

# **Exploration of Opportunities to Address the Impacts of Roads and Traffic on Wildlife and Non-Motorized Trail Access in and around Steigerwald Lake National Wildlife Refuge, Washington**

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<b>STANDARD CONVERSION TABLE – ENGLISH TO METRIC</b>				
<u>Symbol</u>	<u>To convert from</u>	<u>Multiply by</u>	<u>To determine</u>	<u>Symbol</u>
<b><u>LENGTH</u></b>				
IN	inch	25.4	millimeters	mm
FT	feet	0.3048	meters	m
YD	yards	0.9144	meters	m
MI	miles	1.609344	kilometers	km
<b><u>AREA</u></b>				
SI	square inches	645.16	square millimeters	mm <sup>2</sup>
SF	square feet	0.09290304	square meters	m <sup>2</sup>
SY	square yards	0.83612736	square meters	m <sup>2</sup>
A	acres	0.4046856	hectares	ha
MI <sup>2</sup>	square miles	2.59	square kilometers	km <sup>2</sup>
<b><u>VOLUME</u></b>				
CI	cubic inches	16.387064	cubic centimeters	cm <sup>3</sup>
CF	cubic feet	0.0283168	cubic meters	m <sup>3</sup>
CY	cubic yards	0.764555	meters liters	m <sup>3</sup>
GAL	gallons fluid	3.78541	liters	L
OZ	ounces	0.0295735	cubic meters	L
MBM	thousand feet board	2.35974		m <sup>3</sup>
<b><u>MASS</u></b>				
LB	pounds	0.4535924	kilograms	kg
TON	short tons (2000 lbs)	0.9071848	metric tons	t
<b><u>PRESSURE AND STRESS</u></b>				
PSF	pounds per square foot	47.8803	pascals	Pa
PSI	pounds per square inch	6.89476	kilopascals	kPa
PSI	pounds per square inch	0.00689476	megapascals	Mpa
<b><u>DISCHARGE</u></b>				
CFS	cubic feet per second	0.02831	cubic meters per second	m <sup>3</sup> /s
<b><u>VELOCITY</u></b>				
FT/SEC	feet per second	0.3048	meters per second	m/s
<b><u>INTENSITY</u></b>				
IN/HR	inch per hour	25.4	millimeters per hour	mm/hr
<b><u>FORCE</u></b>				
LB	pound (force)	4.448222	newtons	N
<b><u>POWER</u></b>				
HP	horsepower	746.0	watts	W
<b><u>TEMPERATURE</u></b>				
°F	degrees Fahrenheit	5 X (°F – 32)/9	degrees Celsius	°C
<b><u>DENSITY</u></b>				
lb/ft <sup>3</sup>	pounds per cubic foot	16.01846	kilograms per cubic meter	kg/m <sup>3</sup>
<b><u>ACCELERATION</u></b>				
g	freefall, standard	9.807	meters per second squared	m/s <sup>2</sup>

TO CONVERT FROM METRIC TO ENGLISH, DIVIDE BY THE ABOVE CONVERSION ACTORS.

# 1 Introduction

## 1.1 Background

Steigerwald Lake National Wildlife Refuge (NWR) ("the Refuge") is a 1,049-acre floodplain and wetland located along the Columbia River, just east of Washougal, Washington (Figure 1). The Refuge was established in 1987 to offset habitat loss associated with construction at the Bonneville Dam (USFWS, 2024) (Figure 2). Management is directed at the protection and restoration of wetland, riparian and upland habitat on the Refuge (USFWS, 2024). In addition, the Refuge provides opportunities for wildlife-oriented recreation, education and interpretation by the public.

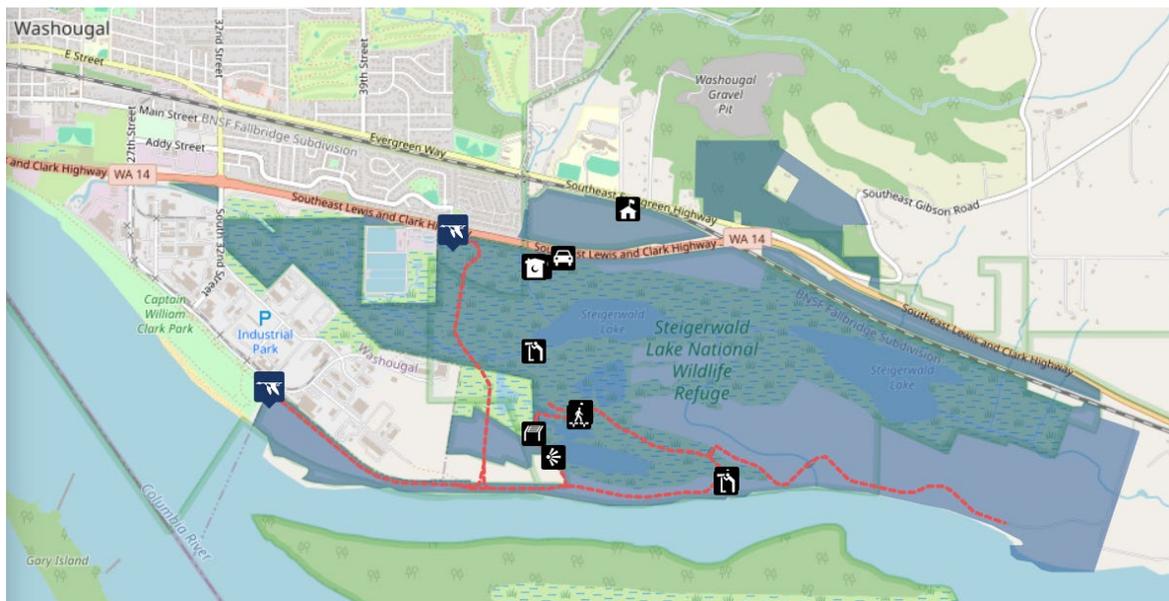


Figure 1: Roads, railroads and trails in and around Steigerwald Lake NWR (Source USFWS, 2024).

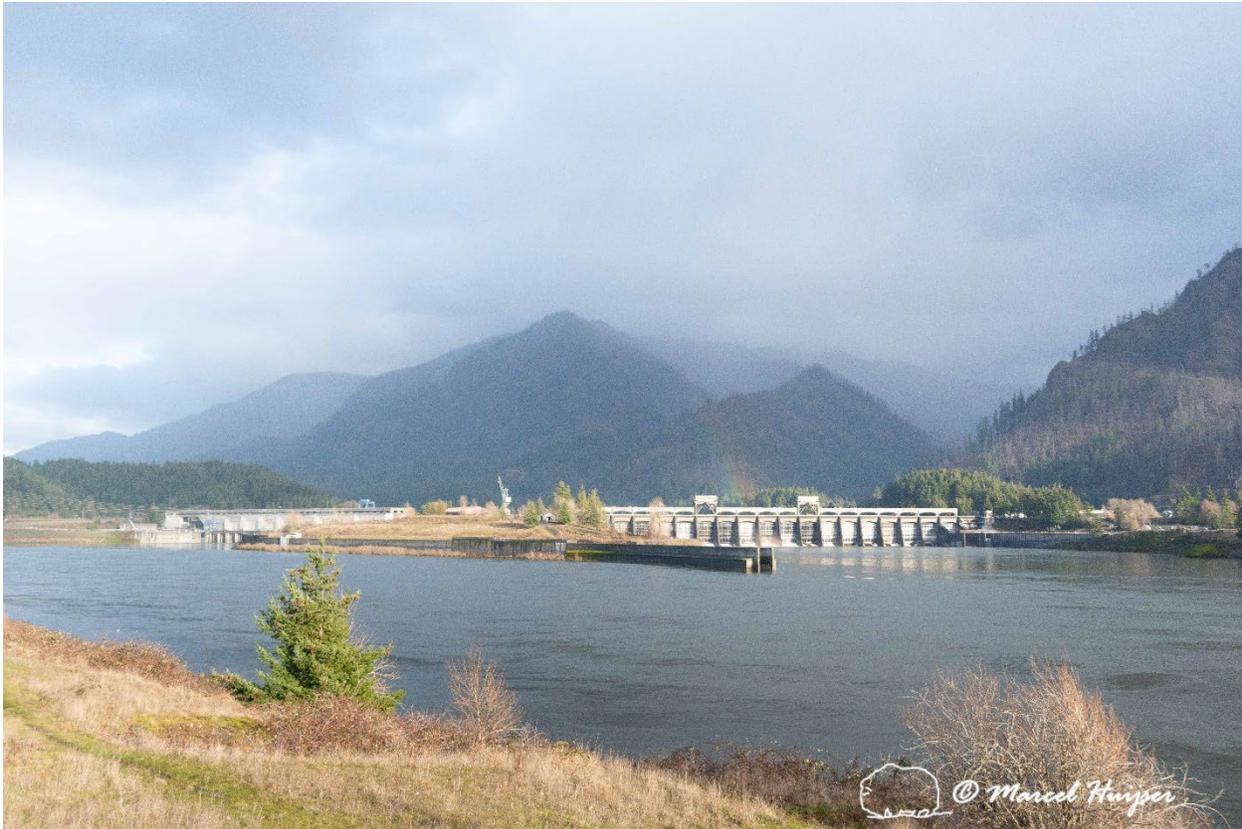


Figure 2: Bonneville Dam, about 19 miles upstream from Steigerwald NWR along the Columbia River.

The “southeast Lewis and Clark Highway” (WA Highway 14), the Evergreen Way, and a railroad run along the northside of the Refuge (Figure 1). In addition, there is a trail system for non-motorized use (Figure 1). There are two entrances to the trail system: Mt. View trailhead along WA Hwy 14, and River trailhead at the county park. In 2020-2022, the roadbed of WA Highway 14 was raised above the 500-year flood level, a levee was removed restoring part of the natural floodplain of the Columbia River, and new levees were built further back (Figure 3). The latter included a removable flood barrier (closure structure) on WA Highway 14 and a flood barrier wall west of Gibbons Creek and north of WA Highway 14 (Figure 4, Figure 5). Finally, a section of Gibbons creek north and south of WA Highway 14 was restored and reconnected to the Refuge (Figure 6), other areas on the Refuge were also restored and planted with native species, and the parking area along WA Highway 14 and the trail system were moved and expanded (Friends of the Columbia Gorge, 2020). Pacific lamprey (*Entosphenus tridentatus*) and salmonids (e.g., coho (*Oncorhynchus kisutch*), cutthroat (*Oncorhynchus clarki*), rainbow trout/winter steelhead (*Oncorhynchus mykiss*), fall chum (*Oncorhynchus keta*) are projected to especially benefit from the habitat restoration (WDFW, 2025a). Note that chinook (*Oncorhynchus tshawytscha*), green sturgeon (*Acipenser medirostris*), white sturgeon (*Acipenser transmontanus*), Dolly varden/bull trout (*Salvelinus malma/S. confluentus*), pink salmon (*Oncorhynchus gorbuscha*), and sockeye (*Oncorhynchus nerka*), are present in the Columbia River but have not been reported from Gibbons creek (WDFW, 2025a).



Figure 3: A levee and trail, just southeast of the main trailhead, looking to the northeast, Steigerwald Lake NWR. The “old trailhead” was in the trees in the center of the image.



Figure 4: Removable flood barrier (closure structure) at WA Highway 14, Steigerwald Lake NWR.



Figure 5: Receivers for the removable flood barrier (closure structure) on WA Highway 14, Steigerwald Lake NWR. Note the flood wall on the other side of the road, protecting the houses from flooding of Gibbons Creek.



Figure 6: A restored section of Gibbons Creek, close to the outflow into the Columbia River, Steigerwald Lake NWR.

## 1.2 Problem statement

Most protected areas, including Steigerwald Lake NWR, need to be connected to other protected areas for their ecological functioning, including for having viable wildlife populations. Changes in land use (e.g., forestry practices, agriculture, urbanization), water management (levees, dams), environmental changes (e.g., increased fire frequency and intensity, and changes in precipitation and associated peaks and lows in river flows) can all affect the ecological connectivity of Steigerwald Lake NWR to its surrounding aquatic, semi-aquatic, and terrestrial habitat types. Other protected areas near Steigerwald Lake NWR along the Columbia River include Ridgefield NWR, Franz Lake NWR, and Pierce NWR, and connectivity along the Columbia River to these other protected areas is especially important for aquatic and semi-aquatic species.

Ecological connectivity to higher areas further away from the Columbia River is a concern at all four NWRs. WA Highway 14 is the busiest road between Steigerwald Lake NWR, Franz Lake NWR and Pierce NWR and the higher areas further north. In addition, Evergreen Way and a railroad parallel WA Highway 14 at Steigerwald Lake. I-5 parallels the Columbia River further to the west and is the busiest highway between Ridgefield NWR and Lewis River and its tributaries as well as higher areas to the east.

Large mammals (e.g., Columbia white-tailed deer, mule deer (black-tailed deer), elk, and black bear that cross highways at-grade are also a human safety issue. Other concerns include connectivity and direct road mortality for smaller mammal species (e.g., beaver (*Castor canadensis*)), and amphibians (e.g. western toad (*Anaxyrus boreas*)). Finally, non-motorized access to the trails of Steigerwald Lake NWR from the urban area north of WA Highway 14, and north of Evergreen Way and the railroad, is a safety concern.

The goal of this project is to explore potential measures aimed at reducing collisions with large wild ungulate species (most notably mule deer (black-tailed deer) and elk), along WA Highway 14, Evergreen Way, and I-5, and improve connectivity for large wild mammals (e.g., Columbia white-tailed deer, mule deer (black-tailed deer), elk, bobcat, mountain lion, coyote, and black bear), and small species (e.g., amphibian and reptile species) between the four Refuges and the higher areas further away from the Columbia River. In addition, we explore non-motorized access to Steigerwald NWR from the built-up area of Washougal and a nearby school.

### 1.3 Tasks

#### 1. Obtain data

- Obtain data on large wild mammal-vehicle collisions (crash data and carcass removal data) for (see Figure 7, Figure 8):
  - WA Highway 14 between the junction with I-5 (Mile reference post 0, west end) and the Bonneville Dam (Mile reference post 40, east end).
  - Evergeen way (about 3-mile long section, west end: jct with Washougal River Rd.), east end: jct with WA Highway 14 / SE Gibson Rd.). (Figure 8, green line).
  - I-5 from the bridge across the Columbia River (Mile reference post 0, south end) to just north of exit 27 (Dupont Rd/Todd Rd/Port of Kalama) (Mile reference post 28, north end).
  - BNSF railroad adjacent to WA Highway 14 near Steigerwald Lake NWR.
- Obtain Annual Average Daily Traffic (AADT) data for the highway sections listed above.
- Obtain existing plans or visions for landscape level connectivity in the areas around Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR, and Pierce NWR both terrestrial (to higher grounds) as well as along the Columbia River.
- Obtain data on the presence of large wild mammals and threatened and endangered species (amphibians, reptiles and small-medium-sized mammal species) in the four Refuges and surrounding areas.

