Amphibian Occurrence on South Okanagan Roadways: Investigating Movement Patterns, Crossing Hotspots, and Roadkill Mitigation Structure Use at the Landscape Scale

by

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Authors Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

Road expansion and increased traffic likely exacerbates barriers to amphibian migration and dispersal. Within British Columbia's south Okanagan valley there is particular concern that the COSEWIC-listed blotched tiger salamander (*Ambystoma mavortium melanostictum*) and Great Basin spadefoot (*Spea intermontana*) are vulnerable to road effects in their annual movements from upland overwintering habitat to lowland breeding areas. My study utilizes a before after control impact approach to assess amphibian movement and population threats across this highway-bisected landscape. Throughout the spring and summer of 2010-2012, fifty two kilometers of roadways (31 km of highway, 21 km of paved backroad) were repeatedly surveyed from the Canada-USA border to north of Oliver, BC; surveys were carried out utilising vehicles and on foot. Along Highway 97, a three kilometer four-lane highway expansion project was constructed through 2010 and open to traffic use in 2011. Adjacent to a floodplain, survey effort was focused throughout this transect for informed roadkill mitigation structure placement and ongoing ecopassage effectiveness monitoring. Automated camera trap monitoring of culverts within highly concentrated amphibian road hotspots during spring and summer 2011 (three culverts) and 2012 (two culverts) resulted in over eight hundred amphibian culvert events observed. Two sample Wilcoxon tests revealed differences between years in amphibian occurrence between 2010 and 2012 ($W = 4679.5$, $p = 0.02$), and mortalities among transect areas, with the largest differences between years within the Osoyoos passing lanes transect. Amphibian mortalities within the passing lanes transect were significantly reduced with the implementation of mitigation structures ($\bar{x}_{2010} = 13.2 \pm 32.5$, $\bar{x}_{2011} = 4.7 \pm 12.8$, $\bar{x}_{2012} = 2.3 \pm 7.3$; 2010 vs. 2012: $W = 1535.5$, $p < 0.001$). Roadkill mitigation structures proved effective in observed amphibian occurrence of the entire passing lanes stretch as well as at distances 100 m and 200 m from observed culverts. Double fenced areas resulted in a 94% reduction in amphibian road occurrence. Five species of amphibians were observed over the three survey years (4051 road incidences over 657 survey hours): Pacific chorus frog (*Pseudacris regilla*), Western toad (*Anaxyrus boreas*), long-toed salamander (*Ambystoma macrodactylum*) plus blotched tiger salamander and Great Basin spadefoot. This study aims to provide a better understanding of amphibian hotspots on roadways and ecopassage use within the south Okanagan. It may act as a catalyst to further wildlife-vehicle interaction studies with improved mitigation solutions for amphibian roadway fatalities.

Keywords: road ecology, wildlife-vehicle collisions, roadkill, amphibian, Great Basin spadefoot, *Spea intermontana*, south Okanagan, camera trap

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I dedicate this thesis, with love, to my sister, Alandria.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ANBO – *Anaxyrus boreas* (Western toad, formerly *Bufo boreas*)

AMMA – *Ambystoma macrodactylum* (Long-toed salamander)

AMMV –*Ambystoma mavortium melanostictum*

(Blotched tiger salamander, formerly *Ambystoma tigrinum*)

BC – British Columbia

BCEAA – British Columbia Environmental Assessment Act

BCHR – British Columbia Herpetofauna and Roads workshop/working group

BC MOFLR – British Columbia Ministry of Forests, Lands, and Natural Resource Operations

BC MOTI – British Columbia Ministry of Transportation and Infrastructure

CEAA – Canadian Environmental Assessment Act

COSEWIC- Committee on the Status of Endangered Wildlife in Canada

DOR- amphibians found "Dead on the Road"

EIA- Environmental Impact Assessment

Hwy- Highway

ICOET- International Conference in Ecology and Transportation

IENE- Infra Eco Network Europe

OPL- Osoyoos Passing Lanes

PSRE- *Pseudacris regilla* (Pacific treefrog)

SARA – Species at Risk Act

SVL – Snout to Vent Length

SPIN- *Spea intermontana* (Great Basin spadefoot)

SOUTH OKANAGAN AMPHIBIAN RELATIONSHIPS WITH ROADS & MITIGATION STRUCTURES: FOCUS & LITERATURE REVIEW

Wildlife traverse landscapes whether migrating to reproduce, dispersing to new ponds, or daily movements acquiring resources; their home ranges vary by species and in some cases form narrow corridors where they can survive with reasonable success. Roadways fragment wildlife corridors within such home ranges and traffic creates migration barriers through wildlife-vehicle mortalities, and consequent avoidance zones from traffic noise (van der Ree, et al., 2007; Fahrig and Rytwinski, 2009). Populations can decline because of roads and traffic if the roadkill rate exceeds the rates of reproduction and immigration. In road-dense areas, wildlife can consequently be displaced into island populations with decreased genetic variability (Holderegger & Giulio, 2010).

To lessen the negative stressors that roads put on wildlife, increasingly managers have created active landscape permeability strategies through ecopassages and fencing structures (IENE, 2013; ICOET, 2013; Pagnucco, 2010). Implementation and/or modification of such passage structures as underpasses, wildlife-specific culvert placement, overpasses, and bridges, with coordinating fence line guidance have mitigated impacts (O'Brien, 2006; Clevenger et al., 2009; Cramer and Bissonette, 2005).

The first documented amphibian-specific passageways were built in the 1960s in Western-Europe (e.g. Switzerland and Germany; United Kingdom in the mid-1980s); in the United States, ecopassages for salamander use were first recorded in 1987 (Jackson and Tyning (1989) in Puky, 2003). There are verbal accounts of rattlesnake culverts installed beneath roadways in the south Okanagan by British Columbia Ministry of Transportation staff as early as the late 1950s (Sielecki, 2008).

Within British Columbia's south Okanagan valley, there is increasing risk of wildlife-vehicle interactions due to road infrastructure growth, greater tourism, and human population growth in the Valley (BC MOTI, 2013; Destination Osoyoos, 2013; StatsCan, 2011). The highways serve as main transport corridors for international and domestic goods, as well as local and seasonal domestic traffic. The valley is major tourist destination especially in the summer months (Destination Osoyoos, 2013) while the resident population is increasing (up 2.2% in 5 years; 29.8% in the last 20 years, (Stats Can, 2013)). The same warm climate that draws people to the area facilitates a diverse but rare series of habitats and wildlife communities within British Columbia (BC). This is because the semi-arid steppe plateau landscape only projects narrowly into southern BC. Habitat fragmentation through agriculture, recreation, and urban sprawl has led to increasingly destructive interactions between humans and wildlife within the south Okanagan, including the loss of 84% of lowland wetlands from 1800 to 2005 (BCSIRART, 2008 a, b; Lea, 2008).

Amphibians are under increasing stress from impacts that lower the population throughout the south Okanagan. Within the study area, there is particular concern that the COSEWIC red listed blotched tiger salamander (*Ambystoma mavortium melanostictum*) and blue listed Great Basin spadefoot (*Spea intermontana*) are vulnerable to road effects as an obstacle for migration and dispersal as they traverse the landscape.

In anticipation of, and reaction to human population growth and a four lane highway expansion, my thesis focused on analysing the impacts of roads and traffic on migrating amphibians within British Columbia's south Okanagan valley. Amphibian road occurrence data and landscape variables from our 2010 field season represent pre-highway expansion road activity. In 2011, road mortality mitigation strategies were incorporated through interior substrate enhancement of strategically placed dry culverts, connected in sections by polymer drift fencing. The data collected in 2011 represent post-road construction activity but was also a transition year for mitigation structure erection. The 2012 data represents a full season of settled, post construction, post mitigation surveying.

THESIS GOALS

Predominantly concentrating on amphibian road occurrence, the purpose of my study was to assess amphibian movement and population threats across a landscape bisected by a highway. The goals of my research were to investigate movement hotspots of amphibians as they navigate south Okanagan roadways during their seasonal migrations from upland overwintering sites to lowland breeding wetlands. I focused on assessing the annual spring migrations of the COSEWIC blue-listed Great Basin Spadefoot (*Spea intermontana*) and the red-listed Blotched Tiger Salamander (*Ambystoma mavortium melanostictum*) as they navigate the roadways to their breeding ponds but observed and recorded other road occurring amphibians as well. Furthermore, along a newly expanded four lane section of Highway 97, the observed amphibian road data was used for roadkill mitigation strategies, adaptive management, and observation of post-mitigation occurrences (in collaboration with provincial transportation authorities). In order to achieve the goals, I investigated two main questions, presented in single manuscript style due to their overlapping relationships:

1. To what extent are amphibians impacted by traffic and roads as they traverse the south Okanagan landscape during their annual spring and summer breeding migrations, wetland dispersion and foraging movements?

Prior to this study, amphibian species status reports stated negative population impacts from roads, especially during mass migration and emigration events (BCSIRART a, b, 2008; Leupin et al., 1994; Sarrell, 2004). Yet, few studies within the south Okanagan are focused on amphibian road occurrence (e.g. the Hwy 97, Osoyoos passing lanes Environmental Impact Assessments (Phillips, 2005; Hemmera, 2010)) with the exception of various unpublished and opportunistic data of amphibian migration events (Cunnington, unpublished data, 2013; Haney, unpublished data, 2013; Ashpole, unpublished data, 2014).

During the 2010 to 2012 spring and summer seasons, 52 km of roadways, including 31 km of provincial designated highways, were repeatedly surveyed for amphibian occurrence from the Canada-USA border to north of Oliver, BC. Along the valley bottom, the surveys for amphibian occurrence were performed within three transects along the traffic dense highway with posted speeds of 80 km/ hr, as well as two transects along a secondary winery route roadway posted at 50 km/ hr.

Through this amphibian road occurrence surveillance, I was able to investigate and compare the total (live and dead) amphibian species richness and abundance on south Okanagan roads between years (2010 – 2012), including, mapping statistical clustering of amphibian roadway hotspot areas. Amphibian presence/absence records in relation with weather variables and directional movement trends were also analysed. Amphibian population threats through vehicle mortalities were assessed through traffic density counts during all road surveys, and compared to the resultant amphibian fatalities among years and between transect sections.

2. Are corrugated steel pipe culverts combined with permanent drift fencing an effective mortality mitigation measure?

From 2010 to 2011, the British Columbia Ministry of Transportation and Infrastructure constructed a three kilometer four lane passing expansion parallel to and re-routing from Highway 97. The six-lane expansion area is adjacent to an expanse wetland network of ephemeral, permanent ponds and oxbows that serves as an annual amphibian breeding destination. As the amphibians migrate from their upland overwintering areas, it is necessary for large numbers of amphibians to cross Highway 97.

The Osoyoos passing lanes construction presented an opportunity to ameliorate the effect of wildlife-vehicle mortalities through collaboration with the BC MOTI to erect permanent amphibian fencing and passageway mitigation structures.

Roadkill mitigation data were collected in collaboration with the BC MOTI and the BC Ministry of Forests, Lands and Natural Resource Operations, resulting in eight oversized (900 - 1200 mm), substrate –lined culverts, joined in sections by approximately 2.6 lineal kms of polymer wildlife fencing within the Osoyoos Passing Lanes area. Culverts were placed in areas beneath the highway that would best accommodate high amphibian migration concentrations, based on my 2010 data. Because of geological constraints, some culverts were placed more optimally to recorded hotspots than others. In 2011, the culverts were filled with a sand and gravel substrate layer to allow for greater uniformity from outside and through the culverts.

Before-after impact control data analysis on amphibian occurrence in 2010 (prior to construction) and in 2012 (after all construction and mitigation was complete) gives an indication as to whether the fencing and culverts are effective in re-routing the migrating amphibians. Construction effects were investigated through comparisons with control sections north and south of the passing lanes

Two highway culverts were retrofitted with infra-red cameras in 2011 and 2012; a nearby culvert on the adjoining frontage road also had cameras installed for 2011 only. The purpose of the cameras was to observe amphibian utilisation of the culverts as ecopassages, as well as recording the frequency of other wildlife occurrence.

This is the first in-depth, multi-year examination into amphibian road occurrence within the south Okanagan over a broader temporal and spatial scale. The amount of roadkill mitigation structure effort through culverts and fencing is the first of its kind within the south Okanagan study area.

LITERATURE REVIEW

Incorporating wildlife land use in roadway infrastructure

Habitat value is compromised when landscapes are fragmented by roadways. Roads negatively impact wildlife through direct mortality from vehicular traffic, and road effect zones of noise intolerance, habitat loss and adjacent habitat degradation (Glista et al., 2009; Forman and Alexander, 1998; van der Ree et al., 2011). Despite a paucity of data on the relationship of wildlife and roads, roadway infrastructure construction in Canada increases without much study on ecological impacts (Transportation Canada, 2007). As of December 2009, throughout Canada there were 1,042,300 km of two-lane equivalent roadways; of these roadways, 415,600 km were paved (Transportation Canada, 2011; 2013). Nationwide, rising populations and escalating traffic congestion create a demand for these intensive road networks (Grundlingh, 2011; Transportation Canada, 2007). In 2011, 21.39 million vehicles were registered for Canadian roads, an increase from 16.6 million in 1992 (Coyne, 2011; StatsCan, 2009).

The principal goals of transport efficiency and budget costs for roads overshadow concern for wildlife road mortalities and mitigation (O'Brien, 2006). At the project level, most restoration efforts, beyond legally binding mitigation measures, are opportunistic, are not concerned with the landscape scale, and have little funding attributed to them (Weber and Allen, 2010). This is a missed opportunity, especially in areas of high wildlife mortality where mitigation could be applied, creating permeability and protecting genetic dispersion.

There is however, some legislation that aims to protect at risk species enough to investigate road effects. In Canada, the Species at Risk Act (SARA) (SARA, 2002), the Federal Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and Federal policies such as the Fisheries Act, and Migratory Birds Act mandate precautious and protective action, and necessitate permits (EC, 2011). Under these various protective legislations, there should be a mechanism to ensure wildlife and habitats are protected.

As road ecology becomes more actionable through wildlife road response protocols (e.g. the BC wildlife migration response protocol for highway operations; BC MOTI, 2009), wildlife migration modeling and research at all phases before, during, and following projects, practitioners look to this knowledge for future crossing structure effectiveness (Van der Grift and Pouwels in: Davenport and Davenport, 2006). When determining a roadway permeability plan, engineers must look to what the landscape can support structurally and functionally, to any existing projects, and how economically feasible the solutions are (O'Brien, 2006). Determination of the target species and their reactions to various stimuli are critical to crossing success (O'Brien, 2006; Woltz et al., 2008).

Fahrig and Rytwinski (2009) identified four categories of wildlife types that respond negatively to roads and two types that respond positively (based on a review of 79 studies on the effects of roads and traffic on animal abundance and distribution). Groups that are negatively affected by roads are: (1) drawn to roads and are not able to avoid the traffic; (2) naturally low density species, with low reproductive rates but expansive home ranges (thus experiencing roads more often); (3) small species who avoid habitat adjacent to roads due to traffic disturbance and are not population limited by road-affected predators and (4) small animals that show no hesitancy to roads or traffic and are unable to avoid being run-over (Fahrig and Rytwinski, 2009). Alternatively, there are two groups that are predicted to react positively to roads: (1) scavengers and species that are drawn to the road for resources, but which are able to avoid traffic; (2) groups that are not disturbed by traffic but do avoid roads, and whose key predators are negatively affected by the roads (Fahrig and Rytwinski, 2009).

Migrating amphibians fall into the fourth category, crossing road laden landscapes by necessity and being unavoidably impacted by traffic in impermeable areas. Amphibians are limited in their ability to disperse quickly, effectively (they often cannot overcome physical barriers), and spatially (they tend to disperse near their source). This means amphibians are particularly vulnerable to significant local population declines when habitat loss, fragmentation, and degradation around wetlands alter inter-population movements (Harper et al., 2008). Fragmented habitats and resultant habitat loss are significant contributors to the global decline of amphibian populations (BCSIRART 2008a, b). Roadways divide landscapes, effectively acting as barriers to amphibian dispersal. With their biphasic life-histories depicting use of both the land and water throughout their life stages, amphibians may migrate annually over roadways by necessity from upland overwintering areas to lowland breeding wetlands *en masse*. As such, amphibians and reptiles are among the fauna most negatively affected by transportation planning near wetlands that has ignored wildlife impacts (Aresco, 2005; Forman and Alexander, 1998).

Amphibian migrations

Amphibian migration involves the movements toward and away from breeding sites by primarily resident adults. Secondary migrations can occur throughout foraging habitats, refugia and movement to overwintering habitats, as well as throughout metamorph emigration (Semlitsch, 2008).

Active management of amphibian populations includes understanding the habitat use and site fidelities of the focal species. This can be done through mark-recapture studies and more recently, through the use of radio telemetry. Radio telemetry is valuable in gaining insight into the movement patterns and terrestrial use of amphibians. As technologies evolve to smaller transmitters with longer lasting batteries, the use on smaller species or younger age classes will become more prevalent (Garner, 2012). An empirical review of thirteen radio-telemetry studies on twelve amphibian species (404 individuals) distributed internationally found collective migration movements at 852 m, 664 m, and 93 m for 99%, 95% and 50% isopleth values, respectively. These studies were all performed in the non-breeding season and tracked movements away from breeding ponds (Rittenhouse and Semlitsch, 2007). Of the thirteen amphibian species, frogs migrated farther from breeding ponds than salamanders (703 m versus 245 m at the 95% isopleths) (Rittenhouse and Semlitsch, 2007; Figure I-1, Appendix I).

Amphibian migration distance from natal or breeding ponds is largely dependent on the availability of quality non-breeding habitat and cluster density of appropriate breeding wetlands (Semlitsch, 2008). Eggert (2002) observed nightly movements of the common spadefoot (*Pelobates fuscus*) between successive burrows and found movements up to 88.7 m and as few as

0.2 m distance between retreats. Garner (2012) observed through radio tracking a subset of Great Basin spadefoot individuals (n= 19), that spadefoots foraged up to 371 m from their breeding pond (max. straight-line distance; $\bar{x}$ = 136 m). Oaten (2012) found spadefoots travelling at distances up to 2.35 km within BC's Thompson Okanagan region (n = 14, $\bar{x}$ = 750 m). As a fossorial species, spadefoots repeatedly use the same burrows in their core foraging grounds (Eggert, 2002). Garner (2012) found the use of burrows so predictable, that they were able to locate multiple spadefoots in their retreats after their transmitter batteries had expired. Adult amphibian migrations were observed to occur in a non-random pattern, traversing the landscape as set travel routes and entering/exiting in the same places (Semlitsch, 2008; Eggert, 2002). Given there is some certainty to patterns, practitioners can use this information in planning strategic guidance and roadway mitigation structures.

Establishing the distance of metamorph emigration from ponds is more difficult than determining adult migrations. Pitfall traps and transect line surveys are useful in determining occurrence, but studies are not as informative as those with radio telemetry on adults. Dispersal from natal sites is unidirectional from the birth pond to habitat areas not part of the local population (Semlitsch, 2008). Semlitsch (2008) hypothesizes that metamorphs randomly disperse in stages over multiple years. Finding alternative breeding sites from the natal pond at unknown distances requires the metamorph to enact exploratory behaviour with the ability to perceive environmental cues (Semlitsch, 2008).

Road surveys as a measure of amphibian occurrence and distribution

Road surveys, either by walking transects or driving at slow speeds, are a common method of observing wildlife abundance, hotspots, migrational routes and species diversity along or near roadways (Fahrig, et al., 1995; Langen et al. 2007; Puky, 2003; Mazerolle, 2005; Gerow, 2010; Pagnucco, 2012).

Past studies have observed amphibian road occurrence at driving speeds anywhere between 20 to 50 km/hr (Sillero, 2008; Gerow, 2010; Langen et al. 2007; Teixeira et al., 2013). In comparison to walking road transects, driving surveys present a lower level of immediate detection, but can cover greater areas in less time (Sillero, 2008). There are positive benefits in either case; driving may lead to recording more fresh carcasses that otherwise may not persist in the time it takes to walk the transect. Hels and Buchwald (2001) found walking road transects inefficient when comparing findings from routine monitoring versus control monitoring and estimating the total number of road mortalities. They found a discrepancy depending on the species observed ranging from 7% (for *Triturus vulgaris* and *T. cristatus*) to 67% (for *Pelobates fuscus*) of the total estimated road mortalities.

As with other wildlife presence-absence studies in an open environment; observations cannot and need not be exhaustive. Extrapolations of recorded individuals or analysis through mark-recapture observations give practitioners a better understanding of population abundance. Hels and Buchwald (2001) presented an equation for the proportion of amphibian mortalities as a function of traffic density and amphibian velocity while crossing the road (Hels and Buchwald, 2001).

The information gathered from road surveys is increasingly used in association with Geographical Information System programming to observe trends in spatial and temporal road occurrence (Clevenger et al., 2009; Garrah, 2012; Malt, 2010). Concentrations of individuals can then be identified and managed through hotspot analyses and mitigation such as wildlife crossing structures and fencing (Pagnucco, 2010; Clevenger et al., 2003).

