HABITAT CONNECTIVITY AND INTERSTATE-5: SITE EVALUATION OF WILDLIFE PRESENCE WITHIN THE I-5 NORTHERN LINKAGE ZONE

By

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ABSTRACT

Habitat Connectivity and Interstate-5: Site Evaluation of Wildlife Presence Within the I-5 Northern Linkage Zone

Garrett Stockton Brummel

Interstate 5 (I-5) is a barrier to wildlife habitat connectivity in the southwest portion of Washington State. There is a significant lack of habitat connectivity surrounding the I-5 corridor between Olympia, WA and Vancouver, WA. This lack of connectivity in the region paired with the barrier imposed by I-5 threatens to functionally sever wildlife connectivity between the Cascade Mountains to the Washington coast. Despite research showing wildlife overpasses improve connectivity and reduce costly and dangerous Wildlife-Vehicle Collisions, there are currently no wildlife overpass crossing structures over I-5 in this region. Habitat corridors or linkages act as connective pathways between larger habitat areas for native fauna impacted by human caused habitat loss and fragmentation. Recent habitat connectivity models have identified several linkage zones as the last best chance for reconnecting and preserving connectivity across I-5. One of these linkages, the I-5 Northern Linkage Zone, offers the most direct path for wildlife between the Olympic Peninsula and east of I-5. This linkage encompasses several unique wildlife areas and Priority Habitat types in the South Puget Sound lowlands. In addition to the habitat connectivity models used to identify this linkage, there are other methods available to examine wildlife connectivity. More research is needed within these I-5 linkage zones near I-5 to determine both wildlife abundance and species diversity on both public and private lands.

This study took place within the I-5 Northern Linkage Zone on a 120-acre private property bordering the eastern shoulder of I-5 near Rochester, WA. Using wildlife data collected with remote cameras this study recorded the species diversity and abundance on site beginning in October 2020. This study found wildlife on site that could benefit from the creation of nearby wildlife crossing structures. There were trends in species detection by season, time of day, and habitat type. The methods employed in this thesis can be used to assess wildlife presence, contribute to wildlife connectivity data, and increase partnership with private landowners whose land management practices impact the habitat that creates these wildlife corridors.

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I would like to take the time to acknowledge the people who have helped or inspired me through this process starting with my lovely wife Nora. My parents for their love, support, and financial investment into my academic endeavors. My Thesis Reader, Faculty Emeritus Ralph Murphy, I am sorry for continuing to tether you to academia for two entire years after the start of your well-deserved retirement. Brian Stewart, for introducing me to the fine community of people that is Conservation Northwest and for his unwavering dedication to researching local wildlife. Deston Denniston, for his integral role in establishing the study on site. Cory Mounts, for your tireless effort in data entry and site visits. My classmates, for engaging and pressing through the program beginning in 2020, a very unique year for graduate students. My friends for their support and understanding during all the times I felt obligated to stay home and work on this Thesis. Thanks to Danaher, my expedition support animal. Thank you all so much.

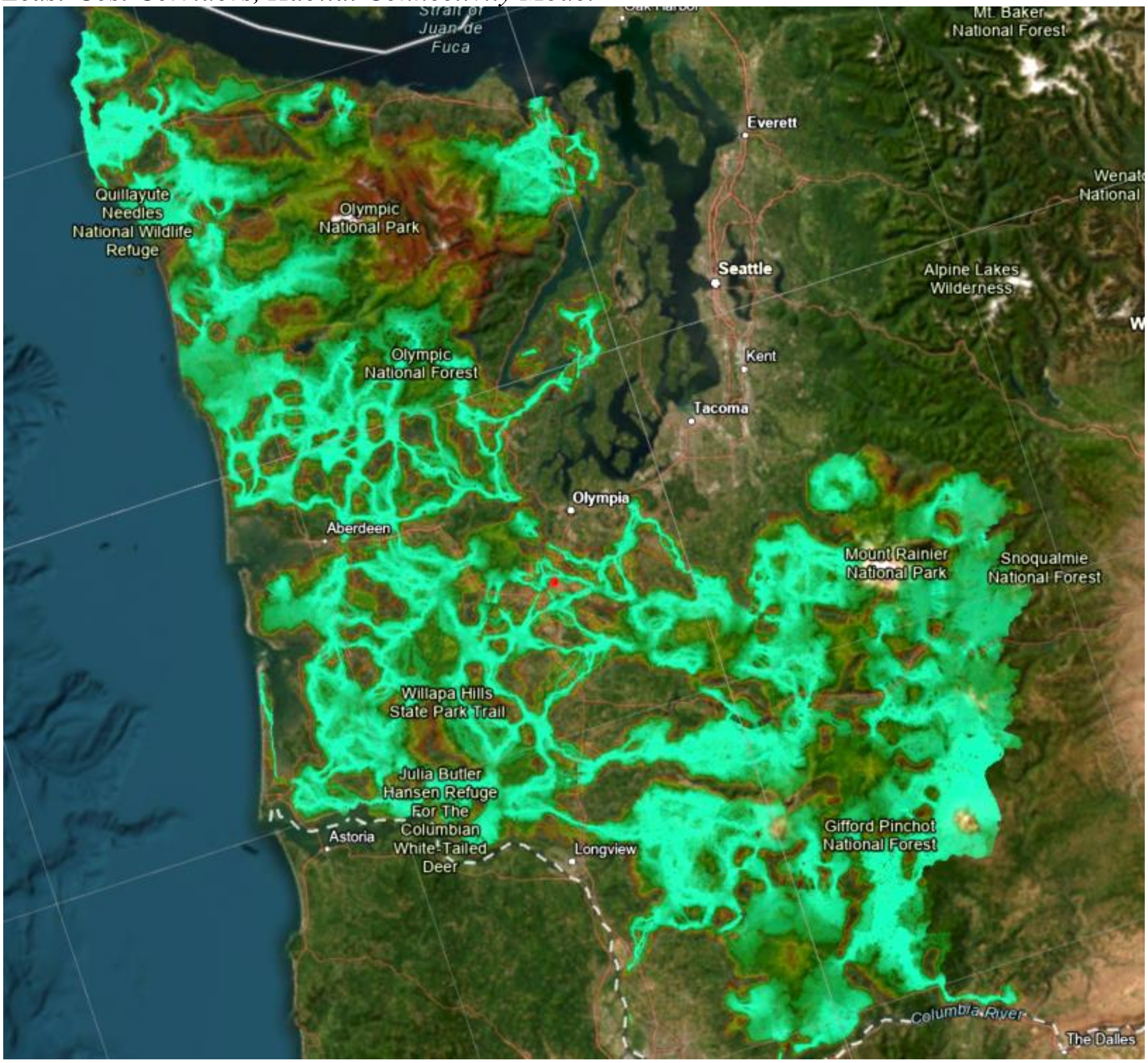
1 Chapter I. Thesis Introduction

This thesis examines habitat connectivity in the South Puget Sound lowlands region of Southwest Washington and its impact on wildlife. What follows is a substantive study of the issues that impact wildlife movement and habitat connectivity in the region.

Habitat connectivity and how it can be impacted by human activity has been a growing area of interest and research in recent years. Attention is now drawn to the relationship between wildlife usage of the landscape and changes to the landscape stemming from human influence. Several studies have focused on understanding the manner in which habitat within specific regions is connected at the local level. While researching habitat connectivity in Southwest Washington, several habitat connectivity models were created by Washington Wildlife Habitat Connectivity Working Group (WHCWG) that highlighted areas of high connectivity, zones connectivity is lacking, and regions that are at risk of isolation should connectivity worsen between them. After mapping the flow of connectivity expected to offer the least resistance to wildlife travel, several zones with limited connectivity were identified in the region of Southwest Washington, particularly around significant populations centers. Large roadways like Interstate 5 (I-5) have also been identified as major barriers that limit connectivity in these models. The area surrounding the I-5 corridor poses a threat to wildlife connectivity from increased human activity in addition to road avoidance and the barrier effect from the interstate itself. There are only a limited number of linkages within the I-5 corridor, also referred to as the I-5 Fracture Zone, that still have high connectivity on either side of the roadway. Having a high level of connectivity on each side of a roadway is a crucial factor in the functionality and success of wildlife crossing structures. There are currently no wildlife crossing structures aiding connectivity within the I-5 corridor in Southwest Washington. Connectivity models (Figure 1.1.), like the Least-Cost Corridor model, created in partnership with Washington Wildlife Habitat Connectivity Working Group (WHCWG), have identified three linkage zones within the I-5 corridor that are of high importance to establishing and maintaining habitat connectivity for wildlife between the Cascade Mountain Range in the southern half of the state to the Washington coast (Gallo et al., 2019).

Figure 1.1

Least-Cost Corridors, Habitat Connectivity Model



Note. Least-Cost Corridors habitat connectivity model created by (Gallo et al., 2019). The web of bright green areas represents the highest levels of connectivity, or where wildlife movement encounters the least resistance from the landscape. The site location, represented by small red circle, is located 12 miles south of Olympia, WA along Interstate 5. ArcGIS Pro 3.2. Edited by Garrett Brummel, 2023.

While these habitat connectivity models provide focus and direction for efforts to restore connectivity between the two regions divided by I-5, there is still a lack of information about the wildlife that inhabit the linkage zones where they meet the interstate. Within the linkage zone closest to Olympia Washington, the I-5 Northern Linkage Zone (NLZ), there is limited public land, and the area is mostly comprised of private ownership. To better understand the wildlife presence on private lands where this high priority linkage zone meets I-5, wildlife data must be collected from the area. This thesis will conduct a site evaluation study of wildlife presence from a private property inside the NLZ with the intent of capturing the greatest diversity and abundance of wildlife present on the property. The data collected in this study will provide on-the-ground counts of wildlife species present on roughly 120 acres of private property within the I-5 Northern Linkage Zone that also borders I-5. Pairing knowledge of areas best situated to maximize connectivity from habitat connectivity modeling with proof of the wildlife diversity and abundance provided by this case study can strengthen the validity of this linkage's importance to habitat connectivity in Southwest Washington.

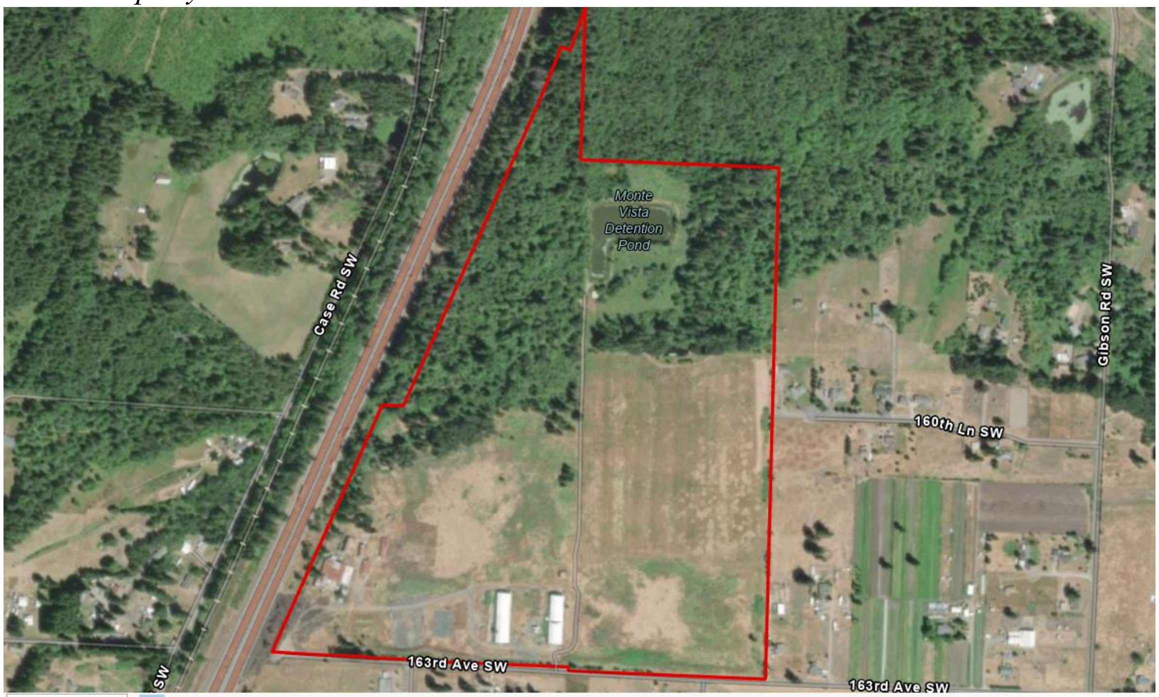
1.1 Research Problem

Knowledge of wildlife diversity and abundance within the I-5 Northern Linkage Zone (NLZ) is lacking. Knowledge of wildlife presence in this linkage, particularly where it meets the barrier of I-5, is needed. A substantial amount of land within this linkage is privately owned, and there is no data currently available for on the ground counts of wildlife on private land within the NLZ. The habitat connectivity studies of Southwest Washington show that the NLZ is a priority for restoration efforts to increase connectivity across the I-5 Fracture Zone (Washington Wildlife Habitat Connectivity Working Group, 2024), but the wildlife that are actually present within the NLZ, on government or private land, have not yet been documented.

This thesis has chosen to address the problem of lacking wildlife data on private land within the NLZ by installing remote cameras to capture wildlife presence on a site that is located within the I-5 Northern Linkage Zone whose property boundary rests on the border of I-5. Veterans Ecological Trades Collective owns a parcel of land (Figure 1.2) 120 acres in size that borders I-5 in Rochester, WA. The site contains unique and rare priority habitat types preferred by some of Washington’s most threatened species as well as habitat suitable for more generalist wildlife species. This property is an ideal location to study wildlife on private property within the NLZ as its location abuts I-5 and a distinct change in both habitat type and level of connectivity as the property transitions from forest to grassland. Conducting a remote camera study to answer what wildlife are present within the property and in what abundance will provide much needed knowledge of a portion of the NLZ where knowledge is lacking. This study will also seek to answer if the data collected provides supporting evidence of a wildlife linkage on the property, and if this evidence aids in validating the WHCWG connectivity model’s identification of the I-5 Northern Linkage Zone.

Figure 1.2

VETC Property



Note. Veterans Ecological Trade Collective (VETC) property in red. I-5 displayed in orange parallel lines along the western property boundary. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

Wildlife within VETC, as the subject of analysis in this study, is linked to the research problem of lacking wildlife data in the NLZ because VETC is located within the NLZ, it is private property with unique habitat types, and collecting wildlife diversity and abundance data will show what wildlife exists on the property. This case study can act as a reference point for what wildlife presence may be found within similar properties within the NLZ. Data identifying the wildlife that can travel to this property and utilize its habitat, until movement is obstructed by I-5, could provide evidence into whether efforts to restore connectivity in this area are likely to be beneficial or not. Or at least, what wildlife are currently present on the property of this case study that stand to benefit from these efforts to increase connectivity nearby.

1.2 Why is Real World Wildlife Data Important to Investigate?

Connectivity between the Cascades and Washington Coast is lacking, specifically within the I-5 corridor. Few areas remain across this I-5 corridor that still retain suitable levels of connectivity and can be utilized by a wide variety of species for travel and resources. Funding and resources for improving connectivity in this region are limited, thus the priority for connectivity efforts should be directed to the places best situated to return the greatest amount of connectivity. The habitat connectivity models provided by WHCWG have identified this I-5 Northern Linkage Zone as one of the last best places to maintain habitat connectivity for wildlife across the I-5 Fracture Zone (CTCA, 2024). Real world wildlife data within the Northern Linkage Zone is lacking in general, and private lands comprise a large portion of this area. Permission to conduct research on private land is typically more difficult to access, and this study can provide a unique insight into what wildlife are present on this site. The wildlife detected in this case study may be representative of wildlife on other similar private properties within the NLZ. This information is valuable as it provides numerical data that complements the work of these habitat connectivity models. The significance of the lack of wildlife detection data within the NLZ is that these habitat connectivity models show this NLZ as an area wildlife are expected to travel and use, but no physical evidence of wildlife use in this area is currently available. The need for increased habitat connectivity through I-5 has been established, wildlife present in the NLZ that would benefit from this increased connectivity have not. The same camera trapping methods employed on VETC's property can be utilized to help locate where wildlife bridges/underpasses/fencing would be most beneficial to wildlife. The implementation of wildlife structures such as these would aid in an increase of landscape connectivity.

Data collection and analysis of wildlife presence within this study site is an appropriate approach for determining what wildlife are present on this property within the NLZ. Much of the land in the I-5 Northern Linkage Zone is privately owned and this case study is likely to represent wildlife presence in properties of similar size and habitat type within the linkage. The data collected in this study is beneficial in addressing the problem of what wildlife will benefit from crossing structures, and if efforts to increase connectivity in this zone will in fact provide connectivity to a significant population of wildlife.

1.3 Prior Knowledge of Connectivity in the Region Prior to This Study?

Landscape connectivity, in one of its most common definitions, refers to "the degree to which the landscape impedes or facilitates movement among resource patches." (Taylor et al., 1993). The level of connectivity impacts the genetic diversity of plant and animal species as well as species distribution on the landscape. Having strong connectivity helps mitigate habitat loss or fragmentation due to human development and infrastructure. Habitat corridors and linkages also act as pathways for climate adaptation, allowing species access to suitable resources in changing ecosystems due to climate change. Habitat corridors are defined in this paper as being a functional connecting link between habitat patches for native flora and fauna. The term "habitat linkages" is incredibly similar to habitat corridors, the main difference being that corridors are generally larger continuous areas of habitat that connect landscapes, and linkages are smaller localized connections with less habitat but that still allow localized movement of wildlife (Forman & Alexander, 1998; Beier & Noss, 1998). Linkage Zones, often referenced in this paper, are defined by WHCWG "Areas that cross major fracture zones (e.g., major highways), but are characterized by a few, long and mostly narrow linkages, which may require enhancement to provide functional connectivity for many species" (Washington Wildlife Habitat Connectivity Working Group, 2024).

The ecosystems of Southwest Washington and the wildlife that exist within them depend on habitat connectivity and functional wildlife corridors to persist and adapt to changing environmental stressors. While this is true of all ecosystems, the presence of safe passages or linkages through the I-5 Fracture Zone would connect thousands of acres in the Cascade Mountain Range to its western neighbors, the Olympic Mountains and the Washington Coast.

A lack of connectivity has been documented across the I-5 corridor by multiple different models (Gallo et al., 2019; Washington Wildlife Habitat Connectivity Working Group, 2024) as well as genetic testing (Wultsch et al., 2023). There is interest from several wildlife and conservation organizations as well as state agencies that are eager to pursue means of establishing permanent and secure connectivity across I-5. The most current WHCWG habitat connectivity models show where wildlife is likely able to travel based on several factors including selected focal species, landscape integrity, habitat parameters, resistance parameters, cost weighted distance surfaces, and others (Gallo et al., 2019; Washington Wildlife Habitat Connectivity Working Group, 2024). While this modeling is likely to be highly accurate and follows both common and expert understanding of wildlife behavior and habitat preferences, investing in connectivity improvement projects in these areas without first confirming wildlife presence firsthand would be a major misstep that could easily be avoided. Several methods exist that can provide supporting evidence to these habitat connectivity models. Wildlife Camera Data, Movement Data, Wildlife-Vehicle Collision Data, Genetic Analysis, and Field Surveys are all viable methods that differ from GIS generated connectivity models. A collection of different methods providing supporting evidence to the validity of a connectivity linkage in the areas identified by WHCWG would be more conclusive and beneficial for establishing a basis of need than one method alone. This study will be useful as it will provide a second method of establishing a basis of need that has not yet been explored, remote camera wildlife data of a significant site within the NLZ

1.4 Will This Study Produce New Knowledge of the Northern Linkage Zone?

Wildlife camera data collected within the study site will provide a numerical perspective to aid in the decision-making process of where potential wildlife crossing structures in this linkage would be most beneficial. Providing stakeholders with sensible real world wildlife data that complements current habitat connectivity models can make wildlife presence and usage within the Northern Linkage Zone more tangible. This particular property is suitable as a case study to address the research problem (lacking because it is a large private site with several distinct habitat types and the landowner was an eager participant that allowed access for wildlife data collection. The methods used in this site evaluation can be replicated on other lands if further study of wildlife presence within the NLZ is deemed necessary. Having accurate on-the-ground data of where animals currently exist is imperative for guiding resources to the preservation of linkages and potential new construction of wildlife crossing structures. Facilitating connectivity where wildlife species are present in both diversity and abundance should provide a greater insight for investing in I-5 connectivity projects like wildlife infrastructure.

This thesis will examine the unique ecosystems and habitat types present in the region and on this study site as well as a verbal history of this particular property. The ecological importance of habitat connectivity as well as the causes of, and effects stemming from, loss of connectivity will also be addressed within the Literature Review. Specific threats to connectivity posed by roadways and functional options used to mitigate and improve roadway connectivity will be explored. Methods available for use in the identification of habitat corridors as well as examples of local methods employed near this site will be reviewed. This thesis will explain the process and methods used to collect wildlife data on the property and the results of this data collection. The data within *Chapter V. Results* of this study will provide wildlife species Detections and Count of Animals, as well as analysis of detection trends over time, from camera sites located in differing habitat types. In addition to the "As Captured" wildlife data, this thesis has created a replicable formula for "Cumulative Forecast Data" to correct for error during the camera data collection process and to situate camera site results over a standard integer of time for equal comparison to other camera sites and studies. Finally, the conclusions and recommendations of this study will be offered as well as final thoughts on habitat connectivity within the I-5 Northern Linkage Zone.

2 Chapter II. Site Introduction and Local Ecosystems

2.1 Study Origins

The process of wildlife data collection first began in September 2020 in partnership with the non-profit Veterans Ecological Trades Collective (VETC) as a project under Conservation Northwest's Cascades to Olympics program. VETC, hoping to improve and recover habitat connectivity on their property, reached out to Conservation Northwest to help monitor and identify current wildlife usage on the landscape using their existing monitoring program Community Wildlife Monitoring Project (CWMP). The project objective was to record species diversity and quantity by location with remote cameras as the wildlife naturally moved across the property. This site location was of particular interest to Conservation Northwest (CNW) because of its immediate proximity to I-5, and its ability to provide wildlife data from within the I-5 Northern Linkage Zone (NLZ) that connects the Olympic Peninsula to the greater Cascade Mountain Range. Both parties were interested in what wildlife was present on the VETC property despite its proximity to I-5. Specifically, what wildlife species are present on the property and in what abundance.

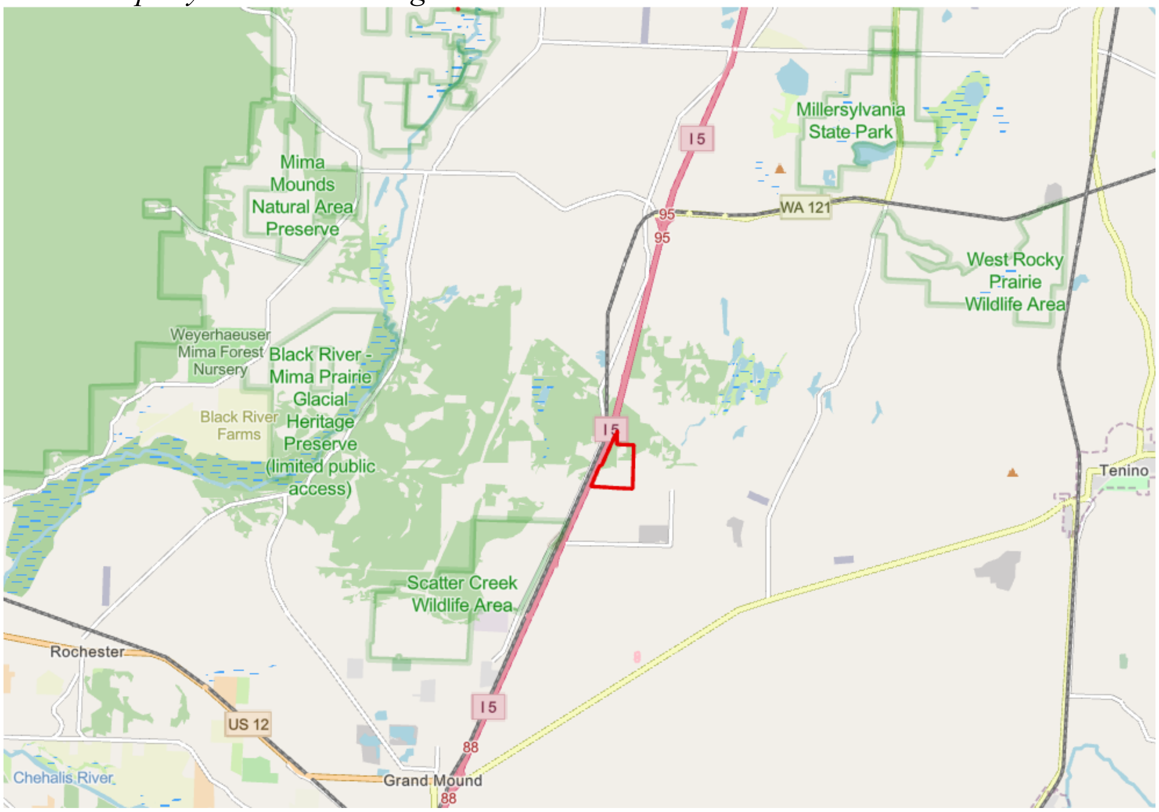
This information is important to Conservation Northwest, VETC, and other interested organizations because the camera data collected could provide useful wildlife data about site, and by extent, the greater NLZ itself. This data could help guide restoration effort decisions by documenting existing demand for habitat connectivity improvements along I-5. The need for increased habitat connectivity across the I-5 corridor has been established, wildlife present in this area that would directly benefit from increased connectivity has not. These same camera trapping methods employed on VETC's property can be utilized to help locate additional areas where wildlife bridges/underpasses/fencing would be beneficial to wildlife. The implementation of such wildlife structures would aid in an increase of landscape connectivity. Having accurate on the ground data of where animals currently exist is imperative to guide resources for the preservation of linkages and potential new construction of wildlife under/overpasses. Facilitating connectivity where wildlife species are present in both diversity and abundance should provide a greater cost/benefit ratio than investing in infrastructure where convenient but with less demand. Using the existing CWMP program and methodology, work began to capture and record as much of the wildlife activity as possible through the use of available remote cameras.

2.2 Site Introduction

The property where this study's data collection took place lies in the lowlands south of Puget Sound in Washington State. Located 12 miles South of Olympia, Washington in Rochester, Washington (Figure 2.1). The boundary of the roughly 120 acres of land is somewhat triangular in shape, with Interstate 5 (I-5) along its entire western border.

Figure 2.1

VETC Property and Surrounding Conservation Areas

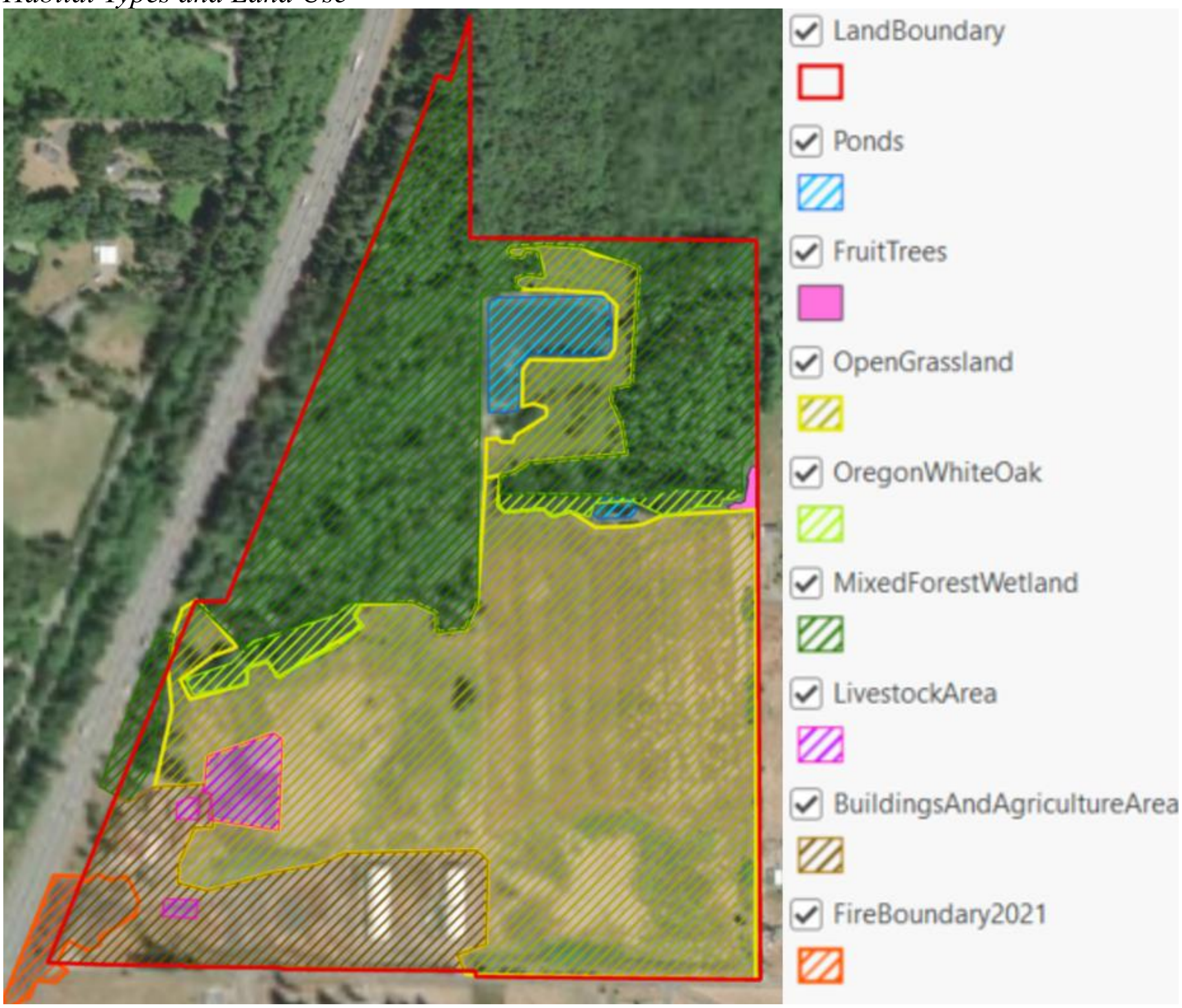


Note. VETC property boundary in red. I-5 west of property in lighter red. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

There are several dilapidated industrial buildings in the southern portion of the site, remnants from previous ownership, and a county road abuts its southern boundary. There are two standing bodies of water, small ponds, that exist on the site year-round and provide aquatic habitat for a variety of species. The property contains a transition zone between two distinct habitat types: prairie grasslands and forest. Prairie grasslands are present in the southern half, a portion of the locally named South Puget Sound prairie. This South Puget Sound prairie ecosystem is also known as Westside prairie by Washington Department of Fish and Wildlife (WDFW) if it meets specific Priority Habitat criteria. The forested half begins with a partial border of mature Oregon white oak (*Quercus garryana*) along the grasslands before transitioning to mixed deciduous/coniferous forested wetland in the northern portion. An old dirt access road leads through the middle of the property to the larger of the two ponds. Property boundaries, as well as habitat types and land use, can be viewed in Figure 2.2.

Figure 2.2

Habitat Types and Land Use



Note. Habitat type and land utilization during the data collection period of this study. I-5 borders the western edge of the property. A fire spread from I-5 through the SE corner of the site. Livestock present on site included goats, domestic turkey, and hogs. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

2.3 Current Property Boundary and Recent History

The following paragraphs are a partial recent history of the site provided by a local resident. This history was compiled during interviews with this individual who is also a member of the non-profit organization that currently owns the property.

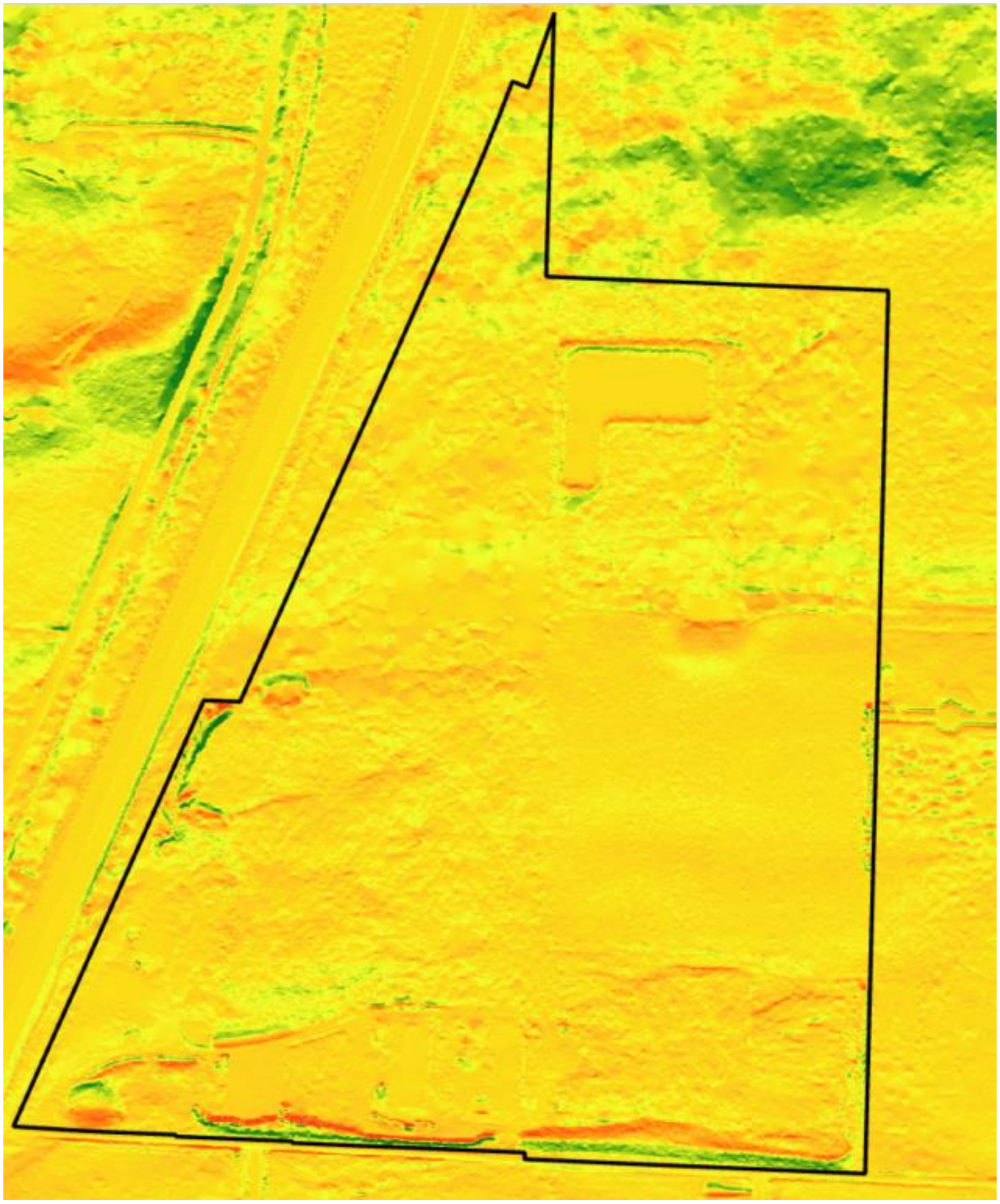
The property was historically part of a two-to-three-hundred-acre family homestead and small dairy farm prior to the construction of Interstate 5 (I-5) in the 1960's. The original homestead was divided by the construction of I-5, and the remaining parcels were then sold into smaller farming plots. Monte Vista Poultry bought a portion of property east of I-5 and operated a commercial chicken processing facility there for several years from 1972-1976. They built the majority of structures on the site such as two large poultry barns, processing warehouses, and offices next to the freeway. There is also a small human-created pond on the property that still bears their name, Monte Vista Poultry Detention Pond. This pond's construction was to aid in the processing of poultry in the northern portion of the site that receives seasonal flooding and has an adjacent pump house still standing. The company failed to reach the competitive level of production that other poultry producers achieved at the time and shut down after four years.

After Monte Vista Poultry went out of business in 1976, there is a gap in this thesis's knowledge of ownership until 1995, when a large-scale compost company named South Sound Soils LLC operated on location from 1995-2001. In 2001 the company was sold to Soil Key Compost Facility who operated on location from approximately 2001-2014. Soil Key constructed two large fabric covered steel truss domes over the footprint of Monte Vista's poultry barns, to aid with their operations composting organic waste. There were significant changes to the southern half of the property during this period of ownership. Compost and topsoil were spread across the fields and mounded in some locations by heavy machinery, for example the earthen walls along much of the southern and eastern border, flattening unique to the region Mima mound structures. Much of the natural Westside prairie ecosystem that had not already been altered by earlier cattle grazing was affected at this time. An E-coli outbreak at the facility led to a temporary shutdown in 2014. However, during the pause in operation the owner of Soil Key passed away and work never resumed, leaving the site idle for some years.

Fremont Dock Company of Seattle was underwriting Soil Key and took control of the property during this time. They briefly leased the eastern field (see smooth square area in Figure 2.3) for farming purposes to a local farm whose main operations were within 100 meters to the east of the property. Veterans Ecological Trades Collective (501c3), or VETC, was formed in 2016 with the mission of "providing veterans space to cultivate community to heal themselves through healing the land." (*Mission, Vision, Values – Veterans' ETC*, n.d.). In 2018 the owners of the property, Fremont Dock Company of Seattle, donated their 120 acres of mixed-use industrial agriculture and forested wetlands to VETC to use for their operations. (D. Denison, personal communication, February 4, 2022). VETC is committed to restoring the natural ecosystem processes on the site and is working to obtain funding and implement conservation programs where possible. Ideas currently being explored include replacing barbed wire fencing with wildlife movement friendly hedgerows, placement of agricultural fields to be non-disruptive to wildlife movement, and the development of a forestry plan on site that maximizes priority Oregon white oak woodland habitat and connectivity.

Figure 2.3

Lidar Terrain View.



Note. Lidar imagery of site shows mounded earthen walls on southern border and flattened grassland that would have held Mima mounds prior to heavy earth moving under Soil Key. Mima mounds can be seen outside of the eastern boundary line at about the midway mark, just below a cul-de-sac that makes a circular shape (enhanced view in Figure 2.4.). The eastern field is significantly smoother in this image, potentially due to past farming or mowing efforts to remove invasive scotch broom (*Cytisus scoparius*). Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

The prairie lands in this area have gravelly coarse soils that are well drained and nutrient poor. These conditions were caused by sediment deposits during the retreat of the Vashon Glacier some 15,000 years ago (Hanna & Dunn, 1997). The prairie lands in this particular area fall within the former path of glacial outwash (meltwater deposits) and Scatter Creek. Some mysterious sediment structures unique to the area, commonly known as Mima mounds (the particular mounds at this site are sometimes referred to as Tenalquot/Scatter Creek Mounds) (Figures 2.3. & 2.4.), are hypothesized to have formed during this glacial retreat (Logan & Walsh, 2009). Another leading hypothesis has models that show the meter high Mima mounds could have been formed over 500-700 years through the burrowing habits of hundreds of generations of the now endangered Mazama pocket gopher (*Thomomys mazama* ssp.) (Gabet et al., 2014). However they formed, these unique features remain in South Puget Sound prairie land to this day. (Figure 2.4). The word “mima” comes from a word in the Chehalis language meaning “newness,” and a similar Chehalis word “mianumn” means “to be surprised” (Washington Geological Survey, n.d.). The path of glacial outwash along Scatter Creek on and near the site can been seen in Figure 2.5. in Lidar and Satellite imagery.

