91	-0.10
Red squirrel	95	0.52	-0.65	-0.34
Snowshoe hare	19	0.10	-2.30	-0.23
Wolf	1	0.01	-4.61	-0.05
Total:	**183**			**-1.68**
Shannon Diversity Index:	**1.68**			

Table 1 Description: A table mirroring the above format for the “Snake Hills” site was generated for each survey location. Shannon Diversity Index (H), uses the following formula: $H = -\sum (P_i) \times \text{Ln} (P_i)$, Where *Pi* = the proportion of individuals in each species. Carnivore species detected at this site are highlighted in GREY.

Although it could be argued that comparing surveys of different lengths (trapping effort) could account for differences in the population metrics, the correlation coefficient (CE) here says otherwise (**see table 2**). The Correlation Coefficient demonstrates whether two datasets are significantly correlated. A number close to 1 (≥ 0.7) would mean that a very strong correlation is present. A number close to 0 would mean that hardly any correlation exists. To see if trapping effort was significantly correlated with either relative abundance, species richness, or diversity index values, the CE was run using Excel. There was not a strong correlation between trapping effort and relative abundance, resulting in a CE value of 0.3783697143. Species richness and trapping effort also did not have a strong correlation, with a CE value of 0.5312839974. When diversity was tested against trapping effort, the correlation was yet again not strong, with a CE value of 0.4981720732. A range of 0.37--0.53 also does not eliminate the possibility of correlation (this correlation could partially explain differences in these three metrics).

Table 2: Correlation Coefficient Comparisons

Trapping effort vs Relative Abundance	Trapping Effort vs Diversity Index	Trapping Effort vs Species Richness
0.3783697143	0.5312839974	0.4981720732

Table 2 Description: The Correlation Coefficient demonstrates whether two datasets are significantly correlated. A number close to 1 (100%) would mean that a very strong correlation is present. A number close to 0 would mean that hardly any correlation exists. Here there is not a strong correlation between trapping effort and relative abundance, diversity, or species richness. A range of 0.37--0.53 also does not eliminate the possibility of correlation (this correlation could partially explain differences in these three metrics).

Table 3: Summary of Abundance, Species Richness, and Diversity

Site Name	Trapping Effort (Days)	Relative Abundance	Species Richness	Diversity Index
City of Cloquet (Carlton County)	47	98	9	1.62
Eagle Lake Pine (Carlton County)	98	29	6	1.65
Franks Rd (Carlton County)	99	211	9	1.25
Hollywood (Carlton County)	111	24	7	1.36
Munger Trail (Carlton County)	78	82	6	1.44
Nemadji River White Pine (Carlton County)	105	38	3	0.9
Sawyer Pine (Carlton County)	57	92	5	1.27
Snake Hills (Carlton County)	155	183	10	1.68
WMA (Carlton County)	43	65	4	0.35
Forest Rd (Carlton County)	48	11	2	0.24

Table 3 Description: A summary is presented for all 10 camera survey sites in Carlton County and their associated values for: relative abundance, species richness, and shannon diversity index. Trapping effort refers to the total days the camera was operational during monitoring periods.