Amphibian receptivity to ecopassage structure features

Ecopassage structures, in theory, are excellent mitigative tools however the best dimensions and materials for use vary between species. The trend in the recent literature is toward providing functional passageways, as short in length as functionally possible, while allowing wildlife safe passage beneath a roadway. Structures intended for amphibian use are most effective when they include natural substrate flooring, adequate light permeability, and minimal temperature variability through airflow availability (Puky et al., 2007; Jackson, 1996; Puky, 2003; Woltz et al., 2008; Jochimsen et al., 2004). Structure attributes to consider when erecting crossing passages for amphibians include: aperture diameter, structure length, light permeability, substrate type, and drift fence height (Cramer and Bissonette, 2005). Specific tunnels designed for amphibians that have slots along the top for moisture and temperature regulation is increasingly common throughout North America and Europe (ACO, 2011; Pagnucco, 2012).

Amphibians prefer to traverse short lengths of pipe as opposed to lengthier ones. Woltz et al. (2008) found that green frogs and northern leopard frogs used 9.1 m length culverts (the longest pipe in the study) as a means of egress but did not prefer it. Pagnucco (2012) found long-toed salamanders utilising 12 meter long amphibian specific culverts in Waterton Lakes National Park. Whether amphibians will travel through a long underpass necessary to traverse a major highway, or whether shorter tunnels with an intermediate island habitat is more effective needs to be investigated further (Jackson, 1996).

Measuring the distance amphibians can jump consecutively without fatigue is helpful in determining effective mitigation structure lengths while determining where refuge may be beneficial in providing rest areas. Determining the rate of amphibian energy loss to fatigue may aid in determining rest recovery strategies when crossing over roadways. During lab trials where adult amphibians were required to consecutively jump 65 times, toads (*Bufo americanus, B. fowleri, B. terrestris*) maintained equal jumping performance throughout and did not show sign of exhaustion. Four species of hylids (*Acris crepitans, Hyla cinerea, H. crucifer, H. versicolor*) and three species of ranids (*Rana catesbiana, R. clamitans, and R. virgatipes*) exhibited a progressive decline in locomotor performances (Zug, 1985). Ideally, the closer the structures are to the breeding pond, the more utilised they are by amphibians (Jochimsen et al., 2004).

Light permeability in ecopassage structures

Some anurans respond positively to the effects of light permeability within crossing structures. Recommendations for tunnels to include light shafts or holes in order to represent maximum use by the most species are common (Puky, 2003; Puky et al., 2007). Jochimsen et al. (2004) suggests that ambient light penetration into ecopassages plays an important role in orientation during migration. Both green frogs and leopard frogs prefer pipes with the greatest density of permeability (4% of the pipe's surface area) on the upper surface (Woltz et al., 2008). Spotted salamanders (*Ambystoma maculatum*) appeared hesitant to enter dark tunnels in one study; when artificial light was provided, the time it took salamanders to cross the structure was dramatically reduced (Jackson, 1996). Lack of light may cause the species to hesitate or abort entering the tunnel (Jochimsen et al., 2004). Ambient light may be maximized by using larger tunnels accompanied by grates built into the median of the road.

Temperature variance through culvert underpass aperture diameter

The amount of airflow going through the passage affects amphibian movements. Small underpasses may create temperature disparities that deter use by some amphibians (Jackson, 1996). Larger underpasses or open-top systems increase airflow which may lead to less variance between the inner and outer environments. Puky (2003) recommends that if the tunnel is longer than 20 m, its size should be larger than 100 cm diameter up to 200 cm diameter to create less temperature effects for amphibians.

Woltz et al. (2008) observed green frogs (*Rana clamitans*) and leopard frogs (*Rana pipiens*) in several selection-based experiments on culvert attribute effectiveness. The study found that given a choice of varying pipe diameters (0.3 m, 0.5 m, 0.6 m, 0.8 m) both anuran species preferred the larger diameter tunnels (> 0.5 m).

Substrate requirements for moisture retention and refuge within ecopassages

The preference for a substrate bottom is observed in many amphibian passage studies, as amphibians are prone to desiccation and a soil lining retains moisture (Lesbarreres et al., 2004 (*Rana dalmatina, Rana esculenta*); Woltz et al., 2008 (*Rana clamitans*); Jochimsen et al., 2004; Glista et al., 2009). Openings along the crown of the crossing structures would allow rain to moisten the substrate within the underpasses. Yanes et al. (1995) found that after a rainy day 75% of monitored culverts registered anuran crossings.

A substrate layer is observed to be significant for maximum tunnel usage by multiple species of amphibians. Juvenile western toads (*Bufo bufo*) and red-legged frogs (*Rana aurora*) exhibited greater movement in culverts with substrate as opposed to culverts without (Glista, 2009), while 68% of water frogs, agile frogs, and common toads preferred tunnels lined with soil instead of bare concrete (Lesbarreres et al., 2004). Green frogs, an aquatic species, were found to favour gravel and soil-lined tunnels (Woltz et al., 2008).

Drift fencing composition and effectiveness

Drift fences or barriers should be constructed in order to effectively direct amphibians to crossing structures. Combining a funnelling structure to guide the amphibians to a passageway is proven to be an effective strategy in reducing vehicular wildlife mortalities (Woltz et al., 2008; Aresco, 2005; Yanes et al., 1995; Jochimsen et al., 2004; Puky et al., 2007; Glista, 2009; Fahrig, 2009; Clevenger, 2005). A barrier wall in combination with a culvert system was effective in reducing wildlife road mortality 94% in the Paynes Prairie State Preserve, Florida (Dodd et al., 2004).

Fencing materials such as plastic, concrete, and metal mesh have been utilised with varying success over many studies, depending on the species and budgetary constraints. Erosion control fencing requires frequent maintenance as the wooden stakes rot (approx. 18 month lifespan) and vinyl fabric breaks down from sunlight exposure (Aresco, 2005). Concrete structures have a much longer lifespan, but are expensive. ACO Fencing Ltd. specialises in amphibian crossing structures and fencing with a concave, polymer blend fence for amphibians (ACO, 2013). ACO brand fencing was used in the present study.

It is essential to encompass the size and kinetics of specific amphibians within fencing and passage design. At a Jackson Lake, Florida site all aquatic, semi-aquatic, and terrestrial amphibians were able to scale or climb a 0.6 m woven vinyl fence buried 0.2 m into the ground (Aresco, 2005); among these amphibians were eastern spadefoots. Woltz et al. (2008) found that corrugated plastic fences 0.6 m in height were effective barriers to green frogs and leopard frogs; however, they suggest adding inward facing lips at the tops of the barriers for greater amphibian retention. A review of wildlife crossing structures across Central-Europe concluded the optimal height for drift fences to be 45 - 60 cm; with plastic mesh size no larger than 4 mm for maximum amphibian retention (Puky, 2003). Fences were found effective when erected vertically, with the bottom 10 cm buried into the ground to avoid amphibians escaping beneath the fence. The top of the fence should be curved concavely away from the road in order to prevent amphibians from climbing over (Puky, 2003).

In magnetoreception studies, adult common toads (*Bufo bufo*) that had a fence within their traditional migrational corridors were found to orient themselves along test fencing within arena observations. Landler and Gollmann (2011) hypothesized that the toads may have imprinted the fence line on their internal maps with the knowledge that if they followed it, it would lead them to their breeding ponds.

Monitoring ecopassage use

As road kill mortality studies involving species metapopulation analysis become more prevalent, greater monitoring opportunities will be presented. Adaptation periods may take several years while the species experience, learn and adjust their behaviour to the wildlife crossings (Clevenger, 2005).

Long-term monitoring efforts would be most beneficial yet for the majority of projects, monitoring is underfunded. Lately, more rigorous study designs include a pre-construction versus post-construction comparison of animal movements across highways or using a before-after-control-impact (BACI) study design (Clevenger, 2005). Throughout a road widening project, for example, BACI design would give practitioners insight into migrational occurrence across the road, wildlife-vehicle mortalities, and movement patterns through the unaltered adjacent landscape prior to observing construction effects and mitigation effectiveness during and after the road modification.

Previous to and following the establishment of multiple box culverts varying in size from 1.8 m^2 to 2.4 m^2, Dodd et al. (2004) performed funnel trap monitoring for wildlife passage. Capture success increased tenfold between the pre- and post-construction surveys; most pronounced in the number of individual amphibians using the culverts (amphibian species using the culverts escaladed from 5 to 13 species).

Recognition of road impacted amphibians

Through species metapopulation data and wildlife crossing structure evaluations, mitigation measures are potentially more effective today in aiding connectivity dynamics worldwide (IENE, 2013; ICOET, 2013; BCHR, 2011). Current research on roadways and amphibian conservation objectives has become further recognized throughout British Columbia with the formation of the BC Herpetology and Roads Group (BCHR) in 2011. The BCHR group is formed from the provincial governments' environmental and transportation employees, consultants, and academics throughout North America and as far as Europe (BCHR, 2011). Ongoing collaborative projects within BC include amphibian monitoring of fencing and underpass use along a two kilometer section of the Sea to Sky Highway (Malt, 2010) as well as amphibian-vehicle collision mitigation along Highway 4 in Pacific Rim National Park Reserve on Vancouver Island (SPLAT Project; (Beasley, 2008)); and Summit Lake Toadfest, an annual event hosted by BC Hydro electrical company that utilises volunteers to transport western toads (*Anaxyrus boreas*) across Highway 6 adjacent to Summit Lake (BC Hydro, 2012). Continual research and awareness of road impacts and the pursuit of habitat connectivity means greater sustainability in our increasingly developed environment.

Threats to south Okanagan amphibians

Amphibian populations within British Columbia's south Okanagan are subjected to multiple stressors beyond road and traffic trauma. Since the 1900s the south Okanagan valley has been altered for agriculture, including habitat conversions to orchards and vineyards, cattle use, and channelization of the Osoyoos river through the 1950s (Cannings et al., 1998; BCSIRART, 2008). In 2005, less than 40% of the natural low elevation wetlands remain from the year 1800 (Lea, 2008). Agricultural and urban development from 1988 to 2010 diminished remaining wetlands by 30% through mostly draining and infilling (Harrison & Moore, 2013).

Because of off-target (drift) impacts from the majority of agricultural practices, the majority of ponds remaining in the lowland elevations are exposed to pesticides (Bishop, et al., 2010). Bishop, et al. (2010) found pesticide drift at a minimum of 500 m from sprayed orchards, and since all lowland wetlands in the valley are within agricultural areas, they are most likely all contaminated. Hatching success in Great Basin spadefoots was lowest (ranging from 0 - 92%) in wetlands exposed to purposely sprayed pesticides in adjacent crops. Decreased hatching success correlated with increased pesticide and nutrient concentrations.

Invasive species are another stressor on native amphibians within the south Okanagan. For example, the fibrous roots of cheat grass (*Bromus tectorum*) have taken over areas where native bunch grasses would normally grow (OASISS, 2013). Species such as the Great Basin spadefoot burrow to escape predators or the heat of the summer, and need friable soil, whereby the matted roots create a barrier. Invasive fish such as carp, goldfish, and bass, and also bullfrogs *(Lithobates catesbeianus)* have been introduced into the areas wetlands (Anthony, 2010; BCSIRART, 2008a; BCSIRART, 2008b; OASISS, 2013). Fish devour amphibian eggs and deoxygenate the water, while bullfrogs will eat native amphibian species (especially juveniles) as well as out-compete them for resources (Anthony, 2010).

Chytridiomycosis is an infectious skin disease of amphibians, caused by the Chytrid fungus (*Batrachochytrium dendrobatidis*). A debilitating consequence of infection is excess skin sloughing which impairs cutaneous respiration and osmoregulation, resulting in sores and crippling death. It has been found in western toad (Deguise and Richardson, 2009) and northern leopard frog (Voordouw et al., 2010) populations in the southwest portion of the province. Surveys have been ongoing throughout BC since 2008 to gain a better sense of where the deadly fungus is occurring (Anthony, 2010).

Focal amphibian species in the South Okanagan Valley

The south Okanagan landscape is unique within British Columbia as it is a pocket desert that projects narrowly into the province as an extension of the United States' Great Basin Desert (BCSIRART, 2008a, b). Species within this ecosystem are tolerant of this arid desert climate.

The Great Basin spadefoot (*Spea intermontana*) is a desert-adapted amphibian that migrates in the spring to small, permanent and ephemeral ponds. The spadefoots' range within BC extends from the south Okanagan through a narrow band of alluvial plains north to 70 Mile House in the southern interior region. Its area of occupancy assuming a 1 km radius around known sites is approximately 619 km^2 (COSEWIC, 2007; BCSIRART, 2008a; Garner, 2012; Oaten, 2012). With characteristics of both frogs and toads, this species can be identified by their dry skin and squat bodies, with oval, cat-like pupils in golden eyes, and pug noses. Keratinized tubercles protrude from each hind foot; 'spades' which are used for burrowing. Adult spadefoot range from four to six centimeters snout to vent length (SVL) (Stebbins, 1985) and show variations from light green to brown with red spotted skin, and two light dorsal stripes in an hourglass form (Buseck, et al., 2005). Nusbaum (1983) identified sexually mature males at 40 mm SVL and females at 45 mm; Wright & Wright (1949) recorded mature males from 40 - 59 mm and females 45 - 63 mm SVL. The mating call of spadefoots is comparable to a loud snore and is distinct among other native amphibian species.

Great Basin spadefoots are associated near wetlands in open grassland, shrub steppe and open pine forest (BCSIRART, 2008a). This small amphibian buries itself underground for the majority of the year, only surfacing and using shallow burrows when relocating to breeding ponds in the spring, or between foraging periods through to early fall (Garner, 2012; Oaten, 2012). Radio telemetry studies within BC have observed spadefoot movements at the northern periphery of their range, moving a maximum distance of 371 m from the breeding pond (min. 25 m), with movement to burrow retreats at a mean distance of 100 m ± 79 m during the breeding season (Garner, 2012). Further south, in the Thompson-Nicola Region of BC, observed spadefoots fell into two categories of movements. Spadefoots that resided close to the breeding pond stayed within 500 m of it, while those that travelled far from the pond reached distances greater than

750 m and, for one individual, 2.35 km (Oaten, 2012). The COSEWIC assessment and update status report on the Great Basin spadefoot (2007) advise that spadefoots show site fidelity and use habitats within 500 m and up to 1 km from breeding wetlands.

Although there are no population trend data for BC, spadefoots' population size is estimated at about 10, 000 individuals (COSEWIC, 2007). Though likely the population is in decline because of large amounts of wetland and grassland habitat loss, such as in the south Okanagan where less than 40% of the wetlands remain (BCSIRART, 2008b, Lea, 2008). Spadefoot are currently blue-listed (threatened) under the BC Species at Risk Act (SARA, 2002), and federally listed as threatened (COSEWIC, 2011).

Another burrowing amphibian species of concern in the valley is the Blotched Tiger Salamander (*Ambystoma mavortium melanostictum* (previously *Ambystoma tigrinum*)). Blotched tiger salamanders are provincially red-listed, as they face imminent threats of habitat loss and fragmentation, roadkill, fish and bullfrog introduction to breeding wetlands, and chemical contamination (SARA, 2002; COSEWIC, 2012). A mole salamander, this amphibian is identified by its small eyes on either side of its wide, blunt head. Blotched tiger salamanders show variability in colour from yellow tones with darker brown, grey or black mottling, which range 14 - 22 cm snout-vent length (Sarell, 2004). Larvae are aquatic with long, external feathery gills; paedomorphism as well as terrestrial forms occur within this species.

Due to its elusive nature, the blotched tiger salamanders' range and population size are not well known. Sarell (2004) reports south Okanagan tiger salamanders observed up to a kilometer away from known breeding sites. Tiger salamanders have been found from valley floors to 1250 m elevation in BC. The index of area occupancy within BC using a 2x2 km grid is 232 km^2 (COSEWIC, 2012). Movement to breeding areas starts as soon as March, and the breeding season continues through August. Metamorphosed salamanders emigrate from permanent ponds in August or early September, on wet nights (Sarell, 2004; BCSIRART, 2008b; COSEWIC, 2012). Based on radio telemetry studies, blotched tiger salamanders move within 250 m of breeding ponds but have been found periodically over 1 km from suitable breeding areas

(Richardson et al., 2000 & Sarell and Robertson, 1994 (as cited in COSEWIC, 2012). Population estimates range from 2,500 to 10,000 adults (COSEWIC, 2012).

Figure 1. Target species: (*left*) Great Basin spadefoot adult (*Spea intermontana*) (Threatened provincially) and (*right)* blotched tiger salamander adult (*Ambystoma mavortium melanostictum*) (Endangered provincially). Photo credit J. Crosby (2012).

Amphibian species also occurring in the south Okanagan valley are: the Western toad (*Anaxyrous boreas* (previously *Bufo boreas*)), Long-toed salamander (*Ambystoma macrodactylum*), Pacific treefrog (*Pseudacris regilla*), Columbia spotted frog (*Rana luteiventris*) and the non-native invasive American bullfrog (*Lithobates catesbiana*).

South Okanagan & general survey section description

British Columbia's south Okanagan valley lies at the base of the province between the Cascade and Columbia mountain ranges. The valley is characterised by an arid desert climate within the bunch grass (BGxh1) biogeoclimatic zone (Meidinger and Pojar, 1991) and is known by its very hot, dry summers and mild winters (Lloyd et al., 1990).

The sensitive ecosystem of the south Okanagan has seen rapid change through habitat loss and fragmentation. The arid desert grasslands with wetland pockets throughout have been overtaken with urban sprawl and bisected by roadways and channelization of the Osoyoos River (Lea, 2008). This area is within the Agricultural Land Reserve (BC, 2002), and as such is heavily modified for agricultural use; vineyards and orchards dominate the landscape from the valley floor up to the steep shale slopes (Lea, 2008).

Osoyoos Passing Lanes site description

The Highway 97 four lane expansion project extends for 2.8 km with 100 m buffer on either end of the expansion from Deadman Lake at the north end of the project, to the north end of Osoyoos Lake. The project affects approximately 77 hectares (Hemmera, 2010).

Adjacent to this expanse of highway, are wetlands and marshes to the east and mainly orchards and vineyards to the west. The Osoyoos River floodplain to the east was modified in the 1950s when the river was channelized for agricultural purposes (Lea, 2008); the decommissioned Kettle Valley Railway (KVR) bed and agricultural fields are also evidence of this highly modified landscape (Phillips, 2004). Though modified, the Osoyoos River oxbows and surrounding environment provide critical habitat for a high diversity of rare and endangered wildlife species (Booth, 2001). This area of high diversity is classified by the BC government as the South Okanagan Wildlife Management Area (crown lands)/ Osoyoos Oxbow Fish and Wildlife Reserve (Phillips, 2004). Amphibian breeding has been recorded in the floodplain within its seasonal ephemeral pools, remnant Osoyoos River oxbows, and natural and constructed permanent ponds (Anthony, 2010).

On the south end of the project, west of the frontage road (old Hwy 97) there was a decommissioned gravel pit overgrown with endangered vegetation (i.e. Antelope brush (*Purshia tridentate*)) prior to construction. This gravel pit was altered during the construction period and transformed partially into a paved vehicle pullout, with the remaining ground hydro-seeded with a native seed mix, and a water retaining area that was dug out and left as an ephemeral wetland (J. Crosby, pers. obs., 2011).

Osoyoos Passing Lanes project background & environmental impact assessments

The British Columbia Ministry of Transportation and Infrastructure (MOTI) proposed the widening of a section of highway north of Osoyoos Lake, B.C. with recruitment of environmental impact assessments (EIA) by Summit Environmental Consultants Ltd. (Summit) in November 2004, and Hemmera consultants in 2010 (Phillips, 2004; Hemmera, 2010). The development is a multi (3.5) million dollar highway expansion project for the region's main travel route, Highway 97 (MOTI, 2010). The passing lane project involved the addition of a four-lane highway expansion 2.8 kilometres in length adjacent to the old highway section. The project also included interchanges at two locations along the passing lane so that local residents and tourists may get to the adjoining old two lane highway frontage road (Figure 2).

Field assessments were conducted for preliminary baseline data in winter 2004, with detailed assessments completed in spring 2005. Summit submitted the final environmental impact assessment report of the proposed project in June 2005 (Phillips, 2004). In 2010, Hemmera was contracted to provide an updated EIA for the MOTI, building upon the 2005 Summit EIA report for the proposed road expansion project between Deadman Lake and Osoyoos Lake, BC (Hemmera, 2010). Both EIAs were undertaken as a due diligence measure given the provincially and federally listed at-risk species surrounding the project Identification of environmentally sensitive areas and wildlife, and wildlife habitat features within the proposed development area were performed and mitigative actions proposed.

Figure 2. Osoyoos Passing Lanes (OPL transect) prior to fencing installation and interchange to frontage road (completed, 2011); Northwest facing photo. Straight-line distance from upland (westward) frontage road ditch slope across to (eastward) lowland floodplain is approx. 108 m. Photo credit J. Crosby 2012.