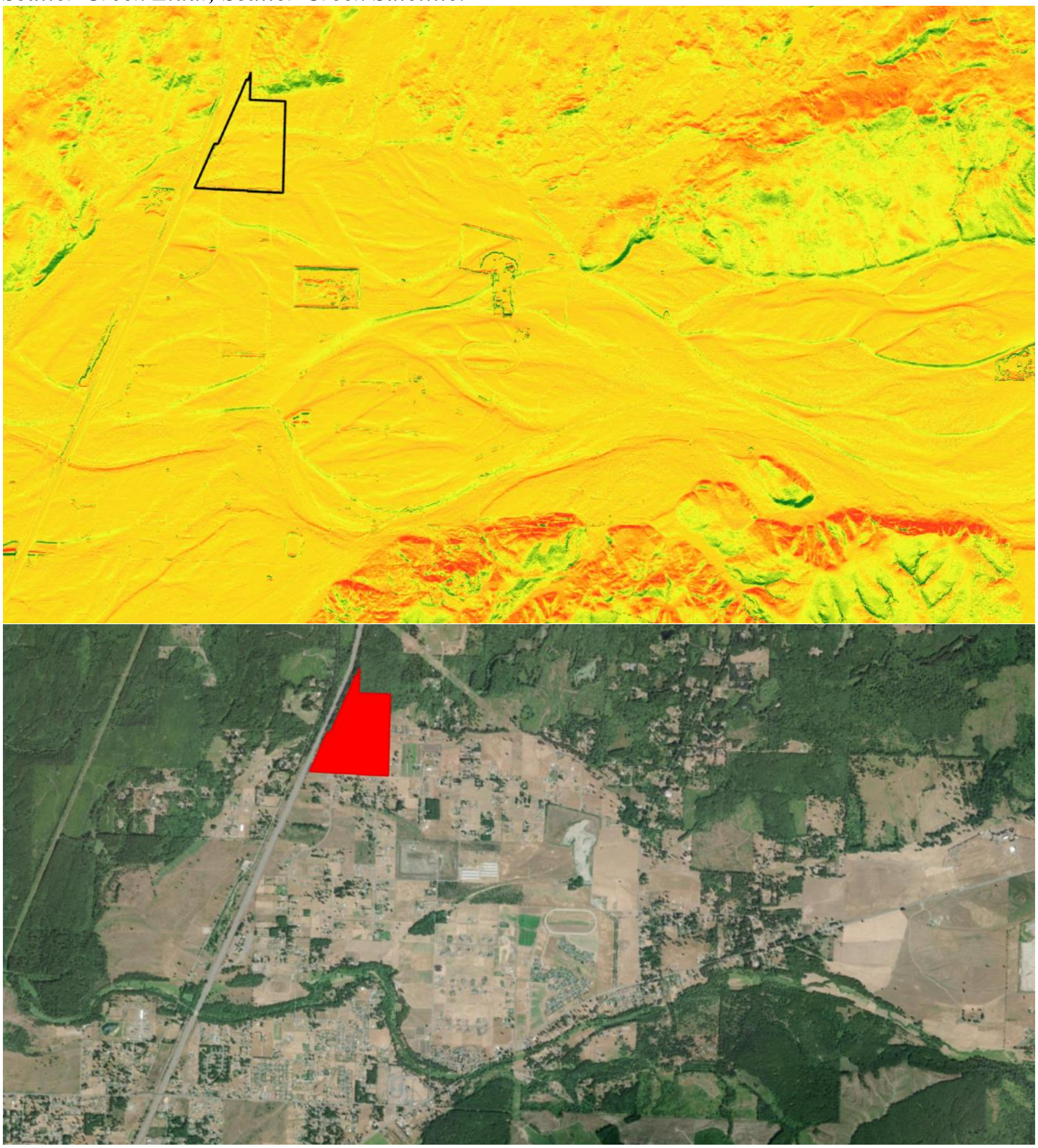
Figure 2.4

Mima Mounds.

Note. To the left of the red property boundary line in this satellite image is the VETC property where the field has been leveled with heavy machinery. To the right are Mima mounds that have not been removed, located just below the cul-de-sac. This figure is enhanced, and the same area can also be seen in *Figure 2.3. Lidar Terrain View* about midway on the east (right) edge of the property. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

Figure 2.5.

Scatter Creek Lidar, Scatter Creek Satellite.



Note. Top: This Lidar image shows the topography of the area with the site's outline in black. The impacts of fluvial geomorphology are evident in this area by the anabranching river channels formed by Scatter Creek, and historic glacial outwash events, over what is now mostly grasslands, rural housing, and small farms. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

Bottom: Property in red. Scatter Creek, bordered by riparian oak woodlands, is visible in green crossing through grassland and across Interstate 5. Garrett Brummel, 2021. ArcGIS Pro 2.8.2.

2.4 Local Ecosystems

2.4.1 Historic Oregon White Oak Habitat in the Region

Historically, the South Puget Sound prairie lands experienced lower intensity grassfires frequently enough that fuel accumulation remained low, preventing higher intensity fires. The only native oak species in Washington, Oregon white oak (*Quercus garryana*), is naturally fire resistant and frequent burnings allowed the species to thrive on the grassland prairies formed over glacial soils. White oaks are distinct in their ability to grow in select types of soil such as deep grasslands soil, seasonally flooded riparian areas, and gravelly glacial soils (Hanna & Dunn, 1997). Fire enabled the oak to avoid succession by less resistant coniferous forests comprised primarily of Douglas-fir (*Pseudotsuga menziesii*) (Tveten & Fonda, 1999). Oregon white oak (*Quercus garryana*) woodlands historically formed into one of three unique oak habitats in this region. Hanna & Dunn, (1997) listed the unique habitat types as wetland oak, riparian oak woodlands, and lastly oak savannahs and open woodlands.

Oak savannas and open woodlands were comprised of mature oak trees with grassy understories spaced much further apart than other oak habitat types. They were the driest of the three and experienced wildfire most frequently. From soil analysis and traditional ecological knowledge of the area, we have learned that this habitat type was managed with near annual deliberate burnings by Native Americans of the Cowlitz and Coast Salish people (*Westside Prairie*, n.d.). Oak savannas and open woodlands provided Native Americans with several plant-based food sources like acorns and camas lily (*Camassia quamash*), as well as hunting opportunities for wildlife that grazed on the fresh regrowth. Once common in South Puget Sound prairie, this habitat type now only exists in low quantities of isolated fragments (Hanna & Dunn, 1997).

Riparian oak woodland habitat retained more moisture and provided greater canopy cover than oak savannas, leading to an understory more diverse with a lower frequency of fires. This habitat, comprised of taller skinnier oaks, typically formed thin lengthy forests creating a buffer between grasslands along streams and creeks (see Figure 2.5. above for imagery of riparian oak woodland forest along Scatter Creek, Tenino, WA) (Hanna & Dunn, 1997). Riparian oak woodland provided shade from the open prairie, reducing high summer water temperatures. Riparian oak habitat would provide shelter and food for a variety of terrestrial and aquatic wildlife such as the western pond turtle (*Actinemys marmorata*).

Wetland oak habitat has the least frequent fire interval, burning only during years that are unusually dry. Wet soil and thick closed canopy provided a dense and more diverse understory for shade tolerant species. Forming near the edges of wetlands and saturated soils, wetland oak habitat areas typically occurred smaller in size than riparian oak forests. This habitat type remains the least changed from historic times and this can be contributed to many conifers inability to tolerate the saturated soil. However, without active thinning or fires, faster growing tree species that find the soil acceptable will eventually succeed the oaks (Hanna & Dunn, 1997).

2.4.2 Oregon White Oak Ecosystems, Species at Risk

The various habitat types formed by Oregon white oak (*Quercus garryana*) provide distinct and critical habitat for several rare species of plants and animals. Columbian white-topped aster (*Sericocarpus rigidus*) and small-flowered trillium (*Trillium albidum* ssp. *parviflorum*) are two flower species that occur in oak habitat woodlands and are listed as sensitive by Washington State. The trillium, a shade tolerant species, prefers the damp soil and canopy cover found in wetland or riparian oak habitat, while the aster benefits from open oak woodlands and frequent fire disturbance (Hanna & Dunn, 1997).

The western pond turtle (*Actinemys marmorata*) has been listed as an endangered species by Washington State since 1993. In 1994, only an estimated 156 turtles remained in the state (Hallock et al., 2017). Through breeding and other recovery programs, the population had reached 800 to 1000 turtles in 2015 but would likely near extirpation again without supplementation (Hallock et al., 2017). Observed living in the lowlands of South Puget Sound prairies and the Columbia River Gorge, they prefer oak habitat that receives high sun exposure and overwinter terrestrially in Oregon white oak foliage (Hays et al., 1999). In fact, western pond turtles often utilize oak habitat near water during any season (Reese & Welsh, 1997). In addition to overwintering and being born on land, some of their other terrestrial activities include dispersal, nesting, and estivating or burying themselves in oak foliage and going dormant to wait out dry or hot periods (Reese & Welsh, 1997; Hays et al., 1999). Western pond turtles were historically present in limited distribution as far north as British Columbia Canada, where they have since been declared extirpated (Environment Canada, 2015; Hallock et al., 2017).

The western gray squirrel (*Sciurus griseus*) is an oak-obligate species that has declined to the extent that Washington State has listed it as an endangered species (Hanna & Dunn, 1997). Currently there are only three isolated populations of western gray squirrels in Washington State. One of those populations exists just nine miles northeast of the study site, in the oak woodlands of Joint Base Lewis-McChord (*Western Gray Squirrel*, n.d.). Joint Base Lewis-McCord (JBLM) also holds the largest area of remaining historic prairie in the region and has partnered with organizations such as Washington Department of Fish and Wildlife (WDFW) to research and restore their oak woodlands and prairie habitat (*Westside Prairie,* n.d.).

Another native animal reliant on oak woodlands and westside prairie habitat, the four subspecies of Mazama pocket gopher (*Thomomys mazama* ssp.) have been federally listed as threatened since 2014 (U.S. Fish and Wildlife Service, 2022). The pocket gophers in this region are associated with glacial outwash prairies and oak savanna habitat where they forage for underground tubers and roots (U.S. Fish and Wildlife Service, 2022; Hanna & Dunn, 1997). Three of the four species, Olympia pocket gopher (*Thomomys mazama pugetensis*), Tenino pocket gopher (*Thomomys mazama tumuli*), and Yelm pocket gopher (*Thomomys mazama yelmensis*), have estimated ranges that either overlap with the borders of the study site, or can be found less than 1000 meters away (U.S. Fish and Wildlife Service, 2022). Pocket gophers were mentioned earlier in reference to the 2014 hypothesis that they are responsible for the creation of unique Mima mound formations (Gabet et al., 2014), perhaps it is more than just correlation that ranges of the two often overlap. One of two option is likely, either the mounds were created through rocky glacial deposits and outwash that also formed the perfect ecosystem for the Mazama pocket gophers to inhabit, or the gophers took this glacially created oak and prairie ecosystem and built mounds throughout.

2.4.3 South Sound Prairie

Figure 2.6.

Camas Meadows Prairie in Spring

Note. Mima Mounds Natural Area Preserve, Olympia, WA. Photo: (Washington DNR, 2009*)*

After the retreat of the glaciers, the South Puget Sound prairie land (Figure 2.6) with Oregon white oak woodlands formed a spectacular and rare ecosystem within Washington State that is seldom seen elsewhere in the world. These habitat types can exist separately from each other, but in this local area (Figure 2.7.), they formed together and are sometimes referred to as being one joined ecosystem, or separate ecosystems depending on the scope. Westside prairie is the term used by WDFW to describe the prairie in this area. They state that Oregon white oak (*Quercus garryana*) can be present in native Westside prairie, while also stating that oak woodlands often contain understory plants indicative of Westside prairie (Washington Department of Fish and Wildlife, 2008). This section will not attempt to completely separate the two but will instead focus more on specific characteristics of the prairie while acknowledging certain overlapping habitat and wildlife.

2.4.3.1.1 Westside Prairie Habitat

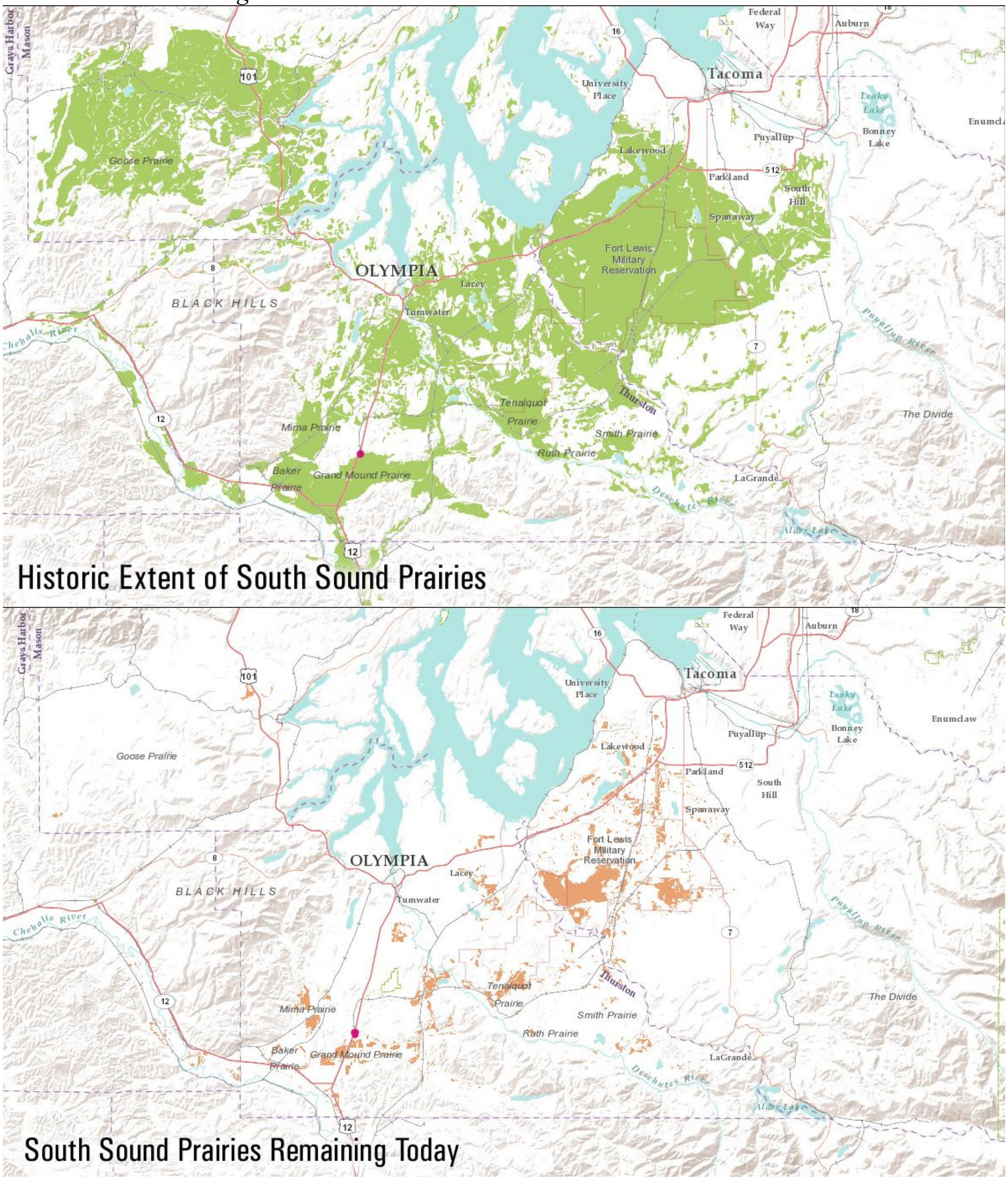
Westside prairies, of the dry upland variety, are vegetated by native grasses like Idaho fescue (*Festuca idahoensis*), California oatgrass (*Danthonia californica*), and blue wild-rye

(*Elymus glaucus*), with the most abundant being the Idaho fescue at 30-70% cover (Chappell & Crawford, n.d.). Many westside native prairie flowers fill the landscape like white-top aster (*Aster curtus*), small camas (*Camassia quamash*), Puget balsamroot (*Balsamorhiza deltoidei)*, and golden paintbrush (*Castilleja levisecta*) (*Westside Prairie,* n.d.). In many of the current Westside prairie areas, the native plants must compete against several dominating native invasive and non-native species like Scotch broom (Cytisus scoparius) that proliferate in the grasslands. The golden paintbrush (*Castilleja levisecta*) had been listed as a federally endangered species since 1997 when it occurred in only ten locations (Fertig, 2021). In July 2023 it was removed from this list due to massive conservation effort success with 48 locations and hundreds of thousands of flowers (*Endangered and Threatened Wildlife and Plants; Removing Golden Paintbrush From the Federal List of Endangered and Threatened Plants*, 2023).

Out of the existing Washington State ecosystems, Westside prairies are one of the scarcest. They have been meticulously cataloged from the geologic conditions that formed them, to the current and historic flora and fauna that inhabit them. Garnering a significant amount of interest from the public and conservation agencies alike, these grasslands have been declared a Priority Habitat by WDFW. Priority Habitat types “contain elements with unique or significant value to a diverse assemblage of species” (Washington Department of Fish and Wildlife, 2008). Eleven terrestrial habitats are considered Priority Habitats by WDFW, with both Oregon white oak woodland and Westside prairie habitat types gracing the list due to their unique vegetation type and dominant plant species. As the South Puget Sound prairie lands shrink and are forced into smaller isolated sections, the urgency to protect those remaining increases. Historic prairie habitat and remaining prairie habitat can be viewed in Figure 2.7.

Figure 2.7.

Historic and Remaining South Sound Prairies



Note. Study site location shown as red dot south of Olympia on I-5 in both maps. USFWS. (2022). Edited by Garrett Brummel, 2024.

Of the Westside prairie remaining in the South Puget Sound, 90% occurs on the largest military base on the west coast, Joint Base Lewis-McChord (JBLM). Due to a lower rate of development than the rest of the region, as well as restoration efforts like prescribed burns, JBLM's prairie lands have avoided the same rate of loss as the rest of the South Puget Sound.

Grasslands must meet certain criteria to be considered Westside prairie according to WDFW (Washington Department of Fish and Wildlife, 2008). They must be herbaceous, maintain less than 60% cover from forest canopy, and they must support specific diagnostic plant species that will determine into which of two categories of prairie they fall, wet prairie or dry prairie. Dry prairie soils are well drained, and in the South Puget Sound region they often are accompanied by Mima mounds in some capacity. Dry prairies must have three of the diagnostic plant species found in Table 2.1. to meet the Priority Habitat criteria. Wet prairies in South Puget Sound are predominately found in swales and riparian areas with flatter slopes. To be classified as wet prairie, the location must have a combination of three species from Table 2.1. Dry prairie and Table 2.2. Wet prairie diagnostic species. (Washington Department of Fish and Wildlife, 2008). The study property has not yet been evaluated to determine if it still meets wet or dry prairie criteria for WDFW Priority Habitat after the ecological damage done under previous ownership. This is an area for further research on site, but restoration through prescribed burning and plantings of native flora have been successful in neighboring prairie areas (*Westside Prairie | Washington Department of Fish & Wildlife*, 2024)

Table 2.1.

Dry Prairie Diagnostic Species

Common came (*Scientific name*)	**Common came (*Scientific name*)**	**Common came (*Scientific name*)**
Spreading Dogbane (*Apocynum androsaemifolium*)	Chocolate Lily (*Fritillaria affinis* v. *affinis*)	Northwestern Saxifrage (*Saxifraga integrifolia*)
Deltoid Balsamroot (*Balsamorhiza deltoidea*)	Hound's-tongue Hawkweed (*Hieracium cynoglossoides*)	Scouler's Catchfly (*Silene scouleri*)
Harvest Firecracker-flower (*Brodiaea coronaria* ssp. *coronaria*)	Prairie Junegrass (*Koeleria macrantha*)	Idaho Blue-eyed-grass (*Sisyrinchium idahoense* v. *idahoense*)
Common Camas (*Camassia quamash*)	Foothills Desert-parsely (*Lomatium utriculatum*)	Curtus's Aster (*Sericocarpus rigidus*)
Long-stolon Sedge (*Carex inops* ssp. *inops*)	Bicolored Desert-gold (*Linanthus bicolor*)	Missouri Goldenrod (*Solidago missouriensis* v. *tolmieana*)
Foot-hill Sedge (*Carex tumulicola*)	Ternate Desert-parsley (*Lomatium triternatum*)	Sticky Goldenrod (*Solidago simplex* ssp. *simplex*)
Golden Paintbrush [1] (*Castilleja levisecta*)	Sickle-keel Lupine (*Lupinus albicaulis*)	Springbank Clover (*Trifolium willdenowii*)
California Oatgrass (*Danthonia californica*)	Prairie Lupine (*Lupinus lepidus*)	Howell's Triteleia (*Triteleia grandiflora* v. *howellii*)
Puget Sound Larkspur (*Delphinium menziesii*)	Cut-leaf Silverpuffs (*Microseris laciniata*)	White Triteleia (*Triteleia hyacinthina*)
Upland Larkspur (*Delphinium nuttallii*)	Douglas Blue-eyed-grass (*Olsynium douglasii*)	Sand Violet (*Viola adunca*)
Henderson's Shootingstar (*Dodecatheon hendersonii*)	Shortspur Seablush (*Plectritis congesta*)	Upland Yellow Violet (*Viola praemorsa* v. *nuttallii*)
Aspen Fleabane (*Erigeron speciosus*)	Fanleaf Cinquefoil (*Potentilla gracillis*)	Meadow Deathcamas (*Zigadenus venenosus* v. *venenosus*)
Common Woolly-sunflower (*Eriophyllum lanatum* v. *leu-cophyllum*)	Western Buttercup (*Ranunculus occidentalis* v. *occi-dentalis*)	Roemer's Fescue (*Festuca idahoensis* v. *roemeri*)
Sierra Sanicle (*Sanicula graveolens*)		

Note. "The presence of certain diagnostic plants is required to establish an occurrence of dry prairie. In particular, three of the diagnostic grasses, sedges, or forbs (Table 2.1) *are required."* Extrapolated from (Washington Department of Fish and Wildlife, 2008).

Table 2.2.

Wet Prairie Diagnostic Species

Common came (*Scientific name*)	**Common came (*Scientific name*)**	**Common came (*Scientific name*)**
Dense Sedge [1] (Carex densa)	**Bradshaw's Lomatium** (Lomatium bradshawii)	Plantain-leaf Buttercup (Ranunculus alismifolius)
Green-sheath Sedge (Carex feta)	Bog Bird's-foot-trefoil (Lotus pinnatus)	Bird's-food Buttercup (Ranunculus orthorhynchus)
Foot-hill Sedge (Carex tumulicola)	Large-leaf Lupine (Lupinus polyphyllus)	Northwestern Saxifrage (Saxifraga integrifolia)
One-sided Sedge (Carex unilateralis)	Wyeth's Lupine (Lupinus wyethii)	Bog Saxifrage (Saxifraga oregana)
Giant Camas (Camassia leichtlinii)	Gairdner's Yampah (Perideridia gairdneri)	**Hairy-stemmed Checkermallow** (Sidalcea hirtipes)
Common Camas (Camassia quamash)	**Oregon yampah** (Perideridia oregana)	**Rose Checkermallow** (Sidalcea malviflora v. vigata)
Tufted Hairgrass (Deschampsia cespitosa)	Fragrabant Popcorn Flower (Plagiobothrys figuratus)	Idaho Blue-eyed-grass (Sisyrinchium idahoense v. idahoense)
Annual Hairgrass (Deschampsia danthonioides)	**Great Polemonium** (Polemonium carneum)	California False Hellebore (Veratrum californicum)
Cascade Downingia (Downingia yina)	American Bistort (Polygonum bistortoides)	American False Hellebore (Veratrum viride)
Oregon Coyote Thistle (Eryngium petiolatum)	Fanleaf Cinquefoil (Potentilla gracilis)	

Note. "Three diagnostic grasses, sedges, or forbs from a combination of the wet prairie diagnostic species list (Table 2.2) *and the dry prairie diagnostic species list* (Table 2.1) *are required to establish the presence of wet prairie."* Extrapolated from (Washington Department of Fish and Wildlife, 2008).

Both wet and dry prairie that meet Priority Habitat criteria can occasionally be found in different soil types, but typically fall into one of these soil types (Table 2.3.). Areas that do have known prairie soil types but also have an impervious surface cannot be classified as either type of prairie (Washington Department of Fish and Wildlife, 2008).

Table 2.3.

Soils That Prairie Commonly Occur Upon

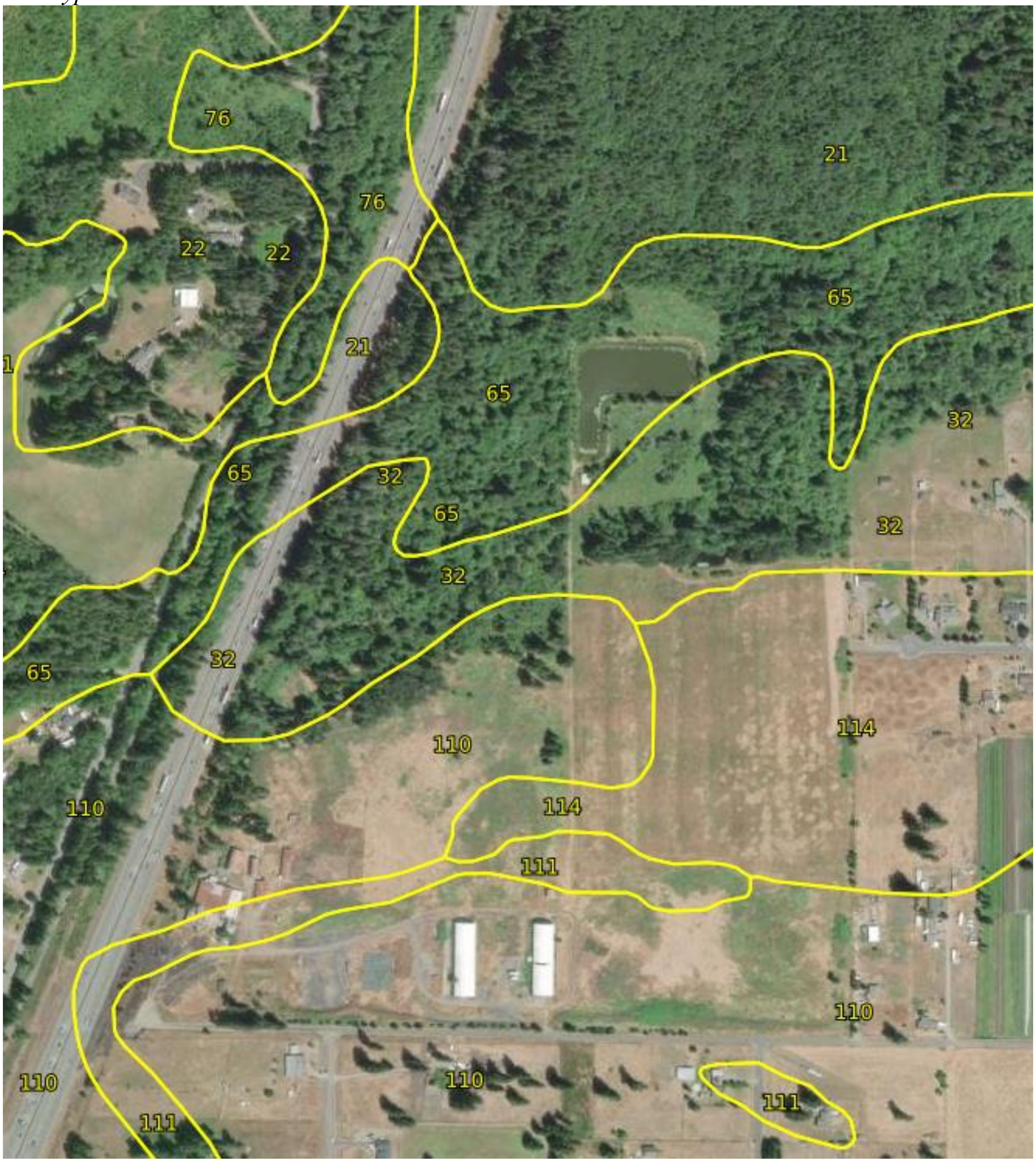
Puget Sound Region		Southwest Washington		Coastal Region
Bozarth	Pilepoint	Bear Prairie	Nisqually	Bear Prairie
Carstairs	Pondilla	Cove	Powell	Carstairs
Coupeville	Prather	Doty	Prather	Quillayute
Coveland	San Juan	Galvin	Sara	Sequim
Ebys	Snakelum	Gee	Sauvie	Spanaway
Galvin	Spana	Hillsboro	Sifton	Wellman
Haro	Spanaway	Hockinson	Spanaway	
Hiddenridge	Townsend	Lauren	Washougal	
Newberg		Mossyrock	Yacolt	
Nisqually		Minniece		

Note. "Although dry and wet prairie can occur on other soils, typically it occurs on any one of the soils known to be associated with prairie." Extrapolated from (Washington Department of Fish and Wildlife, 2008).

Soil types on some of the nearest prairies to the study location (Scatter Creek, Mima mounds, West Rocky Prairie) predominantly consist of soil type (114) 60% Spanaway – 30% Nisqually, (110) 100%Spanaway, and (111) 100%Spanaway (*SoilWeb: An Online Soil Survey Browser | California Soil Resource Lab, n.d.*). The southern portion of the study property is composed of these same soil types, see Figure 2.8. and Figure 2.9. for a comparison between soil types on site and within nearby documented Westside prairie Priority Habitat.

Figure 2.8.

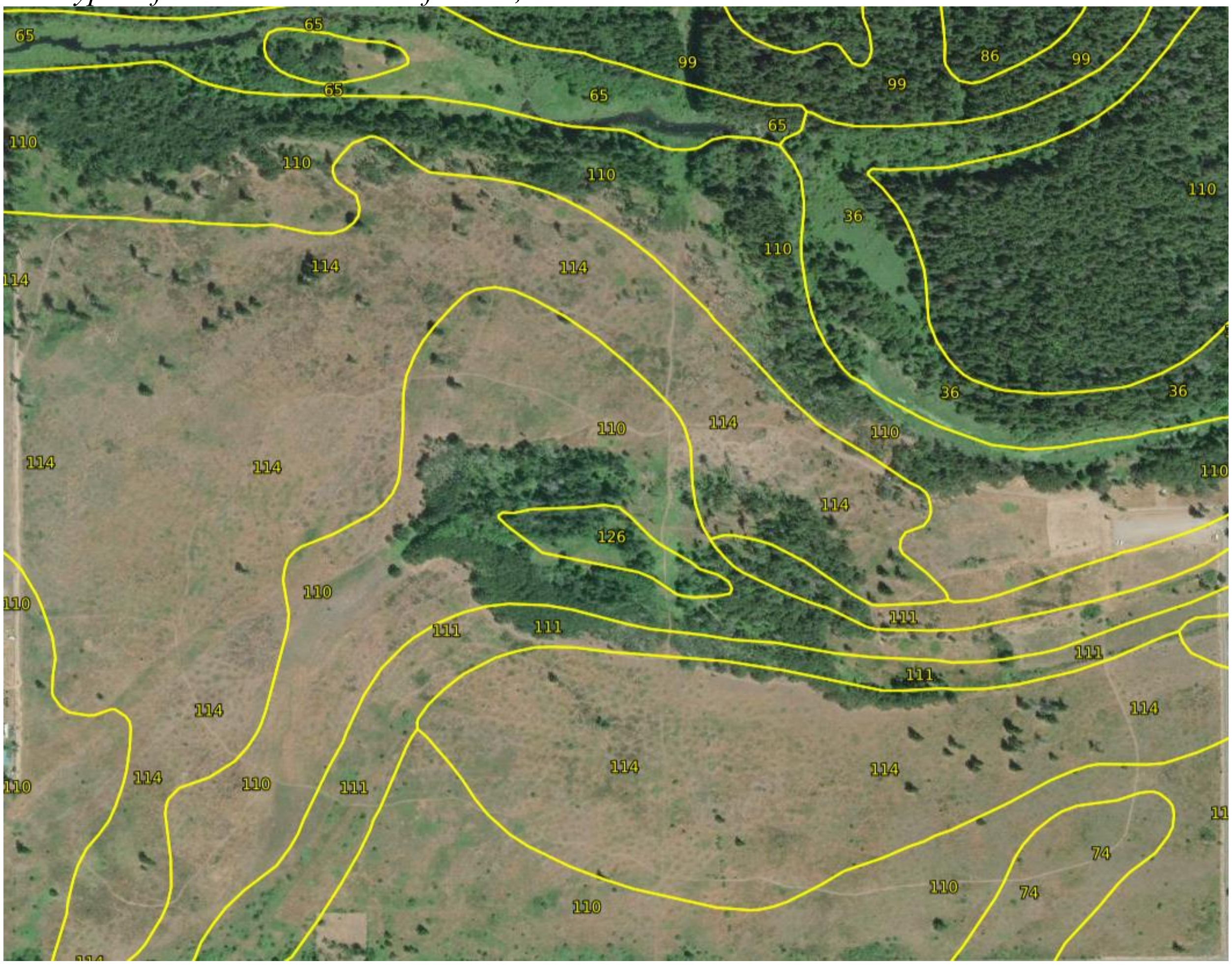
Soil Types on Site



Note. The study location is composed of these soil types. 114=40%Nisqually-60%Spanaway, 110=100%Spanaway, 111=100%Spanaway, 32=80%Everett-10%Alderwood-10%indianola, 65=McKenna85%-5%Bellingham-5%Skipopa-5%Norma, 21=100%Cathcart. (*SoilWeb: An Online Soil Survey Browser | California Soil Resource Lab*, n.d.) Retrieved by Garrett Brummel 2024

Figure 2.9.

Soil Types of Scatter Creek Wildlife Area, SW Portion



Note. Westside prairie habitat shown here in the southwestern portion of Scatter Creek Wildlife Area by soil type, imposed in yellow. Areas of prairie in this figure all occur within known Puget sound prairie soil types. 114=30%Nisqually-60%Spanaway, 110=100%Spanaway, 111=100%Spanaway, 74= 85% Nisqually-3% Yelm-2%-Norma. (*SoilWeb: An Online Soil Survey Browser | California Soil Resource Lab*, n.d.). Retrieved by Garrett Brummel 2024

2.4.3.1.2 Westside Prairie Ecosystems, Species at Risk

Due to the distinct way the prairies in this area were formed, this habitat type is scarce and isolated from similar habitat types by large swaths of thick forest. Historically and today, connectivity to larger grasslands with similar ecosystems has been lacking for many of the wildlife that live in Westside prairies. This genetic isolation led to the development of new traits or characteristics in some prairie wildlife that is now only found within these ecosystems. A subspecies of Pacific gopher snake (*Pituophis catenifer catenifer*) was first reported to be found sparingly in South Puget Sound prairies by naturalist George Suckley in 1859 (Cooper et al, 1859; Leonard & Hallock, 1998). The presence of these snakes in Western Washington was most likely due in part to the South Puget Sound prairies, although no further recordings have been made since. The species is listed as *presumed extirpated* in British Columbia, Canada and *likely extirpated* in Washington State (*Gopher Snake,* n.d.). This rare snake was not alone in becoming extirpated from Westside prairies, the racer (*Coluber Constrictor*) were also recorded by Cooper in 1859 and confirmed sightings continued in outwash prairies and oak savannahs until the last sighting in 1963 by James Slater (Leonard & Hallock, 1998). These species were extirpated somewhat rapidly from South Sound prairies. With even less available prairie lands now, multiple species, including the Mazama pocket gophers (*Thomomys mazama* ssp.), rely on conservation efforts to maintain the remaining habitat.

Many bird species make use of the South Sound Prairies. Three of them in particular are Species of Greatest Conservation Need and rely on Westside prairie habitat. Washington's population of Western bluebird (*Sialia mexicana*) is low and continuing to fall. Their most successful breeding location recorded in western Washington is on the South Sound prairies and oak woodlands of Joint Base Lewis McChord (*Western Bluebird,* n.d.). The Oregon vesper sparrow (*Pooecetes gramineus affinis*) has a listing status of endangered in Washington. They are migratory and travel between Northern California and Southern British Columbia but spend the nesting months of April to September in prairie grasslands. The largest portion (90%) of their population in Washington reside in South Puget Sound, specifically Joint Base Lewis McChord. WDFW estimates only 3,000 remaining Oregon vesper sparrows exist in the world, with 300 of them in Washington (*Oregon Vesper Sparrow*, n.d.). Streaked horned lark (*Erempohila alpestris strigata*) utilize Westside prairie and marine shorelines in Washington, where they hold a state listing of Endangered, and a Federal ESA listing of Threatened. Their small range consists of only Western Oregon and Southwest Washington, now considered extirpated from the San Juan Islands and British Columbia. A 2005 WDFW population assessment of Streaked horned larks estimated 222 birds, or 29% of the population at the time, in the Puget lowlands (Pearson & Altman, 2005) while the current population estimate range-wide is 1,170-1,610 in total (*Streaked Horned Lark,* n.d.). The first priority called for in aiding recovery of the species in South Puget Sound was to restore prairie breeding grounds by removing scotch broom and utilize late summer fire (Pearson & Altman, 2005).

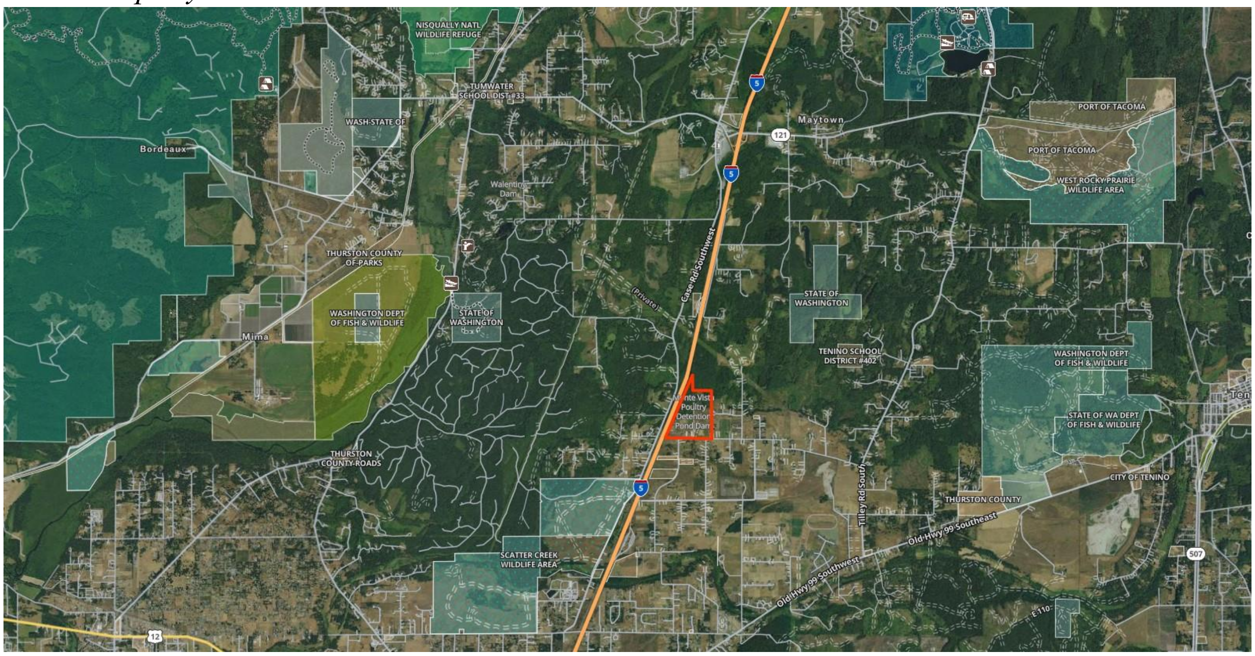
There are several prairie butterfly species listed in Washington's Species of Greatest Conservation Need. The Island Marble (*Euchloe ausononides insulanus*) federally endangered, prefers marine shorelines and Westside prairie habitat, but is extirpated and no longer found in South Puget Sound Prairies. Mardon Skipper (*Polites mardon*) is listed as endangered in Washington and can still be found in South Puget Sound prairies. Taylor's checkerspot butterfly (*Euphydryas editha taylori)* is a federally endangered species living in South Sound prairies that lays its eggs on golden paintbrush (*Castilleja levisecta*) which is utilized as a larval food source. Golden paintbrush has been recently removed from federal protection and has made a resurgence through planting, burning prairies, and other restoration methods. There are seven other species of butterfly that depend on prairie habitat and are considered Species of Greatest Conservation Need in Washington. With more recovery of native vegetation, the chances increase of one day becoming delisted for Taylors checkerspot butterfly and others.