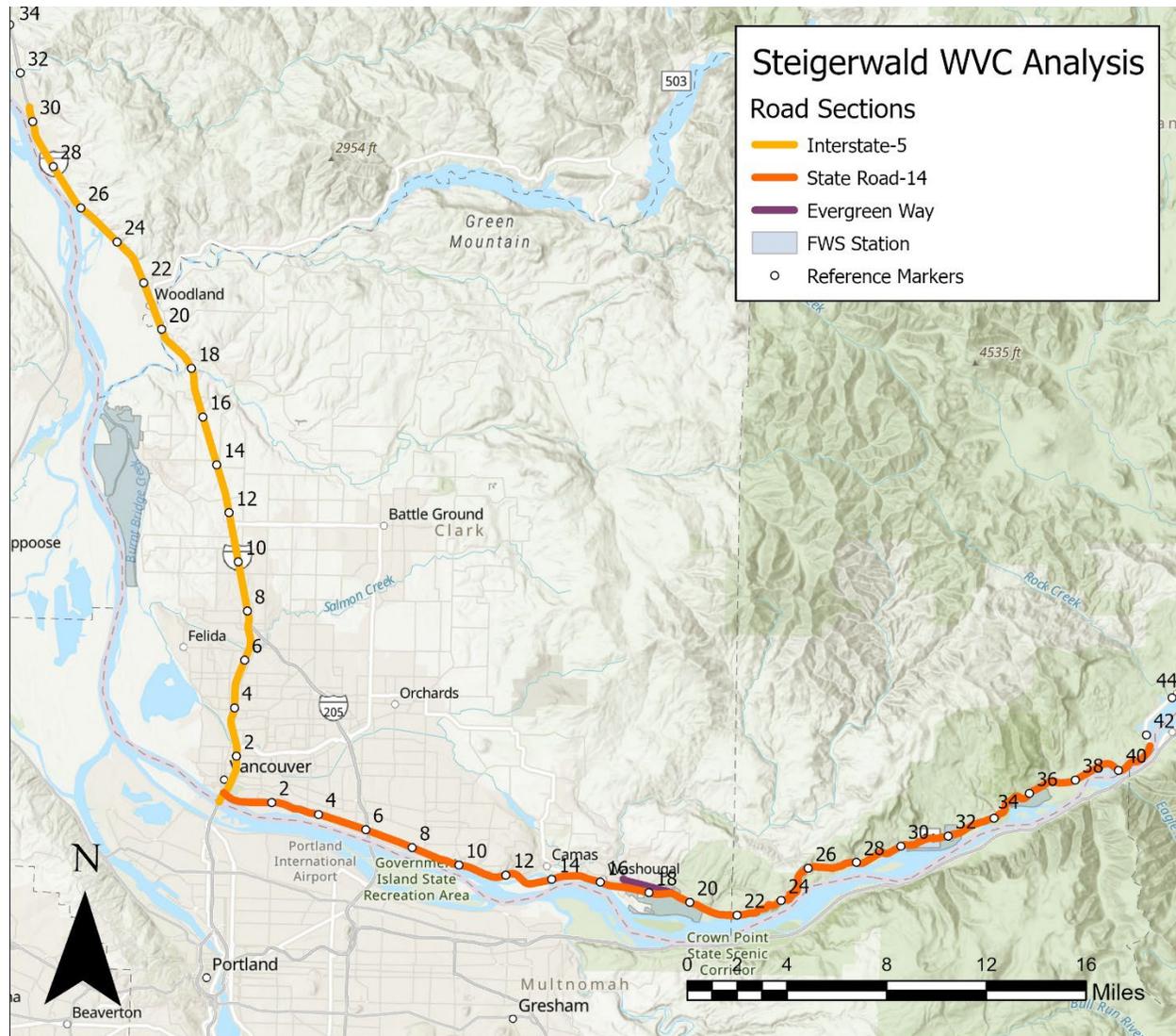


Figure 7: The three road sections near Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR, and Pierce NWR.

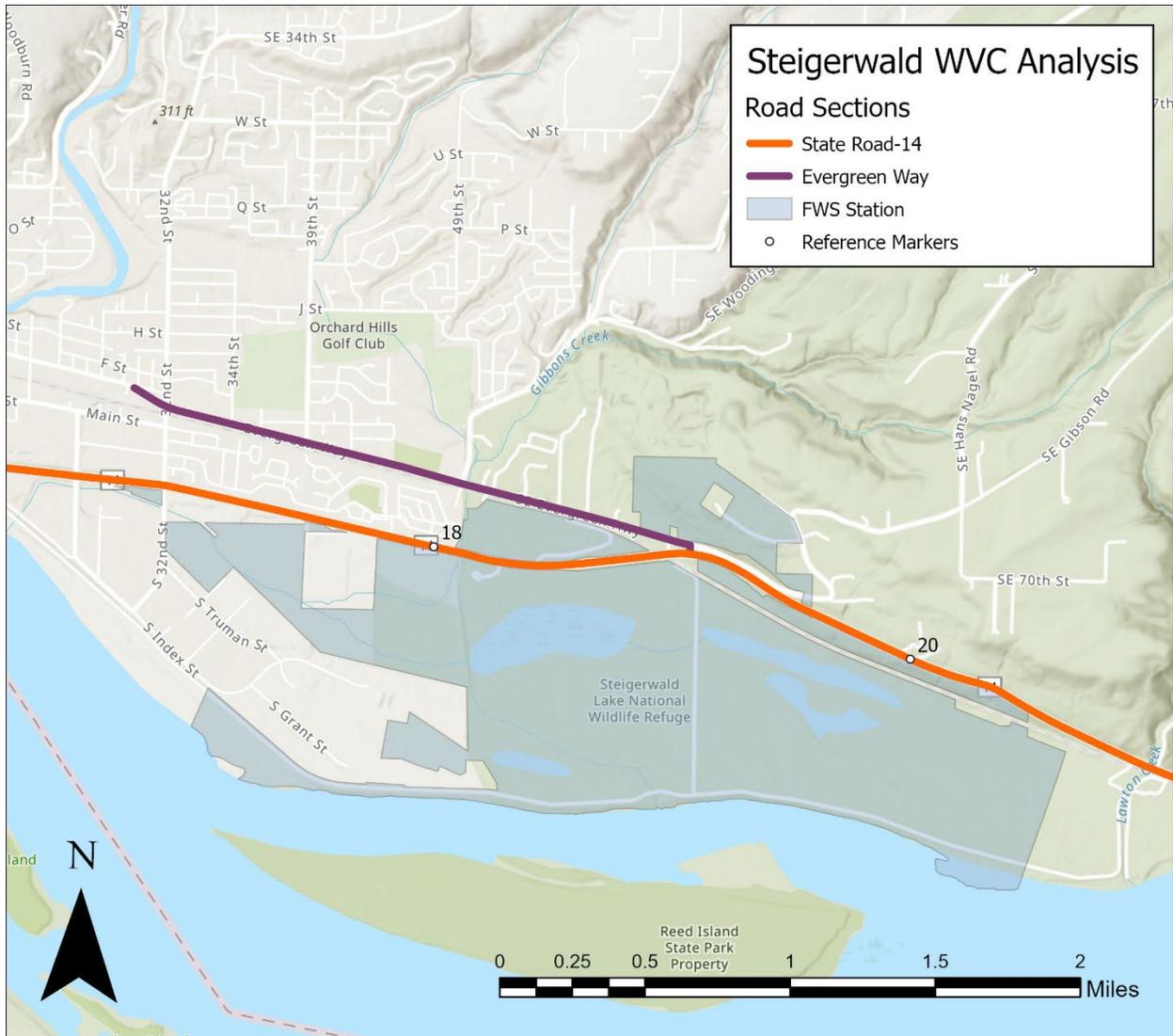


Figure 8: The two road sections at Steigerwald Lake NWR.

## 2. Conduct field review

- Inspect the road sections mentioned above, the Refuge, and the surrounding areas. Visit potential high collision or road mortality road sections and road sections that are important for wildlife connectivity, and for non-motorized access to the Refuge.
- Meet with USFWS representatives to discuss their perspective on wildlife-vehicle collisions (human safety and biological conservation), ecological connectivity for wildlife species, and access to the Refuge for non-motorized recreation.

## 3. Analyses

- Identify relatively high frequency road sections for large mammal-vehicle collisions along the sections of WA Highway 14, Evergreen Way, I-5, and potentially the railroad.
- Identify important areas for the focal species, especially for large mammals. across the highway sections of interest. This can be based on existing movements, historic movements, or policy, or a combination of these perspectives.
- Identify important areas for non-motorized access to the Refuge for people.

## 4. Reporting

- Report on the findings of the analyses.
- Advice on mitigation measures aimed at reducing large mammal-vehicle collisions, at providing or maintaining connectivity for the focal species, and non-motorized access to the Refuge for people across the highway sections of interest. The recommendations can include fences or other barriers, modifications of existing structures built for e.g. hydrology, and designated wildlife crossing structures. Note that fences may need to consider landscape aesthetics along the river and the protected areas.
- Advice on the road sections and locations that the mitigation measures relate to.

## 2 Effects of roads and traffic on wildlife

Roads and vehicles can affect wildlife in several ways. In general, not specific for large wild mammals, there are five different categories of the effects of roads and traffic on wildlife (Figure 9) (e.g. van der Ree et al., 2015):

- Habitat loss: e.g., the paved road surface, heavily altered environment through the road-bed with non-native substrate, altered hydrology, vegetation removal, seeded species and mowing in the clear zone.
- Direct wildlife road mortality because of collisions with vehicles.
- Barrier to wildlife movements: e.g., animals do not cross the road as often as they cross natural terrain and only a portion of the crossing attempts is successful.
- Decrease in habitat quality in a zone adjacent to the road: e.g., noise and light disturbance, air and water pollution, increased access to the areas adjacent to the highways for humans and associated disturbance.
- Right-of-way habitat and corridor: Depending on the surrounding landscape, the right-of-way can promote the spread of non-native or invasive species (surrounding landscape largely natural or semi-natural) or it can be a refugium for native species (surrounding landscape heavily impacted by humans).

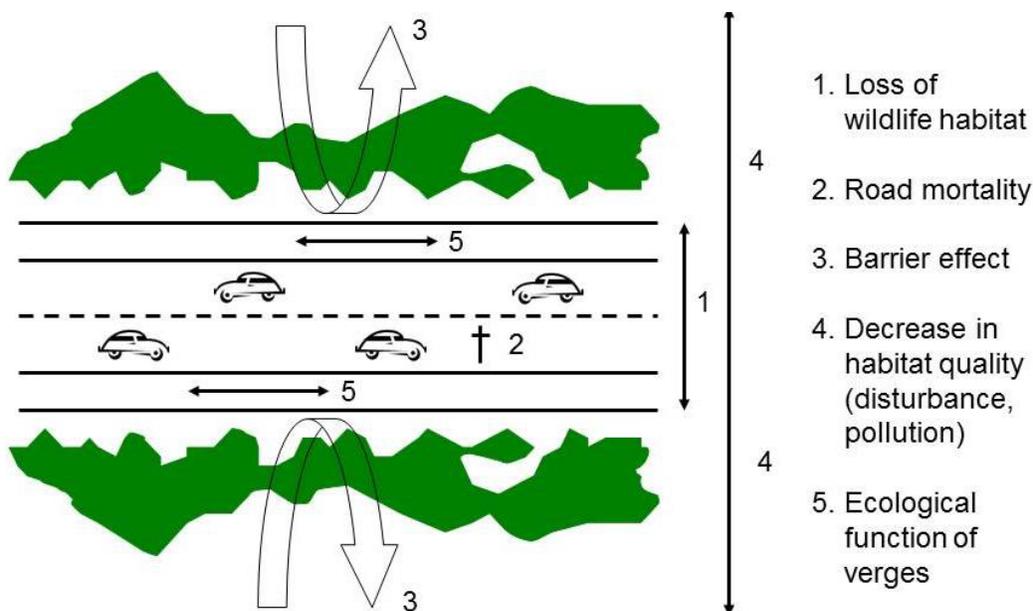


Figure 9: The effects of roads and traffic on wildlife.

While the effects of roads and traffic are varied, direct road mortality, either for the purpose of human safety or biological conservation, and the barrier effect are the most often addressed types of effects. Habitat loss, a decrease in habitat quality in a zone adjacent to a road, and the spread of non-native invasive species are acknowledged and dealt with less often.

### 3 Avoidance, mitigation, and compensation strategies

While mitigation (reducing the severity of an impact) is common, avoidance is better and should generally be considered first (Cuperus et al., 1999; Arlidge et al., 2018). For example, the negative effects of roads and traffic may be avoided if a road is not constructed, or the most severe negative effects may be avoided by re-routing away from the most sensitive areas (Figure 10). If the effects cannot be avoided, mitigation is a logical second step. Mitigation can take place on the road itself or in the adjacent road-effect zone (Figure 10). Mitigation may include measures aimed at reducing wildlife-vehicle collisions and reducing the barrier effect (e.g., through providing for safe wildlife crossing opportunities) (Clevenger & Huijser, 2011; Huijser et al., 2021). However, mitigation may not always be possible, or the mitigation may not be sufficient. In such situations, a third approach may be considered: compensation or off-site mitigation (sometimes referred to as remediation or offsetting (Arlidge et al., 2018)). Compensation may include increasing the size of existing habitat patches, creating new habitat patches, or improving the connectivity between the habitat patches that would allow for larger, more connected, and more viable network of populations. Finally, in some situations, a combination of avoidance, mitigation, and compensation may be implemented.

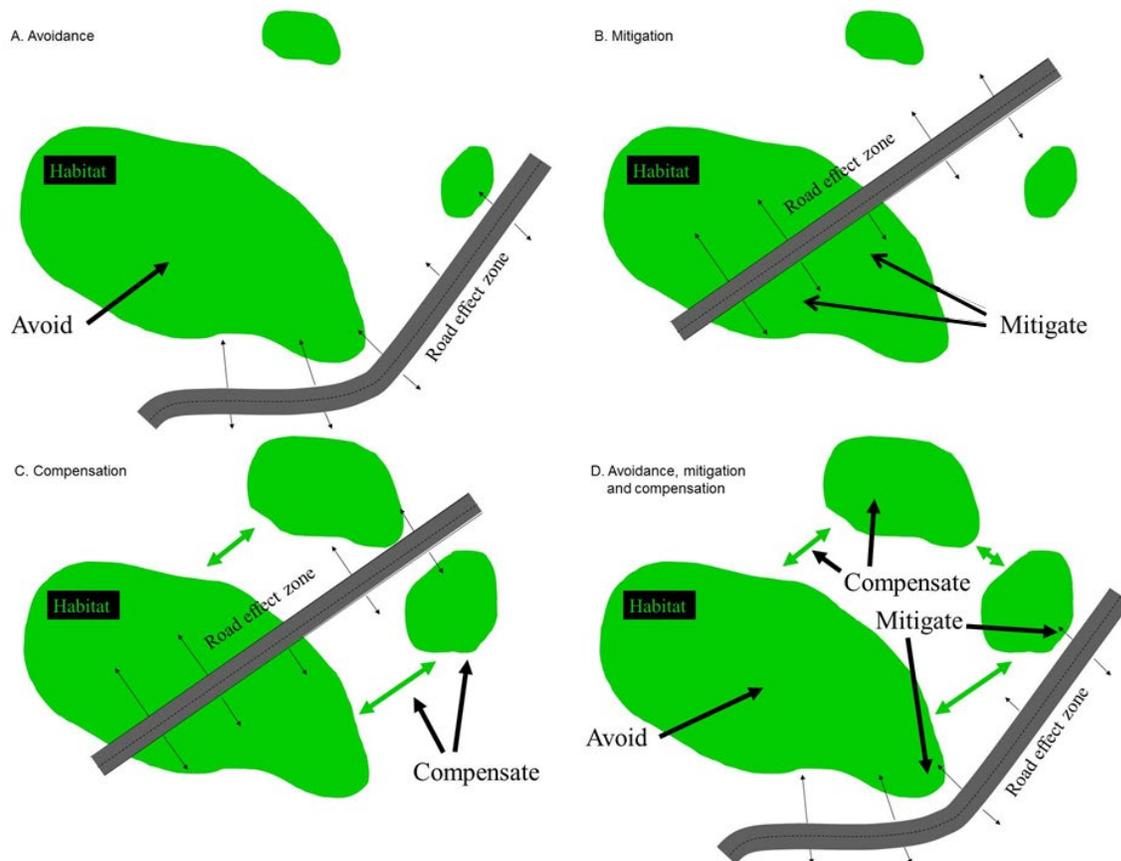


Figure 10: A three-step approach: A. Avoidance, B. Mitigation, C. Compensation, D. Combination of avoidance, mitigation and compensation.

## 4 The functions of fences and crossing structures

Other than permanent, seasonal, or night-time road closures, fences in combination with wildlife crossing structures are the most robust and effective mitigation measure to both reduce collisions with large and small animal species and maintain or improve connectivity for wildlife (Huijser et al., 2021; 2022). However, it is important to be aware of the distinct functions of fences vs. the crossing structures and how that relates to the “departure point” of a mitigation project.