The passing lanes project area was surveyed more often between 2010 and 2012, in order to obtain the best available amphibian road occurrence data for contribution of the mitigation decision process. This provided an opportunity to mitigate the effects of roadways through strategic culvert and drift fencing placement and design. Pre-construction amphibian road occurrence data from 2010 was used in collaboration with MOTI planners and engineers to make adaptive management decisions on the placement of the larger, dry culverts. Proposed culvert positions were in areas of high amphibian movement, with permanent placement where geologically feasible. The purposefully placed culverts with the corresponding drift fencing are to ameliorate the traffic effects and perform as passageways by amphibians. Construction began in spring 2010 and continued through summer 2011. Prior to mitigation efforts, this road expansion presented a six lane traffic barrier (approx. 16 m of paved surface) for amphibians to migrate across (Figure 2).

This is the first in-depth, multi-year examination into amphibian road occurrence within the south Okanagan. It is also an important collaboration between the British Columbia Ministry of Transportation and Infrastructure, BC Ministry of Forests, Lands and Natural Resource Operations, and the University of Waterloo whereby, decisions on effective placement of amphibian road mortality mitigation structures were based on a rigorous pre-construction dataset. In order to make informed decisions on future infrastructure and ecosystem mitigation, there needs to be greater research into roadway effects on wildlife and continual precautionary and adaptive management within the valley.

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AMPHIBIAN ROAD OCCURRENCE, TRAFFIC IMPACTS AND MITIGATION EFFECTIVENESS IN THE SOUTH OKANAGAN VALLEY, BRITISH COLUMBIA, CANADA (2010-2012)

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Abstract- Roadways fragment the landscape while effectively acting as barriers to wildlife dispersal. Wildlife-vehicular mortalities occur frequently across taxa associated with roadway corridors. Mitigation measures associated with species' metapopulation studies and wildlife crossing-structure evaluations are important to the persistence of connectivity dynamics. Within British Columbia's south Okanagan amphibians are negatively impacted by roads and traffic effects. Throughout the spring and summer of 2010 to 2012, I assessed amphibian incidence throughout 52 km of a main highway and rural route near Osoyoos and Oliver, BC. Survey effort was concentrated within a 3 km four lane highway expansion project utilizing a before after control impact approach for pre and post construction effects. Road mortality mitigation strategies were incorporated through interior substrate enhancement of strategically placed dry culverts, connected in sections by polymer drift fencing in consultation with the 2010 amphibian road occurrence data. Two sample Wilcoxon tests revealed amphibian road occurrence was significantly less in 2012 than 2010 ($W = 4679.5$, $p = 0.02$). Amphibian mortalities within the passing lanes transect were significantly reduced with the implementation of mitigation structures ($\bar{x}_{2010} = 13.2 \pm 32.5$, $\bar{x}_{2011} = 4.7 \pm 12.8$, $\bar{x}_{2012} = 2.3 \pm 7.3$; 2010 vs. 2012: $W = 1535.5$, $p < 0.001$). Roadkill mitigation structures proved effective in observed amphibian occurrence of the entire passing lanes stretch as well as at distances 100m and 200m from observed culverts. Double fenced areas resulted in a 94% reduction in amphibian road occurrence. Automated camera trap monitoring of culverts within established amphibian hotspot areas was in operation spring and summer 2011 (three culverts) and 2012 (two culverts). Over eight hundred amphibians were observed in time-lapse photos during both years, with 2012 occurrence greater than 2011. Through mitigation structure management, road permeability has proven effective for amphibians along a heavily traffic impacted area adjacent to an expanse of wetland network within the lower south Okanagan.

Keywords- road ecology, roadkill, ecopassage, amphibian, Great Basin spadefoot, *Spea intermontana*

INTRODUCTION

Wildlife traverse the landscape in order to maintain their requirements for resources and procreation. When constructed in areas of concentrated wildlife corridors, roads and corresponding traffic result in frequent wildlife mortalities (Clevenger et al, 2009); whereas roadkill rates of wildlife are highest near ponds and wetlands (Forman and Alexander, 1998). Roadways fragment these movement corridors, displacing wildlife populations by acting as migration barriers and avoidance zones, which may lead to decreased genetic variability and island populations (Holderegger and Giulio, 2010). Local populations may suffer declines where the roadkill rate exceeds the rates of reproduction and immigration. Barrier effects, road avoidance zones from noise disturbance, road mortalities (Forman and Alexander, 1998), and genetically isolated populations (Holderegger and Giulio, 2010) are recognized as the main negative effects of roads on wildlife communities.

Throughout Canada, in 2009, there were 1.04 million kilometres of two-lane equivalent roadways; of these roadways, 415,600 kilometres were paved (Transport Canada, 2011). Traffic volume is increasing federally: in 2011, 21.4 million vehicles were registered for the road (up from 16.6 million in 1992) (StatsCan, 2009; Coyne, 2011). Within British Columbia, in 2013, there were 47,519 km of provincial roads (up from 42,000 km of provincial roads in 2003) (BC MOTI, 2013). Traffic volume is increasing within the province as well, in 2009, the amount of registered vehicles increased to 2.77 million in British Columbia (from 1.98 million registered vehicles in 1991) (StatsCan, 2009).

In order to mitigate for the mounting fragmentation effects of escalating roads and traffic, including, decreased population persistence, wildlife crossing structures are becoming increasingly integrated into transportation projects. Practitioners have created diverse passage structures for wildlife; combined with fencing, this provides effective guidance to cross above or beneath roads (Aresco, 2005; Dodd et al., 2004). Structures may be constructed and/or modified for effective wildlife passage including multi-species overpasses, open-span bridge underpasses, box culverts, corrugated steel pipe culverts, and species-targeted tunnels (i.e. amphibian tunnels) (Beckmann et al., 2010; ACO, 2013; Clevenger et al., 2009; Pagnucco, 2010).

Whereas, passageways can be retrofitted, it is more cost effective to incorporate them within the roadway planning stages (Clevenger et al., 2009; Forman and Alexander, 1998; Beckmann et al., 2010). Cost effectiveness of roadkill mitigation structures is an obstacle in the majority of projects; yet as more structures are erected and shown as utilised, there is greater tolerability of cost by decision makers.

Amphibians can be quite susceptible to traffic and road effects due to their biphasic life cycles where they require access to breeding wetlands as well as the surrounding terrestrial habitat (Semlitsch, 2008). The first documented amphibian-specific passageways were built in the 1960s in Western-Europe (e.g. Switzerland and Germany; United Kingdom in the mid-1980s); in the United States, ecopassages for salamander use were first recorded in 1987 (Jackson and Tyning (1989) in Puky (2003)). The effectiveness of such road impact mitigation structures vary, while the process continues to be a complex endeavour of trial and modification depending on site specific diversity and the needs of the affected wildlife communities (van der Ree et al., 2007). Through increasing species road occurrence and metapopulation studies, practitioners continue to gain perspective on which species are utilising or avoiding specific types of structures (e.g. Beckmann et al., 2010; Forman et al., 2002).

Within British Columbia's south Okanagan Valley, amphibian movement and breeding viability is threatened by the highway bisected landscape. The purpose of my study was to assess the extent to which amphibians are impacted by traffic and roads as they traverse the south Okanagan landscape during their annual spring and summer breeding migrations, wetland dispersion and foraging movements. Throughout the spring and summer of 2010-2012, fifty two kilometers of roadways (31 km of highway, 21 km of paved backroad) were repeatedly surveyed from the Canada-USA border to north of Oliver, BC; surveys were carried out utilising vehicles and on foot. I focused on assessing the annual spring migrations of the COSEWIC blue-listed Great Basin spadefoot (*Spea intermontana*) and the red-listed blotched tiger salamander (*Ambystoma mavortium melanostictum*) as they navigate the roadways to their breeding ponds, recording other road occurring amphibians as observed.

From 2010 to 2011, the British Columbia Ministry of Transportation and Infrastructure constructed a three kilometer four lane passing expansion parallel to and re-routing from Highway 97. The six-lane expansion area is adjacent to an expanse wetland network of ephemeral, permanent ponds and oxbows that serves as an annual amphibian breeding destination. As the amphibians migrate from their upland overwintering areas, it is necessary for large numbers of amphibians to cross Highway 97. The Osoyoos passing lanes construction presented an opportunity to ameliorate the effect of wildlife-vehicle mortalities through collaboration with the BC MOTI to erect permanent amphibian fencing and passageway mitigation structures. I could find no records of prior transportation authorities placing or modifying culverts for amphibian-specific use in the south Okanagan Valley, however, there are verbal accounts of rattlesnake culverts installed beneath roadways by British Columbia Ministry of Transportation staff as early as the late 1950s (Sielecki, 2008).

The Osoyoos passing lanes project area was surveyed regularly throughout the survey period in order to obtain the best available amphibian road occurrence data for contribution to the mitigation decision process. Pre-construction amphibian road occurrence data from 2010 was used in collaboration with MOTI planners and engineers to make adaptive management decisions on the placement of eight large, dry culverts. Proposed culvert positions were in areas of high amphibian movement, with permanent placement where geologically feasible. Construction began in spring 2010 and continued through summer 2011 with monitoring from the 2010 through 2012 spring and summer seasons.

Prior to this study, within the south Okanagan, there were few studies on amphibian road occurrence, although the Hwy 97, Osoyoos passing lanes environmental impact assessments (Phillips, 2005; Hemmera, 2010), species reports (Sarell, 2004; COSEWIC, 2007; COSEWIC, 2012), and various unpublished opportunistic data reported amphibian road occurrence events. In short term studies there may be various climatic or populational cycles that affect the amount of amphibians observed within a season, therefore only general conclusions can be drawn. This is the first in-depth, multi-year examination into amphibian road occurrence within the south Okanagan over a broader temporal and spatial scale.

MATERIALS & METHODS

Study area

The project study site is located within the Osoyoos-Oliver region in the south Okanagan Valley, British Columbia, Canada. The survey route is approximately fifty two kilometres in length, extending north along Highway 97 from 12th avenue (just north of the Canada/USA international border) to Tuc-Ul-Nuit road (north of the town of Oliver). The survey sections continue south, parallel to Highway 97, following 71st Street into Blacksage Road to the Number 22 Road (No. 22 Rd) and back to Highway 97 (Figure 3). The two lane highway has a speed limit of 80 km/hr, except through the towns of Osoyoos and Oliver, where it is 50 km/hr. Blacksage Road and the number 22 road are secondary two lane roadways with posted speed limits of 50 km/hr.

Osoyoos passing lanes site description

During the spring and summer of 2010, a three kilometer section of the highway was expanded to a four lane passing lane, adjacent to the previous Highway 97 (now frontage road); two interchanges connect the passing lanes with the frontage road. The Osoyoos passing lanes (OPL) project extends from Deadman Lake at the north end of the project, to the north end of Osoyoos Lake. Adjacent to this expanse of highway, are wetlands and the Osoyoos river floodplain to the northeast and orchards and vineyards to the south west. The project construction directly affected approximately 77 hectares (Hemmera, 2010).

South Okanagan road transects for amphibian occurrence

To determine the abundance of amphibians on south Okanagan roads, surveys were performed in transect sections while travelling along Highway 97 and secondary roadways. Highway 97 survey transects were designated around the Osoyoos passing lanes construction area. The OPL transect included the projected four lane area and a few hundred meters on each side of the impacted area.

Subsequent control areas of the highway which were not impacted by the construction included transects north and south of the OPL transect. A fourth transect was established along rural roads

(Blacksage Road and the No. 22 Rd) with less traffic and speed limits of 50 km/hr. The No. 22 Rd connects Blacksage Road with Highway 97 at the OPL area, which otherwise run parallel to one another. The two parallel roads are divided by the Osoyoos river channel (Figure 3).

Throughout the 2010 field season within the Hwy 97 OPL transect section, surveys were executed along the original Highway 97 (now a frontage road). The OPL was open to traffic during the spring of 2011, so consequent surveys were carried out along the new section of four lane highway with incidental observations recorded from the original two lane Hwy 97/frontage road.

South Okanagan road survey effort

Survey effort was concentrated within the Hwy 97 Osoyoos passing lanes transect in order to convey a rigorous dataset for mitigation structure placement and subsequent monitoring. The No. 22 Rd was also surveyed often; the reason being, that in the original BC MOTI construction plans, the No. 22 Rd was to be impacted at its Hwy 97 intersection. Later comparisons of traffic density, posted speed limit and the limited effect from the construction on Hwy 97 led to the decision to pair the No. 22 Rd with Blacksage Road as a secondary route.

The survey time period per road transect was dependent on the amount of observances recorded and time taken to process them (see Results: Table 1).

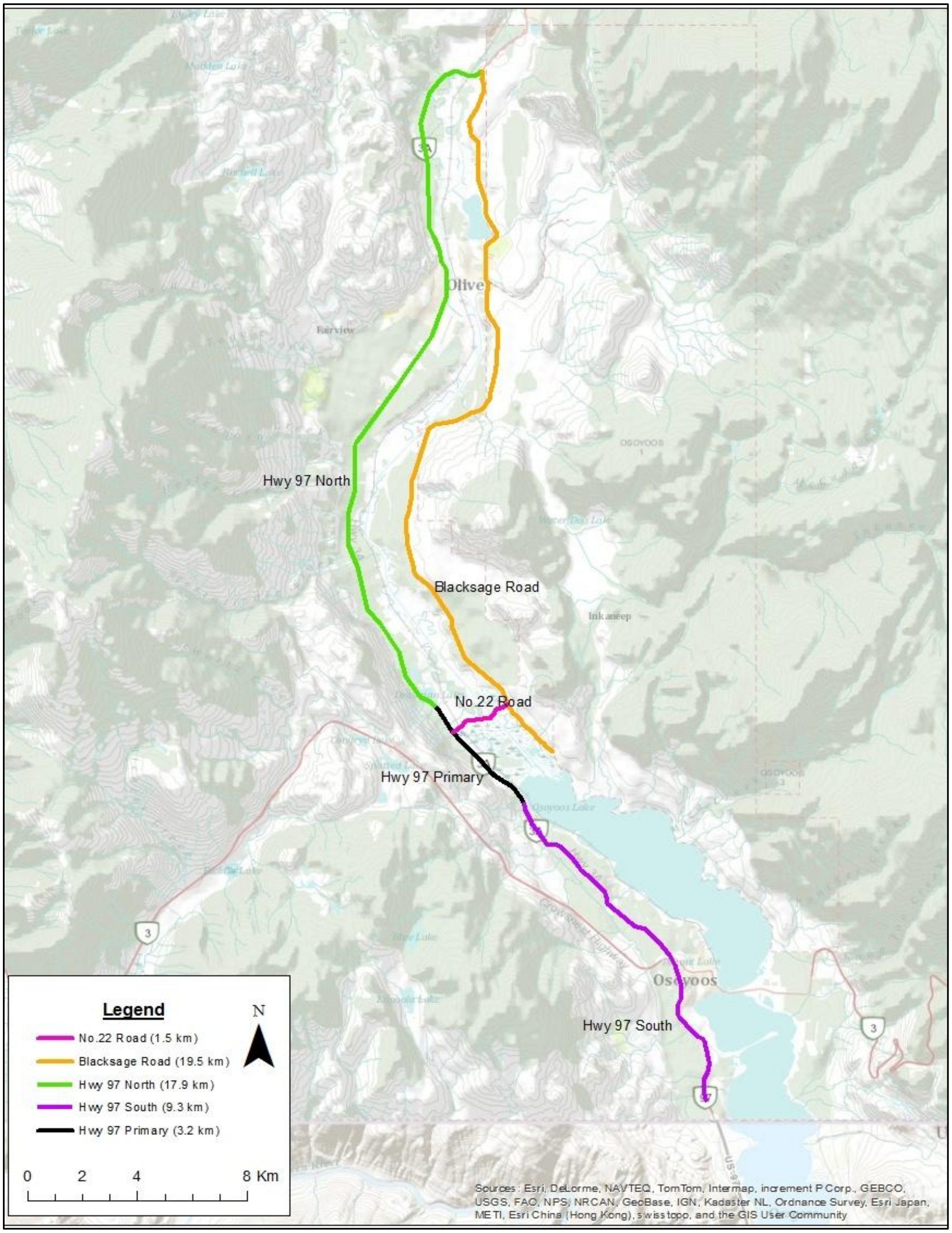


Figure 3. South Okanagan amphibian road survey route transects (52.1 km total): Hwy 97 south (purple), Hwy 97 primary (OPL) (black), Hwy 97 North (green), Blacksage Road (orange) and the Number 22 Road (pink). Hwy 97 OPL transect road monitoring was performed on foot and by vehicle; all other transects were performed by vehicle only.

South Okanagan road survey data collection

Surveys were carried out one half hour after dusk, utilising vehicles (driving at 20km/h), and by surveying on foot (Hwy 97 OPL transect only). Fence line surveys were executed on foot.

For each amphibian observation, recorded data included: the date and time of occurrence, survey transect, style of transect search (e.g. walk or drive cruise), species identification, snout-to-vent length (mm), gender, life stage, health status (live/mortality), UTM location, lane placement, direction of travel, behaviour, the current climate conditions, and traffic volume throughout the period of the survey (recorded using a handheld counting device). Global positioning of observed occurrences was obtained through a handheld Garmin GPS device (©Garmin Ltd.) with a mean accuracy of 3 m.

Amphibians were recorded to the species level when possible. Bone and skin fragments identifiable as only amphibian were documented as 'unidentifiable amphibian' if no defining characteristics were found. Gender was characterised as 'unidentifiable' if the amphibians did not shown characteristic gender traits (e.g. Great Basin spadefoot males with nuptial pads and dark throats; females with eggs) and/or had not reached sexual maturity.

All wildlife mortalities were recorded and then removed immediately from the roadway to prevent being recorded twice. All deceased individuals were removed from the roadway to the adjacent cover away from the road as to not attract scavengers to the roadway. Amphibians that were fatally injured by vehicles were euthanized by pithing. Live individuals were handled following the BC Ministry of Environment interim hygiene protocols for amphibian researchers (BC MOE, 2008); once documented, live individuals were taken well off the road in their original direction of travel. Wildlife handling permits were obtained from the University of Waterloo Office Of Research Ethics (Animal Utilization Project Proposal #11-09) as well as from the BC MOFLR (Wildlife Act permits PE10-61772, PE11-69853, PE12-79651).

For simplicity, we recorded amphibian direction based on the northbound and southbound lanes, so that live amphibians heading directly perpendicular to the highway lanes were designated east or west, and following the headings between them accordingly. Our designations therefore are not true headings but in relation to the parallelism of the roadway with the landscape. Depending on what side of the channelized Osoyoos river the survey was on, if an amphibian was heading in an east direction (E, NE, SE) from the highway (west of the river) they were more likely headed towards a pond (into the valley wetlands and oxbows). Alternately, on the east side of the river, amphibians heading westward (W, NW, SW) were likely on their way to the breeding ponds. This was verified by auditory surveys along the survey route as well as geography of the wetland landscape. All deceased amphibians were recorded with unknown directionality, as vehicle impact may have compromised their chosen heading. Occurrences along the No. 22 Rd were harder to quantify since the road is surrounded by wetlands as it bisects the floodplain; directional data was recorded but it was omitted from this analysis.

Weather variables were recorded with every documented individual, as well as for each overall survey period. Grant et al. (2009) found that mass migrations of nocturnal amphibians to breeding sites, amplexus, and spawning events may be triggered by lunar light, so the moon phase was also recorded during the surveys (on a scale of 0-4, as quarters). Climatic and abiotic variables were recorded as: temperature, wind (scale of 0-4 from calm to wind whistling), cloud cover (0-4, clear to overcast), precipitation (0-3, dry to downpour), and presence/absence of rain within approximately12 hours prior to surveying.

Incidental auditory observances of calling amphibian males were recorded along the survey routes on top of regular auditory surveying of long-term breeding sites within the study area. Data was recorded at 5 minute intervals following the standardized inventory methodologies for amphibian auditory surveys (Gartshore et al. (1992): calling index: no male amphibians calling was recorded as 0; distinct individuals call was a 1; some calls overlapping with few distinguishable was 2; full undistinguishable chorus was recorded a level 3).

Hwy 97 Osoyoos passing lanes culvert placement and inner environment enhancement

The eight culverts ranging in diameter from 900 mm – 1200 mm (Figure 4) were placed beneath the passing lanes in areas of higher amphibian road concentrations based on my 2010 data. The culverts were enhanced in 2011 to create continuity between the roadside and culvert landscapes. Culverts were lined with a sand-gravel substrate by road crews spraying a mound of substrate with water from a water truck to distribute the substrate throughout the length of the culvert underpass. Substrate depth ranged 15-30 cm, composed of a 70:30 sand-gravel mix. Oaten (2003; in COSEWIC, 2007) found that juvenile Great Basin spadefoots readily burrowed into sandy clay loam, fine gravel, sand and brown chernozemic soils, but preferred the former two substrates. Eastern spadefoot (*Scaphiopus holbrookii holbrookii*) adults and toadlets most easily burrow in sand, and loose, friable soils (Jansen et al., 2001).

Artificial refuge was placed every few metres throughout the length of the culverts to provide protection for prey animals while travelling the passages. Refuge habitat included clay pot fragments, 30 cm cement tubes and cover boards supported by rocks.