Camera Monitoring Survey Stations by Shannon Diversity Index

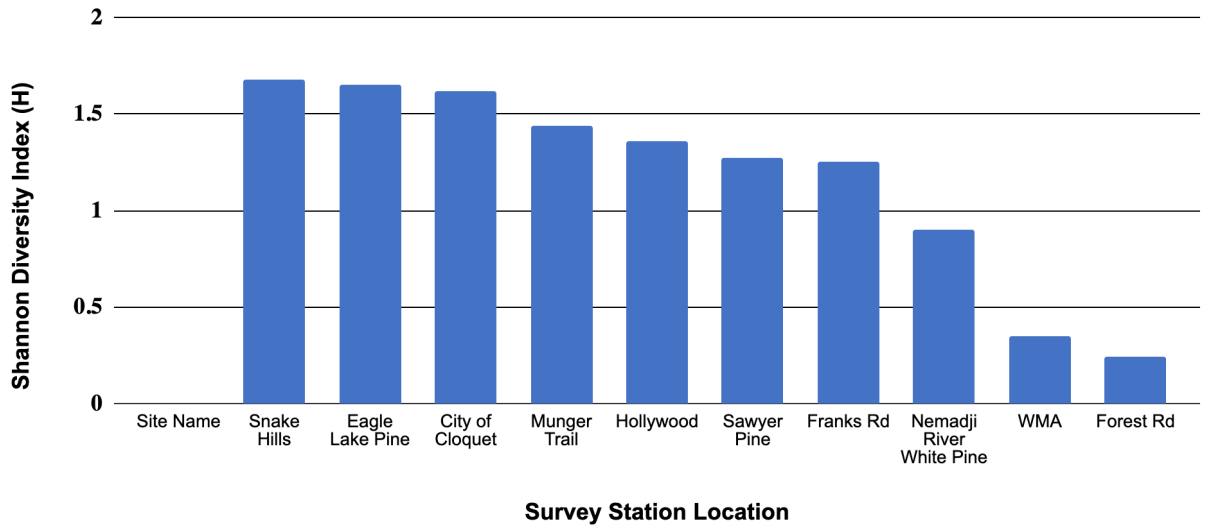

Figure 2 Description: The *Y axis* shows the Shannon Diversity Index (H) from a scale of 0 to 2. On the *X axis* are the camera survey station locations. From left to right the locations are graphed in order of highest Shannon Diversity Index (Snake Hills) to Lowest (Forest Rd).