If human safety and direct road mortality of a species are the primary concern, then:

- Road sections with a high concentration of collisions and dead animals are identified and prioritized (e.g., Spanowicz et al., 2020). The target species may be large common mammals if human safety is the primary concern (e.g. Huijser et al., 2008). If reducing unnatural mortality for rare species is the concern, the target species can be of any body size (e.g. Kramer-Schadt et al., 2004; Huijser et al., 2008; Boyle et al., 2021).
- From a human safety perspective, it is logical to identify and prioritize road sections that currently have a concentration of collisions. However, from a biological conservation perspective, direct road mortality may have already caused population depletion. This means that the greatest threat to population persistence due to direct road mortality may not always be along the road sections that currently have the highest concentration of dead individuals of the target species (Teixeira et al., 2017).
- Fences or other barrier types are the primary measure, as the primary purpose of fences along roads is to keep animals off the highway and reduce animal-vehicle collisions (Huijser et al., 2016).
- Since fences alone would result in an absolute or near-absolute barrier for the target species, fences are typically combined with safe crossing opportunities for wildlife, especially wildlife crossing structures (underpasses and overpasses) (Moore et al., 2021).
- The secondary function of the wildlife fences is to guide or funnel wildlife species to these crossing structures (Dodd et al., 2007; Gagnon et al., 2010).
- If constructed over at least 3 miles of road length, wildlife fences almost always reduce collisions with large wild mammals by 80-100% (Huijser et al., 2016, 2021). Shorter mitigated road sections are on average less effective (about 50%) and highly variable in their effectiveness depending on local circumstances (Huijser et al., 2016).
- For fenced road sections to be effective in reducing collisions with large wild mammals on a larger spatial scale, we must avoid moving the collisions to adjacent road sections (Huijser & Begley, 2022). In this context, the mitigation measures may need to be implemented at road sections that are even longer than 3 miles in length. For example, it is considered good practice for the mitigation measures to cover the entire suitable habitat for the species, including an adjacent buffer zone based on the size of the home range of the target species (Huijser et al., 2022). In practice this means that the length of the mitigated road sections for large wild mammals should probably be many miles, potentially dozens of miles.

If habitat connectivity for wildlife is the primary concern, then:

- Road sections where habitat connectivity needs to be maintained or restored are identified and prioritized. This may be based on the connectivity needs (genetic, demographic) for individual species (the “target species”), a wide suite of species or species groups, seasonal migration of certain species (e.g. for ungulates), dispersal to allow for colonization or recolonization of areas nearby or further away, or ecosystem processes in general (biotic and abiotic parameters), including those associated with climate change (e.g. Kramer-Schadt et al., 2004; Clevenger & Huijser, 2011; Sawaya et al., 2013; 2014; Lister et al., 2015; Sawyer et al., 2016; Jarvis et al., 2018).
- While it seems logical to identify and prioritize road sections that currently have observations of animals living or moving close to the road and observations of animals crossing the road (both unsuccessfully and successfully), the greatest population level conservation benefit of reducing the barrier effect of a road may not be where most animals are currently. From the perspective of biological conservation at the population level, areas where most animals are now may have high population viability, potentially despite being isolated because of the barrier effect of transportation infrastructure. In such cases, reducing the barrier effect does not necessarily lead to an increase in population viability. Instead, the greatest population level benefits of reducing the barrier effect can be where small and isolated populations can be made more viable by providing safe crossing opportunities. This may even include road sections that currently isolate unoccupied habitat patches, and that bisect planned habitat corridors rather than existing ones. In other words, crossing structures may also be required or can also be beneficial for population persistence in areas where the target species has low abundance or where it is currently entirely absent.
- Wildlife crossing opportunities, especially wildlife crossing structures, are the primary measure, as the purpose of wildlife crossing structures is to provide safe crossing opportunities.
- Wildlife crossing structures provide safe crossing opportunities for wildlife and can increase permeability compared to an unmitigated road with a smaller footprint, allow for seasonal migration of large ungulates to continue, and can help improve population viability for select species (review in Huijser et al., 2021).
- Crossing structures as a stand-alone measure do not necessarily reduce collisions (Rytwinski et al., 2016). Therefore, wildlife crossing structures are typically combined with wildlife fences.
- An added benefit of connecting crossing structures to wildlife fences is that the fences can guide or funnel wildlife to the crossing structures which can increase wildlife use of the structures (Dodd et al., 2007; Gagnon et al., 2010).

In this context, it is also important to be aware of the limitations of existing crossing structures that were not built for wildlife versus designated wildlife crossing structures. While designated wildlife crossing structures should be located where connectivity for wildlife is needed most, existing structures that were not built for wildlife are not necessarily located where connectivity for wildlife is needed most. Nor are existing crossing structures necessarily of the right type (e.g. overpass vs. underpass) or dimensions (width, height) given the target species, and there are typically limits to potential modifications to existing structures to improve the suitability for the target species.

In conclusion, fences and wildlife crossing structures are almost always implemented together, regardless of whether the primary objective is to reduce animal-vehicle collisions or to reduce the barrier effect of roads and traffic for wildlife. However, the road sections where the measures are implemented are very much dependent on the primary objectives or departure points, and they may include road sections where the target species is not hit or no longer hit, and where the target species may have low population density or where it is currently not present at all.

## 5 Spacing of wildlife crossing structures

The appropriate spacing of wildlife crossing structures can be determined in more than one way and is dependent on the goals one may have. Examples of possible goals are:

- Provide permeability under or over the road for ecosystem processes, including but not restricted to animal movements. Ecosystem processes include not only biological processes, but also physical processes (e.g. water flow). It is good practice to design structures that are primarily needed for hydrology in such a way that they can also function for wildlife. However, only providing wildlife crossing opportunities in low and wet areas means that no connectivity is provided for species that depend on high and dry habitat. Thus, a possible strategy is to identify the different ecosystems and habitat types (not just streams, rivers or wetlands) and ecosystem processes that permeability needs to be provided for and then provide appropriate mitigation measures in each of those ecosystems or habitat types.
- Allowing a wide variety of species, or selected target species, to change their spatial distribution drastically, for example in response to changing environmental conditions.
- Maintaining or improving the population viability of selected species based on their current spatial distribution. This includes striving for larger populations with a certain degree of connectivity between populations (including allowing for successful dispersal movements).
- Providing the opportunity for individuals (and populations) to continue seasonal migration movements (e.g. mule deer, pronghorn or elk) as this can be seen as a component of the ecological integrity of an ecosystem.
- Allowing individuals of selected target species that have their home ranges on both sides of the highway to continue to use these areas. This may result in a road corridor that is substantially permeable to those species, at least for the individuals that live close to the road.

A further complication is that individuals that disperse, that display seasonal migration, or that live in the immediate vicinity of a road may display differences in behavior with regard to where and how they move through the landscape, how they respond to roads, traffic, and associated barriers (e.g. wildlife fencing), and their willingness to use safe crossing opportunities. For example, dispersing individuals may grow up far away from the areas adjacent to roads and may shy away from human disturbances and human made features, they may not move through habitat the way we might expect them to, and they typically travel long distances, much further and quicker compared to resident individuals. Safe crossing opportunities may not be encountered by dispersing individuals as they are new in the area and are not familiar with their location, and when confronted with a road or associated wildlife fence, they may return or change the direction of their movement before they encounter and use a safe crossing opportunity. Furthermore, if dispersing individuals do encounter a safe crossing opportunity, they may be more hesitant to use it compared to resident individuals that not only know about their location, but that also have had time to learn that it is safe to use them. Since dispersal can be a relatively rare phenomenon, one may not be able to afford to have a dispersing individual fail to cross the road. Therefore, even though dispersers travel much further than resident individuals, safe crossing opportunities for dispersers may not allow for a greater distance between safe crossing opportunities compared to safe crossing opportunities for resident individuals.

Population viability analyses can be very helpful to compare the effectiveness of different configurations of safe crossing opportunities. However, for this report the authors choose a simpler approach and suggest the distance between safe crossing opportunities to be equal to the diameter of the home range of the species concerned (Figure 11). In theory, this allows individuals that have the center of their home range on the road to have access to at least one safe crossing opportunity. However, individuals that may have had their home range on both sides of the road do not necessarily have access to a safe crossing opportunity (Figure 12). Finally, this approach assumes homogenous habitat and distribution of the individuals and circular home ranges, while in reality habitat quality may vary greatly, causing variations in density and home range size of individuals and irregular shaped home ranges. Species that have smaller home ranges need the crossing structures to be closer together than species with large home ranges (Figure 11).

This approach does not necessarily result in viable populations for every species of interest, and not every individual who approaches the road and associated wildlife fence will encounter and use a safe crossing opportunity. In addition, the approach described above is not necessarily the only approach or the approach that addresses the barrier effect of the road corridor and associated fencing sufficiently for all species concerned. However, the approach chosen is consistent, practical, can be based on available data, and is likely to result in considerable permeability of the road corridor and associated wildlife fencing for a wide array of species. Note that a mismatch between the spacing of wildlife crossing structures and the distance over which the animals are able and willing to move along a fence can result in severe population decline (Ottburg & van der Grift, 2019). In other words, if an insufficient number of crossing structures is provided, if the distances between consecutive crossing structures is too great, the mitigation can be detrimental rather than helpful to wildlife conservation; doing something is not necessarily better than doing nothing.

Another way to decide on “appropriate distance” between safe crossing opportunities is to evaluate what the spacing is for wildlife crossing structures on other wildlife highway mitigation projects. The average spacing for large mammal crossing structures in Montana (US Hwy 93 North and South), I-75 in Florida, SR 260 in Arizona, Banff National Park in Canada, and ongoing reconstruction on I-90 in Washington State is 1.2 mi (1.9 km) (range for the average spacing of structures in these individual areas is 0.5-1.8 mi (0.8-2.9 km)). However, the 1.2 mi (1.9 km) spacing is simply what people have done elsewhere, and it is not necessarily based on what may be needed ecologically, and the requirements for the target species in one area may be different from what is needed in another area. The distance between suitable crossing structures for amphibians is often much shorter, e.g., only several dozens of feet (12.5 m) (Brehme et al., 2021).

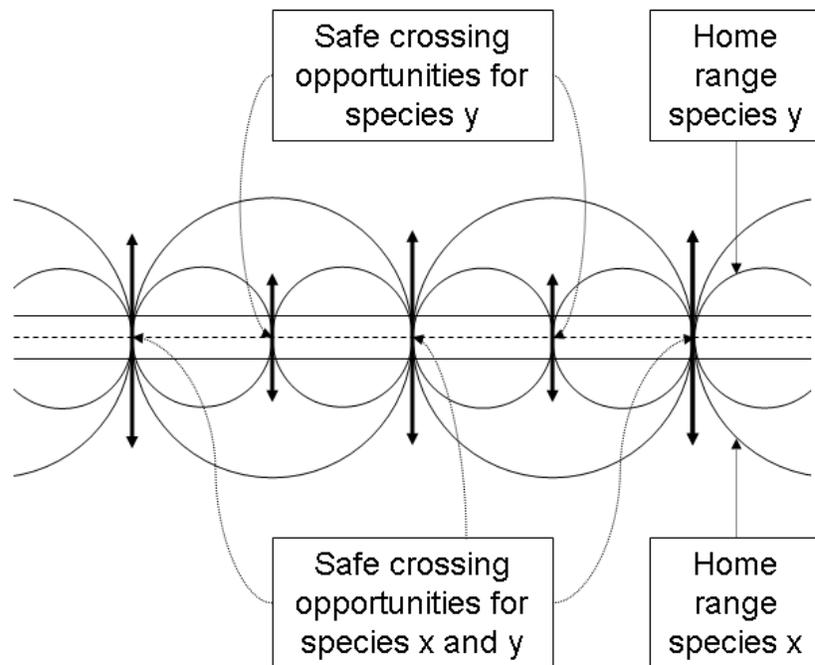


Figure 11. Schematic representation of home ranges for two theoretical species projected on a road and the distance between safe crossing opportunities (distance is equal to the diameter of their home range).

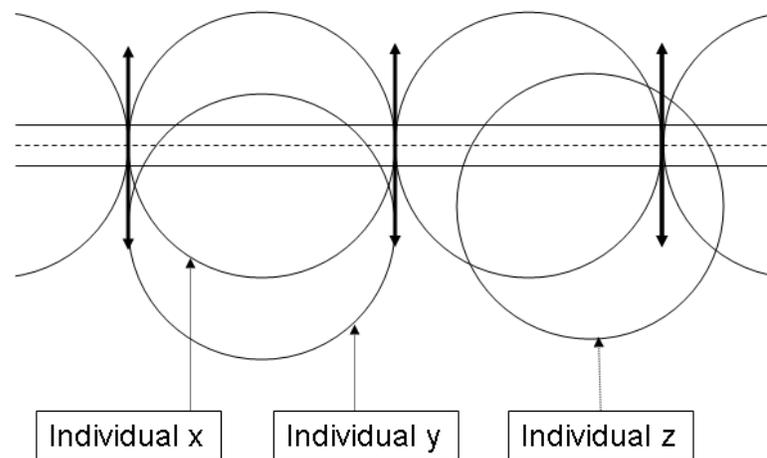


Figure 12. Schematic representation of home range for an individual (x) that has the center of its home range on the center of the road (access to two safe crossing opportunities), an individual (y) that has the center of its home range slightly off the center of the road exactly in between two safe crossing opportunities (no access to safe crossing opportunities), and an individual (z) that has the center of its home range slightly off the center of the road but not exactly in between two safe crossing opportunities (access to one safe crossing opportunity).

## 6 Landscape level ecological connectivity

### 6.1 Aquatic and terrestrial connectivity

Steigerwald Lake NWR is situated along the Columbia River. The Refuge is a floodplain of the Columbia River, but this is also where a creek (Gibbons Creek) flows into the Columbia River. The area is dominated by several lakes, ponds, marshes, open grasslands and riparian woodlands.

Steigerwald Lake NWR's habitat types are characteristic of the Columbia River and its floodplains. Therefore, landscape level connectivity for Steigerwald Lake NWR is mainly along the Columbia River (Figure 13, Figure 14). This relates to both aquatic and riparian habitat. Some floodplain habitat along the Columbia River is protected through other Refuges (Ridgefield NWR, Franz Lake NWR, Pierce NWR). Many of the other sections along the Columbia River have lost their floodplains because of levees and residential and industrial development. In addition, connectivity for aquatic organisms is affected by dams in the Columbia River and its tributaries (e.g., Bonneville Dam). Additional aquatic and riparian connectivity at a more local scale at Steigerwald Lake NWR is along the recently restored Gibbons Creek (Figure 14). Lawton Creek is just east of the Refuge and is also likely to be important for aquatic and riparian connectivity in the immediate area (Figure 14).

Terrestrial connectivity for Steigerwald Lake NWR, Franz Lake NWR and Pierce NWR is mainly to the grasslands and forests to the north and northeast (Figure 13). These grasslands and forests ultimately connect to the Cascade Range (Figure 13). Major transportation infrastructure cutting through the connectivity corridor to the Cascade Range at Steigerwald Lake NWR include the railroad, Washington State Highway 14 and – to a lesser degree - Evergreen Way (Figure 14). Much of the terrestrial connectivity between Steigerwald Lake NWR and the lowlands in the Puget Trough is affected by development. However, Lacamas Lake and Creek is likely the best remaining corridor (Figure 13). Ridgefield NWR connects to other lowlands in the Puget Trough through Lewis River, East Fork Lewis River and its tributaries (Figure 15). I-5 is the major infrastructure that cuts through this connectivity corridor (Figure 15).

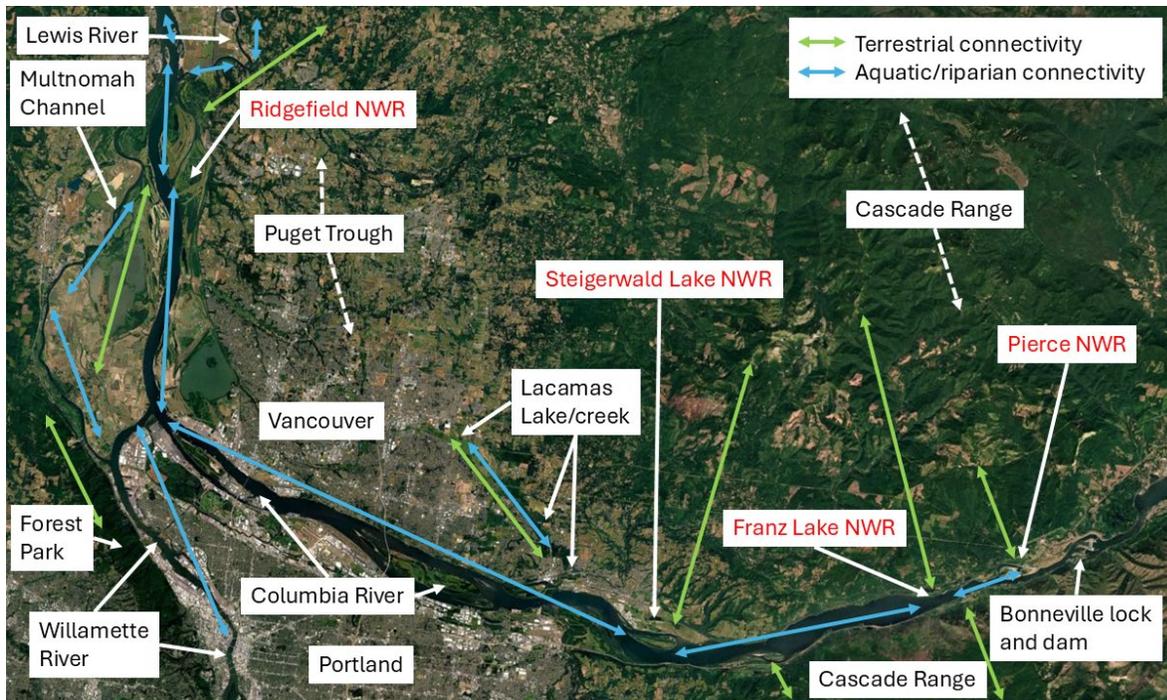


Figure 13: Landscape level connectivity around Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR and Pierce NWR. (Source satellite image Google Earth).

