Western Toad Migration at Summit Lake
2012 Field Season

Prepared for:

Fish & Wildlife Compensation Program
Nelson, BC

Prepared by:

Jakob Dulisse
Jakob Dulisse Consulting
Nelson, BC

&

John Boulanger
Integrated Ecological Research
Nelson, BC

March 2013

EXECUTIVE SUMMARY

Summit Lake hosts a significant breeding population of western toads (*Anaxyrus boreas*). The western toad is internationally listed as *Near Threatened* by the World Conservation Union, federally listed as *Special Concern* by the Committee on the Status of Endangered Wildlife in Canada and *Blue-listed* by the B.C. Conservation Data Centre. Substantial numbers of adult and juvenile toads (toadlets) are killed by vehicle traffic every year on Highway 6 as they migrate to and from the lake. There are three main migrations as adults move to and from the lake for breeding and toadlets leave the lake for upland habitat. Migration is intermittent, taking place primarily during warm, wet nights for adult toads and following rain events for toadlets.

This is the third year of a project initiated to assess road mortality on long-term western toad population trends. The objectives were to estimate the location, timing, direction and severity of highway mortality; determine the efficacy of two underpass tunnels installed by the Ministry of Environment in 2006; and investigate and outline potential remedial measures. In 2011, we began efforts to identify breeding distribution and adult abundance using mark-recapture techniques and through the 2012 field season, we increased our efforts to document nocturnal adult migration locations.

In 2012, we detected 142 live and 188 dead adult toads on Highway 6 from 5 May to 28 September. Although individuals were found along the entire length of road surface sampled, there are several movement hotspots which generally correspond to known breeding sites.

We captured and PIT-tagged 472 adult western toads in 2011 and 477 in 2012, totaling 765 males and 184 females. Only 15 toads (12 males and three females) tagged in 2011 were recaptured in 2012. This low recapture rate precluded any population estimates this year. Movement information gathered from within-year recaptures show that adult males often move between breeding areas in one season. It also appears that many adult toads may move long distances (up to 2000m) in the lake before they leave the area. Recapture locations also suggest some adults may overwinter to the north of Summit Lake, but radio-telemetry would be required for confirmation.

In combined captures from 2010-2012, the sex ratio of adult male to female toads varied depending on capture location from 0.2:1 in the subdivision area to 7.9:1 at the breeding areas. Other breeding sites within the species' range are known to have up to 17 adult males for every breeding female. The male-biased adult sex ratio, coupled with the fact that adult females may not breed every year, may indicate that adult (especially gravid female) highway mortality may be most critical to the local population.

In 2011, breeding was noted at six sites but breeding occurred in much greater densities at two sites. Five of the six sites were known from 2010 and one new breeding site was discovered in 2011. All six of these sites were active again in 2012 and an additional

breeding site was found near the rest area. Breeding was first observed on 6 May and the first hatchlings were seen on 24 May 2012.

We used repeated sampling of a series of permanent toadlet transects and analysis of habitat and environmental conditions to evaluate toadlet migration. In 2012, overall numbers of migrating toadlets was higher than in 2010 or 2011. Although there were annual differences in magnitude and timing, the relative distribution of dead toadlets on the highway appears similar from 2010 to 2012, suggesting that the toadlets are crossing Highway 6 at comparable sites this season. One exception was increased toadlet mortality likely associated with migration from breeding area 9, a newly discovered site this season. In 2012, we compared the toadlet and adult distribution patterns on Highway 6 and found a reasonably good relationship between the two age categories.

On 22 and 23 August 2012, over 500 people attended the annual toadfest and an estimated 14753 toadlets were successfully moved in 541 buckets across Highway 6.

Through still camera photography, it appears that use of both amphibian underpass tunnels is very low in relation to overall numbers of migrating individuals. The concrete barriers and fences do result in blocking toads from reaching the highway but our data (and anecdotal operations) suggest that these structures also trap individuals on the road, increasing the chances of mortality for some individuals. Also, toadlet mortality is magnified at the ends of these barriers which suggests the fences and barriers are effective at directing animals, but not necessarily through the tunnels.

Currently, these barriers and culverts cover a small area of the migration zone. We recommend the installation of more underpass structures and fences at several candidate adult and juvenile hotspots. Because toadlets and adults are associated with moist sites, we suggest these structures be installed along existing streams which are currently culverted. The restoration of the riparian zones along these streams under Highway 6 would allow the passage of western toads and other wildlife including reptiles, small mammals, fish and invertebrates.

The design of the underpasses and fences will depend on topography and budget but in general, toads are more likely to use wide, short, non-metallic tunnels with natural light, good ventilation with natural substrate and vegetation. We recommend (in order of priority and effectiveness) the use of the bridge, open bottomed culvert, box culvert, pipe arch culvert or box culvert. The bridge design is most preferable because is allows the best preservation of surrounding environmental conditions to persist under the structure (light, moisture temperature and vegetation), does not require a grated top, allows for the creation of a riparian travel corridor for use by multiple species (including aquatic organisms) and provides increased flooding protection for the roadway. Several underpass and fence designs are discussed in this report.

ACKNOWLEDGEMENTS

Thanks to BC Hydro Fish and Wildlife Compensation Program (FWCP) and Columbia Basin Trust (CBT) for funding this project. Irene Manley and Trevor Oussoren at FWCP provided administration while Kathleen McGuinnes (Touchstone GIS Services Inc.) provided mapping and GIS support. Clint Swanson, Barb Houston and Myriam Mailhot assisted with field work. Thanks also to Angus Glass, Brent Persello, Terry Anderson, Dave Heagy and Bruce Lintott for partnering on this project. Thank you to all the toadfest volunteers who made the event an even bigger success this year. We wish to extend a special thanks to Debra Haas and Jim Hawes, operators of the Summit Lake Provincial Park campground, for their genuine concern for the toads and their continuing, enthusiastic support for the project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 Introduction

The western toad (*Anaxyrus boreas*), has undergone dramatic population declines in southern parts of its range and as a result was assessed as "Near Threatened" by The World Conservation Union (Hammerson et al. 2004). Federally, it is considered a species of special concern (COSEWIC 2002) and it is blue-listed provincially (CDC 2012). Canadian populations appear stable, however little information exists on population trends (COSEWIC 2002) and there is concern that Lower Mainland and Vancouver Island populations may be declining (Davis 2002). The species decline is attributed to a combination of factors including disease, habitat loss and modification, susceptibility to UV radiation, acid precipitation, road mortality and predation (Davis 2002).

The western toad occurs in forested habitats in western North America over a wide range of elevations. The species is predominantly terrestrial but requires standing or slow moving water less than 50 cm deep for breeding (Corkran and Thoms 1996). Communal mating takes place in ponds, lakes, permanent wetlands and flooded meadows from late January to August, depending on environmental conditions (Davis 2002). Females lay eggs in long strands which average 12,000 eggs. Eggs hatch in seven to ten days and tadpoles remain in the breeding body of water for two to three months. Some breeding sites support millions of tadpoles and they often metamorphose into small toads (metamorphs or toadlets) synchronously (Davis 2002). These concentrated abundances of tadpoles and toadlets support a diversity of predators including reptiles, birds and mammals. Toadlets may disperse greater than one kilometer from breeding ponds into terrestrial and wetland habitat and home range sizes are less than one hectare (Davis 2002). Adults spend most of their time under cover and important terrestrial habitat features include coarse woody debris and mammal burrows. During dry periods, adults may be found near streams or wetlands.

The West Kootenay region supports a high density of breeding western toads (Dulisse and Hausleitner 2010). The population of western toads at Summit Lake likely represents a significant portion of the species' breeding population regionally and provincially. However, toads experience significant annual road mortality when migrating individuals cross a five kilometer stretch of Highway 6 (Ohanjanian 1997, Seaton et al. 2005, Seaton 2008, Dulisse et al. 2011). The toad migration at Summit Lake consists of: 1) adults moving from upland, non-breeding habitat in the early spring to the lake to breed; 2) adults leaving the lake and returning to their non-breeding habitat in late spring through fall after breeding; 3) toadlets leaving the lake for non-breeding habitat in late summer or in some cases the following spring. Migration is intermittent; taking place at night for adults and during the day for toadlets, but in all cases involves crossing the highway (Dulisse et al. 2011).

This project was initiated to assess the implications of road mortality on long-term western toad population trends. Specifically, the 2012 objectives were to: 1) identify and map seasonal western toad mortality sites at Summit Lake; 2) assess relative risk to provincially significant population from juvenile and adult highway mortality; 3) recommend highway mitigation options to maintain functional movement corridors for western toad population persistence and; 5) engage the public in assisting with mortality reduction and educational outreach activities on site at Summit Lake.

1.1. Study Area

Summit Lake is located adjacent to Highway 6, 15 km southeast of Nakusp and 27 km northwest of New Denver (Figure 1). The lake is located at 764 m in elevation and covers an area of 150 hectares with 8400 m of shoreline. It is approximately 3.6 km in length and ranges from 360 m to 611 m wide with a mean depth of 4.4 m and a maximum depth of 17 m. Eight creeks flow through culverts under Highway 6 and into Summit Lake (Figure 1).

Highway 6 runs along the south shore of the lake and ranges from 5-300 m from the shoreline. An abandoned rail right of way runs along the north shore of the lake. This rail line has been converted to a multi-use trail. Summit Lake Provincial Park (6 ha) is located on a peninsula which extends northward into the lake from the highway (Figure 1). Facilities in the park include a boat launch, day use picnic area, public beach and 35 vehicle-access camp sites. The park is open seasonally from 27 April to 27 September. To the east of the park, there is a day-use rest area with picnic tables and a boat launch (Figure 1).

Summit Lake falls within Moist Warm Interior Cedar-Hemlock (ICHmw2) biogeoclimatic subzone of the Arrow-Boundary Forest District. The ICHmw2 subzone occurs between 500 m and 1450 m in elevation and is characterised by hot, moist summers and very mild winters with light snowfall (Braumandl and Curran 1992). Tree cover is made up of mixed species including Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), hybrid white spruce (*Picea engelmannii X glauca*), western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*). The most common shrubs are falsebox (*Paxistima myrsinites*) and black huckleberry (*Vaccinium membranaceum*). Common herbs include twinflower (*Linnaea borealis*), prince's pine (*Chimaphila umbellata*), queen's cup (*Clintonia uniflora*) and one-leaved foamflower (*Tiarella trifoliata*) (Braumandl and Curran 1992).