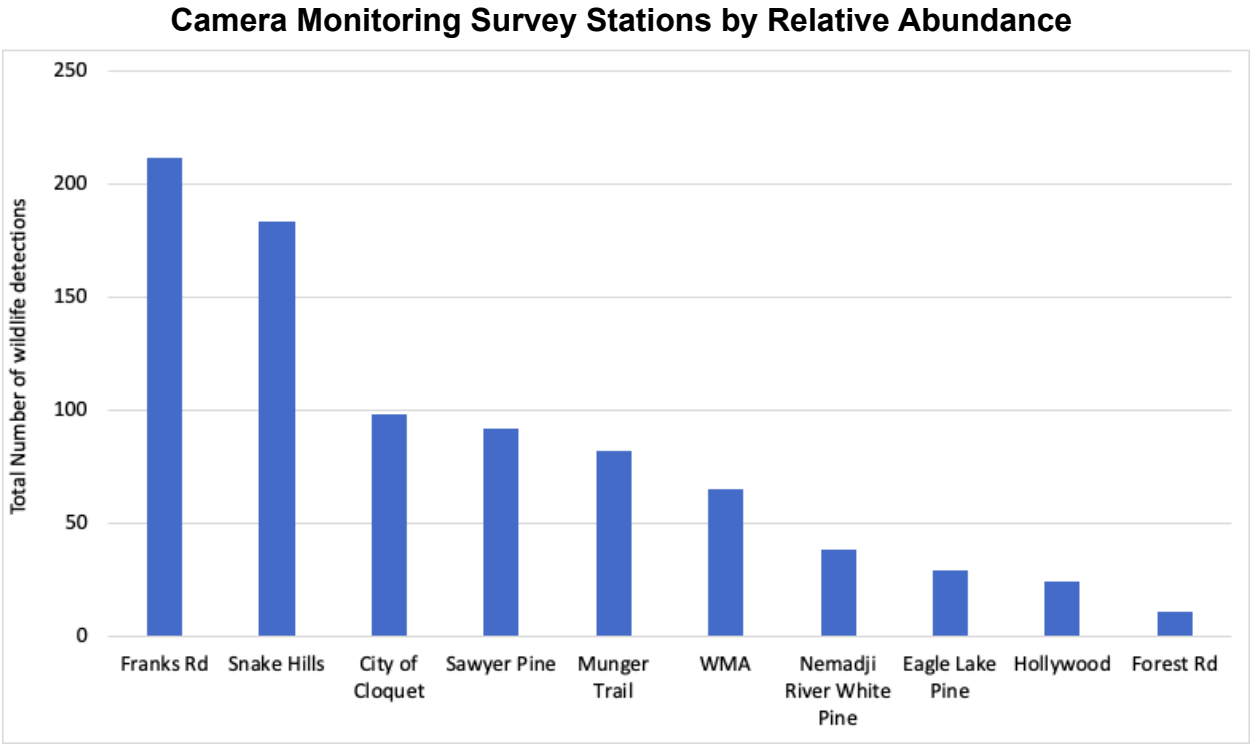

Figure 3 Description: The *Y axis* shows the relative abundance. On the *X axis* are the camera survey station locations. From left to right the locations are graphed in order of highest relative abundance (Franks Rd) to Lowest (Forest Rd).

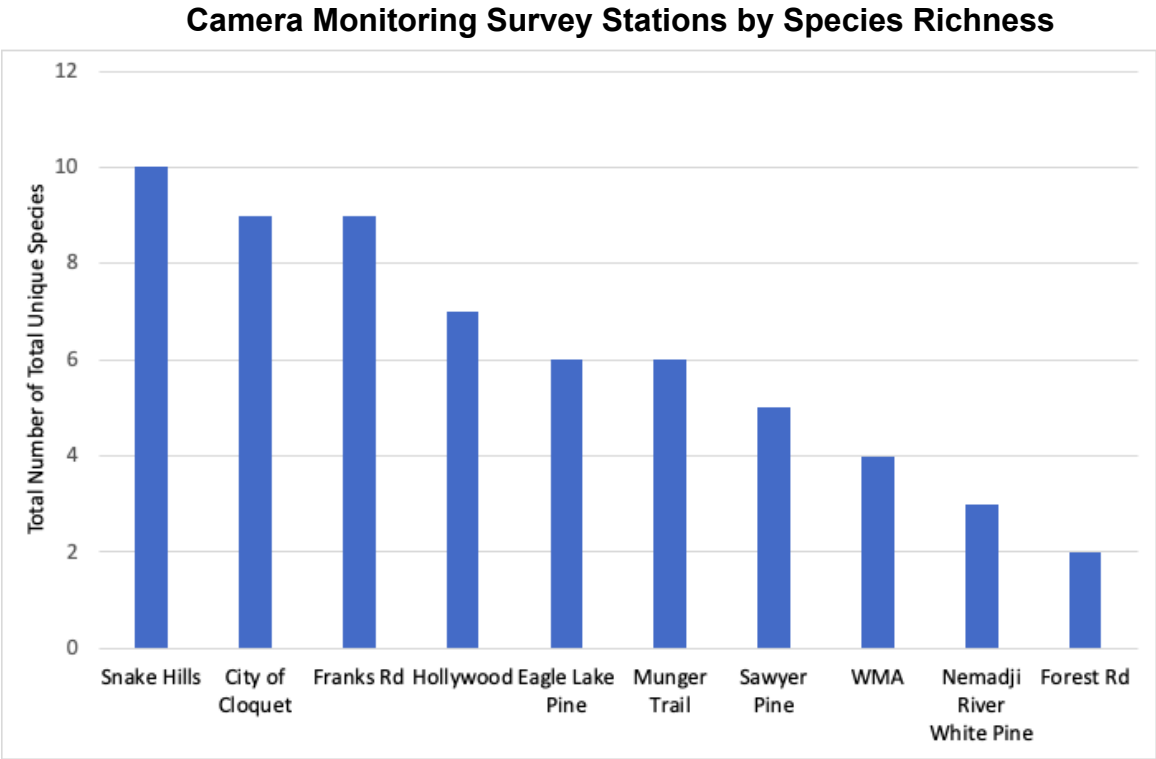

Figure 4 Description: The *Y axis* shows the species richness. On the *X axis* are the camera survey station locations. From left to right the locations are graphed in order of highest species richness (Snake Hills) to Lowest (Forest Rd).

