Analysis of Megafauna Detections

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Abstract

Animal crossing structures are increasingly being recognized as a way for transportation agencies to reduce dangerous encounters that motorists have with wildlife. At the Washington State Department of Transportation, this was recognized and implemented as early as the mid 1970's, but little monitoring followed the installation of these structures to better understand how wildlife interacts with the highway system if a safe crossing opportunity was present. It is a long held theory that wildlife is most active at crepuscular periods, but does that theory hold true for animals that use these crossing structures to access the other side of the highway? For this thesis I monitored 6 wildlife crossing locations on Washington State highways using motion triggered trail cameras to better understand species composition and temporal patterns of animal crossings. Camera images were converted to detections data that included species, time, and ambient temperature when the animal was detected. Detection times were included in a data matrix that related each detection to sunrise and sunset. Chi Squared tests were used to analyze whether peak activity was concentrated in the hour before and after sunrise and sunset. Temperature at time of detection was analyzed to determine if animals are more active during particular temperature ranges. Traffic volume data for the subject stretch of roadway was also analyzed to determine if elevated volumes are a predictor of frequency and use of crossing structures. I expect this information to be used by the Washington State Department of Transportation to produce a better understanding of the use of crossing structures by wildlife.

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1. Introduction

Human expansion is occurring at levels never experienced in history. An expanding transportation system is inevitable with this current pace of human expansion. With this expanding infrastructure comes a greater risk of animal-vehicle collisions that further exposes flora and fauna to the risks of habitat fragmentation and the negative consequences of island biogeography. Transportation planning should occur with awareness of roads in the context of surrounding habitats, ecosystems, and ecosystem processes as well as the infrastructure network and land use. As a result of these trends, the consideration of wildlife and their habitats in road planning and construction is becoming increasingly common. The term for this new paradigm is road ecology.

Road Ecology by definition suggests an interdisciplinary approach to the problems facing transportation agencies, wildlife, and other stakeholders. It is defined as a sub-discipline of ecology that focuses on understanding interactions between road systems and the natural environment including hydrology, wildlife biology, plant ecology, population ecology, soil science, water chemistry, aquatic biology, and fisheries (Lloyd, 2011 and Forman et al, 2003). Although road ecology is still in its infancy, a piecemeal approach to this paradigm would be useless. Therefore, theories and concepts that encompass road ecology only work from an interdisciplinary approach.

Involving stakeholders and the public at all levels of the planning and implementation of a project is essential to success. Non-governmental Organizations (NGOs) and the public have taken advantage of their ability to lobby government officials to persuade them to adopt measures that protect the driving public. These measures also provide safe crossing opportunities for animals, allowing natural gene flow, and continued use of historic ranges.

2. Background

2a. History of Road Ecology

Although the paradigm of road ecology has only recently been nationally recognized as a sub-discipline of ecology, interactions between wildlife and roadways date back to before European settlers arrived. Many of the main highways in use today were once historic trails established by the Native Americans. Take I-90 for example; the I-90 corridor through the Cascade Mountains includes the lowest elevation pass to eastern Washington. Puget Sound tribes, such as the Nisqually, would journey to the mountains in search of wild game, berries, materials for clothes and baskets, and for religious purposes. Eastern Washington tribes used that same corridor from the east to access the mountains for their needs as well. These native peoples also travelled across the mountains to trade and visit relatives, since inter-marrying between groups was not uncommon. Many of the local wildlife species recognize these well-traveled routes and use them for migration from summer to winter forage areas in the fall and reverse the migration in the spring, when the snow melts in the highlands.

I-90 has evolved over the last century. Starting as a hunting and gathering trail, it became a wagon trail accessible only when weather allowed. Eventually it developed into a two lane mountain road, and as transportation evolved, the route became a six lane highway, linking the Northwestern corner of the United States to the rest of the country. Wildlife has been present during the whole metamorphosis of the corridor and they recognize the highway is an obstacle that cannot be easily navigated around.

The challenge facing transportation agencies today is the mandate to provide a safe and efficient transportation system while following sound environmental practices in the planning, design, construction, operation, and maintenance of Washington State Department of Transportation's (WSDOT) transportation systems and facilities (Executive order 1018.01, 2007). Washington State is trying to improve the impacts that roadways, and especially busy roadways, have on the environment. As a result, in July 2007, WSDOT Secretary Douglas MacDonald signed Executive Order E 1031. This Order recognizes the need for the Department of Transportation to realize the impacts that the transportation system places on the environment and outlines goals for biodiversity protection. Through the Environmental Services Office within WSDOT, the goals set forth by the Executive Order are (Executive Order 1031, 2007):

> 1. To identify affected fish and wildlife habitats as early as possible during the planning process for projects and programs and in preparation of regional and statewide long-range transportation plans. The planning should seek to

integrate state conservation and biodiversity plans and other available natural resource information. Transportation planning should recognize and respond to particular concerns and opportunities for habitat preservation and the need for habitat connections. The earlier that habitat concerns are taken up in project planning, the likelier that good habitat approaches to state investment in habitat protection and habitat connectivity can be incorporated into projects.

2. To locate specific opportunities to restore habitat connectivity already damaged by human transportation corridors. Such opportunities should be prioritized for maximum ecological benefit by taking account of such factors as the multiplicity of benefits shared, as well as the opportunity to support recovery of threatened and endangered species, the long-term security and viability of the habitat connection, and the cost effectiveness if achieving connectivity gains. Such opportunities can be located and achieved both as part of capital projects and in ordinary maintenance activities.

3. To cooperate and coordinate with other agencies involved in wildlife habitat protection. This aim will ensure compatibility of natural resource and habitat management in adjacent areas so that wildlife connections provided at roadways will link to functional and permanently protected wildlife corridors. Ultimately, WSDOT and other agencies should seek to develop a statewide habitat connectivity plan to better integrate overall habitat management with transportation planning.

4. To support the use of site appropriate native plant species in roadside landscaping and vegetation management and to protect adjacent natural plant communities.

5. To develop and follow design criteria for transportation structures that help promote fish and wildlife movement and minimize habitat degradation. WSDOT recognizes the Washington Department of Fish and Wildlife manual, *Design of Road Culverts for Fish Passage (2003)*, as a primary source for information on fish passage designs. Guidance, criteria, and manuals for structures affecting terrestrial species will be developed.

6. To protect and enhance important wildlife habitat areas near highways on highway right of way in ways compatible with highway operations, and to support efforts to promote the traveling public's awareness and enjoyment of wildlife in the state.

Even before WSDOT's Executive Order E 1031 was enacted, the WSDOT's Environmental Services Office was coordinating a collaborative, multi-organization effort to address habitat connectivity. The Washington Wildlife Habitat Connectivity Working Group, led by Washington Department of Fish and Wildlife (WDFW) and Washington State Department of Transportation was formed from voluntary public and private organizations. This group recognizes a science based approach to transportation and community planning. Its function is to recognize the role state agencies, tribes, and public stakeholders have in conserving and connecting critical habitats. The Working Group's mission statement sums up their objectives: "*Promoting the long-term viability of wildlife populations in Washington State through a science-based, collaborative approach that identifies opportunities and priorities to conserve and restore habitat connectivity*" (WHCWG, 2010)

During most of the twentieth century, road construction focused on roads integrating with the terrain and vegetation as a means of aesthetic appreciation. It was not until the later part of the twentieth century that wildlife and natural processes were considered as part of the planning process for road construction. This came about as the increase in vehicles using the roadway system also saw an increase in the number of wildlife vehicle collisions. Figure 1 shows that while the number of car accidents per year has remained relatively constant, wildlife vehicle collisions are trending upward.

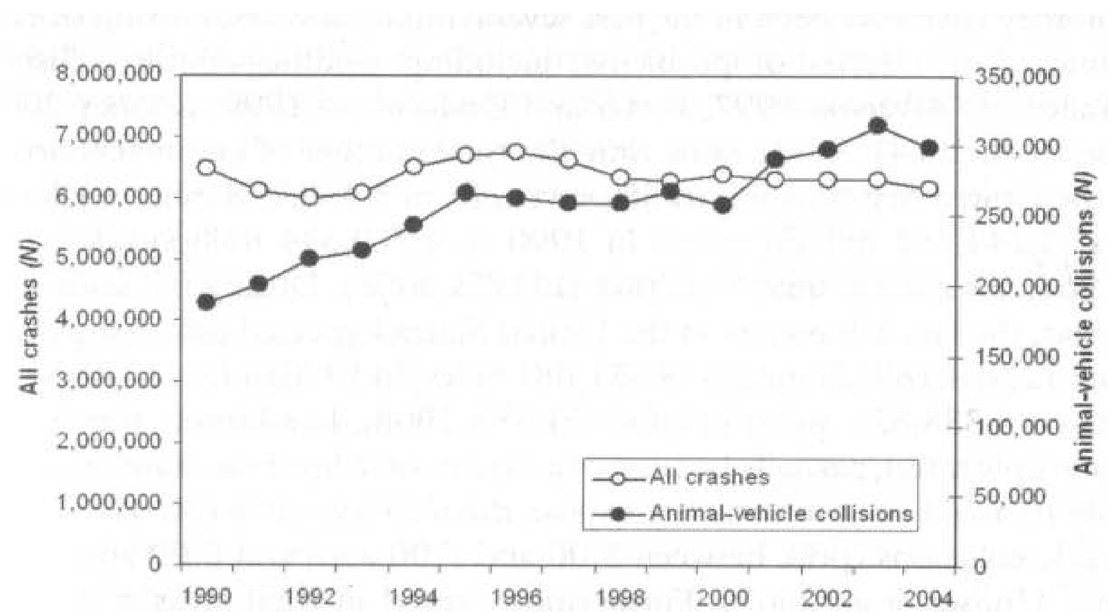


Figure 1. All car vehicle collisions compared to animal vehicle collisions (Huijser and McGowen 2010)

Not only do wildlife related collisions cost the country over $8 billion a year (USDOT, 2008), they may be significant enough in some places to affect populations of some animals. Mortality from wildlife vehicle collisions can affect population growth rates if mortality is greater than recruitment from immigration and birth rates. If animals are afraid to cross roads, subpopulations could suffer from a lack of gene flow or demographic dispersal.

There is evidence that some animals avoid roads at various distances. For example, grizzly bears (*Ursus arctos horriblis*) have been documented to avoid roadways by 500 meters (Waller and Servheen, 2005). Deer (*Cervidae* family) and elk (*Curvus Canadensis*) studies indicate a 200 meter avoidance buffer (Rost and Baily, 1979). Wolves (*Canis lupus*) are known to avoid high density roadway areas as well (Thurber et al, 1994).

Animals are not only impacted by animal-vehicle collisions, but by habitat fragmentation (Charry et al, 2009). Although direct habitat loss appears small from an ecosystem perspective, occupying only 1% of the total land area in the United States, the ecological impact is much greater affecting 15-20% of the landscape (Charry et al, 2009). Large-scale edge effects can drive species that inhabit central habitat core to local extirpation from habitat fragments and protected areas. These species are among the most threatened species in fragmented landscapes (Ewers et al, 2008).

Wildlife needs freedom of movement across the landscape and requires the following (Beckmann and Hilti 2010):

1.) Large expanses of land for their daily, seasonal, or annual ecological needs;

2.) Migratory movements between seasonal ranges for food and breeding; and

3.) Connection between separate subpopulations for genetic variation.

These criteria are especially true for animals that are rare, low density, or wide-ranging (Beckmann and Hilti, 2010). Some studies have indicated that habitat fragmentation is the number one source for diminished populations of animals whose habitat is near a road system (Hilti et al, 2006).

Solutions to current habitat connectivity problems have been explored in Banff, Canada. The park has developed a system of safe wildlife crossing opportunities. They include a series of wildlife crossing structures that allow opportunities for wildlife to cross the highway safely, 8' tall exclusionary game fencing to funnel wildlife to the crossing structures, and a series of jump-outs that allow trapped animals inside the exclusionary fencing an opportunity to escape the roadway.

2b. Banff National Park, Canada

Since 1975, Parks Canada has made habitat connectivity a priority for the large ungulates and carnivores in and around Banff National Park. The Trans-Canada Highway (TCH) bisects the park as it runs along the Bow Valley floors. These same valley floors are used as migratory corridors for species with migratory habits such as bighorn sheep (*Ovis canadensis*), elk, and deer species. Other species with large home ranges also benefit from a series of animal crossing structures that facilitate freedom of movement within their home ranges.

Parks Canada has recognized the vital role of the TCH in providing a corridor that connects eastern and western Canada. The highway, originally built in the 1950's, started out as a scenic two lane mountain road. Today it sees 25,000 vehicles per day in the busy summertime tourist season. This is also home to the most diverse assemblages of ungulate and large game species in North America. A busy highway running straight through the park gave Canada and its parks department an opportunity to create one of the most wildlife friendly stretches of road in the world.

Roadways affect wildlife populations in several ways: increased mortality due to wildlife-vehicle collisions, creating a barrier preventing animals from moving freely, reducing habitat, and facilitating the spread of invasive species (Foreman et al, 2003). The most obvious affect comes from wildlife vehicle collisions. Wildlife vehicle collisions impact humans and animals alike; affecting human safety, causing property damage, increasing insurance costs and impeding wildlife conservation (Beckmann and Hilti, 2010). Different species have different needs for survival and mating, therefore a broad approach to connect habitats in Banff National Park was needed.

