The impact of roadway mortality on a long-lived freshwater turtle, *Chrysemys picta bellii*

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Abstract

Road mortality poses a significant threat to freshwater turtles globally, including the western painted turtle (*Chrysemys picta bellii*). Even low levels of road mortality can severely impact the long-term survival of these long-lived reptiles. While mitigation infrastructure is employed to reduce mortality, its effectiveness may vary depending on the location and species involved. Population viability analysis can be a valuable alternative for wildlife managers to assess the viability of the populations they monitor and the potential impact of management decisions, but are most useful when data from target populations is available. This research project aimed to evaluate the long-term persistence of a rural western painted turtle population experiencing road mortality. The study first investigated the effectiveness of a turtle tunnel and drift fencing in reducing road mortality. Parameters derived from the population were then used to model the long-term viability of the turtle population in the program Vortex under various scenarios of ongoing road mortality. This study analyses three years of mark-recapture, ratio telemetry tracking, and road mortality surveys done by contractors and summer hires of the Ministry of Water, Land, and Resource Stewardship at Baynes Lake, BC. The turtle population was estimated to be 1,451 (SD= 75) individuals, with a female-biased sex ratio (1.5 females: 1 male). Only a quarter of sexually mature females were found to be gravid in a given year, with gravid females laying only one clutch. Subadult and adult survivorship were calculated using the same dataset employed for the population estimate, resulting in a survivorship rate of 96.4% (SD = 1.3%) per year. Radio telemetry was used to assess the number of road crossings made in a given year. Gravid females were found to make a higher average number of road crossings (1.6 road crossings per season) than males (0.1 road crossings per season) or non-gravid females (0.7 road crossings per season). In 2021, an under-road turtle tunnel was installed in Baynes Lake, followed by the installation of drift fencing in the spring of 2023. Over time and after the implementation of drift fencing, more turtles were observed encountering the installed turtle tunnel. However, evidence regarding the complete traversal of the turtle tunnel was not conclusive. Before the installation of the turtle tunnel, casual community-led surveys in 2021 estimated a mortality rate of 1% of the population. Mortality rates, calculated over the duration of the survey periods, decreased after the installation of the turtle tunnel (0.1 mortalities per day in 2022) and further decreased after drift fencing was installed (0.03 mortalities per day). The long-term viability of the Baynes Lake population was modeled in Vortex, with additive road mortality modeled as a percentage loss of the population. The road mortality rate of 1% additive mortality, seen before road mortality reduction strategies, resulted in a 60% decrease of the initial population after 100 years. This indicates that even low levels of additive adult road mortality can lead to declines in the Baynes Lake western painted turtle population. Sensitivity testing of the model indicates that the Baynes Lake population is highly sensitive to changes in adult/subadult and juvenile mortality. Pre-mitigation mortality levels had the potential to dramatically impact the population of Baynes Lake. It is crucial to acknowledge and address what may appear to be relatively low levels of roadway mortality in rural areas, as even these seemingly modest rates can have a significant impact on western painted turtle populations.

Keywords: western painted turtle; *Chrysemys picta bellii*; roadway mortality; population viability modeling; population estimate; scavenge rate

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Chapter 1. Introduction

1.1 Background

1.1.1 Road mortality

Roads can have a significant impact on herpetofauna populations (Ashley & Robinson, 1996), acting as barriers to dispersal (Daigle, 2010; Gibbs, 1998; Shepard et al., 2008), causing habitat fragmentation (Aresco, 2005), permanent loss of habitat (Daigle, 2010; Marsh & Jaeger, 2015), and direct mortality (Crawford et al., 2014; Howell & Seigel, 2019; Winton et al., 2020). Road mortality, in particular, has been identified as a significant threat to many freshwater turtles worldwide (Beaudry et al., 2008; Gibbs & Shriver, 2002; Steen & Gibbs, 2004).

Even low levels of roadway mortality can dramatically impact the population viability of long-lived reptiles. Winton et al. (2020) found that additive road mortality rates as low as two percent (%) could cause population declines in western rattlesnakes (*Crotalus oreganus*). A long-term study on Maximilian's snake-necked turtle (*Hydromedusa maximiliani*) concluded that the species likely could not sustain more than 2-3% annual additive adult mortality (Howell et al., 2019).

In 2018, British Columbia (BC) had approximately 719,000 kilometres (km) of roads, with 34% of the provincial land base being within 500 metres (m) of a road (Environmental Reporting BC, 2018). Road networks are expanding in many areas (Daigle, 2010) and the population of BC is expected to steadily increase, with a 46% increase projected by 2046 (BC Stats, 2024). This will likely lead to an increase in both traffic and road density. Increasing traffic density may increase amphibian and reptile mortality (Mazerolle, 2004). In a study conducted on Highway 27 in the United States, the probability of turtles successfully crossing the four-lane highway decreased from 32% in 1977 to 2% in 2001, attributed to a 162% increase in traffic volume (Aresco, 2010). High road density has been associated with male-biased sex ratios in painted turtles, indicating that roads may disproportionately result in the mortality of females (Nicholson et al., 2020; Steen & Gibbs, 2004). Increasing road speed, often associated with larger roads, has been associated with increasing road mortality of wildlife (Farmer & Brooks, 2012).

In BC, reptiles and amphibians are the most at-risk species group, with over half of species considered as a species of concern either federally or provincially (Ministry of Environment and Climate Change Strategy, 2020). Roadway mortality has been identified as a major potential cause of population decline for western painted turtles (*Chrysemys picta bellii)* in BC (COSEWIC, 2016).

1.1.2 Ecology and conservation status of western painted turtles

Painted turtles are a medium-sized freshwater turtle species native to North America (COSEWIC, 2016). The population is divided into four subpopulations: western painted turtles, midland painted turtles (*Chrysemys picta marginata*), eastern painted turtles (*Chrysemys picta picta*), and southern painted turtles (*Chrysemys picta dorsalis*) (COSEWIC, 2016). Western painted turtles range across central North America, from southern Ontario and Missouti in the east to eastern Colorado and Montana and up into the coast of southern BC in the west (Figure 1). In the south, the population ranges into Oklahoma and Kansas, becoming fragmented in the southwest. The northern range extends into southern Canada, from BC to Ontario.

The western painted turtle is BC's only extant native freshwater turtle (Ministry of Environment and Climate Change Strategy, 2020). Western painted turtles have two discrete, broad population regions in BC; the Intermountain-Rocky Mountain population unit and the Pacific Coast population unit (COSEWIC, 2016). The Committee on the Status of Endangered Wildlife in Canada (COSWEIC) has categorized the Pacific Coast population as threatened, a category just below endangered, and the Intermountain-Rocky Mountain population as a Special Concern, indicating they are at-risk of becoming threatened if the disturbances to their population are not mitigated or reversed (COSEWIC, 2016). The Pacific Coast population unit resides on the western coast of BC (COSEWIC, 2016). Turtles can be found in water bodies in the Lower Fraser Valley of BC, from approximately Chilliwack to the coast in Greater Vancouver, and north along the coast to the Powell River area (Barela & Olson, 2014). Populations can also be found on Texada Island and Vancouver Island (Barela & Olson, 2014). The Intermountain-Rocky Mountain population is geographically separated from the Pacific Coast population by the Rocky Mountains (COSEWIC, 2016). This population unit resides in the valley bottoms of the Okanagan Valley, the Thompson River Valley, and the southern Cariboo region (COSEWIC, 2016). This population unit is at the northern edge of the population's extent into BC, ending in Williams Lake (Barela & Olson, 2014; COSEWIC, 2006). The northern extent of these turtles may be limited by low temperatures exceeding the thermal tolerance of hatchlings overwintering in nests (St. Clair and Gregory 1990).

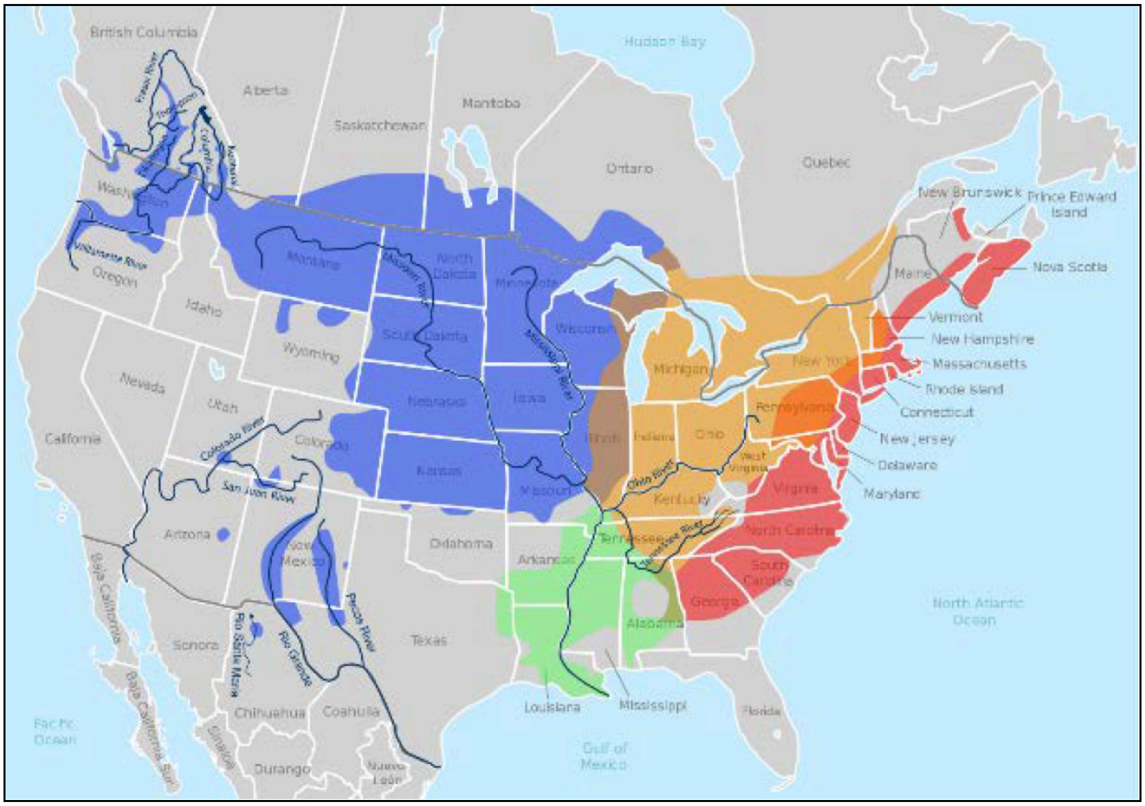

Figure 1. Range map for painted turtles. Blue indicates the range of western painted turtles (*C.p. bellii*), orange indicates ranges of midland painted turtles (*C.p. marginata*), red indicates range of eastern painted turtles (*C.p. picta*), and green indicates range of southern painted turtles (*C.p. dorsalis*). From COSEWIC (2016).

Western painted turtles are characterized by the distinct bright orange colour on their plastron, typically surrounding a black and yellow blotch. The carapace is typically black or dark green in colour and divided into individual plate-like scutes. These turtles exhibit sexual dimorphism, with females being on average larger than males (Berry & Shine, 1980; Lindeman, 1996). Their size ranges by latitude and location, with populations in the northern part of their range typically growing larger than those farther south (MacCulloch & Secoy, 1983). Western painted turtles are thought to reach sexual maturity at a certain size as opposed to age (Lindeman, 1996), with turtles in the northern portion of their range reaching sexual maturity later than their more southern counterparts (MacCulloch & Secoy, 1983; St. Clair et al., 1994).

The life history of western painted turtles involves both aquatic and terrestrial habitat components. (Marchand & Litvaitis, 2004). These turtles primarily inhabit ponds, lakes, and wetlands (Bury & Germano, 2003), where they engage in activities such as basking, foraging for food, mating, and hibernating (Cosentino et al., 2010; Gibbons, 1968a; Marchand & Litvaitis, 2004). Western painted turtles hibernate over winter in the muddy beds of water bodies (Cosentino et al., 2010). Their active season begins when they emerge in the spring and continues until the middle of the fall (COSEWIC, 2016). Mating occurs throughout the active season (Ernst et al., 1994), with peaks in spring and fall (Gibbons, 1968a). Painted turtles venture onto land for nesting and migratory movements (Gibbons, 1968a). Nesting begins in the northern portion of their range from late May into June (Ernst et al. 1994). Turtles in the southern latitudes can have multiple clutches per year (Lindeman, 1992), while turtles in northern latitudes are typically limited to one (MacCulloch & Secoy, 1983). Overland migrations occur throughout the active season for both males and females, with turtles moving between nearby water bodies to find additional foraging opportunities, mates, or sufficient water depth during drought conditions (Aresco, 2005; Cosentino et al., 2010).

1.1.3 Western painted turtles susceptibility to roadway mortality

The life history characteristics of western painted turtles make them susceptible to roadway mortality, with possible long-term impacts on their population structure (COSEWIC, 2016). Terrestrial land movements are an essential aspect of freshwater turtles' life history. Adult turtles of both sexes engage in overland movements for various purposes, including nesting, breeding, seasonal migrations, and relocating from unfavourable habitats (Gibbons, 1968b; Gibbs & Steen, 2005; Steen & Gibbs, 2004). Some of these migrations can be extensive, with documented overland movements in adult western painted turtles ranging from 100 to 500-m (Barela & Olson, 2014; Basaraba, 2007; Krochmal et al., 2021), and individual records surpassing 1.3-km (House et al., 2010). As nesting sites can be chosen up to 80-m inland from a water body, juvenile turtles are also required to make this overland trek (Delaney et al., 2019; Murphy et al., 2022).

High fidelity to migration routes may also encourage movement over roads. Painted turtles show high fidelity to previous nesting sites (Lindeman, 1991) and migration routes (Krochmal et al., 2021). Krochmal et al. (2021) found that eastern painted turtles were only able to navigate using previously learned routes after the age of four. Individuals encountering roads during migration face the risk of roadway mortality. Western painted turtles exhibit slow movement on land, a trait shared with other slow-moving freshwater turtles that are unsuccessful at road crossings (Aresco, 2005). A study in Florida, USA revealed a 98% chance of mortality during a single road crossing, with over 95% of turtle fatalities occurring during the initial encounter with the road along the shoulder (Aresco, 2005).

The loss of adults within a painted turtle population can have significant long-term impacts, as populations may be slow to recover. Western painted turtles have the characteristic life history of a long-lived pond turtle: high adult survivorship (Iverson, 1991), delayed sexual maturity (St. Clair et al., 1994), and low juvenile survival (Clark & Grueing, 2003; Iverson, 1991; St. Clair & Gregory, 1990). Adult western painted turtles have been confirmed to reach ages of over 30 years (Guderyahn et al., 2023) and related subspecies have reached ages exceeding 50 years in the wild (COSEWIC, 2016; Congdon et al., 2003). While some evidence suggests that pond turtles senesce in the wild (Warner et al., 2016), the impact on fecundity is likely small in painted turtles. Congdon et al. (2003) found that egg and hatchling size increased with age for female painted turtles and there was no decline in reproductive output. To maintain a steady population, adult females would be expected to maintain a similar level of reproductive output throughout their lifecycle.

Western painted turtles at the northern end of their range may be more vulnerable to the loss of adults. Turtles in northern parts have been found to have overall slower population recruitment than their southern conspecifics (Marchand et al., 2018), with higher hatchling mortality (St. Clair & Gregory, 1990) and fewer clutches per year (St. Clair et al., 1994). Females in northern regions may not reach sexual maturity until they are 15 (St. Clair et al., 1994). This can lead to northern populations being more sensitive to additive sources of mortality.

1.1.4 The Baynes Lake Western Painted Turtle Project overview

Data for this study came from The Baynes Lake Western Painted Turtle Project (also known as Increasing Western Painted Turtle Survival at Baynes Lake). The project was initiated by Debbie Powell in 2020 in response to the rising incidence of roadway mortality among western painted turtles in the Baynes Lake community. Following the loss of at least 15 adult turtles in 2019, the project's primary objective was to gather data that could guide long-term conservation efforts for western painted turtles in Baynes Lake (Paul, 2021).

In 2020, citizen scientists in the Baynes Lake community collected data on nest-site locations, roadway mortality, and locations of turtle crossings. The Ministry of Transportation and Infrastructure in BC installed a large culvert (referred to as the turtle tunnel) in the fall of 2020. The corrugated metal tunnel was installed in the area identified as a hotspot for turtle crossings and roadway mortalities along Jaffray-Baynes Lake Road. The project was expanded in 2021 to include monitoring the culvert and tunnel for use, collecting morphological data, and shell notching for the purposes of turtle identification. Radio transmitters were attached to a series of turtles, tracking their movements to assess crossing locations, map their seasonal range, and locate nesting sites.

The Ministry of Transportation and Infrastructure installed drift fencing to lead turtles to the turtle tunnel in the spring of 2023 (Figure 5). Fencing was installed along Jaffray-Baynes Lake Road on May 15, 2023, with the intention of directing turtles into the turtle tunnel. Black landscaping fabric was stapled to wooden stakes pounded into the ground. A total of around 500-m of fencing was installed, 200-m on the west side and 300-m on the east side of Jaffray-Baynes Lake Road.