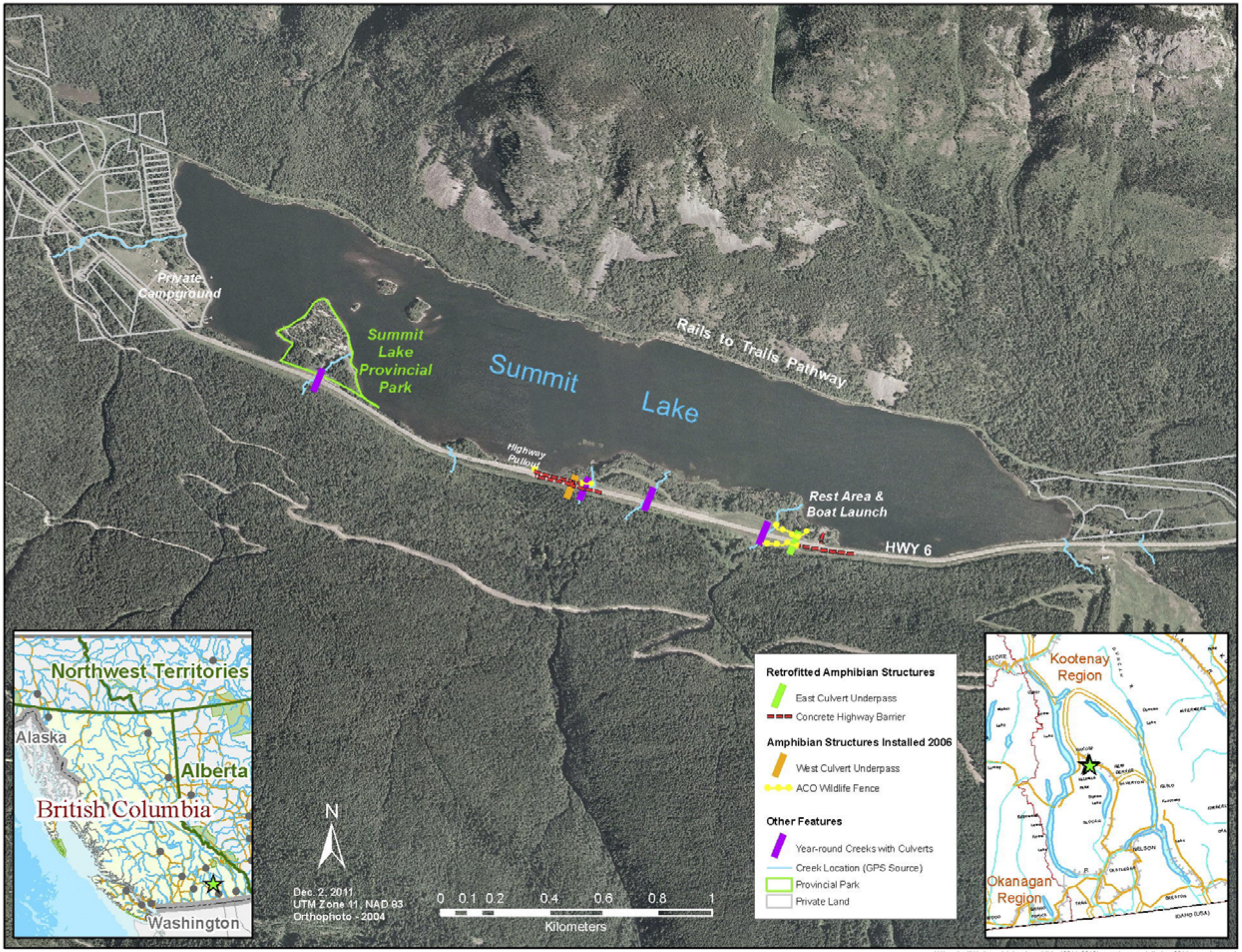


Figure 1. Summit Lake study area showing the locations of existing amphibian infrastructure and creeks.

2.0 Methods

Field work was conducted from 22 April- 1 October 2010, 5 May- 13 October 2011 and 5 May – 28 September 2012 and consisted of: 1) nocturnal road surveys for adult migration; 2) canoe surveys for breeding adults, egg masses and tadpoles; 3) mark-recapture of adult toads; 4) permanent toadlet sampling transects; 5) time-lapse photography stations within underpass tunnels and; 6) hosting of an annual on-site education outreach event (toadfest) held in August.

2.1. Adult migration

We used three methods to sample for adult toads on Highway 6: drive-by-surveys, time elapsed surveys and incidentals. Drive-by-surveys were conducted from 5 May to 16 July 2011 and 5 May to 27 September 2012 along a 4.8 km stretch of Highway 6 from Summit Road just east of Summit Lake to Kingfisher Road, west of Summit Lake (Figure 1). A daytime pass was made prior to sampling: all carcasses were recorded as incidental and removed from the highway. These surveys were conducted from a vehicle driving 30-40 km/hour. They were conducted after sunset between 21:55 and 00:23 and took an average of 15 minutes.

We conducted time elapsed surveys from 12 May to 10 August 2011 and 9 May to 13 June 2012. For the time elapsed survey, we subdivided the highway into six subsections of 800 m. In order to sample the entire highway each night, we used stratified random sampling to select one, 100 m section within each 800 m subset. Each 100 m section was surveyed by two individuals walking the entire length twice for a total of five minutes. The locations of all live/dead toads were recorded and individuals were removed to avoid double-counting within the sampling time.

All adult mortalities observed outside of the nocturnal sampling and those observed during toadlet migration surveys (24 August – 13 October 2011 and 16 May – 28 September 2012) were recorded as incidentals.

For each survey, we recorded start and end time, humidity, current precipitation, rain in the past 24 hours, air, pavement and lake temperatures, whether the toad was alive or dead, age (adult vs. subadult), gender, recapture identification and location (UTMs) of the toad.

Of key interest was whether there were “hotspots” of mortality and live counts of adult toads on the highway. To investigate this further we pooled data from 2010-2012 and tabulated counts of live and dead toad for each highway segment. We estimated that observations before 15 June each year were immigrating toads whereas movements after 15 June corresponded to random movement or emigration from the lake. We therefore considered observations from these two “seasons” as categories. We also considered distance from the lake, distance from identified breeding areas, distance from the nearest stream, and whether there were barriers to movement on the lake side (north) or the far side (south) of the highway. We used an analysis of covariance (ANCOVA; Milliken and Johnson 2002) that assumed counts of adult toads were distributed as a negative binomial. We used a stepwise model selection procedure (Hosmer and Lemeshow 2000) to select significant covariates. Distance from breeding area was correlated with distance from lake so these terms were considered separately in models to avoid parameter confounding. All analyses were conducted in proc GENMOD in SAS statistical package (SAS Institute 2000).

2.2. Breeding surveys

We conducted canoe surveys throughout the 2011 and 2012 to document the timing and location of breeding and to capture and PIT-tag adult toads. The entire shoreline of the lake was surveyed but survey effort was concentrated near known breeding areas during the breeding season. We recorded current weather, wind, rain in the past 24 hours and start and end times. Breeding sites were identified as those having multiple pairs of adult toads in amplexus (mating position). Toads observed were identified to life stage A=Adult, E=Egg, J=Juvenile (tadpole/larva), S=Subadult (includes juveniles and young of the year). Tadpoles were aged according to Gosner (1960): 1=No limb buds (GS ≤ 25), 2=Limb buds (GS 26-30), 3=Ankles and small feet (GS 31-35), 4=Large feet (GS 36-40), 5=Arm buds (GS 41), 6=Arms and tail (GS 42), 7=Tail resorbing (GS 43-45), 8=Tail resorbed (GS 46). We made estimates of tadpole lengths and numbers and took notes on tadpole movements and habitat use within the lake.

2.3. Mark-recapture

We captured individuals for mark-recapture by net or hand from 5 May - 25 August 2011 and from 16 May - 27 September 2012. Individuals > 40 mm and in good physical condition were marked with a uniquely numbered Biomark 9-mm, 134.2 kHz glass passive integrated transponder (PIT) tag (Ferner 2007). An insertion was made on the upper dorsal section using a new scalpel and a sterilized PIT tag was massaged under the skin toward the back of the animal. We followed provincial hygiene protocols for amphibian fieldwork (MoE 2008) to help reduce the risk of spreading disease. For each animal, we used a single pair of disposable talc-free latex gloves, a new scalpel blade and new plastic sandwich bags for measuring and weighing.

Toads were placed in a holding bucket and released at the site of capture after processing. We did not capture any females while they were laying eggs. Pairs in amplexus were processed and placed, together in a separate chamber until they were reunited and released as a pair. At the time of capture, we determined the gender and mass of each individual and measured snout-vent length. We recorded the capture location, date, search time, pavement, air and lake temperatures, current precipitation, rain in past 24 hours, overcast or sunny, wind, humidity, time of processing, the estimated number of individuals in the group, and recorded if they were vocalizing, in amplexus or basking.

After the first capture, all toads recaptured were scanned using a hand-held PIT-tag scanner. For each recapture event, we recorded the date, time and location and whether individuals were vocalizing, in amplexus or basking. Early in the field season, recaptures were done at the breeding sites and as adults dispersed from the breeding sites, recaptures were conducted by searching the perimeter of the lake for basking individuals. This season, we increased our nocturnal sampling efforts on the highway to capture more migrating adults.

2.4. Toadlet migration

To estimate toadlet abundance and movement patterns over space and time, we sampled a 2.3 km stretch of Highway 6 from the rest area to just west of Summit Lake Provincial Park campground entrance 12 times in 2011 from 24 August - 13 October and seven times in 2012 from 15 August - 22 September. We placed 29 transects perpendicular to and across the highway every 100 m. In areas where toadlets were more abundant, an additional six transects were placed at 50 m intervals (Figure 9). Along each transect we sampled a total of eight, 1 m x 0.5 m plots permanently marked in 2010 (Dulisse et al. 2011). Four plots were placed north of highway (between the lake and the highway) at 20 and 5 m intervals from the highway edge. Two plots were on the highway at 3 and 5 m from the northern edge of the pavement, coinciding approximately with the highest impact area on the road. Finally, two plots were placed 20 m south (uphill side) of the highway (Dulisse et al. 2011). This systematic sampling design standardised the assessment of toadlet counts to evaluate relative impacts of road and assessment of spatial and temporal variation in toadlet densities (Underwood 1997).

We chose a quadrat size (0.5 m2) that could be sampled quickly as toadlets are highly mobile. Additionally, we selected a plot rectangular in nature (1 m x 0.5 m) as toadlet distribution is patchy and a long quadrat covers more patches (Krebs 1989). For each plot, we recorded the time of sampling and the number of live and dead toadlets. To avoid double counting, all dead toadlets in the plots on the highway were removed following sampling by scrubbing with a metal brush.

Within each quadrat, we estimated percent habitat cover for the canopy (A layer), shrub (B1, B2), herb (C) and bryophyte layers (D; Anonymous 1998). We measured surface temperature at the center of each quadrat on each sampling occasion using a hand held, infrared thermometer.

Bubble plots were created from toadlet sampling to assess spatial and temporal variation in the data set. For these graphs, plots were subdivided as counts of live toadlets on the lake (north) side of Highway 6 and the uphill (south) side of the highway, and dead toadlets counted on the highway. The numbers of dead toadlets in the non-highway plots and live toadlets on the highway plots were not appreciable and therefore not considered.

2.5. Comparison of adult and toadlet highway distribution

The adult and toadlet surveys overlapped for the 2.3km section of the adult survey that was closest to the lake breeding areas. Therefore, comparison of the distribution of live and dead adult and toadlet counts provided a partial way to determine if adults and toadlets were crossing the road in the same general areas. For this analysis, we cross referenced the adult toad segments with toadlet transects. In some cases more than one toadlet transect was contained within an adult segment. We then estimated the mean count of live and dead toadlets (pooling surveys) for each adult segment. We then compared this to the relative percentage of adult (live and dead) counts for the given segment. Correlation analysis (Zar 1996) was used to test for the significance of association between adult and toadlet segment counts.

2.6. Time-lapse Photography

We used time-lapse still photography to record toad use in both tunnels. A camera was fixed to the ceiling and positioned approximately 2m inside the south exit of each tunnel. The cameras were positioned near the south exits in order to capture images of toadlets that had already travelled the length of the tunnel (avoiding individuals that entered the tunnel and turned around). Canon PowerShot S45 (4 megapixel) digital cameras were used. We recorded the time and date each photo was taken, the number of individuals in each frame and the direction they were traveling. Photographs were taken at 30 minute intervals for a total of 49 hours each session. The cameras were in place from 26 May – 06 October 2011 and 15 June – 22 September 2012 (camera malfunctions delayed the start of the 2012 sampling period).

2.7. Toad outreach event

The third annual toadfest bucketing event, hosted by FWCP, BC Parks, Ministry of Environment, MoTHI and CBT, was held on the afternoon of 22 August and the morning of 23 August 2012 at Summit Lake Provincial Park. Several agencies and organizations, including FWCP, attended with information tables. Volunteer tour leaders escorted groups to carefully collect toadlets for transfer across the highway—the crossing location was controlled by MoTI flaggers. After collection and prior to release, toadlets were counted or weighed at the FWCP table in order to estimate the total number of individuals moved across the highway. Toadlets that were not developed enough (ie, those that still had tails present) were removed from attendee's buckets and released without transporting them across the highway.

3.0 Results

3.1. Adult Migration

In 2010 we detected 12 live and 42 dead adult toads on Highway 6 from 22 April to 1 October. In 2011, adult toads were present at the start of nocturnal surveys on 5 May 2011. The lake was ice-free on the 29 April 2011 and we detected 81 live and 101 dead adult toads from 5 May to 13 October that season. In 2012, adult toads were found on the highway at the start of the field season on 5 May to the last sampling date, 28 September (adults may have been migrating before and after our sampling season). With increased nocturnal highway effort this season, we detected 142 live and 188 dead adult toads on Highway 6 adjacent to Summit Lake. These detections are summarised by 100m highway segment in Figure 2. Fifteen highway segments show adult migration hotspots of 15 or more adult toads per 100m and eight segments show a density of 20 or more adult toads per 100m with D1 showing the highest (Figure 2).