In 1979, The Canadian government recognized the increased traffic volumes on the TCH and proposed a project that would double the capacity of the highway by adding an additional lane to each lane of traffic, a process known as "twinning" the highway (Ford et al, 2010). The project was to proceed in a series of phases, beginning with Phase 1 in 1979, continuing through today with phase 3B (Ford et al, 2010).

Phase 1 covered the first 13 kilometers of the TCH through Banff. The Federal Environmental Assessment and Review process for this portion of highway identified wildlife vehicle collisions as a major source for concern for motorists and wildlife conservation issues. During 1978 alone there were over 110 elk vehicle collisions in these first 13 kilometers (Ford et al, 2010). Therefore, the twinning project focused on mitigation measures to reduce wildlife vehicle collisions, especially for larger animals such as ungulates and carnivores. A wildlife exclusionary fence 2.4 meters (7.9 feet) high was constructed on both sides of the highway to keep animals from entering the roadway. The fence funneled animals to one of six underpasses that allowed for animal movement under the highway. Figure 2 shows an example of exclusionary fencing.

Figure 2. Wildlife fencing installed to keep deer and elk off of the roadway (www.wsdot.wa.gov, 2012.)

Phase II of the twining project began soon after Phase I, covering the next 14 kilometers. It was competed in September 1987 with the exclusionary fencing and four additional animal crossing underpasses. The two phases created a total of ten animal crossing structures in 27 kilometers.

Next, the Canadian government submitted plans to widen the next 21 kilometers of the TCH, Phase III. This was a time of new mitigation measures for the Canadian government. They introduced an ecological integrity based management system within the national parks. This management system recognized the need for large carnivores to be considered as part of mitigation plans and should receive priority for animal crossing structure design (Parks Canada, 1995). The fence system saw improvements in functionality. A one meter section of chain link was added to the bottom of the fence and buried to discourage animals from digging and passing under the fence (Ford et al, 2010).

Originally, underpasses were planned as part of mitigation, but the recent recognition of large carnivores as a priority caused the transportation community to look closer at what animals were using what structures. They found that some of the large carnivores (grizzly bears and wolves primarily) preferred not to use the confining underpasses. Consequently, two 50 meter wide overpasses were constructed in Phase III along with ten additional underpasses. The wide open spans proved preferable to the target species as well as several ungulate and small mammal species. Phase III was completed in 1997 for a total of 23 wildlife crossing structures over 45 kilometers of highway.

Monitoring the structures and fence for effectiveness fell on Parks Canada. Park wardens, research biologists, and other trained staff drive the improved stretch of highway on a daily basis, looking for signs of breaches in the fencing as well as animal carcasses. This allows for complete and accurate data regarding the effectiveness of the fence and crossing structure system as a whole. The information collected is stored in a central database and includes the date, coordinate and descriptive location, species, number of individuals, and information obtained from necropsies (Ford et al, 2010).

At the completion of each phase, a pattern of reduced wildlife vehicle collisions was emerging. The fence and crossing structure system reduced wildlife vehicle collisions with ungulates by 90% and with large mammals in general by 86% (Clevenger et al, 2002). The results are a promising sign that the mitigation measures are working to reduce wildlife vehicle collisions.

Monitoring animal crossing structure use proved to be different from monitoring the exclusionary fence. Researchers wanted to know more about what species were using what structures and how often they were being used. Before the advent of motion triggered cameras, a series of sand track pads were deployed. The sand track pads capture the animals' tracks as they move in and around the crossing structures. Monitoring the track pads became a task that occurred every 2-3 days and accurately assessed what animals preferred what structures. Monitoring in this fashion took place for 12 years. Species, direction of movement, and number of individuals of megafauna were recorded. Figure 3 shows an example of track pads and the maintenance required for their use. Recently, motion triggered cameras have replaced the sand track pads. Motion triggered cameras offer greater reliability to capture animals using the crossing structures. They also add the convenience of a longer uninterrupted monitoring period, often going up to a month in between scheduled maintenance for changing batteries and memory cards. The cameras also provide recordings of times of animal crossings, animal behavior in response to crossing structures, and ambient temperature during each crossing detection.

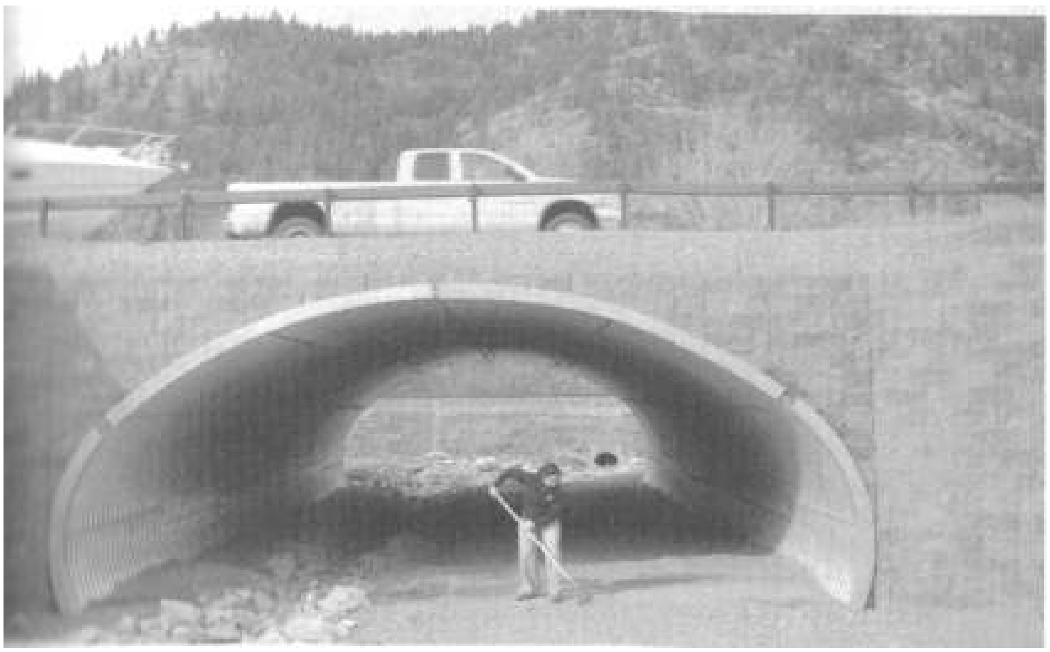


Figure 3. A biologist rakes a track pad after identifying species composition (Becker and Basting, 2010)

Armed with a better understanding of how animals respond to the different crossing structures, the final 35 kilometers of the TCH is currently under construction. This area consists of a different assemblage of species than the first three phases. It is home to more large mammal species with low population densities that are sensitive to human disturbances, such as wolverine (*Gulo gulo*), grizzly bears, lynx (*Lynx Canadensis*) and moose (*Alces alces*), compared with the typical fauna species found in the middle and lower Bow Valley, such as cougar (*Felis concolor*), black bear (*Usis americanus*), wolves, elk and deer (Ford et al, 2010). Consequently, larger, more open crossing structures (70 meters wide overpasses instead of 50 meters) at closer intervals (roughly 1.5 kilometers between structures instead of 2.7 kilometers) are planned for the final stretch of the twinning project (Ford et al, 2010).

Figure 4. An animal crossing overpass structure in Banff National Park (ARC solutions.org, 2012)

The twinning project on the TCH in Banff National Park has produced three main lessons for other DOTs:

1. A long term monitoring program is needed to fully understand animal behaviors and animal crossing structure effectiveness (Ford et al, 2010). A minimum of three years of data is needed to fully grasp the effectiveness of the crossing structures. For some species, such as grizzly bears and wolves, it may take up to five years for them to feel comfortable enough to use a crossing structure (Parks Canada Website www.pc.gc.ca, 2011). This allows time for resident animals to recognize where the opportunities are for safe crossings and what time of day to feel comfortable enough to use the structure. That minimum length of time

also allows for migratory species to establish a migratory corridor for future generations that include safe places to cross highways provided by these structures.

2. Use a diverse mix of crossing structures. By using a mix of under and overpasses, culverts and expansive bridges, and monitoring them for the minimum length of time described above, highway planners were able to determine the appropriate crossing structure for a particular target species in a cost effective manner (Ford et al, 2010).

3. Mitigation effectiveness should not be measured to only include the reduced number of wildlife vehicle collisions, but how effective the structures are in facilitating wildlife gene flows, population and subpopulation dynamics, and ecosystem functions and processes (Ford et al, 2010).

Looking at Banff National Park as a case study, research and observation prove the animal crossing structures to work. As of July 2010, eleven different species of large mammals have used 24 animal crossing structures more than 220,000 times since 1996 (www.pc.gc.ca, 2011). The key to making the project an overall success is communicating to the public, especially to local communities, that dollars used for wildlife crossing structures are justifiable. Camera images and video footage provide the best evidence to the public that creating wildlife crossing opportunities is a good decision for the driving public and wildlife alike (Ford et al, 2010).

2c. WSDOT Study / Internship

Washington State Department of Transportation (WSDOT) has long recognized the importance of keeping wildlife off its road surfaces. They are using interns to continue the work of Patricia Cramer Ph.D. of Utah State University and Julia Kintsch of ECO-resolutions, LLC who were contracted by the

WSDOT to perform a permeability study of existing structures for terrestrial wildlife. The researchers were hired to develop a Passage Assessment System (PAS) to help WSDOT evaluate existing transportation infrastructure for its ability to provide terrestrial wildlife movement from one side of a roadway to another, without the animal crossing the road at grade. The PAS system ranks infrastructures based on Structural Functional Classes, which describes the type of bridge or culvert. The system creates a common terminology of crossing structures used by animals as well as assessment of the suitability for individual animal species, classifying them into Species Movement Guilds (WHCWG 2010). The system was then field tested along Washington roadways in linkage areas identified in the Washington Statewide Habitat Connectivity Assessment of the Washington Connected Landscapes Project: Statewide Analysis (Kintsch and Cramer 2011). To validate the field tests, a series of motion triggered cameras were installed near known animal crossing locations to assess animal use and habits when using or approaching these structures. Seven locations were initially selected, but due to theft and other logistical reasons, some locations were monitored for only a couple of months.

This study is using the images captured during that initial study and continuing monitoring efforts to assess species composition and preferred crossing times. The sites examined in this thesis contain at least a full years' worth of monitoring, with two exceptions. The first exception is the western animal crossing structure on I-90 near North Bend. This site has less than a years' worth of data but was included due to its close proximity to the eastern I-

90 animal crossing structure. These structures were installed during the same road construction upgrade of I-90 in the mid 1970's and have established themselves as successful crossing structures for over 35 years.

The other exception is the fish passage culvert structure at Deadman Creek on US 2 in Spokane. After camera installation in the summer of 2011, the number of crossings by white-tailed deer (*Odocoileus virginianus*) quickly stood out as being very successful with an average of over 6 (6.3194/day) deer detections per day for the first six months of monitoring. Another way to look at it is the structure averages one white-tailed deer detection every three hours and 20 minutes.

The other locations where crossing structures were monitored are Willapa River at SR 6, Mosquito Creek at US 101, Tucker Creek at I-90, and the eastern animal crossing structure at North Bend at I-90. These sites also represent the diversity of habitats and deer species found in the state of Washington.

2d. Site Location

SR 6 at Willapa River

The Willapa River flows under State Route 6 just to the east of Raymond. The bridge structure is an open span concrete bridge with riparian vegetation associated with it. Managed forest land is in the vicinity as well as nearby rural residences. This site is frequented by fishermen during the fall salmon and winter steelhead season. It has been established for over 20 years and allows for passage of larger animals that prefer a more open crossing opportunity. There is no exclusionary fencing associated with this structure.

<u>US 101 at Mosquito Creek</u>

Just south of the Montesano cutoff (State Route 107) on US 101 is Mosquito Creek, a tributary of the North River. A three sided box culvert was installed within the last three years to aid spawning salmon and trout, replacing a smaller corrugated pipe that spanned the width of the highway. Using current standards for fish passable culverts, a stream simulation model was used to determine the size of the new installation. This approach provides dry stream banks inside the culvert for most stream flow conditions. WSDOT identified the crossing structure as a priority for small and medium-sized animals, but suggested that it was too small for larger animals with broader ranges, such as elk and black bear. The structure measures 7 feet high x 15.75 feet wide x 138 feet long. At normal flows, Mosquito Creek allows small animals to utilize the exposed banks in the box culvert, but most deer pass through the structure by walking in the streambed. The surrounding habitat is managed Douglas fir (*Psuedotsuga menzesii*) / Western hemlock (*Tsuga heterophylla*) forests with no associated fencing to encourage animals to use the crossing structure. Cameras were installed June 9, 2010 facing the openings of each side of the structure. WSDOT estimates average traffic flow at 5,000 cars per day (Kintch and Cramer, 2011).