1.1.5 Study site

Field research was conducted in the community of Baynes Lake [49°13' N, 115°13' W] in the East Kootenay of BC, Canada (Figure 2). Baynes Lake is an unincorporated rural community located 50-km outside of Cranbrook. The community is characterized by Baynes Lake and its adjacent ephemeral wetlands, which support a population of western painted turtles. Baynes Lake resides in the Interior Douglas Fir Biogeoclimatic Zone at an elevation of 800-m (Meidinger & Pojar, 1991). This zone is characterized by warm, dry summers and cool winters (Meidinger & Pojar, 1991). The average yearly temperature has historically been between 1.6-9.5°C (Meidinger & Pojar, 1991). Baynes Lake receives an average of 454.5 millimeters (mm) of precipitation per year, 107.2-mm of which is snowfall (Environment Canada, 2024).

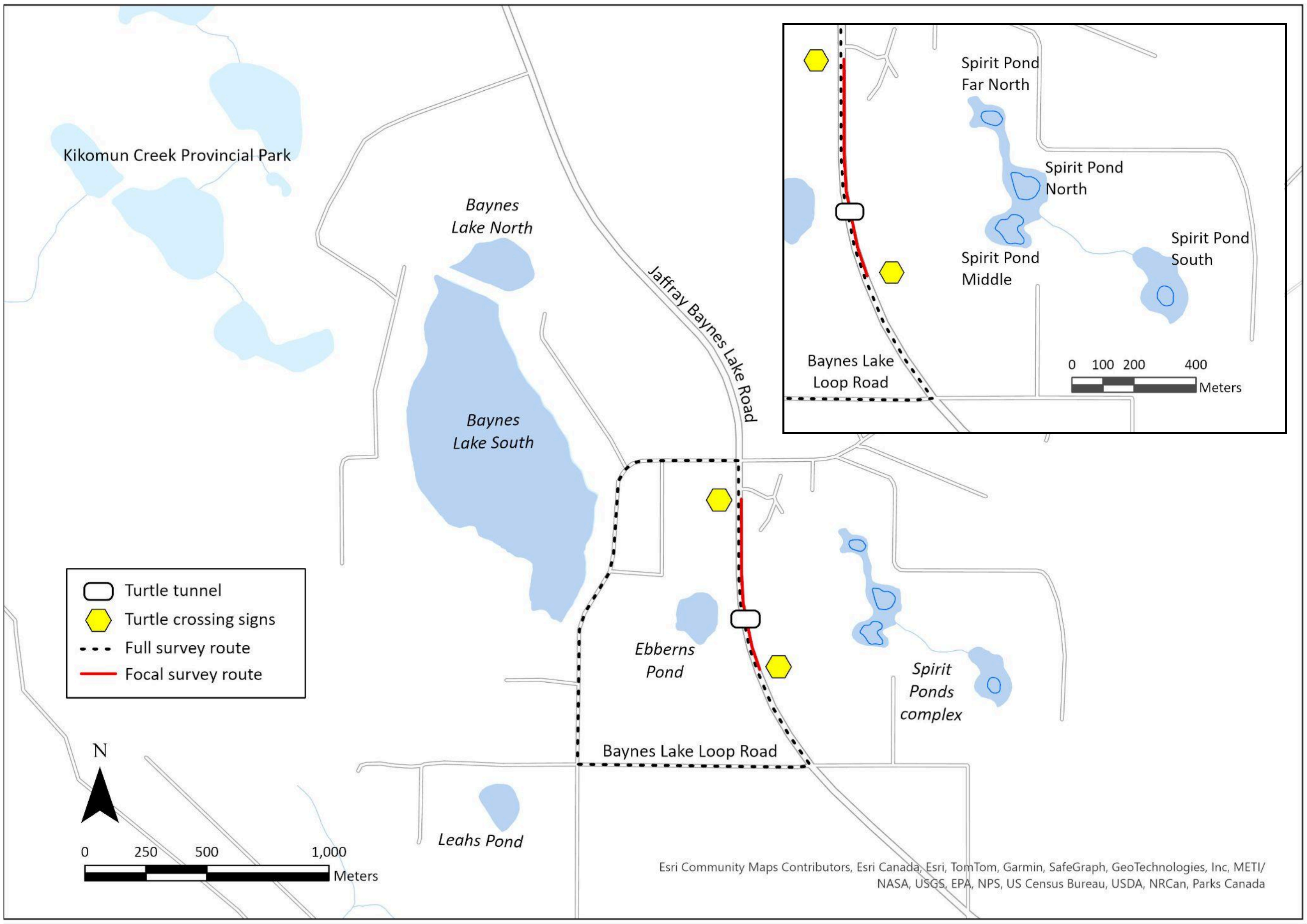

Figure 2. Western painted turtle monitoring project site in Baynes Lake in the East Kootenays, BC. Monitoring of turtle populations was conducted in Baynes Lake, Baynes Lake North, from April to September 2023. The yellow hexagons represent the turtle crossing signs. The dotted and red lines represent the focal and complete routes along which mortality surveys were conducted. Inset: The Spirit Ponds complex is made up of four bodies of water: Spirit Pond Far North, Spirit Pond North, Spirit Pond Middle, and Spirit Pond South.

Baynes Lake is located 1.5 km east of Lake Koocanusa, a 114-km-long reservoir created by Libby Dam that is popular for recreational use (Regional District of East Kootenay, 2023). The Baynes Lake community and the immediate surrounding area have a population of around 600. Over half of landowners in the immediate community are seasonal residents (Regional District of East Kootenay, 2021; Regional District of East Kootenay, 2023). Kikomun Creek Provincial Park, the only provincial park along Lake Koocanusa, is situated 3-km from the community. Waldo Cove was developed into a regional park in 2020 and is primarily accessed through Baynes Lake. Seasonal recreational use is expected to increase in the area, and there has been a steady increase in land purchases in the community since 2000 (Regional District of East Kootenay, 2023).

Morphological and population data collection took place in four wetlands: Baynes Lake (north and south), Ebberns Pond, Spirit Ponds (far north, north, middle, and south), and Leah's Pond (Figures 2 and 3). Baynes Lake consists of Baynes Lake South (24 ha) and Baynes Lake North (20 ha). An old railway bed separates the two water bodies with a gravel road. The path is primarily used as a walking or biking path but is open to traffic. Private properties surround Baynes Lake South, many with beaches and docks. The lake is used for recreation, including fishing, swimming, and paddling. Agricultural fields primarily surround Baynes Lake North with a 30- to -70-m riparian buffer zone.

Figure 3. The four wetlands where monitoring of western painted turtles was conducted at Baynes Lake in 2023. A) Baynes Lake North; B) Baynes Lake South; C) Spirit Pond Middle; D) Ebberns Pond.

The nearest water bodies to the Baynes Lake complex are Ebberns Pond (260 m), an unnamed wetland within the Kikomun Creek Provincial Park (350 m), and Leah’s Pond (440 m). Ebberns Pond is a 0.9-ha wetland located on private property. It is an open water wetland with a deep, muddy bottom. The land on the eastern side of the ponds slopes up to Jaffray-Baynes Lake Road. The other half of the pond is surrounded by lawns. Spirit Ponds are a shallow wetland complex historically made up of four main bodies of water: far north (0.05 ha), north (0.08 ha), middle (0.08 ha), and south Spirit Pond (0.5 ha). The Baynes Lake area has been witnessing a decline in overall water levels, and the Spirit Pond complex has been particularly affected due to its shallow nature (Rood, 2023). Spirit Pond South was completely dry in 2023 and was not included in the data analysis, as there were no turtles in the wetland. Trapping in 2023 occurred primarily in Spirit Pond Middle, with limited trapping in Spirit Pond North. The Spirit Ponds are surrounded by agricultural fields and a few residential buildings. The south and west of Spirit Pond Middle are forested with an unofficial walking path.

Roadway mortality surveys occurred on Jaffray-Baynes Lake Road and Baynes Lake Loop Road (Figure 2). Jaffray-Baynes Lake Road is the main route through the community. It passes the community hall and the location of the popular farmers market that takes place weekly in the summer. It intersects the shortest turtle crossing route between Ebberns Pond and the Spirit Pond complex. Baynes Lake Loop Road provides access to Baynes Lake. This road is also the recommended route to access Waldo Cove. It intersects the shortest turtle crossing path from Ebberns Pond to Baynes Lake South. The roads are paved and have a small, gravel shoulder. The grassy ditches on the side of the roads are cut in the summer, and the grass browns soon after the weather warms up (Figure 4).

Figure 4. Images of the survey route for road mortality in Baynes Lake, BC. Left: Jaffray-Baynes Lake Road looking south. Right: Baynes Lake Loop Road looking west. Both photos were taken during the summer 2023.

Tunnel use monitoring took place around the turtle tunnel (Figure 5) and a smaller drainage culvert (referred to as the small culvert) north of the turtle tunnel. Both tunnels cross under Jaffray-Baynes Lake Road. The small culvert was only monitored in 2023.

Figure 5. A culvert (turtle tunnel) and drift fencing installed at Baynes Lake, BC. Left: The Baynes Lake painted turtle tunnel installed on Jaffray-Baynes Lake Road. The white tag slightly obscured the installed wildlife camera, pointing into the tunnel. Picture was taken in 2023 facing east. Right: Drift fencing installed in 2023 along Jaffray-Baynes Lake Road to direct turtles to the turtle tunnel.

Since the Baynes Lake community is anticipating growth and an increase in traffic with the expansion of nearby recreational facilities, it is important to assess the potential impact on road mortality rates, both before and after the implementation of these mitigation strategies. This understanding can guide the development of informed, long-term conservation strategies and facilitate the evaluation of the effectiveness of the implemented mitigation measures.

1.2: Objectives

The goal of this study is to evaluate the impact of road mortality on the long-term viability of a rural western painted turtle population.

The objectives of this project are to:

1. Determine the rate of roadway mortality before and after roadway mitigation infrastructure installation;
2. Estimate and characterize the population of western painted turtles inhabiting the Baynes Lake wetland complex;
3. Model the long-term viability of the western painted turtle population at Baynes Lake using the varying road mortality rates.

Chapter 2 examines the use of road mortality infrastructure and the rate of road mortality at Baynes Lake over three years. The rate that scavengers removed carcasses was evaluated. Chapter 3 begins by characterizing and estimating the size of the population at Baynes Lake. A population viability analysis was done using the population-specific parameters calculated from Baynes Lake and the observed road mortality rate.

1.3 Literature Cited

Aresco, M. J. (2005). Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. *The Journal of Wildlife Management*, *69*(2), 549–560. https://doi.org/10.2193/0022-541x(2005)069

Ashley, E.P. & Robinson, J.T. (1996). Road Mortality of Amphibians, Reptiles and other Wildlife on the Long Point Causeway, Lake Erie, Ontario. *The Canadian Field-Naturalist*, *110*, 403-412.

Barela, K. L., & Olson, D. H. (2014). Mapping the western pond turtle (*Actinemys marmorata*) and painted turtle (*Chrysemys picta*) in western North America. *Northwestern Naturalist*, *95*(1), 1–12. https://doi.org/10.1898/nwn12-24.1

Basaraba, N.R.C. (2007). The ecology of western painted turtles (*Chrysemys picta belli*) in a northern Canadian reservoir. Master's thesis, Thompson Rivers University, Kamloops, BC.

Beaudry, F., DeMaynadier, P. G., & Hunter, M. L. (2008). Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. *Biological Conservation*, *141*(10), 2550–2563. https://doi.org/10.1016/j.biocon.2008.07.016

BC Stats. (2024) Sustaining Growth: Population and Demography for B.C. and Canada.

Prepared for the Ministry Of Municipal Affairs, British Columbia, Canada. https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/population

Berry, J. F. & Shine, R. (1980). Sexual size dimorphism and sexual selection in turtles (Order Testudines). *Oecologia*, *44*:185-189.

Bury, R. B., & Germano, D. J. (2003). Differences in Habitat Use by Blanding's Turtles, *Emydoidea blandingii*, and Painted Turtles, *Chysemys picta*, in the Nebraska Sandhills. *American Midland Naturalist*, *149*(1), 241–244. https://doi.org/10.1674/0003-0031(2003)149

Clark, R. & Grueing., A. (2003). Painted turtle (*Chrysemys picta bellii*) nest site enhancement and monitoring, Elizabeth Lake, Cranbrook, B.C Progress Report. Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C.

Congdon, J. D., Nagle, R. D., Kinney, O. M., Van Loben Sels, R. C., Quinter, T., & Tinkle, D. W. (2003). Testing hypotheses of aging in long-lived painted turtles (*Chrysemys picta*). *Experimental Gerontology*, *38*(7), 765–772. https://doi.org/10.1016/s0531-5565(03)00106-2

COSEWIC. (2006). COSEWIC assessment and status report on the Western Painted Turtle (*Chrysemys picta bellii*) Pacific Coast population, Intermountain-Rocky Mountain population and Prairie/Western Boreal - Canadian Shield population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vii + 40 pp.

COSEWIC. (2016). COSEWIC assessment and status report on the Western Painted Turtle *Chrysemys picta bellii*, Pacific Coast population, Intermountain – Rocky Mountain population and Prairie/Western Boreal – Canadian Shield population, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxi + 95 pp. http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1

Cosentino, B. J., Schooley, R. L., & Phillips, C. A. (2010). Wetland hydrology, area, and isolation influence occupancy and spatial turnover of the painted turtle, *Chrysemys picta*. *Landscape Ecology*, *25*(10), 1589–1600. https://doi.org/10.1007/s10980-010-9529-3

Crawford, B. A., Maerz, J. C., Nibbelink, N. P., Buhlmann, K. A., & Norton, T. M. (2014). Estimating the consequences of multiple threats and management strategies for semi-aquatic turtles. *Journal of Applied Ecology*, *51*(2), 359–366. https://doi.org/10.1111/1365-2664.12194

Daigle, P. (2010). A summary of the environmental impacts of roads, management responses, and research gaps: A literature review. *Journal of Ecosystems and Management*, *10*(3). https://doi.org/10.22230/jem.2010v10n3a38

Delaney, D. M., Hoekstra, L. A., & Janzen, F. J. (2020). Becoming creatures of habit: Among- and within-individual variation in nesting behaviour shift with age. *Journal of Evolutionary Biology*, *33*(11), 1614–1624. https://doi.org/10.1111/jeb.13701

Environment Canada. (2024). Canadian Climate Normals 1981-2010 Station Data: Baynes Lake Kootenay River. Government of Canada. https://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnProv&lstProvince=BC&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=1167&dispBack=0

Environmental Reporting BC. (2018). Roads & roadless areas in British Columbia. State of Environment Reporting, Ministry of Environment and Climate Change Strategy, Victoria, B.C. http://www.env.gov.bc.ca/soe/indicators/land/roads.html

Ernst, C.H., Lovich, J.E., & Barbour, R.W. (1994). *Turtles of the United States and Canada,* Smithsonian Institution Press, Washington, D.C.

Farmer, R. G., & Brooks, R. J. (2012). Integrated risk factors for vertebrate roadkill in southern Ontario. *The Journal of Wildlife Management*, *76*(6), 1215–1224. https://doi.org/10.1002/jwmg.358

Gervais, J., Rosenberg, D., Barnes, S., Puchy, C., & Stewart, E. (2009). Conservation Assessment For The Western Painted Turtle In Oregon (*Chrysemys picta bellii*) Version 1.1. U.S.D.I. Bureau of Land Management and Fish and Wildlife Service. https://oregonwildlife.org/documents/Western%20Painted%20Turtle%20Conservation%20Assessment%20in%20Oregon%20Vers%201_1%20sept2009.pdf

Gibbs, J. P. (1998). Amphibian movements in response to forest edges, roads, and streambeds in southern New England. *The Journal of Wildlife Management*, *62*(2), 584. https://doi.org/10.2307/3802333

Gibbs, J.P. & Shriver, W.G. (2002). Estimating the effects of road mortality on turtle populations. *Conservation Biology*, *16*(6): 1647-1652.

Gibbs, J.P., & Steen, D.A. (2005). Trends in sex ratios of turtles in the United States: implications of road mortality. *Conservation Biology*, *19*(2), 552–556.

Gibbons, J. W. (1968). Reproductive potential, activity, and cycles in the painted turtle, *Chrysemys picta*. *Ecology*, *49*(3), 399–409. https://doi.org/10.2307/1934106

Gibbons, J. W. (1968b). Population structure and survivorship in the painted turtle, *Chrysemys picta*. *Copeia*, *1968*(2), 260. https://doi.org/10.2307/1441752

House, W. J., Nall, I. M., & Thomas, R. B. (2010). Interpond movements of western painted turtles (*Chrysemys picta*) in east-central Kansas. *Southwestern Naturalist*, *55*(3), 403–410. https://doi.org/10.1894/gc-201.1

Howell, H. J., & Seigel, R. A. (2019). The effects of road mortality on small, isolated turtle populations. *Journal of Herpetology*, *53*(1), 39. https://doi.org/10.1670/18-022

Iverson, J. B. (1991). Patterns of survivorship in turtles (order Testudines). *Canadian Journal of Zoology*, *69*(2), 385–391. https://doi.org/10.1139/z91-060

Krochmal, A. R., Roth, T. C., & Simmons, N. T. (2021). My way is the highway: The role of plasticity in learning complex migration routes. *Animal Behaviour*, *174*, 161–167. https://doi.org/10.1016/j.anbehav.2021.02.005

Lindeman, P. V. (1992). Nest-Site Fixity among Painted Turtles (*Chrysemys picta*) in Northern Idaho. *Northwestern Naturalist*, *73*(1), 27. https://doi.org/10.2307/3536569

Lindeman, P. V. (1996). Comparative Life History of Painted Turtles (*Chrysemys picta)* in Two Habitats in the Inland Pacific Northwest. Copeia, 1996(1), 114.