2.4.4 Fire in South Puget Sound, Westside Prairie and Oak Ecosystems

Fire suppression had become customary practice among non-Indigenous settlers, and intentional burning was largely discontinued upon their arrival to the area starting in the 1850's (Tveten & Fonda, 1999). According to the 1998 study by Hanna & Dunn, the Oregon white oak woodlands of the South Puget Sound have been reduced by over 50% in their former range. This loss of unique oak forest habitat can be attributed to logging, agriculture, grazing, and the end of routine burning thus allowing Douglas-fir (*Pseudotsuga menziesii*) to outcompete oaks and absorb grasslands (Hanna & Dunn, 1998). Washington Department of Fish and Wildlife (WDFW) estimates that of the 180,000 acres of South Puget Sound Prairie in existence prior to non-Indigenous settlement, only 3% of original prairies remain (*Westside Prairie*, n.d.). Through traditional ecological knowledge and new management practices, prescribed burning of remaining oak habitat and prairie lands in this area has once again become a popular method of land management to reverse prairie degradation and repel invasive Scotch broom (*Cytisus scoparius*) (Couch, 2023). Scatter Creek Wildlife Area is located just eight hundred meters southwest of the study site across I-5 (Figure 2.10.), still retains a substantial population of Oregon white oak woodlands and remaining South Puget Sound prairie. In 2022 and 2023, WDFW completed prescribed fire treatments under Oregon white oak (*Quercus garryana*) within the wildlife area to improve habitat (see Figure 2.11.) (Couch, 2023). Scatter Creek Wildlife Area is one of several focal points for prairie and oak woodland restoration in the region. WDFW, and partners such as the Confederated Tribes of the Chehalis Reservation, have focused efforts toward restoring this habitat though various projects that include collecting and sowing native seeds, planting native plants, prescribed burning, and other restoration methods (*Westside Prairie,* n.d)

Figure 2.10.

VETC Property and Government Land



Note. Site location in red, bordering Interstate 5. Map of greater surrounding area with public lands highlighted. (WDFW) Scatter Creek Wildlife Area, (WDFW) West Rocky Prairie Wildlife Area, (WDFW) Black River Wildlife Area, (WA, DNR) Mima Mounds Natural Area, (USFWS) Nisqually National Wildlife Refuge, (WA) Capitol State Forest, (WA) Millersylvania State Park, (Thurston County Parks) Glacial Heritage Preserve, and other un-named pieces of land owned by Washington State, Washington Department of Fish and Wildlife, Thurston County, Port of Tacoma, City of Tenino, and Tenino School District. Garrett Brummel, 2024. Screenshot OnX Maps.

Figure 2.11.

Burning Scotch Broom

Note. Scotch broom (Cytisus scoparius) burns under Oregon white oaks (Quercus garryana) during a 2022 prescribed burn in Scatter Creek Wildlife Area. Photo: Tveten, 2022

2.5 Chapter II Conclusions

This study location is part of an area with a fascinating history and unique ecosystems. Its proximity to wildlife areas and other governmental lands (Figure 2.10.) makes it a perfect candidate to explore the wildlife that lives and travels within its borders. This site and the surrounding area have unique, and mostly diminishing, ecosystems whose restoration is a priority for multiple conservation organizations. Through partnership with private landowners, this site can provide valuable data about the wildlife that inhabits this ecosystem in close proximity to I-5 and expand our understanding of the area. The following chapter will examine the role habitat connectivity plays with regards to wildlife, and some of the effects or interactions of roadways on that connectivity.

3 Chapter III: Literature Review

This chapter broadly reviews the relevant literature on the importance of habitat connectivity, threats to habitat connectivity, roadway specific threats to connectivity, and ways to improve roadway habitat connectivity. This chapter also examines different methods to identify habitat corridors and specific identifying methods used near the location of this study.

3.1 What is Habitat Connectivity and Why is it Important?

Landscape or habitat connectivity refers to the level at which different fragments of habitat area are connected to one another. The level of connectivity impacts the genetic diversity of plant and animal species and, as well, species distribution on the landscape. Having strong connectivity helps mitigate habitat loss or fragmentation due to human development and infrastructure. When asked to visualize wildlife habitat, most people would imagine large areas of undisturbed forest or grassland. These large patches will inevitably border more urban areas at some point in which wildlife is more scarce. Ideally, the habitat areas are not completely isolated and there are routes in and out that allow wildlife to disperse from zone to zone. These passages between the patches are called habitat corridors, and their existence allows safer travel, aiding animals in their search for breeding partners, food, and seasonal migration.

Without habitat corridors, patches become separated, isolating species from connecting with others outside of their patch. In some instances of isolation, such as mountain lions in California's Santa Monica Mountains, there is low genetic diversity. As such, the species' failing population faces extirpation and suffers health defects from inbreeding (Huffmeyer et al., 2022). Walled off by the Pacific Ocean and hemmed in by freeways and urban sprawl, this island-like population of mountain lions holds the lowest levels of genetic diversity documented in the Western United States. The only population of mountain lions with a lower recorded genetic diversity was the southern population of Florida panthers in the 1990s (Mulholl et al., 2021). Fragmentation of habitat caused by freeways and roads, coupled with insufficient wildlife crossings has resulted in Wildlife-Vehicle Collisions (WVCs) being the foremost cause of death for Santa Monica’s mountain lions (Mulholl et al., 2021). A mountain lion genetics study conducted within Washington State found that Olympic Peninsula mountain lions have the lowest genetic diversity and highest levels of inbreeding throughout Washington (Wultsch et al., 2023). Despite having a vastly larger area than the Santa Monica mountain lions, lions of the Olympic Peninsula share a similar situation. Hemmed in on three sides by the Pacific Ocean, Columbia River, and Puget Sound, the only land route lies to their east where Interstate 5 acts as a barricade between them and the larger more interconnected Cascade Mountain range.

In wildlife populations where there are no freeways to cause WVCs, other issues can still arise from lack of connectivity. One example is the case of the rare tule elk herd of Tomales Point in Point Reyes National Seashore California. Here, the herd is confined within the park’s peninsula to 2,600 acres by an eight-foot fence that stretches for three miles. The fence keeps the elk herd away from active ranching and grazing that occurs for thousands of cattle on leased land within the park. This fencing limits habitat connectivity that is essential for access to other areas with natural resources such as food and water. The elk population declined in 2012-2014 from 540 to 286 elk, and again in 2019-2021 from 445 to 221 elk due to poor forage conditions caused by drought (National Park Service et al., 2023). Since 2021, the National Park Service has been supplementing the herd with water and vitamin/mineral resources as needed in time of drought (National Park Service et al., 2023) rather than removing the elk fence and allowing connectivity to other water sources outside the peninsula. As of August 25, 2023, the park is in the process of deciding to manage the elk herd in three separate ways. Alternative A, no change to current policy. Alternative B, existing elk fence removal allowing connectivity and cease water supplementation. Alternative C, the elk fence stays up and elk are culled (lethally removed) to a lower population in hopes that the available water and forage will be enough for the remaining elk during drought (National Park Service et al., 2023). With climate science showing California droughts to be increasing in both severity and frequency (Mann & Gleick, 2015), connectivity to suitable habitat for tule elk could be imperative to their survival.

Are there any negative consequences of increasing habitat connectivity? In the case of the tule elk, the National Park Service has argued that removing the fence could expose the elk to diseases such as chronic wasting disease (CWD) found in other parts of the country or spread of disease from elk to domestic cattle. In fact, Tomales Point elk have tested positive for Johne's Disease, an infectious and incurable gastrointestinal disease caused by a bacterium found in domestic and wild ungulates (Cobb, 2010). This suggests that, at times, habitat connectivity could be dangerous to species' health. Identifying habitat corridors and limiting corridor access during contagion events could be useful in preventing the spread of wildlife diseases because the pathways along which diseases spread are that of their host species (Vander Wal et al., 2014). On the other hand, open wildlife corridors allow genetic adaptations and disease resistance from surviving animals to aid other populations through genetic dispersal. Negative consequences of increased connectivity are a complex issue that is best examined in the context of specific areas and situations. Identifying and monitoring the corridors that provide connectivity is beneficial for examining both the positive and potential negative consequences of habitat connectivity.

Whether transferring disease or dispersing desperately needed genetic diversity into an area, habitat corridors have a role to play. By allowing escape out of areas with depleted resources, habitat corridors help prevent die offs and genetic bottlenecking. The role habitat corridors play in connectivity across the landscape is deserving of continued research as its importance rises with shrinking habitat and a changing climate. While Washington and California differ in human population, climate, wildlife species, and level of habitat connectivity, the Evergreen State is not immune to similar issues caused by decreased habitat connectivity and increased fragmentation. Washington should be investigating its own connectivity shortcomings but can also apply the issues confronting California as an example of what is to come if connectivity is not maintained.

3.2 Negative Effects on Connectivity

3.2.1 What is Threatening Habitat Connectivity between the Olympic and Cascade Mountains?

"*Habitat fragmentation is the most serious threat to biological diversity and is the primary cause of the present extinction crisis*." (Wilcox & Murphy, 1985).

Globally, the leading cause of biodiversity loss is loss and fragmentation of habitat due to human development and land use (Brondizio et al., 2022; IPBES, 2019). In Western Washington, several land use issues are endangering habitat connectivity: development, urbanization, industry, climate change, forestry, energy, agricultural development, and roadways can fragment habitats and impede wildlife movement across the terrain. The distribution and quality of habitats as well as the migration patterns of wildlife are all susceptible to effects of climate change, which is a developing concern. Urbanization is increasingly shown to have negative effects on biodiversity through habitat fragmentation and loss (Elmqvist et al., 2016). Population increase, development, logging, and roads are all stressors that contribute to habitat loss and fragmentation. Once diminished, habitat loses some of its natural processes and carrying capacity for wildlife. The results of habitat loss on wildlife includes displacement and can lead to higher mortality rates caused by food quality, wildlife conflict with removal, and Wildlife-Vehicle Collisions (WVCs).

This study's research site borders the I-5 roadway which has six lanes of travel, concrete center barrier, high traffic, and a 70mph speed limit at this location. Roadways such as this pose a significant barrier to wildlife movement (Forman & Alexander, 1998) as they fragment habitat and wildlife corridors on a larger scale than a smaller two-lane road with fewer obstructions. For 2022, the Average Annual Daily Traffic (AADT) at points three miles above and below the site location on I-5 were reported at 68,000 and 67,000 vehicles per day respectively (*WSDOT - Historic Traffic Counts*, 2022). According to Charry et al. (2009) and Washington State Department of Transportation (WSDOT), "10,000 vehicles per day or greater is generally considered a total barrier to wildlife movements." (Washington State Department of Transportation, 2022). WVCs are a safety concern for wildlife and motorists alike, with only a fraction of these being reported. WSDOT suggests that a minimum of 5,000 collisions with deer and elk occur each year in Washington State alone (*Reducing the Risk of Wildlife Collisions | WSDOT*, 2022). As stated by Forman & Alexander (1998), in the United States, it is estimated that one million vertebrates are killed on roadways per day. Of the various threats to habitat connectivity, this literature review focuses primarily on the obstacle roadways present to habitat corridors. This study's site location allows a unique glimpse of wildlife near the I-5 roadway in what several connectivity models (Washington Wildlife Habitat Working Group, 2024; WSDOT - Habitat Connectivity Investment Priorities, n.d) and organizations have identified as a high-priority habitat corridor that could link the Cascade and Olympic Mountain ranges (Washington Wildlife Habitat Connectivity Working Group, 2024; *I-5 Wildlife Habitat Connectivity Study | WSDOT*, 2023; Butcher & Conservation Northwest, 2021)

3.3 Roadways and Habitat Connectivity

3.3.1 Flora

Roadways, especially high-volume roadways like Interstate 5 in Washington State, have multiple negative effects on wildlife and habitat connectivity. The first negative effect an interstate has on connectivity is habitat loss when the land is logged, leveled, and paved. The negative effects of the roadway do not stop with habitat loss and extend far past the pavement in many cases. Invasive species like Scotch broom (*Cytisus scoparius*) fill the shoulders in many sections of I-5 in Washington and must be mowed often to reduce fire danger from lit cigarettes or sparks from vehicles. Many roadways act as a corridor for invasive plant seeds carried by people and vehicles from one area to another (Meunier & Lavoie, 2012). With the alteration of the landscape bordering the roadway, new non-native plant species may be better adapted to fill the place of native flora, but do not provide the same benefits to native wildlife. One example of this effect, occurring on Joint Base Lewis-McChord and just nine miles northeast of this study's research site, again involves Scotch broom (*Cytisus scoparius*). Here, the plant is forming dense monotypic thickets within which few native prairie plants can survive (Dunn, 1998). Preventing this replacement of native prairie species requires constant removal efforts. The niche native prairie plants and the wildlife that live amongst them have often been isolated and adapting together for so long that a significant displacement of native species such as this, and especially in cases that involve the extirpation of a species, can create chain reaction throughout the ecosystem. Adaptive invasive species have been shown to benefit both from habitat provided by roadways as well as increased dispersal routes (Lemke et al., 2021). As roadways divide the landscape, invasive flora can spread outward from the disturbance and push the formerly connected flora backwards into two separated fragments. This disconnection removes genetic material from the available gene pool. It also changes the type of previously provided cover and forage for wildlife that may then also be restricted to one side or the other of the fragmented habitat.

3.3.2 Aquatic Fauna

The construction of a roadway alters the hydrology in the area by diverting road water into ditches and redirecting smaller streams into culverts. Chemicals from the road like motor oil or road salt can pollute the runoff water as well as altering the soil chemistry near the roadway (Nikolaeva et al., 2021). Species like amphibians and fish that are highly susceptible to changes in potential of hydrogen (pH), may find these pollution conditions inhospitable (McIntyre et al., 2018). In addition to the effects of chemical runoff from roadways, aquatic species like salmon, can have their habitat fragmented by impassable culverts, denying them passage to upstream habitat or spawning grounds. After the removal of a formerly impassable culvert on Padden Creek in Western Washington, Allan et al. (2023) found through eDNA water sampling that the number of target fish species dramatically increased in an upstream section once reconnected.

While the focus of this study is on terrestrial habitat connectivity, the importance of aquatic habitat connectivity is also being recognized and reconnected in Washington State. Improved aquatic connectivity can positively impact terrestrial connectivity in some situations. In March of 2013, the U.S. District Court issued a permanent injunction requiring Washington State to significantly increase removal of state-owned culverts that block habitat for salmon by 2030. These culverts are sometimes being replaced with larger bridges that also aid terrestrial wildlife in passing roadway barriers. Padden Creek culvert near Bellingham, Washington, was a mere 1.5x1.5-meter square extending for 130 meters under the northbound and southbound lanes of I-5. The single culvert was replaced with two large 13.4-meter bridges. Shortly after bridge completion, black-tailed deer (*Odocoileus hemionus columbianus*) were documented crossing in safety as they continued through the Chuckanut Wildlife Corridor (Kanzler et al., 2023). The wildlife crossing structures on Padden Creek are of particular interest to this study due to the lack of structures specifically aimed at aiding wildlife crossings on I-5. The feasibility of establishing similar wildlife structures through I-5 near this thesis's study area that could benefit both aquatic and terrestrial habitat connectivity is of great interest.

3.3.3 Terrestrial Fauna and Wildlife-Vehicle Collisions

Another negative effect roadways have on habitat connectivity that is one of the most visible to humans is Wildlife-Vehicle Collisions (WVCs). A deer carcass in the median or on the shoulder of an interstate is a clear indication that the roadway physically prevented at least that specific animal from crossing to the habitat on the other side. Carrion from roadkill attracts scavengers, which can themselves become victims of WVCs (Dean et al., 2019). In the United States alone between 2020-2021 the number of WVCs topped 2.1 million, an increase of 7.2% from the previous 12 months (Ortega, 2022).

It can be difficult to assign monetary value to habitat connectivity, and some might rightfully assume that wildlife bears the brunt of its loss. However, in the case of WVCs, the average costs incurred per WVC have been calculated, and it is humans who must pay the bill. A 2022 Transportation-Pooled Fund study (TPF-5(358)) led by Nevada DOT, with contributing partners including Washington DOT (WSDOT), re-evaluated the costs associated with WVCs using 2020 USD ($) since initial estimates were completed in a 2009 study using 2007 USD ($) (Huijser et al, 2022). Re-evaluated WVC costs can be seen in Table 3.1.

Table 3.1

Vehicle, Injury, and Fatality Costs per WVC

Vehicle repair costs, average human injury costs and average human fatality costs per collision for deer, elk, and moose in 2007 and 2020.

Animal	Vehicle Repair Costs per Collision		Average Human Injury Costs per Collision		Average Human Fatality Costs per Collison	
	2007	2020	2007	2020	2007	2020
Deer	$2,850	$4,802	$2,702	$6,116	$1,002	$3,408
Elk	$4,550	$7,666	$5,403	$14,579	$6,683	$23,200
Moose	$5,600	$9,435	$10,807	$26,811	$13,366	$46,400

Note. If you find some of these costs to be low, for example Human Fatality Cost, remember that this is the average cost per *Collision*, not per *Fatality*. The cost of a human fatality remains static regardless of what animal species is hit. The ratios of fatalities per collision by animal species is what drives these costs. Extrapolated from (Huijser et al, 2022) originally ***Table 4.***

The study also evaluated the average total cost per collision including the average "passive use value" for the loss of the animal in 2020 USD ($). Average "passive use value" was calculated in the study and defined as "*The values individuals place on the existence of a given animal species or population as well as the bequest value of knowing that future generations will also benefit from preserving the species.*" (Huijser et al., 2022) The study did not include any direct costs associated with the collision like carcass removal, towing fees, or accident investigation. The study also did not include "direct costs" value of the wildlife such as the costs of purchasing a hunting permit for the animal or the restitution value assigned by the government for the loss of various big game species. Had "direct costs" been included in the analysis the total cost per WVC would have been higher. This more recent economic cost analysis allows us to place a more accurate monetary value on WVCs by species and compare this value to the cost of implementing wildlife structures which would prevent WVCs. Cost per WVC including “passive use value” can be found below in Table 3.2.

Table 3.2.

Vehicle, Injury, Fatality, and Passive Use Costs per WVC

	Costs per collision							
Cost category	Deer	Elk	Moose	Gray wolf	Grizzly bear	Cattle	Horse	Burro
Direct costs								
Vehicle repair	$4,418	$7,666	$9,435	$4,418	$4,418	$9,435	$9,435	$7,666
Human injuries	$6,116	$14,579	$26,811	$6,116	$6,116	$26,811	$26,811	$14,579
Human fatalities	$3,480	$23,200	$46,400	$3,480	$3,480	$46,400	$46,400	$23,200
Sub total	$14,014	$45,445	$82,646	$14,014	$14,014	$82,646	$82,646	$45,445
Passive use value	$5,075	$27,751	$27,751	$40,342	$4,235,770	?	?	?
Total	$19,089	$73,196	$110,397	$54,356	$4,249,784	$82,646	$82,646	$45,445

Note. Costs in 2020 USD ($). Extrapolated from (Huijser et al, 2022) originally ***Table 6***.

3.4 Road Avoidance and Barrier effect

What is less obvious to the human eye than the aftermath of WVCs, is all the animals that were kept from crossing due to road avoidance. The detrimental effects of highways on wildlife movement and habitat connectivity are collectively known as the "road barrier effect" (Forman et al., 2003). When roads block or restrict wildlife from moving between habitat patches, it can result in direct mortality, habitat fragmentation, behavioral changes, genetic isolation, noise pollution, and other problems (Forman et al., 2003; Trombulak & Frissell, 2000). The populations of wildlife may suffer severe harm as a result of these effects, efforts are needed to mitigate them and maintain habitat connectivity across roadways (Forman et al., 2003; Trombulak & Frissell, 2000).

The road barrier effect that wildlife must contend with holds the potential to inflict a greater loss of wildlife connectivity, than the loss of wildlife from WVCs. In fact, larger high traffic roadways like I-5 create a greater barrier effect but often see much lower rates of WVC per Average Annual Daily Traffic (AADT) than smaller quiet two-lane roads. Wildlife scared away from I-5 are less avoidant of the smaller low traffic roads where they encounter less resistance. This leads to more wildlife crossing on roads with less barrier effect and thus higher instances of WVC on these roads. Despite the higher rates of WVC per AADT, these smaller lower traffic roads offer greater connectivity as the road is more permeable to wildlife.

Removing one or a few individuals from the population as the result of a WVC should have a negligible effect on the overall population if the population is already robust. For example, a black-tailed deer buck (*Odocoileus hemionus columbianus*) is hit and killed before the November mating rut. The fawns born the following year may not have that specific buck's genetic material, but within a healthy population other bucks will have fathered any offspring the original buck would have, and the overall herd population and percentage of fawns born will be the same as if he had not been hit. The impact of removing an individual from a scarce or threatened population is quite different. Take wolverines (*Gulo gulo luscus*) for example, in addition to being federally listed as threatened, Washington Department of Fish and Wildlife (WDFW) has identified them as a "Species of Greatest Conservation Need" and a "Priority Species." WDFW believes the greatest threat the species faces in Washington comes from the loss and fragmentation of habitat in addition to climate change. On the WDFW wolverine website, Habitat Loss or Fragmentation is listed under known threats to the species and they specify "Barriers or impediments to movement across Interstate 90." and "Large highways." (*Wolverine*, n.d.). They estimate that there are fewer than twenty-five wolverines in the state.

With three Washington wolverine (*Gulo gulo luscus*) WVC mortalities documented through carcass removal between 2018-2022, the effect of each death on the population is much more drastic. However, if road avoidance and the barrier effect had been great enough early in their recovery to prevent Wolverines from even attempting to cross into new territories, the population in Washington would likely be only a fraction of what it is today.

Another invisible impact roadways can have on wildlife is the edge effect. Edge effect, as defined by Mirriam-Webster, is the effect of an abrupt transition between two quite different adjoining ecological communities on the numbers and kinds of organisms in the marginal habitat (Merriam-Webster, n.d.). According to the United States Department of Agriculture, habitat fragmentation reduces the area of original habitat and increases the total lineal feet of edge, favoring species that inhabit edges at the expense of interior species that require large continuous patches (Habitat Fragmentation, n.d.). Wolverine (*Gulo gulo luscus*) and American fisher (*pekania pennanti*) have different habitat requirements, but both require larger continuous interior habitat and they avoid areas with significant development or human activity (*Fisher*, n.d.; *Wolverine*, n.d.). Black-tailed deer (*Odocoileus hemionus columbianus*) on the other hand, thrive and prefer habitat with more lineal edge (Kremsater & Bunnell, 1992). Fragmentation of continuous interior forest habitat due to roadways create habitat for different plant and animal species that was previously unavailable. The edge effect does not create an area devoid of wildlife, it just increases the amount of a different habitat type and the species that require large interior habitat are left with less.

Roadways and automobiles will not soon become outdated, in fact they should continue their current trend with more vehicles in operation (Hedges & Company., 2024) and more roads to handle the increased volume. Preventing fragmentation and restoring connectivity for wildlife through habitat corridors should be a focus for new road construction and in modification of existing roadways. The most effective types of wildlife roadway modifications and where to apply them is the topic this thesis will address in the following section.

3.5 Ways to Reduce WVCs and Improve Connectivity

Wildlife overpass crossing structures such as the installations on the Trans-Canada Highway help allow safe passage across the four-lane barrier and could lead to a reduction in WVC incidents (Sawaya et al., 2013). Underpasses and bridges can be adapted to be more accommodating to the travel of wildlife (Stewart, 2019a; Stewart 2019b). Fencing is also useful in preventing wildlife access onto roadways (Clevenger et al., 2001) and when used in conjunction with over or underpasses, can significantly increase successful crossing and connectivity. Fencing used without wildlife passage structures will lower WVCs but exacerbate the barrier effect of roadways.

3.5.1 Wildlife Roadway Structure Review

A literature review by Nevada Department of Transportation (NDOT) explored the most effective mitigation measures employed to prevent WVCs and their ability to promote connectivity (Ament et al., 2022) The study included domestic large mammals like horses, donkeys, and cattle in their review as well as large wild mammal species, so the term Animal Vehicle Collisions (AVC) was used in place of Wildlife-Vehicle Collision (WVC). In their literature review, twenty-four different mitigation measures were explored but only ten measures achieved a reduction of 50% or greater. Of these ten, there were only three measures that could be called “highly effective” with a reduction of AVCs by 80-100%. Two of those three “highly effective” measures, road closures and fencing, are not practical in application towards the goal of lower AVCs *and* higher connectivity. Road closure may achieve both goals, but cannot be practically implemented in most areas, especially not I-5, and completely fencing roadways will significantly reduce connectivity. The only remaining “highly effective” mitigation measure found in the review that both reduced AVCs/ WVCs and promoted connectivity, was the combination of fencing and crossing structures (Ament et al., 2022). A table from the study showing the ten measures capable of achieving 50% AVC reduction can be viewed in Table 3.3.

Table 3.3.

Mitigation Measures with 50% AVC Reduction.

Measure	Effectiveness in reducing collisions with large mammals	Effectiveness in reducing the barrier effect of roads and traffic
Mitigation measures aimed at influencing driver behavior		
Seasonal wildlife warning signs	9-50%	None
Roadside animal detection systems (RADS)	33-97%	None
Seasonal closure	100% during closure	Reduces barrier effect of traffic but not the road itself (during closure only)
Increase visibility: roadway lighting	57% - 68%	None. May increase barrier effect for some species
Reduce speed with traffic calming measures	Unknown-59%	Unknown
Mitigation measures aimed at influencing animal behavior or population size		
Wildlife culling	49-84%	None
Wildlife relocation	30-94%	None
Mitigation measures that attempt to separate animals from the road		
Wildlife barriers (fencing/walls/boulders)	80-100% (83% on average)	None. Fences alone make the road into more of a barrier than without fences
Underpasses and overpasses without fencing	Varies greatly depending on structure design and/or location	Barrier effect can be reduced
Underpasses/overpasses and fencing	80-100% (83% on average)	Barrier effect can be reduced

Note. Extrapolated from *Final report: Animal-vehicle collision reduction and habitat connectivity, cost effective solutions.* ***Table 2***. *"Summary of the ten most effective of the 24 mitigation measures reviewed in the literature review report; they had to achieve at least a 50% reduction in AVCs with large mammals. Each measure was evaluated to determine if it reduced the barrier effect of roads to wildlife movement. Green signifies highly effective, yellow indicates moderately effective and red signifies ineffective."* (Huijser et al, 2022)

According to (Huijser et al. 2016), to be most effective the fencing used in tandem with the structures should be at least five kilometers in length. The most frequently used methods in North America to reduce AVCs are aimed at changing the awareness or behavior of automobile drivers. The majority of wildlife crossing signs and other measures to change driver behavior were found to reduce collisions by less than 50% in this review. The few, (4), driver behavior modifications that did manage to produce reduction of AVC rates at 50%, were found to not improve long term habitat connectivity (Ament, et al, n.d.).

3.5.2 Modifying Existing Roadway Structures to be More Conductive to Wildlife Crossing and Reduce Wildlife-Vehicle Collisions

A comprehensive and thorough report titled *Best Practices Manual to Reduce Animal-Vehicle Collisions and Provide Habitat Connectivity for Wildlife* lists various methods and practical information about mitigation measures (Huijser et al, 2022b) These methods aim to both reduce rates of WVC and improve connectivity. They include but are not limited to animal detection systems, virtual fencing, access points, jump outs, fence-ends, cattle guards, escape ramps, and a multitude of other options including many for the modification of existing structures. There exists a multitude of roadway structure modification options that have been experimented with and tested. Each structure deserves to be individually assessed and have potential modification tailored to the habitat and species needs near the specific structure, but as discussed in the previous subsection, a combination of fencing and under or overpasses remains the most effective for larger mammal wildlife.

A thesis by Brian Stewart (2019a) assessed roadway structures on I-5 in Southwest Washington to determine their permeability to ungulates. This study analyzed thirty-three bridges and viaducts existing on I-5 and utilized the Passage Assessment System (PAS), as well as remote camera documentation of wildlife usage at select structures to assess how permeable these structures are to wildlife. After analysis, there were recommendations made for improvements that would aid in improving connectivity and reducing WVCs. A subsequent whitepaper prepared for Conservation Northwest recommended five structures in Southwest Washington for enhancement to improve and maintain habitat connectivity on I-5 (Stewart, 2019b). Finding ways to modify existing structures to allow better connectivity is a much more cost-effective method than the creation of all new wildlife structures. As the previous section identified, a combination of fencing and under or overpasses both improves habitat connectivity and reduces instances of WVCs. These structures were built to support traffic traveling on I-5, they were not designed to act as wildlife corridors. The study found that on average, large "natural" crossing structures were associated with higher WVC rates than in areas without (Stewart, 2019a). This higher WVC rate 0.5 miles in either direction from large crossing structures may indicate several things. The study hypothesized that one explanation for this WVC increase could be higher wildlife use in more "natural" structures and when spooked they cross the interstate and are hit. The study called for more research to explain any type of causation for this finding (Stewart, 2019a).

Modifications to existing roadway structures like fencing help reduce instances of WVC, and modification under the structures may improve permeability and habitat connectivity. This is a great step to restoring wildlife passage through I-5, but the structures themselves were not built in their locations because of high wildlife concentrations or because it was an ideal location to maximize connectivity. Improving these road structures without the addition of new wildlife specific crossings runs the risk of attempting to funnel wildlife where it is convenient for us, rather than where it is most beneficial to wildlife. Wildlife specific crossing structures are still necessary and would ideally be placed in areas where there is both high demand, and high abundance of quality habitat to be connected. There are many important considerations to consider when selecting mitigation measures that can accomplish both goals, reduced WVCs and improved connectivity. The first, and perhaps most important step towards protecting habitat corridors, is to properly identify the corridors and make sure mitigation efforts are directed where they are most needed.

3.6 Methods of Identifying Habitat Corridors

Locating habitat corridors and determining their level of use by wildlife can be a difficult undertaking. This section will explore some of the different methods that can be used to assess or identify suspected corridors.

3.6.1 Wildlife-Vehicle Collision (WVC) Models

Higher frequencies of WVCs in certain areas can be indicative of a wildlife corridor's existence. By compiling WSDOT Wildlife Collision data, one can find high WVC rates, which in turn suggests potential habitat linkage. The conclusion of Gunson et al.'s 2011 article mentions how WVCs can help managers predict where wildlife mitigation may be most effective, but also recommends that areas with low WVCs and depressed populations not be overlooked for recovery efforts. High volume traffic areas like I-5 generate significant noise and motion that many wildlife species avoid (Forman & Alexander, 1998). This road avoidance can lead to lower than would be expected numbers of WVCs in some areas and disruption of the habitat corridor. Other smaller roads crossing the same habitat corridor with lower volume traffic may have much higher rates of WVCs due to less road avoidance. As such, it is important to look at more factors than just WVC incidents when determining likely corridors.

3.6.2 GIS Habitat Connectivity Models

Another tool to identify potential habitat corridors are GIS habitat connectivity models, which can be used to find areas where wildlife would encounter less restriction or resistance to their movements based on a multitude of different factors. These models can consider the various levels of resistance separate species experience while on the landscape and show where the areas of least resistance overlap. For example, the level of resistance to high elevation mountain peaks or wide river systems like the Columbia River would be vastly different between Mountain Goats (*Oreamnos americanus*) and Beavers (*Castor canadensis*). Distinct species also have varying levels of resistance to human development/presence on the landscape. Recently, the Washington Wildlife Habitat Connectivity Working Group (WHCWG) released a synthesis of five focal species and landscape integrity connectivity maps in Southwest Washington (Gallo et al., 2019; Washington Wildlife Habitat Connectivity Working Group, 2024). The five focal species were selected to represent wildlife with different habitat and movement requirements, these models could then be paired with landscape integrity to highlight the areas where focal species need and connectivity exist. The five species selected were Cougar (*Puma concolor*), Western gray squirrel (*Sciurus griseus*), Mountain beaver (*Aplodontia rufa*), Pacific fisher (*Pekania pennanti*), and American beaver (*Castor canadensis*)(Washington Wildlife Habitat Connectivity Working Group, 2024). This naturalness-based connectivity mapping produced models that can be used in real-world decision making (Gallo et al., 2019). Models such as these can be used to locate areas of least resistance (suspected corridors) where they intersect with barriers like I-5. These models can also help evaluate the importance of specific corridors by examining the amount of low resistance habitat they connect and the quality or number of other corridor options.

3.6.3 Remote Cameras

Remote motion sensing cameras are an effective method of recording wildlife presence within suspected wildlife corridors. Remote cameras allow recording of wildlife species at all times of day with minimally intrusive gear. Cameras are relatively low cost compared to GPS collars, but do require regular checks to upload photos, change batteries, and ensure the camera's field of view remains unobstructed. Camera data provides location, species, and time of day the species was detected. Some cameras provide additional information like temperature, humidity, and phase of moon cycle. Continuous collection of camera data in an area can help inform us of wildlife movement patterns and population estimates. One downside to remote cameras is that it is difficult to have a camera set up that can work well for both large mammals and smaller species closer to the ground, requiring different cameras for different sized wildlife. Analysis has been done on some existing I-5 underpasses to determine their permeability to wildlife through collection of motion camera data (Stewart, 2019b). Camera monitoring data provides real world wildlife data that can be more informative than other methods and can identify wildlife species present in locations with less start up and maintenance effort. With Camera data there is an opportunity to evaluate sites suspected of being wildlife corridors.

3.6.4 Field Surveys

Field surveys involve assessments of the location through observing wildlife in person, wildlife tracks, noting vegetation patterns, and evaluating landscape elements including topography, hydrology, and vegetation structure. This method can be done on the ground or through aerial surveys that are often used by wildlife managers to estimate population size. Either type of Field Survey is immensely helpful as wildlife can be observed interacting with the landscape without utilizing more invasive methods like movement data, which include capture and attaching tracking devices to wildlife. Aerial surveys are more costly, and both ground and aerial surveys are limited by the visibility of the location. Forested areas are much more difficult to locate and observe wildlife. Field Surveys are also limited in their ability to constantly monitor all wildlife activity and are limited to only data observed during the surveys. Assessing wildlife sign like droppings, game trails; or animal tracks can be very helpful in determining wildlife usage but is limited by not being able to count individual wildlife. It is also limited to species that leave a more visible sign of their presence. It can be particularly useful to visit sites in person as Field Surveys can offer greater detail than satellite imagery models can provide. Drone imagery of sites can help identify heavily used game trails by hooved wildlife and provide a better understanding of wildlife movement patterns than ground surveys alone. Multiple Field Surveys at separate times of day and in different weather and seasons may yield more complete data but are still severely restricted by the effect of changing wildlife behavior due to human presence and narrow observation windows. Field Surveys are best used in conjunction with other methods of determining habitat corridors. These surveys aid in the understanding of wildlife behavior on location and guide the implementation of more accurate methods of recording wildlife at the site.

3.6.5 Genetic Analysis

Genetic analysis is one of the more in-depth methods that can evaluate the level of connectivity between different populations of a species. Elevated levels of genetic crossover between populations indicate high connectivity and the presence of a wildlife corridor. This method examines patterns of gene flow and genetic diversity throughout a landscape to find prospective corridors using genetic data. Gene flow bottlenecks and highly connected regions can be found from genetic analysis. This method is helpful in establishing if two areas are connected through a corridor or linkage but does not help pinpoint the location of that corridor. The genetic analysis method has been used on populations of mountain lions (*Puma concolor*) to examine gene flow in Washington State (Wultsch et al., 2023). The study was able to identify that the Olympic Peninsula population was the least genetically diverse in the state, and that while there was occasional genetic dispersal out of that population, there was little to no genetic flow in.

3.6.6 Movement Data

Movement data may be collected from animals by using tracking devices and can be used to identify prospective corridors based on their migratory patterns and environmental preferences. Movement data can be used to locate places with high connectivity and potential obstructions to movement. This method is useful for locating specific corridors in use by the tracked animals, but requires first capturing and attaching the tracking devices, typically radio telemetry or GPS, to the wildlife. Radio Frequency Identification (RFID) tags, also known as Passive integrated transponder (PIT) tags can be used in some instances, typically with pets and livestock, but also for fish or aquatic mammals like beavers. This tiny microchip under the animal's skin can update movement data when the animal passes by an array that can read the identification tag. These PIT tags cannot provide an exact location at any given time but can be used to identify individual animals when scanned. This method is used in river systems like the Columbia River to track salmonid movement when the chip is scanned as fish pass through PIT tag arrays in dams. Using GPS or radio collars to track large mammals can require the use of helicopters, net guns, and chemical immobilization, making the process much more difficult to accomplish than on smaller or aquatic species like salmonids. The world's longest Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) migration corridor was discovered by researchers in Wyoming using a GPS tracking collars, with one deer traveling 242 miles in one direction (Kauffman, 2023). This data allows wildlife managers to improve habitat and crossings structures along the migration corridor where it is needed the most.

Of the available methods for assessing corridors or levels of connectivity, there are a few examples of their use within Southwest Washington near the location of this study's research site. The methods and models that have been utilized in this region (Southwest Washington) will be addressed in further detail within the following section.

3.7 Methods of Assessing Wildlife Corridors in Southwest Washington: WVC, Camera, GIS Habitat Connectivity Models

Locally, there are several methods recently used in Southwest Washington: WVC carcass removal data; use of remote cameras; and GIS resistance modeling. Washington State Department of Transportation (WSDOT) has compiled data on roadkill removal since 2015 and several studies in Southwest WA along I-5 have utilized this data to identify areas of increased WVC rates (Stewart, 2019b). Remote cameras are used in the collaborative I-5 Wildlife Habitat Connectivity Study (*I-5 Wildlife Habitat Connectivity Study | WSDOT*, 2023) in progress at the time of this writing, examining wildlife presence along I-5 in Southwest Washington. Conservation Northwest's Community Wildlife Monitoring Project utilization of remote cameras to monitor wildlife is another example of Remote Cameras in the area. Washington Wildlife Habitat Connectivity Working Group (WHCWG) has collaboratively created and analyzed Southwest Washington connectivity corridors using GIS habitat connectivity modeling (Washington Wildlife Habitat Connectivity Working Group, 2024). This study will briefly examine the use of these methods in Southwest Washington.

3.7.1 <u>Using WSDOT Wildlife-Vehicle Collision Data in Southwest Washington</u>

Data collected by Washington State Department of Transportation (WSDOT) from the removal of wildlife carcasses as a result of WVCs is available upon request from the department. Within Southwest Washington, this data has provided studies with the species and count of

WVC's in areas with existing traffic structures (bridges, overpasses). Stewart (2019a) used this data in conjunction with Average Annual Daily Traffic (AADT) also provided by WSDOT, to assess rates of WVCs at different structures in Southwest Washington and compared them to WVC rates in sections of roadway without structures. WSDOT created their Habitat Connectivity Investment Priorities model, a map showing one-mile segments of state managed highway/interstate categorized into Low, Medium, or High Priority. These rankings assessed Ecological Stewardship and Wildlife-related Safety, by using WVCs rates, AADT, and models showing high landscape integrity (WSDOT - Habitat Connectivity Investment Priorities, n.d.). The Safety Rank used in this model was drawn directly from WVC carcass removal data.

WSDOT is able to provide complete carcass removal data on I-5 between milepost 70 and milepost 105 (northern half of I-5 corridor ending in Olympia) for years 2015 onward. This data is primarily comprised of carcass removal from WSDOT crews using Highway Activities Tracking System (HATS), but also includes Washington State Patrol collision reports as well as wildlife salvage permit data from WDFW. This WVC data provides date, species, gender, location, and represents the minimum counts of WVCs. It is generally believed by experts that about three times as many WVCs occur than are reported (G. Kalisz, personal communication, March 7, 2022; Lee et al., 2021). WVC data can only tell part of the story about habitat connectivity, high or low WVC rates alone are not indicative of a habitat corridor due to a multitude of other variables like the barrier effect.

3.7.2 Local Camera Studies in Southwest Washington

Remote Cameras have been used in Southwest Washington for a number of studies. In 2019, Stewart (2019a) used remote cameras to monitor wildlife usage at two bridge structures on I-5 for one year. Collecting data from three cameras at Owl Creek and three on Lacamas Creek.

The study was targeting the permeability of bridges, underpasses, and other roadway structures for wildlife with a focus on ungulates. Prior to Stewart's study, the Cameras were installed by WSDOT as a result of the research project leading to the development of the Passage Assessment System (PAS). PAS is designed as an evaluation tool to assess a structure's ability to act as a wildlife passage and also assess a structure's potential to improve wildlife permeability through modifications (Kintsch & Cramer, 2011). WSDOT began this camera program in 2011 and after the study ended continued their use in several locations to collect data on state traffic structures (Kintsch & Cramer, 2011).