<u>I-90 at Tucker Creek</u>

The structure at Tucker Creek on I-90 spans a small seasonal creek. A larger structure was installed in recent years to aid snow melt and water runoff under I-90. A double box culvert was utilized with some exposed banks on each side of the underpass. The structure measures 4’10” high x 9’ wide x 58’3” long. At normal flows, Tucker Creek allows small animals to utilize the exposed banks in the box culvert. Black-tailed (*Odocoileus hemionus columbianus*) and mule deer (*Odocoileus hemionus*) pass through the structure using the streambed. A railroad runs parallel to the highway along the south side of the structure. The surrounding habitat and vegetation are composed of managed forest land with nearby residential areas. There is a barbed wire right of way fence associated with both sides of the openings. Traffic volumes vary seasonally, but average 25,000 to 65,000 cars/day (Kintsch and Cramer, 2011).

Deadman Creek US 2 Spokane

Just north of the city of Spokane US 2 intersects Deadman Creek. The culvert was recently replaced to aid access to fish habitat. A large corrugated steel pipe was used to allow natural stream flows through the structure. At normal flows, there are exposed banks on either side of the river channel; however the white-tailed deer that utilize the crossing structure often pass through using the stream bed. The surrounding area is a typical riparian area that has been enhanced through re-vegetation after the installation of the new structure. There is no fencing associated with the highway in this area, however the highway is built on deep fill and steep slopes above the riverbed that act as barriers that impede animals from crossing at grade. The area in the immediate vicinity of the structure is heavily frequented by humans, especially during the warmer summer months.

I-90 North Bend West

On the west side of North Bend, I-90 is a divided highway where there are two pairs of crossing structures: a pair referred to as I-90 West and a pair referred to as I-90 East. Although these pairs of crossing structures are only two miles apart, they demonstrate distinctly different characteristics in terms of crossing structure attributes and the diversity of fauna that are utilizing them.

The crossing structures at I-90 West are open concrete bridges, but are only about 12 feet high inside the structures. There is a small drainage ditch that runs through the structures, but never fully inundates the substrate under the structure, leaving ample dry ground for animals to cross underneath. The north side of the structures is maintained for overhead power transmission lines with a wetland just beyond the cleared transmission line right of way. The south side of the structure is a mixed managed forest that has an abandoned access road that parallels the highway. There is significant human activity on the access road based on cars parked at the entrance to the access road and humans encountered during site visits to change memory cards and batteries in the cameras. There is an 8' exclusionary fence associated with both sides of the crossing structure, however numerous breaches in the fence were present until January 31, 2012 when holes were mended and the fencing material re-attached during a site visit. One location on the north side of the structure is still currently breached due to large downed trees that have landed on the fence.

I-90 North Bend East

The other structures near North Bend are the I-90 East structures. They are large corrugated steel bottomless arch culverts measuring about 12 feet high. A creek runs from the south to the north, but goes sub-surface when it reaches the entrance to the culvert. It re-emerges at the north end of the south structure, meandering freely through the north structure. Both ends of the crossing structure are heavily wooded by managed forests and riparian areas associated with the creek. The vegetation type is consistent throughout the large median area as well. An 8' exclusionary fence is associated with both sides of the highway, however several breaches were present until January 31, 2012 when breaches were mended and the fencing was re-attached. There are still several locations where the fence is damaged due to fallen trees and snags. A chainsaw is required to fully remove the downed woody debris.

To fully understand the significance of both the I-90 wildlife structures some historical back ground is needed.

3. The I-90 Crossing Structures: The Whole Story

In the mid 1960's the Washington State Department of Highways was looking for ways to fix the congestion problems on US 10 that ran through the heart of the growing city of North Bend. During this time the interstate highway system was renumbered to meet the American Interstate Highway System, creating Interstate 90. So in 1964, The Bureau of Public Lands authorized an expansion and straightening of Interstate 90 on the west side of Snoqualmie Pass. An Advanced Study Plan was conducted from Issaquah to North Bend by two consulting firms, Sverdrup, Parcel & Associates and Hammond, Collier & Associates, which concluded in July, 1966 (Final EIS 1973). The plan was approved by the Federal Highway Administration in March 1967. A coordinating committee was formed to include the representatives from various agencies that had a stake in the massive project. A meeting was held on December 3, 1969 in North Bend to discuss the route options the new I-90 would take. Several were considered including using the existing route through the town of North Bend. The Highways Department distributed the plans of the various route options for comment to other agencies and local governments. North Bend citizens voiced their concerns for having a highway run straight through their town that was expected to balloon in traffic volumes over the next thirty years. Following the meetings a request for a corridor was submitted to the Federal Highway Administration and a corridor was approved for plan 'A3.' This would route I-90 to the south of North Bend at the base of Rattlesnake Mountain, allowing for natural growth of North Bend in the future. Unfortunately, it required 2.34 miles of Issaquah Creek to be relocated (Final EIS 1973). Issaquah Creek was a free flowing salmon bearing stream with miles of spawning habitat available to returning salmon. Any alteration of streams in Washington State requires a Hydraulics Project Approval (HPA) permit to be issued by the Department of

Fisheries. The "Hydraulics Code" was enacted in 1943 and gives regulatory authority to the Department of Fisheries to ensure water quality standards during construction projects. The size of the I-90 expansion project was so massive the agency had to share the permit issuance duties with the Department of Game.

The newly adopted National Environmental Policy Act of 1969 went into effect on January 1, 1970. Consequently, the Federal Highway Administration prepared an Environmental Impact Statement in May of 1970. Again, the plans with their environmental impacts were sent to all of the government agencies affected by the project. Most agencies, having to comment on an Environmental Impact Statement for the first time, gave the go ahead on the project. A few notable exceptions were the Washington Department of Ecology stating:

> "…because of their ecological and esthetic values, marsh areas, lakes and streams should essentially be kept in their natural settings (Final EIS 1973)."

The Department of Fisheries voiced concerns over lost salmon rearing habitat and requested other stream sections in the vicinity be enhanced to make up for the loss of habitat. The highways department responded, saying:

> "The Department of Highways does not acknowledge responsibility for replacing lost spawning areas in other sections of the stream outside of the project area" (Final EIS 1973).

The Department of Fisheries agreed to pursue their mitigation through issuance of the HPA permit and ultimately signed off on the project.

The Department of Game, having leverage with the hydraulics permit, voiced their concern that the proposed route would eliminate historic game trails where deer and elk migrate between winter and summer ranges. Carl Crouse, Director of the Department of Game, wrote in a letter, dated July 31, 1973, to the district engineer:

> "In general, you do try to adjust your plans and construction activities to prevent or lessen losses to fish; a similar approach towards terrestrial and avian wildlife is not apparent. This is unfortunate" (Final EIS 1973).

The Highways Department responded by saying:

> "Contacts with the Regional Office for the Department of Game failed to identify methods by which impacts to terrestrial and avian wildlife can be mitigated…" (Final EIS 1973).

However, a letter contained in the draft EIS, dated January 22, 1971, two and a half years before Carl Crouse's letter, from Eugene Dziedzic, Assistant Chief for the Department of Game, stated:

> Construction should provide a tunnel approximately 10' high by 30' wide for the game crossing portion. Lighting should be provided for peak hours of use; the State of Colorado found 64% of their use in tunnel crossings by wildlife occurred between 2:00 am and 5:00 am when the tunnels were lighted. The floor should be left natural, or dirt covered, and entrance and exits left in as natural a state as possible. Fencing should start in the vicinity of Echo Lake and extend to the overpass at approximately mile post 30. Fencing specifications should include use of 11' long, 7" x 9" penta-treated posts, buried a minimum of 2 1/2'. New woven wire fencing of 10 gauge top and bottom wires, and 12 ½ gauge filler wire should be used. The fence should be constructed of 47" widths of such wire, giving it a total height of approximately 7' 10" above the ground. The woven wire should be 2 or 3" above the ground and well stretched and stapled with 1 ½" staples, at a rate of 14 staples per post. The two widths should be laced together with lacing wire of not less than 12 gauge size or hog rings of 9 gauge size" (Final Environmental Statement 1971).

This letter was reinforced by another letter from Carl Crouse who stated:

> "Fencing will be required to eliminate danger from wildlife crossing the highway. These fences, along with tunnels, will minimize wildlife mortality and also assure passage and use of habitat on either side of the highway" (Final Environmental Statement 1971).

The Department of Highways did agree to install exclusionary game fencing along the corridor to eliminate terrestrial wildlife entering the roadway and to funnel game through stream crossings under the highway. However, the Department of Highways was still trying to decide whether to install expansive bridges or culverts. Culverts, being the cheaper option, were preferred, but would restrict fish and wildlife from utilizing them for safe passage under the highway. Presented with mitigation alternatives two and half years prior to the department's response to wildlife mitigation, it appears the Department of Highways was still unsure of the crossing structures.

The Department of Game, having the authority to issue hydraulics permits, insisted the animal crossing structures be installed in order for the permit to go through (DeShazo email). With recent bridge recommendations being ignored on a different project (South King County bridge design (Bob Pfiefer email)) and losing court cases in the recent past (Department of Game vs. Department of Highways in Sunnyside) the Department of Game was not going to back down on this matter.

An Environmental Report was obtained through the Washington State Library system for the reach that contains the present day game crossing structures under I-90 near North Bend. The report does not contain the agreement that was reached; however, through tough negotiations between both departments the animal crossing structures were installed. It's a good thing they did. The I-90 East structure is one of the most successful black bear crossing structures in the Western United States.

4. Research Question and Hypothesis

There has been a long held theory that wildlife is most active at dawn and dusk. The behavior associated with twilight times is called crepuscular behavior. This research aims to quantify crepuscular behavior for megafauna species, therefore my research question is:

> Do megafauna species exhibit crepuscular activity when offered a safe opportunity to cross a highway?

Using the data available on the images from the motion triggered cameras, a quantifiable relationship of peak activity time and sunrise and sunset was developed to disprove the null hypothesis:

H_o: There is no difference in peak activity times for megafauna species, between crepuscular periods and other periods, near our highways.

H_a: Peak activity time occurs within one hour of dawn and one hour of dusk.

5. Methods

As mentioned earlier, this study was initially set up by Dr. Patricia Cramer and Julia Kintsch for WSDOT. Motion triggered cameras were deployed throughout the state at bridges and culverts to capture images of animals that use the structures to safely pass under the roadway. Thousands of images stored on the WSDOT hard drives were catalogued and, with some added formulas for data analysis, the data matrix started to take shape. The finished inventoried pictures describe the camera location, the date of the detection, the time of the initial detection, the temperature, animal species, species gender if identifiable, age class of the animal if identifiable, whether the animal used the structure to pass safely through, and if the animal was repelled. Being repelled refers to an animal that crossed under the structure and, for various reasons, returned the way it came from; usually within a minute. Each animal detection was characterized as a single species. If more than one species was observed in the same image, they were characterized as two separate detections. If a species was observed for a prolonged period of time, it was considered one detection, regardless of whether the same or different individuals were involved. If identifiable features were seen in the image, such as antlers or an ear tag, the number of individuals was characterized accordingly. If there was an interruption between photos of more than 30 minutes, the detection was split into two separate events. Although the primary research considers megafauna, smaller animals were recorded as well. Megafauna was identified as coyote size and bigger. Considering damage caused from wildlife vehicle collisions, WSDOT was primarily interested in megafauna.

The original intent of this study was to provide evidence for the assumption that megafauna is most active at sunrise and sunset. To achieve this, the date of the detection was used as a starting point. Using excel, a numeric value was assigned to each date. Excel calculates the value by how many days the detection was since January 1, 1900, giving each date and time a unique numeric value. Using the time stamp in the photos, the time of the detection was converted to the fraction of the day that it corresponds to. For an example, a detection time and date from Tucker Creek where a mule deer was detected on July 9, 2010 at 4:00 am will be used. July 9, 2010 is 40,368 days from January 1, 1900. 4:00 am equals .16667 of the day; therefore July 9, 2010 at 4:00am is equal to the numeric value of 40,368.16667.

Sunrise and sunset were determined at midpoints of two week intervals associated with the detections. The same formulas and calculations were used to determine a numeric value for sunrise and sunset. The numeric values were then compared to determine how close to sunrise or sunset a detection took place. A formula was then written in excel to choose if the detection was closer to sunrise or sunset (Thanks Judy Cushing), regardless of if it was closer to the past crepuscular time period or the future crepuscular period. The output of the formula left a comparable number that stated how far from sunrise or sunset a detection took place. This information was put into histograms indicating how many crossings occurred during a given time (usually seasonally) and how far from sunrise and sunset the detections took place.

A look at raccoons at I-90 West tested the formulas and methods. Raccoons (*Procyon lotor*) are nocturnal animals so they would be expected to exhibit activity peaks before sunrise and after sunset. Sunrise and sunset are indicated with a black line, which falls in the middle of the graph. The blue bars show night time detections and the yellow bars (not apparent with raccoon detections) show daytime detections. The red bars describe the crepuscular period one hour before and after sunrise and sunset. As the figure 6 graphs show, raccoon activity, indeed, peaks after sunset and before sunrise.