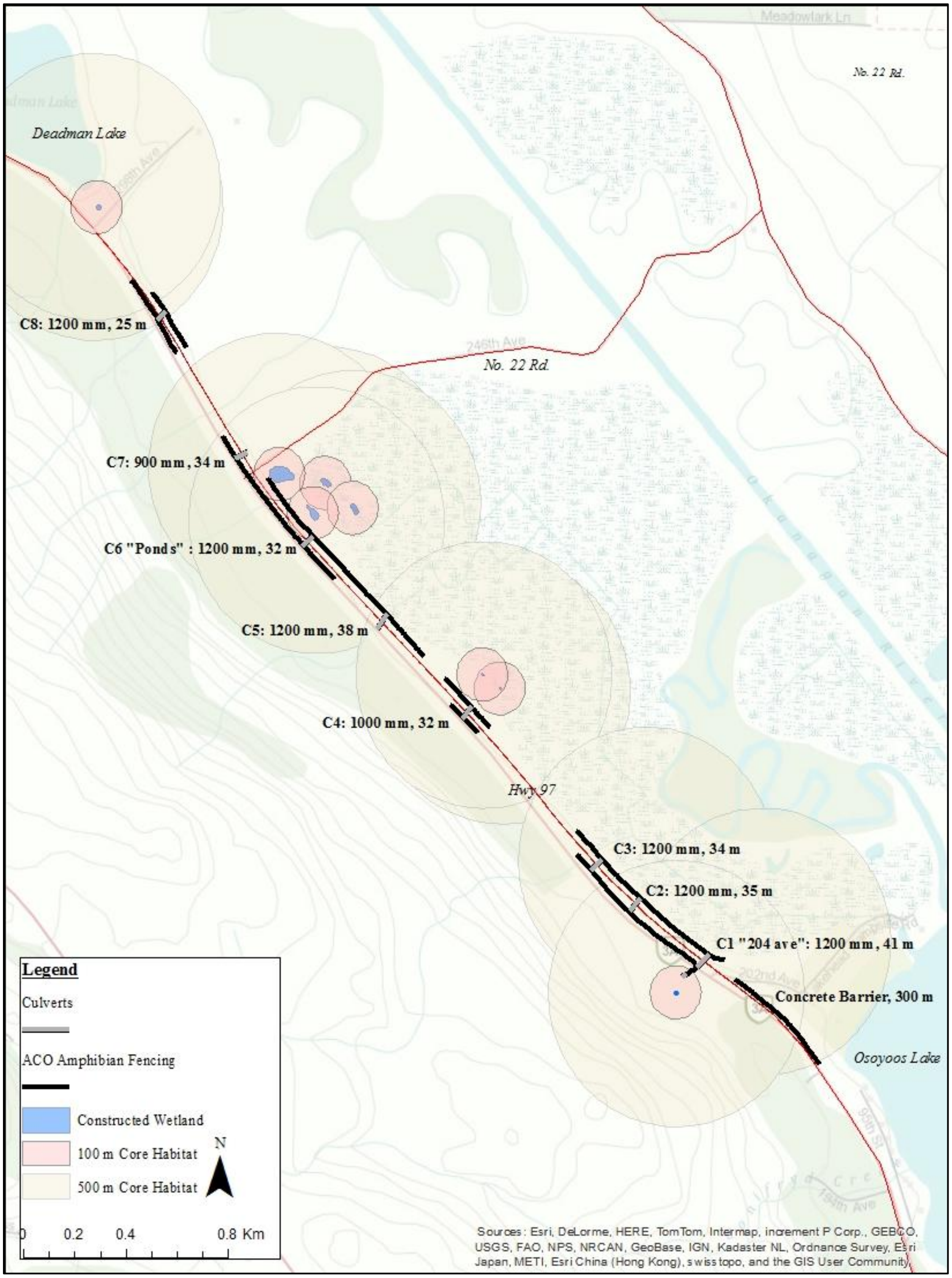


Figure 4. Highway 97 Osoyoos Passing Lanes culvert placement (C1 to C8), diameter (mm), and length (m) as well as constructed wetland locations and core movement habitat at 100 m and 500 m scales from possible breeding ponds and known floodplain breeding areas directly adjacent to Highway 97. Culvert measurements from: BC MOTI Hwy Engineering, Hwy No. 97 Osoyoos Lake passing lanes drawing No. R2-783-101.

Camera trap culvert monitoring

Culverts (n = 3 (in 2011), n = 2 (in 2012)) in previously observed amphibian road hotspot areas were setup with Reconyx RC55 Rapidfire cameras (in 2011) and PC800 Hyperfire cameras (in 2012) (Reconyx, USA) in each end to photo 'trap' wildlife occurrence. In 2011, one set of cameras beneath the Frontage Road, one set near 204 avenue (11+40 culvert) and a pair near the restoration pond at the No. 22 Rd (25+30 culvert) recorded occurrences between May 14 and July 13. In 2012, cameras were setup in the 204 avenue and Ponds culverts, April 28 to July 13 (Figure 4; Figure II-1).

The 'Ponds' culvert (32 m in length) is located in close proximity to four identified amphibian breeding wetlands, three of which are constructed wetlands. The '204 Ave' culvert (41 m in length) is located just north of 204th avenue; this culvert is located next to a large floodplain on the east side. The Frontage road culvert (17 m in length) runs below the Frontage road 31 m west of the 204 ave culvert.

Cameras were hung from the ceiling three metres inside the culvert openings facing angled outward (see photo in Appendix II, Figure II-1). Cameras were set to time lapse (1 photo/minute between 2100 h and 500 h) on the advanced trigger setting, on very high sensitivity, plus rapid fire infrared photography for warm blooded wildlife. Three rapid fire photos were taken per trigger interval with no delay. A four GB card would yield approximately 20, 000 photos. Batteries and SD memory cards were refreshed every two to three days.

Amphibian incidence was only recorded for amphibians that were shown within the culvert but not at the mouth of the culvert within the photos. Only culvert occurrences were recorded so to not double count if they entered at a later time or if they were just walking past. Other wildlife species were recorded for abundance of wildlife species occurrence and any predatory behaviour.

Fencing mitigation structure monitoring

Along the highway passing lane, 2.6 lineal kilometres of amphibian-specific drift fencing (ACO brand, ACO USA) was installed in spring 2011 to guide amphibians parallel to the roadway and through the culverts beneath the highway. The polymer fencing is concave with an overhang, supported every 1 m by a 0.4 m high post, and backfilled with soil (Figure 5).

Figure 5. Permanent ACO polymer plastic amphibian fencing along the Hwy 97 Osoyoos passing lanes area. Left photo: Fence line connecting to the 'Ponds' culvert, adjacent to a bike path. Right photo: fencing when first installed west of Hwy 97 across from the No. 22 road.

The fence sections are parallel along some areas of the road, and in some areas only one side of the road or the other is lined by fencing. Fence line data was categorized, therefore, by 'double fence', 'single fence', and 'bare' area amphibian occurrence.

Walking surveys of the fence line were performed during all Hwy 97 OPL road surveys. All occurrences within 1 m of the fence were recorded as fence line occurrences. The purpose of these surveys was to determine if the fences act as a trap for the amphibians (by evidence of desiccation), if they are an effective barrier (by contrasting fence occurrence to road occurrence within fenced areas) and if they are effective in guiding the amphibians towards the culverts (as observed in time lapse photos from culvert openings).

Highway 97 OPL occurrence versus culvert observations

Amphibian road occurrence was compared along the entire OPL transect to occurrence within the two camera trap monitored culverts, as time and resources did not allow for monitoring in all eight highway culverts.

To obtain a more representative comparison between the relationship of amphibian road occurrence and specific nearby culvert activity, I also observed road occurrence 50 m and 100 m on either side (northbound and southbound) of the camera-trap monitored 204 ave and Ponds culvert openings (100 m and 200 m total distance surrounding each monitored culvert).

Statistical analysis

All data were statistically analyzed in the statistical program R (R version 3.0.1, ©2013 The R Foundation for Statistical Computing), unless otherwise stated. Data were first examined for normal distributions using Shapiro-Wilk test of normality ($p < 0.05$); the majority of data were not normally distributed therefore non parametric tests including two sample $\text{Wilcoxon}_{0.05,}$ paired $\text{Wilcoxon}_{0.05,}$ and Chi-squared tests for independence were performed.

Amphibian occurrence analysis among transects and between years

Two sample $\text{Wilcoxon}_{0.05}$ tests were used to analyze total amphibian occurrences throughout the south Okanagan survey area, between years (2010 - 2012); as well as in analysis of vehicle traffic per hour and consequent amphibian road mortalities within each transect among years and between transects. ‘Total amphibian occurrence’ includes all amphibian species, alive and deceased. By separately observing different transects of the highway south and north of the construction impacted four lane transect, I was able to test for impacts the road expansion caused. Observing amphibian incidence along the secondary roadways of Blacksage and the No. 22 Rd gave a greater perspective on amphibian movement along a much less traffic dense area.

Within the Osoyoos passing lanes transect, two sample $Wilcoxon_{0.05}$ tests were used in analysis of total amphibian occurrence between years, and a Before-After Control Impact analysis between 2010 (pre-construction) and 2012 (post-construction, completed mitigation) roadway only occurrence. Live amphibian directional movements were compared within transects for easterly and westerly directions for trends in arriving or departing from wetlands. East and west direction observations were contrasted with northern and southern directional movements to observe patterns, if any, of intentional shortest distance, perpendicular crossing or movements in regards to other effects; a two sample $Wilcoxon_{0.05}$ test was used. Amphibian culvert occurrence (camera trap data) and road incidence from the same survey days were analyzed using paired sample $Wilcoxon_{0.05}$ tests for 2011 and 2012.

Abiotic factors and amphibian road presence

Multiple regression within generalized linear models were used in analysing weather variable effects on total amphibian occurrence. Categorical terms of wind, cloud cover, moon phase, air temperature, and precipitation were analysed for their relationship with the continuous response variable, total amphibian occurrence.

Pearson Chi-square was used to analyze the presence/absence precipitation data. Incidents of amphibian roadway movement occurrence were observed for whether they were dependent on the presence or absence of precipitation events, within 12 hours of the survey period, throughout all survey areas and between years.

Traffic and amphibian road mortalities

Generalized linear models (Poisson distribution, log linked) were used to observe the relationship of amphibians found DOR and the amount of traffic during survey periods. Highway 97 transects (Hwy 97 south, Hwy 97 north, and Hwy 97 OPL) were combined for analysis of primary roadway traffic effects on amphibian mortality response. Secondary roadway amphibian mortalities, along the Blacksage Road and no.22 rd transects, were compared to traffic occurrence also.

Amphibian road occurrence hotspot analysis

Global positioning data from road occurrence records were uploaded into Environmental Systems Research Institute (ESRI)'s geographical program ArcGIS 10.2.1 Getis-Ord Gi* Hotspot Analysis statistical analysis was run on the data to determine statistical clustering of amphibian movement areas. The hotspot analysis calculates z-scores from road occurrence clusters by comparing them to a random distribution (Getis and Ord, 1992). Occurrence data were grouped with an XY tolerance of 3 m in order to account for GPS unit accuracy before running the hotspot analyses. The outputs are a range of z-scores resulting in hot and cold spot designations. Hotspots are defined by z-scores ≥ 1.96 (p = 0.05).

RESULTS

Amphibian occurrence on south Okanagan roadways

Survey effort was concentrated within the Highway 97 Osoyoos passing lanes and the No. 22 Rd survey events during all survey years, followed by control transect survey events; less hourly effort corresponded with fewer occurrences among years (Table 1 and Table 2).

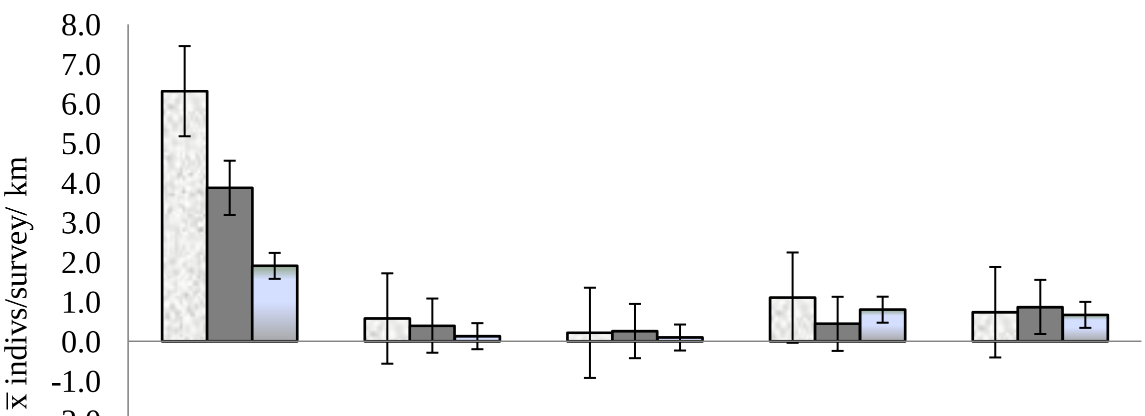
Table 2. Amphibian road survey effort between years: number of survey events, total hours effort, and mean survey time per survey transect.

Year		Hwy 97 OPL	Hwy 97 North	Hwy 97 South	Blacksage Road	No. 22 Road	Total Effort (hrs)
2010	Survey Events	46	20	23	22	37	
	Effort (hrs)	94	45	25	55	10	227
	$\bar{x}$ survey time (hours) ± SD	2 ± 2	2 ± 1.3	1 ± 0.4	1.2 ± 1.3	0.2 ± 0.2	
2011	Survey Events	77	28	27	33	73	
	Effort (hrs)	117	46	25	60	15	262
	$\bar{x}$ survey time (hours) ± SD	0.8 ± 0.8	1.6 ± 0.9	0.9 ± 0.5	1.8 ± 0.8	0.2 ± 0.1	
2012	Survey Events	46	19	18	19	52	
	Effort (hrs)	99	21	11	29	9	168
	$\bar{x}$ survey time (hours) ± SD	0.7 ± 0.6	0.6 ± 0.3	37 ± 10	1.5 ± 0.9	0.2 ± 0.1	

Amphibian observances throughout the survey area were significantly less in 2012 than in 2010 and 2011. Throughout the entire survey area, between 2010 and 2012 there was a significant difference among amphibian occurrence (W (105) = 4679.5, p= 0.02) but not between 2010 and 2011, or 2011 and 2012 (W (111) = 10677, p = 0.12; W (105) = 8420, p = 0.29) (Two sample Wilcoxon$_{0.05}$ test, Table 2). Mean individuals per survey were divided per kilometer survey transect to show amphibian distribution among transects (Figure 6).

Table 2. Amphibian occurrences by survey transect area per year, 2010-2012; total occurrence per kilometer survey transect.

Survey Transect	**Length (km)**		**2010**	**2011**	**2012**	**Grand Total**
Hwy 97 OPL	3.7	Total Amphibians	939	978	297	2214
		Amount Dead	627	368	106	1101
		Occur/Km	253.8	264.3	80.3	
Hwy 97 South	9.3	Total Amphibians	52	65	17	134
		Amount Dead	29	45	11	85
		Occur/Km	5.6	7	1.8	
Hwy 97 North	18	Total Amphibians	208	204	43	455
		Amount Dead	162	153	19	334
		Occur/Km	11.6	11.3	2.4	
Blacksage Road/ No. 22 Road	21.1	Total Amphibians	514	379	355	1248
		Amount Dead	239	161	85	485
		Occur/Km	24.4	18	16.8	
Total	**52.1**	**Total Amphibians**	1713	1626	712	4051
		Amount Dead	1057	727	221	2005



	Hwy 97 OPL	Hwy 97 North	Hwy 97 South	Blacksage Rd	No. 22 Rd
2010	6.3	0.6	0.2	1.1	0.7
2011	3.9	0.4	0.3	0.4	0.9
2012	1.9	0.1	0.1	0.8	0.7

Figure 6. Comparative occurrence by survey transect: mean number of amphibian individuals per survey period per kilometer of section length, by year (2010 - 2012). Error bars ± SEM.

Amphibian species on south Okanagan roads

Five species of amphibians were found over the three survey seasons: Pacific treefrog (*Pseudacris regilla*), Western toad (*Anaxyrus boreas*), long-toed salamander (*Ambystoma macrodactylum*), blotched tiger salamander and Great Basin spadefoot (Figures 7 to 10, Table 3). All amphibian occurrences were modelled within a hotspot analysis for recognition of high concentration clusters of amphibian road occurrence (Figure 11, Table 4).

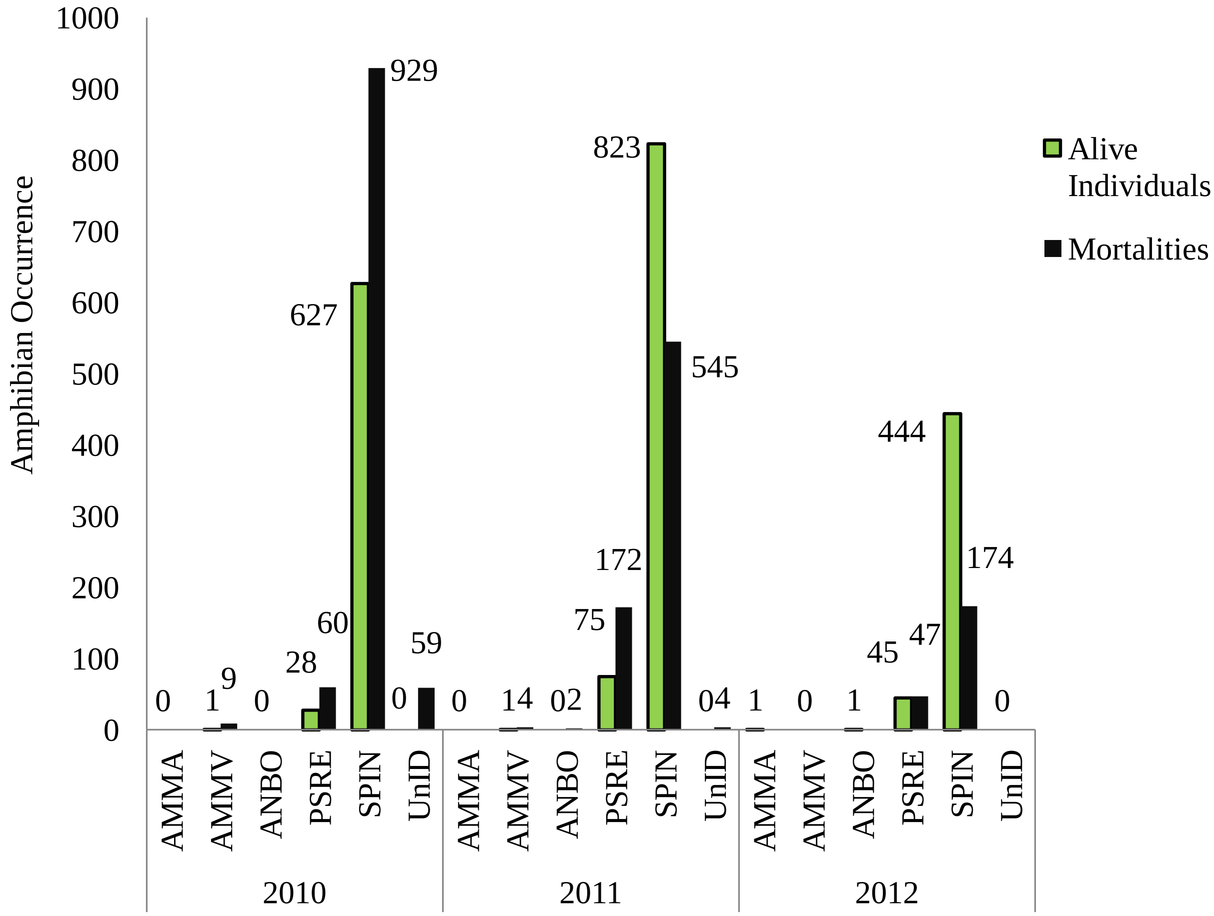


Figure 7. Yearly comparative amphibian road occurrence by species, live and dead, throughout the entire 52 km south Okanagan road survey area, 2010 –2012. Long-toed salamander (AMMA, total n = 1 (live)), blotched tiger salamander (AMMV, total n = 15, (2 live), Western toad (ANBO, total n = 3, (1 live), Pacific treefrog (PSRE, total n = 427, (148 live), Great Basin spadefoot (SPIN, total n = 3542, (1894 live)), and Unidentifiable amphibians (UnID, total n = 63, (0 live).

Table 3. Species incidence comparisons among years, south Okanagan survey area, 2010-2012.