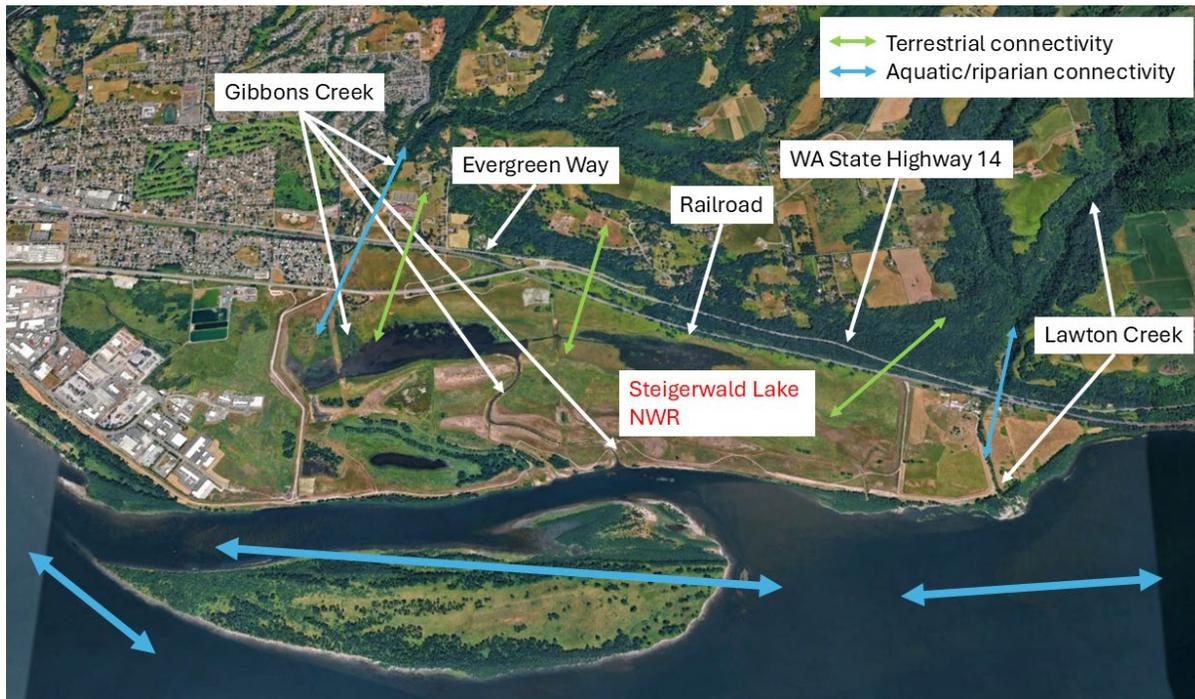


Figure 14: Landscape level connectivity around Steigerwald Lake NWR (Source satellite image Google Earth).

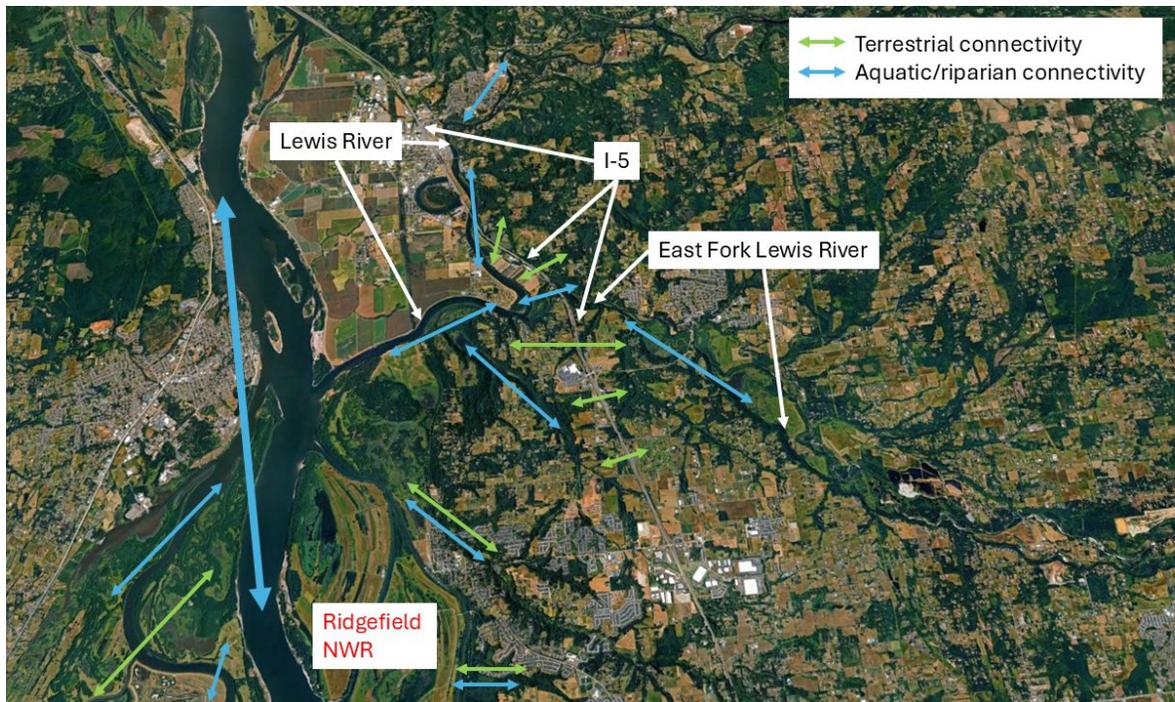


Figure 15: Landscape level connectivity around Ridgefield NWR (Source satellite image Google Earth).

## 6.2 Connectivity studies in the region

The Washington Wildlife Habitat Connectivity Working Group evaluated the area between the Cascade Range and the Pacific Coast region in Washington State for wildlife connectivity (Washington Wildlife Habitat Connectivity Working Group, 2022). Consistent with our own analysis in the previous section, this study identified connectivity from Steigerwald Lake NWR, Franz Lake NWR and Pierce NWR to the Cascade Range. Connectivity to the Puget Through is mostly through Lacamas Lake and Creek (Figure 13). For Ridgefield NWR this study identified connectivity through and alongside the Lewis River and its tributaries (Figure 15).

## 7 Wildlife-vehicle collisions

### 7.1 Introduction

This chapter summarizes the wildlife-vehicle collisions along the major highways in the larger study area surrounding Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR, and Pierce NWR. Note that we were informed by Burlington Northern Santa Fe (BNSF) Railway that they do not collect data on wildlife strikes by trains in this area (Pers. Com. Matthew Jones, Executive Director Public Affairs, BNSF Railway).

We use the term collisions for a combination of wildlife-vehicle crash data and carcass removal data. Wildlife-vehicle crash data are typically collected by law enforcement personnel. Carcass removal data are typically collected by road maintenance personnel. Both wildlife-vehicle crash data and carcass removal data are managed by transportation agencies.

### 7.2 Methods

#### 7.2.1 Large wild mammal-vehicle crash data

We obtained crash data from Washington State Department of Transportation for the three highway sections (WA Highway 14, Evergreen Way, I-5) for ten full calendar years (1 January 2015 through 31 December 2024). We selected the crash records that relate to animals (i.e., both wild and domestic species). The selected records relate to the following crash scenarios:

1. The vehicle hits the animal.
2. The vehicle does not hit the animal but still crashes as a result of the animal's presence (e.g., swerved and then crashed).

We summarized the number of crashes distinguishing between domesticated animal species and wild animal species, and whether the vehicle hit the animal or whether the vehicle did not hit the animal but still crashed. We provided this summary for each of the three road sections and also for the three road sections combined.

We then selected the records that related to wild animals to identify road sections that have a relatively high concentration of wildlife-vehicle crashes. All spatial analyses were conducted using ArcGIS Pro 3.3.2. For analysis purposes, divided highways and parallel road segments were consolidated by removing duplicate routes, ensuring that each road was represented as a singular linear feature. These processed road sections were then systematically divided into road segments of 0.1 mile (160.9 meters) in length. Crash and carcass data within 25 m from any of the three roads were spatially joined to the nearest road analysis unit. Then We conducted two different types of spatial analyses to identify and prioritize road sections with the highest number of wildlife-vehicle crashes and large wild mammal carcasses:

- Kernel Density Estimation: The Kernel Density Estimation (KDE) analysis was used to assess point features of crash or carcass locations. A bandwidth of 0.5 miles (804.67 m) was applied, meaning that crashes and carcasses within 0.5 miles of each tenth-of-a-mile reference point

influenced the hotspot analysis. This is consistent with the spatial accuracy of the carcass removal data from MDT and the scale at which mitigation measures (e.g., wildlife fences and crossing structures) need to be implemented, typically over several miles of road (Huijser et al., 2016). The search radius is also aligned with similar studies (Gomes et al., 2009). The analysis produces a density surface where each cell's size is 161 m by 161 m and its value represents the estimated density of collisions per square mile. The resulting heat map was divided into five percentage-based categories (<5%, 5–<25%, 25–<50%, 50–<75%, and 75–100%), identifying road sections with the highest densities (i.e., <5%) of collisions and carcasses. This is a descriptive method that always indicates where the highest concentrations of incidents occur. The KDE analyses were conducted using the Spatial Analyst extension in ArcGIS Pro 3.3.2.

- **Getis-Ord  $G_i^*$ :** The Getis-Ord  $G_i^*$  (GOG) analysis used the Getis-Ord  $G_i^*$  statistic to identify statistically significant spatial clusters (hotspots and cold spots) of crashes and carcasses. Unlike the KDE, which is purely descriptive, this analysis identifies road segments where the concentration of crashes or carcasses significantly deviates from a random distribution. A fixed distance band of 0.5 miles was applied, consistent with the KDE analysis. No standardization of spatial weights was applied; all wildlife species were considered equal in contributing to the collision events. This analysis was conducted using the Hotspot Analysis (Getis-Ord  $G_i^*$ ) tool within the Spatial Statistics toolbox in ArcGIS Pro 3.3.2.

### 7.2.2 Carcass removal data

We obtained carcass removal data from Washington State Department of Transportation for the three highway sections (WA Highway 14, Evergreen Way, I-5) for ten full calendar years (1 January 2009 through 31 December 2018). We selected the crash records that relate to wild mammal species (i.e., excluding domestic species, excluding bird species). We summarized the number of carcasses per species for the three road sections combined. We then selected large wild mammal species for Kernel Density Estimation and Getis-Ord  $G_i^*$  analyses. These analyses included white-tailed deer, black-tailed deer, “mule deer” (i.e., black-tailed deer), “deer” (i.e., deer species was not identified), elk, and black bear (236 records in total).

## 7.3 Results

### 7.3.1 Large wild mammal-vehicle crash data

For all three road sections combined, there were 222 crashes that related to wild animals (out of the 6868 crashes in total) (Table 1). Out of these 222 crashes, 192 related to “deer”, 2 related to elk, and 28 related to “unidentified species”. Based on the Kernel Density Estimation, the highest concentration of crashes with large wild mammals occurred along I-5 (mile reference post 18-19 and 24-28) (Figure 16). Smaller concentrations occurred further south along I-5 and along WA Highway 14 including near Steigerwald Lake (mile reference post 19-21). Based on the Getis-Ord  $G_i^*$  analysis, significant concentrations of crashes with large wild mammals occurred between mile reference posts 12-20 and 23-29 (Figure 17).

Table 1: The number of crashes with animals (domestic species vs. wild species) and the number of crashes not involving animals along the three road sections.

Highway	Crash type	Animal hit or avoided	Deer-vehicle crashes (N)	Elk-vehicle crashes (N)	Unknown species-crashes (N)	Non-animal crashes (N)	Total (N)	Total (%)
WA Highway 14	Non-animal crash	N/A	0	0	0	2022	2022	95.69
WA Highway 14	Unknown species	Avoided	0	0	4	0	4	0.19
WA Highway 14	Unknown species	Hit	0	0	0	0	0	0
WA Highway 14	Domestic species	Avoided	0	0	2	0	2	0.09
WA Highway 14	Domestic species	Hit	0	0	0	0	0	0
WA Highway 14	Wild species	Avoided	0	0	13	0	13	0.62
WA Highway 14	Wild species	Hit	66	1	5	0	72	3.41
WA Highway 14	Total (N)		66	1	24	2022	2113	100.00
WA Highway 14	Total (%)		3.12	0.05	1.14	95.69	100.00	
Evergreen Highway	Non-animal crash	N/A	0	0	0	250	250	99.21
Evergreen Highway	Unknown species	Avoided	0	0	0	0	0	0
Evergreen Highway	Unknown species	Hit	0	0	0	0	0	0
Evergreen Highway	Domestic species	Avoided	0	0	0	0	0	0
Evergreen Highway	Domestic species	Hit	0	0	0	0	0	0
Evergreen Highway	Wild species	Avoided	0	0	0	0	0	0
Evergreen Highway	Wild species	Hit	2	0	0	0	2	0.79
Evergreen Highway	Total (N)		2	0	0	250	252	100.00
Evergreen Highway	Total (%)		0.79	0.00	0.00	99.21	100.00	
I-5	Non-animal crash	N/A	0	0	0	4362	4362	96.87
I-5	Unknown species	Avoided	0	0	3	0	3	0.07
I-5	Unknown species	Hit	0	0	0	0	0	0
I-5	Domestic species	Avoided	0	0	0	0	0	0
I-5	Domestic species	Hit	0	0	3	0	3	0.07
I-5	Wild species	Avoided	0	0	5	0	5	0.11
I-5	Wild species	Hit	124	1	5	0	130	2.89
I-5	Total (N)		124	1	16	4362	4503	100.00
I-5	Total (%)		2.75	0.02	0.36	96.87	100.00	
All roads combined	Non-animal crash	N/A	0	0	0	6634	6634	96.59
All roads combined	Unknown species	Avoided	0	0	7	0	7	0.10
All roads combined	Unknown species	Hit	0	0	0	0	0	0.00
All roads combined	Domestic species	Avoided	0	0	2	0	2	0.03
All roads combined	Domestic species	Hit	0	0	3	0	3	0.04
All roads combined	Wild species	Avoided	0	0	18	0	18	0.26
All roads combined	Wild species	Hit	192	2	10	0	204	2.97
All roads combined	Total (N)		192	2	40	6634	6868	100.00
All roads combined	Total (%)		2.80	0.03	0.58	96.59	100.00	