The non-profit Conservation Northwest (CNW) has been conducting remote camera monitoring since 2001 when it started the Rare Carnivore Remote Camera Project in coordination with WDFW. Since then, the program has expanded and changed its name to the Community Wildlife Monitoring Project (CWMP) utilizing 100s of Volunteers yearly to set and check remote cameras in efforts to aid in ongoing research and wildlife recovery (Conservation Northwest, 2023.). With the success of this program, its scope expanded to include more than rare carnivores but also habitat connectivity around wildlife overpasses along I-90. The creation of CNW's Cascades to Olympics Program led to the volunteer monitoring program to be employed as a tool to evaluate wildlife presence in the I-5 corridor in Southwest Washington.

The most current and ongoing study using remote cameras in Southwest Washington is the I-5 Wildlife Habitat Connectivity Study conducted by WSDOT in close collaboration with Washington Department of Fish and Wildlife, Washington Wildlife Habitat Connectivity Working Group, Conservation Northwest, The Olympic Cougar Project and more. This study's remote camera data will be used to provide a technical report of wildlife activity within habitat linkage zones across I-5. This report will in turn help inform the also in progress I-5 Wildlife

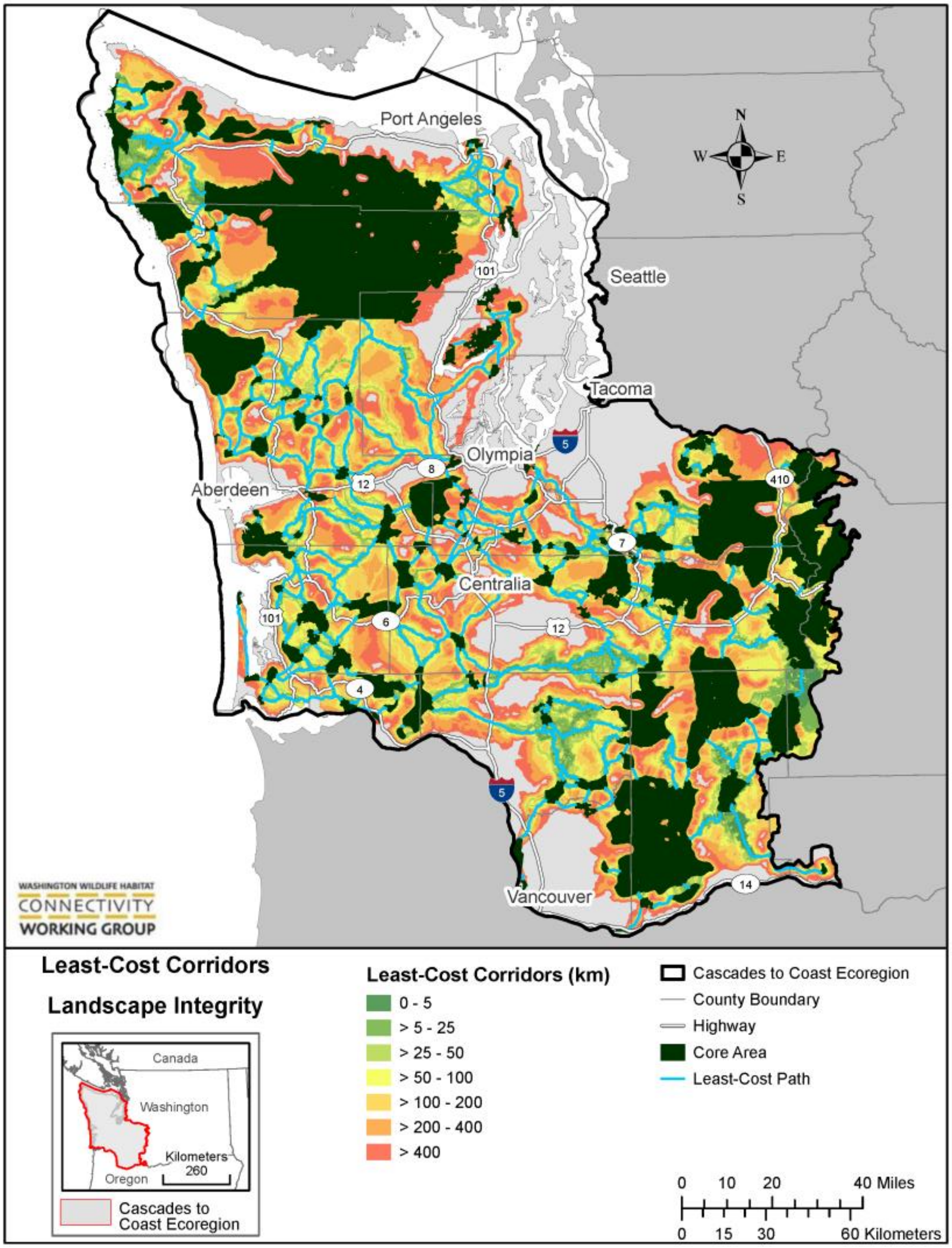
Crossing Structure Feasibility Study that will provide recommend wildlife crossing structure locations, structure types, and conceptual structure designs that include cost estimates for implementation (*I-5 Wildlife Habitat Connectivity Study | WSDOT*, 2023).

3.7.3 Southwest Washington WHCWG Habitat Connectivity Models

In an effort to identify areas that provide critical habitat connectivity to wildlife in Washington, the Washington Wildlife Habitat Connectivity Working Group (WHCWG) has been developing a collaborative scientific analysis of connectivity at different scales in the state (Washington Wildlife Habitat Connectivity Working Group » Habitat Connectivity Analyses, n.d.). The group is comprised of state, federal, university, tribal, and non-profit conservation organizations and societies that can be found on the organization's website as the list grows and changes (Washington Wildlife Habitat Connectivity Working Group » About the Working Group, n.d.). Realizing that large scale conservation of habitat is not always feasible or cost-effective, WHCWG believes that in some cases, the linking of habitat can meet conservation goals of maintaining plant and animal populations (Washington Wildlife Habitat Connectivity Working Group, 2010). The connected habitat as an entire system may be greater than the sum of its fragmented patches. WHCWG suggests that wildlife movement through land cover types differing from those needed to maintain a resident population can lead to new partnerships and strategies for conservation of connectivity (Washington Wildlife Habitat Connectivity Working Group, 2010). Under Conservation Biology Institute with data provided by the US Fish and Wildlife Service, a series of models and layers named *Connectivity of Naturalness in Western Washington* was co-created by John Gallo, Erin Butts, Thomas Miewald, and Kai Foster with direct advice and final product selection from WHCWG (*Least-Cost Corridors, Western Washington | Data Basin*, n.d.; *Connectivity of Naturalness in Western Washington | Galleries | Data Basin*, n.d.; Gallo et al., 2019). This analysis was created with the goal of examining methods of assessing habitat connectivity within Western Washington. Out of this analysis came many models identifying Habitat Concentration Areas (HCAs), Connectivity Priority Areas, Linkage Value of Every Cell, Pinch points, Cost Weighted Distance, Naturalness Connectivity Priority Areas, Least-Cost Pathways, Least-Cost Corridors, and several more. Of these, the Least-Cost Corridor (LCC) model that came from this collaborative effort to better understand connectivity in Western Washington, is one of particular interest to those invested in locating Wildlife Corridors along I-5. The Least-Cost Path (LCP) is a line representative of the most direct path with the least resistance cost to wildlife between Habitat Concentration Areas (HCA) or core habitat areas. The Least-Cost Corridor (LCC) is the area surrounding each LCP. Its width is determined by the value (cumulative resistance cost to wildlife) of Cost Weighted Distance (CWD) as the LCC projects outward from the center of the LCP. In areas of low wildlife resistance cost (high permeability) the LCC is wider, and in areas of high wildlife resistance cost (low permeability) it shrinks closer to the LCP. As wildlife are unaware of the LCP model and are unlikely to strictly adhere to its narrow path, the LCC gives a better visual understanding (Figure 3.1.) of the corridor wildlife would likely travel through on the landscape between Habitat Concentration Areas than LCPs do alone. The “Cost” in LCC and LCP refers to the cost to wildlife in terms of resistance for movement, not the least expensive place to build a structure in USD ($).

Figure 3.1.

Least-Cost Corridors Model



Note. This map was extrapolated from the *Cascades to Coast Analysis* 2024 report, labeled ***Figure 1.3.6***. *landscape integrity connectivity model, including core areas, Least-Cost Paths, and Least-Cost Corridors* (Washington Wildlife Habitat Connectivity Working Group, 2024).

The use of these three assessment methods, WVC/Camera/GIS, have resulted in the identification of priority areas along I-5 for the reduction of WVCs, assessments and recommendations for wildlife permeability in I-5 structures, and the creation of connectivity maps that have helped identify major fracture zones and priority linkages through them. The following sections will further examine the use of GIS habitat connectivity modeling and some of WHCWG's findings from their *Cascades to Coast Analysis*, as well as how it relates to the focus area of this study.

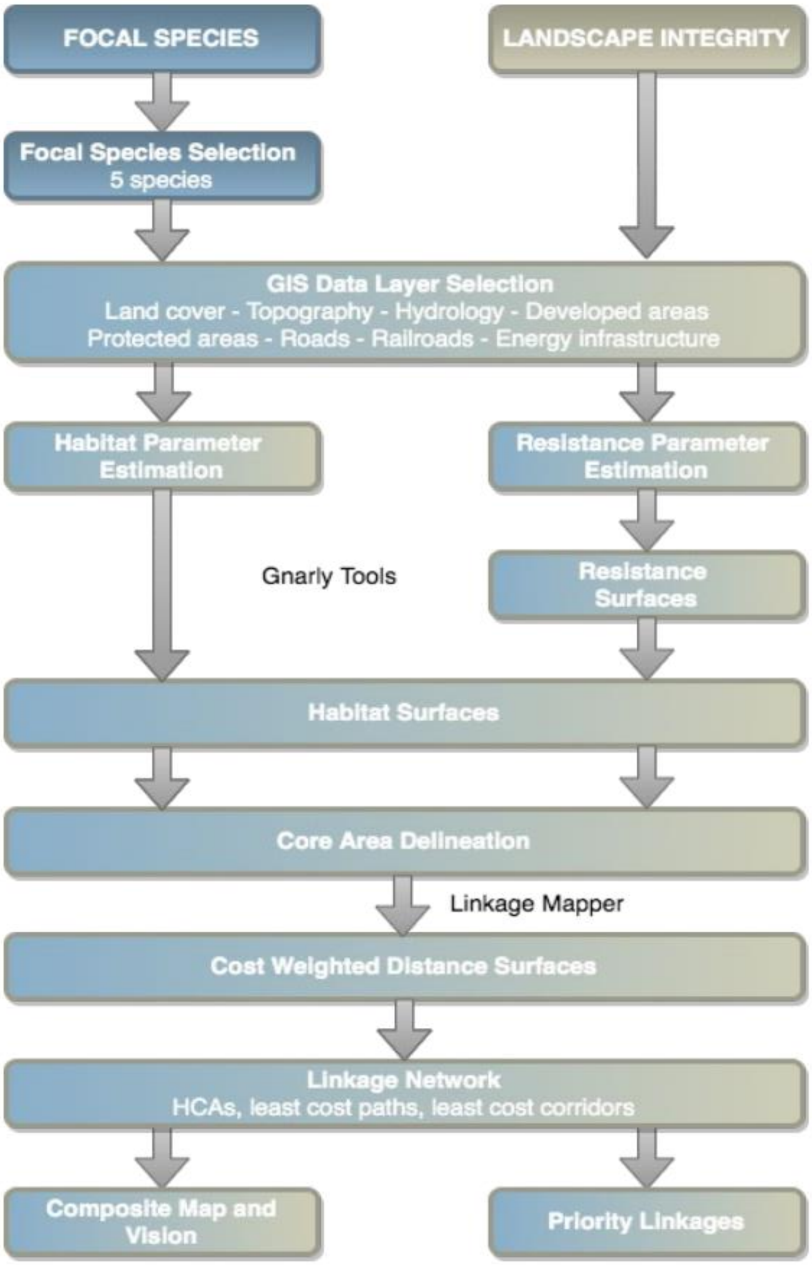
3.8 Cascades to Coast Analysis 2024

In May 2024, Washington Wildlife Habitat Connectivity Working Group (WHCWG) published their final report of the *Washington Connected Landscapes Project: Cascades to Coast Analysis*. Previously in 2010, WHCWG conducted the *Washington Connected Landscapes Project: Statewide Analysis* that identified landscape connectivity patterns throughout the state, but the need for a focused and scaled study in Western Washington was recognized by the authors (Washington Wildlife Habitat Connectivity Working Group, 2024). In selecting the best way to approach this study, they settled on two main models, Landscape Integrity, and Focal Species. Landscape Integrity is the size, proximity, and quality (level of naturalness) of habitat across the landscape without considering how different wildlife species use or move through this landscape. The Focal Species model examines individual species' habitat needs and movement patterns on the landscape. Rather than create a new model for every species individually, WHCWG thoughtfully selected two terrestrial, one semi-aquatic, one semi-arboreal, and one arboreal species believed to best represent movement and habitat needs characteristic of most wildlife within Western Washington. The five species selected were Cougar (*Puma concolor*), Western gray squirrel (*Sciurus griseus*), Mountain beaver (*Aplodontia rufa*), Pacific fisher

(*Pekania pennanti*), and American beaver (*Castor canadensis*). More information on the selection process and habitat representation can be found in ***Section 3*** of their report (Washington Wildlife Habitat Connectivity Working Group, 2024). When Landscape Integrity and Focal Species methods are combined, they model regional habitat connectivity representative of a variety of wildlife with different habitat needs and movement patterns local to Western Washington (Washington Wildlife Habitat Connectivity Working Group, 2024). The following flow chart from Washington Wildlife Habitat Connectivity Working Group (2024) shows the processes leading to the identification of priority linkages and high-quality composite maps (Figure 3.2.).

Figure 3.2.

Composite Map & Priority Linkages Flow Chart.



Note. Extrapolated from *Washington Connected Landscapes Project: Cascades to Coast Analysis*. Original title ***Figure 1.2.1.*** *Flow of the Cascades to Coast Analysis*. (Washington Wildlife Habitat Connectivity Working Group, 2024). For more information on the creation of these models, please visit the WHCWG website (https://waconnected.org/coastal-washington-analysis/) and read the full final report.

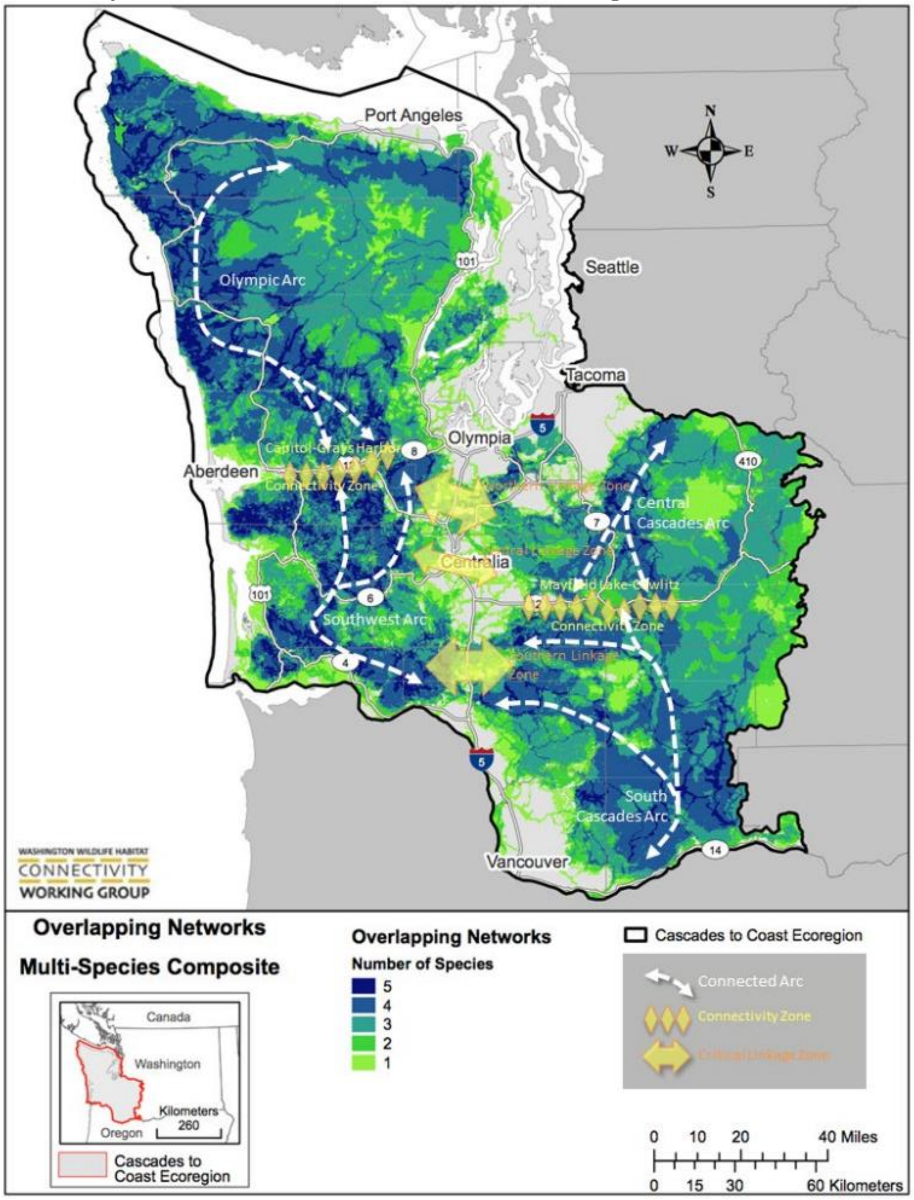
3.9 2024 Cascades to Coast Analysis: Findings Summary

In one key finding of their analysis, large fracture zones with limited connectivity were identified around major cities and the I-5 corridor, with the most significant lack of connectivity occurring around the Puget Sound. WHCWG also identified four Connected Arcs, highly connected and stable lands, defined in the paper as "*broad and long swaths of lands where the linkage networks of multiple species and landscape integrity overlap*" (Washington Wildlife Habitat Connectivity Working Group, 2024). Two north-south Connectivity Zones were identified, they possess less reliable connectivity than those of Arcs and according to WHCWG are "*characterized by many short, redundant linkages spread out along the majority of fracture zone, and occur where the fracture zone is relatively narrow, with high permeability lands on both sides.*" Three east-west Linkage Zones that cross the I-5 fracture zone were also identified, providing a much narrower and less connected pathway than that of Connectivity Zones or Connected Arcs.

The I-5 fracture zone is much larger and poses more serious connectivity issues than the less imposing fracture zones associated with the two Connectivity Zones. Linkage Zones are "*areas that cross major fracture zones - characterized by a few, long and mostly narrow linkages, which may require enhancement to provide functional connectivity for many species"* (Washington Wildlife Habitat Connectivity Working Group, 2024). The few Linkage Zones that cross east-west through the 1-5 fracture zone are the best remaining areas suited to connect Habitat Concentration Areas (HCAs) in the Cascades to those in the Olympics. While north-south connectivity is vitally important, the current analysis of Southwest Washington's connectivity shows that great priority should be placed on the smaller east-west linkages. This is due to the limited width and number of linkages available, the vast size of the I-5 fracture zone, and the resulting loss of accessible habitat should connectivity be severed between the Olympics and the Cascades. Reference Figure 3.3. for a map of the four Connected Arcs, two Connectivity Zones, and three Linkage Zones identified by the Cascades to Coast Analysis in Southwest Washington.

Figure 3.3

A Vision for a Connected Cascades to Coast Region



Note. This map was extrapolated from the *Cascades to Coast Analysis* 2024 report, labeled ***Figure 1.3.10***. *A vision for a connected Cascades to Coast region.* (Washington Wildlife Habitat Connectivity Working Group, 2024).

3.9.1 <u>Linkage Zones</u>

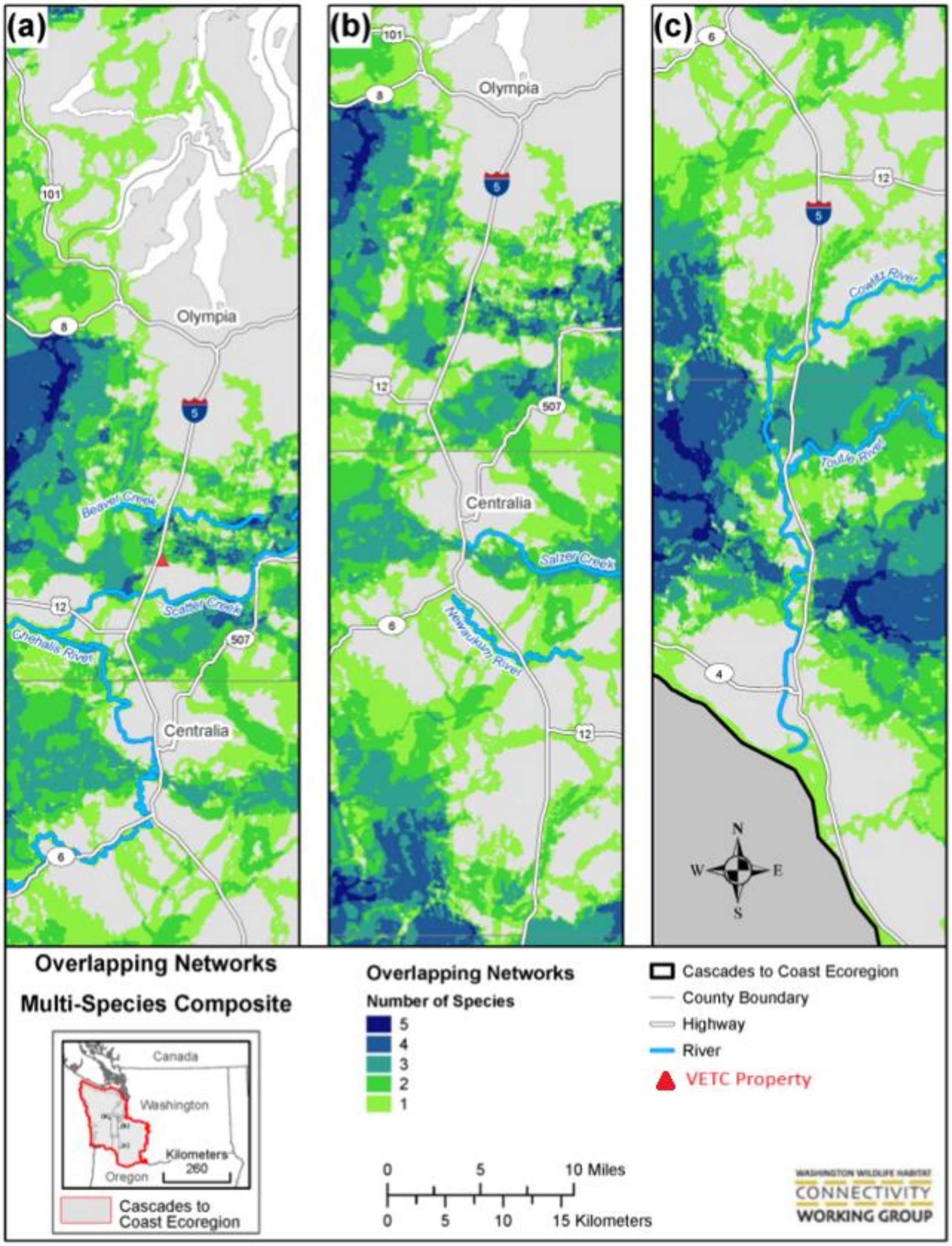
The largest of the three I-5 linkage zones, dubbed the *Southern Linkage Zone: Toutle and Cowlitz Rivers*, provides connectivity for multiple species as a wide path across that integrates into the north-south connected networks on the eastern and western sides of I-5. This area is primarily forested and has a relatively low number of landowners within its borders. Ownership is primarily large timber operations and state-owned land. See Figure 3.4. (c).

The most precarious I-5 linkage zone, the *Central Linkage Zone: Newaukum River and Salazer Creek*, consists primarily of thin lengthy linkages that the model shows as being part of only 2-3 of the five focal species connectivity networks. With limited crossing areas available along I-5 and the extended distance between the Northern and Southern Linkages, this Central Zone provides essential connectivity value to wildlife in the area despite needing structural improvements to achieve permanent and full connectivity. See Figure 3.4. (b).

The *Northern Linkage Zone: Scatter and Beaver Creek* consists of several interconnected linkages that provide connectivity to multiple species existing between developed lands in the I-5 Fracture Zone. The Northern Linkage Zone also forms secure connections to the ecologically unique Lower Nisqually River area, including Joint Base Lewis McCord (JBLM) land, home to core habitat for oak-prairie/woodlands species represented in the five-focal species by western gray squirrel (*Sciurus griseus*). The importance of this region's oak and prairie Priority Habitat types were discussed earlier in this thesis within ***Section 2.4.*** *Local Ecosystems*. Figure 3.4. shows WHCWG's diagram of the three main linkage zones across the I-5 corridor, with a composite of the five-focal species and landscape integrity's linkage network. This thesis's study site falls squarely between Beaver Creek and Scatter Creek within the I-5 Northern Linkage Zone. See Figure 3.4. (a).

Figure 3.4.

Linkage Zones Across the I-5 Corridor



Note. This map was extrapolated from the *Cascades to Coast Analysis* 2024, labeled ***Figure 1.3.12.*** (Washington Wildlife Habitat Connectivity Working Group, 2024). Edited to show thesis's study location (Red Triangle) within the I-5 Northern Linkage Zone (a). Garrett Brummel, 2024.

3.9.2 The I-5 Northern Linkage Zone

There are several attributes that make the Northern Linkage Zone (NLZ) different from the other two Linkage Zones crossing I-5. First, it is the northernmost and most direct route between the Cascade Mountains and the Olympic Mountains with a relatively large and functional degree of connectivity. Its close proximity to the Lower Nisqually River area and Joint Military Base Lewis McCord (JBLM) east of I-5, as well as several unique wildlife areas and the large Capitol State Forest west of I-5, place it in an ideal location to facilitate connectivity around the South Puget Sound region where connectivity has been discovered to be severely lacking. Second, it possesses a larger area with higher connectivity than that of the Central Linkage Zone, whose cost of restoration and habitat improvement could be a significant limiting factor. Yet, the NLZ is smaller and less connected than the Southern Linkage Zone much further away, leading to increased priority for preservation of this linkage as the local habitats types and species provided connectivity by the NLZ would not be well served by the Southern Linkage Zone. This is especially true for the oak obligate western gray squirrel (*Sciurus griseus*) as found by WHCWG when exploring the species Habitat Concentration Areas (HCA) and Least-Cost Corridors (LCC) (Washington Wildlife Habitat Connectivity Working Group, 2024).

Without the NLZ, this thesis estimates that wildlife travel between Elbe Hills State Forest in the Central Cascade Arc to the timberland north of McCleary WA in the Olympic Connected Arc would be lengthened by roughly 85 miles. Those animals, rather than a more direct east to west or Central Cascade-NLZ-Olympic Arc path, would travel down and around through both Connectivity Zones, all four Connected Arcs, and the Southern Linkage Zone by the time they reached highly connected habitat in the Olympic Peninsula. Wildlife originating from JBLM would have an even more dramatic detour traveling to the west of I-5 without use of the NLZ, and in the case of some species like the oak obligate western gray squirrel (*Sciurus griseus*), natural dispersion across I-5 in this direction would appear impossible.

Since the start of this study in October 2020, there have been several other studies focused on examining the I-5 Northern Linkage Zone. The 2024 WHCWG *Cascades to Coast Analysis* has already published and some of its findings are discussed in this thesis. Incidentally, some of the preliminary results from this thesis were published in the Analysis ***Section 2:*** *Case Study 2 – Wildlife Movement Across Private Lands, Northern Linkage Zone Example* (Washington Wildlife Habitat Connectivity Working Group, 2024). Two other studies relevant to the Northern Linkage Zone are expected to publish this year in Fall 2024. One study, a habitat connectivity camera study identifying the wildlife found bordering I-5 within the linkage zones is intended to inform the other, investigating the cost and feasibility of implementing wildlife crossing structures within the Northern and Southern Linkage Zones. What this means is that wildlife knowledge within the NLZ is rapidly expanding and there are now preliminary locations selected for potential wildlife crossing structures. In an update on the *Interstate 5 Wildlife Crossing Structure Feasibility Study* in August 2024, WSDOT provided drafts of proposed areas for enhancement within the Northen and Southern Linkages (Kalisz & Washington State Department of Transportation, 2024). While these results are not published or finalized, the location of one of these proposed crossing structures is of great relevance to this study (Figure 3.5.). Preliminary potential crossing structures highlighted in this *Feasibility Study* update included two overpasses (located at Milepost-92.8 and Milepost-96.1), removal of fish barriers at Salmon and Beaver Creek, and a retrofit of the I-5 Scatter Creek bridge to enhance its permeability to wildlife. Items identified as next steps in this process included continued wildlife camera research with the addition of a few species-specific models, the formation of working groups to address land use/land protection issues, and identifying and securing funding requirements for these projects (Kalisz & Washington State Department of Transportation, 2024). The implementation of wildlife crossing structures may not come before the security of connectivity on the land is established as the crossing structures will rely on this continuing to function as intended.

Figure 3.5

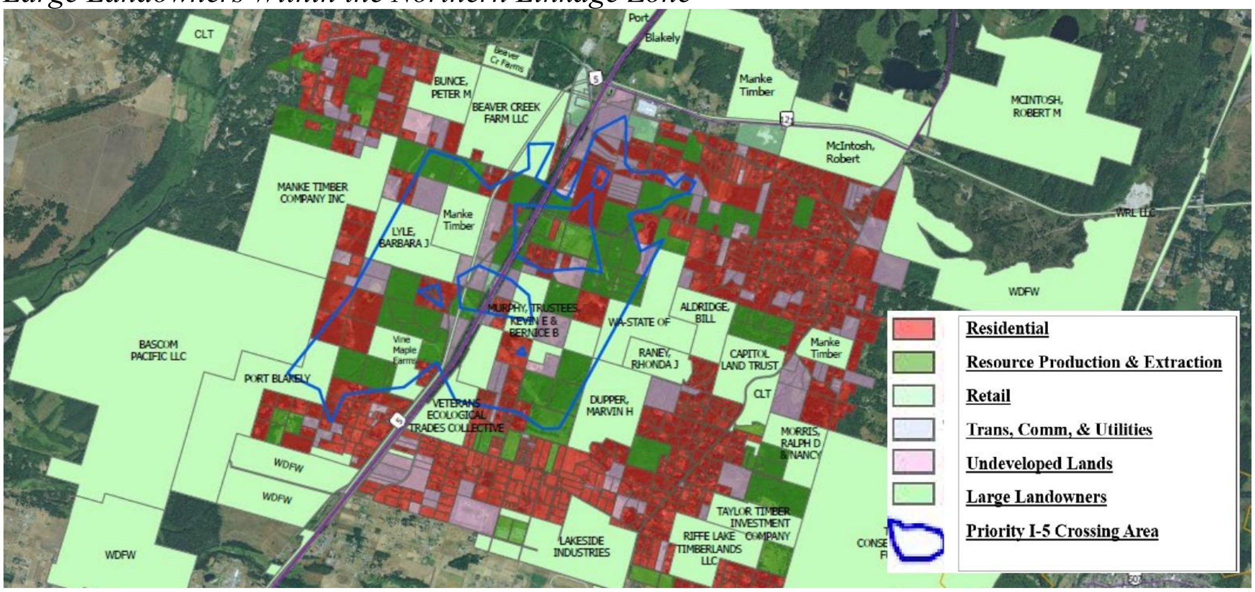
Potential Wildlife Overpass, Milepost 92.8

Note. This Figure was extrapolated from (Kalisz & Washington State Department of Transportation, 2024). It has been edited to show an enhanced view of the VETC property (light blue property to the right of I-5) and the location of the potential wildlife overpass (blue dot on I-5). The property to the left of I-5 was unnamed but was identified as "*Private Lands with Connectivity Focus*" alongside VETC. Garrett Brummel, 2024.

Options as of this writing are currently being investigated to ensure continuing connectivity and security of the I-5 Northern Linkage Zone. Private landowner investment within this linkage is a high priority for the feasibility of establishing wildlife crossing structures (Figure 3.6.). The increased importance of landowner buy in is due to the inability of any public lands/land trusts ability to maintain the connectivity of the linkage alone. The Southern Linkage Zone benefits from having relatively few landowners (primarily private timberland and WA, DNR) where it meets I-5 and is less developed than the NLZ in general.

Figure 3.6

Large Landowners Within the Northern Linkage Zone



Note. Figure extrapolated from (Michalak, 2023). Edited to enhance landowners and legend.

These are exciting developments for connectivity in the region, but with a greater number of private lands in the Northern Linkage Zone, the importance of partnership and collaboration with private landowners will surely be a priority if connectivity is to be reestablished.

3.10 Key Thesis Literature Review Conclusions

The review of the literature on habitat corridors and habitat connectivity demonstrates emerging research and modeling how habitat connectivity, wildlife movements, and investments in wildlife infrastructure interact to address the barrier effect caused by major roadway systems such as I-5 in Southwest Washington. Habitat corridors and connectivity are important to maintain several crucial ecological processes statewide. Roadways like I-5 are barriers to wildlife movement and greatly diminish connectivity. There are both monetary and ecological costs associated with WVCs and poor connectivity. Solutions to reduce WVCs while improving connectivity are possible, and the best practices have been identified and tested (Huijser et al., 2022). Methods exist to aid in the identification of suspected corridors and some of these methods (GIS habitat, WVC, and Remote Camera models) have already been or are currently in use near this study's research site. The following chapter will discuss the methods utilized in this thesis to examine the wildlife present on this privately owned property that is both within the Northern Linkage Zone and adjacent to I-5.

4 Chapter IV: Methods

4.1 Selection of Methods for Site Analysis

In the Literature Review, six different methods that can be used to determine the location/presence of habitat corridors or linkages were explored. WVC Models, GIS Habitat Connectivity Models, Remote Cameras, Field Surveys, Genetic Analysis, and Movement Data. Of these six methods, Remote Cameras and Field Surveys were selected for data collection in this study. WVC Data, GIS Habitat Connectivity Models, Movement Data, and Genetic Analysis methods were not used in this study for data collection. The top priority of this study was to capture the greatest diversity and abundance of wildlife present on the site within the limitations of available equipment and technology.

Movement Data would provide the most detailed data on wildlife land use and highlight the actual paths used for travel between habitats. It would also only provide data on individual animals with tracking devices. This study's goal is to capture the diversity and abundance of species present on this particular property, rather than the movements of a specific animal on or off the site. Currently, WDFW restricts public access to the radio telemetry and GPS wildlife Movement Data collected to protect wildlife from human disruption. Inquiries were made to WDFW about access to any potential Movement Data and access was denied. As such, Movement Data is not publicly available near the location of the site. Even if data were publicly available, it is unlikely this method would include the full diversity of species present on site that this study is interested in recording. Collecting Movement Data for this study would be prohibitively expensive, time consuming, and require proper training and permitting. For these reasons, Movement Data was not used for analysis in this study.

Some Genetic Analysis data about Washington's wildlife is publicly available, however, similar to Movement Data, this method would also likely lack the full diversity of wildlife species present at the site. By design, this method cannot identify specific locations of corridors, just the presence or absence of genetic crossover between two regions for species tested. Genetic Analysis is prohibitively expensive, time consuming, and requires proper training and permitting. For these reasons, Genetic Analysis data was not used in this study.

Collecting WVC Data to determine the presence of wildlife corridors would not be a very practical method to use in studying this site due to limited quantity of WVC records along the site and inability to know if those animals were ever on the site or coming from the other side of the freeway. WVC carcass removal data along I-5 has been compiled since 2015 by WSDOT on a scale that would not be practical to generate independently. While WVC Data cannot pinpoint the location of a habitat corridor due to the barrier effect and roadway avoidance, it can provide insight into what species were struck in the roadway near the study location. The range of this WVC Data allows for comparisons between I-5 in close proximity to this study site and other sections of I-5. WVC Data may also be used for comparison of suspected fracture zones and suspected linkage zones found in GIS Habitat Connectivity Models. WVC Data was not selected as a method of determining the diversity and abundance of wildlife species on the site. This method may very well prove useful in providing new knowledge about wildlife within the I-5 Northern Linkage Zone by examining local WVC data and how it relates both to this site and to GIS habitat connectivity models of the area.

GIS Habitat Connectivity Models can be incredibly useful in determining areas of high connectivity like habitat corridors or linkages. This study did not construct its own GIS Habitat Connectivity Model of the study site because it would not be the most effective method to collect data on what wildlife is present on site. This study seeks to collect data that shows what wildlife is present in this particular location. How the data collected in this study relates to larger existing GIS Habitat Connectivity Models is certainly of interest to this study. Specifically, the Least-Cost Corridors (LCC) model where it occurs within the I-5 Northern Linkage Zone (NLZ) identified by WHCWG in their *Washington Connected Landscapes Project: Cascades to Coast Analysis 2024* (Washington Wildlife Habitat Connectivity Working Group, 2024). These connectivity models give rise to increased interest in the NLZ and increased demand for on the ground wildlife usage data within the NLZ. This method was not selected as a primary method of data collection within this study; however, the mapping results from models using this method were heavily influential in the selection of this study's location.

Field Surveys typically involve assessments of the location through observing wildlife in person, wildlife tracks, noting vegetation patterns, and evaluating landscape elements including topography, hydrology, and vegetation structure. Field Surveys are also limited in their ability to constantly monitor all wildlife activity and are limited to only data observed during the surveys. Assessing animal sign like droppings, game trails, or animal tracks can be very helpful in determining wildlife usage but is limited to species that leave more visible sign of their presence. It can be particularly useful to visit sites in person as Field Surveys can offer greater detail than satellite imagery models can provide. Drone imagery of sites can help identify heavily used game trails by hooved wildlife and provide a better understanding of wildlife movement patterns than ground surveys alone. Field Surveys may affect wildlife behavior due to human presence and only offer a narrow observation window. Field Surveys can be used in conjunction with other methods of assessing habitat corridors, specifically Remote Cameras. This method can aid in the understanding of wildlife behavior on location and can guide the implementation of more accurate methods of recording wildlife at the site. Field Surveys were selected for use in this study to identify locations for Remote Camera placement that could best detect wildlife diversity and abundance.

4.2 Field Survey - Camera Location Selection

Representatives from both VETC and Conservation Northwest conducted a Field Survey of the study site to determine the camera locations best suited for capturing wildlife. After inspecting the site, selections for camera locations were made based on the camera sites' probability of capturing an abundance and diversity of wildlife. Location selection was consistent with camera protocol from Conservation Northwest's Citizen Wildlife Monitoring Project (Moskowitz et al., 2017). With additional site-specific requirements for this study. Several factors weighed heavily into the camera placement process. The three requirements for the placement of cameras included Differing Habitat Types, Camera Spatial Requirements, and Wildlife Sign. Convergence areas or bottlenecks, food and water sources, and distance from human activity were all additional factors considered during selection for placement of the four remote cameras available to this study. The following sections will discuss the requirements and other factors explored during the Field Survey.

4.2.1 Habitat Types – Requirement I for Camera Location Placement

Differing Habitat Types: Selecting camera locations for diversity of habitat allows capture of varied species, some species prefer open fields, some rarely leave the cover of dense brush, and others require mature forest. With the intent of including as many species as possible, camera site locations were selected to be representative of the range of habitat types found on the property. With the limited equipment available and several distinct habitat types, it was a requirement that the four camera locations did not share identical habitat types.

4.2.2 Camera Spatial Requirements – Requirement II for Camera Location Placement

There are two primary categories of spatial requirements necessary to set up a successful remote camera location. There are the physical area requirements for installing cameras (i.e., ability to mount camera, clear field of view) as well as placement requirements for successfully capturing identifiable photos of the target species.