The analysis of covariance revealed that count of adult toads was significantly related to season (immigration <=June 15, emigration >June 15), distance from breeding area, whether a barrier to movement was present on the highway, and an interaction of distance from lake, distance from stream (numbered east to west in Figure 2) and season (Table 1). Counts were highest during immigration (<=June 15) (standardized mean count per segment=1.33 (CI=1.08-1.93)) compared to emigration (>June 15) (mean=0.93, Ci=0.67-1.29). Barriers on the uphill (south) side of the highway (concrete barriers and ACO wildlife fencing) decreased the count of toads whereas barriers on the lake (north) side of the highway increased the count of toads on the highway. The interaction of season, lake, and stream suggested that counts increased at further distances from stream during emigration but increased at distances closer to stream during immigration but this overall effect was weak as indicated by p-values and relatively small slope coefficients.

Table 1. Covariance analysis of adult toad counts on Highway 6 at Summit Lake.

Parameter	Season	Estimate	SE	CI		χ^2	$P(\chi^2)$
Intercept		1.36	0.31	0.76	1.96	19.62	<.0001
season	emigration	-1.46	0.49	-2.43	-0.50	8.82	0.003
	immigration	0.00	0.00	0.00	0.00	.	.
Distance from breeding area		0.00	0.00	0.00	0.00	9.86	0.0017
Barrier (uphill side of highway)		-4.09	1.55	-7.13	-1.05	6.94	0.0084
Barrier (lake side of highway)		1.77	1.08	-0.34	3.88	2.70	0.1002
Log(lake)*log(stream)*season	emigration	0.04	0.02	0.00	0.08	4.84	0.0278
	immigration	-0.01	0.02	-0.04	0.02	0.47	0.4939

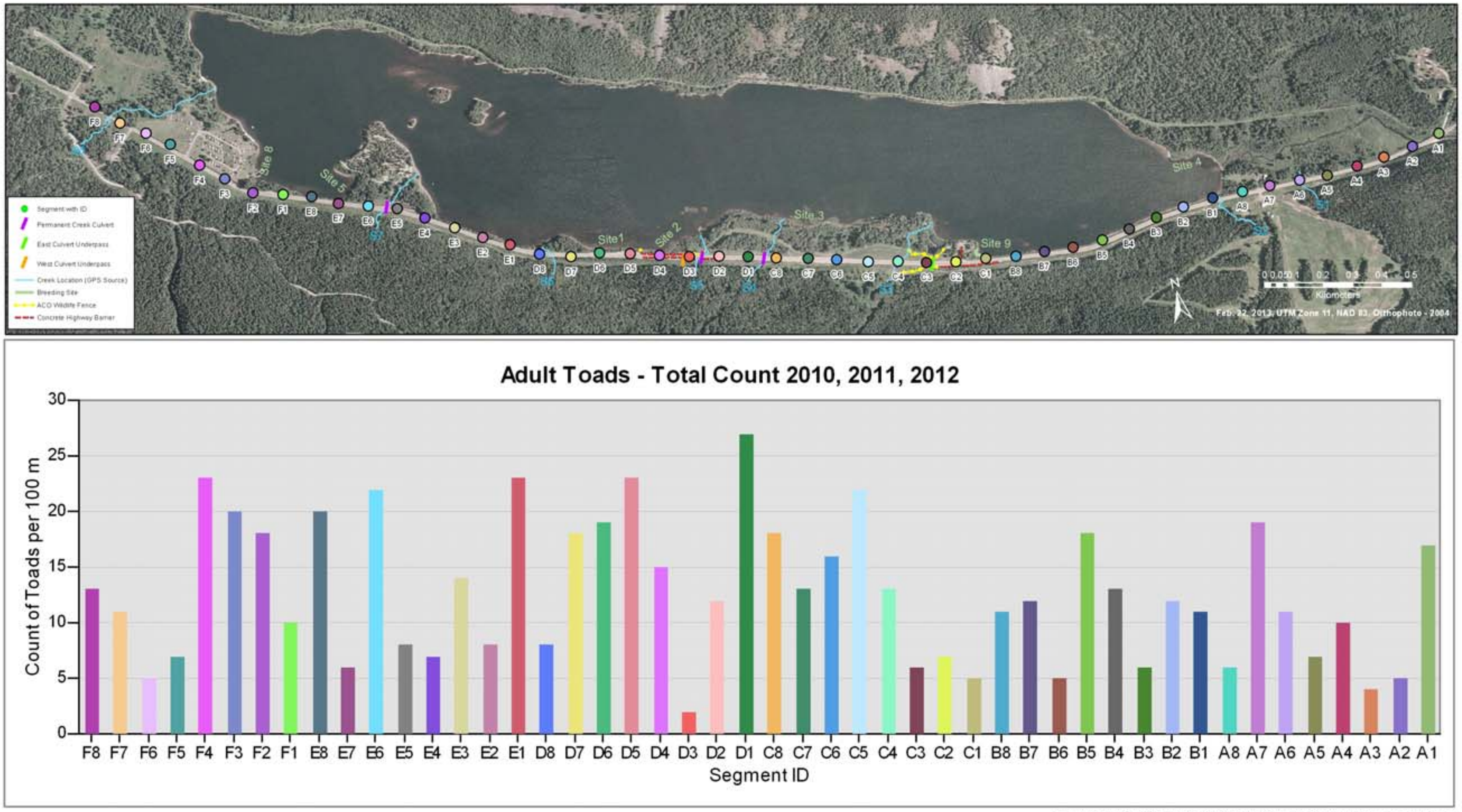


Figure 2. Adult western toads recorded on the Highway 6 at Summit Lake. 2010, 2011 and 2012 field seasons are combined and total counts are shown by highway segment. The colour-coded segment bars below correspond to the segment locations on the map at the top of the figure.

Plots of model predictions relative to observed counts revealed that the model did a reasonable job of predicting the main peaks and valleys in counts (Figure 3).The low counts observed in C1-C3 and in D2-D3 were due to the presence of barriers on the uphill side of the highway. In most cases peaks were related to proximity of breeding areas. Confidence limits of model prediction contained observations except for very high or low (0) counts in some cases. Model predictions suggest several hotspots of toad counts (e.g. F2-3, D5-7 and C6-7).

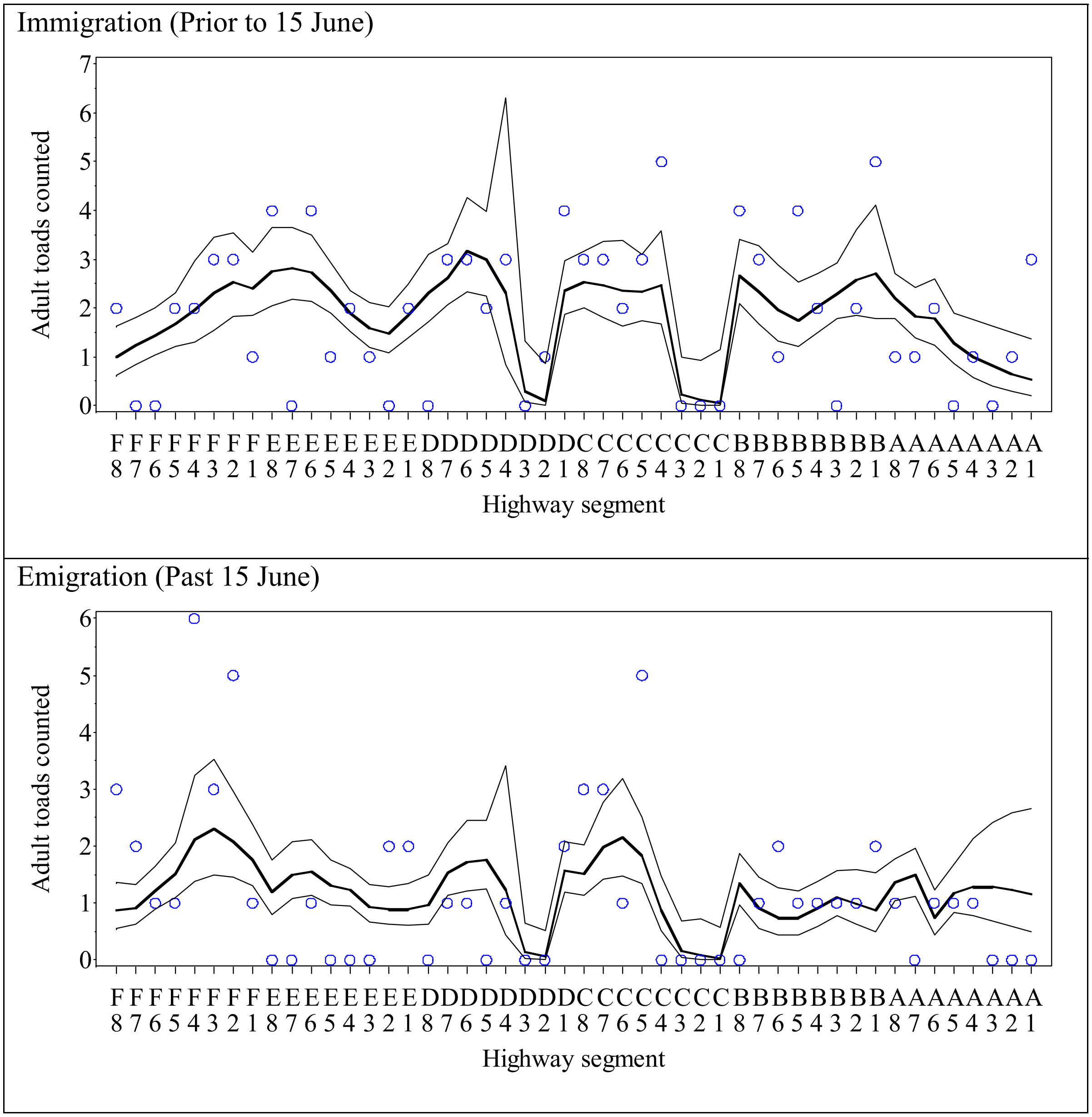


Figure 3. Model predictions of adult counts on highway as a function of highway segment and season. Actual counts of toad (live and dead) are given as blue dots and model predictions (and confidence limits) are shown as black lines.

3.2. Breeding Surveys

The first observations of breeding activity at Summit Lake on 6 May 2012 was similar in timing to 2010 (10 May) and 2011 (12 May). Hatchlings were first noted on 24 May 2012 compared to 5 June in 2010 and 26 May in 2011. Tadpoles were beginning to disperse by 7 June 2012 and toadlets were first staging along the shoreline on 9 Aug.

Interestingly, three distinct bouts of breeding activity were observed this year: a) the first week of May when the adults first arrived at the lake, b) on 25 May, and c) on 21 June, a seemingly late date.

Breeding activity was noted at all six breeding areas known from 2011 and a major new breeding area was used in 2012: breeding site 9 (Figure 2) was located near rest area boat launch may have been active in the past but was not used in 2010 or 2011.

3.3. Mark-recapture

We have captured and PIT-tagged total of 933 adult western toads within the study area (on the highway and in the lake) over the 2011 and 2012 field seasons (Table 2). Mean mass of males was approximately half that of females (Table 2).

Of 405 males marked in 2011, 12 were recaptured in 2012 and only three out of 67 females were recaptured in 2012, totaling a very low between-year recapture rate of 15 out of 472 (Table 2). 461 toads were marked in 2012, and 59 were recaptured (38 males and 21 females) the same year (Table 2).

Table 2. Mark-recapture effort, mean mass (g) and snout-vent length (mm) by gender of western toads at Summit Lake in 2011 and 2012

	Gender	Number Pit-tagged	Number recaptures 2011	Number recaptures 2012	Mass (g) (SD)	SVL (mm) (SD)
2011	Male	405	107	12	56.4 (14.2)	76.9 (7.8)
	Female	67	8	3	117.6 (32.1)	92.7 (8.8)
2012	Male	360	-	38	62.0 (15.0)	81.8 (6.4)
	Female	117	-	21	116.7 (33.6)	95.2 (8.9)
Total		933	115	74	-	-

Breeding areas 3 and 5 were sampled in 2012 for 6 and 3 sessions respectively. Unlike 2011, the number of recaptured toads between sessions within the same breeding areas was quite low. Lack of within year and across year recaptures precluded estimation of population size for these breeding areas (Figure 4) and for the population as a whole.