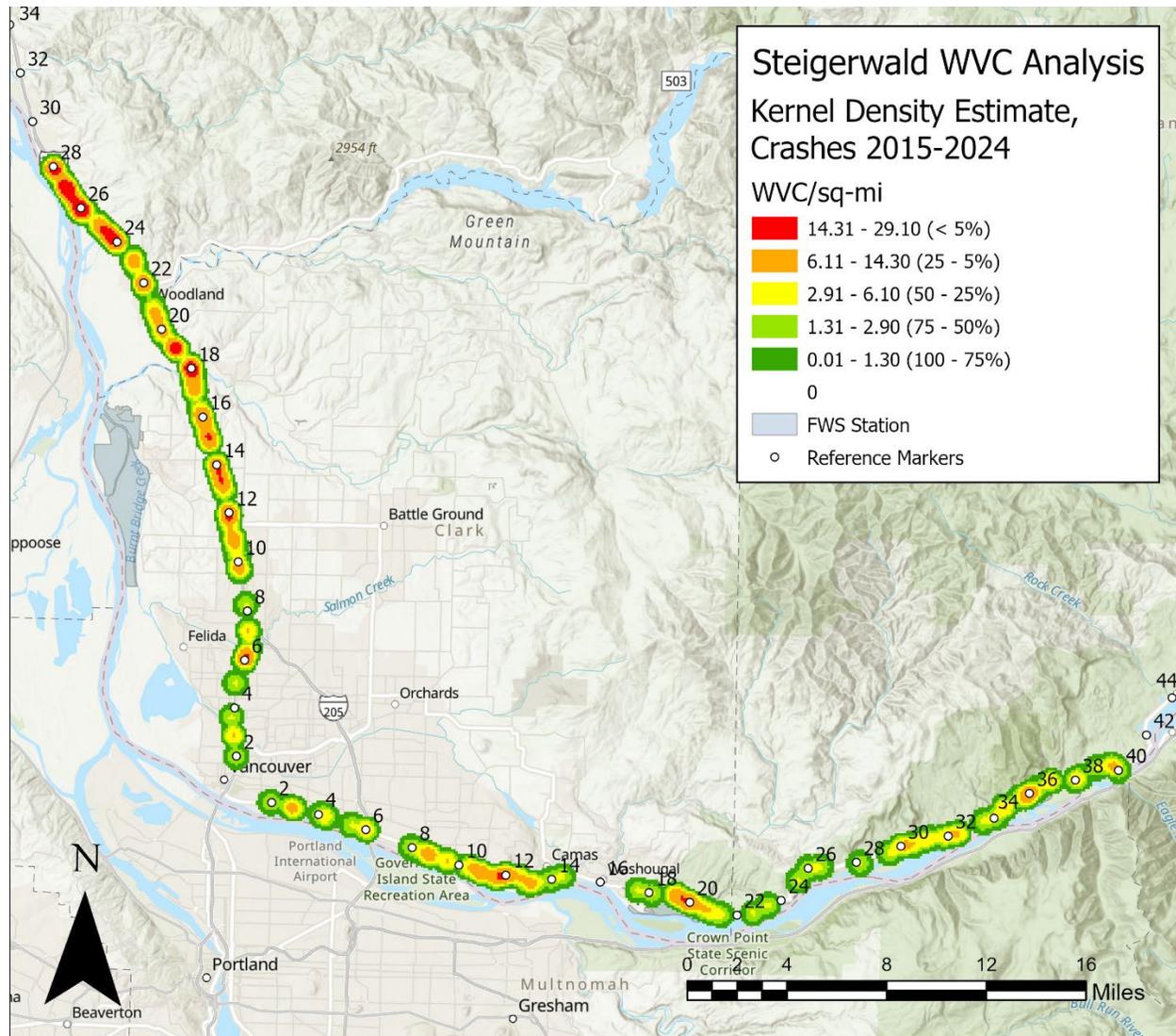


Figure 16: Kernel density hotspot map using percentiles for wildlife-vehicle crashes along the three road sections (2015–2024).

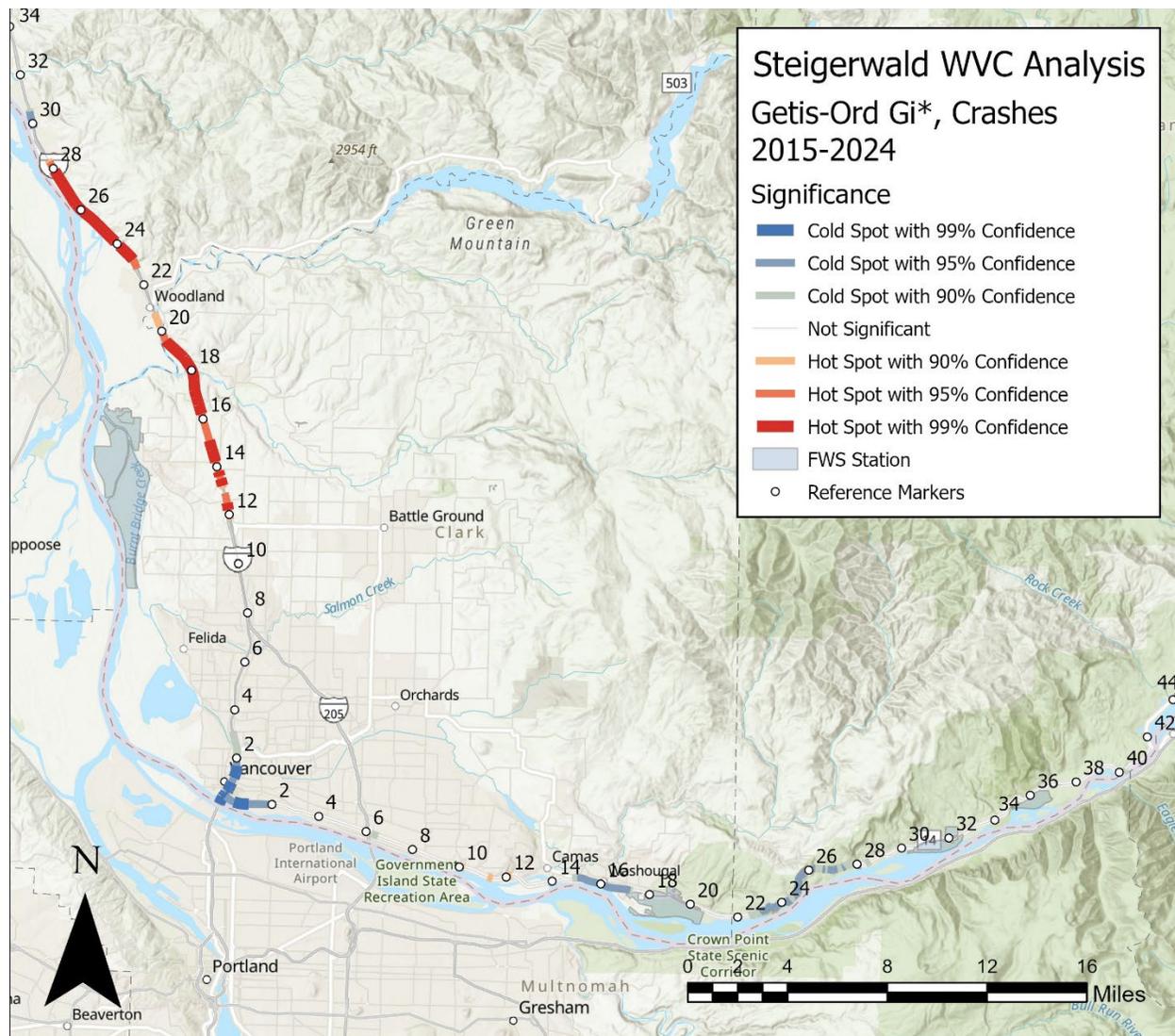


Figure 17: Getis-Ord  $G_i^*$  significant hotspot map for wildlife-vehicle crashes along the three road sections (2015–2024).

### 7.3.2 Carcass removal data

Black-tailed deer (i.e., a subspecies of mule deer) was the most frequently recorded wild mammal species in the carcass removal data (Table 2). Three of the four white-tailed deer carcasses were recorded on the eastern third of WA Highway 14, outside of the known current distribution of Columbia white-tailed deer, indicating potential species identification errors. This is also where two road-killed black bears were recorded. The fourth road-killed white-tailed deer was recorded on the north end of I-5, east of Ridgefield NWR and surrounding areas that host a small population of Columbian white-tailed deer. There was one road-killed elk recorded on the north end of I-5. This is inside the known range of elk. Based on the Kernel Density Estimation, the highest concentration of large wild mammal carcasses occurred along I-5 (mile reference post 5, 19), WA Highway 14 (mile reference post 10-15, 29-31, and 33-37) (Figure 18). Based on the Getis-Ord  $G_i^*$  analysis, significant concentrations of large wild mammal carcasses occurred along WA Highway 14 between mile reference posts 10-14 and 29-37 (Figure 19).

*Table 2: The number of carcasses of wild mammal species for the three road sections combined (2009-2018).*

<b>Species</b>	<b>N</b>	<b>%</b>
Black-tailed Deer	212	63.66
Mule deer	1	0.30
White-tailed deer	4	1.20
Deer (unspecified)	16	4.80
Elk	1	0.30
Beaver	9	2.70
Porcupine	1	0.30
Raccoon	72	21.62
Coyote	15	4.50
Black bear	2	0.60
Total	333	100.00

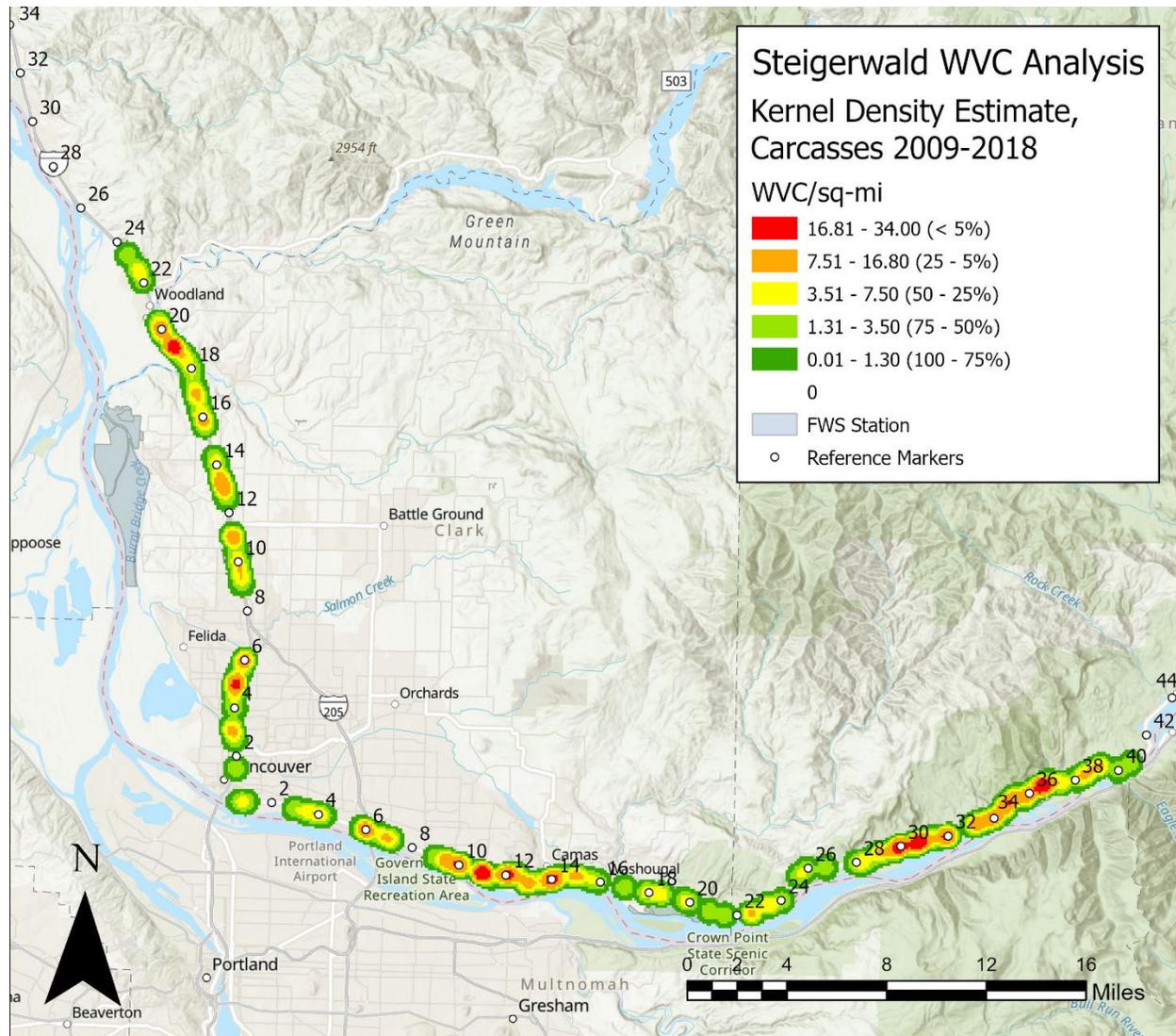


Figure 18: Kernel density hotspot map using percentiles for large wild mammal carcasses along the three road sections (2009–2018).

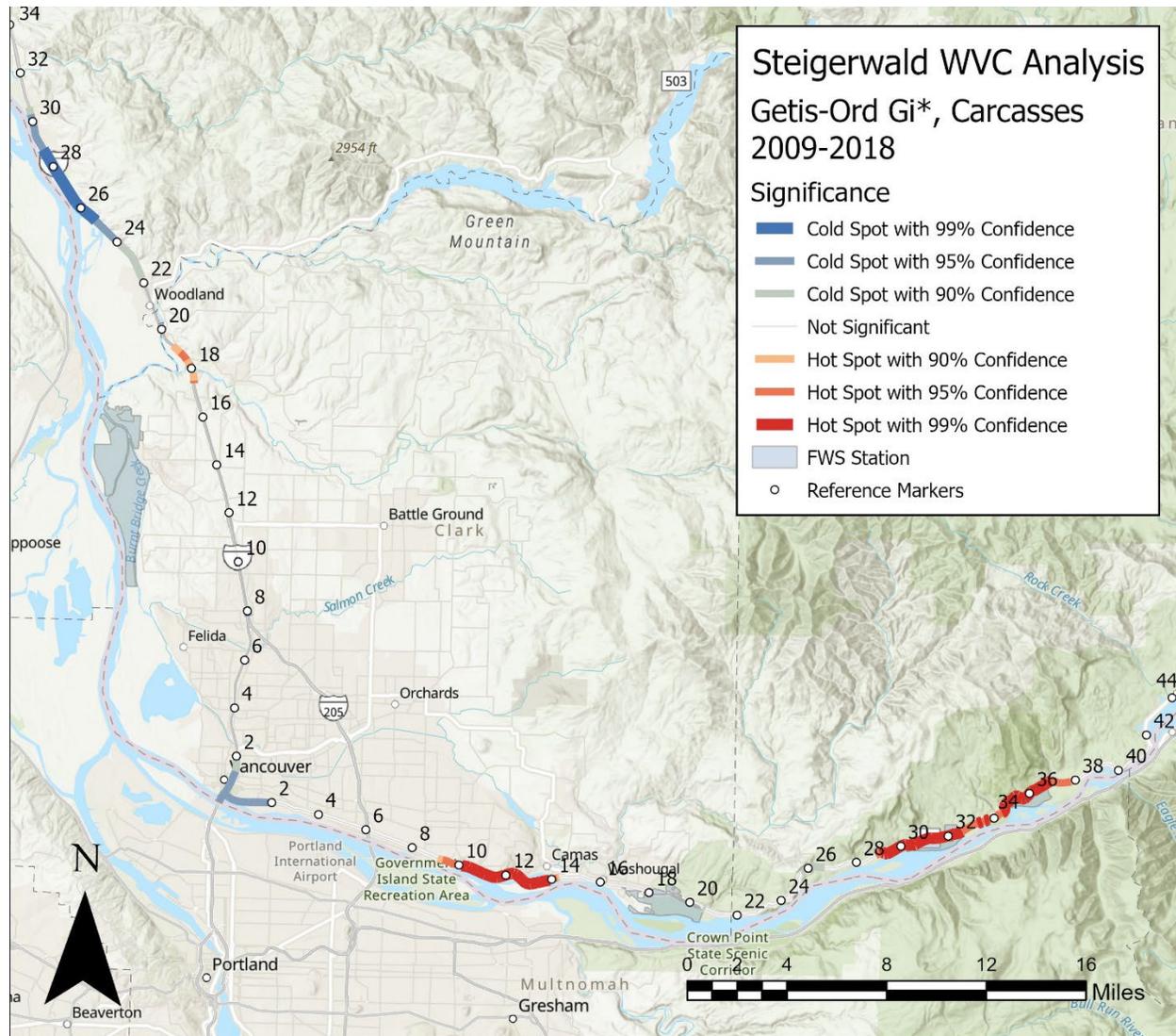


Figure 19: Getis-Ord  $G_i^*$  significant hotspot map for large wild mammal carcasses along the three road sections (2015–2024).