Species		**2010**	**2011**	**2012**
Great Basin Spadefoot	Mean ± SD	21.7 ± 24.5	11.2 ± 12.9	11.9 ± 14.9
	N individuals	1556	1368	618
	2 sample Wilcoxon, *W*	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
		2230.5*	1605, ns	1038.5*
Pacific Treefrog	Mean ± SD	3.3 ± 5.1	9.4 ± 14.1	3.6 ± 5.4
	N individuals	88	247	92
	2 sample Wilcoxon, *W*	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
		233.5*	219, ns	319, ns
Blotched Tiger Salamander	Mean ± SD	1.4 ± 0.8	1.7 ± 1.2	0
	N individuals	10	5	0
	2 sample Wilcoxon, *W*	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
		11.5, ns	9, ns	21*

$p < 0.05$*, $p < 0.01$ **, $p < 0.001$***

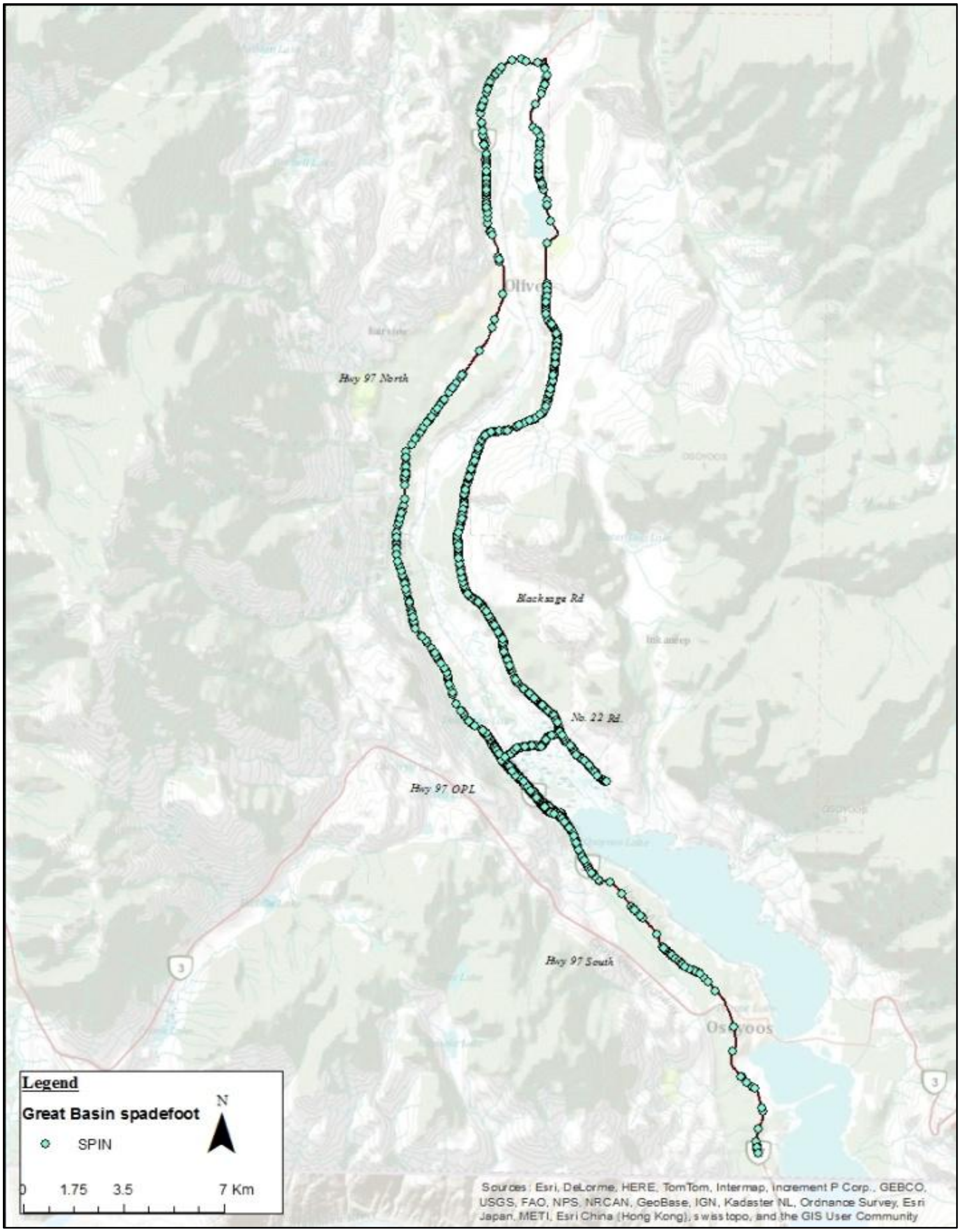


Figure 8. Great Basin spadefoot road occurrence map over entire south Okanagan survey area (52.1 km).

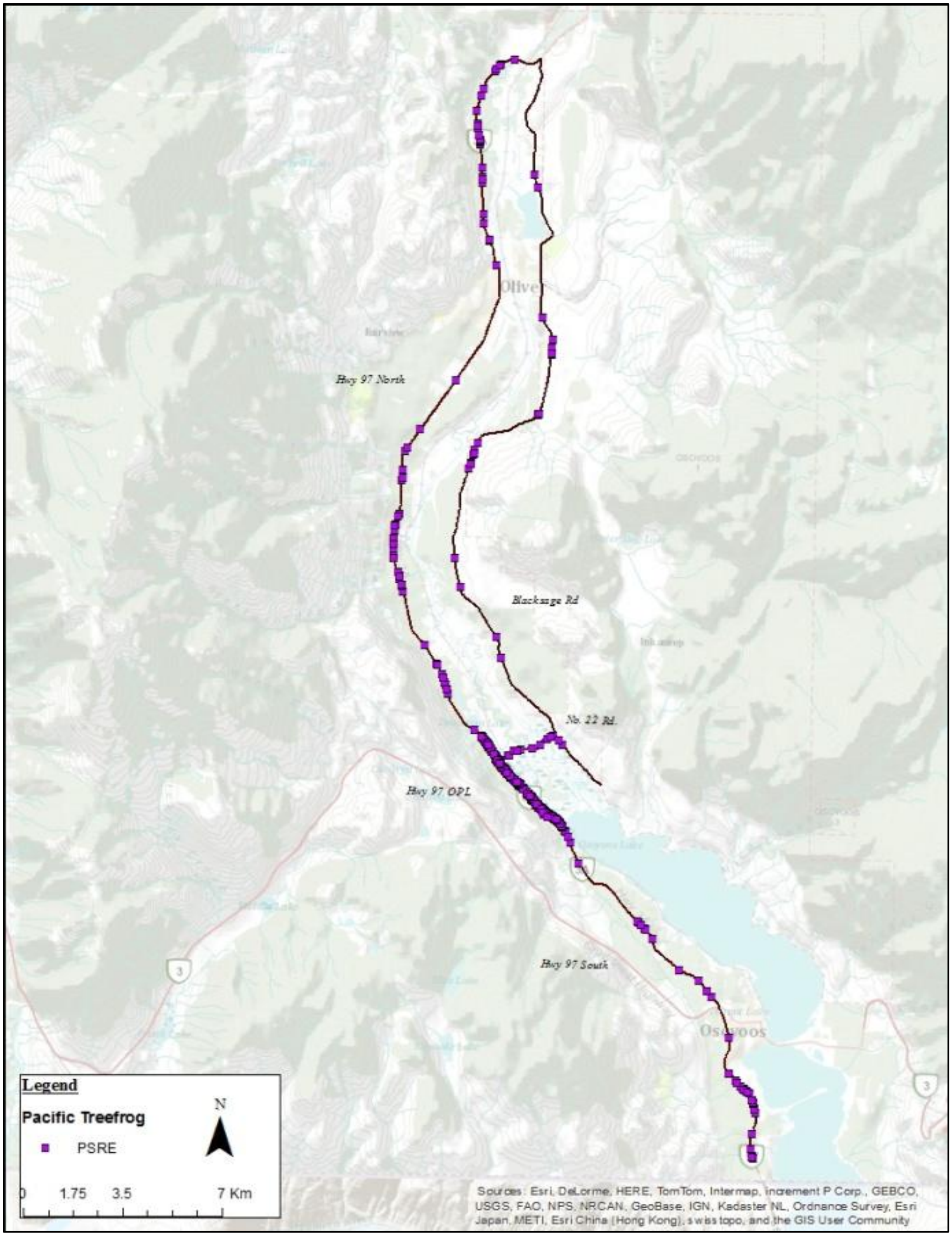


Figure 9. Pacific treefrog road occurrence map over entire south Okanagan survey area (52.1 km).

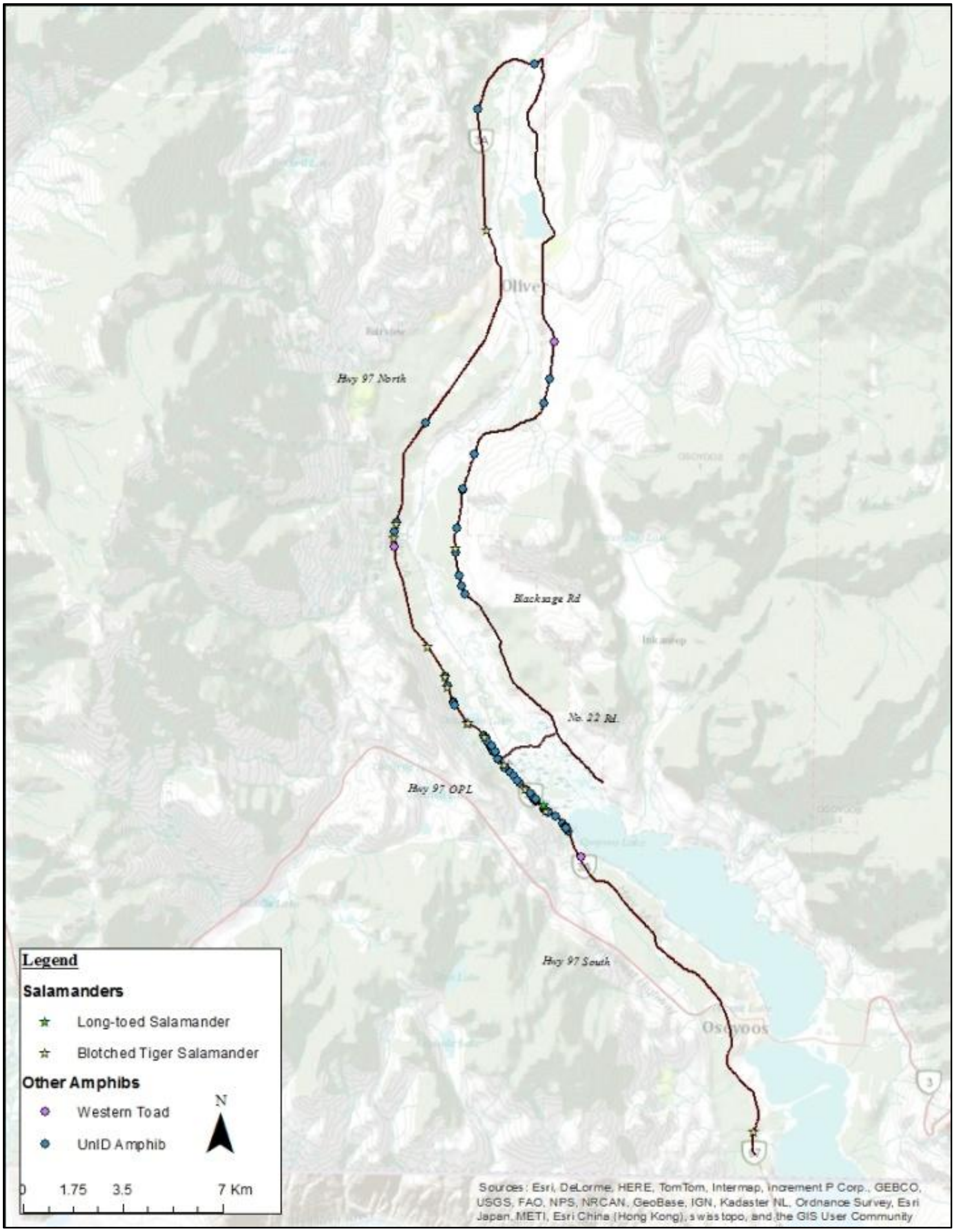


Figure 10. Long-toed salamander, blotched tiger salamander, Western toad, and unidentifiable amphibian road occurrence map over the entire south Okanagan survey area (52.1 km).

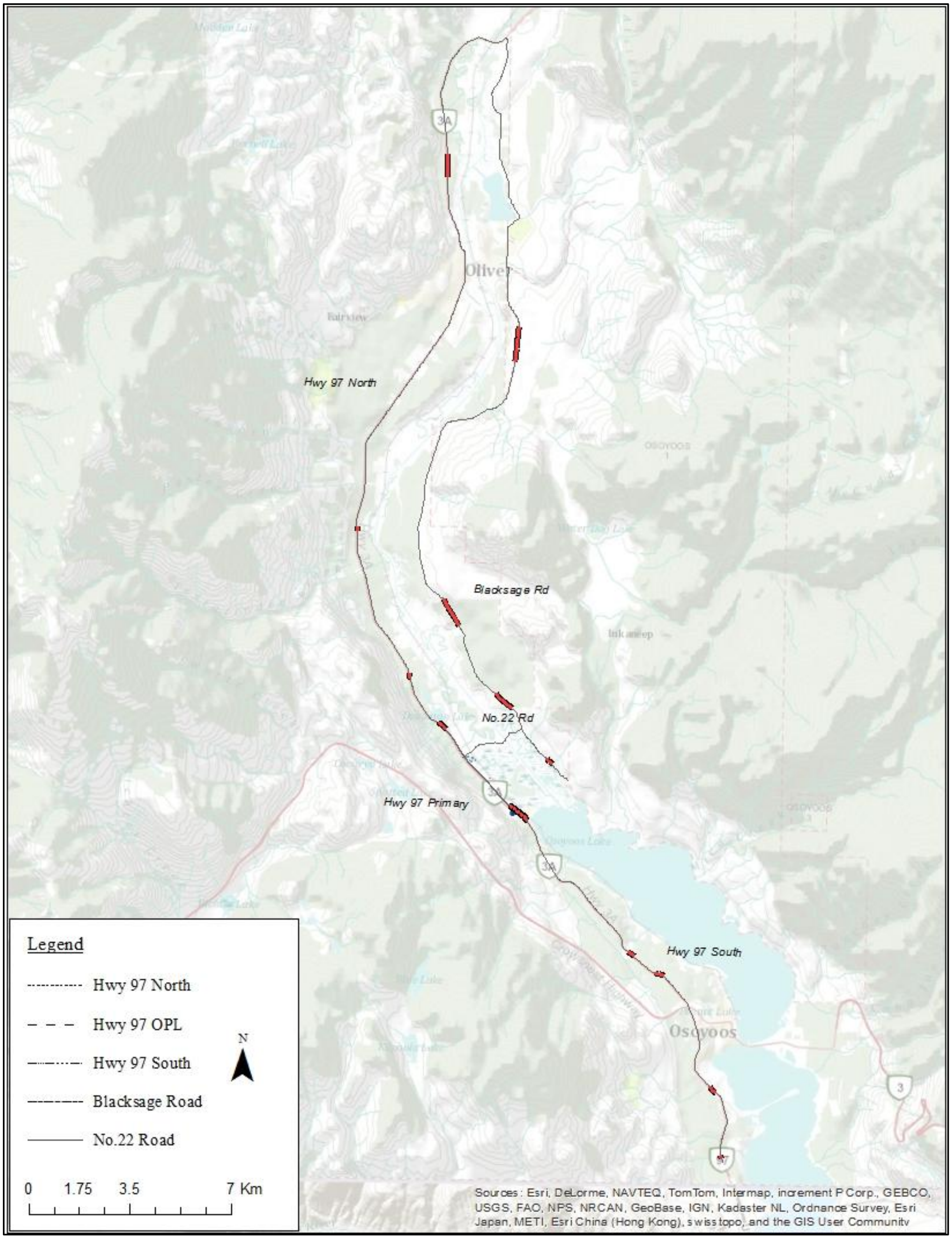


Figure 11. Amphibian occurrence hotspots; entire south Okanagan survey route, all years 2010-2012 (z-score ≥ 1.96, $p < 0.05$).

Table 4. South Okanagan Amphibian Road Occurrence Hotspots (2010 – 2012) with distance to the nearest permanent wetland (m).

Transect	Proportion Length (m)	Hotspot Clusters	Total Length (m)	Total Amph Count	Amph Count $\bar{x} \pm SD$	Gi z-score $\bar{x} \pm SD$	*p*-value $\bar{x} \pm SD$	Nearest wetland (m) $\bar{x} \pm SD$ (max, min)
Hwy 97 OPL	100	1	500	1006	201.2 ± 98.4	3.3 ± 1.1	0.009 ± 0.02	45
	50	1	400	918	114.8 ± 55.4	3.7 ± 1.7	0.01 ± 0.01	45
Hwy 97 North	100	7	900	90	10 ± 7.8	3.7 ± 1.4	0.007 ±0.01	410.9 ± 430.1 (980, 30)
	50	5	1250	133	5.3 ± 3.2	3.6 ± 1.9	0.01 ± 0.02	278.2 ± 396.3 (975, 30)
Hwy 97 South	100	7	700	26	3.7 ± 1.5	2.2 ± 0.2	0.03 ± 0.01	276.7 ± 241.9 (788, 67)
	50	9	650	24	1.8 ± 1.1	2.3 ± 0.4	0.03 ± 0.01	345.2 ± 281.2 (830, 67)
Blacksage Road	100	4	2200	347	15.8 ± 5.8	3.3 ± 0.8	0.006 ± 0.01	213.75 ± 186.3 (430, 30)
	50	4	1950	320	8.2 ± 3.5	3.3 ± 1.1	0.008 ± 0.01	213.75 ± 186.3 (430, 30)
No. 22 Rd.	100	0	0	na	na	na	na	na
	50	1	150	34	11.3 ± 7.6	2.3 ± 0.2	0.02 ± 0.01	140

Peak mean amphibian occurrence, 2010-2012

Pacific treefrog peak mean occurrence, during the combined 2010 - 2012 survey seasons, was observed during the first week of May ($\bar{x}$ = 54.7 ± 57, n = 165). Blotched tiger salamanders were at their peak occurrence during the same week ($\bar{x}$ = 2 ± 1.7, n = 6). Great Basin spadefoot adults were most represented during May 23 - 31 ($\bar{x}$ = 163 ± 123.4, n = 489); May 16 - 22 is also significant in occurrences ($\bar{x}$ = 148.3 ± 110, n = 445). Metamorph incidence occurred during the last week of June and the first two weeks of July (Figure 12). Mean peak metamorph occurrence among the combined survey years was between June 23 - 30 ($\bar{x}$ = 201.7 ± 185.9, n = 605) (Figure 5). Western toad and long-toed salamander occurrences were too rare to be comparable in this temporal analysis.

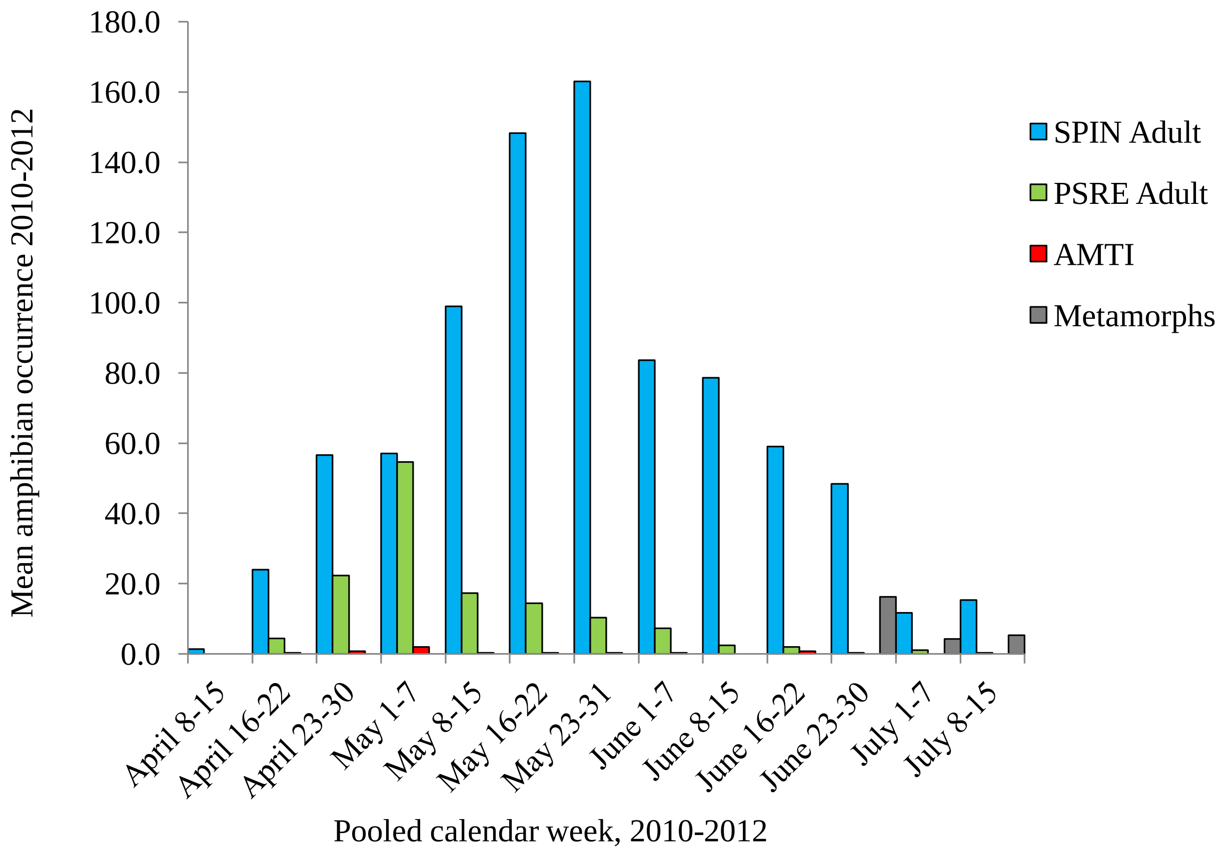


Figure 12. Average amphibian occurrence per calendar week, all years pooled (2010-2012), over the entire south Okanagan survey route: Great Basin spadefoot adult, Pacific treefrog adult, blotched tiger salamander individuals (juveniles and adults), and spadefoot/treefrog metamorph emigration occurrence.