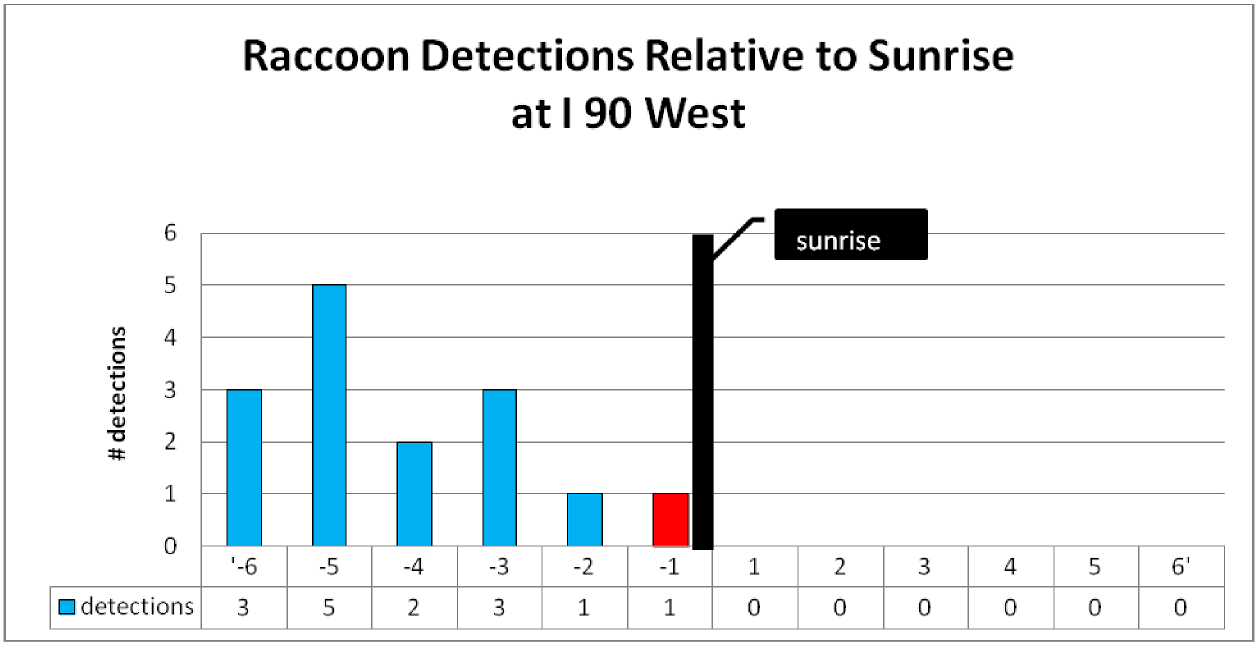


Figure 5. Raccoon sightings relative to sunrise at I 90 West.

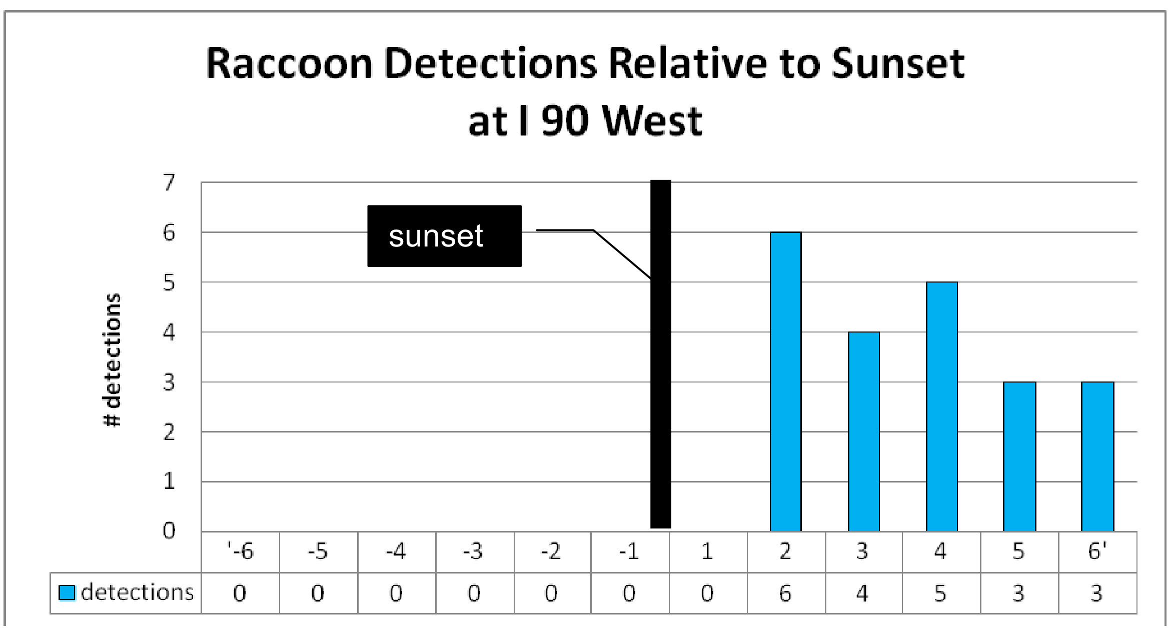
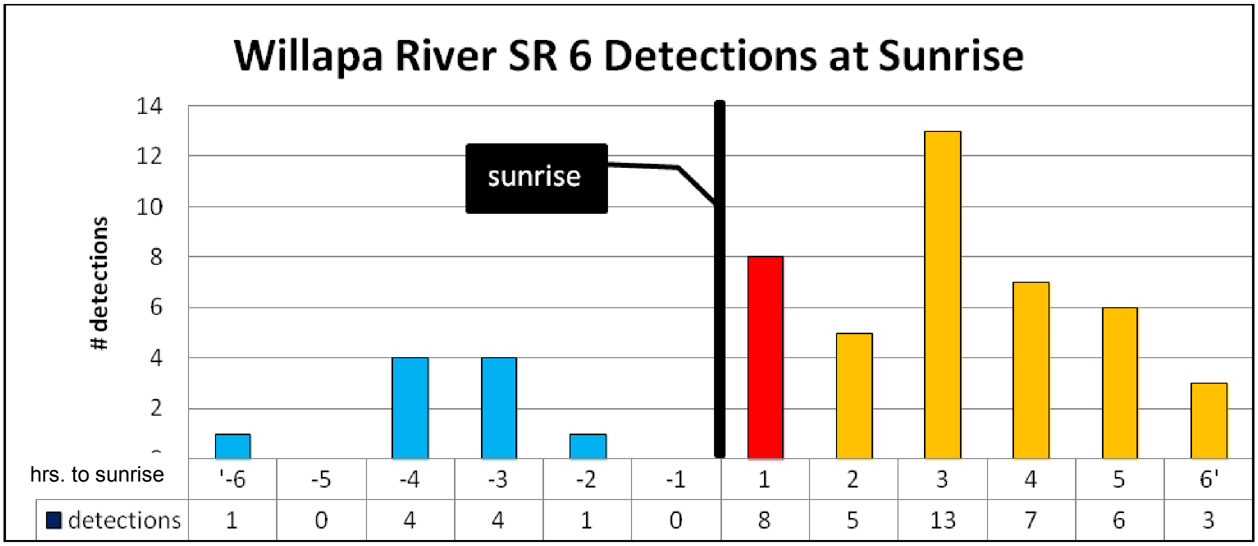


Figure 6. Raccoon sightings relative to sunset at I 90 West.

6. Results

Willapa River

The dominant species at the Willapa River site was black-tailed deer with 101 individual detections and 23.27% of the total species composition. Frequency of detections was .3 deer detections per day. Six coyote (*Canis latrans*) detections were recorded, making up the only other megafauna species at this site. Other species included raccoons, possums (*Didelphis virginiana*), and striped skunks (*Mephitis mephitis*). Summer was the most active season and winter had the lowest detections and frequencies for all species except for possums which exhibited a spike in activity during the winter months. Deer at this site tended to cross at a temperature range of 50-70 degrees Fahrenheit, making up 75.36% of detections. This site lacked enough data to do a standard chi squared test, so the G-adjusted chi squared test was done. The results show that crepuscular activity is not significant at alpha = .05 for sunrise and sunset. See figures 13-16 for the statistical analysis. These results are also seen in the histograms in figure 7:



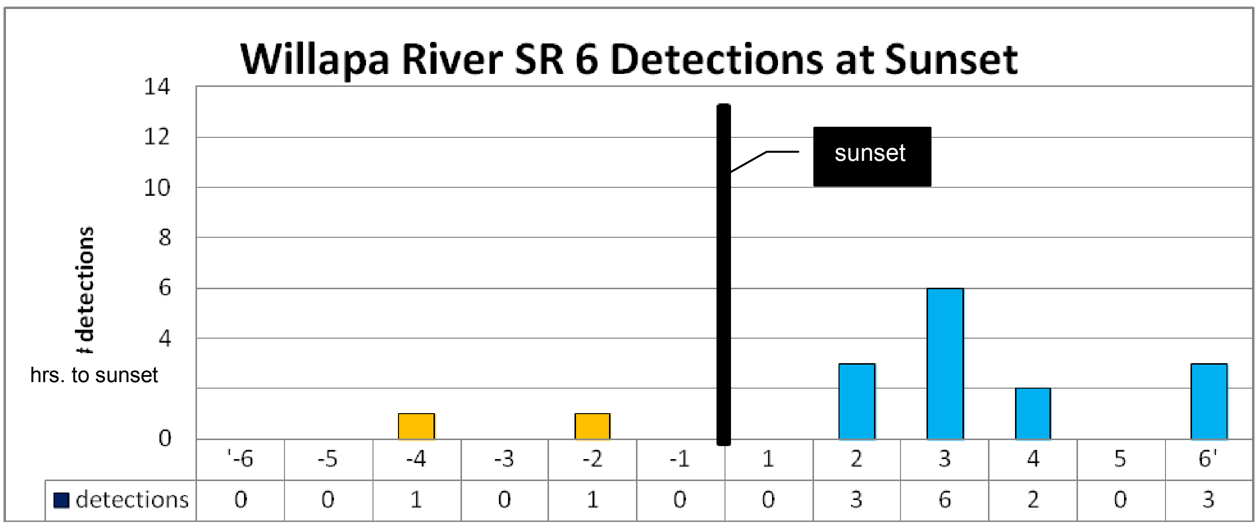
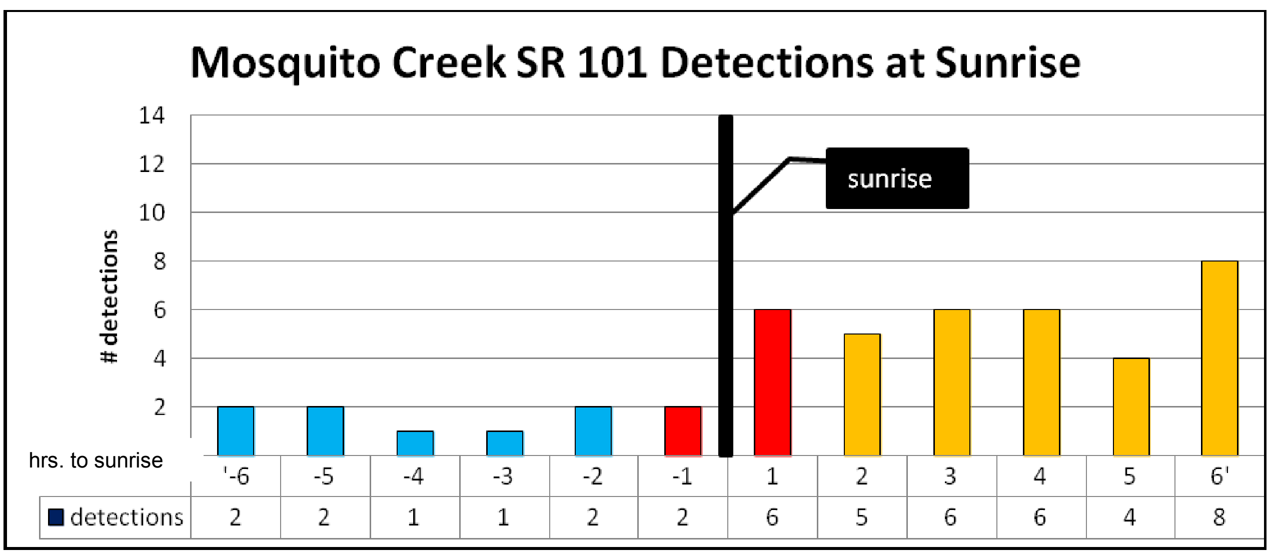


Figure 7. Histograms characterizing detections in relation to sunrise and sunset at Willapa River

Mosquito Creek

The dominant species at Mosquito Creek was black-tailed deer with 164 detections and a frequency of .31 deer detections per day over the study period. Black-tailed deer made up 60% of the species using this structure. Elk were the only other megafauna species captured on camera at his location. They have appeared at the west entrance, feeding on the herbaceous vegetation, but none have attempted to enter the structure. Other species include raccoons which make up 32% and one detection each for a migrating salmon and mink (*Neovison vison)*. Summer exhibited the majority of the detections and no megafauna were detected during the winter months. The preferred temperature range for deer crossings was between 40 and 60 degrees Fahrenheit which accounted for 78.68% of detections.

This site lacked enough data to do a standard chi squared test, so the G-adjusted chi squared test was done. The results reflect that crepuscular activity is not significant at alpha = .05 for sunrise and sunset. See figures 13-16 for the statistical analysis. Histograms in figure 8 describe peak activity times may suggest a peak evening activity period.