## 7.4 Discussion

While there is some overlap between where concentrations are of crashes involving large wild mammals and where concentrations are of large wild mammal carcasses, there are also differences. The crash data mostly indicate sections of I-5 whereas the carcass removal data mostly indicate section of WA Highway 14.

## 8 Traffic volume

### 8.1 Introduction

This chapter summarizes traffic volume along the three highways (WA Highway 14, Evergreen Way, I-5).

### 8.2 Methods

We compiled traffic volume data from Washington State Department of Transportation and Southwest Washington Regional Transportation Council (RTC, 2025; WSDOT, 2025). Traffic volume data are described as Average Annual Daily Traffic volume (AADT).

### 8.3 Results

WA Highway 14 is a very busy highway between I-5 and Washougal with AADT between 18,000 and 63,000 (Table 3). From Washougal further east the Average Annu traffic volume drops to 6,000-7,000 and then to about 5,000 (Table 3). Evergreen Way is especially busy within the built-up area of Washougal (10,000-12,000 AADT) and less so along the northern edge of Steigerwald Lake NWR (about 3,000 AADT). I-5 is an extremely busy highway with AADT between 58,000-136,000.

Table 3: The Annual Average Daily Traffic volume (both travel directions combined) along the different segments of the three highways.

Highway	MP	ID	AADT	Year
SH-14	0.39	CS05806	63392	2024
SH-14	1.93	R125	53822	2024
SH-14	2.23	CS10917	57691	2024
SH-14	3.69	CS02551	59686	2024
SH-14	4.86	CS04158	63717	2024
SH-14	6.97	CS01147	77148	2024
SH-14	9.02	CS01910	58020	2024
SH-14	10.46	CS11877	43860	2022
SH-14	17.7	P07	44945	2024
SH-14	12.49	CS05353	29865	2024
SH-14	14.1	CS00155	29659	2024
SH-14	15.44	CS07496	25320	2024
SH-14	16.1	CS12788	18063	2024
SH-14	17.7	P07	7480	2024
SH-14	17.84	CS11429	6108	2024
SH-14	21.77	CS05856	5365	2024
SH-14	23.42	CS11690	4967	2024
SH-14	34.26	CS11995	4713	2024
SH-14	37.43	CS06028	4605	2024
Evergreen Way (E st)		east of Washougal River Rd.	9549	2021
Evergreen Way (E st)		west of 32nd Street	9729	2024
Evergreen Way (E st)		east of 32nd Street	12325	2024
Evergreen Way (E st)		east of Sunset View Rd.	3200	2922
I-5	0	CS05901	122839	2024
I-5	0.78	CS01686	130133	2024
I-5	1.38	CS11899	127803	2024
I-5	1.98	P5S	136382	2024
I-5	2.52	CS09980	101256	2024
I-5	3.31	CS04990	97445	2024
I-5	4.79	CS06397	88821	2024
I-5	5.8	CS05923	81256	2024
I-5	8.24	CS11545	130034	2024
I-5	9.94	CS12757	58259	2024
I-5	12.18	R109	109771	2024
I-5	14.58	CS00518	94883	2024
I-5	20.14	R045	83831	2024
I-5	22.15	CS01653	75276	2024
I-5	23.18	CS05827	74296	2024
I-5	28.22	CS05870	72630	2024

## 8.4 Discussion

The AADT along I-5 is likely a very substantial barrier to many species, but black-tailed deer still get hit by vehicles in relatively high numbers compared to the other highways. WA Highway 14 is also likely a very substantial barrier to most wildlife species between I-5 and Washougal. WA Highway 14 is better passable by at least some wildlife species east of Washougal. The same applies to the section on Evergreen Way that is adjacent to the northern section of Steigerwald Lake NWR. Pedestrians crossing WA Highway 14 between the built-up area of Washougal and the new parking area and trailhead are confronted with about 6,000-7,000 AADT which can make at-grade crossings difficult.

## 9 Focal species

### 9.1 Introduction

This chapter lists the focal species for this project. We distinguished between 1. Large wild mammal species that could be considered a threat to human safety in case of a collision, and 2. Species of conservation concern (amphibians, reptiles, and non-arboreal mammals).

### 9.2 Methods

We selected large wild mammal species and species of conservation concern known to be present, or potentially present on one or more of the Wildlife Refuges (Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR, and Pierce NWR). Large wild mammal species were defined as coyote/bobcat and larger, and species of conservation concern were defined as Species of Greatest Conservation Need (SGCN) identified in the Washington State's Wildlife Action Plan (WDFW, 2015; WDFW, 2025b). We selected the species that fell into one of these two categories and that were present in the general area. We also noted whether they have been recorded on the individual Refuges (Ridgefield NWR, Steigerwald Lake NWR, Franz Lake NWR, and Pierce NWR) (USFWS, 2025a). Furthermore, for the selected Species of Greatest Conservation Need (SGCN) we evaluated both their international conservation status (IUCN, 2025) and their legal status in the United States based on the Endangered Species Act (USFWS, 2025b).

### 9.3 Results

Large wild mammal species in the area include large ungulates and carnivores (Table 4). One of the ungulate species, the Columbian white-tailed deer, is listed as threatened on both the state and federal level (USFWS, 2025b; WDFW, 2015; WDFW, 2025b).

Table 4: Large wild mammal species in the study area.

Common name	Scientific name	In general area?	Observed on any of the 4 Refuges?	Ridgefield NWR	Steigerwald Lake NWR	Franz Lake NWR	Pierce NWR
Columbia white-tailed deer	<i>Odocoileus virginianus leucurus</i>	Yes	Yes	X			
Mule deer (black-tailed deer)	<i>Odocoileus hemionus</i>	Yes	Yes	X	X	X	X
Elk	<i>Cervus canadensis</i>	Yes	Yes	X		X	X
Bobcat	<i>Lynx rufus</i>	Yes	Yes	X	X	X	?
Mountain lion	<i>Puma concolor</i>	Yes	Yes	X	X	X	X
Coyote	<i>Canis latrans</i>	Yes	Yes	X	X	X	X
Black bear	<i>Ursus americanus</i>	Yes	Yes			X	X

Species of conservation concern in the area include salamanders, frogs, toads, snakes, turtles, rodents, mustelids, and ungulates (Table 5).

Table 5: Species of conservation concern in the study area.

Common name	Scientific name	Conservation status				In general area?	Observed on any of the 4 Refuges?	Individual Refuges			
		IUCN <sup>1</sup>	Federal <sup>2</sup>	State <sup>3</sup>	SGCN <sup>4</sup>			Ridgefield NWR <sup>5</sup>	Steigerwald Lake NWR <sup>5</sup>	Franz Lake NWR <sup>5</sup>	Pierce NWR <sup>5</sup>
Cascade torrent salamander	<i>Rhyacotriton cascadae</i>	Near threatened		Candidate	Yes	Yes	Yes		X	X	X
Cope's giant salamander	<i>Dicamptodon copei</i>	Least concern			Yes	Yes	Potentially				
Larch Mountain salamander	<i>Plethodon larselli</i>	Least concern		Sensitive	Yes	Yes	Potentially				
Van Dyke's Salamander	<i>Plethodon vandykei</i>	Least concern		Candidate	Yes	Yes	Potentially				
Oregon spotted frog	<i>Rana pretiosa</i>	Vulnerable	Threatened	Endangered	Yes	Yes	Potentially				
Western toad	<i>Anaxyrus boreas</i>	Least concern		Candidate	Yes	Yes	Yes		X	X	X
Ringneck snake	<i>Diadophis punctatus</i>	Least concern			Yes	Yes	Potentially				X?
California mountain kingsnake	<i>Lampropeltis zonata</i>	Least concern		Candidate	Yes	Yes	Potentially				
Sharp-tailed snake	<i>Contia tenuis</i>	Least concern		Candidate	Yes	Yes	Potentially				
Western pond turtle	<i>Actinemys marmorata</i>	Vulnerable		Endangered	Yes	Yes	Yes	X	X	X	X
Brush Prairie pocket gopher	<i>Thomomys talpoides douglasii</i>			Threatened	Yes	Potentially	Probably				
Gray-tailed vole	<i>Microtus canicaudus</i>	Least concern		Candidate	Yes	Potentially	Potentially				
Western gray squirrel	<i>Sciurus griseus</i>	Least concern		Endangered	Yes	Yes	Probably				
Fisher	<i>Martes pennanti</i>	Least concern		Endangered	Yes	Potentially	Potentially				
Western spotted skunk	<i>Spilogale gracilis</i>	Least concern			Yes	Yes	Potentially				
Columbian white-tailed deer	<i>Odocoileus virginianus leucurus</i>		Threatened	Threatened	Yes	Yes	Yes	X			

<sup>1</sup> IUCN, 2025<sup>2</sup> USFWS, 2025b<sup>3</sup> WDFW, 2015; WDFW, 2025b<sup>4</sup> SGCN = Species of Greatest Conservation Need (WAP, 2015; WDFW, 2025b).<sup>5</sup> USFWS, 2025a. Species list on websites of the individual Wildlife Refuges.

## 9.4 Discussion

Mitigation measures along the major infrastructure in the area should probably be designed for large wild mammal species and smaller species including salamanders, frogs, toads, snakes, turtles, rodents, mustelids, felids, canids, bears, and ungulates.

## 10 Non-motorized trails at and around Steigerwald NWR

### 10.1 Introduction

This chapter summarizes the non-motorized trails in and around Steigerwald National Wildlife Refuge.

### 10.2 Trail access issues

In 2020-2022, the Refuge entrance, parking area, and trail system were reconfigured in association with the habitat restoration of Gibbons Creek and reducing flood risk to the surrounding areas (Friends of the Columbia Gorge, 2020). Based on the conversations with stakeholders, there appear to be two main problems related to access of the Refuge.

**Problem 1:** The new entrance and parking area appear to function well for people visiting the Refuge with motorized vehicles (Figure 20). However, pedestrians who want to access the Refuge from the neighborhood to the north of the entrance must cross WA Highway 14 (Figure 21). This section of WA Highway 14 has an estimated traffic volume of 6,108 AADT, and a posted speed limit of 55 MPH.

**Problem 2:** Just north of the Refuge, the railroad and Evergreen Way, is the Jemtegaard Middle School (Figure 22). There are reports that children play on or near Evergreen Way and the railroad regularly.

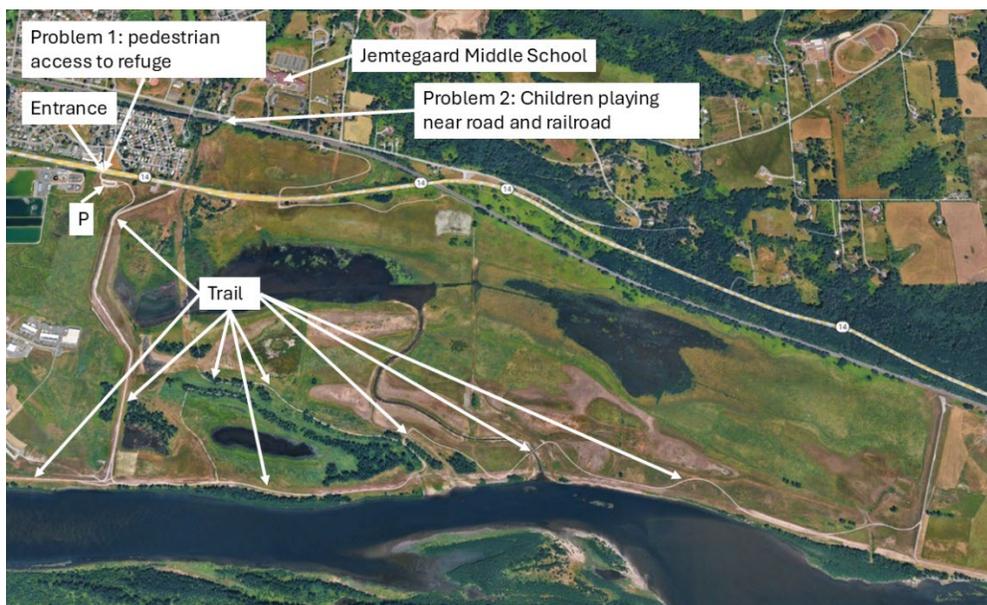


Figure 20: Trail system and access problems at and around Steigerwald NWR (Source satellite image Google Earth).



Figure 21: WA Highway 14 at the entrance to the Refuge (left) and 45<sup>th</sup> St (right), Steigerwald NWR, Washougal, Washington.



Figure 22: Evergreen Way and the railroad at the Jemtegaard Middle School (on the left in the distance) near the northern edge of Steigerwald NWR, Washougal, Washington.

## 10.3 Suggestions

### 10.3.1 Suggestions to address problem 1:

**Option 1:** With a traffic volume well below 10,000 AADT, a high-visibility (i.e., painted crosswalk), well lighted (to enhance the visibility of the painted crosswalk and people on or approaching the crosswalk), and signed and marked crosswalk (e.g., signed that say yield to and stop for pedestrians, shark's teeth markings on pavement)) may be considered (FHWA, 2021). To further enhance the visibility of the crossing area, pedestrian actuated Rectangular Rapid Flashing Beacon (RRFB) may accompany a pedestrian warning sign (FHWA, 2021).

**Option 2:** There are two roundabouts on WA Highway 14 just to the west of the Refuge entrance with access to Washougal:

- 0.80 miles west of the Refuge entrance (32nd St)
- 1.75 miles west of the Refuge entrance (Washougal River Rd)

A third roundabout at the Refuge entrance would be consistent with these other two roundabouts. The posted speed limit between the junction with Washougal River Rd and 32<sup>nd</sup> St, between 32<sup>nd</sup> St and the Refuge entrance, and east of the Refuge entrance is 55 MPH. Adding a third roundabout at the Refuge entry would not change the posted speed limit west and east of the new roundabout at the Refuge entrance. However, the new roundabout would lead to:

- Much lower vehicle operating speed on the approaches of the roundabout and the roundabout itself where pedestrians would be crossing.
- An "island" for pedestrians so that they can navigate one travel direction on WA Highway 14 at a time.
- A safer entry and departure of WA Highway 14 for the housing area to the north and the Refuge parking area.

Note that the roundabout would also have a high visibility (i.e., painted crosswalk), well lighted (to enhance the visibility of the painted crosswalk and people on or approaching the crosswalk), and signed and marked crosswalk (see suggestion 1).

**Option 3:** A grade-separated pedestrian crossing (underpass or overpass) across WA Highway 14 would provide a connection between the neighborhood north of the highway and the parking area and trailhead of Steigerwald NWR south of the highway (Figure 23, Figure 24, Figure 25). This could eliminate the desire or need for a roundabout at the Refuge entry, at least from pedestrian's perspective. A grade-separated crossing would not reduce the danger associated with leaving and entering US Highway 14 with a vehicle from either the neighborhood or the Refuge parking area. There are also downsides to grade-separated crossings. Underpasses can be unsafe for the users because of higher crime rates associated with places that are less visible to other people from further away (Manthiriku et al., 2022). On the other hand, overpasses may allow for other types of problems including people dropping rocks or other objects on the road and vehicles. These problems can be at least somewhat countered through lighting in an underpass, continuous camera surveillance and protective barriers on an overpass

(Manthiriku et al., 2022) (Figure 24). Note that an underpass must be in a location where it does not negate flood reduction measures.

An alternate, or perhaps even a second location for a grade-separated pedestrian crossing could be where Gibbons Creek goes under WA Highway 14. There is very little clearance under the bridge for Gibbon Creek (Figure 26). For a trail to go under WA Highway 14 at Gibbons Creek, the roadbed would have to be raised, probably over hundreds of yards on each side, only a few years after the roadbed was reconstructed to reduce flooding. However, an overpass can both span WA Highway 14 and Gibbons Creek with one structure. On the south side it could connect to an existing trail (Figure 23). On the north side the overpass would connect to a meadow (Figure 23). This meadow is part of Steigerwald NWR. If a repurpose of the meadow north of WA Highway 14 is considered, a trail could connect the structure across WA Highway 14 and Gibbons Creek (south end) to another grade-separated pedestrian crossing across the railroad and Evergreen Way near the Jemtegaard Middle School (Figure 23). See also “problem 2” in the section below.