MacCulloch, R. D., & Secoy, D. M. (1983). Demography, growth, and food of western painted turtles, *Chrysemys picta belli*i (Gray), from southern Saskatchewan. *Canadian Journal of Zoology*, *61*(7), 1499–1509. https://doi.org/10.1139/z83-202

Marsh, D.M. & Jaeger, J.A.G. (2015). Direct effects of roads on small animal populations. In: Roads and ecological infrastructure: concepts and applications for small animals. K.M. Andrews, P. Guidelines for herpetofauna conservation during road building &

management activities 118 Nanjappa, S.P.D. Riley (editors). Johns Hopkins University Press, Baltimore, Md., pp. 42–56.

Marchand, M., & Litvaitis, J. A. (2004). Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. *Conservation Biology*, *18*(3), 758–767. https://doi.org/10.1111/j.1523-1739.2004.00019.x

Marchand, K. A., Poulin, R. G., & Somers, C. M. (2018). Western painted turtles (*Chrysemys picta bellii*) in a highly urbanized system: Unexpected variation in resource use among age classes and sexes. *Herpetologica*, *74*(3), 217–225. https://doi.org/10.1655/herpetologica-d-17-00071.1

Mazerolle, M. J. (2004). Amphibian road mortality in response to nightly variations in traffic intensity. *Herpetologica*, *60*(1), 45–53. https://doi.org/10.1655/02-109

Meidinger, D. and J. Pojar (compilers and editors). (1991). Ecosystems of British Columbia. Special Report Series No. 6. British Columbia Ministry of Forests, Research Branch, Victoria BC. 330 pp.

Ministry of Environment and Climate Change Strategy. (2020). Guidelines for Amphibian and Reptile Conservation during Road Building and Maintenance Activities in British Columbia. Version 1.0., March 30, 2020.

Murphy, R. E., Martin, A., & Fahrig, L. (2022). Reduced predation on roadside nests can compensate for road mortality in road‐adjacent turtle populations. *Ecosphere*, *13*(2). https://doi.org/10.1002/ecs2.3946

Nicholson, E., Manzo, S., Devereux, Z., Morgan, T. P., Fisher, R. N., Brown, C. W., Dagit, R., Scott, P., & Shaffer, H. B. (2020). Historical museum collections and contemporary population studies implicate roads and introduced predatory bullfrogs in the decline of western pond turtles. *PeerJ*, *8*, e9248. https://doi.org/10.7717/peerj.9248

Paul, K. (2021) Increasing Western Painted Turtle Survival at Baynes Lake (COL-F21-W-3342). *Fish & Wildlife Compensation Program, Columbia Region.*

Regional District of East Kootenay (2021). *2021 Census: Population & Dwelling Count*. https://www.rdek.bc.ca/web/pdf/2021_census/2021_CensusPopulationDwellingCount.pdf

Regional District of East Kootenay (2023). *Baynes Lake Official Community Plan Bylaw No. 2319, 2011*. https://www.rdek.bc.ca/web/planningbylaws/bayneslakeocp/BL2319-BaynesLakeOCPConsolidation-July14_2023.pdf

Rood, S. (2023, February). The Lower Elk Aquifer -Studies and Status. [Conference Presentation]. *Collective for the Lower Elk Aquifer Restoration (CLEAR)* - Technical Meeting, East Kootenay. https://doi.org/10.13140/RG.2.2.18457.29280.

Shepard, D. B., Kuhns, A. R., Dreslik, M. J., & Phillips, C. A. (2008). Roads as barriers to animal movement in fragmented landscapes. *Animal Conservation*, *11*(4), 288–296. https://doi.org/10.1111/j.1469-1795.2008.00183.x

St. Clair, R., & Gregory, P. T. (1990). Factors affecting the northern range limit of painted turtles (*Chrysemys picta*): winter acidosis or freezing? *Copeia*, *1990*(4), 1083. https://doi.org/10.2307/1446492

St. Clair, R., Gregory, P. T., & Macartney, J. M. (1994). How do sexual differences in growth and maturation interact to determine size in northern and southern painted turtles? *Canadian Journal of Zoology*, *72*(8), 1436–1443. https://doi.org/10.1139/z94-190

Steen, D.A. & Gibbs, J.P. (2004). Effects of roads on the structure of freshwater turtle populations. *Conservation Biology*, *18*(4): 1143-1148.

Warner, D. A., Miller, D. a. W., Bronikowski, A. M., & Janzen, F. J. (2016). Decades of field data reveal that turtles senesce in the wild. *Proceedings of the National Academy of Sciences of the United States of America*, *113*(23), 6502–6507. https://doi.org/10.1073/pnas.1600035113

Winton, S. A., Bishop, C. A., & Larsen, K. W. (2020). When protected areas are not enough: low-traffic roads projected to cause a decline in a northern viper population. *Endangered Species Research*, *41*, 131–139. https://doi.org/10.3354/esr01017

Chapter 2. Road mortality rates and mortality mitigation infrastructure use at Baynes Lake

2.1 Introduction

There is growing recognition of the negative impacts that roadways have on wildlife and the need for efforts to mitigate these impacts (Aresco, 2005; Crawford et al., 2014; Dodd et al., 2004; Glista et al., 2009). Roadways can fragment or permanently destroy habitat (Aresco, 2005; Daigle, 2010; Marsh & Jaeger, 2015) and act as barriers to dispersal (Daigle, 2010; Gibbs, 1998; Shepard et al., 2008). Direct mortality from road collisions can reduce or eliminate local populations (Crawford et al., 2014; Howell & Seigel, 2019; Winton et al., 2020). The impacts of road mortality may be particularly pronounced in slow-moving animals, such as turtles (Aresco, 2005; González‐Suárez et al., 2018).

Efforts have been made to reduce the interaction of wildlife with roadways in high-risk areas through the use of roadway mortality mitigation infrastructure (Aresco, 2005; Crawford et al., 2014; Dodd et al., 2004; Glista et al., 2009). The infrastructure aims to limit wildlife access to roadways to reduce direct mortality and injury from traffic (Ministry of Environment and Climate Change Strategy, 2020). In BC, the infrastructure is typically designed to enhance connectivity, prevent road access, or influence behaviour (Ministry of Environment and Climate Change Strategy, 2020).

Wildlife bridges and underpasses are infrastructure that facilitate landscape connections, allowing wildlife to cross the road without directly interacting with traffic (Ministry of Environment and Climate Change Strategy, 2020). Overpasses are typically designed to accommodate large wildlife, while under-road tunnels or culverts are often tailored for amphibians, reptiles, and small mammals (Glista et al., 2009). Culverts, in particular, are widely favoured over other infrastructure, and are regarded as one of the more cost-effective road mortality mitigation infrastructure solutions to implement (Glista et al., 2009). Drift (or directive) fencing or concrete barriers can prevent road access and direct wildlife through crossing structures (Ministry of Environment and Climate Change Strategy, 2020). Both crossing infrastructure and directive fencing are generally considered effective management strategies, particularly when used in conjunction (Glista et al., 2009).

Infrastructure designed to induce behavioural changes can target either wildlife or road users. Road closures or optional detours can divert traffic from high-risk crossing sites at specific times of the year, such as peak migrations (Ministry of Environment and Climate Change Strategy, 2020). Wildlife-crossing signs and education can be used to influence driver behaviour (Ministry of Environment and Climate Change Strategy, 2020). Strategies for modifying wildlife behaviour, such as the construction of nesting beaches to deter turtles from crossing roads, can also be implemented (Ministry of Environment and Climate Change Strategy, 2020).

The effectiveness of infrastructure to mitigate road mortality depends on the choice of structure and its implementation (Glista et al., 2009) and is likely influenced by location and population-specific factors. . The success of culverts as management tools can depend on many factors. Location, especially considering the needs of less mobile animals like turtles, plays a significant role. The availability of access to cover on the approach to the structure is also an important consideration. The environmental conditions within the culvert, such as moisture, temperature, light, substrate, and noise, further influence the overall success of wildlife underpasses (Glista et al., 2009).

Monitoring is crucial for assessing the effectiveness of this infrastructure (Glista et al., 2009). One indicator of success may be a reduction in road mortality rates. Wildlife road mortality surveys serve as a popular technique for quantifying animal mortality numbers, but are subject to sources of error, such as scavenger removal (Loss et al., 2014; Winton, 2018). When scavengers remove carcasses from roadways between surveys, surveyors can undercount the number of road mortalities (Antworth et al., 2005; Loss et al., 2014; Winton, 2018). Winton (2018) found that 52% of western rattlesnake carcasses were removed from the road after two days. Similarly, Santos et al. (2016) found carcasses of various amphibian, reptile, bird, and mammal species remained for an average of 2.2 days. Santos et al. (2011) found freshwater turtle carcasses persisted for between three and six days. The duration of carcass persistence varies according to several factors, including species (Antworth et al., 2005; Santos et al., 2016), the presence of scavengers (Santos et al., 2016), and location (Flint et al., 2010; Santos et al., 2016; Slater, 2002). Therefore, the scavenging rate needs to be evaluated individually for each location and study species.

This chapter will assess the effectiveness of roadway mitigation infrastructure in Baynes Lake for the conservation of western painted turtles. It will examine changes in the use of the turtle tunnel over time and analyze road mortality rates, including a correction for the rate at which scavengers in Baynes Lake remove carcasses from the roadways.

2.2 Methods

2.2.1 Population tracking

Radio telemetry data was used to determine whether the Baynes Lake turtle population functioned as a separate system from the nearby Kikomun Creek Park population and evaluate the use of mitigation structures. Tracking was done in 2021, 2022, and 2023. All radio telemetry captures and the attachment of transmitters were conducted by Ministry of Water, Land, and Resource Stewardship (MWLRS) staff and contractors under their animal care certificate and wildlife handling permit. I conducted the triangulation, data recording, and data analysis for 2023.

Very high frequency (VHF) transmitters were attached to the lower right side of the turtle using J-b Water Weld Epoxy. In 2022, they were positioned on the bottom right side of the shell on the marginal scutes (between scutes 8-10). In 2023, they were positioned on a lower right costal scute (Figure 6). After the epoxy had dried, a permanent marker was used to darken the cement to better match the colour of the turtle's shell. Transmitters remained attacked until the scute shed off; typically, this occurred in late fall, although some transmitters remained attached until the following year.

In 2021, Holohil radio transmitters were attached to ten turtles in late spring (six gravid females, two non-gravid females, and two males). Turtles were tracked to between 45 and 73 confirmed locations from May 10 to August 25, 2021. In 2022, 17 turtles were tracked between June 2 and August 17 (15 gravid and two nongravid). Four turtles from 2021 were also tracked in 2022. Turtles were tracked to between 21 and 69 confirmed locations. In 2023, R1-2B Holohil radio transmitters were attached to 15 turtles in early July by MWLRS staff and contractors (nine females and six males). No gravid females were tracked, as no gravid females were found during surveys in 2023. Two tagged turtles from the previous year were also tracked. Turtles were tracked between seven and 20 times, depending on when they were tagged, where they were located, and how soon they lost their transmitter. Weather conditions, conditions of the turtle, location, and turtle activity were recorded each year. A total of 42 turtles were tracked between 2021 and 2023.

Figure 6. Ministry staff and contractors mounted Holohil transmitters (R1-2B) using marine-grade quick-drying epoxy to track movements of western painted turtles at Bynes Lake, BC during the summer of 2023.

In 2021 and 2022, tracking was done using a handheld R1000 (Communications Specialist, Orange, CA) and a 3-element directional antenna. In 2023, tracking was done with a Telonics VHF Telemetry Receiver and a RA-2AK VHF antenna. Tracking was done primarily on land, using triangulation to find the location of turtles offshore. When available, a canoe was used to access turtles in open water. Focal monitoring of gravid females was done during the breeding season. Whenever possible, the exact site of nesting was determined.

2.2.2 Turtle tunnel monitoring

Wildlife cameras were used to monitor the use of the turtle tunnel during peak migratory times in 2021, 2022, and 2023. On May 8, 2021, two wildlife cameras (type unrecorded) were installed outside of the turtle tunnel entrance, one facing the eastward and one facing the westward entrance (Wiebe et al., 2022). The cameras were installed approximately 5-m from the tunnel entrance and took a picture at one-minute intervals. On May 26, 2021, an additional camera was mounted within each end of the tunnel to photograph tunnel use. These cameras were set to take three pictures each time the motion sensor was triggered. On May 22, 2022, two cameras were installed within each end of the turtle tunnel, one facing east and one facing west into the tunnel (camera type unrecorded). One picture was taken every minute, and three consecutive pictures were taken one millisecond apart when motion was detected. In 2023, four wildlife cameras (Ryconyx HF2X) were installed at the east and west entrances of the small culvert and the turtle tunnel facing into the tunnel. Cameras were installed on May 11 and 12, 2023. Camera settings varied by date and location (Appendix C). All cameras were taken down at the beginning of September each year.

2.2.3 Road mortality surveys

Roadway-mortality surveys were conducted along Jaffray-Baynes Lake Road and Baynes Lake Loop Road in the summers of 2021, 2022, and 2023. Surveys were done to determine the rate of turtle road mortality per year as well as the number and location of turtles crossing the road. The time of day and weather of the surveys were recorded. The road, ditches, and temporary directional fencing were systematically surveyed, and any sighting of turtles was recorded. When a turtle was encountered, the record included the direction of travel, notch code, and whether the turtle was alive or deceased.

The exact location and timing of the surveys varied by year. The timing between surveys was dependent on surveyor availability. Typically, surveys occurred every two and three days, though there were gaps of between one and five days between each survey over the three years. In 2021, 38 road surveys were conducted between May and July. The route followed the focal survey route (Figure 2) between the turtle crossing signs. This area was previously determined to be a focal point of road mortality and crossings (Wiebe et al., 2022). In 2022, 32 surveys were conducted between June 6 and August 3. The survey route was expanded to the full survey route, which included Baynes Lake Loop Road. Road surveys were conducted between May 23 and August 30, 2023. The focal survey route was walked between May 23 and June 15. The full survey route was walked from June 15 to August 30.

A traffic counter (TRAFx Vehicle/OHV/Mountain Bike Counter, Canmore, AB) was installed each year along Jaffray-Baynes Lake Road. This allowed for a comparison between traffic volume and turtle road mortality. The counter was installed on the east side of Jaffray-Baynes Lake Road by the turtle tunnel (Figure 7). The number of cars passing the sensor per hour was recorded continuously, 24 hours a day. The counter was in operation from May 12 to June 7 in 2021, May 27 to August 18 in 2022, and June 19 to September 5 in 2023.

Figure 7. A traffic counter was installed on the east side of Jaffray-Baynes Lake Road beside the turtle tunnel (large culvert) from June 19 to September 5, 2023.

2.2.4 Scavenging error experiments

Experiments were performed in 2023 to evaluate the rate at which carcasses were removed from the road by scavengers. The goal was to ensure the road surveys did not underestimate road mortalities as a result of predators removing carcasses between surveys. Artificial and real turtle carcasses were monitored with cameras to determine the length of time they remained along the road before a scavenger removed them. The study took place along Jaffray-Baynes Lake Road and Baynes Lake Loop Road in areas previously identified as having a high incidence of turtle mortalities. Wildlife cameras (Ryconyx HF2X) were installed on wooden or metal stakes to capture predator interaction with the carcasses. The cameras were programmed to capture a photograph every minute, as well as a series of five photographs when movement was detected. Eight experiments were conducted between August 19 and September 6, 2023. The length and timing of each trial varied due to access to equipment and turtle carcasses.

Two types of carcasses were used in the study: natural and artificial. Four natural turtle carcasses were sourced from mortalities along Jaffray-Baynes Lake Road and Baynes Lake

Loop Road or relocated from other locations. Due to the limited availability of natural carcasses, an artificial carcass was also constructed.

The artificial carcass was constructed using a turtle shell sourced from Ebberns Pond. The shell was secured to a PVC Carlton conduit body junction box (type X, size: 1/2") using glue and zap straps (Figure 8). The box contained attachment points for the shell and a rope to prevent removal from the site and had a hollow interior with four large, round openings. The bottom opened and was secured with screws, allowing the interior and round openings to be filled with bait. The bait could be smelled by predators but could only be accessed through the small openings. The intent of this design was to simulate the type of access predators may have to a real turtle carcass, which is typically partially crushed during road mortality events, encouraging natural interaction with the artificial structure. The artificial carcass was baited with tuna, corned beef, or cat food.

Figure 8. Artificial turtle carcass constructed from a turtle shell and a Carlton conduit body junction box. The artificial turtle carcass was used to estimate the number of turtle road mortalities removed between surveys at Baynes Lake, BC during the summer of 2023.

Carcasses were placed within 1-m of the road, as most turtle carcasses found during roadway mortality surveys were located within this distance. The artificial carcass was secured to a piece of rebar driven into the ground with a greater than 1-m length of rope. This was to prevent predators from carrying away the artificial carcass, as the number of turtle shells was limited. In consideration of safety issues related to the rope potentially obstructing traffic, precautions were taken to ensure the carcasses were situated in a manner that prevented the rope from reaching the road. To further enhance safety and communicate the ongoing experiment, signs were placed approximately 4-m away from the carcasses. These signs served to both inform the public about the experiment and discourage interference with the carcasses. Carcasses were considered removed if the carcass was moved over 1-m from the starting location.