Image 2 (Above, left): A bobcat (*Lynx rufus*) detected at the “Snake Hills” carnivore survey station in Sawyer, MN.
Image 3 (Above, right): A fisher (*Pekania pennanti*) detected at the “City of Cloquet” carnivore survey station in Cloquet, MN.

Image 4 (Left): A red fox (Vulpes vulpes) detected at the “Munger Trail” carnivore survey station in Carlton, MN.
Image 5 (Right): A coyote (Canis latrans) detected at the “Munger Trail” carnivore survey station in Carlton, MN.

Action Component:

The action component of this project is sharing the data analysis methods and results with the Carlton County Land Department (CCLD) and the Natural Resource Research Institute (NRRI). Both organizations will receive an electronic document of this project in order to document methods and results for future use. The mission of the CCLD is to “professionally manage the County’s forest land base in accordance with Minnesota Statutes 282 and to improve the quality and value of the County’s forest land resources” (CCLD, 2019). In comparison, the NRRI has a mission to “deliver research solutions for local ecosystems that provide for both a sustainable economy and simultaneously a healthy environment” (NRRI, 2019). A relationship between these two entities is mutually beneficial. The CCLD benefits from relevant and innovative research summaries as well as best land management practices generated from such research. The NRRI benefits from having an additional local land base (with a multitude of different timber harvest types, habitats, and forest conditions) to collect biological data from. Conversations and partnerships resulting from this project will be aimed at furthering the relationship and future research opportunities between these two entities. Insights gained from this project will be used by NRRI in order to generate future studies and analysis.

Discussion:

I hypothesize that the results presented in this IAP investigation may be explained by differences in the complexity (or heterogeneity) of the local stand level of the sites and/or of differences at the surrounding landscape level. Things to consider, which have potential to effect these metrics are: seasonal variability in movement patterns of wildlife, seasonal variations in resource use, proximity to development or forest management activities, and many more. The Snake Hills survey station was the site that had the highest diversity. From experience on the ground I can say that the stand and surrounding area includes much variation in topography and includes a forested glacial esker that runs the length of the stand. This ridgeline is potentially a main corridor for many forest carnivores as well as other wildlife species. The site also included a high diversity of tree species with larger

average diameter at breast height (DBH). In addition, the site also contains a high amount of large diameter coarse woody debris and dead standing trees and snags, which are important for a variety of animals including the fisher (*Pekania pennanti*) which had multiple detections (definitive unique individuals determined by variations in pelage) at the Snake Hills site. Fishers have been documented to use tree cavities, hollow logs on the ground, and slash piles--all present at this site (Erb et al., 2008).

To further expand upon this pilot study, a future comparative research question might be: "How does the wildlife diversity at sites in Carlton County compared to the diversity of sites on other ownerships in the northeast region of MN?". The DNR and the NRRI both have data sets (following similar protocols) that could be compared to Carlton County to see if geographic variation yields useful information. Another future investigation could be comparing types of forest stand conditions (**See table 4 below**) or management practices (past or present) to diversity at each site. One such question that could be investigated might be: "How is carnivore diversity in the county influenced by forest stand characteristics or silvicultural prescriptions?". I suspect there could be a higher diversity/abundance/richness in sites with higher heterogeneity (tree species diversity, streams, vernal pools, fruit-bearing shrubs/plants, topography variations, etc) as these sites would be expected to provide a greater variety of resources for different species.

Table 4: Stand Inventory Data for "City of Cloquet" Survey Site

	Tree Species	Average “DBH”	Average Height
Main Cover Type	White Pine	21	70
First Additional Species	Red Maple	7	N/A
Second Species	White Spruce	10	N/A
Third Species	Norway Pine	20	N/A
Overall Stand Age	111 years		
Overall Stand “BA”	54		
Overall Stand Area	30 acres		
Year Last Inventoried	2002		

Table 4 Description: The inventory data associated with this stand is cataloged by the CCLD and is updated when possible. This stand has a mix of large mature white pine, white spruce, norway pine as well as smaller diameter hardwoods. The in-person site-visit revealed a large mature trembling aspen component as well (since the stand had not been updated since 2002, ground-truthing was necessary). “DBH” refers to the diameter of the tree at breast height and “BA” refers to the basal area, a metric described as the total cross-sectional area of all stems in a stand.