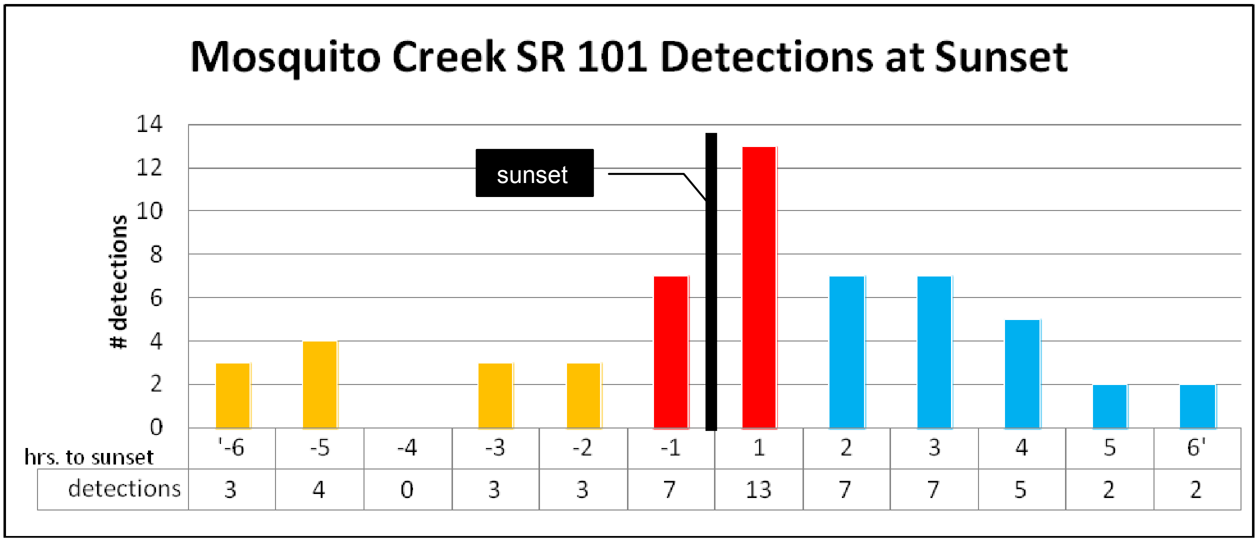


Figure 8. Histograms characterizing detections in relation to sunrise and sunset at Mosquito Creek.

North Bend I-90 West

This study had originally intended the crossing structures at I-90 near North Bend to be considered similar sites or at least similar enough to mirror each other. The structures are approximately the same age, being built in the mid 1970's and with similar habitat on either side of the highway. They are less than two miles apart. The I-90 West site does not have the luxury of having more than one season's worth of data to compare to; however there seems to be a more diverse composition of species using the structure. Black-tailed deer, raccoons, and black bears each make up approximately one third of the species composition (33.95%, 28.4%, and 23.46% respectively). There were a significant number of detections that were unclassifiable at this site due to the camera position at the south end during low light or no light periods. A more advantageous camera position could reveal a single dominant species.

When the study period's data was broken into seasons, a different dominant species emerged for each season. Summer 2011 saw bears as the dominant species with 30 detections and 58.82% of species composition. Black-tailed deer and raccoons were present, but at a lower composition, 17.65% and 13.73% respectively. The fall saw increased activity from black-tailed deer with 34 detections and 44.74% of composition. Raccoon activity also peaked during fall with 23 detections worth 30.26% composition. Black bears fell to 8 detections worth 10.53%. Bobcats (*Felis rufus*) appeared during the fall, although they were rare. As stated before, a more advantageous camera position would have most likely revealed more frequent use by bobcats. Preferred temperatures for the dominant species crossings were in the 30-50 degree range.

This site lacked enough data to do a standard chi squared test, so the G-adjusted chi squared test was done. The results demonstrate that crepuscular activity is not significant at alpha = .05 for sunrise and sunset. See figures 13-16 for the statistical analysis. Histograms in figure 9 do not reveal a particular pattern; however, a noticeable trend emerged from this site: increased activity of large carnivores decreases activity of prey animals and vice versa.

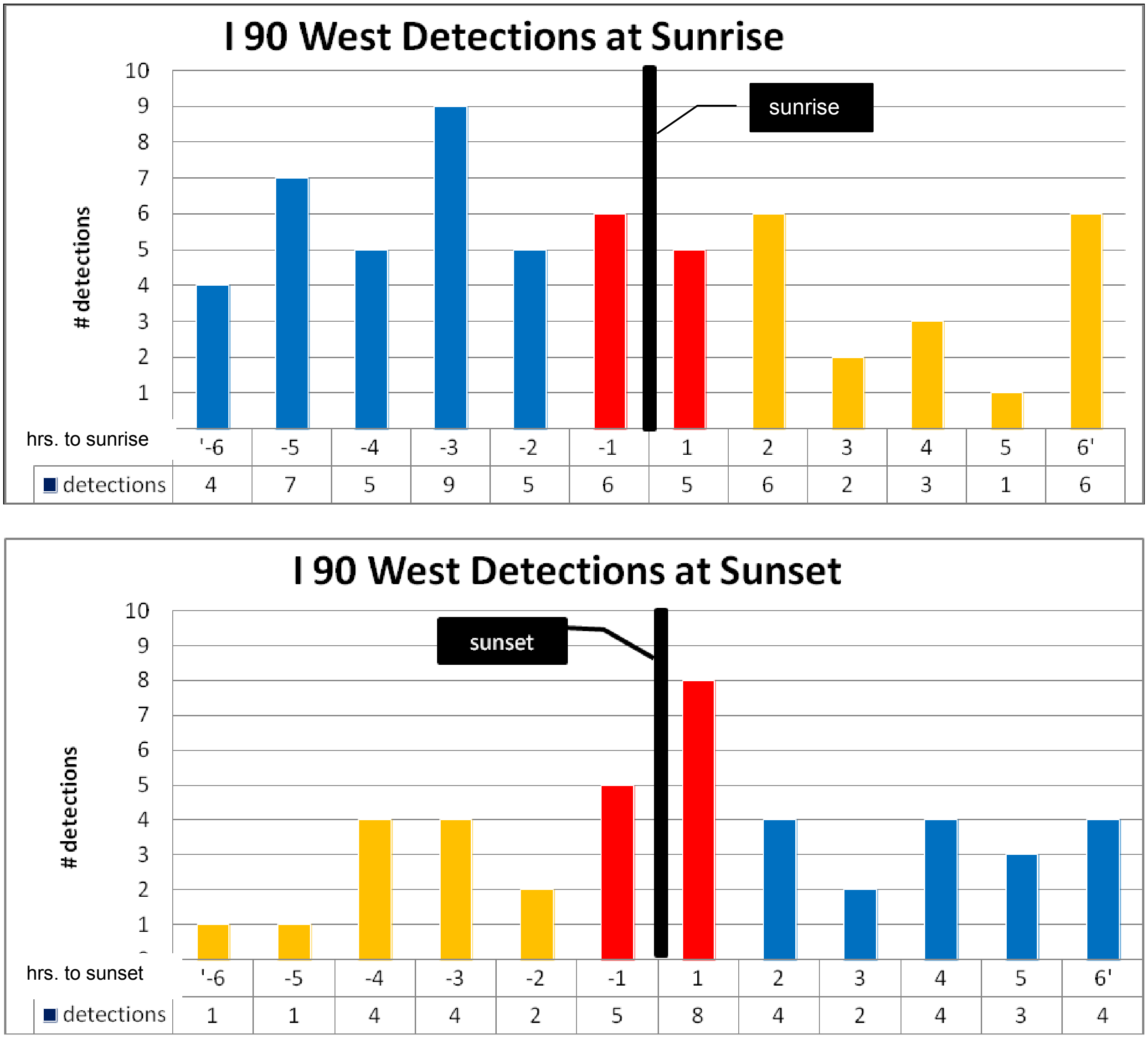


Figure 9 Histograms characterizing detections in relation to sunrise and sunset at I-90 West.

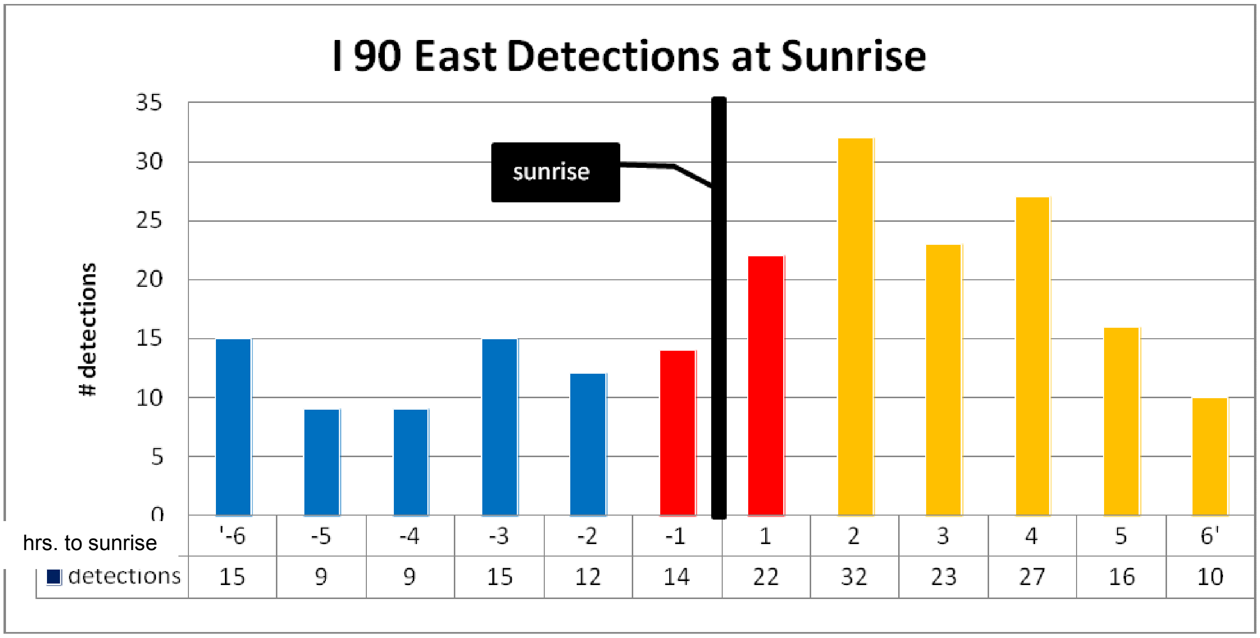
North Bend I-90 East

The site at I-90 East consisted mainly of carnivores. For the study period from summer 2010 to spring 2011, 86.16 % of all animal detections were carnivores. Black bears and coyotes appear to be the dominant species consisting of 40.77% each of species composition. Black-tailed deer were detected, but only 17 animal detections were recorded for the entire study period equating to 9.34%. Bobcats and raccoons were detected as well, each comprising 1.65% of detections. One elk was detected, and it did use the structure.

The second half of the study period, from summer 2011 to winter 2012, demonstrated a remarkable increase in black bear activity. While the previous year recorded 53 bear detections for the whole season making up 40.77% of species composition, during the 2011-2012 season 121 black bear detections were recorded making up 57.62% of all animal detections. Frequency during the summer months increased from .25 bears per day in 2010 to 1.2 bears per day in 2011. The reason for the increase is unclear. Camera operation times and malfunctions could be a contributing factor, but cannot be determined. An equally remarkable trait for this season is that only one black-tailed deer was detected. This, along with the other study site at North Bend, begs the question: *Does increased activity in carnivores deter prey species from using the crossing structure?* Carnivorous animals make up 98.57% of all detections for the 2011-2012 year. Bobcats also increased in frequency with 11 animals being detected as opposed to only 3 detections in the previous study year.

Black bears seem to prefer a temperature range similar to that of black-tailed deer. 92.85% of bear detections occurred in the 40 – 60 degree temperature range. Naturally, peak activity occurs in the summer months.

This site lacked enough data to do a standard chi squared test, so the G-adjusted chi squared test was done. The results demonstrate that crepuscular activity is not significant at alpha = .05 for sunrise and sunset. See figures 13-16 for the statistical analysis. The histograms in figure 10 reveal a preference for crossing during the daytime.