2.2.5 Road mortality rate

The road mortality rate was determined by calculating the number of mortalities per day throughout the entire duration of the surveys. The scavenge-rate experiments were used to calculate the percentage of mortalities that were likely captured during the surveys each year. The scavenger-rate correction was used to calculate the difference in observed versus actual turtle mortalities in 2022 and 2023. Surveys were placed into categories based on the time intervals between each consecutive survey. The probability of a carcass being present on the road after a specific number of days was assigned to each category based on the scavenge rate experiments. The average probability of a carcass still being present when the survey took place was calculated across the entire season.

2.3 Results

2.3.1 Population tracking

Turtles were tracked up to 73 times per year, depending on when it was tagged, where it was located, and how soon it lost its transmitter. Lost transmitters were recovered and replaced, when possible, either on the original turtle or on a new turtle.

Turtles were primarily tracked to one of the six main bodies of water in the Baynes Lake area: Baynes Lake North, Baynes Lake South, Ebberns Pond, the Spirit Pond complex, and Leah's Pond. Over the three years, no turtles were tracked to the Kikomun Creek Park water bodies. In 2023, Leah Pond and Spirit Pond south were mostly dry during the summer. No turtles were tracked to these two locations (Figure 9). Additionally, few turtles were tracked to locations on land. No gravid females were found, so none were tracked, and no turtles were found nesting.

The number of road crossings varied between years. In 2021, tracking started in mid-May or early June and ended in the last week of August. Tagged gravid turtles made between three and five road crossings. In 2022, tracking started in mid to late June and ended on August 17 or August 18 (with one exception where tracking ended on August 8). Tagged gravid females made an average of 1.6 road crossings, ranging from zero to four road crossings. In 2023, both males and non-gravid females were tracked starting between June 30 and July 3. Tracking ended between August 25 and September 5, with the exception of two tracked turtles who lost their trackers in mid-August and two at the end of July. Most males made no road crossings, while one made a single road crossing. Non-gravid females made between zero and two road crossings, with an average of 0.7 crossings.

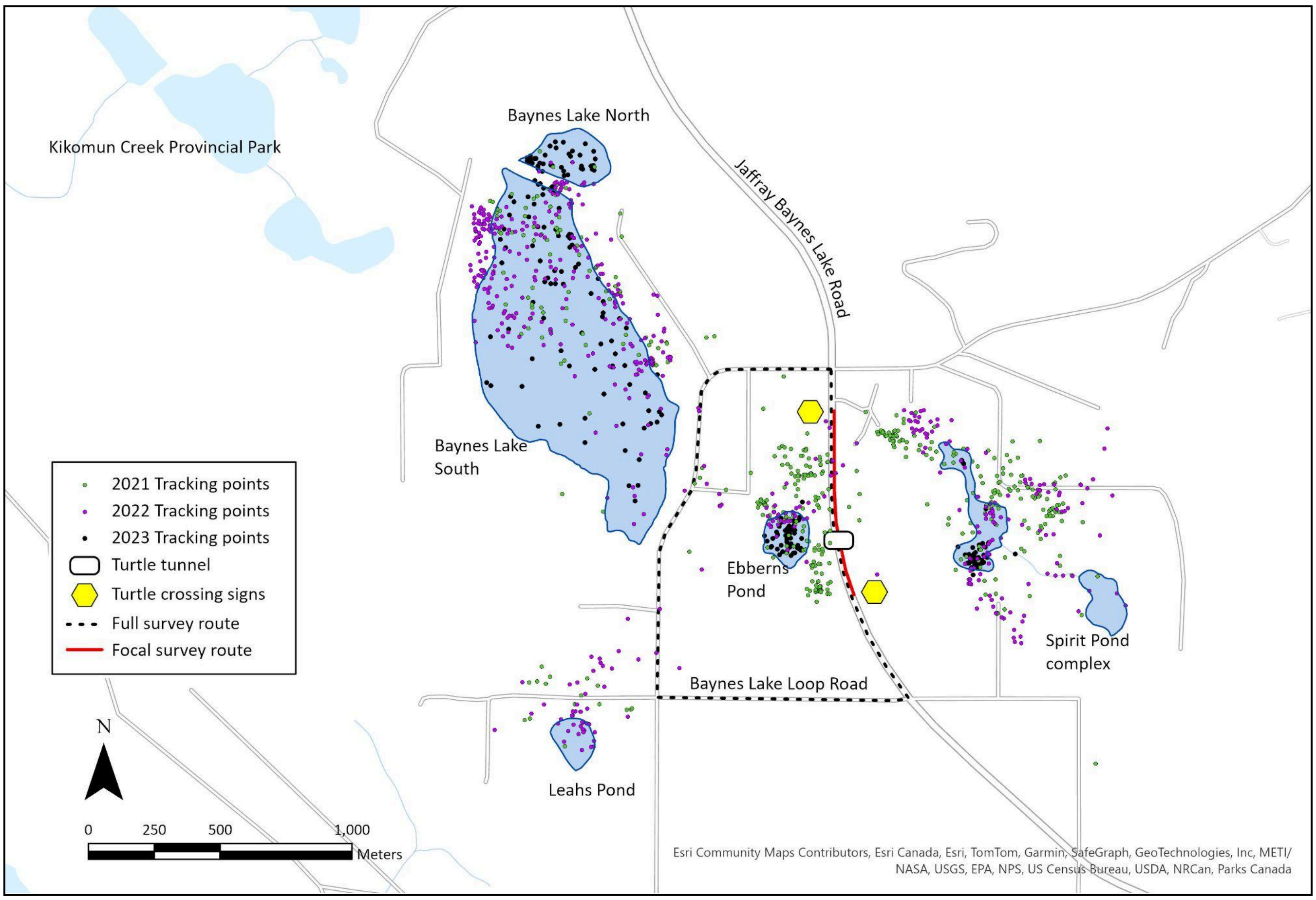

Figure 9. Turtles were tracked at Baynes Lake, BC in 2021, 2022, and 2023. Those tracked in 2021 were marked in green, those in 2022 in purple, and those in 2023 in black. Each point represented a single turtle observation.

2.3.2 Road mortality mitigation infrastructure use

In 2021, a total of 84 instances of animals using the turtle tunnel were captured across the four cameras, four of which were turtles (Table 1). The four turtles were observed around the tunnel in June. However, there was no photographic evidence of movement through the entire tunnel. One turtle entered and then promptly left the tunnel, while the other three were captured outside the tunnel entrance. Turtles were captured interacting with the tunnel between 11:18 PM and 2:00 AM. Other animals that engaged with the tunnel included striped skunks (*Mephitis mephitis*), mice (Muridae; unknown species), squirrels (Sciuridae), domestic cats (*Felis catus*), dogs (*Canis familiaris*), and various species of small birds (Passeriformes). Skunks made up 40% of the observations. Skunks were captured interacting with the tunnel between 11:22 PM and 5:47 AM.

In 2022, a total of 110 instances of animals using the tunnel were captured across the four cameras. Four turtles were captured engaging with the turtle tunnel between June 7 and July 11 (Table 1). Radio telemetry tracking of one turtle indicated a road crossing, although they were only photographed entering the tunnel and not exiting. Two were photographed entering the tunnel and turning around. Turtles were captured interacting with the tunnel between 5:06 AM and 5:00 PM. No turtles were detected interacting with the tunnel overnight. Other animals that interacted with the tunnel included skunks, mice, cats, small birds, and chipmunks (*Neotamias ssp*.). Skunks made up the majority of animals observed at the tunnel, accounting for 54% of all observations. Skunks were generally detected interacting with the tunnel between 8:41 PM and 5:59 AM, although one skunk was detected interacting with the tunnel at noon.

In 2023, a total of 561 instances of animals using the small culvert and turtle tunnel were captured by the four cameras. Three western painted turtles were captured engaging with the small culvert (Table 1). There was no photographic evidence of any traveled all the way through the culvert. Fifteen western painted turtles were captured engaging with the turtle tunnel (Table 1). There was no photographic evidence of a turtle both entering and exiting the tunnel. Four turtles were captured entering and promptly exiting the tunnel in the same direction. Eight turtles were captured exiting the tunnel with no photographic evidence of them entering the tunnel. The final three turtles were captured entering the tunnel but not exiting. Turtles were photographed interacting with the turtle tunnel between 10:35 AM and 8:06 PM. There were no early morning or overnight interactions. Ten types of animals were captured using or interacting with the small culvert and turtle tunnel: mice, birds, cats, dogs, chipmunks, deer (*Odocoileus* ssp.), squirrels, striped skunks, a garter snake (*Thamnophis sirtalis*), and western painted turtles. All animals were captured in both the small culvert and the turtle tunnel, with the exception of deer and dogs, which were captured only interacting with the small culvert, and the garter snake, which was captured in the turtle tunnel. Mice accounted for 58% of the animals captured in the tunnel. Squirrels, striped skunks, and chipmunks were the next three most common animals in the tunnel, at 23, 22, and 21 captures, respectively. Cats, striped skunks, and mice accounted for most animals photographed in the small culvert, at 49, 48, and 38 captures, respectively. A total of 22 striped skunks were photographed moving into or through the turtle tunnel. There was a gap in striped skunk use of the turtle tunnel between June 7 and July 8; however they did not stop interacting with the small culvert (Figure 17). Skunks used the turtle tunnel in the early morning and evening, between 9:44 PM and 6:12:48 AM. This was close to the exact opposite of the timing turtles used the tunnel in 2023.

Table 1: Time of day western painted turtles interacted with the turtle tunnels and small culvert along Jaffray-Baynes Lake Road in Baynes Lake, BC in the summer of 2021, 2022, and 2023. Interactions are classified as any movement into, out of, or towards the turtle tunnel captured by wildlife cameras.

Year	**Time of Day**				**Location**		**Total**	**Turtles per survey day**
	Morning	Afternoon	Evening	Night	Turtle tunnel	Small culvert*		
2021	1	0	0	3	4	NA	4	0.036
2022	2	1	1	0	4	NA	4	0.040
2023	2	4	12	1	15	3	18	0.096

*Morning= 5:00 to 12:00; Afternoon= 12:00 to 16:00; Evening= 16:00 to 22:00; Night=22:00-6:00
**Small culvert was only monitored in 2023

Fencing was monitored in 2023 during road mortality surveys to assess its long-term effectiveness in preventing turtles from accessing the road. Repairs were done periodically throughout the summer. The fence's fabric started to disintegrate by mid-June, making repairs difficult in multiple locations. By mid-August, the majority of the fencing was not capable of preventing turtle movement onto the road.

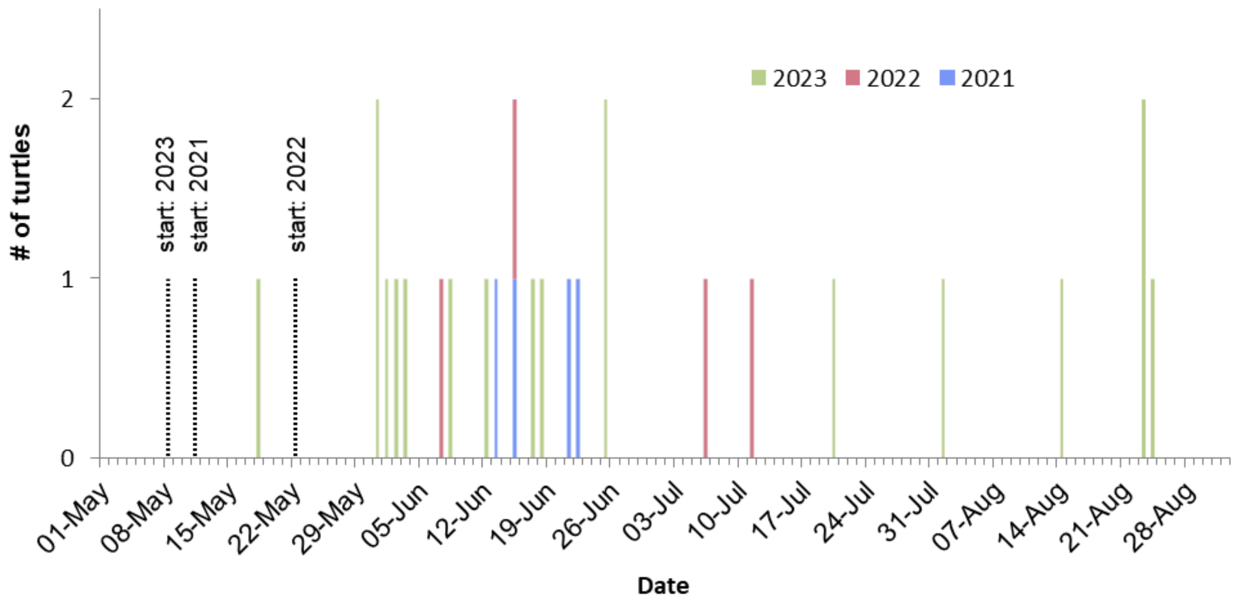

Figure 10. Summary of dates turtles were photographed using or interacting with the small culvert or turtle tunnel at Baynes Lake, BC. Data is from 2021 to 2023. Start dates indicate the first day of each year cameras were deployed.

2.3.3 Road mortality surveys

A total of 121 road surveys were conducted from 2021 to 2023: 32 in 2021, 42 in 2022, and 47 in 2023 (Table 2). Turtle sightings began as soon as the first road survey was conducted in 2022 (May 12) and 2023 (June 1). The first turtle sighting in 2021 was on June 11, despite surveys beginning a month before.

The number of days traffic data was collected varied by year, depending on the availability of field crews and equipment. The counter ran from May 13 to June 7 in 2021, May 27 to August 18 in 2022, and June 19 to September 5 in 2023 (Figure 11). In 2021, approximately 10,000 cars were detected, averaging 385 cars per day. In 2022, 63,305 cars were detected, averaging 763 cars per day. In 2023, 67,238 were detected, averaging 851 cars per day. There was a 60-day period where the traffic counter ran simultaneously in both 2022 and 2023, allowing for a comparison between traffic volumes. Between June 19 and August 17, 51,463 cars were detected in 2022 and 52,986 cars were detected in 2023.

Table 2. Summary of turtle detections and road surveys in 2021, 2022, and 2023. Turtle detections are shown for incidental encounters and official surveys along Jaffray-Baynes Lake Road and Baynes Lake Loop Road, Baynes Lake, BC.

Turtle detections		Morning	Afternoon	Evening	Time unknown	I.E.	Total
2021	WPT Alive	1	2	8	4	14	29
	WPT Dead	0	1	0	1	3	5
2022	WPT Alive	2	5	3	2	-	12
	WPT Dead	1	4	3	0	-	8
2023	WPT Alive	0	3	8	0	8	19
	WPT Dead	0	2	1	0	2	5
Surveys		Morning	Afternoon	Evening			Total
2021	Focal route	11	4	16			32
	Full route	0	0	0			0
2022	Focal route	0	0	0			0
	Full route	13	17	12			42
2023	Focal route	0	3	12			15
	Full route	3	10	19			32

*WTP= western painted turtle; I.E.= incidental encounter; Morning= 5:00 to 12:00; Afternoon= 12:00 to 16:00; Evening= 16:00 to 24:00. Time unknowns = during official surveys, but time of survey not recorded.

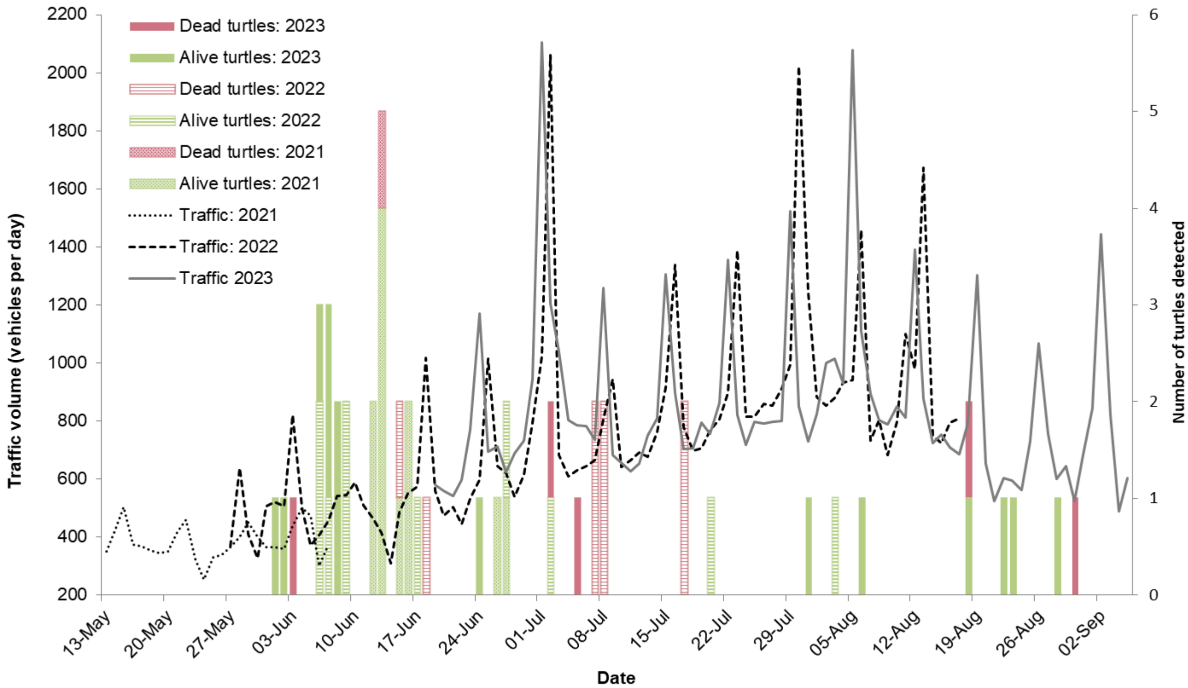

Figure 11. Summary of traffic data from traffic counter and turtle detections during road mortality surveys at Baynes Lake, BC from 2021 to 2023 between May 13 and September 5

2.3.4 Scavenging error experiments

A total of eight turtle carcasses were monitored between August 21 and September 6: three artificial carcasses and five real carcasses. The artificial carcasses had the highest rate of interaction and the highest rate of removal, with an average of 1.4 interactions per 24 hours. Two-thirds of the artificial carcasses were removed: one by a dog after 83 hours and one by an unknown source after 104 hours. The real carcasses had a lower rate of interaction and removal, with an average of 0.75 interactions per 24 hours. Only one real carcass was fully removed from the site after 61 hours by a magpie (*Pica hudsonia*). This was the only juvenile carcass in the experiment. One notable carcass was located several metres north of the turtle tunnels. The carcass was crushed by a motor vehicle on the shoulder of the road but received only one interaction in over nine days and was not removed.