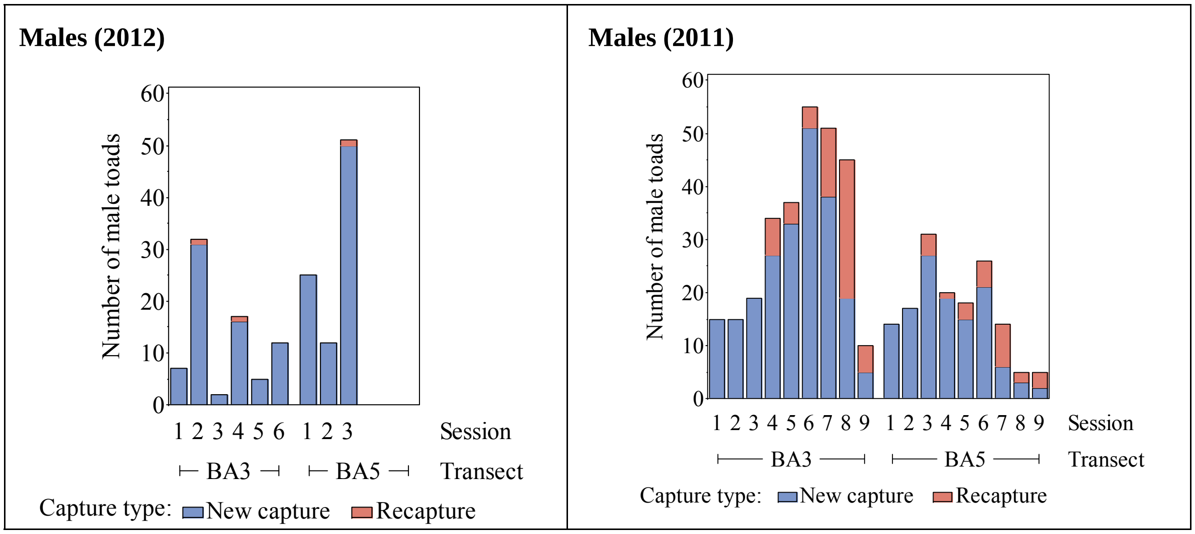


Figure 4. Summary of captures and recaptures of adult male western toads at Breeding Areas 3 and 5 at Summit Lake May – July 201l and 2012.

The lower number of captures and recaptures in 2012 was due to lower abundance of toads at breeding areas and possibly lower fidelity of toads to the breeding area. A plot of toads captured versus capture effort suggest that in most sessions the number of toads detected did not increase with capture effort when compared to 2011 (Figure 5) for breeding area 3. Therefore, it is likely that the relative abundance of toads at the breeding areas was lower for many of the sampling sessions.

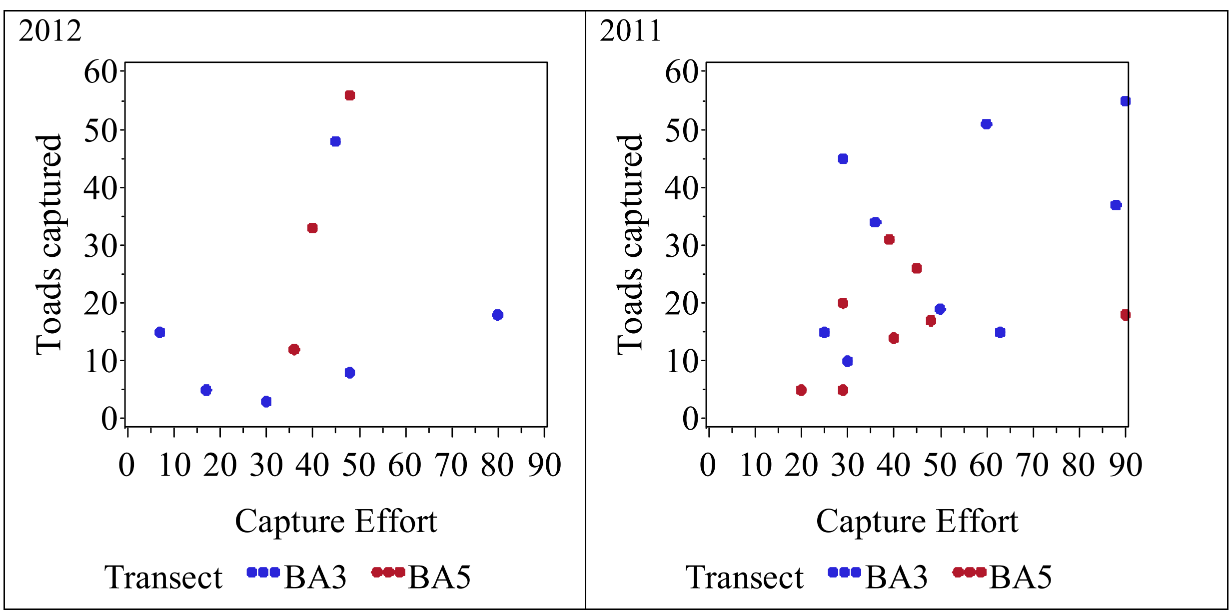


Figure 5. The number of toads captured versus capture effort (minutes spent capturing toads) for Transects BA3 and BA5 (as displayed in Figure 6).

Sampling efforts were also conducted at breeding areas 2, 3, 4, 5, 8, 9, in the general lake area, west end of the lake, on the highway and the subdivision areas. Table 3 summarizes capture and recapture events for each sampling area and movements between areas as detected by recaptures. The columns represent the "previous" area and the rows represent the subsequent area. For example, one toad was detected and then redetected in breeding area 2; two toads that were in breeding area 4 were subsequently redetected in breeding area 2. One toad that was in breeding area 2 was subsequently detected in the lake. Twenty six toads were captured once in breeding area 2. Table 3 shows that more adult toad movement occurred between breeding areas in 2012 compared to 2011 (Table 4). This is likely a partial result of increased sampling outside of breeding areas in 2012.

Table 3. Summary of captures and movements of toads during the 2012 field season. The columns represent the previous area a toad was detected in whereas the rows represent the subsequent area. Grey boxes denote recaptures within the same area in subsequent sessions. Toads that were captured only once are listed in the Cap1x column.

Subsequent area	Previous area BA2	BA3	BA4	BA5	BA8	BA9	Lake	W.End	Hwy	Subd	Cap1x
BA2	1		2				1				26
BA3		3		1		1	1				77
BA4											16
BA5			1	2	2			1			100
BA8					2						13
BA9		2	4								24
Lake	1	5		3			20	1	2		67
West End		2									18
Highway		3		1		1	1		3		71
Subdivision									3	5	2

Table 4. Movements and capture events for 2011. The columns represent the previous area a toad was detected in whereas the rows represent the subsequent area. Toads that were captured only once are listed in the Cap1x column.

	Previous area					
Subsequent area	BA3	BA4	BA5	Highway	Lake	Cap1x
BA3	58		1	1		194
BA4			1			3
BA5	2		26		1	115
Highway	4		3	6		28
Lake	2		2	3	10	34

Female within-year movements for 2011 and 2012 were pooled to assess where females may move relative to breeding areas. In most cases females we recaptured on the highway, or the subdivision area (Table 5).

Table 5. Female only data pooled for 2011 and 2012 within year detections

	Previous area					
Subsequent area	BA3	BA9	Lake	Highway	Subdivision	Cap1x
BA2						5
BA3	1	1				35
BA4						1
BA5						33
BA8						1
Lake	1		19	2		33
Highway	1		1	8		36
Subdivision				2	5	1
West End of Lake	1					9

In terms of between year detections, 15 toads PITT tagged in 2011 were also captured in 2012. Of these, all but three were males (Table 6). Redetections of toads captured in the general lake area in 2011 occurred in breeding areas 2, 4, 5, and 8 in 2012.

Table 6. Recaptures of toad PITT tagged in 2011 (columns) during the 2012 field season (rows). All toads were males except for three females (in parentheses) in the Lake.

Captured in 2012	Captured in 2011							
	BA2	BA3	BA4	BA5	BA8	BA9	Lake	Highway
BA2		1					1	
BA3		1						
BA4							1	
BA5				1			2	1
BA8							2	
BA9								
Lake							4 (3)	1

Figures 6-8 map original and recapture locations of adult western toads captured at least twice during 2011 (Figure 6), 2012 (Figure 7) and between years 2011-2012 (Figure 8).

In 2011, four of the toads travelled between two difference breeding areas in the same season (Table 4 and Figure 6) whereas in 2012, 12 toads were recorded moving between breeding areas (Table 3 and Figure 7). Tables 5 and 6 indicate that all movements between breeding areas were made by male toads.

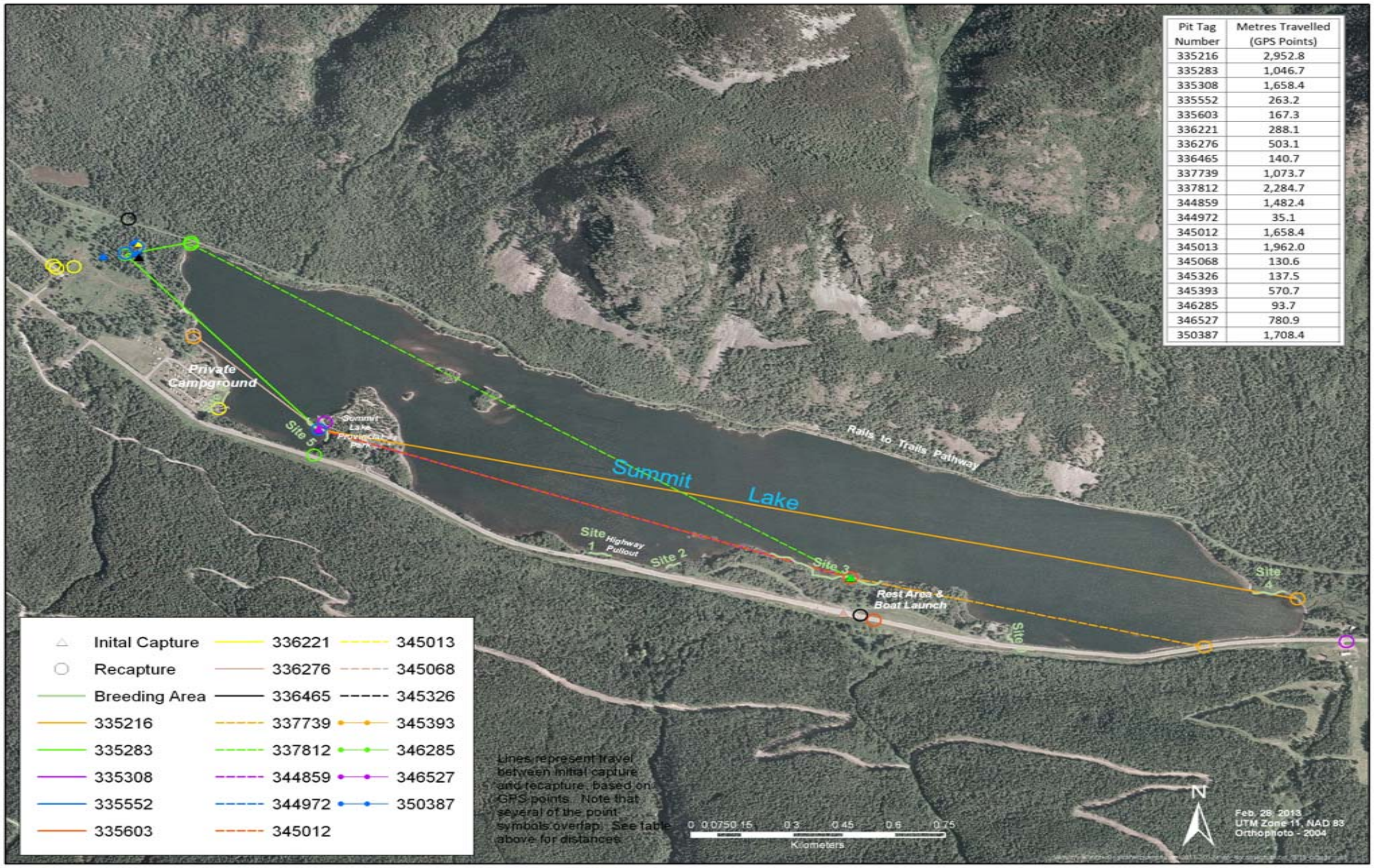
Figure 4 shows more within year movement in 2012 when compared to 2011 (Figure 6). As noted, this may be a result of increased surveys outside the breeding areas but it may have also been due to the longer breeding period in 2012.