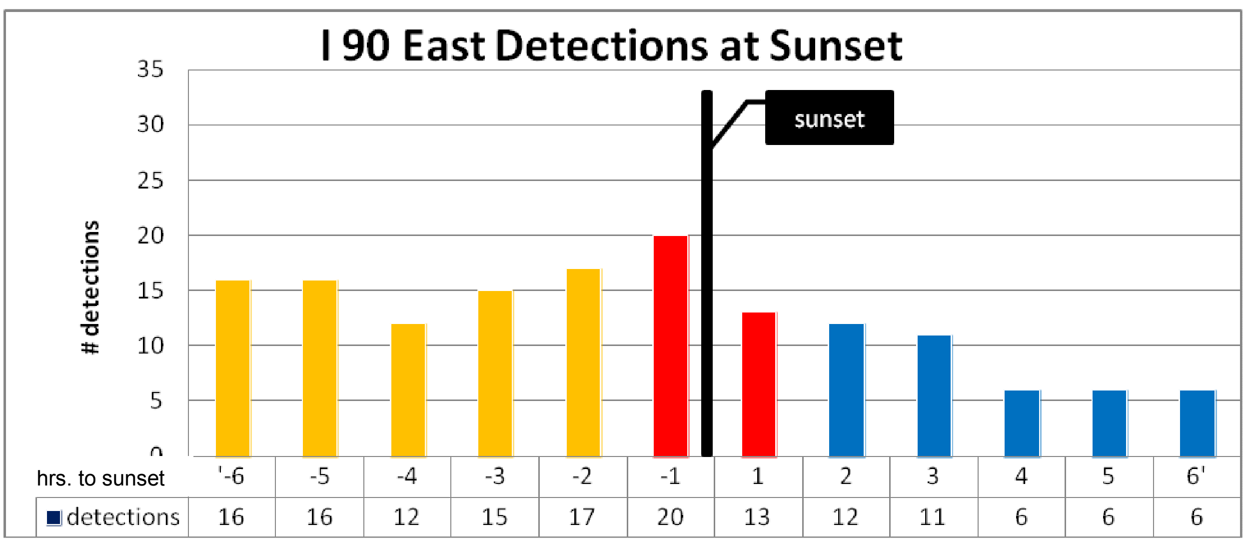


Figure 10. Histograms characterizing detections in relation to sunrise and sunset at I-90 East.

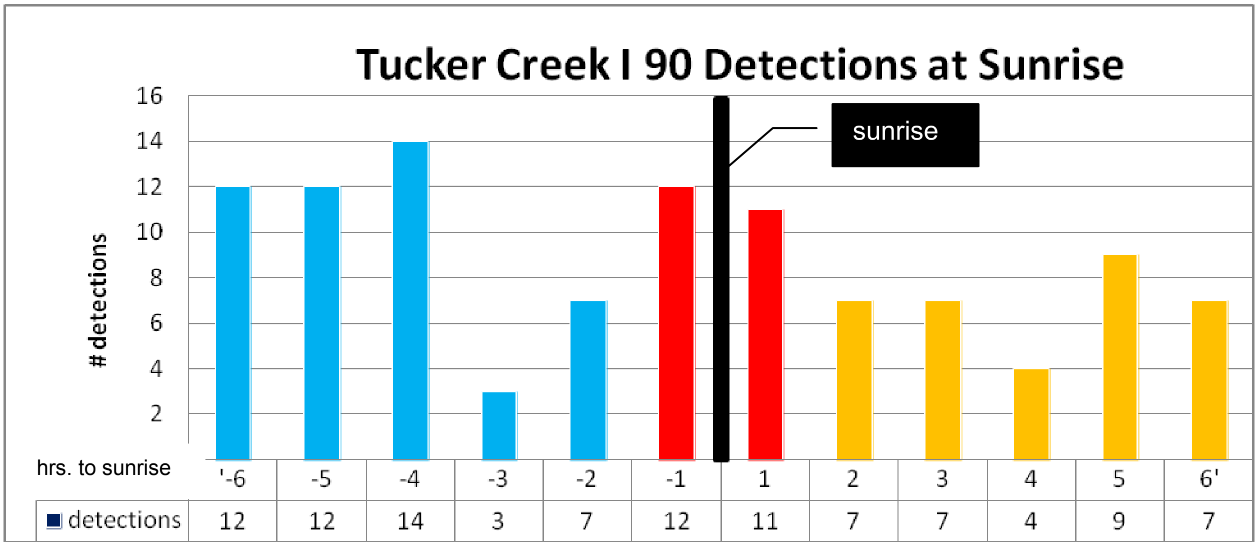
Tucker Creek I 90 mp 73

The Tucker Creek site has a mix of mule deer and black-tailed deer as the dominant species. A summary of the study period from summer 2010 to spring

2011 resulted in 147 deer detections, a total of 70% of the detections. Other species detected at the site are raccoons that make up 10%, a house cat that made up 10.95%, squirrels (*Sciurus carolinensis*) made up 5.24% and rabbits (*Oryctolagus cuniculus*) made up 2.86%. Summer is the most active time of year for deer here with 99 animal detections. Frequency of use is 1.11 deer detections per day. Fall sees a sharp decline in deer detections. Only 15 deer detections were recorded in the fall of 2010 for a frequency of .54 deer detections per day. Winter sees a further decline with nothing being detected in the winter of 2011. It is unknown if this is due to the site being at an elevation where winter time snow could be a factor, pushing animals to the valley floors or if there was a camera malfunction during that time. This site also experiences high water flows during the spring snow melt that could be a factor for the lack of animal detections during that time period. The first deer detection of the 2011 year occurred on May 15. Once deer started to be detected, they seem to increase their frequency of use dramatically with 33 deer being detected for the remainder of the spring season.

Deer at this site often cross in a temperature range of 40 – 60 degrees with 74.53% of detections occurring in that range. However, recall these detections occurred mainly in the summer months, weighting the detections to more summerlike temperatures.

This site lacked enough data to do a standard chi squared test, so the G-adjusted chi squared test was done. The results demonstrate that crepuscular activity is not significant at alpha = .05 for sunrise and sunset. See figures 13-16 for the statistical analysis. The histograms reveal a preference for nighttime activity.



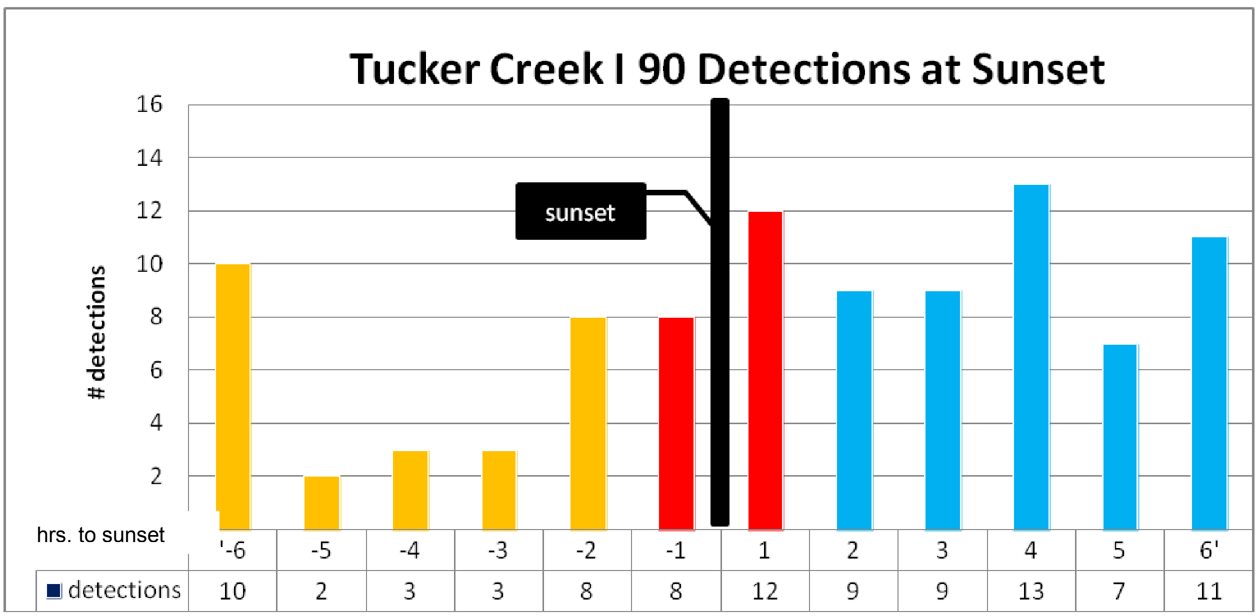


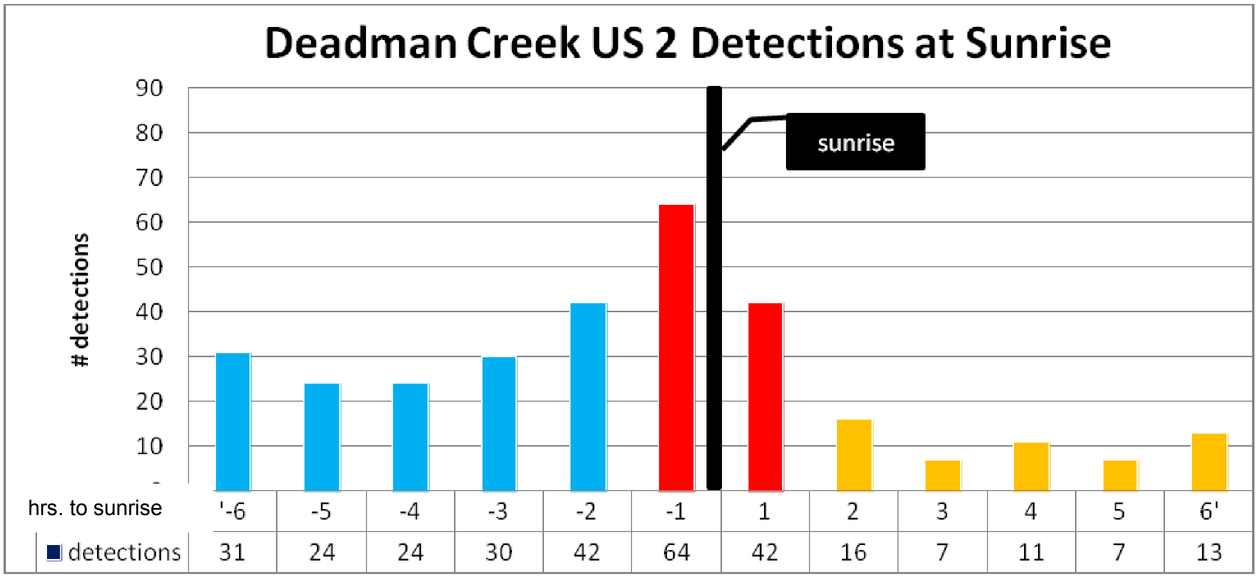
Figure 11. Histograms characterizing detections in relation to sunrise and sunset at Tucker Creek.

<u>*Deadman Creek Spokane US 2*</u>

Deadman Creek animal composition consists of almost entirely white-tailed deer. A summary for the study period of summer through winter of 2011-2012 indicates that 99.25% of all animals using the culvert for a crossing opportunity were white-tailed deer. The most active time of year occurred during the fall when there were 441 white-tailed deer detections for a frequency of 4.96 animal detections per day. The winter season also displays some of the same activity characteristics as the fall with 98.97% of species being white-tailed deer. Frequency of use increased slightly to 5.04 deer detections per day. One moose was detected during the summer, but was repelled from the structure. It looked mainly to be feeding.

The summer months at the Deadman Creek site were the least used for crossing opportunities. 248 white-tailed deer detections were recorded during this time of year for a frequency of 2.99 deer detections per day. Temperature, often exceeding 90 degrees in the daytime, could be a strong factor in the decreased use during the summer. This structure was also under construction during the summer months, affecting frequencies and detection times. Deer at this site prefer to cross at a temperature range from the 20's to the 40's with 73.17% of detections happening in that temperature range.

Using the Chi Squared test, this site was statistically significant for white-tailed deer to exhibit detection times that were different. The histograms in figure 12 reinforce the theory that deer at this site exhibit crepuscular behavior.



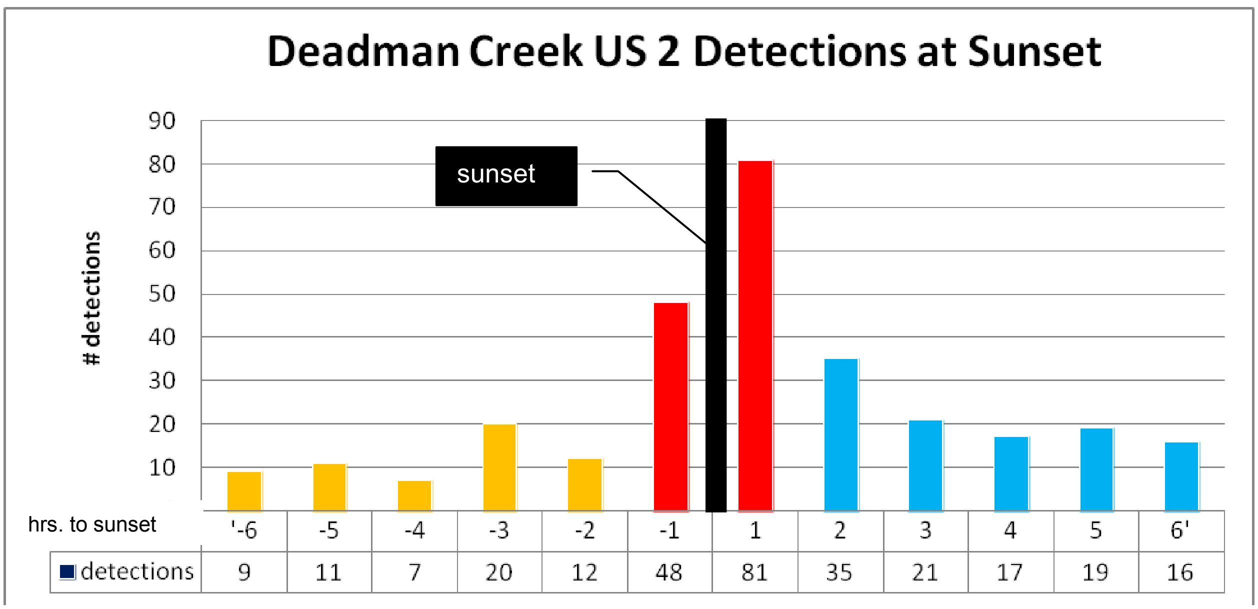


Figure 12. Histograms characterizing detections in relation to sunrise and sunset at Deadman Creek

7. Chi Squared Analysis

A chi squared test was used to determine if the observed time of detection was statistically significant and different from the expected time of detections, which in this case is sunrise and sunset. Using excel, the calculations for the chi squared analysis were created for the six hour time blocks of observed detections surrounding sunrise and sunset, comparing observed times of detections to sunrise and sunset, or what we would expect to observe. The calculations gave chi squared statistics that were compared with a degrees of freedom chart, ultimately determining if the observed detections were statistically significant at the given degrees of freedom.