The length of time carcasses were monitored varied from 49 hours to 235 hours. All carcasses were still present after 48 hours. After the initial 48-hour period, an average of one carcass was removed per 24-hour period. Three carcasses were removed after 48 hours for logistical reasons and are not included in Figure 12.

Overall, the rate of carcass detection for surveys within a two-day period was 100%, based on the scavenge-rate experiments. A 20% reduction in carcasses occurred each day until day 5, where the rate of carcasses still present remained at 40%.

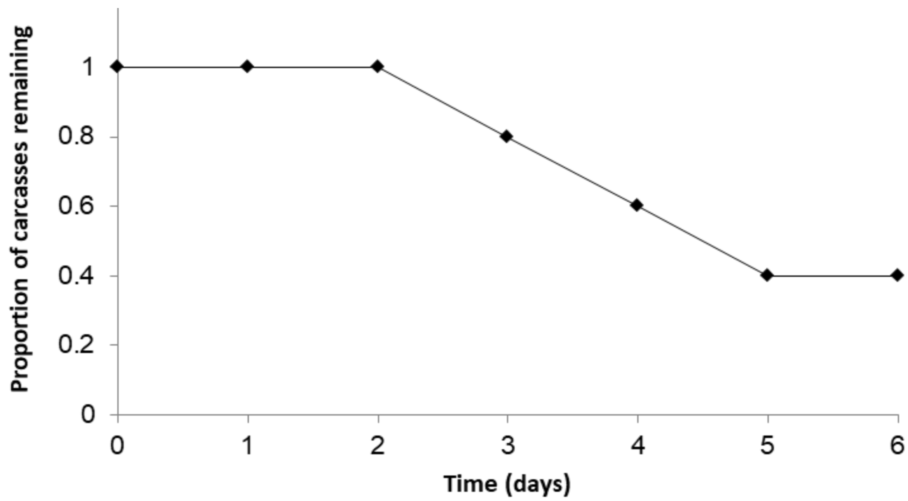

Figure 12. The proportion of turtle carcasses remaining on the roadside per day (n=5). Experiments were conducted at Baynes Lake, BC in the summer of 2023

2.3.5 Road mortality rates and locations

Casual mortality detection surveys took place in 2019 and 2020. As there is no available population estimate for those years, mortalities are measured as the number of occurrences throughout the active season. In 2019 and 2020, there were 15 and five road mortalities per season, respectively. In 2021, some missing data prevented calculations of mortalities per day, as the final survey date is unknown. Five mortalities were recorded between April and July. In 2022, eight mortalities were detected over 83 days, resulting in a rate of one mortality per ten days (or 0.1 mortality per day). In 2023, three mortalities were detected over 98 days, for a road mortality rate of one mortality per 34 days (or 0.03 mortalities per day).

Scavenge-rate correction was calculated for 2022 and 2023 as the number of surveys and period between each survey were known. In 2022, 80% of the 42 road surveys occurred during the two-day window where no carcasses were removed (Figure 12). Four surveys occurred after a four-day gap; thus, there was a 40% chance a carcass was removed during this time. Four surveys occurred with a five-day or more gap, with a 60% chance of a carcass being removed during that time period. Therefore, it was estimated that 90% of the road mortalities were detected over the 83-day survey period in 2022. In 2023, 76% of the 47 surveys occurred during the two-day window where no carcasses were removed (Figure 12). Three surveys occurred with a three-day gap (20% chance a carcass was removed), three occurred with a four-day gap (40% chance a carcass was removed), and five occurred with a five-day gap or more (60% chance a carcass was removed). Therefore, it was estimated that 90% of the road mortalities were documented during the 98-day survey in 2023.

The majority of turtles that were located during road mortality surveys were between the turtle crossing signs on Jaffray-Baynes Lake Road (Figure 13), even when the full survey route was taken. As would be expected, turtle mortalities were concentrated in the same area where live turtles were seen crossing.

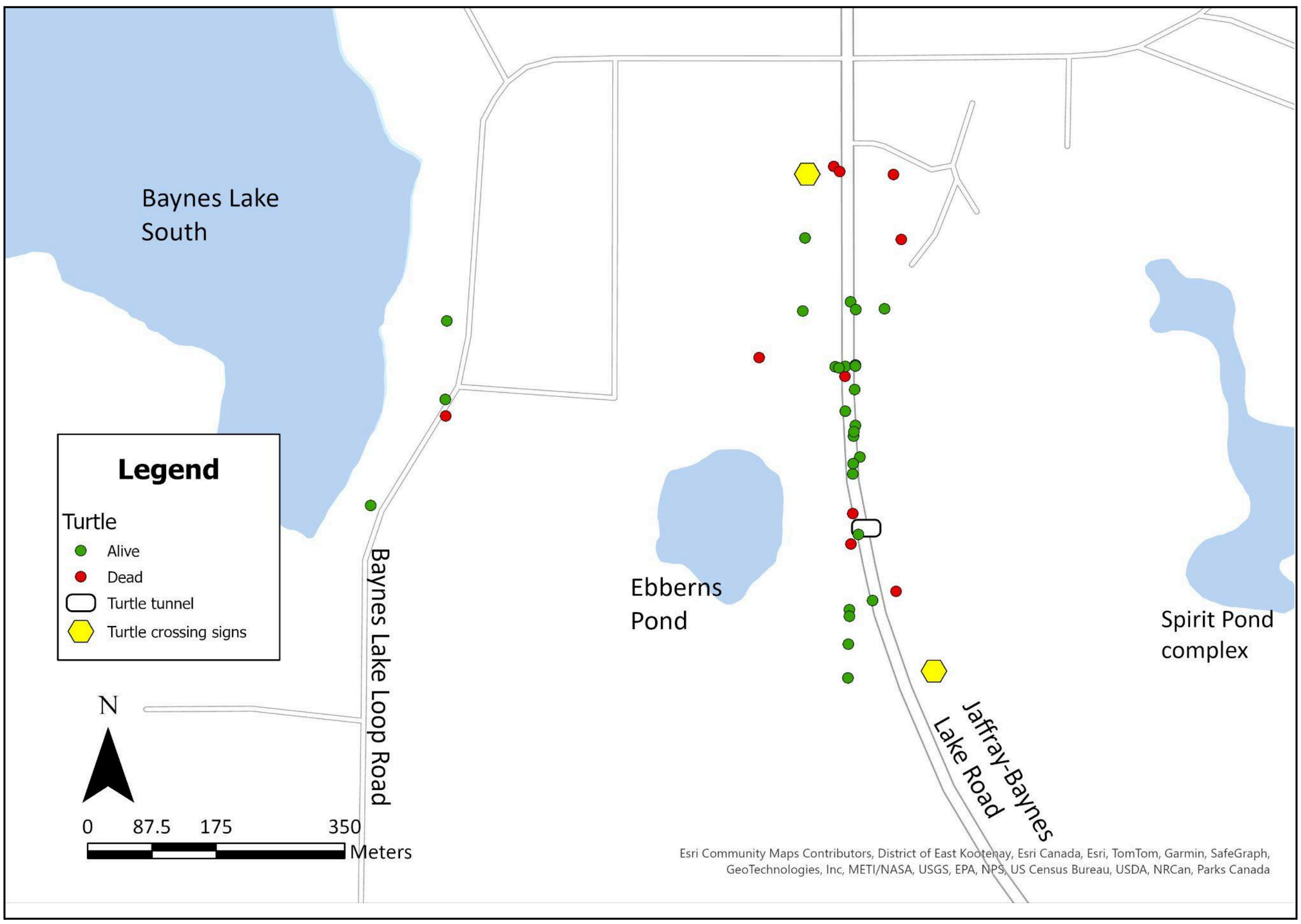

Figure 13: Summary of turtles located during road mortality surveys in Baynes Lake, BC from 2021 to 2023. Data is separated into live and dead turtles.

2.4 Discussion

2.4.1 Population tracking

Radio-telemetry tracking indicated that the Baynes Lake western painted turtle populations are separate from the Kikomun Creek Provincial Park population. No turtles were found moving to water bodies within the park. Turtles have, however, been recorded to move between Leah's Pond and Baynes Lake South, which is a greater distance than Baynes Lake South to the first wetland in Kikomun Creek Park (Wiebe et al., 2022). A potential explanation for the separation may be the slight slope between Baynes Lake South and the nearest Kikomun Creek wetland, with an elevation gain of 11-m over 65-m along the western shore of Baynes Lake South. There is also a concentration of housing in this area. Although turtles have been found to scale substantial slopes (Scott et al., 2023), the combination of slope and people along the shortest route between the wetlands may present enough of a barrier to prevent movement between them. The nearest wetlands may also be less favourable in terms of food or nesting locations than Ebberns Pond or Leah's Pond.

The number of road crossings turtles made varied by the population tracked. As expected, gravid female turtles made a higher number of road crossings than non-gravid females. Gravid females can nest 80-m inland and often migrate to seek nesting locations (Delaney et al., 2019; Gibbs & Steen, 2005; Steen & Gibbs, 2004). Males also made a lower number of road crossings than gravid females, but still did make overland excursions between June and August. Gravid females were tracked to locations on land far more often than non-gravid females. There may have been effort bias associated with this, as turtles were tracked more often in 2021 and 2022 during the period where they were thought to be nesting (Wiebe et al., 2022). Gravid females may be at a high risk of road mortality during the nesting season due to their high rate of overland excursions and road crossings.

With limited, if any, movement between the Kikomun Creek Provincial Park and Baynes Lake turtle populations, loss of wetland area becomes a higher concern. The Baynes Lake area has been experiencing water loss since 2014, when a dam along the Elk River was decommissioned, possibly causing a change in the aquifer’s refile regime (Wynnyk, 2023). The area saw a 2-m drop in water, and many kettle ponds either dried up or have been reduced in size (Wynnyk, 2023). Changes in the size and presence of wetlands may cause changes in turtle-crossing patterns, possibly increasing the number of crossings or changing the location of crossings if previously used locations are traveled to and found to be inhospitable. This may have significant implications both for the long-term viability of the species and for the roadway mitigation infrastructure that is installed at Bayne Lake.

2.4.2 Road mortality mitigation infrastructure use

Interactions with the turtle tunnel have increased since its installation, but it is uncertain whether turtles were using the tunnel. After the installation of the turtle tunnel in 2020, four turtles were photographed interacting but not moving through the tunnel in 2021 and 2022. Fencing was installed in the spring of 2023, and fifteen turtles were seen interacting with the tunnel that summer. Although no turtles were photographed both entering and exiting the tunnel, eight turtles were seen exiting and three were seen entering but not exiting the tunnel.

The low detection of complete tunnel traversals may have been due to either problems with the camera set-up or undesirable tunnel conditions. The cameras used may have difficulty capturing the slow movement of western painted tunnels. Cameras were set to capture both for detected movement and after a certain period of time for most years (Derksen, 2023; Wiebe et al., 2022). Carcasses were not seen within the tunnel, and no predators were seen with turtle carcasses, indicating the turtles seen entering the tunnel did exit the tunnel. A large portion of turtles were seen either exiting or entering the tunnel, indicating movement was not captured consistently by the cameras in the tunnel. The cameras mayhave failed to capture the turtle movement in the tunnels. Boyles et al. (2021) reported a similar problem while monitoring culverts for turtle use. They found that turtles triggered infrared motion detectors only 56% of the time with their Bushnell TrophyMAX wildlife camera. It is likely that at least a few of the turtles photographed entering or exiting the tunnel have gone completely through it. It is also likely that more turtles interacted with the tunnel than were recorded doing so.

Turtles seen exiting the turtle tunnel do not necessarily indicate the turtles traversed the entire tunnel, as turtles may have entered and then exited the tunnel on the same side. This may indicate unfavourable conditions within the tunnel. Conditions within the tunnel were not monitored; however, the Best Management Practices for wildlife underpass construction in BC indicates that turtles are more likely to use crossing structures with higher levels of light (Ministry of Environment and Climate Change Strategy, 2020). The turtle tunnel at Baynes Lake is a closed-top tunnel, only allowing natural light in through the tunnel ends, and contains no artificial lighting throughout the reach of the tunnel. The low-light conditions may discourage the use of the tunnel.

2.4.3 Scavenger rate

Experiments found there was low scavenger interaction with turtle carcasses at Baynes Lake. There was no scavenger interaction in the first two days when carcasses were placed. Over three-quarters of road mortality surveys were conducted within two days during the 2022 and 2023 road surveys. Because of the high rate of carcass persistence, scavengers may have accounted for only a 10% reduction in carcass detection in 2022 and 2023. This assumes scavenger rates are consistent between the two years and are consistent across each month, as surveys were done in August. The use of the artificial carcass may have caused this carcass rate detection to be underestimated, as interaction with the artificial carcass was higher than with the real carcasses.

As has been seen in other studies of carcass persistence (Santos et al., 2016), the rate of carcass removal may depend on the size of the carcass. The one small carcass placed out had the fastest removal time. Overall, the scavenger rate was likely not a significant influence on the detection rate of carcasses at Baynes Lake.

2.4.4 Road mortality

Road mortality varied between years and survey techniques. In 2019 and 2020, opportunistic observations reported at least 15 and five turtle mortalities, respectively, over the active season. Road mortality decreased after the turtle tunnel was installed in the fall of 2020. Road mortality further decreased after the drift fencing was installed in the spring of 2023, even with the expanded survey route.

During years with official surveys, the rate of turtle mortality did not reach the peak reported by the Baynes Lake community in 2020. However, several factors make it challenging to directly attribute the reduction in mortality to the presence of the turtle tunnel and drift fencing. Information campaigns had begun before the research started in the Baynes Lake community and may have contributed to the reduction in mortality. Mortalities were also counted all through the active season before 2021, not just during the summer (Wiebe et al., 2022). There was also limited evidence to suggest that turtles successfully moved through the entire turtle tunnel in any year. However, interactions with the tunnel did increase from 2022 to 2023, indicating more turtles were encountering the tunnel.

The majority of turtles found on the road during surveys were between the turtle crossing signs in all years, within the area the fencing was installed in 2023. This indicates that the turtle tunnel is effectively located in the area most impacted by road crossings, but that the fencing was not effective in preventing turtles from crossing the road. The drift fencing that was installed in 2023 began to deteriorate in mid-June, during which time turtles continued to make road crossings. The number of turtles seen crossing the road while the fence was still intact (before mid-June) indicates the fencing was not effective in preventing interactions with the roadway.

Crossing structures have been found to be effective in mitigating road mortality, particularly when underpasses are used in conjunction with drift fencing (Glista et al., 2009). Turtles have also been found to use culverts and tunnels to cross under roadways, although this link is limited in western painted turtles (Ministry of Environment and Climate Change Strategy, 2020). Future research at Baynes Lake should investigate the cause of turtles not fully using the turtle tunnel and work to more strongly connect the reduction of road mortality with the installation of the crossing structure.

2.5 Literature Cited

Antworth, R. L., Pike, D. A., & Stevens, E. E. (2005). Hit and Run: Effects of Scavenging on Estimates of Roadkilled Vertebrates. *Southeastern Naturalist*, *4*(4), 647–656. https://doi.org/10.1656/1528-7092(2005)004

Aresco, M. J. (2005). Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a north Florida lake. *The Journal of Wildlife Management*, *69*(2), 549–560. https://doi.org/10.2193/0022-541x(2005)069

Boyle, S. P., Keevil, M. G., Litzgus, J. D., Tyerman, D., & Lesbarrères, D. (2021). Road-effect mitigation promotes connectivity and reduces mortality at the population-level. *Biological Conservation*, *261*, 109230. https://doi.org/10.1016/j.biocon.2021.109230

Crawford, B. A., Maerz, J. C., Nibbelink, N. P., Buhlmann, K. A., & Norton, T. M. (2014). Estimating the consequences of multiple threats and management strategies for semi-aquatic turtles. *Journal of Applied Ecology*, *51*(2), 359–366. https://doi.org/10.1111/1365-2664.12194

Daigle, P. (2010). A summary of the environmental impacts of roads, management responses, and research gaps: A literature review. *Journal of Ecosystems and Management*, *10*(3). https://doi.org/10.22230/jem.2010v10n3a38

Delaney, D. M., Hoekstra, L. A., & Janzen, F. J. (2020). Becoming creatures of habit: Among- and within-individual variation in nesting behaviour shift with age. *Journal of Evolutionary Biology*, *33*(11), 1614–1624. https://doi.org/10.1111/jeb.13701

Derksen, J. (2023). *Western Painted Turtle Population Monitoring: 2023*. Unpubl. report prepared for the Ministry of Water, Land & Resource Stewardship.