Figure 6 indicates that some adult toads are marked at a breeding area and recaptured on Highway 6 immediately adjacent the breeding area (e.g. individual 335603) but Figures 6 and 7 also show that many toads do not always migrate away from the lake and across the highway at the nearest point to the breeding area. For example individual 301546 (Figure 6) was initially captured at breeding area 5 and recaptured on the highway half way down the lake, near breeding area 2 and individual 303274 was initially marked at breeding area 3 and recaptured on the highway approximately nearly 800m east.

Several individuals appear to complete longer distance movements in the lake prior to leaving the area. For example, in 2011 individual 337812 was initially captured at breeding area 3 and recaptured at the west end of the lake (Figure 6). In 2012, we recorded several of these longer movements within the lake, including three toads that were tagged at breeding areas and recaptured along the north shore of the lake (Figure 6).

Figures 6-8 also indicate the west end of Summit Lake and the subdivision to the northwest of the private campground are important areas for adult western toads.

Figure 8 shows a small sample of adult toads that were marked in 2011 and recaptured in 2012. Most were recaptured relatively close to where they were initially captured but three males (individuals 344219, 336796, 345013) were captured 850-1962m from their initial capture. One male (individual 344653) was captured in 2011 at breeding area 3 and captured in 2012 at breeding area 4 and again at breeding area 2 (Figure 8).



Pit Tag Number	Metres Travelled (GPS Points)
335216	2,952.8
335283	1,046.7
335308	1,658.4
335552	263.2
335603	167.3
336221	288.1
336276	503.1
336465	140.7
337739	1,073.7
337812	2,284.7
344859	1,482.4
344972	35.1
345012	1,658.4
345013	1,962.0
345068	130.6
345326	137.5
345393	570.7
346285	93.7
346527	780.9
350387	1,708.4

Figure 6. Initial and subsequent locations of PIT-tagged adult western toads captured at least twice during the 2011 field season at Summit Lake. Lines connect capture and recapture locations (Note that several of the symbols overlap). Twenty of the longest distance travelers are displayed.

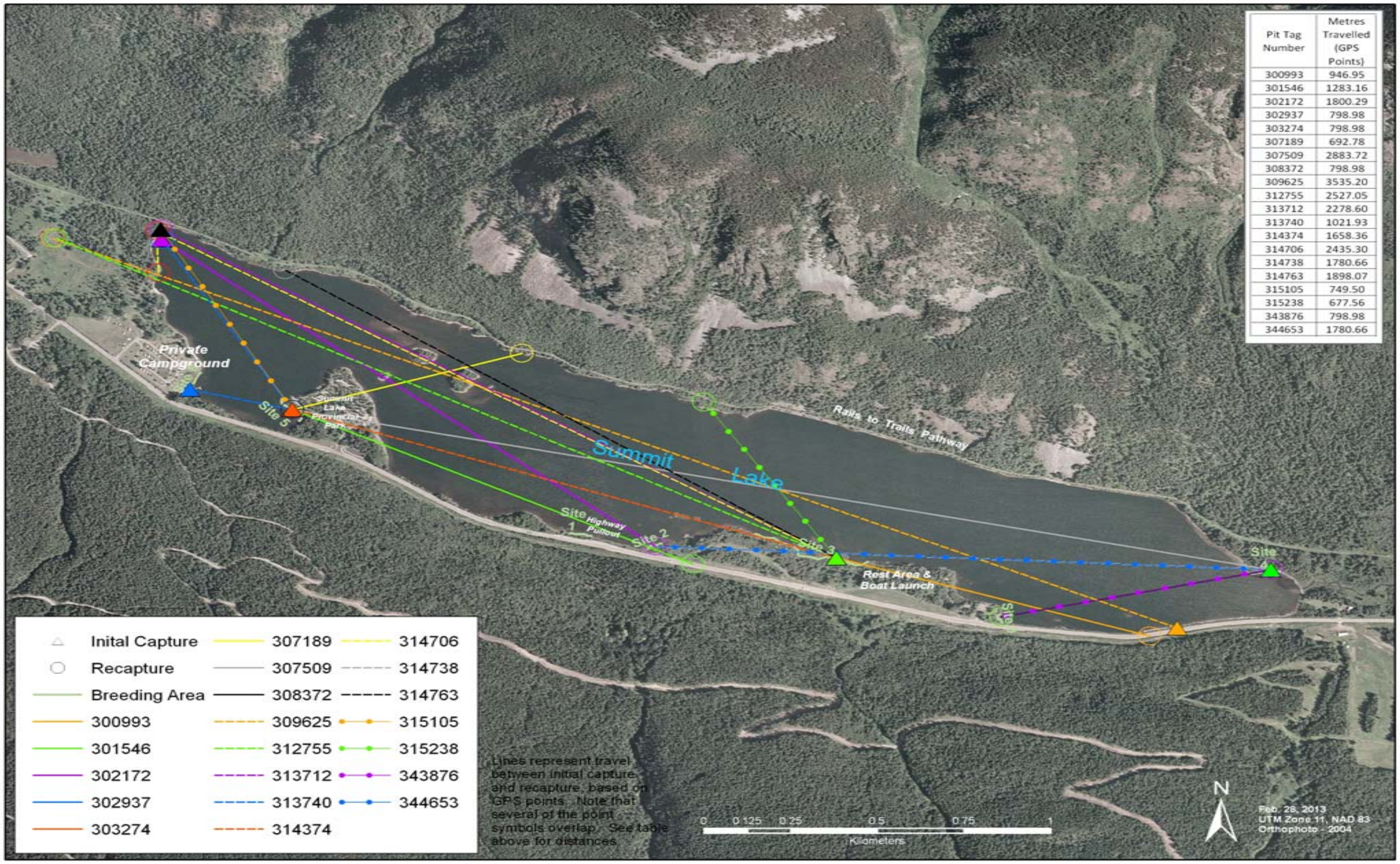


Figure 7. Initial and subsequent locations of PIT-tagged adult western toads captured at least twice during the 2012 field season at Summit Lake. Lines connect capture and recapture locations (Note that several of the symbols overlap). Twenty of the longest distance travelers are displayed.

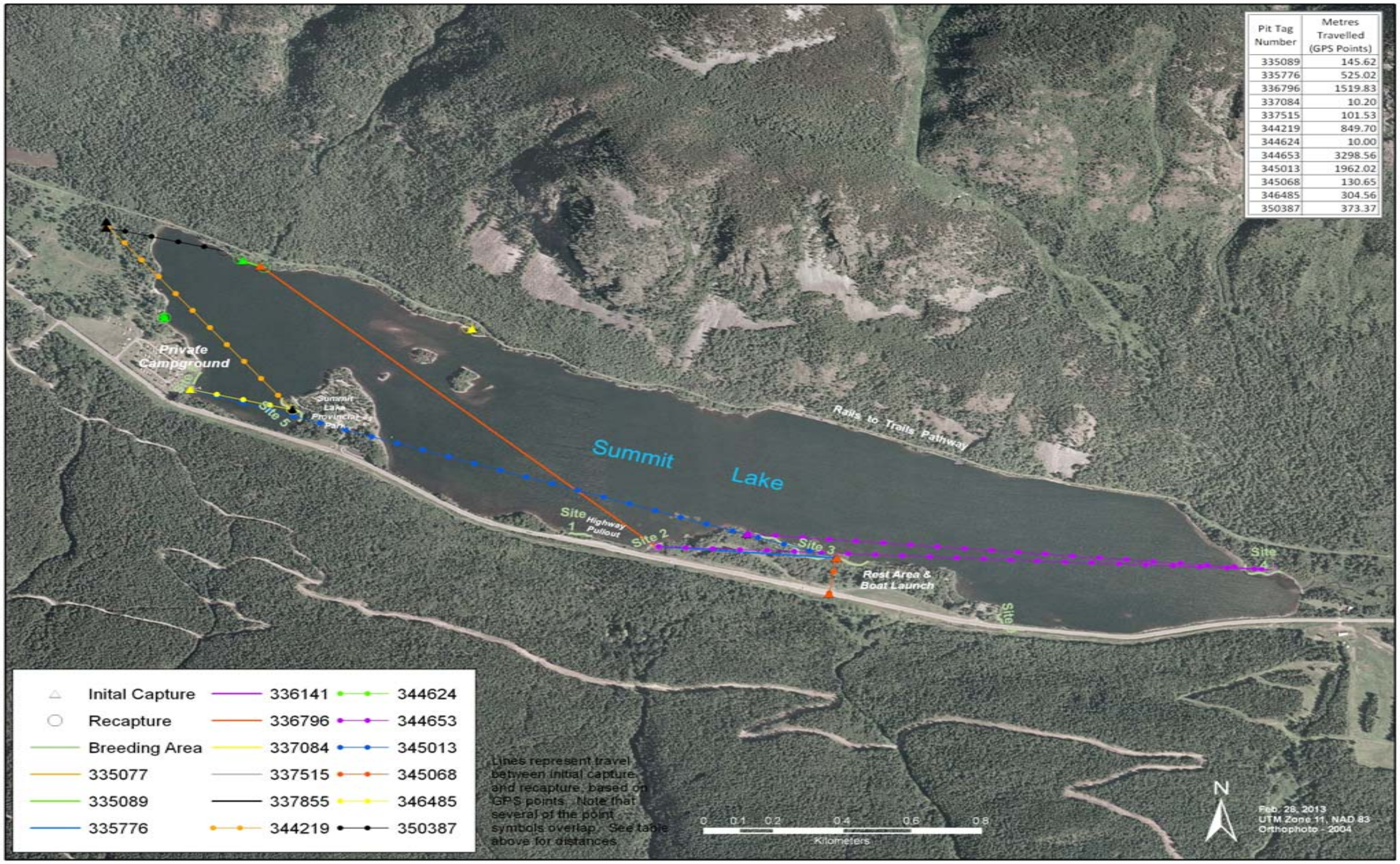


Figure 8. Initial and subsequent locations of PIT-tagged adult western toads captured in 2011 and recaptured at least once in 2012 at Summit Lake. Lines connect capture and recapture locations (Note that several of the symbols overlap). Three toads that were recaptured at their initial capture location are not show.

The sex ratio of adult male to female toads varied depending on capture location from 0.2:1 in the subdivision area to 7.9:1 at the breeding areas (Table 7). This includes combined captures from 2010-2012.

Table 7. Gender ratios of adult western toad initial PIT-tag captures by site within the Summit Lake study area.

	Male (N)	Female (N)	M:F Ratio
Lake Breeding Areas Combined	731	92	7.9:1
Lake Non-breeding Areas Combined	110	80	1.4:1
Highway	81	53	1.5:1
Subdivision	2	10	0.2:1

3.4. Toadlet migration

Toadlet highway mortality patterns among the migration transects were similar for 2010-2012 and Figures 9-12 show several crossing hotspots on Highway 6. The highest toadlet mortality hotspots were located at transects 2, 4, 13, 21 and 22 with higher than 2.5 dead toadlets per square meter recorded (Figure 9).

Figure 9 shows that barrier fences located on the lake side of the highway likely prevent some toadlets from reaching the road surface (transects 3, 11 and 12) but higher mortalities to either side of these barriers (transect 2, 4 and 13) suggest that many toadlets are being channeled around these barriers onto the highway.

The onset of toadlet migration was earlier in 2012 compared to 2010 and 2011 but the completion date of migration was similar and toadlet mortality peaked near the end August in all years (Figure 12).

A notable difference between 2012 and previous years was the larger number of dead toadlets detected on Highway 6 (Figures 12 and 13). For example, most transects had mean counts of toadlets of less than 1 in 2010 and 2011. In contrast, most plots had mean counts between 1 and 3 toadlets in 2012 (Figure 13).

In general, the highest toadlet highway mortality hotspots were adjacent to breeding areas (Figure12). In 2012, there were increased toadlet mortalities along transects 1-4 (Figure 12), near breeding site 9 which was not used in 2010 or 2011.