Physical Requirements: Cameras must have a structure to mount and secure the camera to during installation. Placing cameras higher and having a larger total area allows for more photos of wildlife within the frame, especially if the wildlife is moving quickly, and leads to better identification of wildlife in less visible conditions. Setting cameras much lower and in thicker brush could capture species that might be missed by targeting larger wildlife but come with a host of other issues. Dense brush habitat is typically plagued with motion from leaves and branches that can cause false triggers leading to tens of thousands of photographs without any wildlife on a single SD card. Cameras placed lower have a smaller total area captured in photographs, as well as a higher likelihood of having plant growth block the lens and create more false triggers. Typically, a distance of three meters away from where the wildlife will be captured is ideal. Cameras must not be placed facing upward where rain can obscure the lens or in a direction where sunlight can make species unidentifiable.

Target Species: This study's aim was not to target one particular species but attempt to capture the total abundance and diversity of species on site. Having stated this study's overall goal of species abundance and diversity, there was still bias selectivity in the type of target species camera locations were selected for. Large mammals are much easier to identify on remote camera, and sites that could capture a Roosevelt Elk (*Cervus canadensis roosevelti*) are still capable of capturing smaller wildlife with proper camera angle. Both larger and smaller wildlife tend to follow the path of least resistance when available, and game trails created by larger wildlife are frequently used by the smaller, while the reverse is not always possible. In general, most research of terrestrial wildlife habitat corridors tends to target studying larger mammals, and with limited cameras available this study also chose to select camera locations with larger mammals in mind. This is why no cameras will be located in areas where larger mammals would be undetectable. This larger mammal bias in location selection increased the importance of including diverse habitat types preferred by smaller wildlife.

Camera locations must have met the Spatial Requirements allowing the ability to attach the camera securely, a wide enough area within frame to capture wildlife of varying size, and the ability to take visually un-obstructed photos that are capable of identifying wildlife species.

4.2.3 Wildlife Sign – Requirement III for Camera Location Placement

Amount of Wildlife Sign: The volume of wildlife sign present at or near certain locations weighed heavily into the decision-making process for camera location selection. This sign allows for the identification of species using the location and aids in the prediction of future movements of those species. When wildlife sign is more dispersed, like in bedding or feeding areas, there typically are heavily frequented game trails between the two habitats. Game trails, scat, evidence of browsing on plants, bedding depressions, antler rubs, scrapes, burrowing, claw marks on tree bark, and prints in the mud or dirt are all examples of wildlife sign that could be used during the survey. Knowing the area and how wildlife uses it through their sign allows for camera placement in locations with a higher likelihood of capturing wildlife movement.

In the camera location selection process, it was a requirement that camera locations contain wildlife sign, with more heavily concentrated wildlife sign given preference over sites with less.

Convergence areas and bottlenecks are two examples of areas with heavily concentrated wildlife sign (Figure 4.1.). Distinct species tend to prefer various levels of habitat cover; when examining game trails there often comes a point where another trail comes from a different direction or habitat type to cross or join the original. These areas where two trail types come together are called convergences and are helpful in targeting a higher diversity of species. Bottlenecks are a type of convergence where wildlife are structurally forced to travel through a narrower area. One example is a gap in a fence line where wildlife may pass unobstructed, any physical resistance to an animal's movement can cause a bottleneck. Cameras placed at these locations benefit greatly from the increased quantity/diversity of wildlife using them. Placing cameras near the most obvious convergence areas near the borders of the property increased the likelihood of detecting wildlife as they entered or left the property. Bottlenecks and convergence areas should be highly weighted factors in selecting camera location due to the amount of wildlife sign found within them. While their presence is not an individual requirement for camera placement, one or both were present in every camera location selected but one (Camera site 5).

Figure 4.1

Game Trails, Convergence Areas

Note. The game trails through this field are highly visible in this location and form a convergence area as they exit the property. This site was selected for camera placement (Camera site 6) near the center of this photo twenty meters into the forest facing the convergence. Garrett Brummel 3/25/2022

4.2.4 Additional Factors in Field Survey Selection – Not Required for Camera Location Placement

Distance from Human Activity: Wildlife often avoid areas with higher human activity, and this should be taken into consideration when deciding camera locations. This does not always play a significant role in selecting camera locations because typically with increased proximity to human activity there is decreased wildlife sign, fewer trails to converge, and fewer trees or structures available to attach cameras to. Most camera locations should be a considerable distance from human activity. However, habitat type, camera spatial requirements, and high wildlife sign take precedence in the pursuit of recording the highest diversity and abundance of wildlife.

Food and Water: Unique features like water sources and food on site can be targeted for camera site selection because of their ability to attract a wide variety of species. Certain food sources may be habitat type related as coyote or bobcat may hunt in fields or brushy habitat for food while fields and transition areas may provide more browse for deer and elk than the understory of a mature forest. Seasonally available high calorie food sources like fruit and berries are a strong attractant to some wildlife and may also attract carnivores due to high prey concentrations. This study will not place anything to draw or lure wildlife to the study site or in front of the cameras so any naturally occurring attractants should be utilized if other requirements are met.

4.2.5 Field Survey Findings

Based on the results of the Field Survey, four locations on the study site were selected and remote cameras were installed. two other camera locations were installed at later dates after issues arose at one of the sites. The following Camera Study section will discuss the characteristics of camera locations selected, equipment used, camera installation protocol, and data collection.

4.3 Camera Study

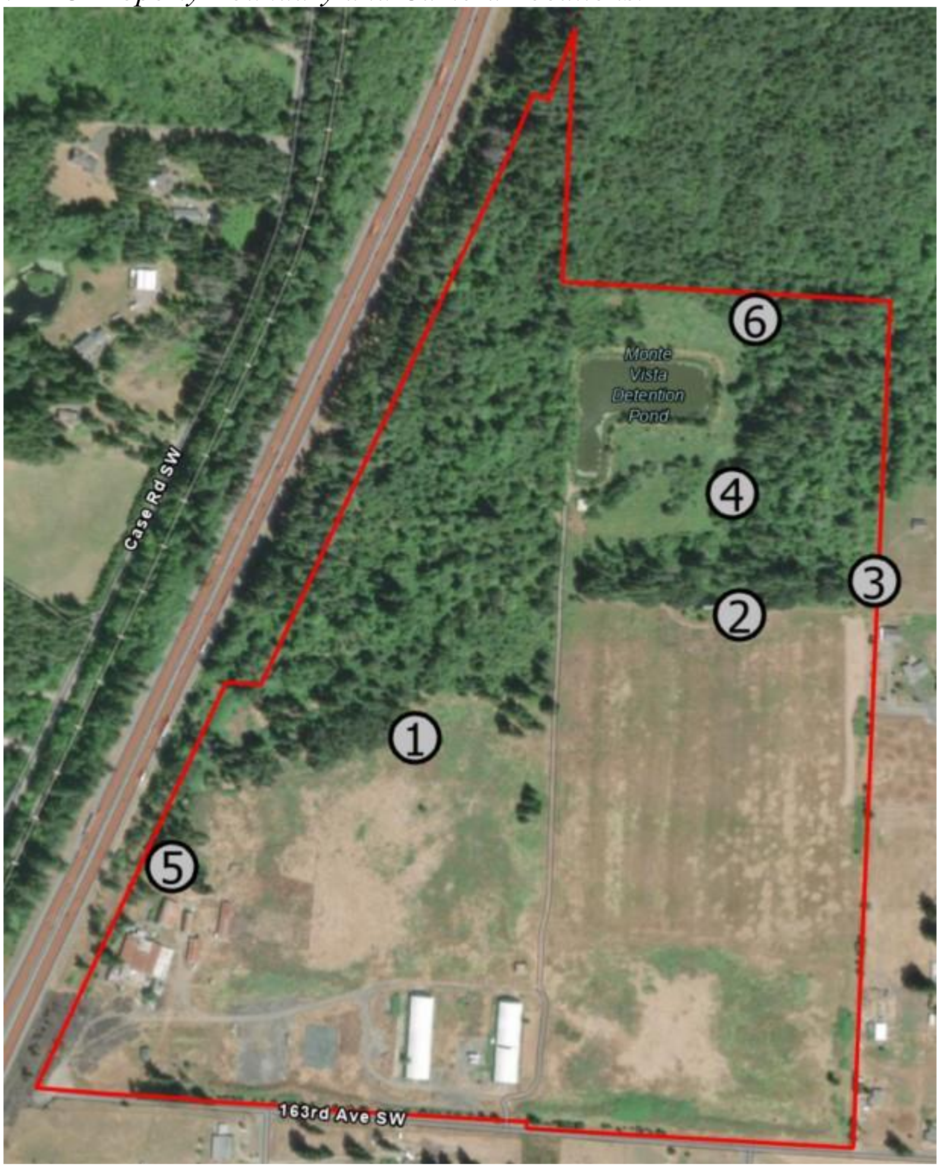
Remote cameras have been, and as of this writing are currently being, used along I-5 to collect wildlife data. This method is frequently used to observe wildlife activity due to their ease of installation and relatively low cost (Stewart, 2019a). Remote cameras provide data that includes wildlife species detected, count of animals, and time of day. Over long enough collection periods this data can provide daily and seasonal trends in wildlife activity as well as cataloging the diversity and abundance of wildlife present on location. Due to these reasons, remote camera use was selected as the primary method of data collection in this study.

4.3.1 Camera Locations

The six camera locations utilized in this study can be viewed in Figure 4.2.

Figure 4.2

VETC Property Boundary and Camera Locations.



Note. VETC property boundary in red with Camera Sites in grey numbered circles. The northbound and southbound lanes of I-5 can be seen to the left (west) of the property as parallel light-orange lines. Garrett Brummel, 2022. Using ArcGIS Pro 3.0.1

Camera sites were numbered in the order they were established, starting with the first sites Camera 1, 2, 3, and 4 installed on October 1, 2020. Camera 2 was discontinued due to changing weather conditions that made the location no longer suitable for terrestrial wildlife (Reference Figure 4.3. Figure 4.4). Camera 5, the relocation site of Camera 2, was discontinued due to hasty selection that did not meet Field Survey Camera Location criteria and was subsequently relocated to Camera 6. Only four game cameras were in operation at any given time during this study, any reference to camera numbers (e.g. Camera 1) pertains to camera site locations and not the name (number) of the physical camera itself.

4.3.2 Camera Site 1

Figure 4.3

Camera 1 Bobcat/Game Trails

Note. Left: A bobcat (*Lynx rufus*) passing in front of Camera 1 during a particularly nice April morning. Garrett Brummel, 2019. Right: A photo of game trails converging in center of photo at the location of Camera 1. Garrett Brummel, 2022

Camera 1 (Figure 4.3, Table 4.1) was placed on October 1, 2020, over a firebreak line in an open field eighty meters from forest and tree cover. This location was selected primarily because it was in an open exposed field without any woody plants. This was important in order to get a sample of this prairie/grassland habitat type as it differed from the other locations that had more tree cover. It should be noted that this site has not yet been tested to ascertain if it meets WDFW Westside prairie Priority Habitat criteria. Because there were no trees to attach the camera to, a nearby branch from a Douglas fir (*Pseudotsuga menziesii)* was driven into the ground three meters from the trail for the camera to be placed on. Due to limited high attachment points this camera was the lowest in elevation at around 1.2 meters high and could have benefited from higher placement but was sufficient to meet Spatial Requirements. Grass occasionally grew high enough to cause false triggers and required maintaining during the spring and summer months. Various wildlife signs were visible in the dirt at this location and there was a convergence of three game trails. Ungulate and canine tracks were observed in the dirt in front of this camera location and there appeared to be a convergence of game trails leading from the woods and merging with the firebreak line that also contained wildlife tracks. This camera location remained throughout the entire duration of this study and discontinued on January 1, 2022, at the end of this study.

Table 4.1

Camera 1, Field Survey Notes

Camera 1	**Field Survey Notes**
Habitat Type	Prairie/Grassland – Limited Cover
Spatial Requirements	Met. Could have benefitted from higher elevation
Wildlife Sign	Heavy - Canine, ungulate, tracks, and droppings
Convergence/Bottleneck	Convergence, 3+ trails
Human Presence	Minimum
Food & Water	No water. Food Source: Grassy browse/roots

4.3.3 Camera Site 2

Figure 4.4

Camera 2, Raccoon/Ducks

Note. Left: A North American racoon (*Procyon lotor*) passes in front of Camera site 2 a few days before flooding. Garrett Brummel, 2020. Right: An unidentified species of duck floats in the bottom left edge of the frame after heavy rains flood the game trail in front of Camera site 2. Garrett Brummel, 2020.

Camera 2 (Figure 4.4, Table 4.2) was established at the start of this study (October 1, 2020) on the trunk of a Washington Hawthorn tree (*Crataegus phaenopyrum*) that overlooked a game trail coming out of the woods towards the field and bordered the edge of a small pond. Several deciding factors that led to the selection of this site included its unique habitat type with sparse trees and the presence of water, heavy wildlife sign, and a game trail bottleneck. There was a convergence of game trails from the field behind this camera that formed a single heavily used trail along the pond. Evidence of ungulate tracks and scat were present at the water's edge and on the game trail at this location. This camera location would eventually be discontinued November 20, 2020, when seasonal rain caused the water level of the pond to rise. The water submerged the game trail, and the tree that the camera was attached to had water one-half meter up its trunk. This made the retrieval of data difficult, and the game trail utilized only by ducks as data showed. Due to these difficulties the Camera 2 location was discontinued on November 20, 2020. The camera from this location was repurposed into a new area, the Camera 5 location.

Table 4.2

Camera 2, Field Survey Notes

Camera 2	**Field Survey Notes**
Habitat Type	Riparian, transition from Prairie to Mature mixed forest – Limited Cover
Spatial Requirements	Met
Wildlife Sign	Heavy - game trail, ungulate tracks, and scat
Convergence/Bottleneck	Convergence, 2+ game trails, partial bottleneck caused by water
Human Presence	Low to Moderate
Food & Water	Water source: Small pond and seasonal flooding

4.3.4 Camera Site 3

Figure 4.5

Camera 3, Black Bear/Drone View

Note. Left: A large adult black bear (*Ursus americanus*) pauses in front of Camera 3 before consuming fruit from a nearby apple tree. Right: Drone imagery of Camera site 3. Trees with white lichen on branches are fruit bearing. The camera was set facing a narrow game trail and the green open patch in center of photo. Garrett Brummel, 2022.

Camera 3 (Figure 4.5, Table 4.3) was established on October 1, 2020, on the eastern most property boundary in a high cover dense brushy habitat along an established game trail/bottleneck. This location was forty meters into the forest from the field and about three meters from a barbed wire fence, on the other side of which was a grass cattle pasture. This location was the closest to human activity out of all camera locations, but elevated levels of wildlife sign and a well-established game trail led to the decision to place the camera. There are three apple trees and one pear at this location with a game trail leading to them that held evidence of canine, most likely coyote, and ungulate tracks, as well as partially consumed fruit on the ground. Because bait or lures were not used at camera locations (or elsewhere), this was an ideal location due to the food source of apples, pears, and blackberries. This would prove to be a frequently visited site once the fruit was ripe and our only location where we captured pictures of a Black Bear (*Ursus americanus*). This camera location was discontinued on January 1, 2022, at the end of this study.

Table 4.3

Camera 3, Field Survey Notes

Camera 3	**Field Survey Notes**
Habitat Type	Dense brush, blackberry, and snowberry. High Ground cover
Spatial Requirements	Met.
Wildlife Sign	Heavy – ungulate tracks and scat, canine tracks, partially eaten fruit, rabbit scat
Convergence/Bottleneck	Slight convergence, strong Bottleneck caused by fence and blackberry vines
Human Presence	High to Moderate
Food & Water	Food source: apples, pears, blackberries, and snowberry

4.3.5 Camera Site 4

Figure 4.6

Camera 4, Elk/Coyote Pup

Note. A bull Roosevelt Elk (*Cervus canadensis roosevelti*) pauses in front of Camera 4 at the beginning (day 17) of this study. This camera was subsequently angled downward to properly frame and capture smaller wildlife utilizing the game trail. Garrett Brummel, 2020. Right: Smaller wildlife utilizing the game trail. An enhanced and cropped image of Coyote pup (*Canis latrans*) detected on 3/17/2021. Garrett Brummel, 2021.

Camera 4 was established on October 1, 2020 (Figure 4.6, Table 4.4). This camera was located within dense mixed forest of mature Oregon white oak (*Quercus garryana*) Douglas fir (*Pseudotsuga menziesii*) and red alder (*Alnus rubra*), at the junction of two game trails merging. It was fully under tree cover but was thirty meters from a transition to brushy meadow habitat. This site was selected primarily because of its increased likelihood of capturing wildlife entering the property due to a convergence of trails at this location coming from the north-eastern property boundary. The meadow around the detention pond held many game trails that converged into one leading to this location (Figure 4.7). This camera location provided a dense forest habitat type with high groundcover of ferns and woody brush. This was the only location found during the Field Survey in mature dense forest that met Spatial Requirements with an area wide and open enough for target species and physical requirements. The camera was attached to a mature Douglas fir tree (*Pseudotsuga menziesii)*. There was a seasonal creek in the background of this location that flowed into the pond present in the Camera 2 location. This camera site was discontinued at the end of this study on January 1, 2022.

Table 4.4

Camera 4, Field Survey Notes

Camera 4	**Field Survey Notes**
Habitat Type	Mature mixed forest (Oak/Douglas fir/red alder). - Dense undergrowth, high Groundcover
Spatial Requirements	Met
Wildlife Sign	Moderate, game trail
Convergence/Bottleneck	Convergence
Human Presence	Minimum
Food & Water	Water source, seasonal stream

Figure 4.7

Camera 4, Meadow Convergence

Note. Meadow game trails converging into one trail that led to the Mature Forest/Dense Undergrowth habitat of Camera site 4. Garrett Brummel, 2022.

4.3.6 Camera Site 5

Figure 4.8

Camera 5, Unidentified Canid

Note. Camera 5 location with an unidentified canid species circled in red. Garrett Brummel, 2020.

Camera 5 (Figure 4.8, Table 4.5) was established for a brief time after flooding occurred at the location of Camera 2 on November 20, 2020. This location was on the property line bordering I-5 near several (inactive) buildings. This camera location was selected hastily on the day the flooding of Camera 2 was discovered; it did not adhere to the protocol for site selection nor was it assessed as a possible location during the Field Survey. The intention of this camera placement was to capture wildlife entering or departing the mowed shoulder of I-5 and was placed on a Douglas fir tree (*Pseudotsuga menziesii)* facing a faint game trail with no visible tracks on the western property boundary. While capturing wildlife in the act of crossing would be important data, the focus of the study was on capturing wildlife presence on the entire site to the fullest extent. Due to lower abundance of wildlife, most likely due to road avoidance, and limited placement options for clear photos, this site was discontinued, and the camera was moved to the location of Camera 6 on December 14, 2020.

Table 4.5

Camera 5, Field Survey Notes

Camera 5	**Field Survey Notes**
Habitat Type	Open Douglas fir forest, I-5 shoulder
Spatial Requirements	Met, not ideal
Wildlife Sign	Not met- Low, faint game trail
Convergence/Bottleneck	No
Human Presence	Very High, 68,000 AADT on I-5 adjacent this location (WSDOT, 2022)
Food & Water	No

4.3.7 <u>Camera Site 6</u>

Figure 4.9

Camera 6, Bull Elk/Mountain Lion

Note. Left: A bull Roosevelt elk (*Cervus canadensis roosevelti*) passes Camera 6, having just entered the property along a heavily used game trail. Garrett Brummel, 2021. Right: An enhanced picture of the only Mountain Lion (*Puma concolor*) captured during this study. Garrett Brummel, 2020.

Camera 6 (Figure 4.9, Table 4.6) was established on December 14, 2020, along the northern section of the property. A second Field Survey was conducted revisiting previously considered camera sites and this site was selected as it met site requirements and was likely to contain a high abundance of wildlife. A deep and well-worn game trail containing heavy ungulate sign transitioned from grassy open meadow around a detention pond to forested area before leaving the property. Several game trails from the meadow converged into one prior to where the camera was positioned on a red alder facing the game trail at an appropriate height (~2 meters) for capturing wildlife. The habitat type at this location was a younger deciduous forest (est. 20-40 years) comprised of primarily red alder (*Alnus rubra*) and had lower rates of undergrowth with primarily grasses as groundcover. This camera site was discontinued on January 1, 2022, at the end of this study.

Table 4.6

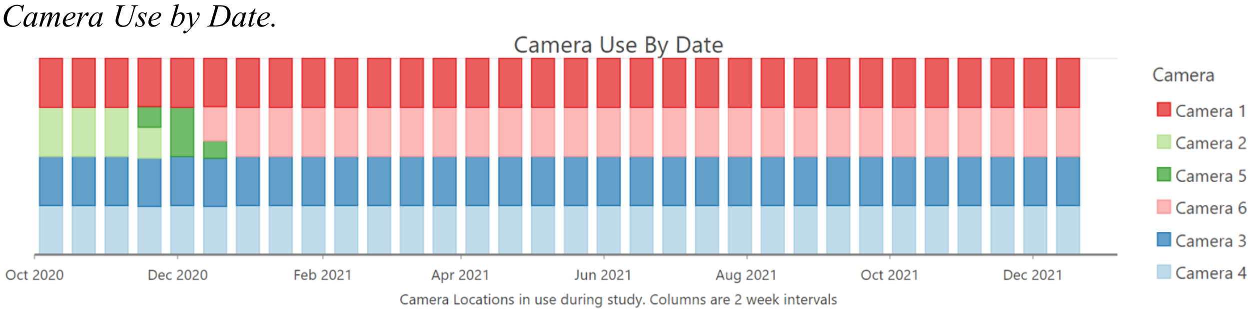
Camera 6, Field Survey Notes

Camera 6	**Field Survey Notes**
Habitat Type	Young deciduous red alder forest – low/mid undergrowth and ground cover.
Spatial Requirements	Met
Wildlife Sign	Heavy – high use game trail, ungulate tracks and scat, evidence of browsing on grasses. Antler rubs on nearby trees.
Convergence/Bottleneck	Large Convergence, multiple trails
Human Presence	Minimum
Food & Water	No water, evidence of browsing on grasses and woody brush in area.

A diagram showing the timeline for camera locations in use during this study and their length of installation can be viewed below in Figure 4.10.

Figure 4.10

Camera Use by Date.



Note. Diagram showing the duration of camera sites in use throughout the study's data collection period. Each vertical column represents a two-week interval. Garrett Brummel, 2024. ArcGIS Pro 3.2.1.

4.4 Equipment Used

The cameras used in this study were Bushnell, Trophy Cam HD model #119537. SD cards used to record data in the cameras began with eight PNY Performance 16GB class 4 SD cards. Using eight cards allowed all four cameras to continue capturing data with minimal down time while cards were changed out. There was data corruption on two of these types of SD card.

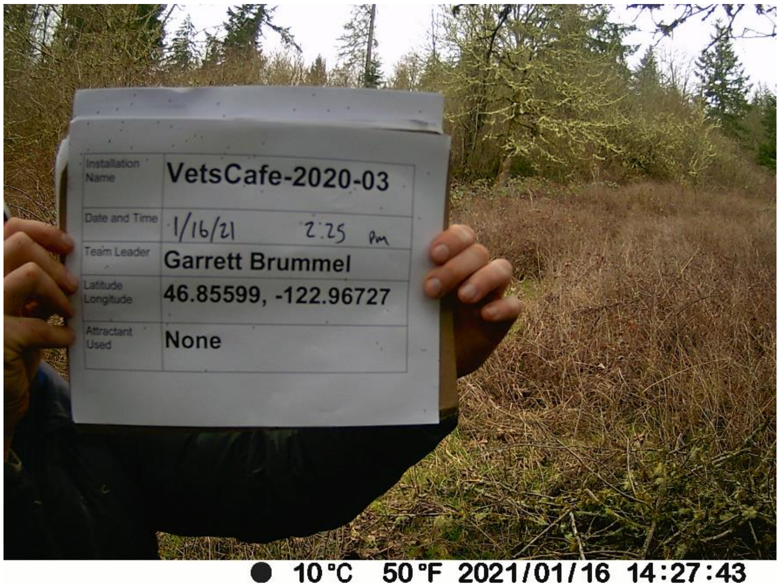
This corruption resulted in a few duplicate images for the first three photos on each card and slowed upload times when transferring photos to a laptop. The class 4 PNY SD cards were replaced with eight SanDisk Ultra 16gb SDHC class 10 SD cards in August 2020 and this issue was resolved.

4.5 Camera Installation Protocol

Trail cameras were placed at a 45-degree angle from the direction of travel to game trails for better quality photos and triggering than perpendicular to or parallel placement with the trail. Cameras were not placed facing east or west to avoid glare from the sun rising or setting directly into the camera, a phenomenon that can cause false triggers or low-quality photos during high wildlife activity periods in the morning and evening. All cameras on location were facing north instead of south to prevent solar glaring in winter months when protective tree foliage is reduced. Cameras were installed roughly three meters from game trails. Nylon straps secured cameras to tree trunks where they were angled and tested to ensure that even small mammals on the path would be fully in picture frame as well as Washington's larger native species like Roosevelt Elk (*Cervus canadensis roosevelti*) and Shiras Moose (*Alces alces shirasi*). Sensitivity settings on cameras were set to medium, instead of CWMP camera protocol of high, to reduce false triggers like moving grass and branches, but sensitive enough to be triggered by the presence of wildlife. Typical camera trapping protocol from CWMP is to apply a lure or attractant within frame of the camera, however for this study no artificial attractants were used. The presence of artificial attractants could have affected the normal habits of wildlife, potentially artificially increasing Detection rates, which was not the intent of this study. Human scent was kept to a minimum when establishing and retrieving data from sites by not eating, drinking, urinating, leaving trash behind, or any unnecessary handling of vegetation while in the field. Camera sites were selected to require minimal alteration of their environment; however, grass and branches were removed in certain instances if they were shown to impede data collection with false triggers. False triggers often occur when a vine or bush would be blown around in front of the motion sensor resulting in thousands of photos without wildlife. The trail cameras used in this study had a screen to review photos and ensure proper placement and trigger function. Cameras also came equipped with a date and time stamp for photos. Cameras were set to deploy a 3-round burst of photos to capture wildlife in motion. This allowed better wildlife identification as once a photo was triggered the camera would take an additional two photos allowing more opportunities to have a photo with the entire animal in frame. When establishing a new camera location or collecting data, a Camera Title Card (Figure 4.11.) is held in front of the camera whenever entering or leaving a camera site. The first photo and last photo on each SD card should be of the Camera Title Card to ensure proper documentation of camera site number, coordinates in decimal degrees, and to verify accuracy of date/time stamps on photos. In colder temperatures camera, batteries would occasionally drain to the point they shut the camera down. Upon warming up, the camera would restart and begin capturing data with the factory default settings and incorrect time/date. Camera Title Cards allow incorrect photo timestamps to be corrected later in photo metadata, retaining an accurate data sequence.

Figure 4.11

Camera Site Title Cards



Note. Conservation Northwest's Citizen Wildlife Monitoring Project protocol included the following information: Camera installation name, date and time, team leader name, latitude & longitude (decimal degrees), and attractant used. The instillation name VetsCafe-2020-03 refers to the site location - year camera location was established - camera location number at study site. Garrett Brummel, 2021.

4.6 Collecting Camera Data

Data was typically retrieved once a week from the field by Community Wildlife Monitoring Project (CWMP) lead project volunteer Garrett Brummel for the first 10 months of the study starting on 10/01/2020. Data collection was shared for the subsequent 5 months of study between the lead project volunteer and another CWMP volunteer. SD cards were removed from the cameras and replaced with blank ones. Camera batteries would be replaced if needed, and camera settings checked to ensure consistent results and proper date/time. The photos from SD cards were sorted by year, camera number, and capture date range before being uploaded to a laptop. Once uploaded, photos were reviewed individually for presence of wildlife, false triggers or photos without wildlife were removed. The photos were then uploaded to Google Drive in folders by year, site location, camera number, and capture date range. By logging into a Conservation Northwest remote desktop portal, the photos were downloaded from Google Drive to the remote desktop hard drive. From the remote desktop it was protocol to upload the folders to a private database for CWMP and add metadata to the photos. Each capture event was then stacked into 5-minute intervals. What that means is all photos, whether 3 or 300 photos, taken of the same species during a 5-minute period are only recorded as one Detection/capture event. A new capture event would be recorded if wildlife presence exceeded the 5-minute interval. Metadata that was added to photos included a copyright by Conservation Northwest, who uploaded the photo, animal species, number of animals, collection site name, latitude and longitude location, camera number, and date/time. Corrections to timestamps could be made to metadata in this program for cameras that had incorrect date/time. Once all data was stored and filed in the database, SD cards could then be cleared of data and reused on the next camera collection date. Data that was retrieved from the database for analysis was placed into Excel spreadsheets for further analysis.

5 Chapter V. Results

5.1 Introduction

Over the course of this study, the four cameras on site collected a robust amount of wildlife data. Tens of thousands of photographs were examined, those with wildlife present were labeled and cataloged. The final totals for wildlife species' presence on site can be separated into two metrics, Detections (DET- species detected within a 5-minute interval) and Count of Animals (COA- number of individual animals of the same species present within the 5-minute Detection interval). Over 457 days and six camera locations, the four remote cameras recorded fifteen identified wildlife species. The cameras captured a total of 1,490 Detections (DET) and a count of 1,955 animals (COA) on site. The cameras' ability to record time of day and date allowed for data to be assessed for trends in Detections over time and season. Comparisons between wildlife presence and habitat type by camera location were also possible. While the camera data collected shows a robust and diverse wildlife presence on the site, it does not provide a complete picture as several problems occurred during the data collection period.

The Camera site 2 and Camera site 5 locations were only active for a brief period of time (as discussed in *Methods* chapter) and their results are excluded from many analyses in this *Results* chapter due to low sample size, but data is included in any analysis involving site totals. Camera sites 1, 3, 4, and 6 were all installed in their locations for over a year and collected a much larger sample of wildlife but were also affected by problems during collection in three ways. First, when cameras were inactive and unable to take photos of wildlife due to mechanical failure (dead batteries) or physical obstructions (elk knocking camera face down) resulted in a loss of potential data. Second, some raw data collected from cameras was inadvertently deleted and unable to be recovered. The third issue was the inability to correctly identify wildlife species due to photo quality that resulted in the creation of the species category “Unidentified” rather than counts going to their actual species. There were 96 “Unidentified” DET recorded during this study. These issues resulted in a significant reduction of available data. Thus, the study’s ability to report a complete dataset for wildlife presence on site was not possible from the collected camera data alone. To remedy this problem, this study has developed a series of forecasts of expected values, referred to as Cumulative Forecast Data, for DET/COA had the above issues not occurred.

To understand what the values of DET/COA would be, had problems not occurred during the study period, three distinct forecasts and analysis are developed in ***Section 5.3*** of this chapter to remediate for lost data, unidentified species, and inequal collection periods between cameras. First, inactive camera days were calculated for each camera to determine the percentage (mean) of time each camera was capable of capturing wildlife. Using this percentage, each camera had its species DET/COA forecast to what would have been expected had it been 100% active. Because camera locations were not all installed for the same number of days these results were not directly comparable, therefore the forecast results were then normalized to the average length of one year (365.25 days). To address the Unidentified species, their values (Unidentified DET/COA) were assigned to the existing species recorded at each camera location. This assignment of unidentified values was done in proportion to the rates (mean percentage) that identified species were detected at each location. The results for camera locations with their Unidentified species assigned were then also forecast at 100% and normalized for comparison. The details of this process will be explained in more detail in ***Section 5.3.***

Using both the “As Captured” and “Cumulative Forecast” data to examine the site by camera location will provide readers with a more comprehensive idea of wildlife presence on site. The following sections provide results for “As-Captured” species totals by camera location, “As-Captured” species Detections over time, forecast and normalized species data, Unidentified assigned forecast and normalized, and comparisons between camera location/habitat sites.

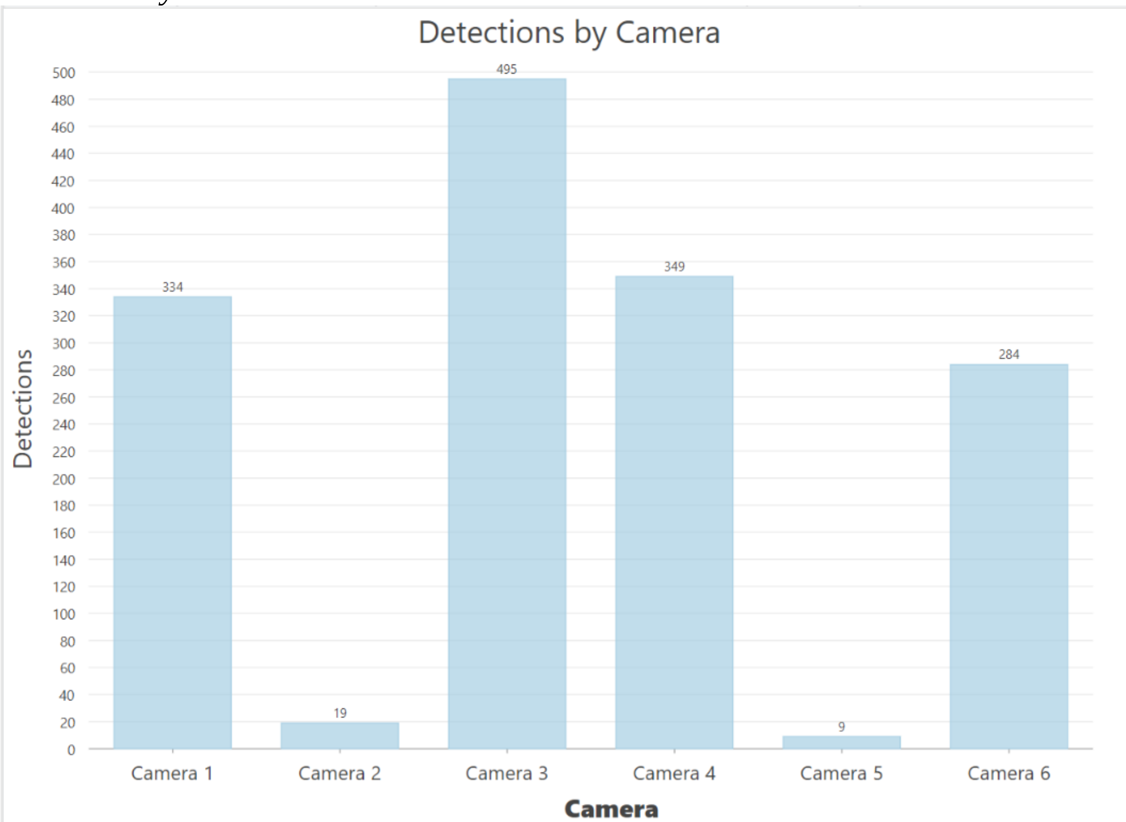
5.2 Camera Wildlife Data “As-Captured”

5.2.1 Camera Location Totals

The results of this thesis’s camera study can separate wildlife species presence collected by camera into two metrics, Detections (DET- identified species within a 5-minute interval) and Count of Animals (COA- number of individual animals present within the 5-minute Detection interval). Camera 1 recorded the third most DET during this study (334) and the second highest COA (430). Camera 2, as discussed in ***Methods 4.3.3,*** was operational for a brief period of time before conditions required it to be moved. While installed it recorded 19 DET and a disproportionally high COA of 59, ranking fifth highest in both categories. Camera 3 led all cameras on site with the highest counts of both DET and COA at 495 and 647, respectively. Camera 4 had the second highest DET count during this study (349) but the third highest COA (410). Camera 5, as discussed in ***Methods 4.4.6***, was only briefly installed on site, and held the lowest DET and COA during this study with count of 9 for both. Camera 6 recorded 284 DET and 400 COA making it the fourth highest in both metrics, reaching similar numbers to Camera 1 and 4 locations despite a shorter active period. Figures 5.1 and 5.2 display DET and COA metrics by camera site location as pulled from the wildlife database prior to any forecasting.

Figure 5.1

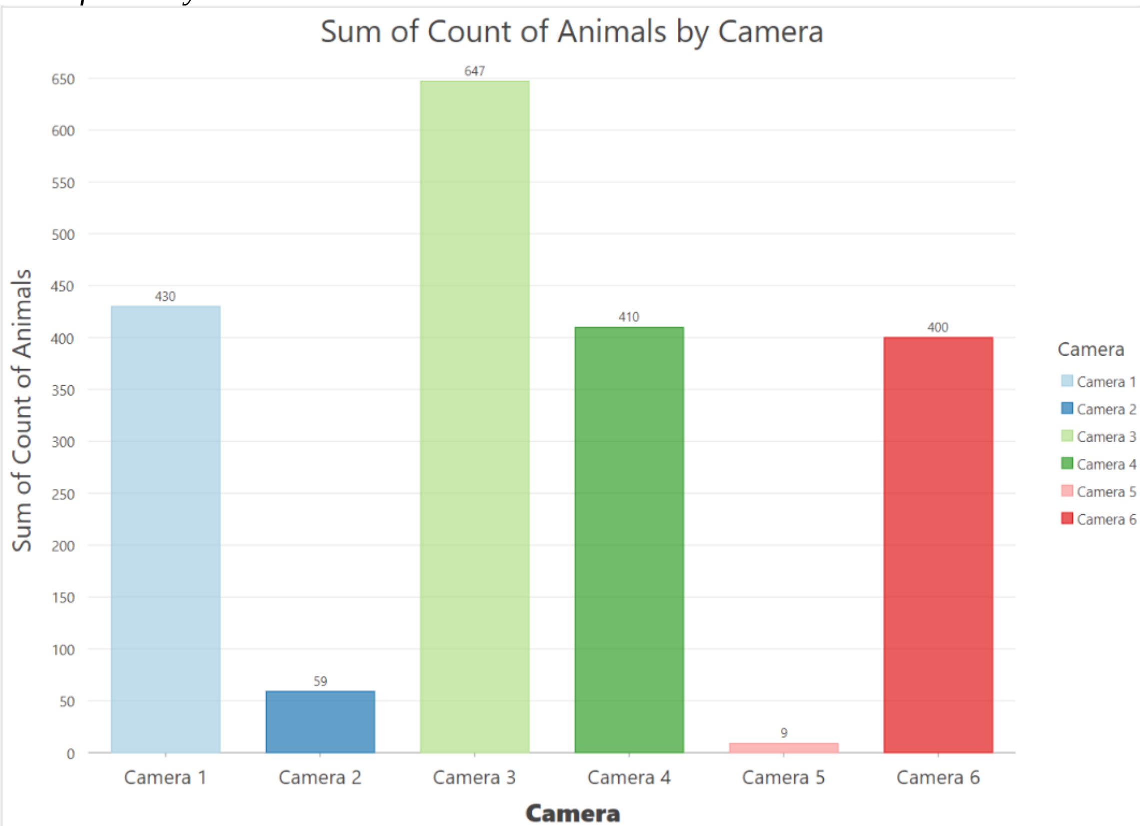
Total DET by All Camera Locations



Note. Total Detections (DET) for all six camera sites in use during this study. Camera 1, 334 DET. Camera 2, 19 DET. Camera 3, 495 DET. Camera 4, 349 DET. Camera 5, 9 DET. Camera 6, 284 DET. Garrett Brummel, 2023. ArcGIS Pro 3.2.

Figure 5.2

Sum of COA by Camera Location



Note. Camera 1, COA (430). Camera 2, COA (59). Camera 3, COA (647). Camera 4, COA (410). Camera 5, COA (9). Camera 6, COA (400). Garrett Brummel, 2023. ArcGIS Pro 3.2.

5.2.2 Species Totals for DET/COA

In ***Section 5.1***, it was stated that there were fifteen wildlife species identified on site, yet the following table (Table 5.1) shows eighteen. The three species categories listed here that were not included in the aforementioned fifteen are "Unidentified," "Bird," and "Domestic Dog." Domestic Dogs have been included in these results despite them not being "wildlife." It was determined that any domestic animals using the site would be included in this report to create a complete summary of all species of animals present during the study. Bird species were not the target of this study, and cameras were not installed with them in mind; however, they have been included in this study as their data helps create a complete model of animals present during the study. Bird species that could not be identified were placed in their own category as "Bird" instead of being included in the "Unidentified" species category. Insects and humans were removed from the camera data completely, although in retrospect it would have been interesting to note any changes in Detections linked to human presence on site. Table 5.1 displays all recorded species COA and DET during this study sorted from highest count to lowest.