Dodd, C. K., Barichivich, W. J., & Smith, L. L. (2004). Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. *Biological Conservation*, *118*(5), 619–631. https://doi.org/10.1016/j.biocon.2003.10.011

Gibbs, J. P. (1998). Amphibian movements in response to forest edges, roads, and streambeds in southern New England. *The Journal of Wildlife Management*, *62*(2), 584. https://doi.org/10.2307/3802333

Flint, P. L., Lance, E. W., Sowl, K. M., & Donnelly, T. F. (2010). Estimating carcass persistence and scavenging bias in a human-influenced landscape in western Alaska. *Journal of Field Ornithology*, *81*(2), 206–214. https://doi.org/10.1111/j.1557-9263.2009.00262.x

Gibbs, J.P., & Steen, D.A. (2005). Trends in sex ratios of turtles in the United States: implications of road mortality. *Conservation Biology*, *19*(2), 552–556.

Glista, D. J., DeVault, T. L., & DeWoody, J. A. (2009). A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning*, *91*(1), 1–7. https://doi.org/10.1016/j.landurbplan.2008.11.001

González-Suárez, M., Ferreira, F. Z., & Grilo, C. (2018). Spatial and species-level predictions of road mortality risk using trait data. *Global Ecology and Biogeography*, *27*(9), 1093–1105. https://doi.org/10.1111/geb.12769

Howell, H. J., & Seigel, R. A. (2019). The effects of road mortality on small, isolated turtle populations. *Journal of Herpetology*, *53*(1), 39. https://doi.org/10.1670/18-022

Loss, S. R., Will, T., & Marra, P. P. (2014). Estimation of bird-vehicle collision mortality on U.S. roads. *The Journal of Wildlife Management*, *78*(5), 763–771. https://doi.org/10.1002/jwmg.721

Marsh, D. M. and J. A. G. Jaeger. (2015). Direct effects of roads on small animal populations. In: Roads and ecological infrastructure: concepts and applications for small animals. K.M. Andrews, P. Guidelines for herpetofauna conservation during road building & management activities 118 Nanjappa, S.P.D. Riley (editors). Johns Hopkins University Press, Baltimore, Md., pp. 42–56.

Ministry of Environment and Climate Change Strategy. (2020). Guidelines for Amphibian and Reptile Conservation during Road Building and Maintenance Activities in British Columbia. Version 1.0., March 30, 2020.

Santos, S., Carvalho, F., & Mira, A. (2011). How long do the dead survive on the road? Carcass persistence probability and implications for Road-Kill Monitoring surveys. *PLOS ONE*, *6*(9), e25383. https://doi.org/10.1371/journal.pone.0025383

Scott, K. M., Berberi, A., Bulté, G., Dakin, R., & Cooke, S. J. (2023). Freshwater turtle climbing abilities: Implications for the design and use of shoreline erosion control structures. *Ecological Engineering*, *196*, 107093. https://doi.org/10.1016/j.ecoleng.2023.107093

Shepard, D. B., Kuhns, A. R., Dreslik, M. J., & Phillips, C. A. (2008). Roads as barriers to animal movement in fragmented landscapes. *Animal Conservation*, *11*(4), 288–296. https://doi.org/10.1111/j.1469-1795.2008.00183.x

Slater, F.M. (2002). An assessment of wildlife road casualties – the potential discrepancy between numbers counted and numbers killed. *Web Ecology*, *3*, 33–42.

Steen, D.A. & Gibbs, J.P. (2004). Effects of roads on the structure of freshwater turtle populations. *Conservation Biology*, *18*(4): 1143-1148.

Trombulak, S. C., & Frissell, C. A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*, *14*(1), 18–30. https://doi.org/10.1046/j.1523-1739.2000.99084.x

Wiebe, S. A., Gray, S., & Paul, K. (2022). *Final Report: Increasing Western Painted Turtle Survival at Baynes Lake (COL-F22-W-3483)*.

Winton, S. A. (2018). Impacts Of Road Mortality On The Western Rattlesnake (*Crotalus Oreganus*) In British Columbia. Master's thesis, Thompson Rivers University Kamloops, British Columbia, Canada.

Winton, S. A., Bishop, C. A., & Larsen, K. W. (2020). When protected areas are not enough: low-traffic roads projected to cause a decline in a northern viper population. *Endangered Species Research*, *41*, 131–139. https://doi.org/10.3354/esr01017

Wynnyk, H. (2023). Baynes Lake, Elko And Area Environmental Screening Report. https://data.cbwaterhub.ca/dataset/baynes-lake-elko-and-kikomun-environmental-reports

Chapter 3. The long-term viability of the Baynes Lake painted turtle population with varying levels of road mortality

3.1 Introduction

Road mortality can have a significant impact on many wildlife species by influencing the structure of nearby populations. One of the most widespread consequences of direct roadway mortality is a loss in abundance (Aresco, 2005; Auge et al., 2023; Crawford et al., 2014; Fahrig & Rytwinski, 2009; Howell & Seigel, 2019; Piczak et al., 2019; Winton et al., 2020). Direct mortality on roadways removes individuals from populations, causing declines and potential local extirpation (Fahrig & Rytwinski, 2009; Howell & Seigel, 2019). Removal of individuals from a population may also be a more significant factor in the loss of genetic diversity than roads acting as barriers to dispersal (Jackson & Fahrig, 2011). Sink populations may also develop in areas that have high roadway mortality but attractive habitat features. Mumme et al. (2000) found fledgling Florida scrub-jays experienced high levels of roadway mortality, but adults still used and may even have favoured roadside habitat for nesting. This created a sink population, maintained by immigration (Mumme et al., 2000).

Road mortality may not uniformly impact individuals in a population. Females may be disproportionately impacted by road mortality in species of turtles where females engage in overland migrations for nesting (Nicholson et al., 2020; Steen & Gibbs, 2004). Steen and Gibbs (2004) found a correlation in painted turtle and snapping turtle populations between male-biased sex ratios and areas with high road density. Changes in adult survivorship have been shown to impact the long-term viability of different turtle populations (Crawford et al., 2014; Heppell, 1998). A disproportionate loss of females may exacerbate these declines (Nicholson et al., 2020).

Population viability analysis (PVA) is used to predict the risk of a species or population going extinct (Lacy & Pollak, 2023).This process involves integrating life-history parameters and quantified threats, allowing the projection of population over time (Lacy & Pollak, 2023). The use of computer models to conduct PVA is widely used in ecology and has been used in the conservation and management of at-risk reptile species (Famelli et al., 2012; Howell & Seigel, 2019; Murphy et al., 2022; Winton et al., 2020). Several ready-made, user-friendly software packages are available online (Lacy & Pollak, 2023). Without long-term data, PVAs can be a valuable alternative for wildlife managers to assess the viability of the populations they monitor and the potential impact of management decisions (Trouillier et al., 2023).

The extent to which PVAs are valuable for wildlife management varies depending on how accurately the input parameters reflect the reality of the wildlife population (Coulson et al., 2001). With careful, targeted use and an understanding of their limitations, PVAs can be a valuable tool to evaluate management choices and quantify observed trends in populations. Brooks et al. (2000) looked at five PVA models and found them all to have similar results that accurately reflected observed conditions in long-term population studies. McCarthy et al. (2004) found that the predictions made by PVA models were slightly more accurate than those made by the subjective judgements of wildlife professionals.

This chapter will investigate the long-term viability of the Baynes Lake painted turtle population with varying levels of road mortality rates using population-specific parameters.

3.2 Methods

3.2.1 Baynes Lake population data collection

Data collection for the The Baynes Lake Western Painted Turtle Project took place over three summers, from 2021 to 2023. Turtles were caught through various active and passive trapping techniques, including dip netting, hoop traps, and basking traps. The data were collected by MWLRS staff and contractors under their animal care certificate and wildlife handling permit.

Morphometric data was collected on new and recaptured individuals. Carapace width and length were measured using a 320-mm Wandersunm Adjustment Stainless Steel Vernier caliper, with measurements rounded to the nearest 1.0-mm. Carapace length was measured as a straight line from top to bottom of the outer shell, while carapace width was measured between the seventh scutes. Turtles were weighed by placing them in a pillowcase and using a Pesola spring scale. Accuracy ranged from 1-g to 10-g depending on the specific scale used. Sex was determined using secondary sexual characteristics (length of the claws) and the position of the cloaca. Each female turtle was palpated to feel for the presence of eggs.

Turtles were given a unique notch on their marginal scutes using a rechargeable rotary tool (Dremel 7760, 3.6 V; Figure 14). The notching process followed the procedure outlined in RISC (1998), according to the notch library established for the project in 2021 (Wiebe, 2022).

Juveniles and turtles with scute damage were not notched. In general, turtles with a carapace length below 85-mm were not considered for notching. Turtles with a carapace length between 85 and 130-mm were considered for notching, depending on their scute size and the softness of their shell.

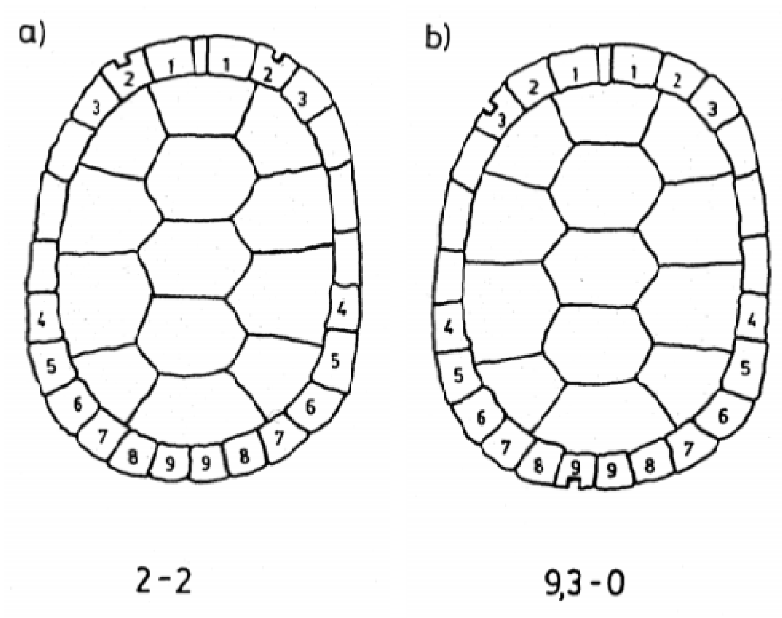

Figure 14: Carapace of a painted turtle showing the notch scheme (from Macartney and Gregory, 1985; located in RISC, 1998).

3.2.2 Sex distribution and number of clutches per year

The sex ratio of the Baynes Lake turtle population was calculated by comparing the number of notched females to notched males over the three years. This method excluded juveniles who were too young to be notched and turtles with damaged shells, even though their sex was known, but prevented the double counting of turtles. A Chi-Square Goodness of Fit Test was performed to determine whether the proportion of females to males was equal between location and trapping method. The total number of females and males caught with each trapping method and at each trapping location in 2021, 2022, and 2023 were used.

The proportion of gravid females in the population per year was calculated for 2021 and 2022. No gravid females were found during surveys in the 2023 field season. Fieldwork was conducted both within and outside the breeding window. The calculation included only sexually mature females captured between the period that the first and last gravid individuals were found. A female was deemed sexually mature if her carapace size exceeded the minimum observed for gravid individuals at Baynes Lake (168-mm carapace length).

The number of clutches per female per year was estimated using radio telemetry data tracking from 2021 to 2023. Gravid females were tracked during the nesting season, in the summer of 2021 and 2022. The location of each nest site was recorded for gravid females tracked during these surveys, allowing for the calculation of the number of clutches each tracked turtle had per year.

3.2.3 Population estimate and survivorship

The population size and survivorship for this turtle population were calculated using three years of mark-recapture surveys. The surveys were conducted twice each summer in 2021, 2022, and 2023, for a total of one initial mark period and five recapture periods. The mark-recapture surveys were performed by MWLRS employees and contractors. MWLRS staff and contractors conducted all trapping and marking under their provincial animal care certificate and wildlife collections permit. I was provided the data for data management, analysis, and population estimation.

Population and adult/subadult survivorship were modeled in the program MARK using the Jolly–Seber model with POPAN formulation (Jolly, 1965; Seber, 1982). This open population model allowed for variation in population size during the study period. The best-fit model was selected based on the lowest Akaike information criterion (AIC) value, where the probability of capture and recruitment varied over time and apparent survivorship remained consistent.

3.2.4 Population viability analysis

The long-term population viability of the Baynes Lake western painted turtle population was modeled using the program Vortex (version 10.6.0). This program is suitable for use with long-lived reptiles with low reproduction rates and allows for the modeling of population loss due to road mortality (Lacy, 1993; Lacy & Pollak, 2023). It has been previously used in the conservation and management of various at-risk reptile species (Famelli et al., 2012; Howell & Seigel, 2019; Murphy et al., 2022; Winton et al., 2020).

The scenario used as a model for population simulations in Vortex was based on population-specific parameters gathered from Baynes Lake and the more general population traits from the COSEWIC report (COSEWIC, 2016; see Table 3). Data collected or calculated from the Baynes Lake population included the population size, adult/sub-adult survivorship, number of clutches per year, and percent of breeding females per year. The age of first and last offspring, maximum lifespan, and clutch size were not known for the Baynes Lake population and were taken from the COSEWIC report (2006). As the sex ratio at birth is temperature dependent (COSEWIC, 2006), it was modeled at a 50/50 male-to-female ratio.

Table 3. Population-specific and species-specific parameters used to model the long-term viability of the population of western painted turtles at Baynes Lake, BC. Parameters were either calculated from population surveys in Baynes Lake from 2021 to 2023 or taken from COSEWIC (2016).

	Parameter	Source
Reproductive system		
Age of first offspring (F)	14 (12-15) years	COSEWIC, 2016
Maximum age of reproduction (F)	40	COSEWIC, 2016
Age of first offspring males (M)	9 (8-10) years	COSEWIC, 2016
Maximum lifespan	40	COSEWIC, 2016
# of broods per year	1	Baynes Lake tracking
Max # of progeny per clutch	23	COSEWIC, 2016
Average # progeny per clutch	13	COSEWIC, 2016
Sex ratio at birth (in % M)	50	
Reproductive rates		
% of breeding F	25.5 %	Average from 2021 and 2022
SD of % breeding	0.71	
Mortality rates		
Survivorship: juveniles	54 %	
Survivorship: adults/subadults	96.5 %	MARK (POPAN)
Initial population size		
Population size	1451 (SE = 75)	MARK (POPAN)

*M=male; F=female

Vortex requires mortality rates for age classes from juvenile to sexual maturity. Painted turtle age can be difficult to determine. Counting growth annuli is the main method to determine the age of a painted turtle, but its reliability decreases significantly past the age of six (Mitchell, 1988). Turtles in the Baynes Lake population were notched based primarily on size, not on age.

However, only notched turtles were included in the adult and subadult survivorship calculation, allowing for an age-class division of adult/subadult (the marked population) and juvenile (the unmarked population). The age range of the juvenile category was estimated using hatchling size and growth rate from Congdon et al. (2018), where hatchlings started at 25-mm and experienced 12.2-mm of growth per year. The maximum age of the juvenile category was taken as the average between the age of the smallest (79-mm) and largest (104-mm) unnotched turtle, which was calculated to be five years. The study by Congdon et al. (2018) took place in Michigan; as painted turtles at the northern end of their range have been found to have a higher growth rate than those in the southern portion of their range (MacCulloch & Secoy, 1983), this likely led to overestimating the age when turtles are first notched in this population.

Juvenile survivorship in the Baynes Lake population is unknown, as juveniles were not included in the mark-recapture population survey. Juvenile survivorship was modeled at a rate that allowed for a consistent population level without roadway mortality.

The changes in population number and the probability of extinction was modeled in Vortex for 100 years, a time period equal to approximately three western painted turtle generations (COSEWIC, 2006; Howell et al., 2019). Road mortality was modeled as a yearly catastrophic event with an occurrence probability of 100%. Each simulation was run 500 times. The quasi-extinction level was set at five individuals. This was the highest population with ≥95% probability of extirpation over 100 years, as modeled in Vortex using the Baynes Lake population parameters with no road mortality. A series of road mortality rates from 0-10% of the population were modeled as additive mortality.

Sensitivity tests were performed to test the influence of life history parameters on the base model scenario (Table 2). Models were run under the same conditions discussed above. The parameters tested were juvenile mortality rate, subadult/adult mortality rate, percent of breeding females, maximum brood size, and sex ratio at birth.