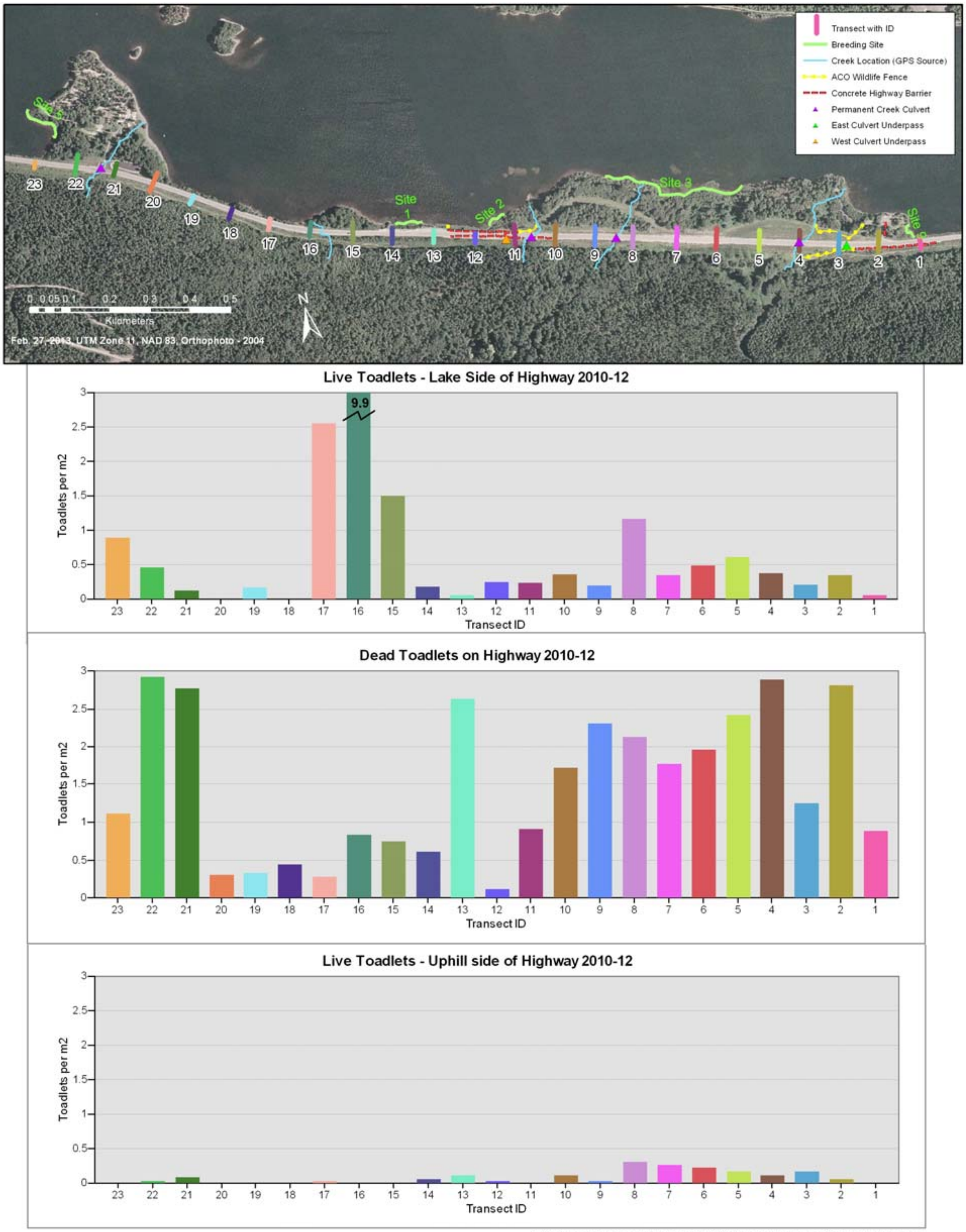


Figure 9. Mean toadlet counts per square meter for 2010, 2011 and 2012 at Summit Lake as a function of plot location. The live toadlet counts represent a "snapshot" count of toadlets whereas the dead toadlets on highway represent a cumulative count of toadlets between successive sampling occasions.

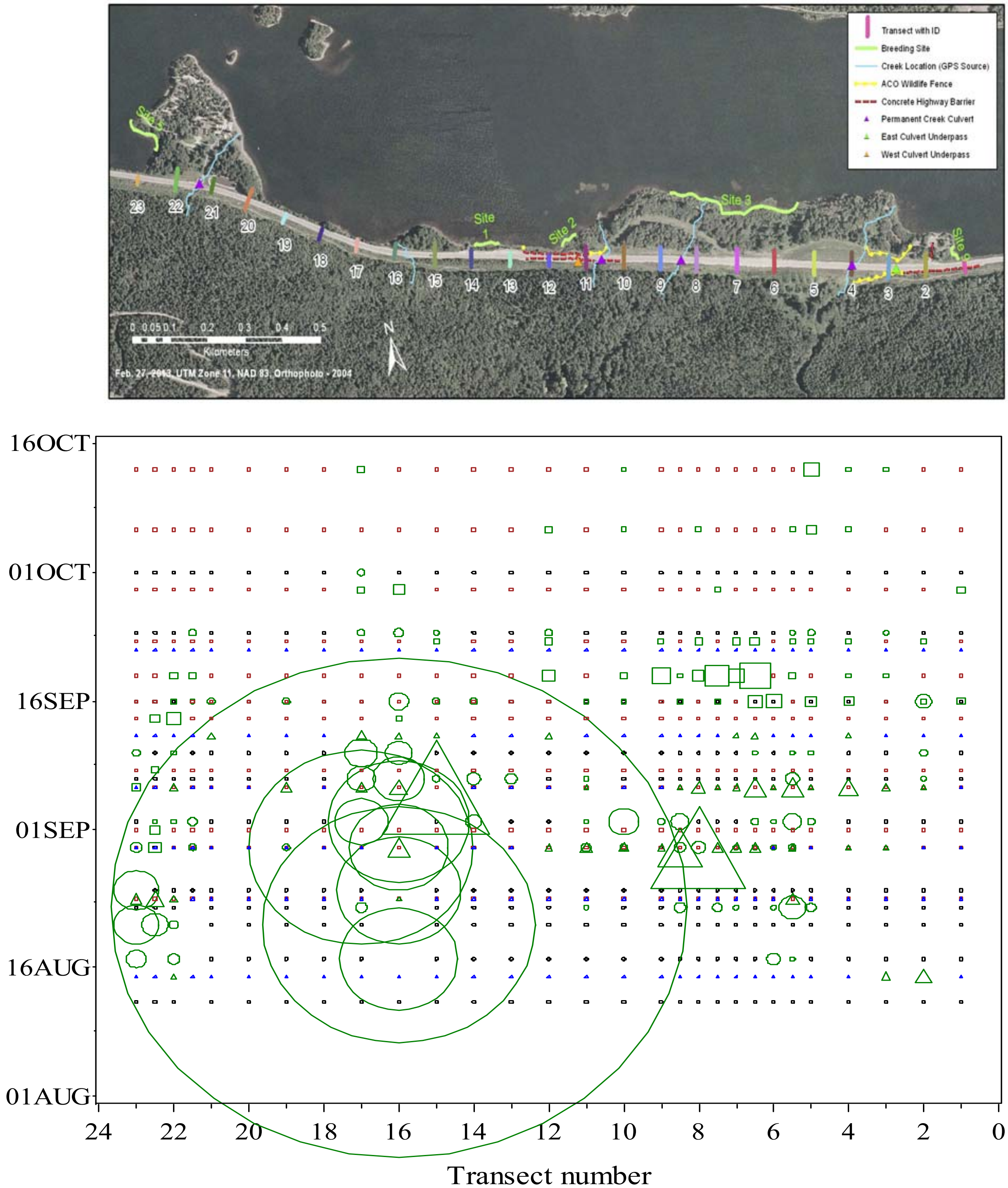


Figure 10. Bubble plots of live toadlets on the lake (north) side of Highway 6 at Summit Lake for 2010 (circles) 2011 (squares), 2012 (triangles) as a function of transect and sampling date. The size of each square or bubble is proportional to the number of toadlets counted. Plots that had no toadlets are denoted by small black circles for 2010 , small brown circles for 2011, and small blue triangles for 2012. . The transect numbers correspond to the coloured transects on the map at the top of the figure.

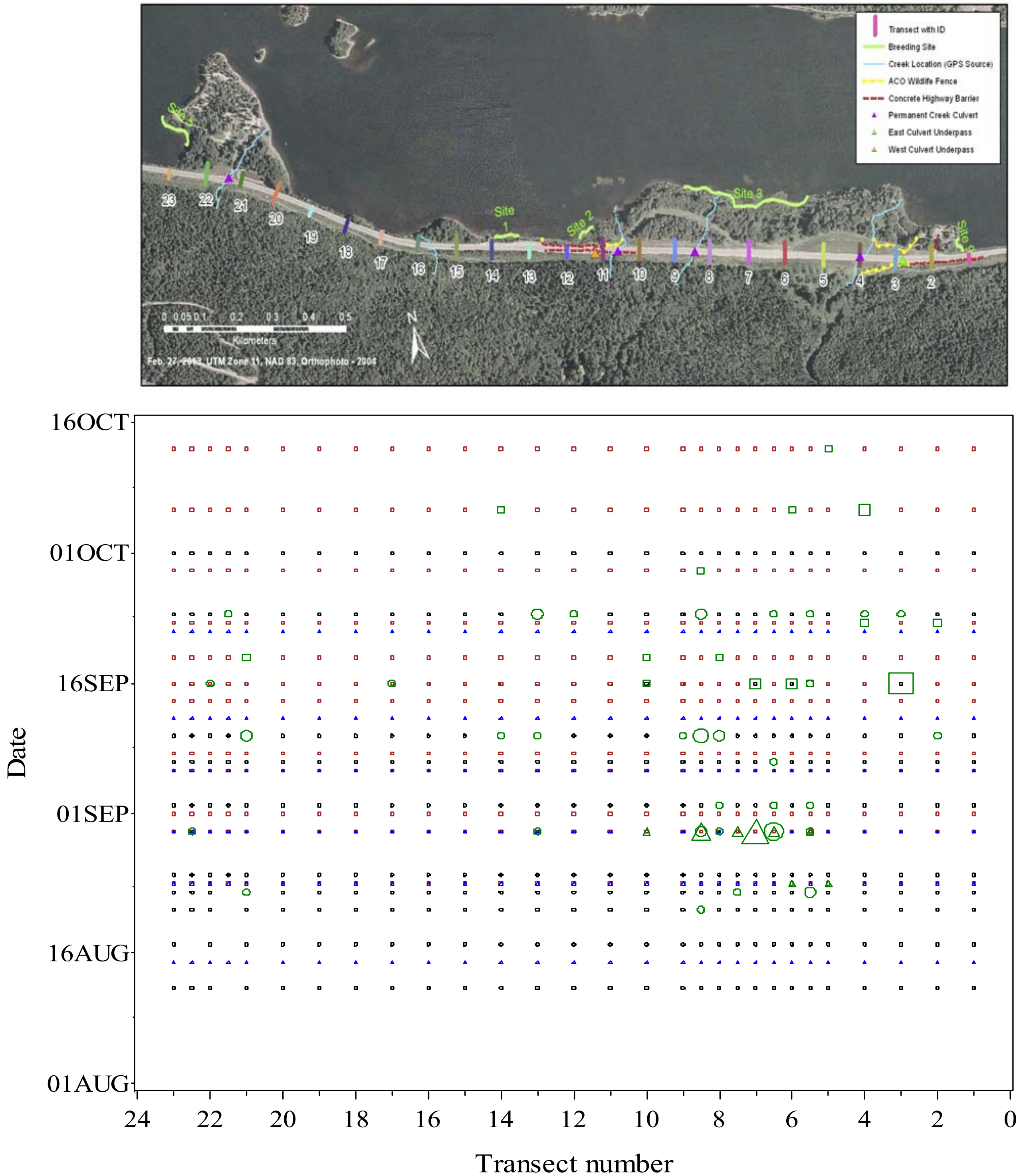


Figure 11. Counts of live toadlets on the uphill (south) side of Highway 6 at Summit Lake for 2010 (circles), 2011 (squares) and 2012 (triangles) as a function of transect and sampling date. The size of each square or bubble is proportional to the number of toadlets counted. Plots that had no toadlets are denoted by small black circles for 2010 , small brown circles for 2011, and small blue triangles for 2012. The transect numbers correspond to the coloured transects on the map at the top of the figure.