Table 5.1

Species COA/DET Totals Sorted High/Low

COA Grand Total	**1955**	**DET Grand Total**	**1490**
Black-tailed Deer	672	Black-tailed Deer	568
Roosevelt Elk	605	Coyote	375
Coyote	414	Roosevelt Elk	293
Unidentified	97	Unidentified	96
Eastern Cottontail	60	Eastern Cottontail	58
Bobcat	26	Bobcat	26
Eastern Gray Squirrel	25	Eastern Gray Squirrel	25
Townsends's Chipmunk	21	Townsends's Chipmunk	21
Bird	17	Bird	14
Domestic Dog	7	Domestic Dog	3
California Scrub Jay	2	California Scrub Jay	2
Raccoon	2	Raccoon	2
Ring-necked Pheasant	2	Ring-necked Pheasant	2
Black Bear	1	Black Bear	1
Duck	1	Duck	1
Great Blue Heron	1	Great Blue Heron	1
Mountain Lion	1	Mountain Lion	1
Steller's Jay	1	Steller's Jay	1

The three most observed species in this study, black-tailed deer (*Odocoileus hemionus columbianus*), coyote (*Canis latrans*), and Roosevelt elk (*Cervus canadensis roosevelti*), had counts of DET/COA that greatly surpassed the fourth most identified species type. These species are sometimes referred to in this paper as the “Big-3”. Black-tailed deer (*Odocoileus hemionus columbianus*) held the highest total counts in both DET/COA during this study. Roosevelt elk (*Cervus canadensis roosevelti*) and coyote (*Canis latrans*) split the second and third positions with coyotes leading elk in DET. Elk COA was more than double their own DET count, taking second in this metric. Unidentified species did not break into the three-digit territory as did deer, coyote, and elk, but came close to doing so as the fourth most observed species type with 97/96 COA/DET, respectively. With the exception of Roosevelt elk (*Cervus canadensis roosevelti*) and coyote (*Canis latrans*), all other species held the same ranked position for both DET and COA. eastern cottontail rabbits (*Sylvilagus floridanus*) were the fourth highest identified species detected. Surprisingly, the fifth highest identified species, bobcats (*Lynx rufus*), were detected more frequently than the remaining species on site. There was a noticeable but less than expected presence of eastern gray squirrels (*Sciurus carolinesis*) and Townsend’s chipmunks (*Neotamias townsendii*). The general “Bird” species category was the ninth most detected. Domestic dogs were recorded in 3 Detections with a COA of 7, and the remaining species were observed in only one or two instances. Although infrequent on site, the presence of mountain lion (*Puma concolor*) and black bear (*Ursus americanus*) were noteworthy appearances this close to I-5.

5.2.3 Species DET/COA Totals by Camera Location

These results show the species DET/COA counts by camera location. The following tables (Table 5.2, 5.3) show both metrics “As Captured” for all cameras. Figure 5.3. DET by Camera and Species is a representation of the same DET data in bar graph form.

Table 5.2

Species Detections (DET) by Camera.

Species DET	Camera 1	Camera 2	Camera 3	Camera 4	Camera 5	Camera 6	Grand Total
Bird	3	1	4	4	0	2	14
Black Bear	0	0	1	0	0	0	1
Black-tailed Deer	217	1	83	146	1	120	568
Bobcat	9	0	10	3	0	4	26
California Scrub Jay	0	0	2	0	0	0	2
Coyote	70	0	204	54	1	46	375
Domestic Dog	0	0	1	0	0	2	3
Duck	0	1	0	0	0	0	1
Eastern Cottontail	0	0	25	33	0	0	58
Eastern Gray Squirrel	0	0	1	24	0	0	25
Great Blue Heron	0	0	0	0	0	1	1
Mountain Lion	0	0	0	0	0	1	1
Raccoon	0	1	0	1	0	0	2
Ring-necked Pheasant	1	0	0	1	0	0	2
Roosevelt Elk	20	12	120	52	0	89	293
Steller's Jay	1	0	0	0	0	0	1
Townsends's Chipmunk	0	0	0	21	0	0	21
Unidentified	13	3	44	10	7	19	96
Grand Total	**334**	**19**	**495**	**349**	**9**	**284**	**1490**

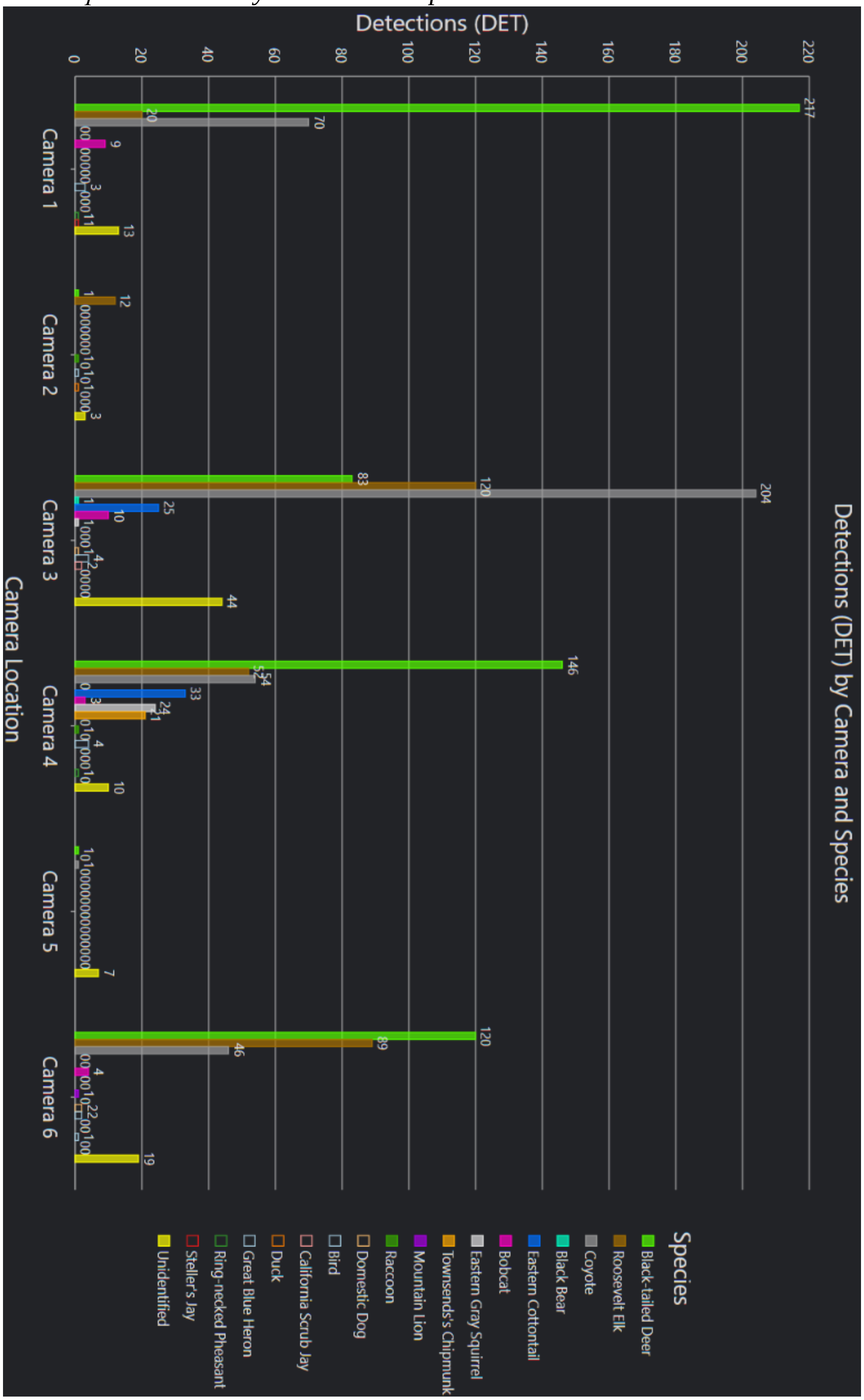
Table 5.3

Species Count of Animals (COA) by Camera

Species COA	Camera 1	Camera 2	Camera 3	Camera 4	Camera 5	Camera 6	Grand Total
Bird	3	1	7	4	0	2	17
Black Bear	0	0	1	0	0	0	1
Black-tailed Deer	286	1	89	158	1	137	672
Bobcat	9	0	10	3	0	4	26
California Scrub Jay	0	0	2	0	0	0	2
Coyote	74	0	225	65	1	49	414
Domestic Dog	0	0	3	0	0	4	7
Duck	0	1	0	0	0	0	1
Eastern Cottontail	0	0	25	35	0	0	60
Eastern Gray Squirrel	0	0	1	24	0	0	25
Great Blue Heron	0	0	0	0	0	1	1
Mountain Lion	0	0	0	0	0	1	1
Raccoon	0	1	0	1	0	0	2
Ring-necked Pheasant	1	0	0	1	0	0	2
Roosevelt Elk	43	52	239	88	0	183	605
Steller's Jay	1	0	0	0	0	0	1
Townsends's Chipmunk	0	0	0	21	0	0	21
Unidentified	13	3	45	10	7	19	97
Grand Total	**430**	**59**	**647**	**410**	**9**	**400**	**1955**

Figure 5.3

"As-Captured" DET by Camera and Species



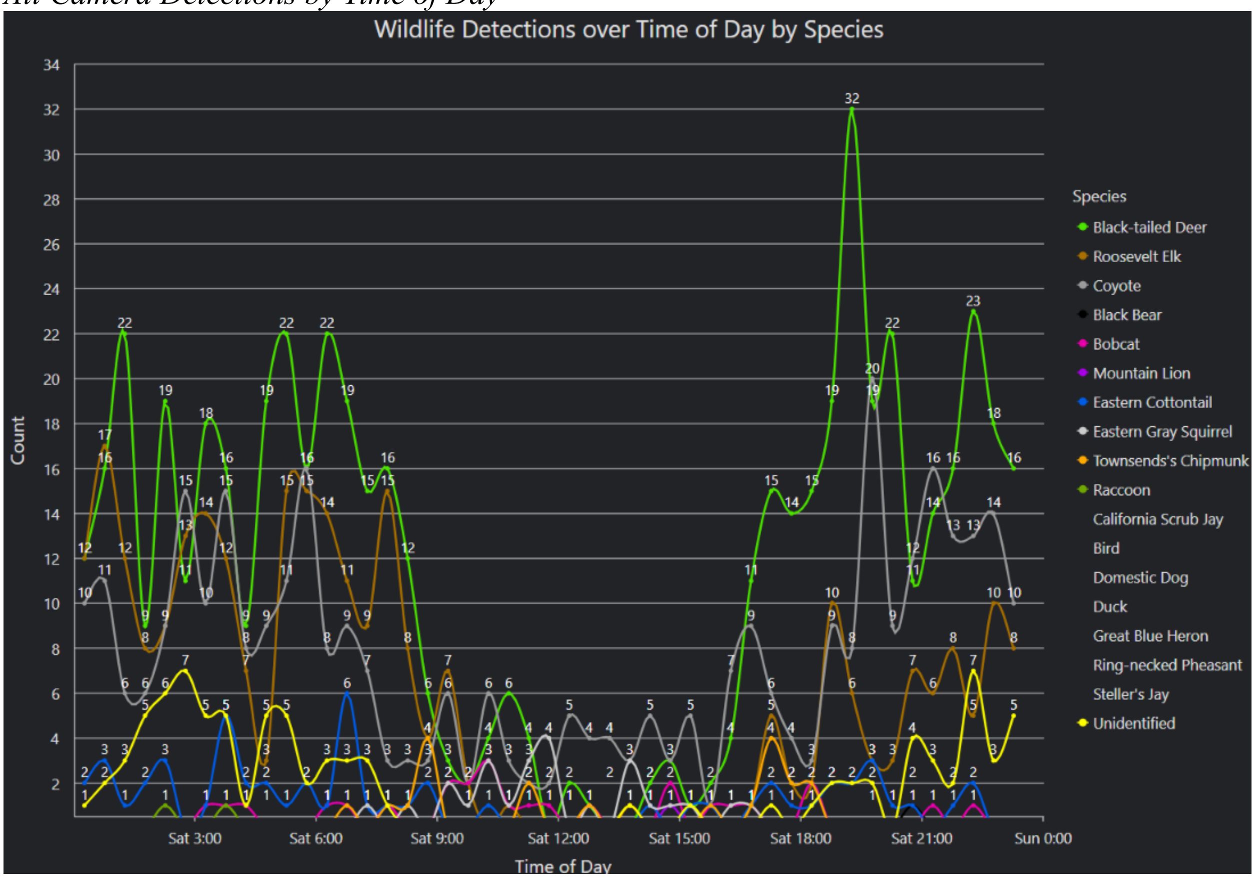
The following subsection will continue to examine the "As-Captured" results for all cameras over time by species.

5.2.4 <u>Detections Over Time-Time of Day, Hourly</u>

Separating the time that wildlife DET were captured from date-captured allowed all camera Detections (including Cameras 2 and 5) from this study to be placed in one (24-hour) graph to better observe patterns of wildlife activity by species (Figure 5.4).

Figure 5.4

All Camera Detections by Time of Day



Note. This graph presents all Detections (DET) collected during this study without normalization or other manipulations. Intervals are grouped in 30-minute bins, both over a 24-hour period. This 24-hour period is labeled Saturday (Sat), and changes to Sunday (Sun) at 0:00 to signify midnight. All bird species have been visibly removed from this graph along with Domestic Dog for easier viewing. Garrett Brummel, 2024. ArcGIS Pro 3.2.2.

The majority of wildlife species Detections (DET) were captured during the evening, night, and morning periods. There were several differences in species DET by time of day. Eastern gray squirrel (*Sciurus carolinesis*) and Townsend's chipmunk (*Neotamias townsendii*) were only captured during daylight hours as they are diurnal (primarily active during daylight). The species most detected in this study, black-tailed deer (*Odocoileus hemionus columbianus*), are known to be crepuscular or most active during the twilight hours of dusk and dawn. The results of this study seem to confirm this with reduced DET during daylight between 8:30 and 16:30, increased DET during night hours, and further increased DET in evenings with the highest DET interval at 19:00-19:30. Roosevelt elk (*Cervus canadensis roosevelti*), coyote (*Canis latrans*), and bobcat (*Lynx rufus*) are also considered crepuscular species, and the data from this study is mostly consistent with that behavior. Peak coyote (*Canis latrans*) DET occurred at dusk (19:30-20:00) while more Roosevelt elk (*Cervus canadensis roosevelti*) DET occurred during the early morning hours. Bobcats (*Lynx rufus*) were detected in much lower quantity than the "Big-3" with their highest concentration of DET between 9:00 and 11:30. Additional bobcat (*Lynx rufus*) DET occurred sporadically throughout the 24-hour period. There is not enough data to determine significant activity patterns for bobcats (*Lynx rufus*). Coyotes (*Canis latrans*) were more active than deer or elk during midday and had the highest DET of all species during this period. Eastern cottontail rabbits (*Sylvilagus floridanus*) are considered a crepuscular/nocturnal species. Their DET in this study occurred primarily during this period with no DET at midday.

5.2.4.1.1 Potential Interactions Between Species and Time of Day

The sample size of black-tailed deer (*Odocoileus hemionus columbianus*), coyote (*Canis latrans*), and Roosevelt elk (*Cervus canadensis roosevelti*) is large enough to make some inferences of inter-species interaction. For most other species there is not enough data to compare. An interesting pattern occurred between deer and coyotes by time of day during this study when data was grouped within 30-min intervals. Peak deer DET did not occur during peak coyote DET intervals when placed in 30-minute bins. The inverse is also true in three distinct occasions on the graph (Figure 5.4). Peak coyote DETs are preceded by a peak deer DET interval, deer DET drop during the coyote DET peak, and deer DET increase again in the following interval when coyote DET drop. This is not the case in every deer or coyote DET peak. These occurrences take place three times between intervals 2:00-2:30, 2:30-3:00, 3:00-3:30; 5:00-5:30, 5:30-6:00, 6:00-6:30; and 19:00-19:30, 19:30-20:00, 20:00-20:30.

Roosevelt elk (*Cervus canadensis roosevelti*) DET seem to follow a more general trend of increasing and decreasing at roughly the same intervals as both coyote and deer species, although elk DET are much lower in the later hours of the night compared to early morning where elk DET are more frequent. Could this pattern be caused by inter-species interaction between deer and coyotes? A possible explanation of this occurrence is deer avoidance of peak coyote DET intervals or peak coyote DET intervals occurring due to high deer DET. Could elk be less affected because they typically travel in a larger herd than deer, or their larger size makes coyotes less of a threat? Another plausible scenario to describe the coyote/deer relationship is that a sizeable portion of deer Detections on site come from deer that are present year-round and are not migratory, with the same situation for the coyotes. The coyotes did have a litter of pups (3/17/2021) and it can be assumed a den nearby. Any deer sharing the same home range as the coyotes would become accustomed to their habits and alter their own activity accordingly. Elk typically have a larger home range than deer and could be less aware of typical peak coyote activity on the site. While coyotes have been known to prey on deer, they have a number of other options for food, and their diet primarily consists of small mammals that can be hunted in the nearby fields. Another possible explanation: the peak coyote DET intervals occur during travel to and from hunting sites at roughly the same time every night and deer are unlikely to increase their activity during these periods. More research is needed to determine any causation for this pattern.

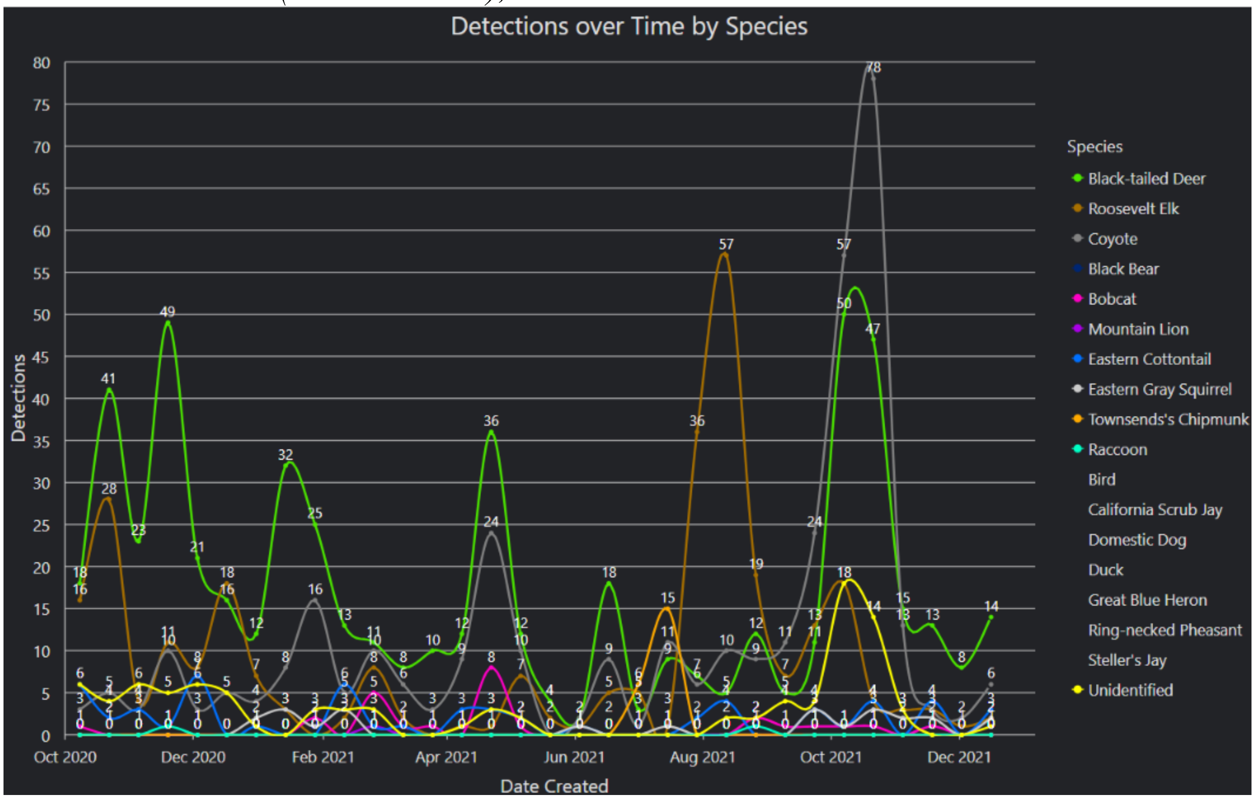
Unidentified species had two significant increases in DET between 1:30-7:30 and 20:30-24:00. This generally did follow trends of increasing DET in the “Big-3” but did not proportionally mimic “Big-3” DET between 16:30-20:30. This suggests that Unidentified species DET are likely more strongly correlated to low light/visibility conditions than increases in “Big-3” DET alone.

5.2.5 Time of Year - Seasonal

The number of DET and COA over the length of our study showed seasonal differences in wildlife presence as well as differences in presence by species. These results are “As Captured.” Figure 5.5 displays all DET by species over the course of this study.

Figure 5.5

Total DET over Time (2-week interval), Seasonal



Note. All camera's DET in 2-week (14 day) bin intervals over the duration of the study. Domestic Dog and all Bird species removed from this graph for clarity. Garrett Brummel, 2024. ArcGIS Pro 3.2.2.

The most immediatley noticable DET intervals in Figure 5.5. are the high DET of elk (7/22/21-9/2/21) and DET of coyote and deer (9/30/21-10/28). Roosevelt elk (*Cervus canadensis roosevelti*) mating season, also known as the rut, typically begins in mid September lasting through October and early November. It is characterized by increased elk activity as bull elk with a harem of cows fight or chase away rival bulls, and bulls without a harem travel great distances to find mates. In the time before the elk rut reaches full swing, as early as late July through August, elk are also traveling more often preparing for the rut and locating other elk. This likely explains the high numbers of elk DET on site during this pre-rut period. Intervals between

9/2/21-10/14/21 still captured elevated numbers of elk DET, but the majority of the population had likely moved further away from the site. The previous year's rut also recorded elevated elk DET in October (10/1/2020-10/29/2020).

Coyote (*Canis latrans*) DET unexpectedly topped the graph in October 2021 (9/30-10/14 and 10/14-10/28) with 57 and 78 DET respectively. This was surely related to a coyote family that had pups in the spring of 2021. The first tiny coyote pup was detected by Camera 4 on 3/17/21. Shortly after the first pup Detection, there was a noticable increase of DET in April 2021. Coyote DETs tended to mimic trends in deer DET during this study, and the exacerbation of this pattern in October 2021 was presumably related to the maturation of the coyote pups, and the coyote family remaining together on/near the site. This high coyote presence has the potential to have surpressed deer DET on site during this time frame.

Black-tailed deer (*Odocoileus hemionus columbianus*) typically have their mating season in November, later in the year than elk as their gestation period is shorter. This was evidened by elevated deer DET between 10/15/2020-11/26/2020 at the start of the study and highest DET from 9/30/2021-10/28/2021. The highest 2021 DET can be explained by pre-rut activity, although it was expected that November 2021 would capture even higher DET than it did in 2020. The DET for the first two weeks of November was lower in both years than the last two weeks of October. The lower deer DET in November 2021 could be atributed to astonishingly high coyote presence, but another major impact on DET during this period was inactive camera days on this study's highest deer DET camera, Camera site 1.

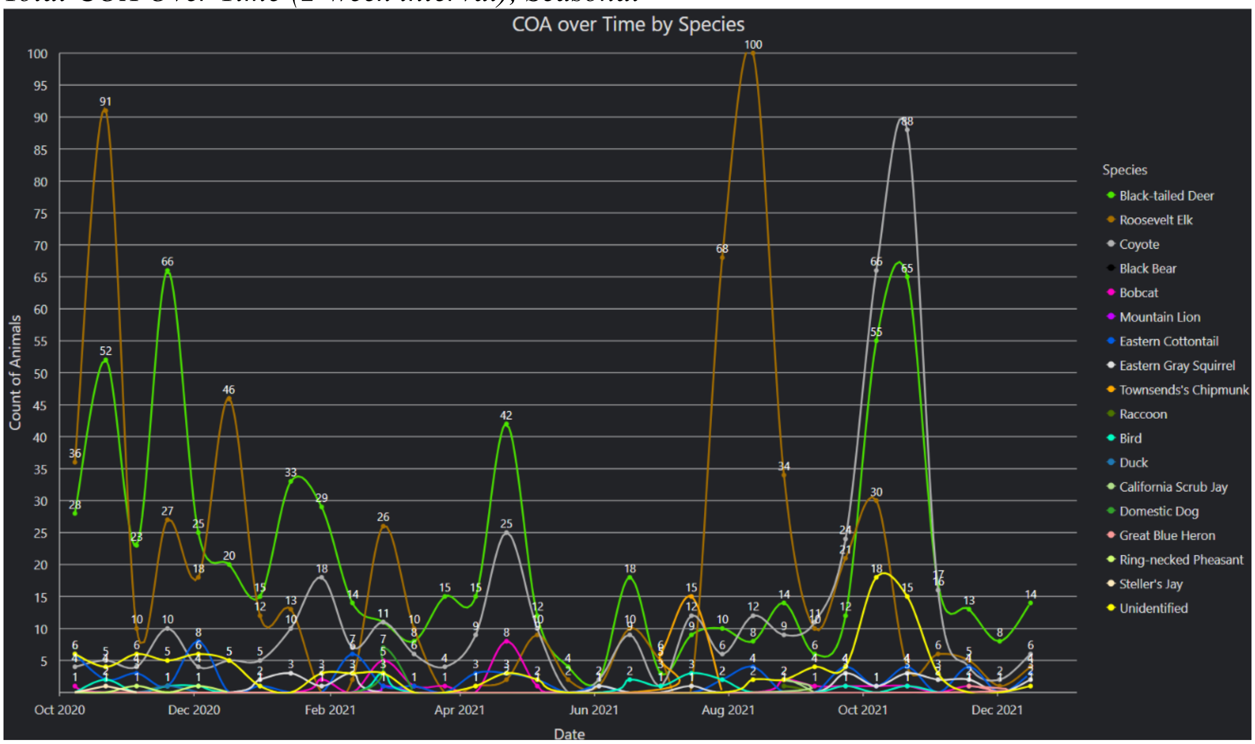
The period in April (4/15/2021-4/29/2021) with elevated DET of deer, coyote, and bobcat appears to be a case of higher predator activity during fawning season, but it is in fact best explained by incomplete data. While black-tailed deer (*Odocoileus hemionus columbianus*) can calve in late April, especially if the early October DET peak was in fact representative of the rut, they typically give birth after a 6-7 month gestation period during May and June. June 2021 had inactive camera days/missing camera data for Cameras 1, 3, and 6, with only Camera 4 (the study's lowest camera DET rates) remaining. This severly depressed the DET of species during this time frame. See figures 5.8 through 5.11 for individual cameras with marked inactivity periods.

Unidentified species Detections increased dramatically for the two intervals between 9/30/2021-10/28/2021, following the increased DET trend of coyote and deer. Elk DET were also elevated from 9/30/2021-10/14/2021 but it would would appear that they likely comprised a smaller portion of the Unidentified species during this timeframe.

For comparison to seasonal DET over time, Figure 5.6. *Total COA Over Time (2-week interval), Seasonal,* provides a graph of COA with identical parameters to Figure 5.5 *Total DET over Time (2-week interval), Seasonal*. In the majority of species Detection events during this study, animals were captured traveling alone and received a COA of 1. Black-tailed deer (*Odocoileus hemionus columbianus*) and coyote (*Canis latrans*) occasionally had a COA of 2-3, usually accompanied with their young. Roosevelt elk (*Cervus canadensis roosevelti*) on the other hand, often traveled in large groups and their total COA (605) for the study was more than double that of their total DET (293). Coyote and deer COA increased slighty from DET, and the most important change to note was in the 10/14/2021-10/28/2021 interval for deer. COA was higher in this period than the previous COA interval (9/30-10/14) despite the opposite being true for DET. This suggests deer travel together more frequently as the November rut approaches. There was only one instance of an Unidentified species with a COA higher than 1 (COA of 2). DET is a very useful metric for determining the frequency of occurance on site for different species; however, the magnitude of individual animals present on site can be lost (especially in the case of Roosevelt elk (*Cervus canadensis roosevelti*)). The COA metric provides a much needed change in perspective from DET.

Figure 5.6

Total COA Over Time (2-week interval), Seasonal

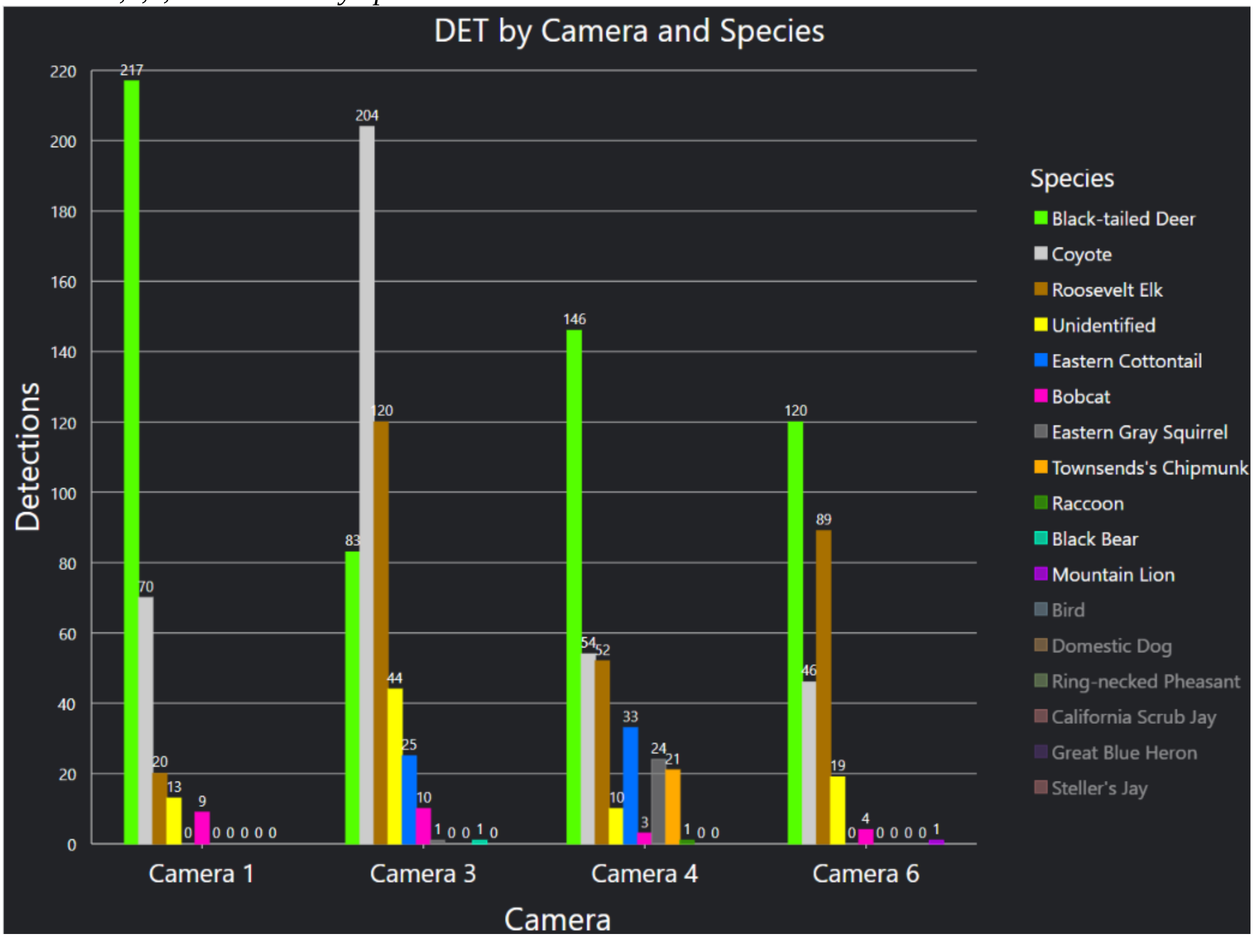


Note. 2-week (14 day) intervals. COA displays a notable change in Roosevelt elk counts from DET. Garrett Brummel, 2024. ArcGIS Pro 3.2.2.

Data collected by Cameras 2 and 5 has been excluded from the remainder of this section (***Section 5.2.5.)*** as their small sample size does not warrant individual analysis. The following graph (Figure 5.7.) displays species DET totals for Cameras 1, 3, 4, and 6 to be used as a reference for the graphs DET over Time that follow it (5.8. DET over Time, Camera 1: 5.9. DET over Time, Camera 3: 5.10. DET over Time, Camera 4: 5.11. DET over Time, Camera 6).

Figure 5.7

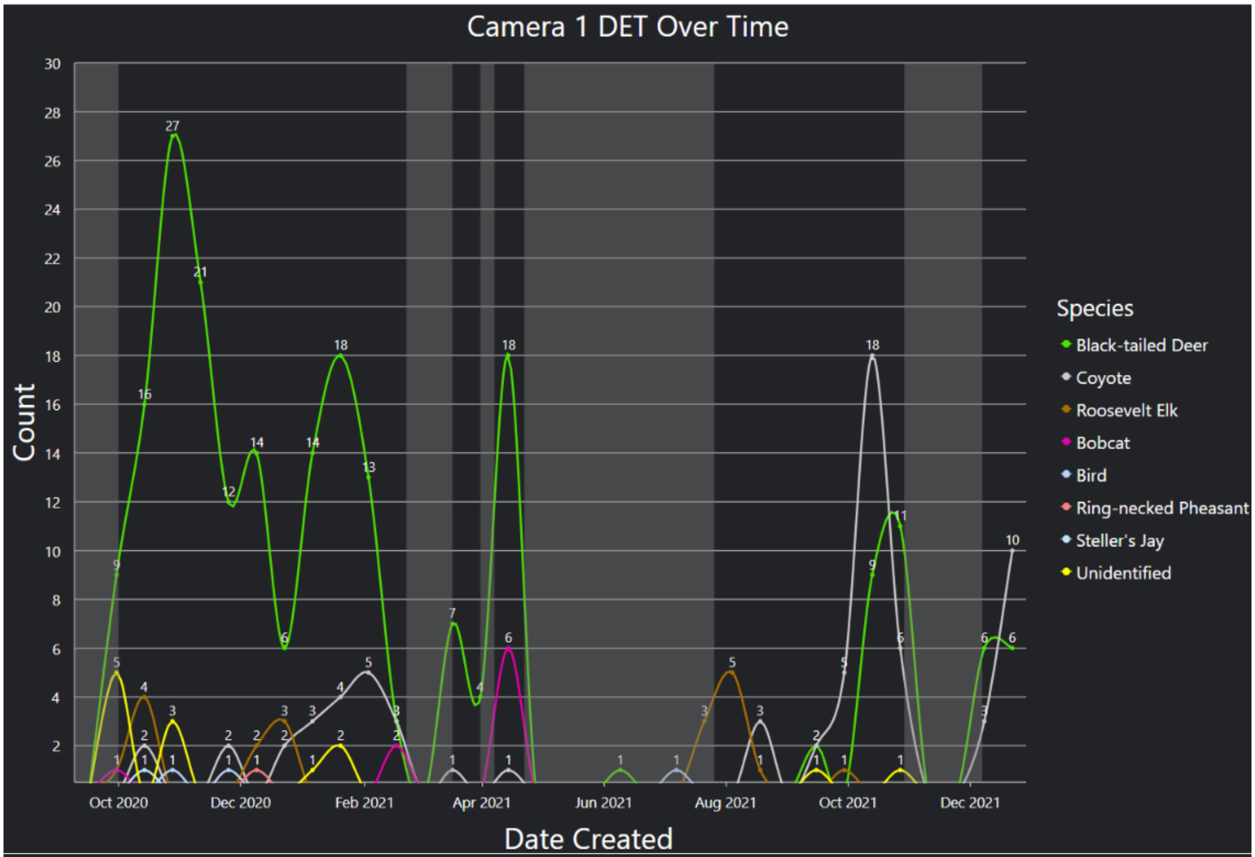
Camera 1,3,4,6 Total DET by Species

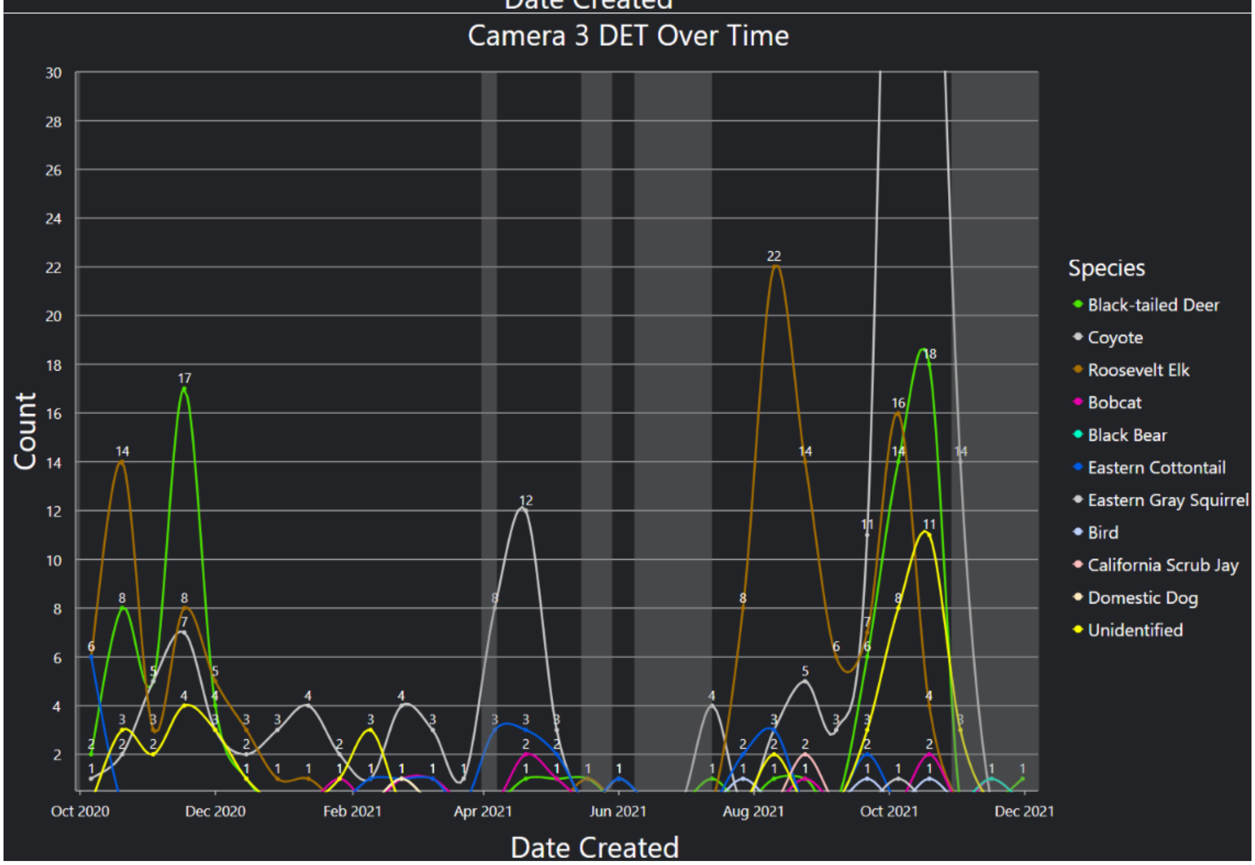


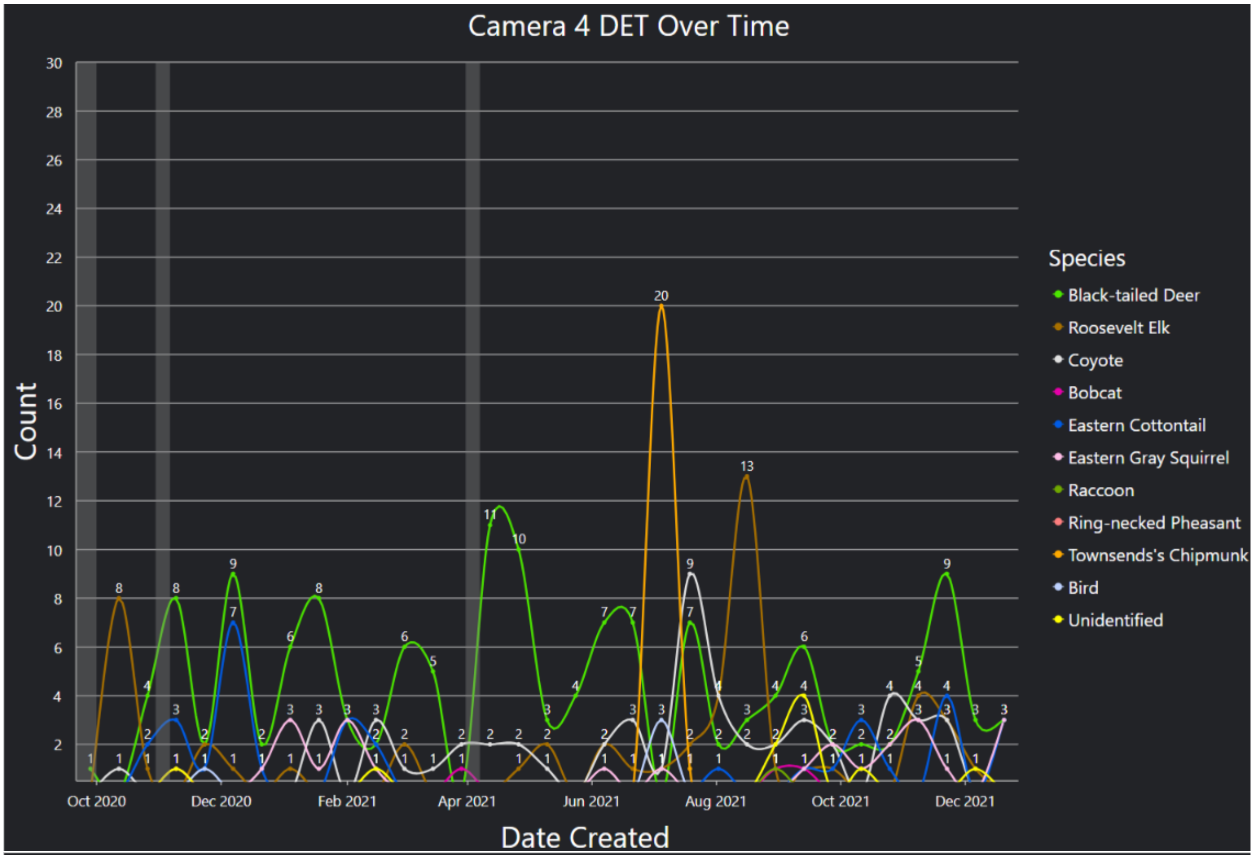
Note. This graph displays total Detections (DET) by Camera and Species. All Bird species and Domestic Dog are removed in this graph to reduce visual clutter. Full species DET by camera available in ***Table. 5.2***. *Species Detections (DET) by Camera.*