3.3 Results

3.3.1 Baynes Lake western painted turtle population-specific parameters

Demographic data was collected on a total of 831 individual turtles between 2021 and 2023 (Table 4). A further 400 turtles were captured in 2023, where only the notch code and sex were recorded. Turtles ranged in weight from a 14-g juvenile to a 1,286-g female. The carapace length of turtles ranged from 29-mm juvenile to a 554-mm female.

Table 4: Average, minimum, and maximum weight and carapace length for western painted turtles surveyed at Baynes Lake, BC. Data were from surveys in the summer of 2021 to 2023.

	Weight (g)			**Carapace length (mm)**		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Female	714 (263)	22	1,286	171 (34)	49	554
Male	498 (25)	77	871	157 (25)	79	202
Juvenile	85 (76)	14	460	58 (19)	29	147

There was a ratio of 1.5 females caught for every one male over the three years. The ratios varied slightly from year to year, with a female-to-male ratio of 1.6:1 in 2021, 1.3:1 in 2022, and 1.4:1 in 2023. The ratio of males to females varied across trapping methods, X^2 (2, N=1,087) = 31.52, p = 1.43e^{-07}. Hoop traps and dip nets caught a higher than expected number of males. The ratio of males to females did not vary across trapping locations X^2 (2, N=1,087) = 2.81, p = 0.25.

Among the potentially sexually mature females captured during the breeding season, only 25% were gravid in 2021, and 26% were gravid in 2022. No gravid females were found in 2023. A total of 33 females were tracked using ratio telemetry between 2021 and 2023: seven in 2021, 17 in 2022, and nine in 2023. Confirmed nesting locations were identified for five females in both 2021 and 2022. No gravid turtles were tracked in 2023. No turtles were recorded laying more than one nest in a season.

3.3.2 Population estimate and survivorship

A total of 189 turtles were initially marked in 2021, of which 111 were females and 78 were males. Subsequently, five recapture events took place between 2021 and 2023, with a total of 1,230 turtles captured. Individuals in the marked population were recaptured between zero and 11 times. Only 40% of the original marked population was recaptured during the study period. The number of marked turtles recaptured during a recapture event varied. In 2021, 38 individuals from the marked population were recaptured. In the first recapture event of 2022, 64 of the marked individuals were caught; in the second, only 13 individuals of the marked population were caught. In 2023, 36 individuals were recaptured in the first recapture event and 38 individuals were recaptured during the second recapture event. The western painted turtle population (standard deviation) in Baynes Lake was estimated to be 1,451 (75) individuals.

Subadult and adult survivorship were calculated using the same dataset used for the population estimate, resulting in a survivorship (standard deviation) of 96% (0.6%) per year. This survivorship rate was consistent across all years of the study.

3.3.3 Population viability analysis

With no roadway mortality, the probability of quasi-extinction of the Baynes Lake painted turtle population was 0 after 100 years, with a mean final population of 1287 individuals (Table 5). A 0.5% additive road mortality rate resulted in a 46.8% decrease in the population, with a final mean population of 772 individuals and an extinction probability of zero (Figure 15).

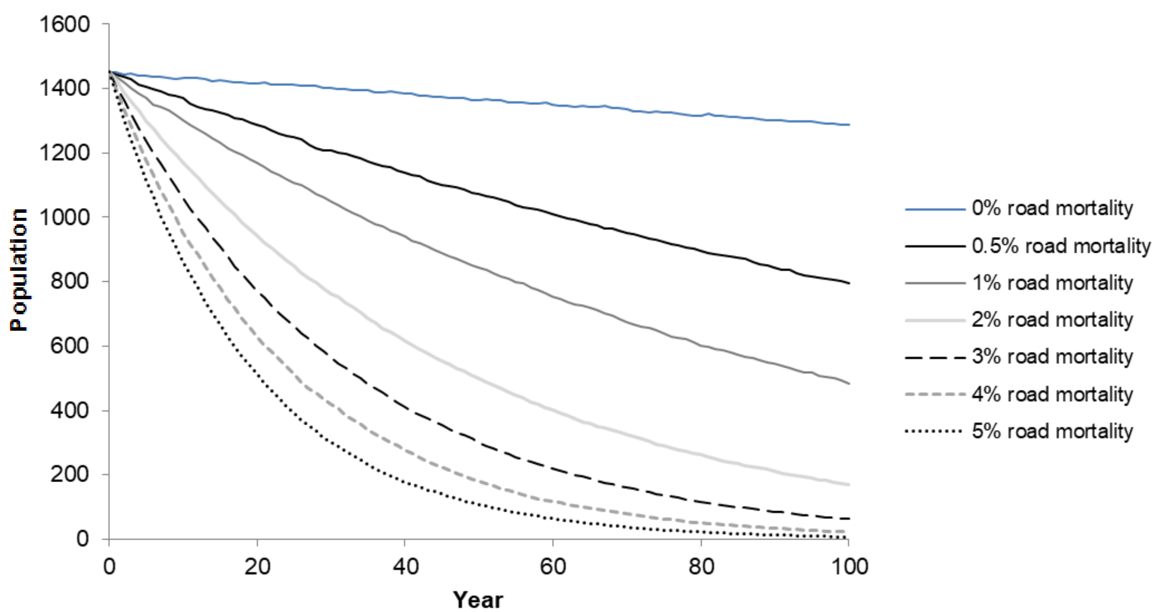

Figure 15: Yearly population size with road mortality for the population of western painted turtles at Baynes Lake, BC. Road mortality was modeled as a percentage of the yearly population and ranges from no road mortality to 5% road mortality.

An increase in extinction probability was seen after a 4% road mortality rate, with a 6% extinction probability at 4% road mortality, 48% extinction probability at 5% road mortality, and

81% extinction probability at 6% road mortality (Figure 15). The quasi-extinction probability reached 100% at an 8% road mortality rate.

Table 5. Final population size, probability of extinction, and stochastic growth rate of the population of western painted turtles at Baynes Lake, BC over 100 years. Based on data collected from Baynes Lake BC from 2021 to 2023. Modeled using the program Vortex (version 10.6.0).

Additive road mortality rate (% of population)	Final population (N)	% Reduction in population after 100 years	Probability of extinction after 100 years (%)	Stochastic growth rate (r)
0	1,299	10.5	0	-0.001
0.5	792	46.8	0	-0.006
1	480	66.9	0	-0.011
2	173	88.1	0	-0.022
3	61	95.8	0	-0.032
4	22	98.5	6	-0.044
5	14	99.2	48	-0.054
6	10	99.3	89	-0.062
7	7	99.5	98	-0.071
8	8	100	100	-0.082

Sensitivity testing of the model found that changes in adult mortality and juvenile mortality rates had the highest impact on the stochastic growth rate (Table 6). Previously, additive mortality was modeled as a catastrophic event with a 100% probability of occurring; here, the total mortality was changed in the respective categories. A 5% increase in adult mortality increased the probability of extinction over 100 years from 0% to 16%, decreasing the population by nearly 100%. A 5% increase in juvenile mortality resulted in a final population of 174 individuals and an overall population decrease of 88%. Other factors tested had a lower impact on the growth rate of the population. A 5% decrease in breeding females resulted in a final population of 547. A reduction or increase of one egg on average per season resulted in a final population of 919 and 1,722, respectively. A 5% change in the sex ratio at birth had a similar impact on population growth. Additive road mortality at a lower population was also modeled. With a starting population of 100 turtles, 5% road mortality (representing the loss of five individuals) reduced the population to ten with a 90% chance of extinction over 100 years.

Table 6. Sensitivity testing for the baseline population viability model for the population of western painted turtles at Baynes Lake, BC. All parameters remain the same as the baseline except for the adjustments noted. Carrying capacity is set at 3,000 individuals.

Scenario	Final population (N)	Stochastic growth rate (r)	Probability of extinction (100 years)
Base scenario	1,299	-0.001	0
Base scenario with inbreeding depression	1,264	-0.001	0
Adult mortality rate: 5% increase	20	-0.046	16
Adult mortality rate: 3.5% decrease (to zero)	3,000	0.027	0
Juvenile mortality rate: 5% increase	174	-0.022	0
Juvenile mortality rate: 5% decrease	2,979	0.021	0
% of females breeding: 5% decrease	547	-0.010	0
% of females breeding: 5% increase	2,657	0.006	0
Average brood size: 1 fewer	919	-0.005	0
Average brood size: 1 greater	1,722	0.002	0
Sex ratio at birth: 55% female	1,919	0.003	0
Sex ratio at birth: 45% female	858	-0.005	0
Starting population 50: 0% road mortality	96	-0.002	1
Starting population 100: 2% road mortality	10	-0.046	99

3.4. Discussion

3.4.1 Baynes Lake western painted turtle population characterization

The Baynes Lake western painted turtle population has a female-biased sex ratio, despite trapping methods disproportionately capturing males. Roadway mortality that disproportionately impacts females has been associated with male-biased population structures in other turtle studies (Nicholson et al., 2020; Steen & Gibbs, 2004). Although gravid females made more road crossings than males or non-gravid females at Baynes Lake, the tracking studies were primarily conducted mid-season during nesting. Males may make a higher number of road crossings outside of the survey window, and experience road mortality that is not captured in this study. Temperature may also play a role in the female bias of this population. Western painted turtles display temperature-based sex determination, with temperatures above 29°C resulting in females (Bull, 1980). The average temperature in this region is increasing. Cranbrook has seen the average temperature in August increase from 17.9°C in 2000 to 20.1°C in 2023 (Government of Canada, 2024). The highest daily departure increased from 34.2°C in 2000 to 37°C in 2023 (Government of Canada, 2024).

It was also found that only a quarter of the sexually mature females were gravid in 2021 and 2022. No gravid females were found in 2023, but this may have been due to a later start in sampling. Previous work modeling the population viability of turtles has assumed 100% of sexually mature females were breeding, unless field research indicated otherwise (Beaudry et al., 2008; Howelle et al., 2019). The proportion of sexually mature females in that breed per year in a given turtle population is frequently unreported. Congdon & Tinkle (1982) reported 50-80% of female painted turtles that were sexually mature in east Michigan bred each year. Beaudry et al. (2008) reported 82.6% of the female Blanding's turtles (*Emydoidea blandingii*) that were sexually mature in the study area bred each year. Sensitivity testing of the Baynes Lake population indicates that small decreases in the number of breeding females (5%) can cause population declines, decreasing the population by 62% over 100 years.

3.4.2 Population viability analysis

Population viability analysis of the Baynes Lake population indicates that low levels of roadway mortality may cause population declines. The maximum level of roadway mortality was 15 turtles in a season, or 1% of the population. This level of road mortality resulted in a 66.9% decrease in the total population over 100 years. In 2022 and 2023, the average road mortality was 0.5% of the population. Even this level of mortality resulted in a 46.8% decrease in the total population over 100 years. Survey timing may also result in an undercounting of turtle mortalities. In 2021 and 2023, turtles were seen as soon as roadway surveys started in May and continued to be seen until surveys stopped at the end of August. This schedule likely misses out on early spring and fall migrations.

Sensitivity testing of the chosen population viability model indicates that changes in adult and juvenile mortality had the greatest impact on the stochastic growth rate. Similar studies on reptiles have also found adult and juvenile mortality has a high impact on population growth projections (Howell & Seigel, 2019; Spencer et al., 2017; Winton et al., 2020). Juvenile mortality was the population parameter with the highest degree of uncertainty in the Baynes Lake population. The value of juvenile mortality was chosen in the population viability analysis to allow for a relatively steady population projection. However, the survivorship of turtles that were not notched was entirely unknown for Baynes Lake. Small changes in the survivorship rate of juveniles at Baynes Lake have the potential to dramatically alter the long-term projection of this population. Juvenile survivorship requires further study before a populational analysis can be used to fully assess the actual projection of this population.

3.5 Literature Cited

Aresco, M. J. (2005). Mitigation Measures To Reduce Highway Mortality Of Turtles And Other Herpetofauna At A North Florida Lake. *The Journal of Wildlife Management*, *69*(2), 549–560. https://doi.org/10.2193/0022-541x(2005)069

Auge, A., Blouin-Demers, G., Hasler, C. T., & Murray, D. L. (2023). Demographic evidence that development is not compatible with sustainability in semi-urban freshwater turtles. *Animal Conservation*. https://doi.org/10.1111/acv.12903

Beaudry, F., DeMaynadier, P. G., & Hunter, M. L. (2008). Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. *Biological Conservation*, *141*(10), 2550–2563. https://doi.org/10.1016/j.biocon.2008.07.016

Brook, B. W., Jj, O., Ap, C., Burgman, M., Hr, A., & Frankham, R. (2000). Predictive accuracy of population viability analysis in conservation biology. *Nature*, *404*(6776), 385–387. https://doi.org/10.1038/35006050

Bull, J. J. (1980). Sex determination in reptiles. *Quarterly Review of Biology*, *55*, 3–21.

Congdon, J. D., & Tinkle, D. W. (1982). Reproductive energetics of the painted turtle (*Chrysemys picta*). *Herpetologica*, *38*(1), 228–237. http://www.jstor.org/stable/3892376

Congdon, J. D., Nagle, R. D., & Kinney, O. M. (2018). Front-loading life histories: the enduring influence of juvenile growth on age, size, and reproduction of primiparous female freshwater turtles. *Evolutionary Ecology Research*, *19*(4), 353–364. http://www.Evolutionary-Ecology.com/issues/v19/n04/ccar3141.pdf

Coulson, T., Mace, G. M., Hudson, E., & Possingham, H. P. (2001). The use and abuse of population viability analysis. *Trends in Ecology and Evolution*, *16*(5), 219–221. https://doi.org/10.1016/s0169-5347(01)02137-1

Crawford, B. A., Maerz, J. C., Nibbelink, N. P., Buhlmann, K. A., & Norton, T. M. (2014). Estimating the consequences of multiple threats and management strategies for semi-aquatic turtles. *Journal of Applied Ecology*, *51*(2), 359–366. https://doi.org/10.1111/1365-2664.12194

Fahrig, L., & Rytwinski, T. (2009). Effects of Roads on Animal Abundance: an Empirical Review and Synthesis. *Ecology and Society*, *14*(1). https://doi.org/10.5751/es-02815-140121

Famelli, S., Pinheiro, S. C. P., Souza, F. L., Chiaravalloti, R. M., & Bertoluci, J. (2012). Population Viability Analysis of a Long-Lived Freshwater Turtle, *Hydromedusa maximiliani* (Testudines: Chelidae). *Chelonian Conservation and Biology*, *11*(2), 162–169. https://doi.org/10.2744/ccb-1001.1

Government of Canada. (2024). Monthly Climate Summaries. https://climate.weather.gc.ca/prods_servs/cdn_climate_summary_e.html

Heppell, S. S. (1998). Application of Life-History Theory and population model analysis to turtle conservation. Copeia, 1998(2), 367. https://doi.org/10.2307/1447430

Howell, H. J., & Seigel, R. A. (2019). The effects of road mortality on small, isolated turtle populations. *Journal of Herpetology*, *53*(1), 39. https://doi.org/10.1670/18-022

Jackson, N. D., & Fahrig, L. (2011). Relative effects of road mortality and decreased connectivity on population genetic diversity. *Biological Conservation*, *144*(12), 3143–3148. https://doi.org/10.1016/j.biocon.2011.09.010

Jolly, G. M. (1965). Explicit estimates from capture-recapture data with both death and immigration stochastic model. *Biometrika*, *52*, 225-247

Lacy, R. C. (1993). VORTEX: a computer simulation model for population viability analysis. *Wildlife Research*, *20*(1), 45. https://doi.org/10.1071/wr9930045

Lacy, R.C. & Pollak, J.P. (2023). Vortex: A stochastic simulation of the extinction process. Version 10.6.0. Chicago Zoological Society, Brookfield, Illinois, USA.

McCarthy, M. A., Keith, D. A., Tietjen, J., Burgman, M. A., Maunder, M. N., Master, L., Brook, B. W., Mace, G. M., Possingham, H. P., Medellín, R. A., Andelman, S. J., Regan, H. M., Regan, T. J., & Ruckelshaus, M. (2004). Comparing predictions of extinction risk using models and subjective judgement. *Acta Oecologica*, *26*(2), 67–74. https://doi.org/10.1016/j.actao.2004.01.008

Mitchell, J. C. (1988). Population Ecology and Life Histories of the Freshwater Turtles *Chrysemys picta* and *Sternotherus odoratus* in an Urban Lake. *Herpetological Monographs*, *2*, 40. https://doi.org/10.2307/1467026

Mumme, R. L., Schoech, S. J., Woolfenden, G. E., & Fitzpatrick, J. W. (2000). Life and death in the fast Lane: Demographic consequences of road mortality in the Florida Scrub‐Jay. Conservation Biology, 14(2), 501–512. https://doi.org/10.1046/j.1523-1739.2000.98370.x

Murphy, R. E., Martin, A., & Fahrig, L. (2022). Reduced predation on roadside nests can compensate for road mortality in road‐adjacent turtle populations. *Ecosphere*, *13*(2). https://doi.org/10.1002/ecs2.3946

Nicholson, E., Manzo, S., Devereux, Z., Morgan, T. P., Fisher, R. N., Brown, C. W., Dagit, R., Scott, P., & Shaffer, H. B. (2020). Historical museum collections and contemporary population studies implicate roads and introduced predatory bullfrogs in the decline of western pond turtles. *PeerJ*, *8*, e9248. https://doi.org/10.7717/peerj.9248

Piczak, M. L., Markle, C. E., & Chow‐Fraser, P. (2019). Decades of Road Mortality Cause Severe Decline in a Common Snapping Turtle (Chelydra serpentina) Population from an Urbanized Wetland. *Chelonian Conservation and Biology*, *18*(2), 231. https://doi.org/10.2744/ccb-1345.1

Resource Inventory Standards Committee (RISC). (1998). Live Animal Capture and Handling Guidelines for Wild Mammals, Birds, Amphibians & Reptiles. Standards for Components of British Columbia's Biodiversity No.3. *Ministry of Environment, Lands and Parks, Resource Inventory Branch*. Version 2.0.