Precipitation events and amphibian occurrence

Incidents of amphibian roadway movements, throughout all survey transect combined were observed for whether they were dependent on the presence or absence of precipitation events within 12 hours of the survey, between years. In 2010 and 2012, there were positive relationships between amphibian road presence and precipitation events ($\chi^2_{(1)} = 4.15$, $p = 0.04$ and $\chi^2_{(1)} = 7.53$, $p = 0.006$). In 2011, there was no evidence of an association between amphibian occurrence and precipitation ($\chi^2_{(1)} = 1.99$, $p = 0.16$).

Climatic variables and amphibian occurrence

Of all the climatic events recorded (moon phase, precipitation severity, wind severity, cloud cover, and air temperature), precipitation and temperature were significant indicators of amphibian occurrence among all transect areas (Hwy97 OPL_{Precip} $p= 0.01$, Hwy97 OPL_{Temp} $p= 0.02$, $F= 0.004$; Hwy97 $N\&S_{Precip}$ $p=3.58e^{-08}$, Hwy97 $N\&S_{Temp}$ $p= 0.0004$, $F= 2.61e\text{-}^{09}$; $BS/R22_{Precip}$ $p= 1.8e^{-10}$, $BS/R22_{Temp}$ $p= 0.0002$, $F= 2.95e^{-12}$). Along the Blacksage/No. 22 Rd transect, moon phase and wind incidence were also significant ($BS/R22_{Moon}$ $p= 0.002$, $BS/R22_{Wind}$ $p= 0.01$).

Direction of species travel & vehicles per hour

Live amphibian direction of travel was most determinant along Blacksage Road, while Highway 97 showed significant differences in eastward versus westward travelling adult amphibians. The No. 22 Rd was omitted from this analysis because it is hard to determine whether the daily movements are among resources or migration travel as this road transect is surrounded by wetlands (Table 5).

Table 5. Adult amphibian direction of travel: perpendicular to the roadways (eastward, westward, E vs. W) and parallel (northbound/southbound) along Highway 97 and Blacksage Road, all years pooled (2010 - 2012).

Adult Amphibian Direction of Travel	**Highway 97**	**Blacksage Road**
Eastward vs. Westward	W = 1065.5*	W = 835*
Eastward	$\bar{x}_{East}$ = 3.5 ± 4.2, n = 194	$\bar{x}_{East}$ = 3.4 ± 3.2, n = 155
Westward	$\bar{x}_{West}$ = 2.0 ± 1.5 , n = 101	$\bar{x}_{West}$ = 5.5 ± 5.6 , n = 276
E/W vs. N/S	W = 2742, ns	W = 176.5***
E/W	$\bar{x}_{East\mathit{West}}$ = 5.4 ± 4.6, n = 295	$\bar{x}_{East\mathit{West}}$ = 8.6 ± 7.7, n = 431
N/S	$\bar{x}_{N/S}$ = 7.8 ± 10.8, n = 690	$\bar{x}_{N/S}$ = 2.6 ± 2.2, n = 65

$p < 0.05$*, $p < 0.01$**, $p < 0.001$***

Traffic was recorded during all road transect surveys (Table 6) and compared with the amount of amphibian mortalities found per road transect per year (Table 7).

Table 6. South Okanagan traffic rate per hour for each roadway transect route, recorded during all amphibian road surveys (2010-2012). Traffic rate within road transects compared between years with 2 sample Wilcoxon$_{0.05}$ test.

Section		**2010**	**2011**	**2012**
Hwy 97 OPL	Mean vehicles/hr	67.5 ± 48.9	61.2 ± 33.1	41.6 ± 19.4
	Min vehicles/hr	0	8.8	0
	Max vehicles/hr	256.7	1028.2	342.9
	2 sample Wilcoxon	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
	Vehicles/hr	*W* (46) = 1703, ns	*W* (45) = 1074.5***	*W* (45) = 1703**
Hwy 97 North & South	Mean vehicles/hr	48.8 ± 38.1	36.7 ± 29.3	53.2 ± 35.8
	Min vehicles/hr	4.4	3.9	6.6
	Max vehicles/hr	162.9	132	144
	2 sample Wilcoxon	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
	Vehicles/hr	*W* (39) = 1180, ns	*W* (33) = 1083.5*	*W* (33) = 701, ns
Blacksage Rd/ No. 22 Rd	Mean vehicles/hr	6.3 ± 7.1	4.6 ± 5.5	5.2 ± 6.6
	Min vehicles/hr	0	0	0
	Max vehicles/hr	60	25.7	43.2
	2 sample Wilcoxon	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**
	Vehicles/hr	*W* (39) = 1605, ns	*W* (53) = 1918.5, ns	*W* (39) = 1156, ns

$p < 0.05$*, $p < 0.01$**, $p < 0.0001$***

Table 7. South Okanagan amphibian mortalities (DOR- Dead on Road) and traffic volume during all road surveys, 2010-2012; Generalized linear model regression between years DOR and traffic per transect, and amphibian mortalities between years (2 sample Wilcoxon$_{0.05}$ test).

Section		2010	2011	2012	All years, $\bar{x}$
Hwy 97 OPL	Total Traffic	4416	5721	4314	4817
	Total DOR	627	368	104	367
	DOR/Vehicle	0.14	0.06	0.02	0.08
	GLM DOR/Traffic coef				0.0004***
	2 sample Wilcoxon test	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**	
	Amphibian mortalities	W= 2344.5**	W = 1532.5, ns	W= 1535.5***	
	Mean ± SD	$\bar{x}_{2010}$= 13.2 ± 32.5	$\bar{x}_{2011}$= 4.7 ± 12.8	$\bar{x}_{2012}$= 2.3 ± 7.3	
Hwy 97 North & South	Total Traffic	3014	2367	1860	2413.7
	Total DOR	191	198	30	139.7
	DOR/Vehicle	0.06	0.08	0.02	0.05
	GLM DOR/Traffic coef				0.007***
	2 sample Wilcoxon test Hwy 97 North	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**	
	Amphibian mortalities	W = 329.5, ns	W = 206.5, ns	W = 143.5, ns	
	Mean ± SD	$\bar{x}_{2010}$= 7.7 ± 12.9	$\bar{x}_{2011}$= 1.6 ± 4.2	$\bar{x}_{2012}$= 0.6 ± 1.5	
	2 sample Wilcoxon test Hwy 97 South	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**	
	Amphibian mortalities	W = 359, ns	W = 251, ns	W = 179.5, ns	
	Mean ± SD	$\bar{x}_{2010}$= 1.2 ± 2.2	$\bar{x}_{2011}$= 1.6 ± 4.2	$\bar{x}_{2012}$= 0.6 ± 1.5	
Blacksage Rd/ No. 22 Rd	Total Traffic	305	390	363	352.7
	Total DOR	239	161	85	161.7
	DOR/Vehicle	0.78	0.41	0.23	0.48
	GLM DOR/Traffic coef				0.05***
	2 sample Wilcoxon test	**2010 vs. 2011**	**2011 vs. 2012**	**2010 vs. 2012**	
	Amphibian mortalities	W = 1825.5, ns	W = 1926.5, ns	W= 1328*	
	Mean ± SD	$\bar{x}_{2010}$= 5.8 ± 11.8	$\bar{x}_{2011}$= 2.1 ± 4.9	$\bar{x}_{2012}$= 1.60 ± 3.2	

$p < 0.05$*, $p < 0.01$**, $p < 0.0001$***

Amphibian road occurrence pre- and post construction: fenced and bare sections

Sections of fencing vary in length along the 3.7 km passing transect with sections devoid of fencing, sections covered by fencing on only one side of the roadway, and fencing on both sides of the highway. In 2010, the future double fenced areas had the most amphibian occurrence. In 2012, the single fenced area had the most amphibian occurrences per section; however total percent occurrences per section (total % area) resulted in the bare area with marginally more amphibians/ m (Table 8 and 9; Figure 13 and 14).

Table 8. Osoyoos passing lanes amphibian occurrence (Highway 97 side only), highway sections with double fencing, single fencing, and bare sections.

Year	Double Fencing	Single Fencing	Bare Sections	Total
2010				
Area with amphibs (m)	94	83	99	276
% Total occupied area	9.6	9.1	7.9	8.8
# Individuals	318	259	313	890
$\bar{x}$ amphibs / m occupied areas	3.38 ± 2.95	3.12 ± 2.63	3.16 ± 2.92	3.22 ± 2.84
$\bar{x}$ amphibs/ m per total area	0.33 ± 1.35	0.28 ± 1.19	0.25 ± 1.19	0.28 ± 1.24
2012				
Area with amphibs (m)	14	46	66	149
% Total occupied area	1.4	5.0	5.3	4.7
# Individuals	17	118	106	282
$\bar{x}$ amphibs / m occupied areas	1.21 ± 0.58	2.57 ± 2.33	1.61 ± 0.93	1.89 ± 1.31
$\bar{x}$ amphibs / m per total area	0.02 ± 0.17	0.13 ± 0.76	0.08 ± 0.42	0.09 ± 0.5
Total Length (m)	981	917	1252	3150
Paired Wilcoxon between years (*V*)	372.5***	2360***	3931***	17941.5***

p <0.001***

During the 2011 transition year, polymer fencing was installed late into the survey season with partial sections back filled; seventeen individuals were found on the habitat side of the fencing during this transition. Three hundred and forty-two metamorph individuals were found along the habitat side of the 300 m concrete barrier at the south end of the passing lanes.

In 2012, I observed no major metamorph emigration up to the highway as in 2010 and 2011. Seventy seven amphibians were observed along the habitat side of the polymer fencing and concrete barrier throughout the survey season. Thirty-three amphibian adults were observed moving along the highway side of the concrete barrier.

Table 9. Amphibian species occurrence within bare, partially and fully fenced sections of the Highway 97 Osoyoos passing lanes transect by year (2010 – 2012).

Species	Fence Section	2010 (No Fencing)	2011 (Partial Fencing)	2012 (Fencing Installed)	2010 - 2012 % Change
Great Basin spadefoot	Bare	271	89	91	-66.4
	Single Fence	281	108	59	-79
	Double Fence	364	206	38	-89.6
Pacific treefrog	Bare	12	50	22	(+) 83.3
	Single Fence	22	40	22	0
	Double Fence	21	68	17	-19.1
Blotched tiger salamander	Bare	1	1	0	-100
	Single Fence	0	0	0	0
	Double Fence	2	1	0	-200
Unidentifiable amphibian	Bare	8	1	0	-800
	Single Fence	0	1	0	0
	Double Fence	0	0	0	0

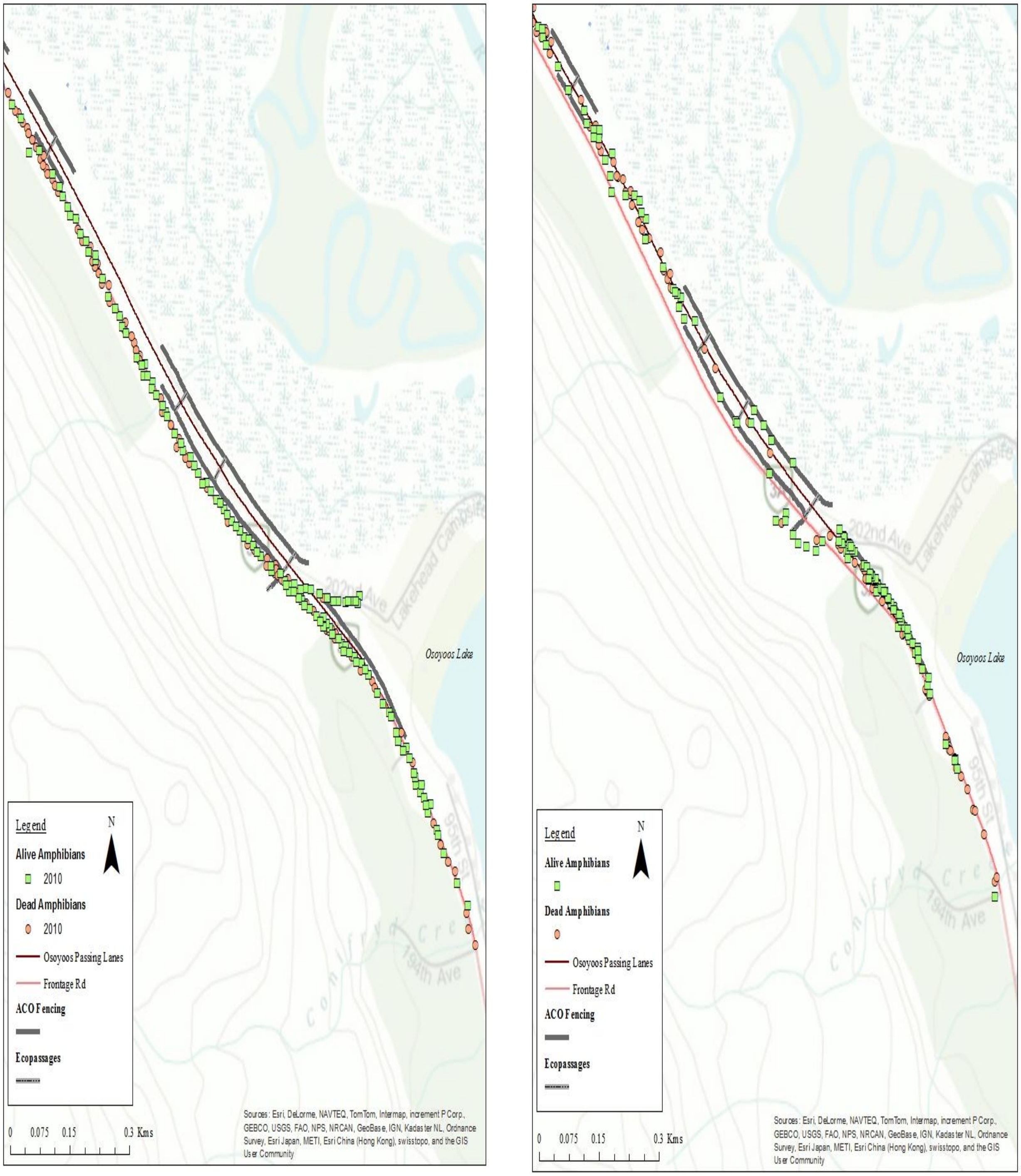
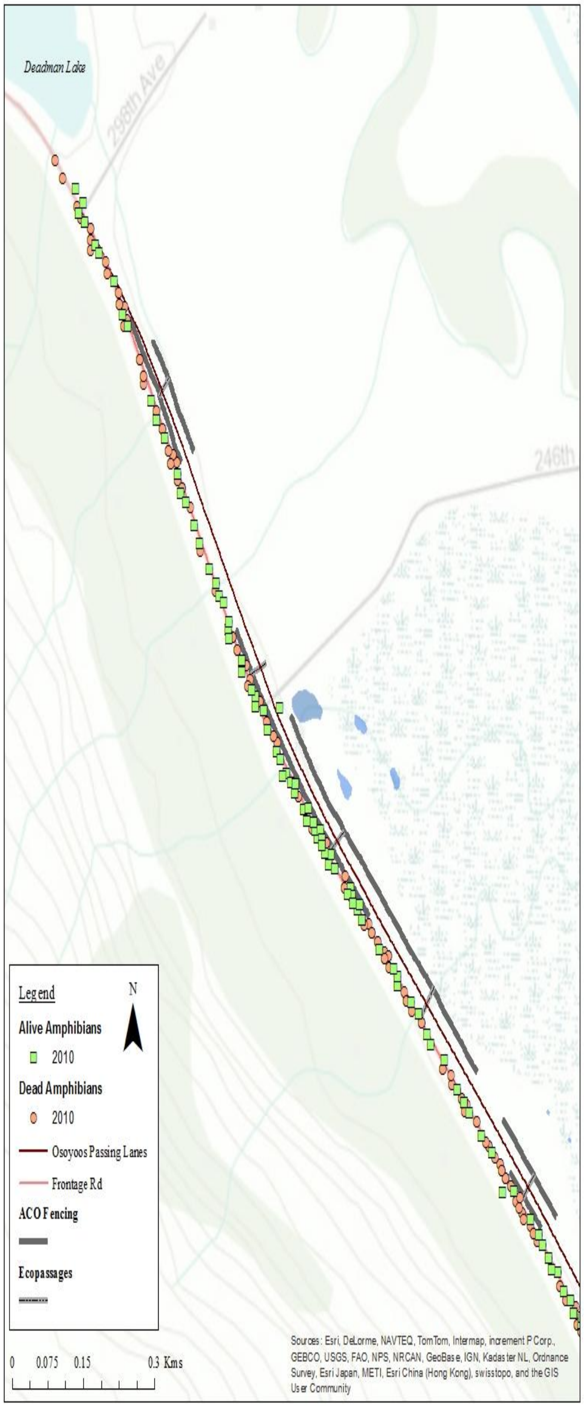


Figure 13. Hwy 97 Osoyoos passing lanes amphibian occurrence north section 2010 and 2012: live individuals (green) and mortalities (pink). 2012 fence line and culverts shown for comparison with 2010 baseline data consulted for mitigation placement.



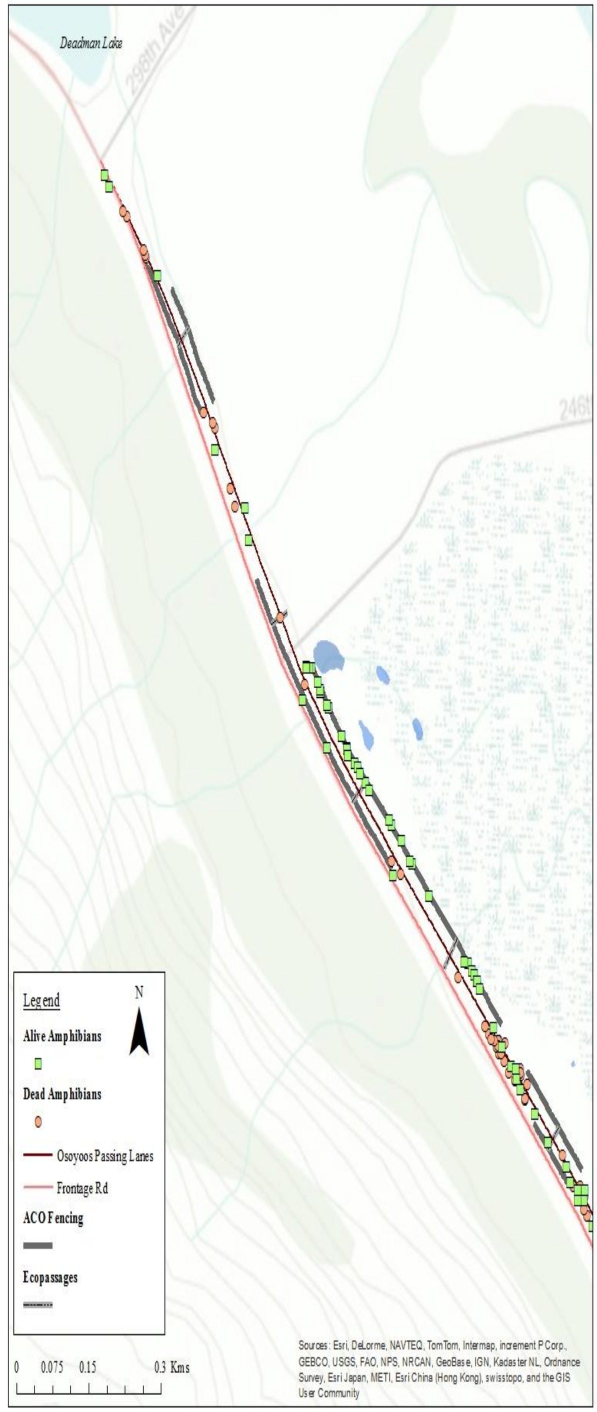


Figure 14. Hwy 97 Osoyoos passing lanes amphibian occurrence south section 2010 and 2012: live individuals (green) and mortalities (pink). 2012 fence line and culverts shown for comparison with 2010 baseline data consulted for mitigation placement.