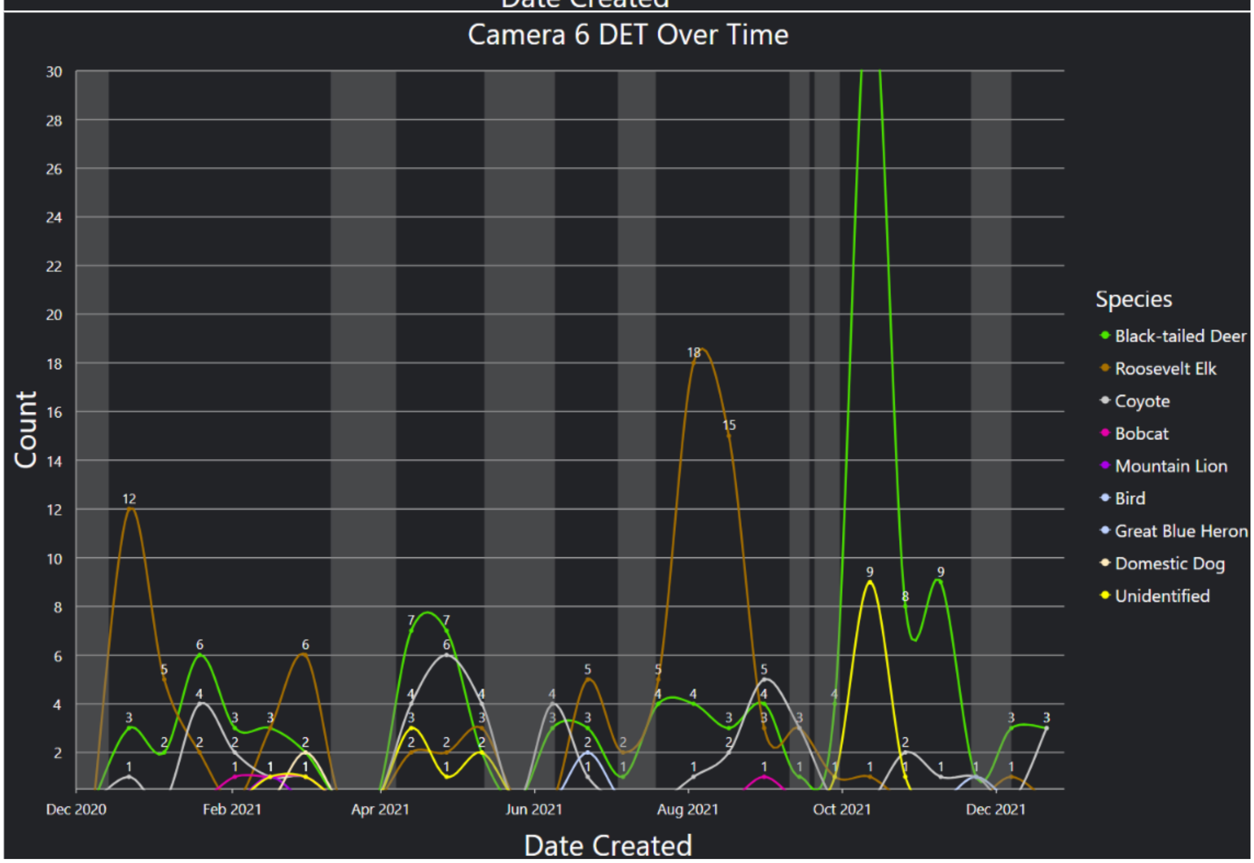
Figures 5.8; 5.9; 5.10; 5.11

DET Over Time, Camera 1; *DET Over Time, Camera 3*; *DET Over Time, Camera 4*; *DET Over Time, Camera 6*


Camera 1 DET Over Time
Count
Date Created
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
Oct 2020
Dec 2020
Feb 2021
Apr 2021
Jun 2021
Aug 2021
Oct 2021
Dec 2021
Species
Black-tailed Deer
Coyote
Roosevelt Elk
Bobcat
Bird
Ring-necked Pheasant
Steller's Jay
Unidentified


Camera 3 DET Over Time
Count
Date Created
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
Oct 2020
Dec 2020
Feb 2021
Apr 2021
Jun 2021
Aug 2021
Oct 2021
Dec 2021
Species
Black-tailed Deer
Coyote
Roosevelt Elk
Bobcat
Black Bear
Eastern Cottontail
Eastern Gray Squirrel
Bird
California Scrub Jay
Domestic Dog
Unidentified


Camera 4 DET Over Time
Count
Date Created
Oct 2020
Dec 2020
Feb 2021
Apr 2021
Jun 2021
Aug 2021
Oct 2021
Dec 2021
Species
Black-tailed Deer
Roosevelt Elk
Coyote
Bobcat
Eastern Cottontail
Eastern Gray Squirrel
Raccoon
Ring-necked Pheasant
Townsends's Chipmunk
Bird
Unidentified


Camera 6 DET Over Time
Count
Date Created
Dec 2020
Feb 2021
Apr 2021
Jun 2021
Aug 2021
Oct 2021
Dec 2021
Species
Black-tailed Deer
Roosevelt Elk
Coyote
Bobcat
Mountain Lion
Bird
Great Blue Heron
Domestic Dog
Unidentified

Note. Data is snapped to the starting date of the study (10/1/2020). Data is binned in 2-week intervals. All figures have included data from partial intervals. All figures have a maximum count of 30 DET on the Y axis. Data points for Camera 3 and Camera 6 that exceed 30 DET per interval have their DET values listed after graphs. Light grey guides delineate periods of inactive camera days/lost data. Five data points were added to these periods (addressed in *Subsection 5.3.1, Collection Periods and Missing Data Ranges*). Grouping data in 2-week intervals makes intervals appear to occur during inactive camera days, but this is not the case (except for 5-data points addressed in *Subsection 5.3.1*,)

Camera 1: Camera site 1 had a large number of inactive days where it was not able to record data. It had the most inactive days of any camera location (159) and had the lowest active camera days rate (65.21%). Despite this down time, Camera site 1 recorded the highest count of black-tailed deer (*Odocoileus hemionus columbianus*) DET of any location (217 DET). October 2020 to February 2021 had the highest rate of black-tailed deer (*Odocoileus hemionus columbianus*) at Camera site 1, however it is difficult to determine if this high Detection rate would have continued as camera failure interrupted the following periods. A second, higher October black-tailed deer (*Odocoileus hemionus columbianus*) Detection period began in 2021 that simultaneously coincided with increased coyote Detections. The increased coyote presence, believed to be influenced by a nearby den with a litter of coyote pups that were recorded visiting the camera sites, may have depressed deer presence. Further, missing data during November-December 2021 was expected to have returned a second black-tailed deer (*Odocoileus hemionus columbianus*) DET peak. Elk were not frequently recorded at this site compared to the three other sites.

Camera 3: Coyotes (*Canis latrans*) were the most frequently detected species at this site. The 9/28/21-10/12/21 interval for coyote had a DET count of 56 (off of the chart), followed by a second coyote DET of 46, (also off chart between 10/12/21-10/26/21). These were the two highest DET intervals (2-week bins) for any camera site or species during this study and were likely influenced by the litter of pups mentioned previously. Roosevelt elk (*Cervus canadensis* *roosevelti*) Detections were higher here than any other site, which was unexpected, as the game trail at this location was narrower and did not hold as much evidence of elk sign as Camera sites 4 and 6 did. Black-tailed deer (*Odocoileus hemionus columbianus*) were not the most detected species at this camera location unlike the other three sites in analysis. Deer were mostly absent at Camera site 3 from December 2020 to September 2021. There is no clear explanation for this, although the production of fruit (apple, pear) may better explain the number of DETs in the fall (10/13-11/24/2020 and 9/14-10/26/2021). Fruit is available at this site starting in September with some fruit remaining on the tree through December as the fruit is not harvested. In fall 2020 and 2021 there was a rise in elk DET followed by a rise in deer DET that does not perfectly align with the mating rut of each species, but pre-rut activity was likely a factor in the increased DET during this period. Eastern cottontail rabbits (*Sylvilagus floridanus*) were most consistently detected in intervals occurring between 2/2/21 and 6/8/2021with no Detections between 10/13/2020 and 2/2/2021.

Camera 4: 6/28/21-7/12/21 had a Detection period containing 20 of the 21 Townsend's Chipmunks (*Neotamias townsendii*) collected during the entire study. Black-tailed deer (*Odocoileus hemionus columbianus*) remained fairly constant seasonally throughout the collection period in low quantity. Roosevelt elk (*Cervus canadensis roosevelti*) had greater than average (mean) DET for this site in October 2020, as well as a peak in August 2021 in the lead up to the September elk mating rut. Eastern cottontail rabbits (*Sylvilagus floridanus*) were more commonly detected on this site during the fall and winter, with zero Detections from 2/22/2021-7/26/2021 during the spring and summer. Camera site 4 was in close proximity to Camera site 3, and when the count of DET at this location dropped during the spring and summer, Camera 3 had an increase in rabbit DET during this same period. It is possible that seasonal changes shifted the population between these two locations. There was only one Coyote (*Canis latrans*) DET at this site prior to mid-January 2021. After that point, coyote Detections remained fairly level throughout the study except for a peak of 9 DET between 7/12/2021-7/26/2021.

Camera 6: The interval between 10/5/21-10/19/21 had a DET count off the chart—a black-tailed deer (*Odocoileus hemionus columbianus*) count of 34. Prior to this October 2021 period, the highest interval recorded was 7 DET. Deer maintained fairly stable and consistent DET through the seasons until the October 2021 exception. Roosevelt elk (*Cervus canadensis roosevelti*) were also fairly consistent throughout the seasons except for high DET anomalies in December 2020 (12/15-12/29 - 12 DET) and August 2021 (7/27-8/10 – 18 DET, 8/10-8/24 – 15 DET). Coyote (*Canis latrans*) DET at this location were consistently low and seemed to avoid the high DET spikes seen at other camera sites, with the highest DET interval reaching only 6 in late April 2021 (4/20-5/4).

The data in this section has provided a comparison between "As-Captured" DET/COA by camera sites and species over time. "As-Captured" data contains differences in the number of days each camera location was active, making equal comparisons between species, camera sites, and habitat type difficult. This issue will be addressed in the following Section.

5.3 Forecasting Camera Site Data

In this section, analyses are developed to understand what the wildlife DET/COA would have been had the study not encountered the problems noted in this chapter's introduction. Camera sites 1, 3, 4, and 6 will be the primary focus of these forecasts, as these sites have a large enough sample size to forecast and establish the expected values. Detections and Count of

Animals (DET/COA) over Date and Time, as found in ***Section 5.2***, will not be forecast for comparison in this section. The lack of multiple years of data from which expected DET/COA counts could be generated by camera sites prevent this from being possible. Active Camera Days will be calculated for all camera locations. A process for forecasting and normalizing the data will be implemented. The counts of Unidentified species will be systematically divided and assigned. After these steps, the total sum counts of expected DET/COA values will be forecast for Cameras 1, 3, 4, and 6.

5.3.1 Calculating Active Camera Days

In order to more accurately compare wildlife DET/COA between camera locations, the results must be compared over the same interval of time (number of days). The number of Active Camera Days for each camera location must be normalized and periods of missing data accounted for. There are several steps needed to generate a Cumulative Forecast of all camera data for comparison.

One of the first steps in interpreting the data collected by remote cameras was to determine not just the range of days each camera was installed at its established site, but also how many of those days it was operational and able to capture wildlife DET/COA. These days are labeled Active Camera Days. Camera site field visits typically occurred at noon to change out SD cards, meaning the first 12 hours of that "in-field day" belonged to the data set ending on that "in-field day." The last 12 hours of the "in-field day" belonged to the following data set that began on that "in-field day." Since each camera date range shared their start date with the end date for the previous date range, this led to the need to subtract 1 day (24 hours) from each of the camera date ranges to be accurate for our calculations. For example, if a camera was installed at noon on 4/19 and ran until noon on 4/21, it was operational over the course of three different calendar days, but in fact only recorded data for two days or 48 hours. When calculating the total range for when cameras were active in the field, days as a measure of time (24-hour periods) are more compelling than calendar dates. These corrections allow more precise calculations when determining DET/COA rates relative to the time available for recording DET/COA.

The days when cameras *could not* record wildlife will not be counted as a day the camera *did not* record wildlife. Inactive Camera Days will be calculated, and their sum removed from the number of days possible for each camera location, giving the actual number of days over which each camera recorded its data.

This calculation of Active Camera Days includes examining camera date ranges that were operational and had successfully recorded data, but inadvertently had their source files deleted. This deletion occurred after the process of cataloging photos on the CWMP database (Adobe Lightroom) was complete. Several folders (source files for database) of camera collection periods were erroneously deleted. Although this only occurred once during this study, data was lost on Cameras 1, 3, and 6 for a loss of 116 Active Camera Days in total. These files were not able to be recovered except for three photos that had been shared by email prior to deletion. Those three photos could be added back into the dataset. There was one other occurrence of an incomplete data range that managed to capture two Detection events. In this instance, the combination of a corrupted SD card and dying camera batteries only managed to capture two intact Detection events, and the camera was not functional for the rest of the date range. All other date ranges where the camera was inactive, or the data was not retrievable, did not have viable photos that could be included in the dataset. These other periods of camera inactivity were caused by elk knocking cameras off the tree, failure to turn camera(s) on, snow blocking the lens, battery loss, SD card data corruption, false triggers filling up all available disk space, or the inadvertent deletion of files. In the two instances mentioned where a few data points exist within an inactive date range, those data points (5 DET/COA Total) will be included in the data, and 1 Active Camera Day will be added to the camera site from which it was recorded. The calculation of Active Camera Days by camera site appears in the Appendix. The following Table 5.4. displays the summary for Active Camera Day results and rates by camera site.

Table 5.4

Summary of Active Camera Days, Sums, All Cameras

Camera Site	Total Active Days/Possible Days	Total Detections (DET)	Total Count of Animals (COA)	Total Days Lost	Average Percent % (Mean) Active	Mean Detections (DET) per Active Day	Mean Count of Animals (COA) per Active Day
Camera 1	298/457	334	430	159	65.21%	1.12081	1.44295
Camera 2	41/41	19	59	0	100%	0.46341	1.43902
Camera 3	340/457	495	647	117	74.40%	1.45588	1.90294
Camera 4	443/457	349	410	14	96.94%	0.78781	0.92551
Camera 5	24/24	9	9	0	100%	0.375	0.375
Camera 6	289/383	284	400	94	75.46%	0.9827	1.38408
All/Mean	**1435/1819**	**1490**	**1955**	**384**	**78.89%**	**1.03833**	**1.36237**

Note. The ratio of active camera days by possible active days. Total sum Detections (DET) by Camera. Total sum Count of Animals (COA) by camera. Average (mean) DET per day by camera. Average (mean) COA per day by camera site.

With Active Camera Days now calculated for each camera site, the process of generating the Cumulative Forecast data between camera sites may begin.

5.3.2 Forecasting and Normalizing Camera Site Data

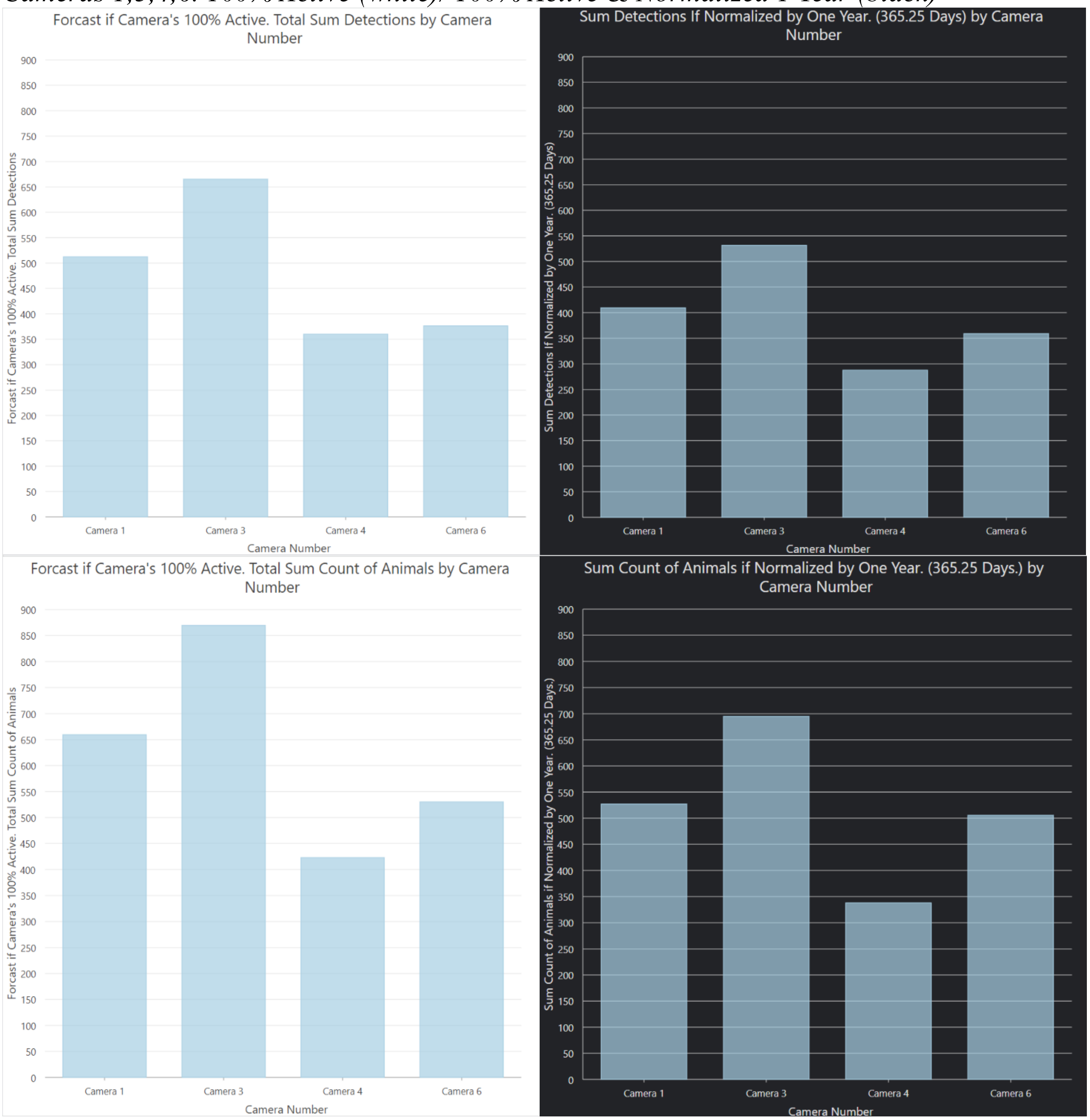
The results for DET/COA for Camera site 2 and Camera site 5 will not be considered valid in this section due to their short collection period and small sample size. The results from Camera sites 2 and 5 have been previously included in this study when relevant, however

Cameras 1, 3, 4, and 6 have robust sample sizes/Active Camera Days and will therefore be the source for expected values generated from this point on.

The next step for camera comparison is to examine the forecast results for each camera as if they had been active and collected data 100% of the time they were in the field. This was achieved by calculating the mean (%) of the time each camera was fully active and forecasting the results of DET and COA as if each camera had been active 100% of its Possible Active Days. Due to the differences in Possible Active Days by camera, the forecasted 100% results were then normalized to the average (mean) length of one year, or 365.25 days. This interval was chosen to normalize the data rather than the entire study period of 457 days. Now all camera results are forecast for 100% Active Camera Days over the same number of days, enabling equal comparison between cameras sites. Figure 5.12 shows DET/COA totals for Camera sites 1, 3, 4, and 6 with results forecasted for 100% Active Camera Days (white), and forecasted for 100% Active Camera Days *and* Normalized by 365.25 days (black).

Figure 5.12

Cameras 1,3,4,6. 100% Active (white)/ 100% Active & Normalized 1 Year (black)



Note. (Upper left, white) DET @100% ACD. (Upper right, black) DET@100% ACD & Normalized by 1-year. (Lower left, white) COA @100% ACD. (Lower right, black) COA @100%ACD & Normalized by 1-year. These four cameras had lower DET/COA counts once reduced from operating at 100% over the entire length of their installment (white) to operating at 100% over 365.25 days (black).

Now that the data is forecast for 100% camera activity and placed over a standard integer of time (365.25 days) it can be compared more equally between camera sites. There still remains another significant issue to be resolved, the “Unidentified” species. The following section will conduct an analysis designed to address this issue.

5.3.3 Unidentified Species Forecasting

During the course of this study, cameras would often capture photos where only the animal’s eyes or body outline was visible. Due to the lighting, weather, or condition of the camera lens, a species type was unable to be assigned to these Detections. Unidentified Detections are from species that could trigger a Detection event, and the presence of eyes or a new animal shaped blur in the photos confirmed that it was not a false trigger (recall 96 DET/97 COA total “Unidentified” in this study). Figure 5.13. is an example of such a photo.

Figure 5.13

Unidentified Species?

Note. This is a typical example of an Unidentified species photo. Can you tell for certain what species it is? Did you notice the second animal's eye reflecting to the left of the first? This photo was one of several from a Camera 1 Detection event. Thanks to the other photographs in the series, these eyes were identified as a black-tailed deer (*Odocoileus hemionus columbianus*) doe and adolescent fawn. Had this photo been the only one available to determine a species, it would have been labeled as Unidentified, 1 DET with a COA of 2.

For the purposes of this analysis, it is assumed that all Unidentified species recorded were in fact comprised of several other identified species detected by the camera site. It will also be assumed that the identified species contributing to the value of Unidentified species occurred in the same ratio (mean, by camera location) as they appeared by camera site.

By calculating the ratio of species DET at each camera site it is possible to take the total DET of Unidentified species and assign them to an identified species type based on each camera's rate of Detection. This thesis believes assigning the Unidentified species values to identified species will produce a more accurate representation of wildlife species DET for Cameras 1, 3, 4, and 6. Small fractions of Unidentified species assigned to seldom recorded identified wildlife species do not meaningfully change their rate of occurrence. The quantity of Unidentified species assigned to the most frequently detected species is likely conservative or an underrepresentation because of the quantity of Unidentified assigned to seldom recorded species. The belief of this thesis is that a forecast that includes the value of Unidentified species assigned to identified species will still produce lower counts than actually occurred for top recorded species and will not significantly alter counts of seldom recorded species.

The majority of Unidentified species' true identity most likely belongs to one of this study's "Big-3" or most observed species, black-tailed deer (*Odocoileus hemionus columbianus*), coyote (*Canis latrans*), and Roosevelt elk (*Cervus canadensis roosevelti*). This is evidenced by Unidentified species being the fourth most common species DET and COA in this study (*Table 5.1. Species COA/DET Sorted High/Low.* It is unlikely a surge of species rarely detected in this study like black bear (*Ursus americanus*), or mountain lion (*Puma concolor*) managed to generate a large number of Detections that would be labeled Unidentified, but there is a chance that one or two may have been classified as such. Aiding the theory that Unidentified species are likely comprised of a similar ratio to identified species, the DET for Unidentified species count mimicked the increase/decrease of the "Big 3" in both Seasonal and Time of Day Detections Over Time (*Figure 5.4*, and *Figure 5.5* in ***Results: 5.2.4.*** *Detections Over Time*.

While processing the metadata and assigning species labels to Detection events with difficult to identify wildlife, the species under consideration most frequently were black-tailed deer (*Odocoileus hemionus columbianus*), coyote (*Canis latrans*), and Roosevelt elk (*Cervus canadensis roosevelti*). Most of these considerations shifted between coyote/black-tailed deer or black-tailed deer/Roosevelt elk. There was a second frequently considered combination of species from photos taken at a slightly closer range that helped in gauging the size of the wildlife. The three species under consideration were coyote (*Canis latrans),* red fox (*vulpes vulpes*), and bobcat (*Lynx rufus*). These species share similar physical features and dimensions and are difficult to distinguish in low visibility photos. The majority of these were likely coyotes, as there were no species of fox positively identified during this study, and identified coyotes outnumbered bobcats about 15:1. Without certainty, these photos were also labeled Unidentified. Much smaller wildlife species like rabbits typically did not trigger the camera until they were much closer and more easily identified.

The following Table 5.5. shows "As-Captured" DET totals of "Unidentified" by camera. This is the quantity of DET that will be assigned amongst the other species at the same camera location. Table 5.6 shows the new species totals after "Unidentified" species counts have been distributed (Assigned) by each species rate of occurrence within each camera site.

Table 5.5

Species DET Totals by Camera Site

	DET, Camera 1	DET, Camera 2	DET, Camera 3	DET, Camera 4	DET, Camera 5	DET, Camera 6	DET, Grand Total
Unidentified Detections (DET) Total	13	3	44	10	7	19	**96**

Note. Total Unidentified Species Detected during the study. Camera 3 accounted for 51.2% of the total "Unidentified" DET amongst the four camera sites (1,3,4,6) during this study.

Table 5.6

Species Detections (DET) by Camera Site with Unidentified species Assigned.

Species	DET, Unidentified Assigned, Camera 1	DET, Unidentified Assigned, Camera 2	DET, Unidentified Assigned, Camera 3	DET, Unidentified Assigned, Camera 4	DET, Unidentified Assigned, Camera 5	DET, Unidentified Assigned, Camera 6	Total Detections W/ Un-identified Assigned
Bird	3.12	1.19	4.39	4.12	0.00	2.14	14.96
Black Bear	0.00	0.00	1.10	0.00	0.00	0.00	1.10
Black-tailed Deer	225.79	1.19	91.10	150.31	4.50	128.60	601.48
Bobcat	9.36	0.00	10.98	3.09	0.00	4.29	27.72
California Scrub Jay	0.00	0.00	2.20	0.00	0.00	0.00	2.20
Coyote	72.83	0.00	223.90	55.59	4.50	49.30	406.13
Domestic Dog	0.00	0.00	1.10	0.00	0.00	2.14	3.24
Duck	0.00	1.19	0.00	0.00	0.00	0.00	1.19
Eastern Cottontail	0.00	0.00	27.44	33.97	0.00	0.00	61.41
Eastern Gray Squirrel	0.00	0.00	1.10	24.71	0.00	0.00	25.81
Great Blue Heron	0.00	0.00	0.00	0.00	0.00	1.07	1.07
Mountain Lion	0.00	0.00	0.00	0.00	0.00	1.07	1.07
Raccoon	0.00	1.19	0.00	1.03	0.00	0.00	2.22
Ring-necked Pheasant	1.04	0.00	0.00	1.03	0.00	0.00	2.07
Roosevelt Elk	20.81	14.25	131.71	53.53	0.00	95.38	315.68
Steller's Jay	1.04	0.00	0.00	0.00	0.00	0.00	1.04
Townsends's Chipmunk	0.00	0.00	0.00	21.62	0.00	0.00	21.62
Unidentified	x	x	x	x	x	x	x
Grand Total	**334**	**19**	**495**	**349**	**9**	**284**	**1490**

Note. Results are rounded to the nearest hundredth. Camera 2 and Camera 5 results are present in this graph labeled in red to highlight the issues facing these cameras from their small sample size as the reason for their exclusion from much of this analysis.

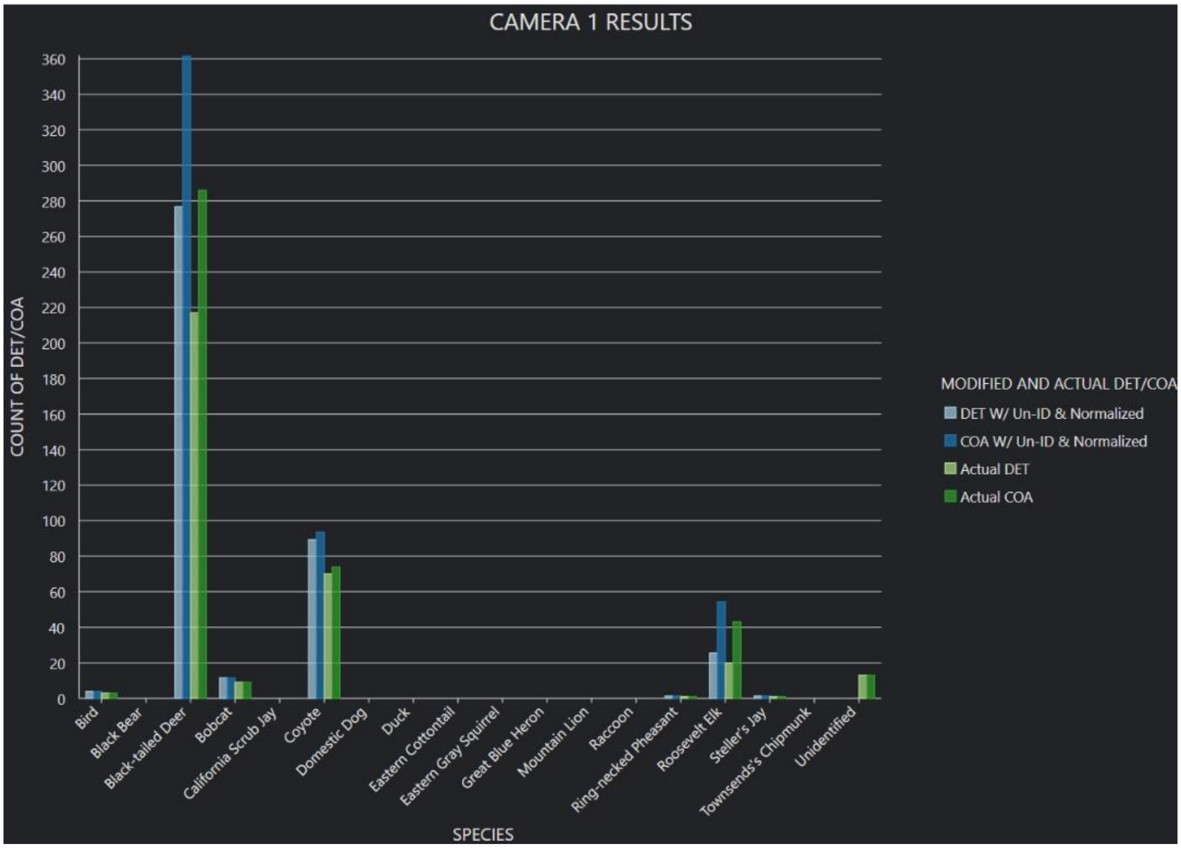
The next step was to take each camera site's new species DET/COA with their Unidentified species assigned, forecast this data for 100% Active Camera Days, and then normalize by one year (365.25 days). The data with all three of these forecasts completed will be referred to as Cumulative Forecast Data.

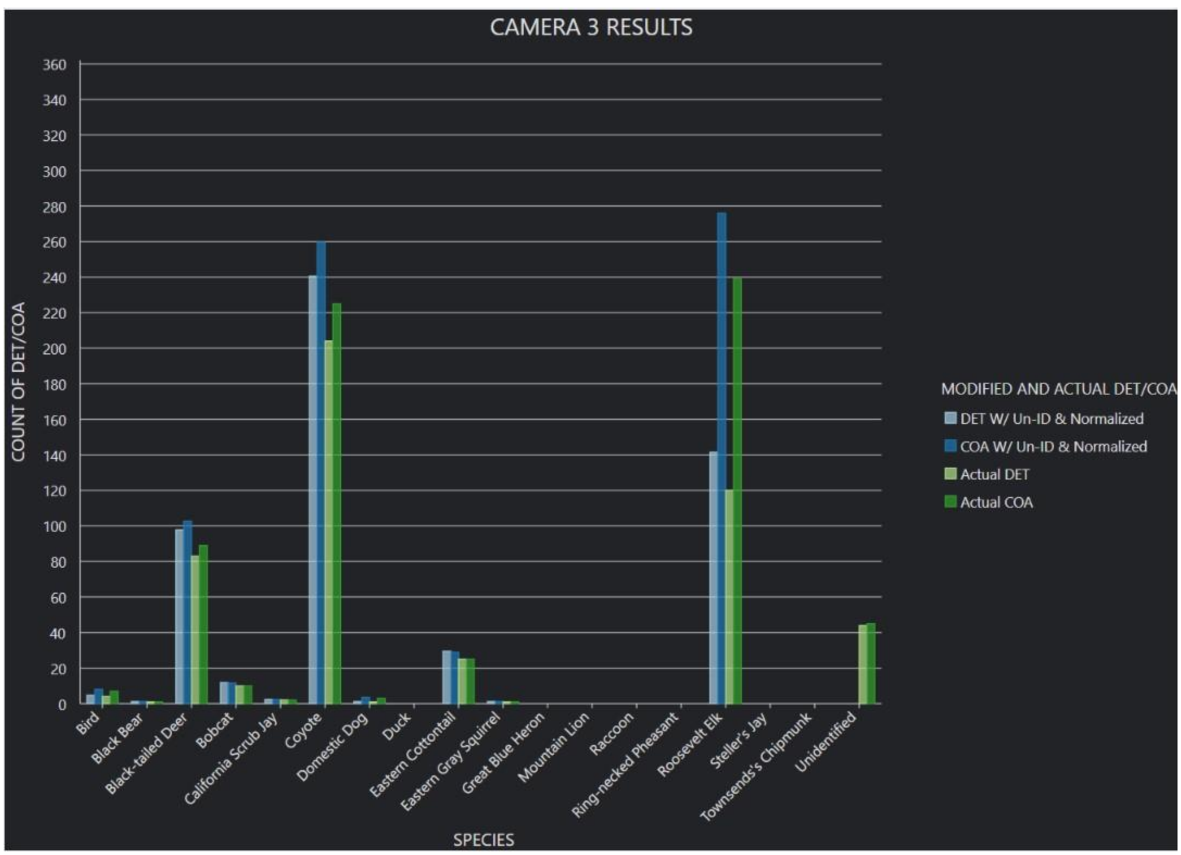
5.4 Cumulative Forecast Results

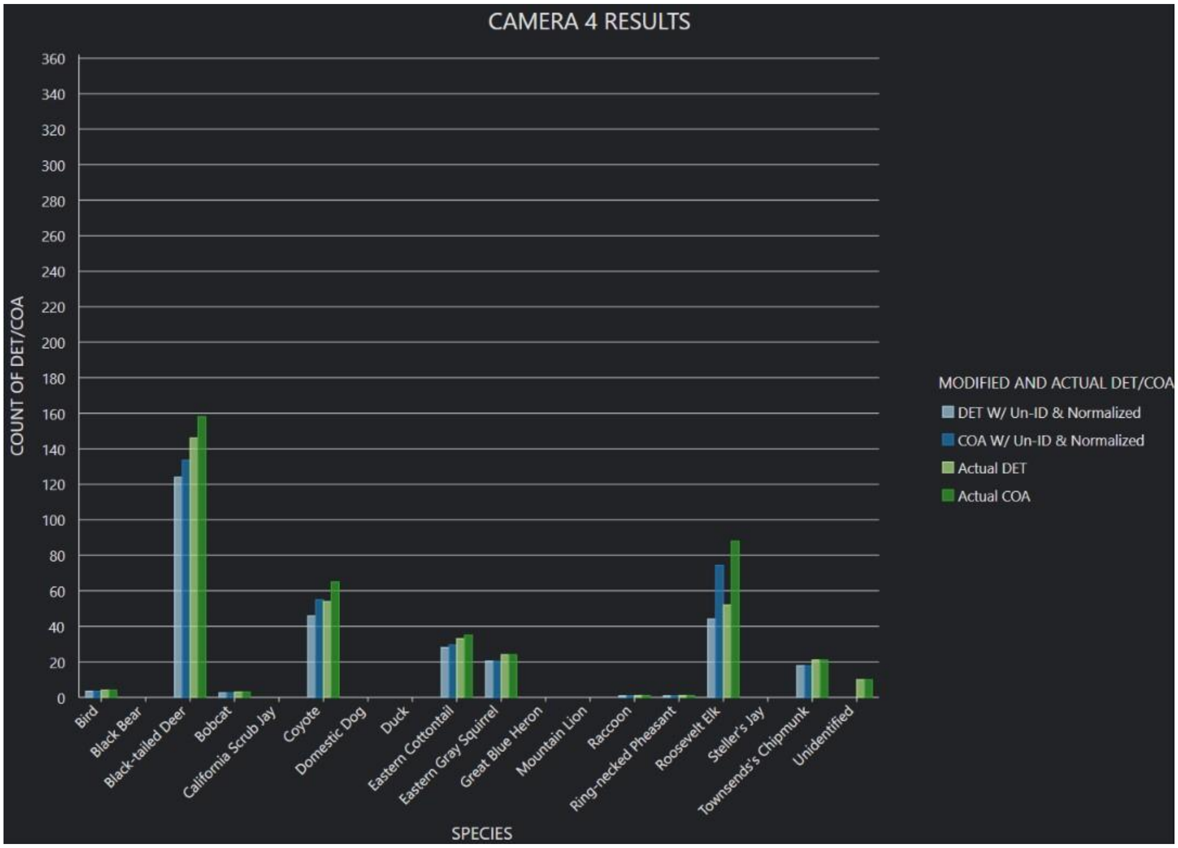
The final results of species DET/COA with Cumulative Forecast Data for Camera sites 1, 3, 4, and 6 may be viewed in the following bar graphs (Figures 5.14., 5.15., 5.16., and 5.17.) alongside the "As Captured" (Actual) data. Cumulative Forecast (Modified) DET/COA data appears in blue and "As Captured" (Actual) appears in green. Graphed results are all shown at the same scale and interval. In almost every camera site the Cumulative Forecast (Modified) counts for species DET/COA increased. The exception to this was Camera site 4, whose 96.94% (mean) Active Camera Day rate and substantial number of Active Camera Days (443 days) led to a decreased DET/COA count across all species when reduced to 365.25 days.