Figure 23: Possible locations for overpasses across WA Highway 14 at the Refuge entrance/parking area, and across the highway and Gibbons Creek. The latter overpass could connect to a trail across the meadow north of WA Highway 14 – which is also part of the Refuge – and connect to another overpass over the railroad and Evergreen Way at the Jemtegaard Middle School (Source satellite image Google Earth).



Figure 24: Bicycle and pedestrian underpass (with surveillance) under WA Highway 14, Steamboat Landing Park, Washougal, Washington.



Figure 25: Pedestrian overpass with protective barriers over a railroad, oaks to wetland trail, Ridgefield National Wildlife Refuge, Ridgefield, Washington.



Figure 26: WA Highway 14 bridge over Gibbons creek looking downstream, Steigerwald National Wildlife Refuge, Washougal, Washington, USA. Note the very low clearance under the bridge.

### 10.3.2 Suggestions to address problem 2:

**Option 1:** Make the road and railroad harder to access through fences. However, there are access roads to the school and across the railroad tracks (Figure 27) which may still allow children to be on or near Evergreen Way and the railroad.



*Figure 27: The railroad crossing close to the Jemtegaard Middle School. There are reports that children play on or near Evergreen Way and the railroad regularly.*

**Option 2:** The northern meadow, south of the railroad, is part of Steigerwald NWR. Purpose of the meadow could be considered and establish a trail that leads south across the meadow and across WA Highway 14 and Gibbons Creek to the main parking area and trailhead of the Refuge (Figure 28). This would be combined with fences along Evergreen Way, the railroad, and WA Highway 14.

**Option 3:** One may also consider having trees and shrubs in part of the meadow and having a zone that would allow for “unstructured playtime” for children. Zoning of the meadow could be considered that would protect the creek, as well as the eastern part of the meadows and the Refuge building (Figure 29). Note that the trail zone and adjacent areas may be planted with shrubs, and lower lying wet areas may also be created. This may allow for a more secluded experience for Refuge visitors and better birding, similar to the “old trailhead area” just east of Gibbons Creek and south of WA Highway 14. The “old trailhead area” is no longer accessible to people since the restoration project that started in 2020. Refuge visitors south of WA Highway 14 are now required to walk on the high levee that lacks shrubs and trees and associated wildlife, especially birds. While the levee allows for better views of parts of the Refuge, the “distance” between what feels “natural” and the Refuge visitors has increased. Repurpose of the northern meadow could potentially somewhat compensate for this change.



Figure 28: The meadow north of WA Highway 14, Steigerwald National Wildlife Refuge, Washougal, Washington, USA.



Figure 29: The potential trail connecting Jemtegaard Middle School to the main trailhead of Steigerwald NWR south of WA Highway 14, Steigerwald NWR, Washougal, Washington. The figure also shows conceptual zoning of a protected area along the creek (zone 1), the trail (zone 2), play area (zone 3) and a no access area (zone 4) (Source satellite image Google Earth).

## 11 Mitigation measures

### 11.1 Introduction

The target species for reducing wildlife-vehicle collisions and for reducing the barrier effect of roads and traffic the mitigation measures influence the design of the mitigation measures. In this chapter we discuss the design specifications of mitigation measures for large wild mammals separately from those for small animal species (i.e., amphibians, reptiles, and small mammals). Finally, we discuss how these mitigation measures can be integrated with non-motorized trails.

### 11.2 Measures for large wild mammals

The target species influence the barrier (fence) design, as well as the number, location, type and dimensions of crossing structures (i.e. wildlife underpasses and overpasses) (for more details see Huijser et al., 2022) (Figure 30, Figure 31, Figure 32, Figure 33, Figure 34, Figure 35). Specific considerations:

1. Implement the mitigation measures at the appropriate spatial scale (see e.g., Huijser et al., 2016; Huijser & Begley, 2022; Huijser et al., 2022) and ensure there is spatial coherence between the different road sections that are mitigated. If the objective includes ecological parameters (e.g., improved population viability through reduced unnatural mortality and increased habitat connectivity) actions on a landscape level are required. Conservation goals cannot be achieved through only treating roads in certain spots or sections without making the connection to the surrounding landscape.
2. Evaluate the effectiveness of the mitigation measures in terms of reaching the objectives.
3. If the objectives are not reached, investigate why and implement adaptive management.



Figure 30. Typical large ungulate fence in North America, 8 ft tall, wooden posts and mesh-wire fence material, US Hwy 93 North, Montana, USA. This type of fence is suitable for e.g., white-tailed deer, mule deer, and elk. Note that there is a dig barrier attached to the main fence material (e.g. for Canids, Ursids).



Figure 31. Fence for Florida panther (*Puma concolor coryi*), 10 ft tall, metal posts, chain-link fence material, and overhang, SR 29, Florida, USA). This type of fence is an appropriate barrier for e.g., mountain lion and black bear.



Figure 32. Wildlife fence for multiple species groups. The black plastic screen is for amphibians (e.g. common toad (*Bufo bufo*)), the fine mesh wire fence is for medium sized mammals (e.g. Eurasian badger (*meles meles*)) and the large mesh wire fence is for large ungulates (e.g. roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*)) at ecoduct Woeste Hoeve A50 near Apeldoorn, The Netherlands.



Figure 33. Wildlife underpass (width 7-8 m, height 4-5 m), suitable for white-tailed deer and mule deer and black bear. Not suitable for e.g., elk.



Figure 34. Wildlife underpass with dimensions that would be suitable for most large mammal species. Note the wooden visual barrier on the structure. The barrier reduces visual and noise disturbance from traffic for the animals that approach the underpass. The pillars allow for more visibility for animals than supporting walls.



Figure 35. Wildlife overpass with dimensions that would be suitable for most large mammal species. Note the berm on wildlife overpass (center image) and the wildlife fence on the right towards the edge of the structure. The berm with root wads and shrubs provides cover on either side and reduces visual and noise disturbance for animals using the structure.

### 11.3 Measures for small animal species

#### General considerations:

- Crash data from law enforcement agencies and carcass removal data from transportation agencies are generally not suitable for small species or species that are rare (Huijser et al., 2022). Explore if and how data collection practices for small or rare species may be improved or initiated. Examples include using an app, automating date, time, and location recording, and having NGO's and agency employees (e.g., USFWS), collect data, potentially using such an app (Ament et al., 2018; 2019; 2021).
- Conduct a data analysis to identify and prioritize road sections that may require mitigation measures aimed at reducing direct road mortality, and other hazards associated with roads and traffic (e.g., impassable curbs, storm drains that act as pitfalls), and where roads may act as a barrier (see e.g., Gunson & Huijser, 2019; Huijser et al., 2022).
- Identify areas that are important to biological conservation and identify potential or existing corridors between them, especially within areas of protected lands (e.g., NWRs) and how those areas fit into the landscape in the wider region. Overlay these important habitat patches and corridors with the transportation network to identify and prioritize road sections that may require mitigation measures aimed at increasing habitat connectivity in areas separated by roads. Rare species may depend on a meta population structure that goes well beyond the boundaries of a single protected area. Small species may not move far or fast and may require mitigation measures at very specific locations, including low volume roads, potentially even gravel roads or dirt roads.
- Identify the objectives and the target species for the mitigation measures and design the measures for these species accordingly. The target species influence the barrier (fence) design, as well as the number, location, type and dimensions of crossing structures (i.e., wildlife underpasses and overpasses) (for more details see Huijser et al., 2021; 2022).
- Implement the mitigation measures at the appropriate spatial scale (see e.g., Huijser & Begley, 2022; Huijser et al., 2022) and ensure there is spatial coherence between the different roads and road sections that require mitigation. If the objective includes ecological parameters (e.g., improved population viability through reduced unnatural mortality and increased habitat connectivity) actions are required on a landscape level. Conservation objectives cannot be achieved by only treating roads in certain spots or sections without making the connection to the surrounding landscape. When mitigation measures are implemented for small species, it is critical to not only implement measures that keep the animals off the road, but to also provide sufficient crossing opportunities that are not too far apart. Mitigation measures that include crossing opportunities that are too far apart can be detrimental to the conservation of a species rather than be helpful (Ottburg & van der Grift, 2019).
- Evaluate the effectiveness of the mitigation measures in terms of reaching the objectives.
- If the objectives are not reached, investigate why and implement adaptive management.

Road removal may not be an option, except for very low volume roads that no longer serve their original purpose. However, seasonal or night-time road closure may be an option for some low volume roads, especially if there is a mortality issue with small species that is spatially concentrated (Figure 36).



Figure 36. Night-time road closure Saguaro National Park Arizona USA.

For most roads, road mortality mitigation for small animal species consists of fences or other types of barriers that keep the animals off the road (Figure 37). One may also consider barriers that are integrated into the road bed (Figure 38). The latter design allows animals that are on the road to escape to the safe side of the barrier anywhere. Some reptile species, such as turtles, snakes and Crocodylia may require taller barriers (e.g. 2-3 ft) (Figure 39).



Figure 37. Plastic sheeting during installation for amphibians, reptiles, and small mammals, Montana, USA. Here the sheet is dug into the ground (8 inches) and attached to an existing large mammal wire mesh fence.



Figure 38. Barrier or wall for amphibians integrated into roadbed Deelenseweg between Hoenderloo and Arnhem Gelderland, The Netherlands.



Figure 39. Barrier wall for turtles, alligators, snakes, and amphibians. Lake Jackson Ecopassage Tallahassee Florida USA.

In general, crossing structures for small species can be smaller than those for large mammals (Figure 40, Figure 41). However, they may need to be no further than a few dozen feet apart as small animal species only move over short distances. As they may take hours, days or even weeks to move across a structure, small animal species may also require everything they need to live, including water, food and cover (Figure 42).

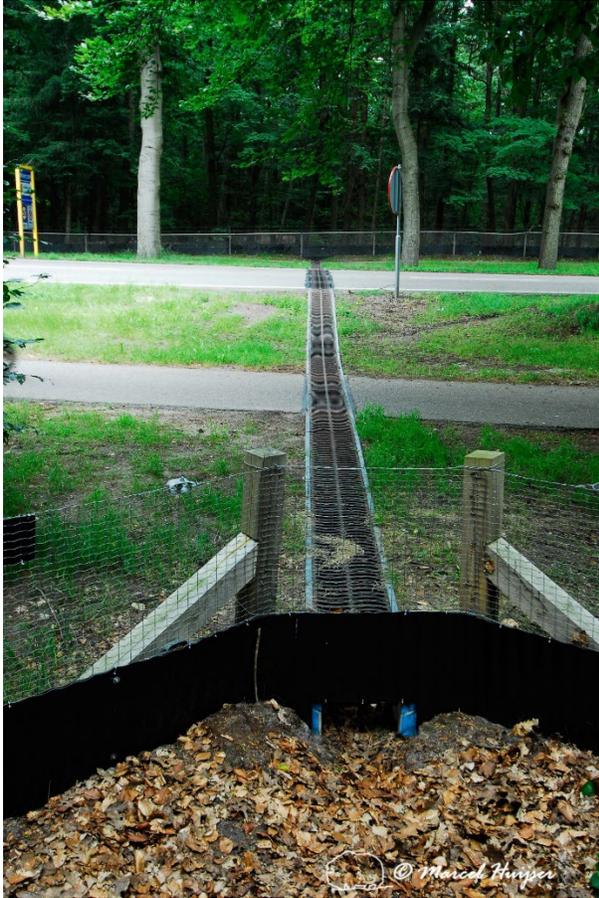


Figure 40. Barrier wall and underpass with slotted roof for common toads, The Netherlands.



Figure 41. Underpass (culvert) for amphibians, including salamander species, Monkton-Vergennes Road Vermont USA.



*Figure 42. Underpass for large wild mammals made more suitable for small mammals, amphibians, and reptiles by placing cover (branches) along the sides, Montana, USA.*

## 12 Mitigation measures for the target species in the study area

### 12.1 Introduction

This chapter described the specific fence and crossing structure designs that would be suitable for the target species in the study area.

### 12.2 Large wild mammals

Effective wildlife fences must be designed with the climbing, digging, and jumping capabilities of the target species in mind, as well as their strength. There are multiple large wild mammal species in the area. Therefore, one may decide to improve human safety and reduce direct road mortality for those other large mammal species with the same fence. This means that one may design a wildlife fence to keep multiple species from accessing highways in the area (Table 6). This means that the target species with the greatest ability to breach a fence would dictate the fence characteristics.

Table 6: The large wild mammal target species in the area and the recommended wildlife fence characteristics (adapted from Huijser et al. 2022b).

Species name	Fence height	Post material	Fence material	Dig barrier/apron	Over-hang	Electric fence or wires
White-tailed deer ( <i>Odocoileus virginianus</i> )	8 ft	Wood	Mesh-wire	No	No	No
Mule deer ( <i>Odocoileus hemionus</i> )	8 ft	Wood	Mesh-wire	No	No	No
Elk ( <i>Cervus canadensis</i> )	8 ft	Wood	Mesh-wire	No	No	No
Bobcat ( <i>Lynx rufus</i> )	8 ft	Metal	Chain-link	Yes	Yes	Yes
Cougar ( <i>Puma concolor</i> )	10 ft	Metal	Chain-link	Yes	Yes	Yes
Coyote ( <i>Canis latrans</i> )	8 ft	Wood	Chain-link	Yes	Yes	Yes
Black bear ( <i>Ursus americanus</i> )	10 ft	Metal	Chain-link	Yes	Yes	Yes

The recommended height is based on the jumping and climbing capabilities of a species, as well as tolerance or intolerance when some individuals breach the barrier. The material for the fence post depends on whether the species can climb wooden posts (metal recommended) or not (wood recommended), but the substrate (rocks) can also dictate the post material. The fence material is based on the size of a species and whether they would be able to pass through the meshes or if they can use

the meshes as “steps” when climbing the fence. A dig barrier is usually a 4-5 ft wide galvanized chain-link fence that is attached to the bottom of the actual fence, angled towards the habitat side of the fence (Figure 43). The buried fence should extend approximately 3.5 ft (1.1 m) under the ground (Clevenger & Huijser 2011). An overhang is attached to the top of the main fence and angles towards the habitat side of the fence (Figure 44). Species or individuals that climb a fence would also have to navigate the overhang to make it to the road side of the fence. Electric fences or electrified wires attached to mesh-wire or chain-link fences can also be considered in the design of a wildlife fence, especially for species that can climb, including bobcat, cougar and black bear (Figure 45). Finally, a high-tensile top wire is recommended when trees are in the vicinity of the wildlife fence (Figure 46). High-tensile top wires can reduce the damage of a fallen tree and prevent a temporary gap in the fence.



*Figure 43. Wildlife fence and dig barrier (“buried fence” or “apron”), Trans-Canada Highway, Banff National Park, Alberta, Canada. The dig barrier in the soil angles (45°) towards the safe side or habitat side; it angles away from the fence and the road on the other side (Clevenger and Huijser 2011). The dig barrier keeps animals from digging under the fence. The dig barrier may consist of a 4-5 ft (1.0-1.2 m) wide galvanized chain-link fence that is attached to the bottom of the actual fence. The buried fence should extend approximately 3.5 ft (1.1 m) under the ground (Clevenger & Huijser, 2011).*



Figure 44. Outrigger or overhang on a fence for Florida panther (*Puma concolor coryi*), SR 29, Florida, USA. Note that the outrigger faces the safe side, the habitat side of the fence. One may consider a longer overhang from chain-link fence material.



Figure 45: Wildlife fence along A28 motorway, near Spier, Drenthe, The Netherlands. The fence is a barrier for medium and large mammal species. The electrified wire is an additional barrier to keep animals out of the fenced road corridor.



Figure 46. Wildlife fence with high-tensile top wire to reduce damage from falling trees, Trans-Canada Highway, Banff National Park, Alberta, Canada.

Effective wildlife crossing structures must be at the correct locations and interval for the target species. The structure type and structure dimensions also depend on the species. For this report we distinguish between different structure types (overpasses vs. underpasses) and structure dimensions (e.g., width, height, length) (Figure 47, Table 7). Note that we define width and length from the animal's perspective rather than the driver's perspective.

Safe Crossing Opportunity type	Indicative dimensions (as seen by the animals)	
Wildlife overpass	50-70 m wide	
Open span bridge	12-30 m wide, ≥ 5 m high	
Large mammal underpass	7-8 m wide, 4-5 m high	
Medium mammal underpasses	0.8-3 m wide, 0.5-2.5 m high	
Small-medium mammal pipes	0.3-0.6 m in diameter	

Figure 47. Crossing structure types and dimensions.