Camera Trap Amphibian Culvert Observances, 2011 & 2012

Greater amphibian incidence was found within the observed culverts in 2012 (Table 7). Comparisons of amphibian occurrence on the Hwy 97 transect and within the observed culverts were significantly different in favour of culvert occurrence in 2012 during the same survey nights (Table 10 -12; Figures 16 and 17). Amphibians occurring in the culverts were Great Basin spadefoots (n_{2011}= 345, n_{2012}= 473), Pacific treefrogs (n_{2011}= 4, n_{2012}= 4), and blotched tiger salamanders (n_{2011}= 3, n_{2012}= 0) (Figure 15).

Table 10. Number of amphibian occurrences by photo capture 2011 and 2012: 204 avenue, Ponds, and Frontage road culverts: Highway 97 Osoyoos passing lanes area.

Culvert Camera	**2011**	**2012**
204 ave East	190	52
204 ave West	84	82
Ponds East	28	253
Ponds West	18	90
Frontage rd East	23	No camera
Frontage rd West	9	No camera
Total	**352**	**477**
Survey Nights	70	84
$\bar{x}$ amphibians / night	4.6	5.6
Photos	141, 448	170, 321

Figure 15. Great Basin spadefoot adult captured by time lapse photography Reconyx RC55 Rapidfire camera trap on east side of the Ponds culvert (2011).

Table 11. Highway 97 OPL transect amphibian occurrence and culvert camera trap amphibian occurrence during same survey nights, 2011(during fencing construction) and 2012 (post mitigation construction).

Monitoring Dates	**Survey Nights**	**Highway Occurrence**	**Culvert Occurrence**	**Paired Wilcoxon$_{0.05}$**
2011 (May 14-Jul 13)	58	$\bar{x}$ = 13.4 ± 36.5, n= 776	$\bar{x}$ = 6.1 ± 15.1, n = 352	V = 447.5, ns
2012 (Apr 28- Jul 13)	72	$\bar{x}$ = 2.5 ± 6.6, n = 183	$\bar{x}$ = 6.6 ± 7.4, n = 477	V = 371***

$p < 0.001$ ***

Prior to the cameras being installed, I observed 179 amphibians on the highway during April 15-May 13, 2011. 2012 road surveys prior to camera installation (Apr. 19 - 27) only resulted in an additional 96 individuals.

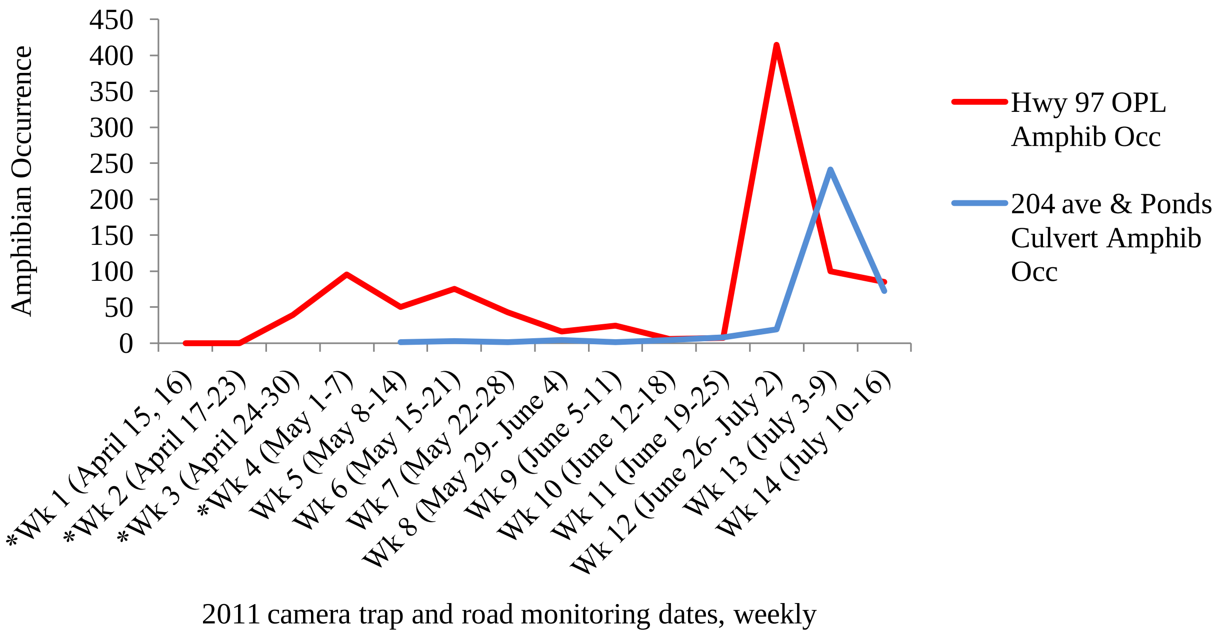


Figure 16. 2011 total amphibian occurrence comparison between weeks during road surveys while having camera surveillance in culverts; Hwy 97 Osoyoos passing lanes transect occurrence (red), and Ponds and 204 avenue culvert camera trap occurrence (blue). Starred weeks are road survey only.

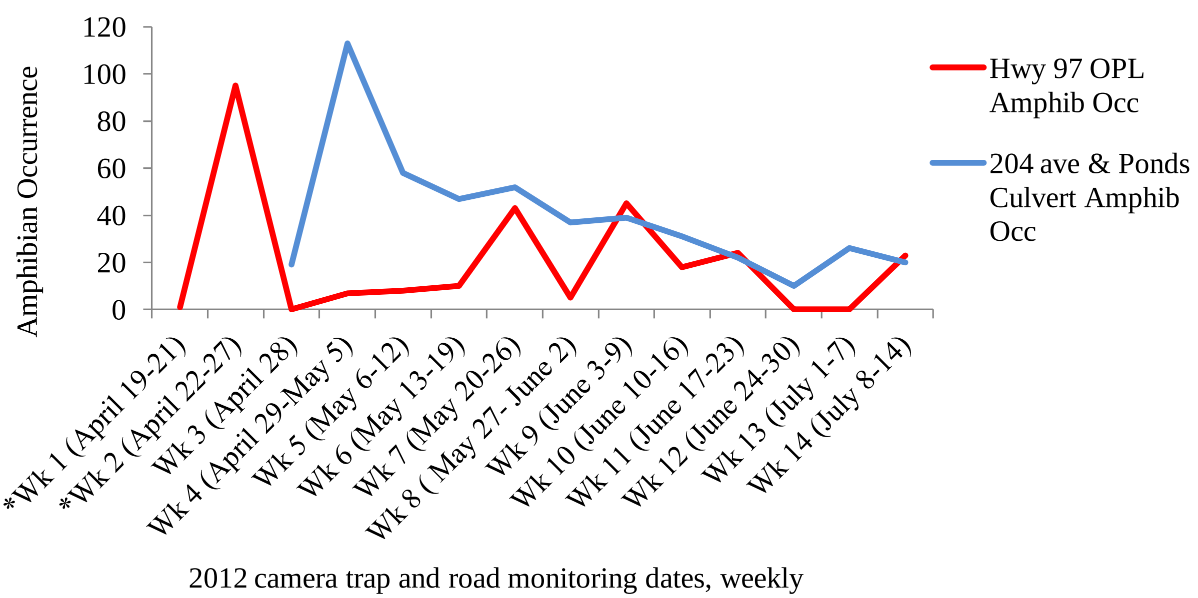


Figure 17. 2012 total amphibian occurrence comparison between weeks during road surveys while having camera surveillance in culverts; Hwy 97 Osoyoos passing lanes transect occurrence (red), and Ponds and 204 avenue culvert camera trap occurrence (blue). Starred weeks are road survey only.

Amphibian culvert occurrence versus surrounding road occurrence

Table 12. Amphibian occurrence within 50 m and 100 m each northbound and southbound from camera-trap monitored culvert openings. Culvert camera trap photo occurrence over entire survey period included for comparison within culvert area**.**

Year	Culvert	Distance From Culvert	Direction From Culvert	Dead	Alive	Total Hwy Amphibs	Amphibs Along Fence	Total Amphib Photo Occurrence
2010	204 Ave	≤ 50 m	South	24	7	31	NA	No Cameras
			North	31	4	35	NA	
		≤ 100 m	South	57	13	70	NA	
			North	41	7	48	NA	
2011	204 Ave	≤ 50 m	South	6	1	7	3	274
			North	19	3	22	12	
		≤ 100 m	South	10	5	15	3	
			North	40	7	47	12	
2012	204 Ave	≤ 50 m	South	0	0	0	0	134
			North	0	0	0	0	
		≤ 100 m	South	3	0	3	0	
			North	0	0	0	0	
2010	Ponds	≤ 50 m	South	1	4	5	NA	No Cameras
			North	12	6	18	NA	
		≤ 100 m	South	6	7	13	NA	
			North	19	12	31	NA	
2011	Ponds	≤ 50 m	South	3	3	6	4	46
			North	2	2	4	1	
		≤ 100 m	South	4	4	8	5	
			North	2	3	5	2	
2012	Ponds	≤ 50 m	South	0	0	0	0	343
			North	0	2	2	2	
		≤ 100 m	South	0	1	1	1	
			North	0	8	8	8	

*frontage road cameras captured 32 amphibian occurrences in 2011

DISCUSSION

The extent to which roads and traffic within the south Okanagan impact amphibians was investigated through rigorous surveying throughout the 52.1 km study area, whilst also concentrating with the construction-affected Highway 97 OPL transect. The data collected throughout has provided essential information on amphibian demographics, and spatial and temporal trends of road occurring amphibians within the south Okanagan during the amphibian spring and summer breeding and foraging movements. Concerns over negative road effects on at-risk amphibian species are warranted; Great Basin spadefoot represented 87.4% of the amphibians found on the roadways with a 46.5% mortality rate overall. Of the recorded blotched tiger salamanders, the mortality rate was 86.7% between three field seasons. Hotspot occurrence analysis has provided valuable information for future road mortality mitigation or other development management decisions. Roadkill mitigation structures within the passing lanes area proved effective in increased amphibian culvert occurrence during the structure transition in 2011, and after construction and mitigation project completion in 2012.

Occurrence and mortality trends between road transects

Occurrence trends among years were dissimilar between the Highway 97 OPL and the secondary control transects. Total amphibian occurrence was significantly higher within the Highway 97 transect than in the surrounding highway transects and along secondary transects. Most likely this is due to the expanse floodplain and wetland breeding habitats adjacent to the 3.7 km highway passing lanes transect (COSEWIC, 2007).

Among the control transects, the Blacksage Road and the No.22 Rd transect had a much greater incidence of observed amphibians than the Highway 97 north and south transects. This transect was on the opposite side of the Osoyoos River channel than the Highway 97 transects, with slower speed limits and significantly less traffic. Haynes Lease Ecological Reserve is within the transect area, totaling 101 ha at the North end of Osoyoos Lake. The reserve is a development restricted area providing valuable habitat for amphibians (BC Parks, 2013).

Total roadway amphibian occurrences between years within the Highway 97 OPL transect revealed significant differences between 2010 and 2012. There was no significant difference amongst years within the control transects. Since the difference was only within the passing lanes area and not among the highway transects north or south of it, the effects may be from the post mitigation structure monitoring in 2012. However, there may also be residual negative effects from the construction of the four lane passing lane in 2010 and into 2011. The construction directly affected 77 ha of habitat (Hemmera, 2010), decreasing the amount of habitat between breeding wetlands and the highway. Construction crew members cited observing amphibians while they were digging up the soil, as well as placing some disturbed amphibians and reptiles into the culverts as refuge (Rick Matthews, pers comm., 2011).

Driving surveys are often less effective for amphibian abundance data than walking surveys due to the combination of surveying at higher speeds and the small body size of the amphibians. The detection biases in these studies (Sillero, 2008; Gerow et al., 2010; Langen et al., 2007) however, were based on driving up to 46 km/ hr. For the present study, walking the entire survey route was not a practical option. Driving at 20 km/ hr with a spotter was effective in observing amphibians while having a small detection bias for quick moving amphibians at the edge of the pavement. At 20 km/ hr we were able to spot 1 cm (snout to vent length) metamorphs on the road. Anything amphibian-sized on the roadway was stopped and examined; anything questionable was observed. Either way, between carcass persistence rates, scavenging, and survey method, walking and driving surveys only present a guide into the actual happening of amphibian road mortality (Langen et al., 2007; Hels and Buchwald, 2001; Teixeira et al., 2013).

Species incidence

Of the amphibians occurring on the south Okanagan roadways surveyed between 2010 and 2012, Great Basin spadefoot were the most prevalent species on the roads, representing 87 % of the amphibians identified. This is not surprising as the spadefoot population of the Osoyoos oxbows area has been cited as one of the largest in the Okanagan, and has been estimated at approximately 10, 000 individuals within British Columbia (BCSIRART, 2008b; COSEWIC, 2007). Highway 97, Blacksage Road and the Osoyoos River channel fragment the south

Okanagan valley whereby, migrating amphibians are very likely to cross the roadways given the range of their migratory movements and proximity of suitable breeding wetlands to the roads. Spadefoots in British Columbia, for example, have been found to travel from 371 m (Garner, 2012) up to 2350 m (Oaten, 2012). The most Great Basin spadefoot occurrence throughout the entire survey route was in 2010; there was much less occurrence of spadefoots, particularly in 2012 with a 60.3 % reduction in occurrence. This coincides with significantly less amphibian occurrence on the roads in 2012 (58.4% reduction overall).

Pacific treefrogs were the next most represented species at 10.5 % of the recorded amphibians identified to species. Treefrogs and spadefoots were often heard calling in chorus alongside the roads. Pacific treefrogs were most significantly represented on the roads throughout the survey route in 2011. The spring of 2011 was cooler to start than the surrounding years; this may have been the reason why there were more treefrogs observed occurring on the roadways. Treefrogs are triggered to begin their breeding migrations during rains between 5-10 ^{o}C in western Oregon and Washington (Nussbaum et al., 1983).

Blotched tiger salamanders were most represented in 2010 and made up 0.4% of the amphibian occurrence over all years. Adult tiger salamanders may make their migrational movements earlier in the spring (e.g. March) prior to when I started surveying in mid-April (COSEWIC, 2012). Incidence rate was expected to be low for the seasonality and the rare designation of blotched tiger salamanders. Amphibians may stay dormant for prolonged periods if the conditions are not suitable breeding or foraging conditions (Seymour, 1973 as cited in COSEWIC 2007). Tiger salamanders generally require warm, wet nights with temperatures over 12 ^{o}C (COSEWIC, 2012).

During the survey periods, only 3 western toads and 1 long-toed salamander were recorded. Low rates of western toad and long-toed salamander occurrences coincide with expected observations, as they are commonly infrequent throughout the survey area due to the habitat. Between 2003 and 2006, Ashpole et al., (2006) observed 108 ponds throughout the south Okanagan, with western toads at only 3 % of the sites while spadefoots were observed at 47 %, treefrogs at 54 %, and tiger salamanders at 15 % of the observed ponds. Columbia spotted frogs (*Rana luteiventris*) were recorded in a wetland near Oliver in years previous (S. Ashpole, unpublished data), however, none were observed on the roads in this present study.

The lower road incidence of dead treefrogs and younger stage spadefoots could be due to the low persistence of their small, delicate carcasses. Vehicle tires have been observed picking up carcasses in their tracks or decimating remains (Langen et al., 2007; Sillero, 2008). During metamorph movements, in late June and early July, effort was concentrated on live individuals while traffic volumes remained high. Metamorph carcasses did not persist under heavy traffic volume and rain conditions. The majority of amphibians found dead on the road were recent mortalities. Any mortality events that occurred post survey were very rarely found during the next survey event. Besides vehicle annihilation of carcasses, anything left would be available to the scavengers. There were many early mornings where crows were seen scavenging off the road. Slater et al. (1985) found that 179 common toad (*Bufo bufo*) corpses counted at dawn all had been removed by scavengers by 0830 hrs. In southwest Wyoming, trials of simulated snake carcasses (filleted burbot (*Lota lota)*) along paved roads resulted in 78% of the specimens scavenged within 60 hours; 44% of the total specimens disappeared during the night (Hubbard and Chalfoun, 2012). With regards to the present study, scavenging could therefore present a bias in the amount of observed and recorded amphibians on the road versus the actual amount of amphibian mortalities.

Temporal and abiotic trends

Annually, on average, Pacific treefrogs and blotched tiger salamanders occurred in greater abundance earlier in the spring than Great Basin spadefoot by a five week span. Movement phonology may be derived from their differing breeding periods, and that spadefoots emerge from deep in the ground when enough heat energy and moisture are present (BCSIRART, 2008a, b).

Warmer air temperature, rain events and corresponding cloud cover were the overall indicators of amphibian occurrence on the roads between all years. Amphibians are prone to desiccation, and as such have often been observed migrating on wet, rainy nights (Langen, 2007). Upon further analysis of the presence or absence of precipitation within the 12 hours prior to road surveys, there were positive correlations in 2010 and 2012 between occurrence and rain events. Seasonal variation in weather and breeding cycles are important factors in amphibian occurrence assessments. Langen et al. (2007) found amphibian road occurrence and consequent mortality was highest on rainy nights. Due to the agricultural landscape surrounding the roadways, it is difficult to quantify the effects of farmers watering their crops more in drought conditions (as in 2011). This form of moisture may encourage amphibian movement even on otherwise dry nights, including the inundation of agricultural ephemeral ponds (Ashpole at al., 2013).

Direction of travel

In comparisons of perpendicular movement with regards to the roadway (representing a definite crossing of the road instead of random movement patterns) significantly more adult amphibians headed towards wetlands than away. Of those travelling in an eastward or westward direction, there was a positive trend for eastward individuals along the highway; where east was the direction of breeding habitat.

There was no significant difference between perpendicular and parallel movements along Highway 97. The orientation to facing oncoming traffic may be a reaction to the headlights, which was observed more on the highway than the quieter Blacksage Road. The reaction to face and freeze in headlights may also explain why the majority of directional observations of amphibians crossing the highway were in a northern or southern direction instead of east or west.

Alternatively, there was a large significant difference between perpendicular and parallel movement on Blacksage Road. Given that Blacksage Road has far less traffic on it and is only 2 lanes, the amphibians perhaps may orientate easier to the wetlands as there is less headlight and noise pollution.

Amphibian mortality trends among transects and between years

Only within the Highway 97 OPL transect were comparisons between amphibian mortalities between years, as well as total occurrence significantly different. There was a significant difference between the amount of amphibians found dead on the road between 2010 and 2012, as well as significant differences in total occurrence among those years. Mean amphibian occurrences revealed much less incidence in 2012 than 2010 which coincides with fewer deaths. Fewer amphibians may have occurred along Highway 97 OPL in 2012 due to mitigative fencing and culvert structures erected prior to the 2012 field season. There was also significantly less traffic per hour in 2012 versus 2010, which may account for less mortality. Reh and Seitz (1990) observed that anuran populations can be decimated by fairly low volumes of traffic. However, adult and juvenile Pacific treefrogs moved a lot quicker across the roadways than adult and juvenile spadefoots; their agility sometimes creating a larger problem as they would jump into oncoming vehicles, instead of remaining still as the vehicles passed over them. Spadefoots were observed to be slower to cross the roads, often freezing in traffic headlights. Use of the paved surfaces for thermoregulation and absorption of water pooled on the pavement were observed as a contributing factor to mortalities, as in other studies (Dodd, 1989; Hodson, 1962).

Relationship between amphibians found dead on the road and traffic frequency

Along all Highway 97 transects, vehicles per hour were significantly different between 2011 and 2012; the Hwy 97 OPL transect was also significantly different in 2010 compared to 2012. There were significantly less vehicles/ hour in 2012. This variance in traffic incidence is dependent, in part, to different community events going on in Oliver and Osoyoos annually. Consideration of what section of the road was being surveyed when those events took place or what time of the night the traffic was recorded is also important.

Traffic volume was recorded at the same time as amphibian road surveys, so the amount of amphibians found DOR is comparable between years. The amount of amphibians found dead on the road per vehicle declined over the three years, which coincides with the culvert and fencing mitigation structures being erected along Highway 97, as well as less traffic on the road.

There was no significant difference in amphibian mortalities per vehicle between years within the Blacksage Road and the No.22 road transects. This is likely due to more of a uniform variance in night time road travel along these secondary, residential roads.

Higher incidence of amphibian mortalities per vehicle occurred on the Blacksage/No.22 Rd transects since there were comparatively greater amphibian road abundances, even though there were far less mean vehicles per hour. Although the amount of Highway 97 DOR/vehicle is less than the Blacksage/No.22 Rd transect, the effect is substantial along the highway because of the amount of nightly traffic impacting road-occurring amphibians.

Amphibian road occurrence pre- and post construction: fenced and bare sections

In 2012, the single fenced area had the most highway amphibian occurrences per section. There were fewer areas with amphibians per meter in 2012 in the single fenced sections than in the bare sections. However, within the single fenced sections, there were marginally more amphibians overall, exhibiting more of a cluster effect within the occupied areas.

Within the Hwy 97 OPL transect there was a significant difference between pre-mitigation and post mitigation years. The most dramatic effects were in the double fenced areas where the amphibians per meter were reduced by approximately 64 % in total occupied areas, and reduced 94% of the mean amphibians per meter within the entire double fenced area. Single fenced areas went down by 18% in mean amphibians per occupied area, and 54 % mean amphibians per total area in 2012. The bare area had less amphibian occurrence than the single fenced area (49 %, 64 % respectively) in 2012.