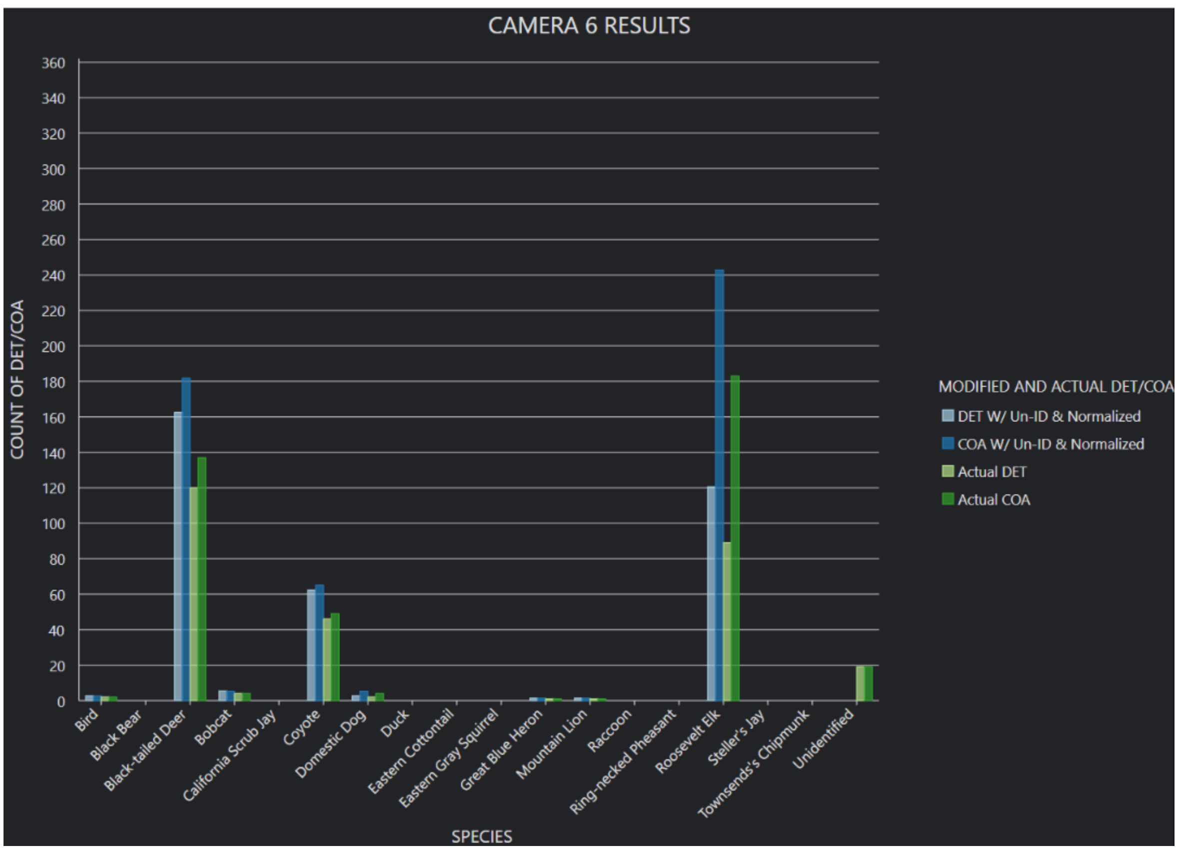
Figures 5.14; 5.15; 5.16; 5.17

DET Over Time, Camera 1; *Results, Camera 3*; *Results, Camera 4*; *Results, Camera 6 Results*


CAMERA 1 RESULTS
COUNT OF DET/COA
SPECIES
MODIFIED AND ACTUAL DET/COA
DET W/ Un-ID & Normalized
COA W/ Un-ID & Normalized
Actual DET
Actual COA
Bird
Black Bear
Black-tailed Deer
Bobcat
California Scrub Jay
Coyote
Domestic Dog
Duck
Eastern Cottontail
Eastern Gray Squirrel
Great Blue Heron
Mountain Lion
Raccoon
Ring-necked Pheasant
Roosevelt Elk
Steller's Jay
Townsends's Chipmunk
Unidentified


CAMERA 3 RESULTS
COUNT OF DET/COA
SPECIES
MODIFIED AND ACTUAL DET/COA
DET W/ Un-ID & Normalized
COA W/ Un-ID & Normalized
Actual DET
Actual COA
Bird
Black Bear
Black-tailed Deer
Bobcat
California Scrub Jay
Coyote
Domestic Dog
Duck
Eastern Cottontail
Eastern Gray Squirrel
Great Blue Heron
Mountain Lion
Raccoon
Ring-necked Pheasant
Roosevelt Elk
Steller's Jay
Townsends's Chipmunk
Unidentified


CAMERA 4 RESULTS
COUNT OF DET/COA
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Bird
Black Bear
Black-tailed Deer
Bobcat
California Scrub Jay
Coyote
Domestic Dog
Duck
Eastern Cottontail
Eastern Gray Squirrel
Great Blue Heron
Mountain Lion
Raccoon
Ring-necked Pheasant
Roosevelt Elk
Steller's Jay
Townsends's Chipmunk
Unidentified
SPECIES
MODIFIED AND ACTUAL DET/COA
DET W/ Un-ID & Normalized
COA W/ Un-ID & Normalized
Actual DET
Actual COA


CAMERA 6 RESULTS
COUNT OF DET/COA
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Bird
Black Bear
Black-tailed Deer
Bobcat
California Scrub Jay
Coyote
Domestic Dog
Duck
Eastern Cottontail
Eastern Gray Squirrel
Great Blue Heron
Mountain Lion
Raccoon
Ring-necked Pheasant
Roosevelt Elk
Steller's Jay
Townsends's Chipmunk
Unidentified
SPECIES
MODIFIED AND ACTUAL DET/COA
DET W/ Un-ID & Normalized
COA W/ Un-ID & Normalized
Actual DET
Actual COA

A comparison of species total DET counts between "As-Captured" data for all six-camera sites over the duration (457 days) of the study and the "Cumulative Forecast" data of the four-camera sites (1, 3, 4, 6) over one year (365.25 days) can be viewed below in Table 5.7. Individual "Cumulative Forecast" species DET counts by Camera site can be viewed in Table 5.8. Table 5.9 shows the percent change in species totals from "AS-Captured" data to "Cumulative Forecast."

Table 5.7

Species "As-Captured" and "Cumulative Forecast" DET Totals

Species	"As Captured" All Site's DET Total	"Cumulative Forecast" of 4 Site's DET Total
Black-tailed Deer	568	661
Coyote	375	438
Roosevelt Elk	293	332
Eastern Cottontail	58	57
Bobcat	26	31
Eastern Gray Squirrel	25	22
Townsends's Chipmunk	21	18
Bird	14	15
Domestic Dog	3	4
California Scrub Jay	2	2
Raccoon	2	1
Ring-Necked Pheasant	2	2
Black Bear	1	1
Mountain Lion	1	1
Duck	1	0
Great Blue Heron	1	1
Steller's Jay	1	1
Unidentified	96	0
Grand Total	**1490**	**1588**

Note. Cumulative Forecast results for this table have counts rounded to the nearest whole DET. The *Grand Total* of DET for Cumulative Forecast results from the sum of these original numbers including their fractions of a DET, and that sum was then rounded to the nearest whole DET. This is why the *Grand Total* does not appear to result in the correct sum.

Table 5.8

Cumulative Forecast Results by Camera and Species

Species	Cumulative Forecast DET, Camera 1	Cumulative Forecast DET, Camera 3	Cumulative Forecast DET, Camera 4	Cumulative Forecast DET, Camera 6	Cumulative Forecast, Four Camera Total DET
Black-tailed Deer	277	98	124	163	**661**
Coyote	89	241	46	62	**438**
Roosevelt Elk	26	141	44	121	**332**
Eastern Cottontail	0	29	28	0	**57**
Bobcat	11	12	3	5	**31**
Eastern Gray Squirrel	0	1	20	0	**22**
Townsends's Chipmunk	0	0	18	0	**18**
Bird	4	5	3	3	**15**
Domestic Dog	0	1	0	3	**4**
California Scrub Jay	0	2	0	0	**2**
Ring-necked Pheasant	1	0	1	0	**2**
Black Bear	0	1	0	0	**1**
Great Blue Heron	0	0	0	1	**1**
Mountain Lion	0	0	0	1	**1**
Raccoon	0	0	1	0	**1**
Steller's Jay	1	0	0	0	**1**
Grand Total	**409**	**532**	**288**	**359**	**1588**

Note. Cumulative Forecast results for this table have counts rounded to the nearest whole DET. The *Grand Total* of DET for Cumulative Forecast results from the sum of these original numbers including their fractions of a DET, and that sum was then rounded to the nearest whole DET. This is why the *Grand Total* does not appear to result in the correct sum.

Table 5.9

Percent change in DET from "As Captured" to "Cumulative Forecast"

Percent Change in Species DET	Camera 1	Camera 3	Camera 4	Camera 6	**Total % Change**
Bird	27.7%	18.0%	-15%	35.5%	**12.7%**
Black Bear	0	18.0%	0	0	**18.0%**
Black-tailed Deer	27.5%	17.9%	-15.10%	35.4%	**16.8%**
Bobcat	27.6%	17.9%	-15%	35.5%	**20.1%**
California Scrub Jay	0	18.0%	0	0	**18.0%**
Coyote	27.5%	17.9%	-15.1%	35.4%	**17.1%**
Domestic Dog	0	18.0%	0	35.5%	**29.7%**
Eastern Cottontail	0	17.9%	-15.1%	0	**-0.9%**
Eastern Gray Squirrel	0	18.0%	-15.1%	0	**-13.8%**
Great Blue Heron	0	0	0	35.0%	**35.0%**
Mountain Lion	0	0	0	35.0%	**35.0%**
Raccoon	0	0	-15%	0	**-15.0%**
Ring-necked Pheasant	28.0%	0	-15%	0	**6.0%**
Roosevelt Elk	27.6%	17.9%	-15.1%	35.4%	**18.0%**
Steller's Jay	28.0%	0	0	0	**28.0%**
Townsends's Chipmunk	0	0	-15.10%	0	**-15.1%**
Grand Total	**22.6%**	**7.4%**	**-17.6%**	**26.4%**	**8.6%**

Note. Percent change from "As Captured" DET to new Cumulative Forecast DET. Percent change rounded to nearest tenth, displaying only 1 decimal point.

5.5 Cumulative Forecast Results by Camera Site/Habitat Type

Prior to creating the Cumulative Forecast Data, this study was unable to accurately compare wildlife data from different camera sites and habitat types to each other. This was due to periods of missing data/camera failure and camera collection periods occurring over different intervals of time. Now that these variables have been mitigated through the Cumulative Forecast, a thoughtful discussion about the differences in species Detections by camera site/habitat type can occur.

The following results of the Cumulative Forecast Data (Unidentified Species Assigned, Forecast Detections for 100% Active Camera Days, Data Collection Period Normalized to 365.25 Days) for the four Camera sites 1,3,4, &6 will be discussed in this section. Total counts or percentages displayed hereafter are derived from these four sites alone unless otherwise noted. When a species "DET rate" is discussed in the following evaluations, it is in reference to the total number of species detected at a camera location out of the total DET for that species Detections between these four sites (1, 3, 4, 6), not that species rate of DET within that single camera location.

5.5.1 Camera Site 1: Prairie/Grassland – Limited Cover

Camera site 1 location recorded the second highest total DET count (409) of the four camera sites trailing the Camera 3 location (532). This camera site/habitat type had the highest black-tailed deer (*Odocoileus hemionus columbianus*) DET rate with 41.9% of the total deer DET for the four cameras. Roosevelt elk (*Cervus canadensis roosevelti*) Detections here were the lowest of the four sites with only 7.7% of the total elk DET coming from Camera 1. The reason deer found this site so favorable while elk did not is unknown. These ungulates share a similar diet and habitat preferences within the South Puget Sound region. The difference in Detection rates in this location/habitat type may have had more to do with this location's proximity to I-5 and differences between the two species' tolerance of human activity/lack of cover rather than their differences in habitat type preference. More data is needed to make any conclusive determinations about these results.

No Detections of small mammal species like rabbits or squirrels were forecast at this site. This is not surprising given the limited cover and exposed area/lack of trees. Field rodents like mice, gophers, or voles are likely to have been present, but were undetectable by the camera. The combined DET count for all bird species at Camera site 1 was 6, which was about average across the four camera locations (combined bird species DET average (mean) across the four sites was 5.25).

The second highest Detection rate of bobcat (*Lynx rufus*) was found in this habitat type with an almost equal number of bobcat DET to the study's highest at Camera 3 (Camera 1: 11 DET; Camera 3: 12 DET). This location held the second highest DET rate of coyote (*Canis latrans*) between the four sites with 20.4% of total coyote DET. This coyote DET rate was not as close to that of the highest location (Camera 3) as it was with the DET rate of bobcat. Coyote DET at Camera site 1 were forecast to be less than half that of Camera 3's coyote DET rate (54.9%). (Camera 1 bobcat 36.8%, coyote 20.4%. Camera 3: bobcat 37.8%, coyote 54.9%). It is unknown the exact reason for higher-than-average predator DET rates at this location, but it may have been influenced by hunting opportunity for ground nesting bird species and undetected rodents present in the field.

5.5.2 Camera Site 3: Dense Brush/Brambles: - High Ground Cover

Camera Site 3 had the highest total count of "As Captured" DET (495) prior to data forecasting and retained the highest total DET (532) of the four sites in Cumulative Forecast Data. This location tied Camera 4 for most species type detected, both holding a count of ten unique species.

This location held the lowest black-tailed deer (*Odocoileus hemionus columbianus*) DET count (98 DET) and highest Roosevelt elk (*Cervus canadensis roosevelti*) DET count (141 DET) of the four camera sites. Black-tailed deer (*Odocoileus hemionus columbianus*) DET at Camera site 3 accounted for only 14.8% of the four sites' deer DET total. On the other hand, Roosevelt elk (*Cervus canadensis roosevelti*) DET at Camera site 3 accounted for 42.7% of the four camera's combined elk DET total.

Camera Site 3 also had the highest count of coyote (*Canis latrans*) DET (241) and highest bobcat (*Lynx rufus*) DET (12) of the four sites. Similarities in habitat type between Camera Site 3 and the second highest coyote and bobcat DET camera site (Camera 1) include close proximity to fields and lack of large mature trees. It is possible that the increased rates of these predator species may have been due to these shared habitat attributes at the Camera site 3 and 1 locations.

The high brushy ground cover found in Camera Site 3 was likely an influence on the Eastern cottontail rabbit (*Sylvilagus floridanus*) DET count, the highest in this study (29 DET). It is also likely that the lack of mature trees at the Camera 3 location resulted in the absence of any Townsend's chipmunk (*Neotamias townsendii*) and only 1 DET of Eastern gray squirrel (*Sciurus carolinesis*).

The only black bear (*Ursus americanus*) DET of the study occurred here on 11/15/2021. In the photos captured, the bear was eating fallen apples from the nearby trees. Fruit found at this site likely impacted the count of DET for wildlife that consume fruit at this location. However, due to the fall seasonal increase of DET in the "Big-3" species across all sites correlating with fall fruit availability at Camera site 3, it is difficult to conclude that this food source alone was responsible for the increase of "Big-3" DET during this time period. Feeding on apples is not limited to herbivores, as evidenced by the black bear Detection. Like black bears, coyotes are also opportunistic omnivores and have been observed eating apples. Rabbits will also partake in feeding on apples.

In October 2020 Eastern cottontail rabbits (*Sylvilagus floridanus*) had their highest DET interval ("As-Captured" data) at Camera 3, while coyote DET in the same interval had only 1 DET ("As-Captured"). The following year, Eastern cottontail rabbits (*Sylvilagus floridanus)* were present briefly in late September, but when the coyote DET skyrocketed (9/28-10/12/2021) they were no longer detected at this location. Attempting to attribute the increase of Eastern cottontail rabbits' (*Sylvilagus floridanus*) DET, or any other species for that matter, to the presence of ripe fruit is difficult due to confounding variables like high coyote presence. The one species that did have increased DET ("As-Captured") only during the fall season (when fruit was ripe) was black-tailed deer (*Odocoileus hemionus columbianus*).

Despite black-tailed deer (*Odocoileus hemionus columbianus*) being the most frequently detected species of the four cameras total, Deer DET (Cumulative Forecast Data) at this Camera 3 location were the lowest of the four camera sites, 98 DET. This is particularly interesting, as Camera 3 had the highest DET total of any camera location, but the lowest of the study's highest DET species. Using "As Captured" data over Time to examine the seasonal changes of Camera 3 deer DET, only 7 of the 83 DET ("As Captured") occurred outside of the fall season when the fruit was ripe. Of these 7 DET outside of the fall, there was no more than 1 deer DET per 2-week interval ("As-Captured"). The majority of black-tailed deer (*Odocoileus hemionus columbianus*) DET (76 Det "As Captured") coincided with periods of fruit availability; however, this can still not be wholly attributed to fruit alone as increases in black-tailed deer (*Odocoileus hemionus columbianus*) DET occurred during the fall season at other sites that did not have fruit.

All that this study will conclude with confidence, is that of the top five species with the highest combined total DET among the four sites, Camera 3 location had the highest DET counts for the four top species following black-tailed deer (*Odocoileus hemionus columbianus*). The highest DET counts for four out of five of these top species (coyote, elk, rabbit, bobcat) occurring at this location/habitat type may have been related to the seasonal availability of fruit.

5.5.3 Camera Site 4: Mature Mixed Forest – Dense Undergrowth, High Ground Cover.

The Camera 4 location had the second highest rate of "As-Captured" total DET for all camera sites. This was likely due to the camera on site being active and recording data 96.94% of the time throughout the full 457 days of the study while other locations had fewer Active Camera Days. In initial "As-Captured" data, the Camera 4 location had a higher total DET count. As such, it appeared to have higher species DET rates than the lowest of the four main sites, Camera 6. However, after the Cumulative Forecast of the data had been completed, Camera 4 still had more species diversity (10 vs. 8), but it now has a lower DET for species in which it previously had more than Camera site 6. Specifically, Camera site 4 had lower DET of black-tailed deer (*Odocoileus hemionus columbianus*) (124/163 DET) and coyote (*Canis latrans*) (46/62DET) than Camera 6.

It is not surprising that 100% of DET from Townsend's chipmunk (*Neotamias townsendii*) and all but 1 DET (Camera 3) of Eastern gray squirrel (*Sciurus carolinesis*) occurred at this camera location with mature mixed forest habitat. This site, with a similarly prominent level of ground cover to the Camera 3 location, also shared a similar count of Eastern cottontail rabbit (*Sylvilagus floridanus*) DET (Camera site 4: 28, Camera site 3: 29 DET), where the other two sites with less brush and ground cover had no rabbit DET. While this location/habitat type held the greatest total DET count of prey species (more total prey DET than Camera site 3 because of squirrel/chipmunk), it detected the fewest predators (bobcat/coyote) of the four sites. More data is needed to determine the causation of high prey/low predator ratio at this location.

DET of coyote (*Canis latrans*) (46 DET) and bobcat (*Lynx rufus*) (3 DET) at this site were the least prevalent of the four camera locations. It is unknown why these two predators were so infrequently detected at this location compared to other locations. Roosevelt elk (*Cervus canadensis roosevelti*) and black -tailed deer (*Odocoileus hemionus columbianus*) also comprised a lower percentage of the four-camera total DET than the 25% expected if species had occurred equally at each site. (Elk, 44 DET, 13.3% of four-camera species total. Deer, 124 DET, 18.7% of four-camera species total.) This habitat had the highest level of forest canopy cover and high brush/undergrowth that appears to have contributed to higher counts of smaller species and lower counts of larger species.

A unique species Detection, a single raccoon (*Procyon lotor*), was recorded at this Camera site but not at any of the other three camera locations.

5.5.4 Camera Site 6: Young Deciduous Forest – Low/Mid Ground Cover.

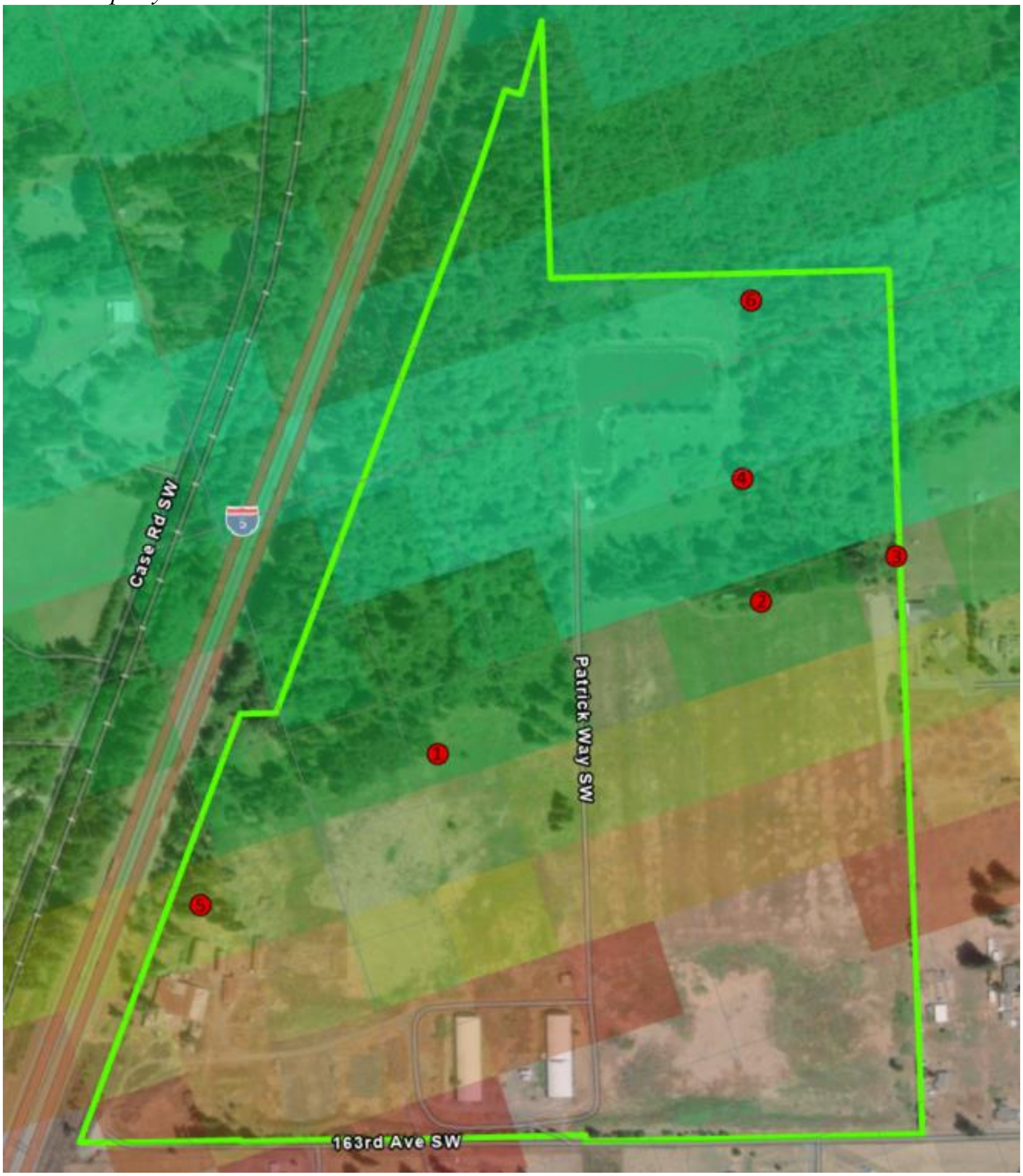
The location of Camera site 6 held the second highest DET count of black-tailed deer (*Odocoileus hemionus columbianus*) (163 DET) and Roosevelt elk (*Cervus canadensis roosevelti*) (121 DET). The game trail at this location was well worn with ungulate hoof prints and appeared to be one of the major entrance/exit points for ungulates on the property. This location held similar Roosevelt elk (*Cervus canadensis roosevelti*) DET (121) to Camera site 3 (141), which was also was located on a game trail believed to act as a major entrance/exit point. Where the two differ, Camera 3 did not detect nearly the ratio of total black-tailed deer (*Odocoileus hemionus columbianus*) DET (14.8%) as this location, Camera site 6 (24.6%). Perhaps there were other locations used by deer to enter and exit the property besides these two game trails, as the highest black-tailed deer (*Odocoileus hemionus columbianus*) DET location was Camera 1, which was much more centrally located on the property.

Coyote (*Canis latrans*) and bobcat (*Lynx rufus*) DET at this location (62 coyote, 5 bobcat) were lower than locations with less tree cover like Camera site 1 (89 coyote, 11 bobcat) and Camera site 3 (241 coyote, 12 bobcat), but had higher DET than locations with higher tree cover, Camera site 4 (coyote 46, bobcat 3).

While there was more ground cover in the deciduous red alder (*Alnus rubra*) forest habitat at this location than Camera site 1, both locations had no Detections of rabbit, squirrel, or chipmunk. It did, however, capture the only great blue heron (*Ardea herodias*) in the study. This large bird was captured while it was likely hunting for food in the seasonally somewhat marshy grass. Rough-skinned newts (*Taricha granulosa*) were observed nearby this camera location during Field Survey portion of this study, and while highly poisonous, their presence indicates suitable habitat for other amphibians less dangerous to hungry herons. Interestingly, the only mountain lion (*Puma concolor*) detected during this study was captured in this location. The reason for this location to be the only one to detect this uncommon species is unknown, but it should be noted that this camera site is the furthest from human activity and shown to be the lowest resistance to according to the WHCWG Least-Cost Corridor model as it overlaps on the site (Figure 5.18.).

Figure 5.18

VETC Property with LCC Model and Camera Locations



Note. Excluding the VETC property outline, areas of brighter green correspond to higher levels of habitat connectivity from the LCC model. Red numbered circles indicate approximate camera locations and with corresponding camera numbers. This figure was created using the *Least Cost Corridor* layer created by (Gallo et al., 2019) with ArcGIS Pro 3.0.3. Garrett Brummel, 2023

6 Chapter VI. Conclusions

6.1 Research Problem/Questions, Conclusions, and Observations

When the first coordination efforts began between Veterans Ecological Trades Collective and Conservation Northwest, the very first question that was asked was, "*What wildlife species are present on site, and in what abundance?*" The answer to this question was important because it held the potential to answer a second and more pressing question about the connectivity between the Cascade Mountain Range and the Washington Coast. That second question, "*Does the data collected from this site provide evidence supporting the presence of a habitat linkage, and does that validate the Washington Wildlife Habitat Connectivity Working Group's (WHCWG) Least-Cost Corridor (LCC) connectivity model within the I-5 Northern Linkage Zone?*"

The answer to the first question "*What wildlife in what abundance?*" has been answered through this thesis. Wildlife presence has been recorded by species in Detections and Count of Animals, Time, and Habitat Type over the 457 days of "As Captured" wildlife data. This study has also provided Cumulative Forecast Data for four camera sites over a one-year interval. "*Did this study provide evidence supporting the presence of a habitat linkage on site?"* Perhaps, the quantity and diversity of species present in this location does provide strong supporting evidence that the site belongs to part of a habitat corridor but does not conclusively prove that it is. "*Do the results of this thesis validate the WHCWG LCC habitat connectivity model and I-5 Northern Linkage Zone?"* The answer to this question is also indeterminate. This study cannot "prove" the existence of the I-5 Northen Linkage Zone with the camera resources provided and one study location alone. Perhaps the data from this study could be used in future wildlife Detection studies that aid in validation of WHCWG's habitat connectivity models within the I-5 Northern Linkage Zone, but this study was not designed in a way that could make that determination.

As it currently stands, more data from both inside and outside of the I-5 Northern Linkage Zone would be needed for model validation. However, the data collected during this study in no way disproves the presence of the I-5 Northern Linkage Zone. The data collection framework and methodology used in this study may be replicated on private or public lands, both inside and outside of the I-5 Northern Linkage Zone. By providing on the ground wildlife counts from within the NLZ, this study has contributed to knowledge of wildlife in the area from a method previously unused, and contributed to solving the research problem of what wildlife are present within the NLZ.

There is no set minimum number of distinct species that, once reached, define an area as a habitat corridor or linkage, just as there is no established population of wildlife that identifies an area as such. Many times, other Community Wildlife Monitoring Project (CWMP) camera sites within Habitat Concentration Areas (HCAs), as defined by the WHCWG, have recorded much lower wildlife species diversity/abundance than recorded by this thesis at this site. This occurs despite a higher rating of habitat connectivity within the HCA than on this property. This does not mean that this connectivity model is disproven because an area that was more "highly connected" recorded less wildlife. Wildlife density and wildlife permeability are two vastly different metrics that, while often related, are not interchangeable. The lack of large scale highly connected habitat surrounding the I-5 Fracture Zone compresses wildlife into the few suitable areas, where wildlife within an HCA can be more widely dispersed without encountering high habitat resistance. Within the I-5 Fracture Zone, much of wildlife's movement is concentrated through existing habitat corridors and linkages, not unlike the way the majority of motor vehicles in this area are found to be concentrated through roadways like Interstate 5. A plethora of species and location variables make absolutely proving a “habitat corridor” by general wildlife density alone exceedingly difficult. However, the fact remains that wildlife abundance and diversity on this site surpasses many of the more remote locations within the CWMP. These remote locations do not have a massive barrier like I-5 nearby. Animals there would not receive nearly as much benefit from a wildlife crossing structure as would the larger wildlife population found on this site and within the I-5 Northern Linkage Zone. This has led Conservation Northwest to advocate for the creation of wildlife crossing structures in this area.

6.2 Findings from the Study Site

The most surprising finding this study discovered was the presence of mountain lion (*Puma concolor*), black bear (*Ursus americanus*), bobcat (*Lynx rufus*), and a sizeable population of Roosevelt elk (*Cervus canadensis roosevelti*) so close to Interstate 5. In other findings of importance over the length of this study (457 days), cameras positively identified fifteen wildlife species and recorded 1,490 Detections (DET) with a count of 1,955 animals (COA) in initial “As Captured” data. This study’s Cumulative Forecast Data, correcting for the camera malfunction and data collection errors, projected 1,588 total wildlife DET and 2,066 COA over a one-year (365.25 day) interval.

Despite camera locations on site being relatively close in proximity to one another, there were large differences in wildlife species DET by habitat type. Species abundance and diversity recorded on the site also varied with seasonal changes.

This study explored the significance of this property both in relation to local habitat connectivity and to the geographically unique and rare habitat types it possesses. This property may play an influential role in the improvement of connectivity within the I-5 corridor. Priority

Habitat types like Westside prairie and Oregon white oak woodlands have greatly diminished in the past century and their conservation/restoration would aid in the recovery of a plethora of threatened species.

If this study was starting over, what would be done differently given what has been learned? Several methods could be employed to better answer the question "*Is this data supporting evidence of the site belonging to part of a habitat linkage?*" and "*Can this data validate the WHCWG Least-Cost Corridor connectivity model within the I-5 Northern Linkage Zone?*" With a significant increase in cameras, around 20, the entire site could be covered in an equidistant grid of cameras with no regard to game trails, wildlife sign, or habitat type. If the number of species and Detections are shown to decrease alongside decreases in habitat connectivity ratings from the LCC connectivity model as it pertains to the site, it would be possible to draw more definitive conclusions. This type of study would also allow for a comparison between species Detection rates and proximity to I-5 to evaluate the barrier effect or wildlife road avoidance.

With regard to protocol that would be done differently in this study given what we have learned, the most important would be in the data collection process. Any camera trapping study should have a high-capacity external hard drive that is used to back up the data from camera SD cards. This back up should occur immediately after retrieval and use an identical filing system to that of the laptop, google drive, remote desktop, and photo database. These raw data backups should be disconnected and separated from the SD card data that is uploaded and edited during removal of false trigger photos prior to database transfer. Other recommended protocol changes include mandatory camera battery changes intervals (no matter how much battery the camera shows remaining) and rain/snow protection for the cameras (no matter how waterproof the camera's label indicates).

6.3 Continuing Research on Site

If research was to continue on this site, there would be several directions worth exploring. With regard to Camera sites 1, 3, 4, and 6, further wildlife research on this site is required to develop a more complete understanding of seasonal changes in wildlife. A larger sample size containing multiple years of data in the same four camera site locations would allow the development of more accurate forecasting for any missing data by the date or month. This would be preferable to using average (mean) species DET rates by camera location over the entire installation period to forecast missing data.

Another interesting option for continued study involves adding cameras to capture wildlife entering and exiting the site. By completely surrounding the perimeter of the site with cameras and selecting camera locations weighted toward high wildlife sign (particularly game trails), a more complete analysis of wildlife travel through the site would be possible. Capturing wildlife entering and exiting the property would provide directional travel information. Cameras already installed in the interior of the property help determine species presence on site and are selected in part by habitat type. The addition of exterior cameras would aid in determining directional wildlife travel and potentially capture wildlife crossing I-5 at this location.

Other options for continued study on site include the placement of multiple cameras in each of the habitat types present on site to better determine trends in species DET by habitat, and selectively targeting for endangered, threatened, or species of concern like western gray squirrel (*Sciurus griseus*), Mazama pocket gopher (*Thomomys mazama* ssp.), or western pond turtles (*Actinemys marmorata*).

6.4 Recommendations

6.4.1 The Northern Linkage Zone

More research is recommended to continue growing the base of knowledge that supports the validity of these habitat connectivity models responsible for identifying the I-5 Northern Linkage Zone. The use of currently unutilized methods for determining habitat connectivity, mentioned in this thesis, is recommended to provide multiple perspectives on wildlife presence within the I-5 Northern Linkage Zone and Southwest Washington in general. From the wildlife data collected on this property, this thesis recommends that an I-5 wildlife crossing structure be built nearby to benefit the wildlife recorded during this study. To improve and preserve connectivity within the I-5 Northern Linkage Zone, this thesis recommends the creation of new wildlife crossing structures, modification of existing roadway structures to better facilitate wildlife permeability, conservation of lands with high connectivity, and continued research.

This study recommends expanding partnerships with private landowners within the I-5 Northern Linkage Zone such as what exists on the study site of this thesis. These partnerships can include additional research studies as well as incentives to limit habitat loss and the subdivision of property. Any property size is beneficial, however larger parcels, 100 acres or more with high connectivity, represent a valuable resource for wildlife connectivity and provide significant opportunities to enhance wildlife linkages like the I-5 Northern Linkage Zone.

6.4.2 Site Recommendations for Habitat Restoration and Connectivity research.

To improve wildlife habitat and connectivity within the property, this thesis has several recommendations. Restore habitat within portions of the site. To restore Oregon white oak woodlands on the property, selective logging, planting of oak saplings, and prescribed burns would be beneficial. Contact the Washington State Department of Natural Resources and establish a Forest Management or Stewardship plan. To restore the prairie grassland habitat, first complete an assessment of the prairie lands on the property to discover if they meet the criteria for Westside prairie Priority Habitat. Whether the site currently meets criteria or not, control invasive/noxious weeds like scotch broom (*Cytisus scoparius*) with mechanical methods and prescribed burns to restore natural systems. Plant and seed native Westside prairie plants in areas with compatible soil types. For restoration of the ponds and forested wetlands on site, first complete a wetland delineation survey and consult the Washington State Department of Ecology about the hydrology features on site. Remove invasive wetland species and plant native vegetation. Consult with biologists from Washington Department of Fish and Wildlife about stocking ponds with native aquatic fauna and determine if the property can meet the recovery site requirements necessary for the introduction of western pond turtles (*Actinemys marmorata*). Restrict any new construction or land disturbances to the southern portions of the property that already contain high human activity and existing structures. Make sure that garbage kept outside is properly secured and limit the use of outdoor lighting at night.

6.5 Final Thoughts

Habitat loss, roadways, climate change, and continued degradation of habitat connectivity threaten wildlife resiliency in Washington State and abroad. Habitat connectivity will play an even greater role in wildlife species' health and survival over the next 50 years. There are a limited number of locations in Southwest Washington that contain high habitat connectivity on both sides of I-5 that could provide wildlife with less restrictive travel to core habitat areas. It is unlikely that habitat connectivity surrounding I-5 will improve without intervention and conservation efforts. Wildlife-Vehicle Collisions are costly and dangerous to drivers in Washington State. The benefits to drivers resulting from safe and separate wildlife passages across high traffic roadways are valuable enough in their own right to warrant the implementation of wildlife crossing structures before the benefits to be gained by wildlife are even considered. The I-5 Northern Linkage Zone has been identified as one of the last best chances wildlife have in Southwest Washington to maintain connectivity across the wildlife barrier of the I-5 Fracture Zone. While this study could not provide definitive validation of the LCC connectivity model using real world wildlife Detections from this property alone, it has identified the wildlife species living and traveling though this location that stand to benefit from a nearby wildlife crossing structure.

This study has provided insight to the counts and species present in a portion of the I-5 Northern Linkage Zone. Previous knowledge of habitat connectivity in the area did not include on the ground wildlife data counts. This thesis created a framework for selecting camera locations and a methodology of collecting and processing wildlife camera data. This process can be replicated on private or public lands. The results of this study have been forecast in a way that corrects for errors in collection and provides a standard interval of time, by which others may replicate the process and compare wildlife camera data from other locations.

This study has provided wildlife data from a specific location of particular importance to wildlife and habitat connectivity that is of interest to multiple state agencies, conservation organizations, and private landowners. Species found on this site are representative of a portion of wildlife within the I-5 Northern Linkage Zone that utilize the habitat of this site for travel and resources. This study has identified the species present on this property, bordering Interstate 5, which would benefit from a wildlife crossing structure. If future wildlife crossing structures are to be built in this area, wildlife diversity and abundance data should be a crucial factor in their placement.

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8 Appendix

8.1 Appendix A

Table 8.1

Collection Periods and Missing Data Ranges for All Camera Sites

Camera Number	Active Days/Camera Days Possible	Missing date ranges, no data	Total Days Lost.
Camera 1	(10.01.2020-01.01.2022) -1 day between entire range. First day only active 1/2 day and last day of range active only 1/2 day. 458-1 = 457 457-159 = 298 Days 298 Active /457 Possible 65.21% Active	02.22.2021-03.17.2021 03.31.2021-04.07.2021 *04.22.2021-07.26.2021 10.29.2021-12.07.2021 * (From 4/22/21-7/26/21 only two data points exist due to corrupted files and battery issues. One Bird on 7/13/21 and one Black-tailed deer on 6/12/21. To include these data points in the study, 2 Active Camera Days were removed from Days Lost.) *	21-1= 20 Days 8-1= 7 Days 96-*(1+2) =93 Days 40-1 = 39 Days **Total Days Lost = 159 Days**
Camera 2	(10.01.2020-11.20.2020) 42-1=41 41/41 Days or 100% Active	No missing date ranges	**Total Lost = 0**
Camera 3	(10.01.2020-01.01.2022) 457-117=340 Days 340/457 74.40% Active	03.31.2021-04.07.2021 05.15.2021-.05.29.2021 06.08.2021-07.13.2021 *10.29.2021-01.01.2022* *(Source photos and data were accidentally deleted from database, 3 data points, on 3 different days, existed from this data set by email only. These 3 were added back to data. bear, bobcat, deer.)	8-1=7 Days 15-1=14 Days 36-1=35 Days 65-*(1+3) =61 Days **Total Days Lost = 117 Days**
Camera 4	(10.01.2020-01.01.2022) 457-14 = 443 Days 443/457 or 96.94% Active	10.30.2020-11.06.2020 03.31.2021-04.07.2021	8-1=7 Days 8-1=7 Days **Total Days Lost = 14 Days**

Camera Number	Active Days/Camera Days Possible	Missing date ranges, no data	Total Days Lost.
Camera 5	(11.20.2020-12.14.2020) 25-1 = 24 Days 24/24 or 100% Active	No missing date ranges	**Total Lost = 0**
Camera 6	(12.14.2020-01.01.2022) 384-1= 383 383-94 = 289 Days 289/383 or 75.46% Active	03.12.2021-04.07.2021 05.12.2021-06.09.2021 07.04.2021-07.19.21 09.10.2021-09.18.2021 09.20.2021-09.30.2021 11.21.2021-12.07.2021	27-1=26 Days 20-1=19 Days 16-1=15 Days 9-1= 8 Days 11-1=10 Days 17-1=16 Days **Total Days Lost = 94 Days**
Camera Total	**1435 Active/1819 Possible Days: All Cameras Average (Mean) 78.89% Active**		**384 Total Active Camera Days Lost**

Figure 8.1

Detections over Time by Species 1 Hour Interval