Table 7. ● Recommended/Optimum solution; (●) Likely, but no data, ○ Likely marginal or somewhat possible if adapted to species' specific needs; ⊗ Not recommended; ? Unknown, more data required; — Not applicable (Clevenger & Huijser 2011, O'Brien et al. 2013, Ford et al. 2017, Huijser et al., preliminary data; Clevenger, unpublished data).

	<b>Wildlife overpass</b>	<b>Open span bridge</b>	<b>Large mammal underpass</b>	<b>Medium mammal underpass</b>	<b>Small-medium mammal pipes</b>
White-tailed deer	●	●	●	⊗	⊗
Mule deer	●	●	●	⊗	⊗
Elk	●	●	○	⊗	⊗
Bobcat	●	●	●	●	⊗
Cougar	●	●	●	⊗	⊗
Coyote	●	●	●	●	⊗
Black bear	●	●	●	⊗	⊗

### 12.3 Small animal species

Effective wildlife fences must be designed with the climbing, digging, and jumping capabilities of the target species in mind, as well as their strength. There are multiple small animal species in the area that are also of conservation concern. Therefore, one may decide to design a barrier for small animal species – or species group - based on the target species with the greatest ability to breach a fence (Table 8).

Table 8: Potential small and medium sized wild animal species or species groups and the recommended stand-alone wildlife fence characteristics (adapted from Ontario Ministry of Natural Resources and Forestry, 2016; Gunson & Huijser, 2019; Langton & Clevenger, 2020; Huijser et al. 2022b; van der Grift et al., 2023, Animex, 2025).

Species group name	Fence height	Post material	Fence material	Buried fence	Over-hang	Electric fence or wires
Frogs/toads	2-3 ft	Metal	Plastic sheeting	8-12 inches	Yes	No
Salamanders	2-3 ft	Metal	Plastic sheeting	8-12 inches	Yes	No
Snakes	2-3 ft*5	Metal	Plastic sheeting	8-12 inches	Yes	No
Turtles	2-3 ft	Metal	Plastic sheeting	8-12 inches	No	No
Mustelids (Fisher)	7.3 ft (smooth between 1.0 - 2.25 m)	Wood	Small mesh size fence (or chain-link) in combination with plastic sheeting	8-12 inches	No	No
Rodents	2-3 ft	Metal	Plastic sheeting	8-12 inches	Yes	No

The suitability of different types and dimensions of crossing structures for small animal species groups is summarized in Table 9.

Table 9. ● Recommended/Optimum solution; (●) Likely, but no data, ○ Likely marginal or somewhat possible if adapted to species' specific needs; ⊗ Not recommended; ? Unknown, more data required; — Not applicable (Clevenger & Huijser 2011, O'Brien et al. 2013, Ford et al. 2017, Gunson & Huijser, 2019; Huijser et al., 2022).

	Wildlife overpass	Open span bridge	Large mammal underpass	Medium mammal underpass	Small-medium mammal pipes
Frogs/toads	●	●	●	● <sup>1</sup>	● <sup>1</sup>
Salamanders	● <sup>2</sup>	●	● <sup>3</sup>	● <sup>3</sup>	● <sup>1</sup>
Snakes	●	●	● <sup>3</sup>	● <sup>3</sup>	⊗
Turtles	●	●	● <sup>2</sup>	● <sup>2</sup>	⊗
Mustelids	●	●	● <sup>3</sup>	● <sup>3</sup>	○
Rodents	●	●	● <sup>3</sup>	● <sup>3</sup>	○

<sup>1</sup> With open or slotted roof.

<sup>2</sup> With wet habitat provided on top of overpass and on the approaches.

<sup>3</sup> With cover (e.g., rootwads, branches) provided on top, inside and on the approaches.

## 13 Combining mitigation measures for wildlife with non-motorized trails

### 13.1 Why combined use?

People who recreate outside tend to have better physical and mental health (Catalan et al., 2023; Wales et al., 2024). The benefits of spending time outdoors also extend to the overall quality of life and job satisfaction (McFarland, 2017). These principles apply to all settings ranging from urban and suburban to rural and wilderness, including national parks and other protected areas (Stolton & Dudley, 2010; Wolf & Wohlfart, 2014; Catalan et al., 2023). The benefits of physical outdoor activities are greater than those indoors (Niedermeier et al., 2017).

Just like wildlife, people who use trails for non-motorized recreation experience habitat fragmentation because of busy roads, railroads or other linear infrastructure. Crossing structures for hiking, bicycling, and equestrian use across major infrastructure result in larger networks of trails, enhancing recreation opportunities. While it is possible to have separate structures for wildlife and humans using non-motorized trails, there are likely cost savings associated with having wildlife and non-motorized recreation on the same structure rather than two separate structures (van der Ree & van der Grift, 2015). Furthermore, it is possible that more combined use structures would be built than single use structures, potentially allowing for more locations where connectivity for both wildlife and non-motorized recreation by people would be improved.

### 13.2 General risks of combined use

In general, the non-motorized recreational activities by humans have the potential to disturb wildlife (Taylor & Knight, 2003). Non-motorized activities on trails tend to result in greater behavioral response by large mammals than motorized vehicles on roads (Gump & Thornton, 2023). Different large ungulates species moved away from humans on trails if the humans were up to several hundreds of meters away (Taylor & Knight, 2003; Lucas, 2020). However, when humans leave or when human use is very low, ungulates can respond quickly and stop avoiding trails (e.g. Longshore et al., 2013). Others found that wildlife may shift the use of areas near trails to the night or delay their return to areas recently used by recreationists (Westekemper et al., 2018; Gump & Thornton, 2023).

Encounters with species that can be dangerous to people can negatively impact visitor experiences (Takahiro & Shoji, 2014). However, species that can pose a risk to humans such as grizzly bears may also choose to avoid areas with relatively high human use (Mace & Waller, 1996).

### 13.3 Effects of human co-use on wildlife use of crossing structures

Human co-use was negatively associated with large mammal use of wildlife crossing structures in Banff National Park in Canada (Clevenger & Waltho, 2005). This correlation was stronger for large carnivores than ungulates. However, human use tends to be highest close to urban areas which may confound the results. Other studies found mixed effects or no effects of human co-use on wildlife use (review in van der Ree & van der Grift, 2015).

An extensive study on a multi-functional overpass for wildlife and non-motorized use by people in the Netherlands found that people predominantly used the structure during the day (human use was not permitted after sunset to begin with), and that human use was higher in the weekends than during week days (van der Grift et al., 2024). On average between 100,000 and 200,000 people used the structure per year. This translated to about 388 bicyclists, 172 pedestrians, and 7 people on horseback per day on average. The number of (mostly nocturnal) crossings by mammal species was not affected by the number of people that used the overpass during the preceding day, but there was a tendency for mammals to delay their use of the structure by about 1.5 hours if daytime use by people was high during the preceding day. Similar results were found at another multi-functional overpass; mammals crossed the structure on average about 3 hours later on nights following heavy human use (>250 people per day), versus nights following lower human use (<100 people per day) (van der Grift et al., 2022). In multi-functional landscapes almost all mammal species that were present in the wider area were also recorded on crossing structures, but human co-use is associated with animals moving fast across the structure (e.g., running versus walking), especially on relatively narrow structures (van der Grift et al., 2010).

### 13.4 Design principles for multi-use crossing structures

Multi-use crossing structures that are designed for both wildlife species and non-motorized use by people can be especially considered in areas that already have a relatively high human presence and disturbance, and for target species that are tolerant of human presence and disturbance (van der Ree & van der Grift, 2015). In pristine areas with no or few people and little or no permanent human presence, and for target species that are sensitive to human disturbance and that may be threatened or endangered, separate crossing structures for people and wildlife are probably more appropriate.

If a multi-functional crossing structure is designed for both wildlife and non-motorized use by people, a wider structure is required than what would have been suitable for only wildlife. At a minimum, about 15 ft additional width is required to accommodate a recreational trail and visual and sound barriers between the designated trail and the zone designated for wildlife (van der Ree & van der Grift, 2015) (Figure 48). If the target species are sensitive to human disturbance, or if threatened or endangered species are among the target species, the additional width for human co-use may have to be greater than 15 ft, but one may also consider separate structures for people and wildlife.

If a multi-functional crossing structure is designed for both wildlife and non-motorized use by people, it is recommended to implement explicit design features for both people and wildlife (van der Ree & van

der Grift, 2015). This includes a well-maintained designated trail for people on one of the two edges (sides) of a crossing structure, and a designated zone for wildlife on the remainder of the structure (Figure 49, Figure 50, Figure 51). Physical, visual and sound barriers encourage spatial separation of humans and wildlife at the crossing structure. Most importantly, these features discourage people from leaving the trail and venturing out on the designated wildlife zone of a crossing structure. These barriers may include earthen berms, potentially planted with shrubs and small trees, and a fence. Visual and sound barriers should also be installed on the two far edges of crossing structures to reduce noise and visual disturbance from traffic for both wildlife and people. Equestrian use may especially benefit from reducing noise and visual disturbance from traffic. Artificial lighting should not be installed on the structures to discourage people from using the structures at night and to not discourage wildlife at night. Finally, not every crossing structure that has a trail for people and vegetation also provides connectivity for wildlife (Figure 52).



Figure 48. Ecoduct Natuurbrug Zanderij Crailoo, The Netherlands. On the far left is the trail for non-motorized recreation. A fence and vegetated berm separate the trail from the designated zone for wildlife to the right. The corridor is about 50 m wide and 800 m long and connects forests and heathlands on both sides. The corridor consists of embankments and two bridges. One bridge spans a two-lane highway, the other a railroad and railroad yard. The embankment also goes through sports fields.



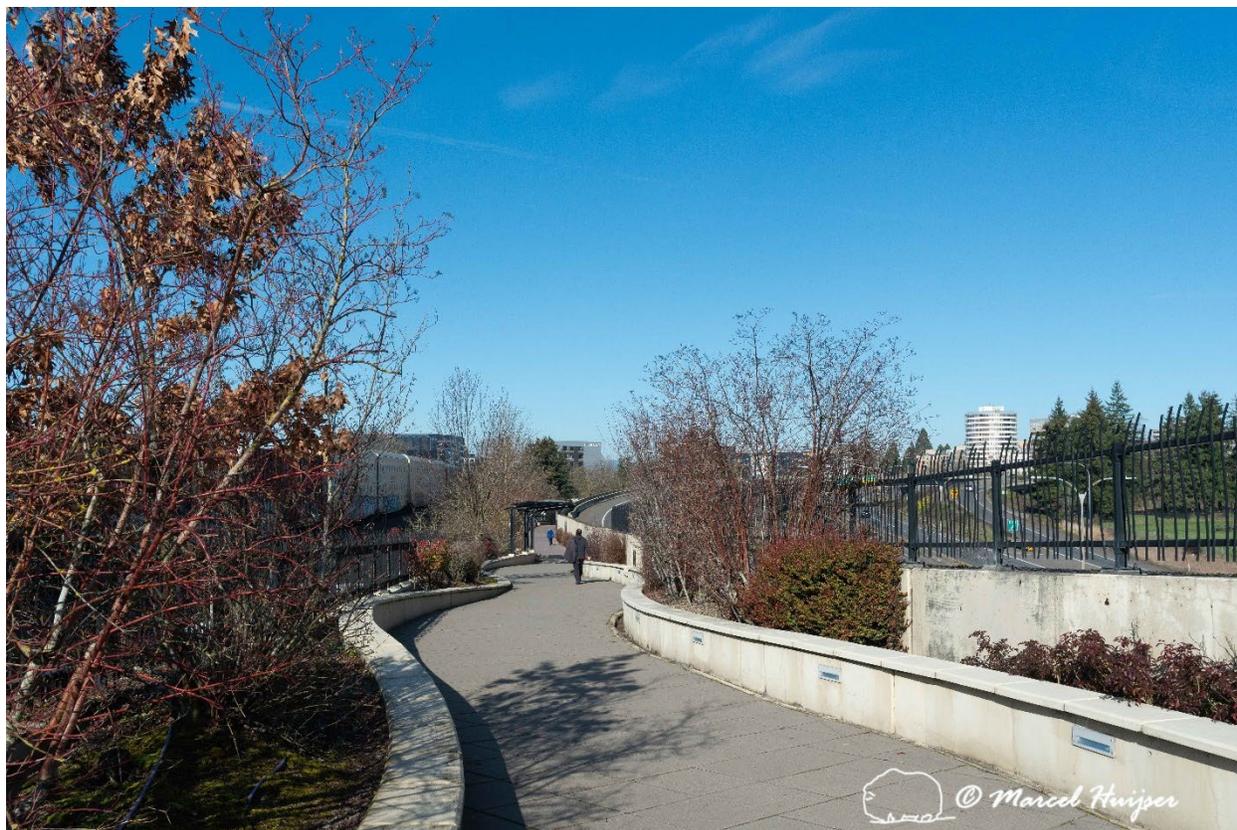
Figure 49. Hiking and biking trail combined with wildlife overpass across railroad tracks Soest The Netherlands. The designated wildlife area is to the left, on the other side of the fence and vegetated berm.



Figure 50. Hiking and biking trail combined with wildlife overpass across railroad tracks, Soest, The Netherlands. The vegetated "wildlife area" on the overpass is further to the left, separated from the trail by a berm and shrubs and trees.



*Figure 51. A provincial road crossed under the 4-lane A27 motorway, near Hilversum, The Netherlands. The structure was made wider to anticipate potential future additional lanes. Instead, this space was used to create habitat for small animal species. Note the black screen on the left that reduces light and other visual disturbance originating from the provincial road. The trail on the right is for non-motorized traffic, including equestrian use.*



*Figure 52. Vancouver land bridge, Vancouver, Washington. Note this this bridge is centered around pedestrians with a design informed by the culture and history of Native American Tribes of the lower Columbia River. It was planted with species characteristic for the prairie, forest and wetlands in the vicinity of the land bridge. Note that this bridge is not designed to provide connectivity for wildlife species.*

## 14 Recommendations

### 14.1 Wildlife mitigation

From a human safety perspective, the wild mammal crashes and large mammal carcasses were not closely associated with the four Refuges. Black-tailed deer is the species that has been most frequently recorded in wildlife crash records or large wild mammal carcass records. Black-tailed deer are hit through the entire length of the highways that parallel the Columbia River and mitigation measures may be considered, starting with the road sections that have the highest concentration of collisions. From a conservation perspective, most species of conservation concern are not large enough to be associated with a vehicle crash or to be detected during carcass removal by road maintenance crews. Nonetheless, fences and crossing structures for species of special conservation concern are likely beneficial, especially close to the four Refuges. The species groups include amphibians (especially salamander species), reptiles (especially snake and turtle species) and small or medium sized mammals. Should culverts or bridges be replaced at stream crossings, they should typically span longer than the full bank width (e.g., 1.5 times full bank width) and they should have either a bottomless structure or a structure that has natural sediment that is not susceptible to erosion. These types of structures are likely passable by many aquatic and semi-aquatic species, and if the height of the structure allows, and if there is a dry and accessible pathway, terrestrial mammal species can also cross under the road. Appropriate barriers (e.g., fences or barrier walls) need to be associated with these structures to keep the animals off the road and to help guide them towards the safe crossing opportunities.

Existing culverts along WA Highway 14 can be a problem for small animal species, especially amphibians such as salamanders. The grates associated with the inboard ditch relief culverts can act as a pitfall for small species (Figure 53). These types of culverts are also problematic as they may not allow species to travel against the flow of the water because of erosion or a drop at the outflow (Figure 54), constricted and relatively high velocity flow inside the culvert without natural sediment, and a vertical climb up towards the grate at the inflow (Figure 53).

### 14.2 Non-motorized access to Steigerwald Lake NWR

We identified two issues for non-motorized access to Steigerwald Lake NWR: 1. Pedestrians who want to access the Refuge from the neighborhood to the north of the entrance must cross WA Highway 14. 2. Just north of the Refuge, the railroad and Evergreen Way, is the Jemtegaard Middle School (Figure 22). There are reports that children play on or near Evergreen Way and the railroad regularly. In chapter 10 we discuss different options to address these 2 problems.



Figure 53. Inboard ditch relief (or ditch relief culvert) along WA Highway 14, east of Washougal, Washington, USA.



Figure 54. Outflow of a ditch relief culvert along WA Highway 14, east of Washougal, Washington, USA.

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