When a Chi Squared test is conducted, there are some assumptions to consider. A Chi Squared test can be used when no more than 20% of the expected counts are less than 5 and all individual counts are 1 or greater (Moore 2001). To properly conduct the analysis, the dominant species for each site was used and in the case of North Bend west, there were multiple dominant species to consider, consequently, multiple species of megafauna were used.

Deadman Creek in Spokane is the only site in this research to have a sufficient sample size to do the standard Chi Squared test. Both the sunrise and sunset Chi Squared analyses reveal a significant statistical result. See figures 13 and 14 for the statistical analysis.

Sunrise Chi Squared Analysis

Site Name	df	sunrise	results
Deadman Creek	10	35.10924	significant @ p-value < .001
Tucker Creek	15	15.93506	NA
North Bend I 90 mp 29 (bears)	15	10.47743	NA
North Bend I 90 mp 27 (multi species)	10	12.76584	NA
Mosquito Creek	15	17.99794	NA
Willapa River	15	11.15743	NA
all sites deer	20	26.0931	NA
all sites dominant species	20	28.28854	NA

Figure 13. Chi Squared analysis for sunrise

Sunset Chi Squared Analysis

Site Name	df	sunset	results
Deadman Creek	10	27.73685	significant @ p-value < .0025
Tucker Creek	15	17.17898	NA
North Bend I 90 mp 29 (bears)	15	6.91093	NA
North Bend I 90 mp 27 (multi species)	10	17.40362	NA
Mosquito Creek	15	16.34875	NA
Willapa River	15	*lacks data (n=12)*	NA
all sites deer	20	24.16685*	NA
all sites dominant species	20	23.59207	NA

Figure 14. Chi Squared analysis for sunset

When a sample size is not sufficient to perform a standard Chi Squared analysis, a G-adjusted Chi Squared test can be used. A G-adjusted Chi Square test accounts for a smaller sample size and is a more conservative analysis. In the case at the Willapa River site, the number of detections relating to sunset was still insufficient to properly conduct a G-adjusted Chi Squared analysis, so the G-adjusted Chi Squared table notes the insufficient data.

Sunrise G-Adjusted Chi Squared Analysis

Site name	df	sunrise	results
Deadman Creek	10	*35.10924*	*significant with Chi Squared analysis*
Tucker Creek	15	16.62973	not significant
North Bend I 90 mp 29 (bears)	15	5.65859	not significant
North Bend I 90 mp 27	10	15.68477	significant @ p-value = .15
Mosquito Creek	15	17.82821	not significant
Willapa River	15	8.05851	not significant
all sites deer	20	25.35177	significant at p-value = .20
all sites dominant species	20	27.70212	significant @ p-value = .15

Figure 15. G-adjusted Chi Squared analysis for sunrise

Sunset G-Adjusted Chi Squared Analysis

Site name	df	sunset	results
Deadman Creek	10	*27.73685*	**significant with Chi Squared analysis*
Tucker Creek	15	17.03612	not significant
North Bend I 90 mp 29 (bears)	15	8.90790	not significant
North Bend I 90 mp 27	10	16.78348	significant @ p-value = .10
Mosquito Creek	15	19.03908	significant @ p-value = .25
Willapa River	15	*lacks data (n=12)*	*NA*
all sites deer	20	24.08331	significant @ p-value = .25
all sites dominant species	20	26.48403	significant @ p-value = .20

Figure 16. G-adjusted Chi Squared analysis for sunset

8. Discussion-

The only site with enough data to do a Chi Squared analysis was Deadman Creek in Spokane. Both crepuscular periods were significant at alpha

= .05, therefore we can reject the null hypothesis that there is no difference in peak activity times for white-tailed deer. The graphs in figures 12 point to a peak activity period an hour before and an hour after sunrise and sunset. This would suggest that white-tailed deer at Deadman Creek exhibit crepuscular activity.

The other study sites were not significant at alpha = .05 using the G-adjusted Chi Squared test. Two factors influenced the conclusions for the western and central Washington sites. The first is that more data is needed. A larger sample size would allow for a standard Chi Squared test as well as better representation of the deer population near the study sites. The second is that there could be other factors influencing megafauna detections near these study sites.

The next logical variable to consider is traffic volumes. Elevated traffic volumes have been shown to be a barrier for species dispersal and could be affecting sites such as the I-90 sites. However if an animal was provided a safe opportunity to cross the highway while traffic levels were elevated, would the animal prefer to use the structures to cross the highway? This dilemma points to confounding influences: Does elevated traffic levels deter animals from using crossing structures because they are uncomfortable around higher traffic volumes or are animals only using the crossing structures during higher traffic because they offer a 100% guarantee of safe passage. I would expect this to be a choice for individual animals to make for the following reasons: If a migrating animal encountered I-90 and was unfamiliar with the local area, would roadway avoidance behavior trump an opportunity to use a crossing structure to safely cross the highway? Likewise, a resident animal in a similar situation, encountering I-90 and having to decide to cross, knowing that a safe opportunity exists in its home range; would that animal be compelled to prefer using the structure when traffic volumes made crossing at grade virtually impossible? Without using a locator system or genetic tests to distinguish individual animals from each other, this type of analysis encounters too many confounding variables to draw any conclusions from.

Other patterns that have emerged from this data and their analyses warrant discussion. The first is the detection results at Tucker Creek. The fact that most of the detections occurred at night point to two variables that could explain that pattern: temperature and human activity. The location of the site, in central Washington, and the fact that most of the detections occurred during the summer months and the deer's preferred temperature range of 40-60 degrees, I would expect that during the heat of the day, deer spent time bedded down avoiding unnecessary movements.

The fact that there was a continued human presence using ATVs in the culvert could also affect ungulate activity patterns. Research shows that human activity around wildlife structures can shift ungulate activity to a nighttime regime (Cramer Email and Evink 2007).

The second pattern to emerge from this data is the species composition at the two North Bend sites. Having black bears utilize crossing structures has proven to be difficult for some areas of the West. Consulting with Patty Cramer revealed the frequency of bear detections here is extraordinary. In her four years of monitoring 4 different states, collecting over 1.5 million photos, she has only encountered roughly 25 successful black bear crossings (Cramer Email). The success at both North Bend sites could be attributed to the age of the structure since both structures have had numerous successful bear crossings and have been established for over 35 years.

The fact that the North Bend sites see an inverse relationship between carnivorous animals and prey animals is unique as well. It does seem logical for a prey species to avoid a predator species, but this would again point to the age of the structures. If carnivorous animals have established themselves as using these structures to access resources, their scent would persist in the culverts, ultimately discouraging use by prey species. Jon Beckman and Jodi Hilti discovered a presence absence relationship between mother moose and her calves and bears (Beckmann and Hilti, 2010). In some cases, mother moose tends to give birth to her calves near roads because she knows it is a safe place away from bears. The research suggests avoidance behavior exists in other ungulate species and could be a factor in the species composition at the North Bend sites. This would suggest the frequency of use by predator species is deterring prey species from using the structure.

Adam Ford and Tony Clevenger (2010) found that there is no evidence to suggest that predators use these wildlife funnels to capture and ambush prey, so the frequent use does not appear to be for capturing prey species; that would further imply that this location is not a significant migration route for migrating or traveling prey species. Continued monitoring at these sites should reveal if the study period species composition and frequencies are consistent.

The third pattern to reveal itself is the frequency of use at Deadman Creek. The fact that the structure sees this many deer is extraordinary compared to the other sites. What makes it even more astounding is the fact that the structure is less than a year old.

A successful wildlife crossing structure is largely based on placement within the landscape. The area to the north of Spokane where this structure is located is in one of the worst hotspot in the state for deer-vehicle collisions. By offering a safe alternative to cross the highway, the whitetail deer at this location are now safely migrating through an otherwise hazardous area.

9. Thoughts for the Future

1. Continue collecting data at regular intervals – There is not enough data to do most statistical analyses. Parks Canada claims that three to five years' worth of data is needed to fully understand the relationships and patterns that develop from wildlife using the structure (www.pc.gc.ca, 2011)

2. This analysis would prove more valuable if there was control data to compare our findings to. Wildlife may exhibit different behavior and peak activity periods when the influences of a roadway are not present. Woody Meyers, a WDFW ungulate biologist, is currently conducting a study that measures activity of mule deer on a scale of every 15 minutes.

3. Target elk as a species of interest. WSDOT thought more elk would be detected with regularity, but they were not, and when they were, they rarely

crossed through the structure. Monitoring the overpass being planned for construction east of Rock Knob near the I-90 summit should reveal if overpasses are preferred by elk or if we need to think differently about how to keep elk off the roads while still providing access to migration routes.

10. Conclusion

Although the study lacked sufficient data to do a standard Chi Squared test, and the majority of the research did not support the theory that megafauna species are most active at twilight, other patterns emerged from organizing and cataloguing the data. Some of these patterns warrant further research. As discussed earlier, the species composition at the North Bend sites is unique. Further investigation at other potential sites will confirm the uniqueness of the structure appearing to favor carnivores.

Nocturnal patterns at Tucker Creek could shed some light on the question of how much human activity could a population tolerate without shifting activity regimes.

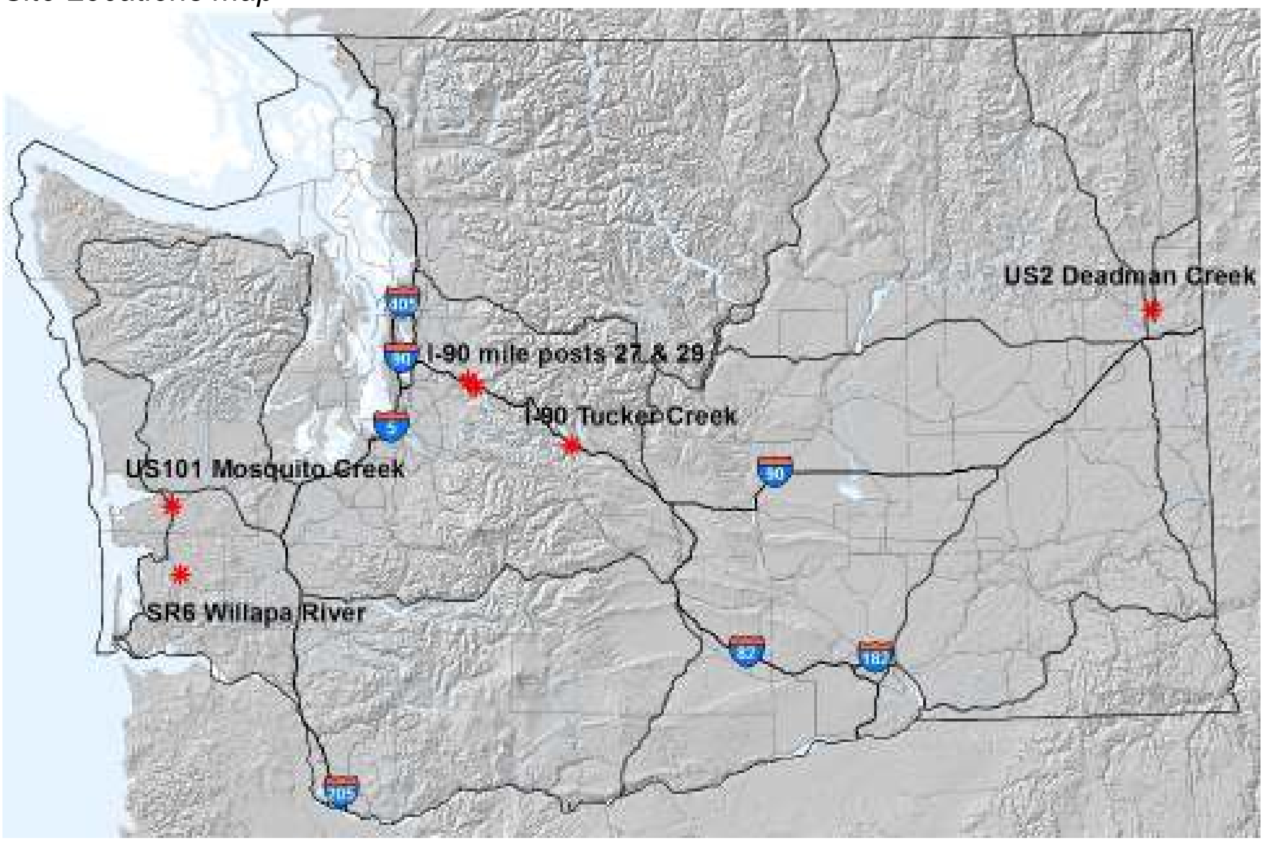
The Deadman Creek area north of Spokane is a success story on how and where to locate crossing opportunities for white-tailed deer. The fact that the structure was used with regularity during construction points to the need for further research for future crossing opportunities in the area.