One reason why the single fenced area had more occurrences than the bare area may be that the fencing was placed in overall higher amphibian road incidence areas. So it can be expected that in areas with only one barrier along the road there will be higher numbers observed. The single fence may also trap some amphibians unwilling to go over the concave edge of the fence to the habitat side. Alternatively, some of the amphibians may have been able to climb the fencing to get onto the highway. Treefrogs are also great ‘adhesive’ climbers and may have climbed the fence or found areas to climb near the culvert or through gaps. In an experiment forming four types of amphibian fencing material into separate enclosures, a juvenile Pacific treefrog (Pacific chorus frog) and two red-legged frogs (*Rana aurora*) escaped from the ACO polymer fencing enclosure. Pacific treefrogs were also observed climbing on the fencing's vertical support stakes (Beasley, 2014). Malt (2012) also observed red-legged frogs avoiding culverts by climbing fencing to get to the road.

Camera trap amphibian culvert observances, 2011 & 2012

Because the culvert cameras were hung within the culverts facing outward, I could only speculate that the amphibians were travelling through the entire length of the culvert. Indication of commitment to movement was the occurrence of amphibians entering the culvert and passing the cameras, and the amount of time prior to observing none or any amphibians returning from behind the camera. Amphibians that did enter and return within the camera view within minutes of observation were counted as one individual. Within the same night, there were tracks shown coming from behind the cameras to the amphibian captured in the camera photo on the opposite end. Likewise, in Ontario's York Region, Gartshore et al. (2005) monitored amphibian use of 1000 - 1200 m, sandy substrate-lined corrugated steel pipe culverts ranging 25 - 31 m in length, similar to the observed culverts in the south Okanagan; American toads (*Anaxyrus americanus*), wood frogs (*Lithobates sylvaticus*), spring peepers (*Pseudacris crucifer*), and Northern leopard frogs (*Lithobates pipiens*) were observed utilizing the culverts. Given the dimensions and enhancement of the south Okanagan culverts, it is comparatively plausible that amphibians would utilize the culverts when funneled with fencing.

Specific individual amphibian identification was not feasible in the present study, as the position of the amphibians to the camera was highly variable. To distinguish amphibians in the photos, especially when several amphibians were observed from the same age and relative size class was beyond the time constraints and resources of this study. In larger amphibians, under different fixed camera angles, identification has been shown effective. Pagnucco et al. (2011) were able to identify long-toed salamander individuals captured in culvert camera traps through comparing occurrence to images of a metric ruler; gender could also be identified for the salamanders.

Culvert species incidence was more represented in spadefoot occurrences than on the roadways; treefrogs were under represented (1 % of the total amphibian species) and blotched tiger salamanders rarely occurred but their representation on the road in the area was low as well. Because they exhibit higher agility than spadefoots, it may be possible that during the 59 seconds of every minute that the cameras were not shooting photos, more treefrogs made it past the cameras than what was recorded.

Other wildlife species observed by the cameras were recorded for future interest in general wildlife use of culverts, predatory behaviour, or records of other species at risk utilising the culverts. Observed wildlife included: 3 amphibian species, 5 reptile species, 14 mammal species (minimum), 5 bird species, and various invertebrates. Of the observed wildlife, 7 are listed as species at risk under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (see Appendix II, Table II-5).

Amphibian culvert occurrence versus surrounding road occurrence

Amphibian culvert incidences increased from 2011 to 2012, with alternatively fewer occurrences along the roads and fencing in 2012. In 2011, amphibian occurrences on the road and incidences caught on culvert cameras within the highway culverts were found to not be significantly different. This is interesting as 2011 was a transition year whereby the fencing construction was not complete, and in areas of fencing most of it was not backfilled. Cameras were installed 4 weeks after road surveys began, after waiting for the substrate infilling of the culverts. Peak occurrence in the culverts was in the first week of July, including metamorph emigration and adult foraging. In 2012, amphibian culvert occurrences were significantly more than 2.5 times the total road occurrence observations during the same time period. The greatest occurrences were during the first week of May (which was not within the camera survey period in 2011).

As only 2 of the 8 large highway culverts were monitored for amphibian occurrence, it was logical to look at the incidence of amphibians directly within the area of the two observed culverts and associated fencing; the results were in favor of the mitigation structures. Fencing occurrence along the finished fencing in 2012 was comparable with the amount of amphibians found on the roadway. The real effect of the mitigation was observed in the markedly less road occurring amphibians at ≤ 50 m and ≤ 100 m from the culvert, to which the amount was significantly higher within the camera-trap monitored culverts. In the 204 ave culvert in 2011, amphibian occurrence in the culvert was 9.5 times those observed within 50 m of the culvert, and 4.4 times those within 100 m. In 2012, there were 134 times more amphibians observed within the 204 ave culvert at less than 50 m, and 45 times more than the highway within a 100 m north and south of the culvert (200 m total). Similar trends were observed in the Ponds culvert: 2011 resulted in 4.6 and 3.5 times more occurrence in the culvert than the highway within 50 m and 100 m either side of the culvert. In 2012, the Ponds culvert had 171.5 and 38.1 times the amphibians observed on the roads within 50 m and 100 m on either side of the culvert.

Management implications

Progress is being made in the field of road ecology. While increasing and modifying road infrastructure may not slow down anytime soon; researchers, practitioners, and the public are increasingly knowledgeable in the varied avenues of wildlife-road mortality mitigation and restoration. Interdisciplinary collaborations, such as for the Osoyoos passing lanes project, contribute to and promote greater adaptively managed wildlife road permeability. This is echoed in international ecology and transportation conferences (e.g. IENE, ICOET) and on many recent projects provincially to internationally. In order to continue moving forward in creating solutions for wildlife permeability, we need to further monitor present structures and adapt to new research and information.

Future considerations:

Fencing: repair, installation and improvements

Prior to the spring amphibian movement, the fences need to be checked and maintained; some areas of the polymer fence had to be repaired in 2012 as it had warped, separated and broke is some sections. Sections had broken and separated from what appears to be weather related causes. In the height of the summer heat in 2012, the fencing buckled and warped in some areas from expansion, and it seems when the fence contracted again in the cooler months some partially overlapped sections were not fastened together well enough and separated. Fence sections were fastened back in place where possible; in other places where a large gap occurred, small wire mesh was attached to either section (Figures III-1 & III-2, Appendix III). In future fencing applications, fencing would best be installed in the cooler periods, and perhaps, fastened in a way that would allow some flexibility as the fence expands and contracts.

Fencing at the base of a slope should be far enough to maintain vegetation growth between the fence and the slope. Along the Highway 97 OPL a section of fencing along the southbound lane, north of 204 ave, was installed very close to the hillside (Figure III-3, Appendix III). The fencing is mere centimeters from the slope in areas, whereby amphibians could stretch or hop across the gap; vegetation maintenance in this area would be non-existent by mechanical means. If there were resources in the future to relocate this section of fencing at least 1.5 m away from the slope, its efficiency would be improved.

The most efficient roadkill mitigation areas were within sections fenced along both sides of Highway 97. Future management efforts should focus on continual fencing in bare and single fenced areas to have greater mitigative success. Along the Highway 97 OPL area, metamorphs emigrate from the flooded pastures at the base of 204 ave in the hundreds. Fencing following the base of 204 avenue, curved back on itself is recommended.

Any future improvements to fencing the Highway 97 OPL or otherwise should have the ends of the fencing fit right to the culvert edge. A baffle perpendicular to the middle of the culvert opening may also better direct amphibians travelling along the fence into the culverts. At the fence ends, modifications should be made to curve the fence back toward itself to help prevent amphibians coming up onto the roads.

Fence line monitoring & vegetation maintenance

Vegetation growing beneath and within 1 m of the fence line is a concern (Figure III-4, Appendix III). It is difficult as an observer to see amphibians travelling along the fence as the vegetation grows, and it may be a hindrance to the wildlife moving along it (although some vegetation may be good for cover). Trees that had been removed for construction have grown into large bushes with roots and branches pushing at the fence structure. In previous years, The Nature Trust crew volunteered their time with a brush cutter which was effective in keeping vegetation maintained for a few weeks in the early summer. Routine vegetation maintenance (at minimum once every 2 months April to August) would assist greatly; fence line occurrence and distribution may be more accurately recorded through a combination of pitfall traps and fence line monitoring.

Concrete barrier permeability

Because the concrete barrier has no scuppers and is impermeable for 300 meters, amphibians were trapped along its highway side. Within the stretch of highway 97 parallel to the concrete barrier there were also high mortality incidences. This may have been due to amphibians crossing the road, hitting the barrier, and turning back, and getting hit. However, it could just be an unfortunate few who were on the road when traffic was going past. More information is needed to see if the barrier helps or hinders the amphibian population more. In past years, it has been an effective obstruction for emigrating metamorphs which otherwise would have gone onto the highway. Future management may include the inclusion of a few scuppered sections that are plugged prior to emigration movements.

Culvert monitoring

As amphibians are small and cold-blooded, the infrared function did not trigger photos. Time lapse photography throughout the night produced hundreds of thousands of photos to analyze and still only captured 1 second out of minute of survey time. This process could be improved upon with the addition of a laser beam trigger attachment to the camera, whereby the animal breaks the beam and a photo is triggered. Another option may be continuous video capture, or time lapse photography, combined with pattern recognition software. This technology would eliminate time-consuming, occurrence-devoid photos from the analysis.

Future culvert monitoring and experimentation could include monitoring some or all of the eight substrate-enhanced culverts along the Highway 97 OPL area, and experimenting with different conditions such as lighting. Solar lights could be installed within the culverts with a cage over the solar panel to protect from vandalism. When artificial lighting was introduced to culverts in one study, spotted salamanders crossed more readily through them (Jackson, 1996). Reliability on amphibians traversing the entire span of the culverts could be improved upon by installing an additional camera in the middle of the culvert.

Volunteer monitoring

In areas of discontinuous fencing within the Highway 97 OPL area, or in other known amphibian hotspot areas, it may be advisable to have volunteers aid the amphibians across the road. This would have to be supervised under strict safety conditions and perhaps under lane closures, or on quieter, secondary roadways. Bucket brigades may be particularly useful on warm, wet nights during peak amphibian movement periods such has metamorph emigrations.

Volunteers may also monitor the presence or absence of amphibians in wetlands surrounding the road survey routes on public lands. For example, a pond was opportunistically constructed in 2011 on the west side of the frontage road by the BC MOTI; whereby monitoring records for 2011 through 2013 have included Great Basin spadefoot at various stages and Pacific treefrog calling. Greater landowner engagement especially in hotspot areas or on parcels with wetlands or flooding, may improve public awareness and landowner mitigative actions. This information must also be communicated and integrated in social, cultural, environmental and economic ways. The collaborative work of fellow stewards and professionals must be put out to everyone in a useful, interesting manner so that more people can relate and contribute to changing the barriers and other effects caused by roadways.

CONCLUSIONS

Roadways and traffic are barriers to amphibian migration and dispersal, fragmenting habitats and threatening amphibian population persistence. In this study I observed the negative impacts of south Okanagan roadways and traffic on amphibians, and demonstrated effective roadkill mitigation through culvert and fencing structure use. Rigorous, multiple year examination into the incidence of amphibians on south Okanagan roadways within this study has better quantified the negative traffic impact effects that may have otherwise been underestimated in opportunistic data capture or short term studies. Hotspots of amphibian road incidence over the three years combined with nearest permanent wetland distances provide data for future management decisions. In the case of the Highway 97 passing lane expansion, strategic placement of culvert and fencing roadkill mitigation structures proved successful with each year recording progressively less amphibians on the highway but greater amphibian use of observed culverts and fence lines. Before and after analysis represents a successful first step into monitoring and adaptive management of the routes taken by migrating amphibians within the south Okanagan valley, British Columbia.

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APPENDIX I: LITERATURE REVIEW SUPPLEMENTAL DATA

Table I-1. Migrational movement distance of amphibians relating to south Okanagan species. Species highlighted in bold are represented in the south Okanagan Valley.

Amphibian Species	Max Dist (m)*	Technique	Movement Classification	Reference	Primary Citation
Ambystoma californiense	130	radio telemetry	adult non-breeding	Rittenhouse & Semlitsch, 2007	Loredo et al. 1996
Ambystoma maculatum	213	radio telemetry	adult non-breeding	Rittenhouse & Semlitsch, 2007	Madison 1997
Ambystoma maculatum	153	radio telemetry	adult non-breeding	Rittenhouse & Semlitsch, 2007	Rittenhouse & Semlitsch, 2006
Ambystoma mavortium melanostictum	**287**	**radio telemetry**	**adult non-breeding**	**Rittenhouse & Semlitsch, 2007**	**Madison & Farrand, 1998**
Anaxyrous boreas	**2324**	**radio telemetry**	**adult non-breeding**	**Rittenhouse & Semlitsch, 2007**	**Muths, 2003**
Anaxyrous boreas	**2278**	**radio telemetry**	**adult non-breeding**	**Rittenhouse & Semlitsch, 2007**	**Bartelt et al., 2004**
Pseudacris regilla	**800**	**Mark-recapture**	**adult non-breeding**	**Stebbins, 1951**	**Stebbins, 1951**
Pseudacris triseriata	213	radio telemetry	adult non-breeding	Rittenhouse & Semlitsch, 2007	Kramer, 1971
Rana luteiventris	**1025**	**radio telemetry**	**adult non-breeding**	**Rittenhouse & Semlitsch, 2007**	**Pilliod et al., 2002**
Spea intermontana	**371**	**radio telemetry**	**adult non-breeding**	**Garner, 2012**	**Garner, 2012**
Spea intermontana	**2350**	**radio telemetry**	**adult non-breeding**	**Oaten, 2012**	**Oaten, 2012**

*Maximum net distance travelled from breeding pond.

APPENDIX II: MANUSCRIPT SUPPLEMENTAL DATA ANALYSIS

Table II-2. South Okanagan amphibian occurrence by life stage and gender per species observed; all years 2010-2012, entire survey route.

	Great Basin Spadefoot		**Pacific Treefrog**		**Western Toad**		**Blotched Tiger Salamander**		**Long-toed Salamander**	**UnID Amphib**	
	Live	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	*Live*	*Dead*	**Total**
Adult											
Female	632	511	59	91		2					**1295**
Male	299	332	42	56	1				1		**731**
UnID Gender	25	269	30	125				12		32	**493**
Juvenile	325	131	3	3			2	1			**465**
Metamorph	613	391*	14	3							**1021**
UnID Life stage		14		1						31	**46**
Grand Total	**1894**	**1648**	**148**	**279**	**1**	**2**	**2**	**13**	**1**	**63**	**4051**

*plus an estimated 4:1 ratio deceased metamorphs on Hwy 97 primary (July 2, 2010) that could not be accurately recorded due to live metamorph extraction from roadway during large emigration and heavy traffic flow.

Table II-3. Amphibian snout to vent lengths by life stage & gender; all years 2010-2012, all transects. "na" represents deceased, recorded individuals whereby the snout-to-vent length could not be established.

Spp & **Life Stage**	**Gender**	**N_Individs**	**Mean SVL**	**StdDev**	**Max SVL (mm)**	**Min SVL (mm)**
Long-Toed Salamander						
Adult	Male	1	67.85	na	67.85	67.85
Blotched Tiger Salamander						
Adult	UnID	12	na	na	na	na
Juvenile	Male	1	75.87	na	75.87	75.87
	UnID	2	84.59	31.09	106.57	62.60
Western Toad						
Adult	Female	2	106.89	na	106.89	106.89
	Male	1	99.04	na	99.04	99.04
Pacific Treefrog						
Adult	Female	150	33.21	4.84	55.85	24.51
	Male	98	31.21	5.58	45.44	24.45
	UnID	155	31.81	4.04	40.48	25.48
Juvenile	Female	2	22.33	0.04	22.36	22.30
	Male	1	na	na	na	na
	UnID	3	21.00	na	21.00	21.00
Metamorph		17	19.65	1.55	21.80	17.58
Great Basin Spadefoot						
Adult	Female	1143	52.99	3.81	67.20	31.03
	Male	631	50.69	3.65	62.35	39.60
	UnID	294	46.17	2.42	50.48	44.76
Juvenile	Female	28	41.07	4.22	44.21	27.52
	Male	3	35.95	7.21	44.28	31.57
	UnID	425	31.92	4.01	43.99	22.00
Metamorph		1004	22.91	2.14	29.50	17.90
UnID Life stage	Female	2	na	na	na	na
	Male	1	na	na	na	na
	UnID	11	na	na	na	na
Unidentifiable Amphibian						
Adult	UnID	32	na	na	na	na
UnID Life stage	UnID	31	na	na	na	na
Grand Total		**4051**				

Table II-4. Great Basin spadefoot and Pacific treefrog demographics from south Okanagan roadway survey records.

	Highway 97		**Blacksage Rd/ No.22 Rd**	
	Females	Males	Females	Males
Great Basin spadefoot				
Mean ± SD	5.2 ± 7.4	2.8 ± 3.8	6.5 ± 9.8	3.6 ± 6.1
N individuals	611	324	555	310
2 sample $\text{Wilcoxon}_{0.05}$	$W(1) = 8872$***		$W(1) = 4448.5$*	
Pacific treefrog				
Mean ± SD	1.2 ± 1.4	0.8 ± 1.5	0.7 ± 0.9	0.6 ± 0.7
N individuals	131	87	16	11
2 sample $\text{Wilcoxon}_{0.05}$	$W = 588$*		$W = 120$, ns	

$p < 0.05$*, $p < 0.01$ **, $p < 0.001$***

Figure II-1 . Reconyx Hyperfire PC800 camera fixed to the ceiling of the culvert at 3 m, angled towards the culvert entrance by a swivel mount attachment (found at www.reconyx.com).

Table II-5 . Camera-trap wildlife species occurrence in 204 ave, Ponds, and Frontage road culverts in 2011 and 2012. Endangered (End), Threatened (Thr), and Special Concern (SC) status under the Committee on Status of Endangered Wildlife in Canada and the British Columbia Species At Risk Act, or NL – Not Listed.

	Common Name	**Scientific Name**	**COSEWIC Status**	**BC Status**
Amphibians	Great Basin spadefoot	*Spea intermontana*	Thr (Apr 2007)	Blue
	Pacific treefrog	*Pseudacris regilla*	NL	Yellow
	Blotched tiger salamander	*Ambystoma mavortium melanostictum*	End (Nov 2012)	Red
Reptiles	Gopher snake	*Pituophis catenifer deserticola*	Thr (Apr 2013)	Blue
	Rubber boa	*Charina bottae*	SC (May 2003)	Yellow
	Yellow-bellied racer	*Coluber constrictor*	SC (Nov 2004)	Blue
	Western terrestrial gartersnake	*Thamnophis sirtalis*	NL	Yellow
	Common gartersnake	*Thamnophis elegans*	NL	Yellow
Mammals	Coyote	*Canis latrans*	NL	Yellow
	Domestic dog	*Canis lupus familiaris*	NL	NL
	Domestic cat	*Felis catus*	NL	NL
	Raccoon	*Procyon lotor*	NL	Yellow
	Striped skunk	*Mephitis mephitis*	NL	Yellow
	Long-tailed weasel	*Mustela frenata*	NL	Yellow
	Eastern fox squirrel	*Sciurus niger*	NL	Exotic
	Deer mouse	*Peromyscus maniculatus*	NL	Yellow
	Bushy tailed woodrat	*Neotoma cinerea*	NL	Yellow
	Nuttall's cottontail	*Sylvilagus nuttallii*	SC (April 2006)	Blue
	mouse *sp.*		-	-
	vole *sp.*	*Microtus sp.*	-	-
	rat *sp.*	*Rattus sp.*	NL	Exotic
	chipmunk *sp.*	*Neotamias sp.*	-	-
Birds	Barn swallow	*Hirundo rustica*	Thr (May 2011)	Blue
	American Robin	*Turdus migratorius*	NL	Yellow
	Brewer's black bird	*Euphagus cyanocephalus*	NL	Yellow
	Mallard (ducklings)	*Anas platyrhynchos*	NL	Yellow
	California quail	*Callipepla californica*	NL	Exotic
Invertebrates	Field Crickets	*Gryllus pennsylvanicus*	NL	NL
	Beetle *sp.*		-	-
	Worm *sp.*		-	-
	Spider *sp.*		-	-
	Moth *sp.*		-	-

APPENDIX III: CONCLUSIONS SUPPLEMENTAL; FUTURE CONSIDERATIONS

Figure III-1. Separation of ACO polymer amphibian fencing from culvert (later repaired with wire mesh overlay), Highway 97 Osoyoos passing lanes.

Figure III-2. ACO polymer fencing repair. Notice at the top of the fence, the section snapped off its joining part. Sand levels are also low in some areas (as shown), where they should be creating an earthen ramp over the fence for any small wildlife caught on the road side.

Figure III-3. Amphibian fence proximity to slope with minimal backfill; poor planning for vegetation maintenance and easily jumped by small wildlife.

Figure III-4. Vegetation overgrowth along amphibian fencing, Highway 97 Osoyoos passing lanes.