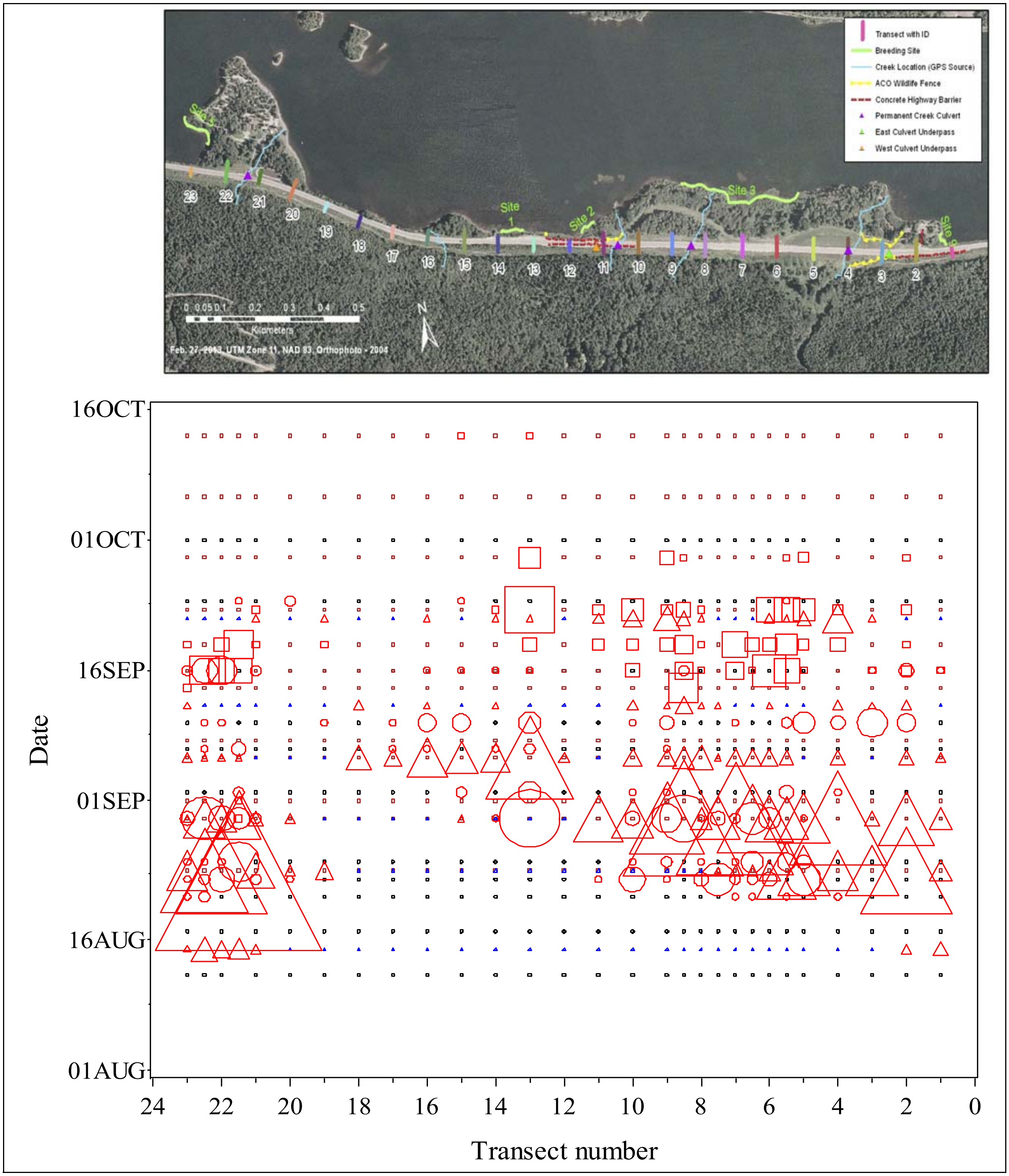


Figure 12. Counts of dead toadlets on Highway 6 at Summit Lake for 2010 (circles), 2011 (squares) , and 2012 (triangles) as a function of transect and sampling date. The size of each square or bubble is proportional to the number of toadlets counted. Plots that had no toadlets are denoted by small black circles for 2010 , small brown circles for 2011, and small blue triangles for 2012. The transect numbers correspond to the coloured transects on the map at the top of the figure.

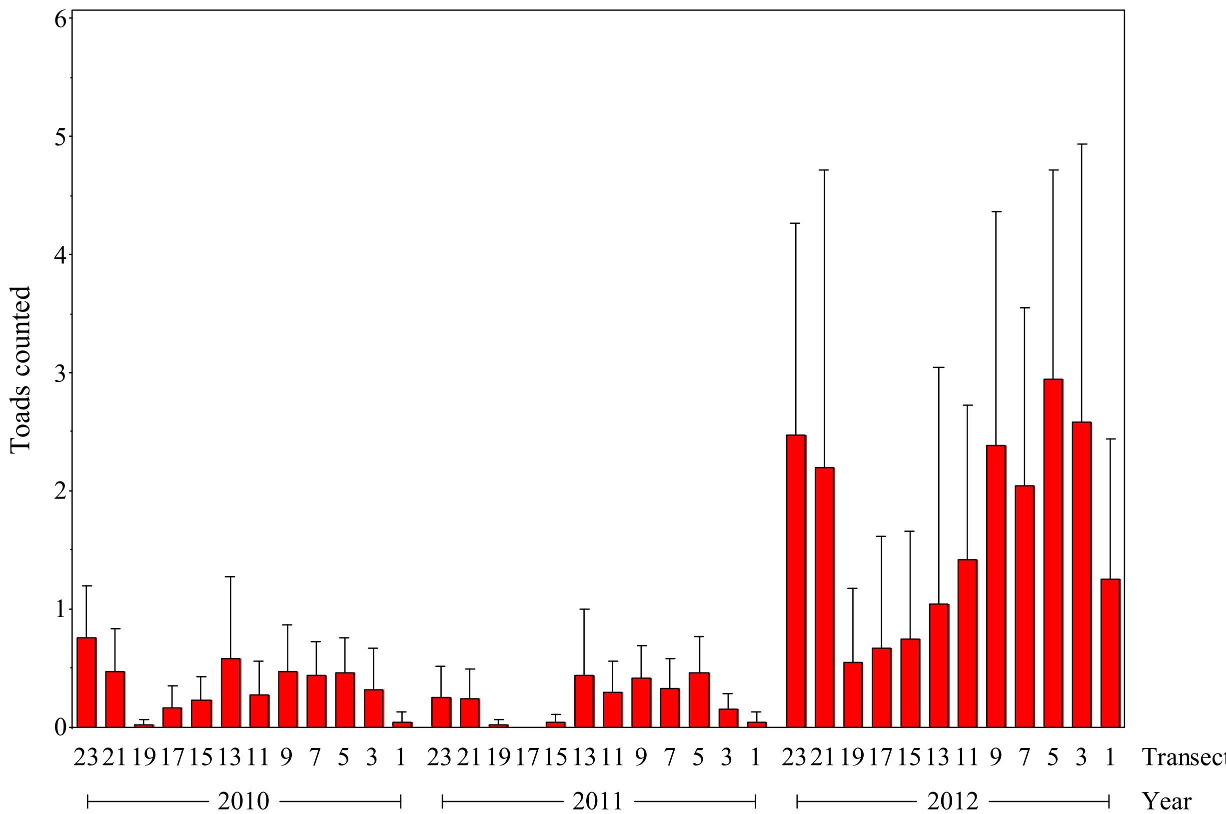


Figure 13. Mean counts of dead toadlets by toadlet transect and year. Error bars indicate one standard error.

3.5 Comparison of adult and toadlet highway distribution

Data from 44 adult drive-by surveys were used to estimate relative percentages of adult toads at each highway segment. Data from all surveys, and live and dead counts were pooled for this analysis since the main objective was to detect spatial rather temporal patterns. Data from drive-by and time-constrained surveys was pooled for the analysis given that both survey types systematically sampled the road. In addition, data with incidental surveys added in was also considered given that the majority of incidental samples were taken during toadlet transects and was therefore also systematic to some degree. The highway segment data was reduced to only include segments that overlapped the toadlet transects so this analysis only covers the portion of Highway 6 shown in Figure 9.

Data from 30 toadlet migration surveys conducted from 2010 to 2012 was used to estimate toadlet distribution. Only toadlets counted on the road plots were used with dead and live counts being pooled for the analysis.

The relative percentage of observations of toadlets was correlated with the proportion of adults (systematic+incidental) on highway segments (ρ=0.37, df=22, p=0.081). Comparison of the distribution of percentage counts suggests correspondence of peaks in toadlet and adult counts at E5-E6, D1-C8, C5 and lower counts at D3-D4. These results suggest relatively similar use of the road by toadlets and adults (Figure 10).

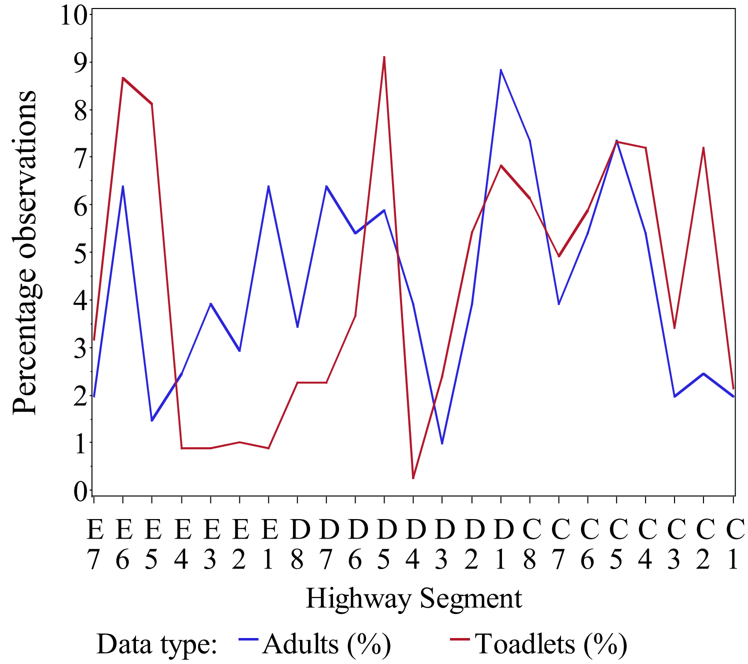


Figure 14. The distribution of toadlets and adults counted on Highway 6 segments. Relative counts is estimated as the percentage of counts in each segment for toadlets and adults.

3.6. Time-lapse Photography

In 2012, we conducted 13 photo sessions in each tunnel from 15 June to 22 September. A total of 542 toadlets were captured in 179 of 2574 frames (7.0%). This compares to 342 toadlets photographed in 209 of 4272 frames (4.9%) in 2011.

As in 2010 and 2011, the west tunnel was used more than the east tunnel. 455 toadlets were captured in 116 of 1278 frames (9.1%) in the west tunnel compared to 87 toadlets captured in 63 of 1278 frames (4.9%) in the east tunnel.

Timing of toadlet tunnel use was similar to 2010 and 2011—toadlets were first observed in the east tunnel on 16 August and in the west tunnel on 30 August 2012. Toadlet use of the tunnel continued through September and dropped off by 22 of September when sampling was concluded.

No adult toad use was recorded in either tunnel in 2010, 2011 or 2012.

3.7. Toad outreach event

Over 500 people attended "Toadfest" in 2012 and an estimated 14753 toadlets were successfully moved in 541 buckets across the highway. The mean weight of each toadlet in 2012 was 0.44 g. This compared to the approximately 5000 toadlets moved in 2011 with, each with a mean weight of 0.47g.

4.0 Discussion

4.1. Adult Migration

Adults migrate across Highway 6 to Summit Lake as soon as the lake is free of ice in late April or early May. However, it appears that a large proportion of females leave the breeding area after egg-laying or become less detectable. This may also explain our low rate of recaptures for females (Table 2). The variability of capture rates of males versus females (Table 4) may also suggest adult females may be more difficult to capture at the breeding areas.

Our results show that adult migration across the highway to Summit Lake spikes in the early spring but migration away from the lake after breeding is much more protracted in time and extends through September and into October.