The only conclusion the research offered was white-tailed deer exhibit crepuscular activity at one site. Further monitoring at other research sites in Washington State could reveal if white-tailed deer are more prone to crepuscular activity or if other influences affect activity patterns.

Cataloguing and organizing the data was not just to test crepuscular activity in megafauna species. Data collected to answer the original research question can be applied to answer several other questions. As is common with scientific research, this research revealed more questions than answers gained. That's job security for the biologists and future interns at WSDOT.

Appendix 1

Site Locations map



Appendix 2

Willapa River

Species composition and Frequencies

summary without humans

species	*detections*	*% comp.*	*individuals*	*% comp.*
bt deer	54	20.22%	101	23.27%
human	0	0.00%	0	0.00%
coyote	6	1.71%	6	1.38%
raccoon	59	22.10%	90	20.74%
possum	142	53.18%	147	33.87%
skunk	6	1.71%	6	1.38%
house cat	0	0.00%	84	19.35%
total	267	100%	434	100%

Frequencies

species	*detections*	*frequency/day*	*individuals*	*frequency/day*
bt deer	54	0.16	101	0.30
human	140	0.41	220	0.65
coyote	6	0.02	6	0.02
raccoon	59	0.17	90	0.26
possum	142	0.42	147	0.43
skunk	6	0.02	6	0.02
house cat	84	0.25	84	0.25
total	491		654	
total days	340		340	


Willapa River camera locations

Willapa River East Camera

Willapa River West Camera

Appendix 3

Mosquito Creek

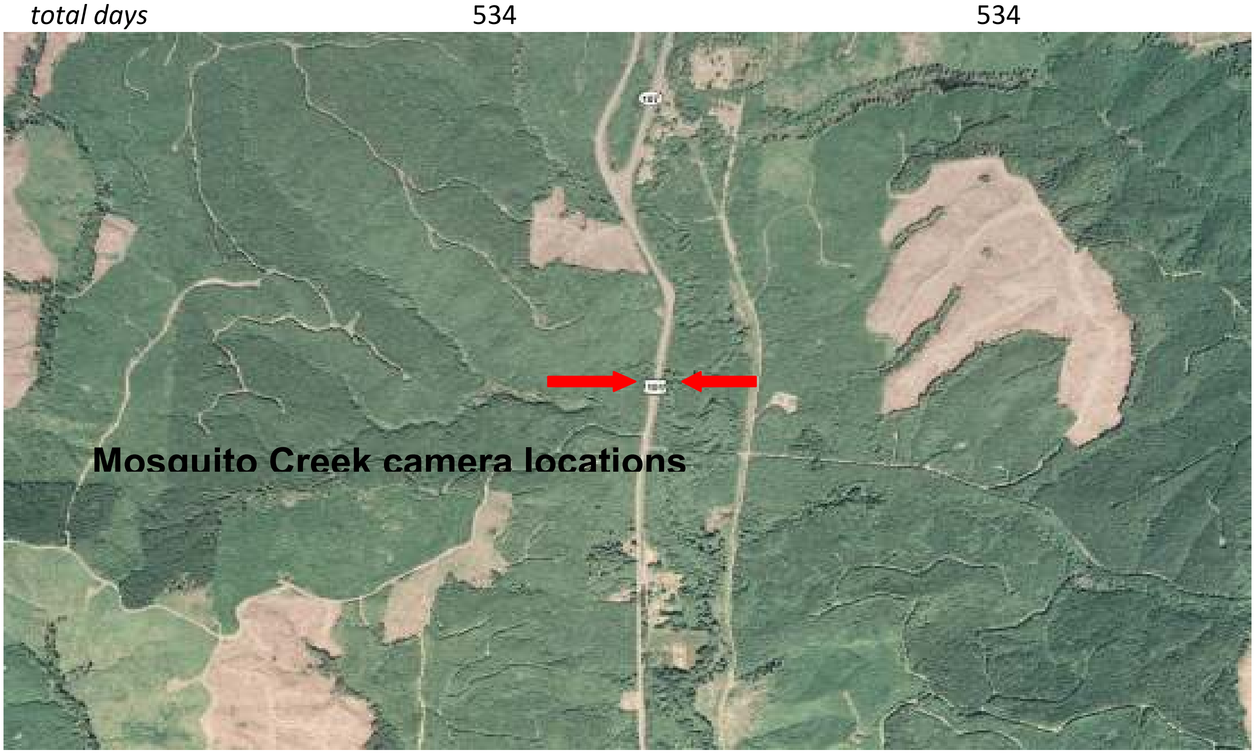
Species Composition and Frequencies

summary without humans

species	*# detections*	*% comp.*	*# individuals*	*% comp.*
elk	1	0.57%	1	0.00%
bt deer	108	62.07%	164	57.00%
human	0	0.00%	0	0.00%
raccoon	63	36.21%	87	43.00%
mink	1	0.57%	1	0.00%
salmon	1	0.57%	1	0.00%
total	174	100%	254	100%

Frequencies

species	*# detections*	*frequency/day*	*# individuals*	*frequency/day*
elk	1	0.0019	1	0.0019
bt deer	108	0.2022	164	0.3071
human	0	0.0000	0	0.0000
raccoon	63	0.1180	87	0.1629
mink	1	0.0019	1	0.0019
salmon	1	0.0019	1	0.0019
total days	534		534	




2011-07-26 07:41:22 M 5/5 56°F
Mosquito Creek East Camera
WSDOT US101 MOSQUITO


2010-07-15 11:41:57 M 3/5 58°F
Mosquito Creek West Camera
US2STP2 WSDOT CRAMER

Appendix 4

North Bend I 90 West

Species Composition and Frequencies

summary without humans

species	*# detections*	*% comp.*	*# individuals*	*% comp.*
bt deer	45	30.82%	55	33.95%
black bear	38	26.03%	38	23.46%
human	0	0.00%	0	0.00%
bobcat	10	6.85%	10	6.17%
coyote	11	7.53%	12	7.41%
rabbit	1	0.68%	1	0.62%
raccoon	41	28.08%	46	28.40%
total	146	100.00%	162	100.00%

Frequencies

species	*# detections*	*frequency/day*	*# individuals*	*frequency/day*
bt deer	45	0.18	55	0.22
black bear	38	0.15	38	0.15
human	29	0.11	41	0.16
bobcat	10	0.04	10	0.04
coyote	11	0.04	12	0.05
rabbit	1	0.00	1	0.00
raccoon	41	0.16	46	0.18
total days	253		253	

I 90 West-North Camera

I 90 West-South Camera

Appendix 5

North Bend I 90 East

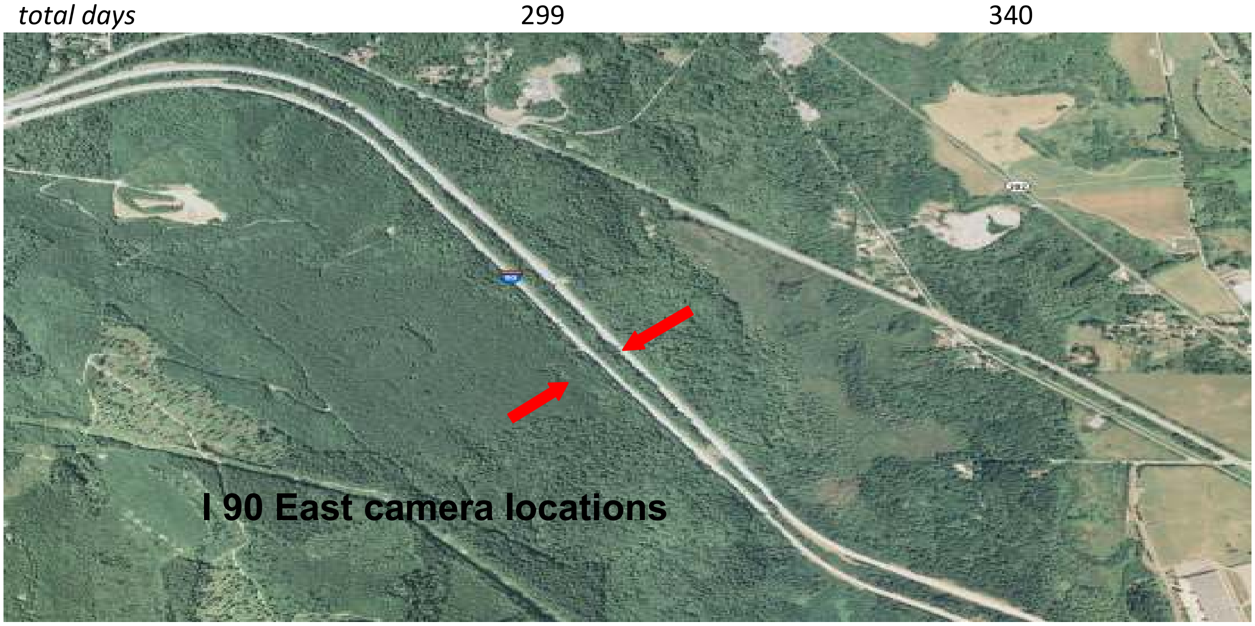
Species Composition and Frequencies

summary without humans

species	*# detections*	*% comp.*	*# individuals*	*% comp.*
elk	1	0.00%	1	0.00%
bt deer	11	0.51%	18	0.48%
black bear	163	61.73%	174	57.62%
human	0	0.00%	0	0.00%
bobcat	14	5.61%	14	5.24%
coyote	100	28.06%	121	32.38%
raccoon	7	2.55%	9	2.86%
possum	1	0.51%	1	0.48%
rabbit	2	1.02%	2	0.95%
total	196	100%	210	100%

Frequencies

species	*# detections*	*frequency/day*	*# individuals*	*frequency/day*
elk	1	0.0033	1	0.0029
bt deer	11	0.0368	18	0.0529
black bear	163	0.5452	174	0.5118
human	0	0.0000	0	0.0000
bobcat	14	0.0468	14	0.0412
coyote	100	0.3344	121	0.3559
raccoon	7	0.0234	9	0.0265
possum	1	0.0033	1	0.0029
rabbit	2	0.0067	2	0.0059
total days	299		340	




2011-06-27 12:19:57
M 1/5
61°F
I 90 East-North Camera
I90MP73SWSDOT CRAMER
RECONYX


2010-06-27 13:43:44
M 7/10
68°F
I 90 East-South Camera
I90MP29S WSDOTCRAMER
RECONYX

Appendix 6

Tucker Creek

Species Composition and Frequencies

summary without humans

species	*# detections*	*% comp.*	*# individuals*	*% comp.*
deer sp (mule &bt)	102	67.55%	147	70.00%
human	0	0.00%	0	0.00%
coyote	1	0.66%	1	0.48%
raccoon	10	6.62%	21	10.00%
skunk	1	0.66%	1	0.48%
house cat	21	13.91%	23	10.95%
rabbit	6	3.97%	6	2.86%
squirrel	10	6.62%	11	5.24%
total	151	100%	210	100%

Frequencies

species	*# detections*	*frequency/day*	*# individuals*	*frequency/day*
deer sp (mule &bt)	102	0.55	147	0.79
human	38	0.20	64	0.34
coyote	1	0.01	1	0.01
raccoon	10	0.05	21	0.11
skunk	1	0.01	1	0.01
house cat	21	0.11	23	0.12
rabbit	6	0.03	6	0.03
squirrel	10	0.05	11	0.06
total days	187		187	

Tucker Creek North Camera

Tucker Creek South Camera

Appendix 7

Deadman Creek

Species Composition and Frequencies

Species Composition Summary w/o humans

species	*# detections*	*% comp*	*# individuals*	*% comp.*
moose	1	0.10%	1	0.07%
wt deer	624	99.12%	1072	99.25%
humans / dogs	0	0.00%	0	0.00%
coyotes	2	0.20%	2	0.14%
raccoons	6	0.59%	8	0.55%
total megafauna	633	100%	1083	100%

Frequencies

species	*#detections*	*frequency/day*	*# individuals*	*frequency/day*
moose	1	0.004	1	0.00
wt deer	624	2.48	1072	4.25
humans / dogs	189	1.25	360	1.43
coyotes	2	0.01	2	0.01
raccoons	6	0.02	8	0.03
total days	252		252	


2011-08-06 05:56:57
M 2/5
48°F
Deadman Creek Downstream Camera
WSDOT US2 DEADMAN CR


M 4/5
76°F
Deadman Creek Upstream Camera
WSDOT US2 DEADMAN CR

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