Another direction for further research may be focusing on a specific carnivore species or comparisons between carnivore species. For example, there are research efforts underway to study the Fisher (*Pekania pennanti*) in northeastern Minnesota. Its population has declined by 50% in the last 20 years in this region (Erb, 2015). I have helped install artificial den boxes and collect trail camera data specifically on the use of these boxes by fishers and other wildlife. Yet another potential comparative question is to analyze the overlap among activity patterns of different carnivore species and between the same species at different geographic locations (landscape variability may create significant differences in movement, hunting behavior, predator avoidance, or space use). “Program R” and “R Studio” can be used to generate a statistical analysis of activity patterns of carnivores in the northeast region of Minnesota (Erb, 2015). The value of activity pattern analysis is in the ability to compare activity patterns of predators with their prey, as well as comparing activity patterns of predators that compete with each other. The revelations will allow the testing of

ecological theories on factors leading to coexistence of competitors. An example of an activity graph using this program is below (**see figure 5**).

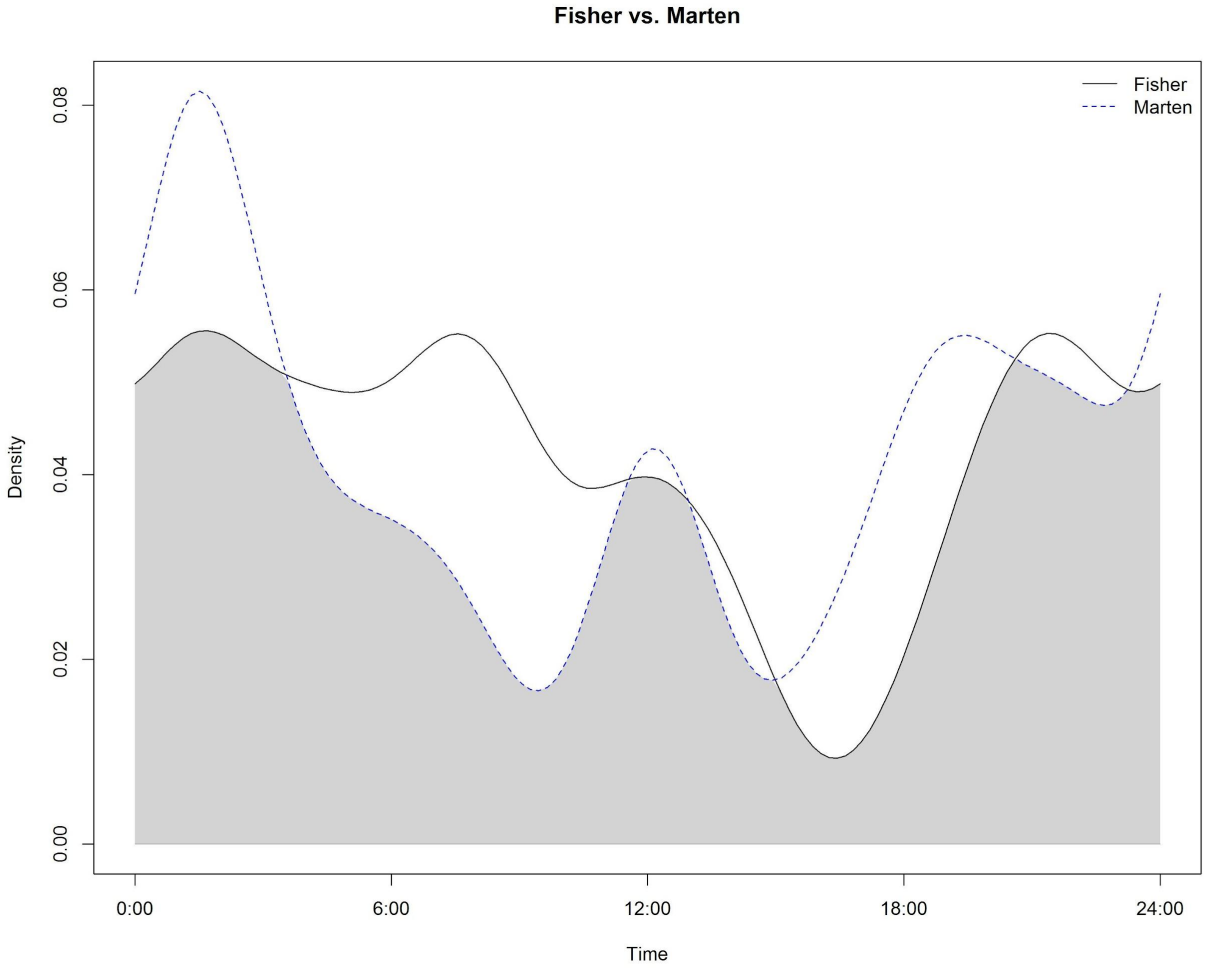

Figure 5: An activity overlap curve of an American marten (*Martes americana*) and a fisher (*Pekania pennanti*) generated by “Program R” using Carlton County Carnivore Survey Data. Note spikes of activity at dawn and dusk for the fisher and similar spikes for the marten, although a more even distribution throughout the day. The greyed-out portion of the graph is where they overlap in activity (83% overlap), meaning they are active (detected at a survey station) during very similar times. The high overlap values between these two carnivores (both are in the family: mustelidae) suggests a high potential for competitive interactions.

Conclusion:

Two and a half years ago, I attended the 2017 annual Forestry & Wildlife Research Review hosted by the Sustainable Forests Education Cooperative (SFEC). The event included a number of speakers in the local scientific community, including a senior research scientist named Ron Moen from the Natural Resources Research Institute (NRRI), a branch of the University of Minnesota. I had a conversation with Ron about the camera trap monitoring we were conducting at the Carlton County Land Department. He mentioned that