Seber, G. A. F. (1982). The Estimation of Animal Abundance and Related Parameters, 2nd edit. London: Griffin.

Spencer, R., Van Dyke, J. U., & Thompson, M. B. (2017). Critically evaluating best management practices for preventing freshwater turtle extinctions. *Conservation Biology*, *31*(6), 1340–1349. https://doi.org/10.1111/cobi.12930

Steen, D.A . & Gibbs, J. P. (2004). Effects of roads on the structure of freshwater turtle populations. Conservation Biology, 18(4): 1143-1148.

Trouillier, M., Meyer, K., Santini, L., & Pe'er, G. (2023). A comparison of population viability measures. *Ecology and Evolution*, *13*(1). https://doi.org/10.1002/ece3.9752

Wiebe, A., Gray, S., & Paul, K. (2022). *Final Report: Increasing Western Painted Turtle Survival at Baynes Lake (COL-F22-W-3483)*.

Winton, S. A., Bishop, C. A., & Larsen, K. W. (2020). When protected areas are not enough: low-traffic roads projected to cause a decline in a northern viper population. *Endangered Species Research*, *41*, 131–139. https://doi.org/10.3354/esr01017

Chapter 4: Discussion

4.1 Conclusion

The main purpose of this project was to evaluate the impact of road mortality on the long-term viability of the Baynes Lake western painted turtle population. This evaluation was done by first estimating and characterizing the population of western painted turtles inhabiting the Baynes Lake wetland complex. The rate of road mortality before and after the installation of a turtle tunnel and drift fencing at Baynes Lake was calculated, and the effectiveness of this road mortality mitigation infrastructure was assessed. Next, the long-term survival of the turtle population was evaluated through a population viability analysis. This analysis incorporated different road mortality rates and specific parameters collected from the Baynes Lake population.

The Baynes Lake population was characterized through three years of mark-recapture surveys and three years of tracking adult turtles with radio telemetry. The Baynes Lake population was found to be separate from the nearby Kikomun Creek Provincial Park population. No turtles that were tracked moved towards Kikomun Creek, despite it being well within their typical movement range. The reason for this is unknown, but it may be due to the high number of homes and a slight slope between Baynes Lake and the nearest waterbody in Kikomun Creek park. Other areas may also be more desirable and accessible to the Baynes Lake turtles. The population (standard deviation) was estimated to be 1,451 individuals (75). In 2016, COSWEIC (2016) estimated the Intermountain-Rocky Mountain western painted turtle population to be between 5,000 and 10,000 adults. While this population estimate includes subadults and adults, the Baynes Lake area may represent a sizable proportion of the total Intermountain-Rocky Mountain population. In addition, tracking of adults found that turtles at Baynes Lake likely only nested once in a season. This is in line with other reports of northern western painted turtle populations, who were also found to only nest once per year (COSEWIC, 2016; MacCulloch & Secoy, 1983).

The Baynes Lake population was found to have a 1.5:1 female-to-male sex ratio. This was unexpected, as populations where females are disproportionately impacted by roadway mortality are expected to have a high number of males (Nicholson et al., 2020; Steen & Gibbs, 2004). Gravid females made a higher number of road crossings per year than non-gravid females and males. This may be explained by the timing of tracking surveys, which do not account for movements in the early spring and fall. The migratory movements of male painted turtles have been found to be concentrated in the spring (Gibbons, 1968).

The yearly road mortality rate was determined through road mortality surveys and community-reported observations. The highest level of roadway mortality was based on community reports from before the turtle tunnel installation. Fifteen turtles, representing around 1% of the population, were hit on the road in one season. After the turtle tunnel was installed, road mortality decreased to eight mortalities in 2022, or 0.1 mortality per day across the survey period. With the installation of fencing in 2023, road mortality decreased to 0.03 mortalities per day across the survey period. The rate at which scavengers removed carcasses was assessed to understand the potential impact on the calculated road mortality rates. Overall, caracasses persisted for a moderate period of time. Scavengers only began to interact with the placed carcasses after two days. Over two-thirds of the road mortality surveys at Baynes Lake between 2021 and 2023 were within two days of one another and were likely detecting all carcasses. Scavenger rate was calculated to reduce the number of carcasses captured in the roadway surveys by only 10%. Scavengers likely did not have a significant impact on the rate of detected turtle carcasses, unlike other species. Winton et al. (2018) found that a combination of observer error and removal by scavengers may have decreased the number of detected rattlesnake mortalities by 270%. Although carcass removal by scavengers has been reported in the Baynes Lake community (Wiebe et al., 2022), a number of factors may explain this low rate of scavenger interaction. The survey area, although rural, is in the center of the community and is a popular walking route. People and their dogs may result in predators avoiding the area. Turtle carcasses may require more effort than they are worth if food is abundant, and relatively low levels of carcasses may not attract consistent predation to the area.

Western painted turtle use of the turtle tunnel was evaluated by comparing data from before and after the installation of drift fencing using wildlife cameras. This was compared to the road mortality rate to determine if there was a correlation between road mortality and the number of turtles using the turtle tunnel. This study is not able to directly link a reduction in roadway mortality to the installation of a turtle tunnel and directional fencing, as a number of other factors may have influenced this correlation. The installation of directive fencing did, however, appear to increase western painted turtle interaction with the turtle tunnel. Cameras installed in the tunnel did not capture turtles fully moving through the tunnel, although they did capture some exiting but not entering. This indicates that the low level of tunnel use by turtles may be the result of a failure to capture use with the wildlife cameras as opposed to avoidance.

However, a minority of turtles were captured entering and promptly exiting the tunnel on the same side, indicating conditions in the tunnel may not be desirable.

Finally, the calculated population-specific parameters were used to model the long-term viability of the Baynes Lake population in the program Vortex. The loss of eight individuals, or 0.5% of the population, was found to cause potential declines in the Baynes Lake turtle population. Pre-mitigation additive road mortality rates of 1% could reduce the Baynes Lake population by up to 60% over 100 years. This finding has significant implications for other, smaller populations. Many western painted turtle populations in BC have less than 100 individuals (COSEWIC, 2016). A loss of eight individuals would represent a much greater proportion of the population in these smaller wetlands. Even what may be considered low levels of roadway mortality in rural areas can have a substantial impact on western painted turtle populations. Therefore, it is important to recognize that even seemingly minor losses may have serious consequences for the long-term viability of western painted turtle populations.

4.2 Study limitations

Scavenge rate analysis was limited by a low number of trials and the use of an artificial carcass due to the scarcity of real turtle carcasses available. As a result, the rate of interaction with the artificial carcass compared to real carcasses could not be accurately evaluated. Additionally, the trial was conducted in August, a period characterized by a low number of actual turtles making road crossings. It is possible that scavenger activity may be higher during peak crossing times, when scavengers may anticipate higher levels of carcasses in the area.

Road mortality surveys were conducted only over a portion of the active season. While the surveys likely accounted for the movement of gravid females, it may have missed spring and fall migratory movements, when male painted turtles are known to migrate. It may not be appropriate to directly compare the road mortality rates of 2021, which were recorded over the entire active season, with those of 2022 and 2023, which were captured only over a portion of the active season. Perceived reductions in road mortality may be an artifact of lower survey effort as opposed to the effectiveness of the roadway mortality mitigation infrastructure and should be considered cautiously.

Cameras missed capturing complete movements through the turtle tunnel, preventing proper assessment of the use of the tunnel and its effectiveness after the installation of drift fencing. It is unknown whether turtles were entering and then promptly leaving the same side of the tunnel or if they were moving entirely through. Findings of increased interaction with the turtle tunnel should be interpreted cautiously.

Finally, it is important to recognize that the usefulness of population viability modeling is dependent upon the accuracy of the parameters used. For the Baynes Lake turtle population, data on juvenile mortality were unavailable. The model demonstrated a high sensitivity to even minor variations in juvenile and adult mortality rates. Therefore, any declines observed in the Baynes Lake population should be interpreted in relation to the stable population baseline modeled before the introduction of additive road mortality, rather than as definitive predictions of future population trends. In addition, the parameters collected at Baynes Lake offer only a snapshot of the population demographics. It is uncertain whether parameters such as survivorship will remain constant over a 100-year period, as assumed in this study. Hence, it is essential to interpret the results of the population viability modeling with the understanding that uncertainties exist and that these models provide estimates rather than precise predictions.

4.3 Management implications and further research

The Baynes Lake western painted turtle population likely functions as a distinct population unit, with minimal mixing from nearby populations. This emphasizes the importance of preserving the wetlands within Baynes Lake. The ongoing loss of water in these wetlands presents a critical issue for the survival of this population. Further research should assess the impact of water loss on this population, evaluating the possible long-term impacts on nesting habitat and food availability.

Gravid females made more road crossings than non-gravid females and males. Consequently, road mortality mitigation strategies that prioritize the conservation of nesting sites near overwintering wetlands and focus on reducing traffic volume or speed during peak nesting movements may prove to be effective. However, community reports suggest a significant number of turtles crossed roads before radio telemetry surveys began at Bayne Lake. Road mortality surveys have also not previously taken place during the earliest portion of the active season. Further research could explore these early movements and assess the impact of road mortality during this period. The maximum rate of road mortality (1% of the population) was reported across the entire active season. Subsequent road mortality surveys were concentrated later in the season. If males are found to exhibit higher rates of movement and experience elevated mortality rates not captured by the surveys, this may help to explain the female sex-bias seen at Baynes Lake.

The percentage of breeding females at Baynes Lake was found to be lower than in other turtle populations. While this factor was shown to have a low impact on the long-term viability of the population compared to adult and juvenile mortality, it still influences the population projection. Understanding why this number is relatively low may lead to greater insight into the factors influencing the long-term viability of painted turtles in BC. This observation could potentially be attributed to various factors, including the northern location of the Baynes Lake turtles or environmental effects specific to the local habitat. By identifying the underlying reasons behind this phenomenon, management strategies aimed at increasing the breeding rate could be implemented.

Confirming the full movement through the turtle tunnel installed at Baynes Lake proved challenging. Although wildlife cameras frequently captured turtles either entering or exiting the tunnel, complete traversal was not confirmed. Future research should focus on assessing the effectiveness of wildlife cameras in detecting turtle movement, particularly in low-light conditions. Additionally, investigating and addressing possible unfavorable conditions within the tunnel may help enhance its use. This could involve installing lighting and monitoring temperature levels. Furthermore, installing sturdy fencing that turtles cannot dig under or move through to direct them towards the tunnel may also be beneficial.

The Baynes Lake painted turtle population, as estimated in this study, may be one of the largest recorded within the Intermountain-Rocky Mountain western painted turtle subpopulation region. Although the population surveyed in this study includes both subadults and adults, additional research may be warranted to further investigate the population structure at Baynes Lake. Given its substantial size, this population could potentially qualify for designation as a Key Biodiversity Area in British Columbia, underscoring its ecological significance and the importance of conservation efforts aimed at its preservation.

4.4 Literature Cited

COSEWIC. (2016). COSEWIC assessment and status report on the Western Painted Turtle *Chrysemys picta bellii*, Pacific Coast population, Intermountain – Rocky Mountain population and Prairie/Western Boreal – Canadian Shield population, in Canada.

Committee on the Status of Endangered Wildlife in Canada. Ottawa. xxi + 95 pp. http://www.registrelep-sararegistry.gc.ca/default.asp?lang=en&n=24F7211B-1

Gibbons, J. W. (1968). Reproductive potential, activity, and cycles in the painted turtle, *Chrysemys picta*. *Ecology*, *49*(3), 399–409. https://doi.org/10.2307/1934106

MacCulloch, R. D., & Secoy, D. M. (1983). Demography, growth, and food of western painted turtles, *Chrysemys picta belli*i (Gray), from southern Saskatchewan. *Canadian Journal of Zoology*, *61*(7), 1499–1509. https://doi.org/10.1139/z83-202

Nicholson, E., Manzo, S., Devereux, Z., Morgan, T. P., Fisher, R. N., Brown, C. W., Dagit, R., Scott, P., & Shaffer, H. B. (2020). Historical museum collections and contemporary population studies implicate roads and introduced predatory bullfrogs in the decline of western pond turtles. *PeerJ*, *8*, e9248. https://doi.org/10.7717/peerj.9248

Steen, D.A. & Gibbs, J.P. (2004). Effects of roads on the structure of freshwater turtle populations. Conservation Biology, 18(4): 1143-1148.

Wiebe, A., Gray, S., & Paul, K. (2022). *Final Report: Increasing Western Painted Turtle Survival at Baynes Lake (COL-F22-W-3483)*.

Appendices

Appendix A

Table A: Interactions by western painted turtles with the turtle tunnels and small culvert along Jaffray-Baynes Lake Road in Baynes Lake, BC in the summer of 2021, 2022, and 2023. Interactions are classified as any movement into or towards the turtle tunnel captured by wildlife cameras.

Year	Date	Time	Location
2023	19-May	6:41 PM	Small culvert
	25-May	6:16 PM	Turtle tunnel
	31-May	10:33 AM	Turtle tunnel
	31-May	8:13 PM	Turtle tunnel
	01-Jun	4:35 PM	Small culvert
	02-Jun	5:57 PM	Small culvert
	03-Jun	4:36 PM	Turtle tunnel
	08-Jun	5:29 PM	Turtle tunnel
	12-Jun	10:35 AM	Turtle tunnel
	17-Jun	7:05 PM	Turtle tunnel
	18-Jun	1:06 PM	Turtle tunnel
	25-Jun	6:23 PM	Turtle tunnel
	20-Jul	7:45 PM	Turtle tunnel
	01-Aug	7:16 PM	Turtle tunnel
	14-Aug	8:06 PM	Turtle tunnel
	23-Aug	3:13 PM	Turtle tunnel
	23-Aug	12:08 PM	Turtle tunnel
	24-Aug	2:43 PM	Turtle tunnel
2022	07-Jun	11:13 AM	Turtle tunnel

	15-Jun	12:25 PM	Turtle tunnel
	06-Jul	5:06 AM	Turtle tunnel
	11-Jul	4:59 PM	Turtle tunnel
2021	13-Jun	11:22 PM	Turtle tunnel
	15-Jun	12:13 AM	Turtle tunnel
	21-Jun	11:18 AM	Turtle tunnel
	22-Jun	1:56 AM	Turtle tunnel

Appendix B

Table B: Summary of scavenger rate experiments for artificial and real turtle carcasses.

	Start date	End time	Time to trial end (hours)	# of interactions	Removed?	Removal date	Time of removal	Species
Real turtle	21-Aug	24-Aug	61.00	4	Y	24-Aug	9:13 AM	magpie
	27-Aug	06-Sep	235.00	1	N			
	06-Sep	07-Sep	30.00	0	N			
	31-Aug	04-Sep	107.00	NA	N			
	04-Sep	06-Sep	51.00	2	N			
Artificial turtle	20-Aug	22-Aug	49.00	4	N			
	22-Aug	27-Aug	104.00	1	Y	27-Aug	5:01 AM	unknown
	27-Aug	31-Aug	83.00	5	Y	31-Aug	8:22 AM	dog

*Y= yes; N= no

Appendix C

Table C: Camera settings for the Ryconyx HF2X culvert cameras, installed along Baynes Lake road to monitor use of the turtle tunnel in 2023.

Camera name	Start date	End date	Activation mechanism	Timed photos (min)	Trigger Sensitivity	Photos per trigger	Video Length per trigger (seconds)
CLW	11-May	17-May	m&t	1	High	5	0
CLE	11-May	17-May	m&t	1	High	5	0
CSW	11-May	17-May	m		High	0	10
CSE	10-May	23-May	m		High	5	0
CLW	23-May	29-May	m&t	1	High	5	0
CLE	23-May	29-May	m&t	1	High	5	0
CSW	23-May	29-May	t		High	0	10
CSE	23-May	29-May	m		High	5	0
CLW	29-May	3-Jun	m&t	1	High	5	0
CLE	29-May	3-Jun	m&t	1	High	5	0
CSW	29-May	3-Jun	m		High	0	10
CSE	29-May	3-Jun	m		High	5	0
CLW	3-Jun	18-Jun	m&t	5	High	3	0
CLE	3-Jun	18-Jun	m&t	5	High	3	0
CSW	3-Jun	18-Jun	m		High	3	0
CSE	3-Jun	18-Jun	m		High	3	0
CLW	18-Jun	5-Sep	m&t	5	High	5	0
CLE	18-Jun	5-Sep	m&t	5	High	5	0
CSW	18-Jun	5-Sep	m		High	5	0
CSE	18-Jun	5-Sep	m		High	5	0

* CLW= Culvert large west, CLE= culvert large east, CSW= culvert small west, CSE= culvert small east

** m&t= motion and time, m=motion, t=time