the NRRI was conducting carnivore surveys using motion triggered cameras in the area and asked if we would host some sites on County managed land. Thus began two years of carnivore survey monitoring on Carlton County lands over two winter seasons (2017-2018 & 2018-2019). The NRRI helped to provide extra cameras when needed, batteries, SD memory cards, and some bait (road killed deer) as well. Another person deserving credit is Michael Joyce, a wildlife research ecologist at NRRI who was instrumental in the partnership. Michael contributed not only to this project, but others on CCLD managed lands, including ongoing fisher research. This IAP investigation was born from the spirit of collaboration and I hope that the partnership develops further. This is an important first step in future collaborative partnerships between CCLD and NRRI aimed at addressing some of the questions that have been generated through this work.

The Shannon Diversity Index for each site offers valuable insights into local wildlife communities at the forest stand that the camera survey station was installed at. It was mentioned earlier that surveys from multiple years were combined for this analysis. As more data is collected over time, it would be beneficial to compare the data by year to give an idea of interannual variability in survey station metrics. Although the statistical power of such an analysis increases with larger sample sizes, even at a smaller scale, this type of comparison can yield useful insights. This baseline data is valuable for future datasets collected in these areas to compare with after timber management activities (harvest, mechanical site preparation, planting trees, mowing brush, soil scarification, etc). The Shannon Diversity Index for each site, may offer insights into local wildlife compositions relative to the forest stand that the camera survey station was installed at. By comparing

sites across the landscape, we can see differences in localized wildlife diversity. Although this investigation does not take a deep look into *why* these areas have different relative abundance, species richness or diversity, it generates more questions to investigate. I hope that the methods explored in this study may be adopted and expanded upon by both the NRRI and the CCLD. I strongly encourage both of these agencies to share their collaborative experience with other land management organizations in the region and encourage involvement in future studies.

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