Adult mortality mainly occurs at night so nocturnal traffic patterns are likely important to western toad mortality. We kept track of vehicle traffic during our surveys and 60% of nocturnal traffic consisted of commercial vehicles. The most critical time to reduce mortality is likely in the early spring, when gravid females are crossing highway. Options to reduce nocturnal vehicle traffic along Highway 6 during peak adult mortality periods should be investigated (e.g temporarily reducing commercial vehicle traffic on warm, wet nights).

The analysis of covariance model further refines areas of higher toad counts as a function of likely covariates (Table 1). This analysis suggested counts of adult toads was significantly related to season (counts were highest prior to 15 June), distance from breeding area, presence of existing barrier structures, distance to lake and distance to stream. Barriers on the uphill (south) side of the highway (concrete barriers and ACO wildlife fencing) decreased the count of toads but interestingly, barriers on the lake (north) side of the highway increased the count of toads on the highway. This suggests that barriers may be trapping adult toads on the highway, especially when they are leaving the lake. It also suggests that the underpass structures associated with the barriers are not working.

The trapping effect is also likely happening with migrating toadlets so we have discussed the possibility of slightly elevating the concrete barriers on the uphill side of the highway to allow the passage of toadlets underneath—they could be elevated enough to allow adults to pass underneath too. However, this may allow more adults on the highway prior to 15 June. This does not solve the fundamental problem that structures blocking highway access may also prevent individuals from leaving the highway.

This emphasizes the fact there are two distinct aspects to amphibian highway mortality mitigation: a) preventing animals from accessing the highway and; b) providing alternate crossing options (e.g. underpass structures) (CTC & Associates LLC 2012).

4.2. Breeding Surveys

Even with variations the onset of snow melt, the arrival of adult toads at Summit Lake seems to occur at a similar time every season: late April to early May. However, development of the tadpoles into toadlets and toadlet migration does vary as it occurred approximately one month later in 2011 than in 2010 or 2012. This may be explained by variations in summer weather patterns and associated lake water temperatures and possibly physical disturbances (e.g. increased wave action resulting from stormy weather). Also, weather and lake levels differ from year to year which affects emergent vegetation distribution and abundance

In 2010 there were five main breeding sites used. In 2011 three of the 2010 sites had nominal numbers of breeding toads and the vast majority of breeding occurred in breeding areas 3 and 5. In 2012, breeding occurred at all sites used in 2010 and 2012 but an additional site (breeding area 9) was discovered near the rest area (Figure 2). Anecdotal evidence suggests this site has been used historically but it was not used in 2010 or 2011. This discovery outlines the importance of collecting multi-year datasets for a project like this.

Tadpoles and toadlets were often observed moving away from breeding sites (Dulisse et al. 2010 and 2012); however toadlet mortality "hotspots" on Highway 6 are roughly in line with breeding sites on the lake. This suggests that most toadlets emerge near the breeding sites.

4.3. Mark-recapture

The results of PIT-tag sampling in 2012 illustrate the dynamic nature and yearly variation in adult toad demography and distribution. Recapture surveys of breeding areas suggested that toads did not stay as long at breeding areas and were potentially less centrally located in the breeding area 3 and 5. Lower abundances and lack of recaptures prevented estimation of population size for the breeding areas. However, the results of 2011 and 2012 demonstrate the linkage of breeding areas, the highway and subdivision areas.

The number of yearly recaptures of toads was low with only three females and 12 males being redetected. It is likely that female toads do not return each year to Summit Lake for breeding and therefore a multi-year effort is needed to get the best estimate of overall population size of females as well as trends in female population size. If sufficient data is collected that documents the mortality of PIT-tagged toads on the highway, it will also be possible to incorporate this data to assess the relative contribution of highway mortality to the survival rates of toads in the Summit Lake area (Barker and White 2001).

We suggest that future field work should continue the population demography project using PIT-tags at Summit Lake. The best approach for assessment of trend would be to repeat sampling in at least one of the sampling areas for at least 1-2 more years to allow estimates of trend as well as determination of demographic factors influencing population dynamics (Nichols and Hines 2002). Future work would continue the systematic sampling of toads during road crossing events in the spring, during breeding, and in higher density areas after breeding. If sample sizes are adequate it would be possible to use a multi-state analysis (Hestbeck et al. 1991, White et al. 2006) to estimate movement rates of toads between the three sampling areas as well as estimate population sizes of females.

4.5. Toadlet Migration

There appeared to be more toadlets leaving Summit Lake this season compared to 2010 or 2012 (pers. obs.) Although toadlets are extremely difficult to count, this observation is supported by the data we collected including higher toadlet mortality counts on Highway 6, increased numbers of toadlets observed in the tunnels and higher numbers of toadlets collected during toadfest.

Summaries of 2010-2012 toadlet counts and analysis of covariance (Dulisse et al. 2012) suggest toadlet distribution and migration events are influenced by a variety of climatic, habitat, and geographic factors.

In general, prior rain events potentially triggered migration events; however migration events were less likely to occur during rainfall (Dulisse et al. 2012). Not surprisingly, seasonality also affected migration events. In 2011, a late spring resulted in lower lake temperatures for egg/tadpole development which may have delayed migration with low counts of toadlets in most plots, and with peak counts occurring in mid-September as opposed to August in 2010 (Figures 10-12). The timing of toadlet movement patterns in 2012 was similar to 2010. Analysis of covariance in 2011 results suggested that toadlets were more likely to be found in areas closer to streams and drainages and on less steep aspects (Dulisse et al. 2012). In addition, toadlets avoided areas with large amounts of bare ground or tree cover (Dulisse et al. 2012).

Although there were annual differences in magnitude and timing, the relative distribution of dead toadlets on the highway appears similar from 2010 to 2012 (Figure 12), suggesting that the toadlets are crossing Highway 6 at comparable sites this season. One exception was increased toadlet mortality at transects 1-3 (Figure 12) which was likely associated with migration from breeding area 9, a newly discovered site this season.

Relatively few live toadlets are captured in lakeside and uphill survey plots (Figures 10 and 11) compared to highway plots showing dead toadlets (Figure 12). This may be due to several factors including:

a) Highway plots record cumulative dead toadlets which collect on the highway over time between weekly sampling sessions. Although dead toadlets are removed from the highway plots after each sampling session, several factors influence the length of time dead toadlets remain on the road including weather conditions, traffic volumes, scavenger presence etc. Live toadlets are also recorded within highway plots but represent a very small fraction of totals compared to dead individuals.
b) Toadlet migration is highly variable spatially and temporally. For example, huge numbers of toadlets may move in a short space of time over a fairly small area and can

therefore be easily missed during weekly sampling sessions. In these respects, enumerating dead toadlets on the highway is a more reliable method of sampling overall movement patterns.

Despite low sample sizes, the toadlet counts on the uphill side of the highway provide a potential way to evaluate the effect of potential future crossing structures. For example, it would be expected that live toadlet counts might increase near the mitigation structures once they were established. The effect of this mitigation could be tested by adding distance from crossing structure in the ANCOVA analysis with the expectation that toadlet counts would be higher in this area compared to previous years when the crossing structure did not exist. Given this, and the fact that toadlet plots represent a small portion of the overall project budget, we suggest that the uphill counts be continued.

It should also be noted that we only conduct toadlet sampling along a 2.3 km section of Highway 6 which we estimated to include the areas of highest mortality at the start of sampling in 2010. Since then, we have observed toadlets migrating across the highway to the east and west of the toadlet sampling transects but budget and time limitations prevent us from sampling the entire length of the lake.

4.6. Time-lapse Photography

Although cameral malfunctions prevented photo sampling of the entire field season (cameras were deployed 15 June – 22 September 2012), we recorded higher toadlet numbers in both east and west tunnels compared to 2010 and 2011. This is likely because overall toadlet numbers were higher this season at Summit Lake, which is also suggested by increased highway mortality data (Figure 12).

As observed in 2010 and 2011, more toadlets used the west tunnel compared to the east tunnel. This is probably because the west tunnel is larger in diameter and plastic (the east tunnel is metal), making it more attractive to amphibians.

In general, it appears that use of both amphibian underpass tunnels is very low in relation to overall numbers of migrating individuals. No adult western toads were recorded by time-lapse photography in the tunnels from 2010-2012, however some movement of adults through the tunnels was noted through the use of video in 2011 (K. Murphy 2012, pers. comm.).

4.7. Toad bucketing Event

Several changes were made to the toad bucketing event starting in 2011. Due to the potential lack of toadlets (depending on migration timing), the emphasis has shifted to education. The varied activities information table format was popular with the public and the agencies hosting the event. Approximately 14750 toadlets were moved across the highway 2012 compared to an estimated 5000 in 2011 so in this respect, the 2012 toadfest was more successful.

Large numbers of toadlets were migrating in the immediate area during toadfest and when the event was concluding and people were leaving in vehicles, a large "push" of toadlets began crossing the highway at the entrance to the park. Flaggers closed the highway for up to 15 minutes at a time in an attempt to allow the toadlets to cross but significant mortality occurred when cars were periodically allowed through. Some toadfest attendees were very disturbed by seeing toadlets being killed first-hand and participating in this mortality. This emphasizes the paradox of creating a large toad conservation event attended by many people and accompanying foot and vehicle traffic, which in turn, increases localized toad mortality.

4.8. Future Mitigation Efforts

From a population perspective we are most interested in mitigations structures that protect adult western toads and especially adult female toads. There is also concern about toadlet mortality and our results suggest that adult and juvenile toad mortality hotspots are correlated (Figure 14) which is good in that mitigation structures will potentially benefit both age classes.

Several of our analyses can be used to guide the location of potential underpass structures including:

a) Cumulative live and dead adult toad counts per 100m highway segment over a 4.8km stretch of Highway 6 from 2010-2012 (Figure 2).
b) The analysis of covariance model predicted several adult toad hotspots, usually associated with proximity to breeding areas (Figure 3).
c) Cumulative toadlet highway mortality on a 2.3km length of Highway 6 show several hotspots (Figure 9). The highest toadlet mortality hotspots associated with breeding areas.
d) Comparison of adult and toadlet distribution along a 2.3km length of Highway 6 (Figure 14).

Our data suggest toadlets are positively associated with streams (Dulisse et al. 2012). We have frequently observed masses of migrating toadlets gather and travel along the shorelines of these creeks, especially in warmer, drier weather. Livo (1998) found that a lack of waterways to or from the breeding site or drying soils surrounding the breeding pond seemed to limit toadlet dispersal. Although toadlets are more susceptible to desiccation due to their smaller body size, adult western toads are also frequently associated with water or moist sites during the non-breeding season (Campbell 1970, Davis 2000).

For these reasons and the fact that there are eight creeks conveniently spaced along Highway 6 within the western toad migration zone (Figure 2), we recommend locating underpass structures at creek locations wherever possible. This will target western toad movements but will also benefit other wildlife that use riparian travel routes including snakes, small mammals, and arthropods. This would also benefit aquatic organisms that currently have their movements blocked by existing culverts, such as fish and invertebrates. We recommend retaining riparian habitat along the creek edges under the structures to provide travel corridors for toads and other animals (see Figures 17-22).

Underpass structures should have grated decking (Figure 26) or be large enough to light, moisture and temperature levels within the underpass are similar to the surrounding habitat (see following discussion).

4.9. Amphibian Underpass Design Considerations

Amphibian underpasses usually consist of a barrier fence to prevent animals from entering the road and to direct them toward one or more tunnels which pass under the road surface. Figure 15 shows the basic design components of an underpass. Barriers may be constructed from plastic, fabric or concrete and the tunnel structures are usually concrete, plastic or metal (Jackson 2003). The underpass systems are generally located where historic migration routes cross busy roadways and have been proven effective at reducing road mortality for a variety of species at many locations worldwide. Underpass systems should be designed specifically for the species that occur in the area because certain design components may work for some species but not for others. For example, toads are known to prefer grated tops and non-metallic tunnels (concrete or plastic) (Amphibian and Reptile Conservation 2009).

The orientation of the barrier fence should angle toward the direction of travel and toward a tunnel entrance. The top view of a properly constructed fence will have a zigzag pattern with the tunnels placed at all the points closest to the road. This way, amphibians encountering the fence will still be able to travel along the fence toward their destination while being directed into a tunnel. This is an important design consideration; for example, an underpass system designed for mole salamanders in California is thought to have failed because the barrier fence was constructed parallel to the road edge, thus not directing the salamanders toward the tunnel entrance (Jackson 2003). The angled design may be difficult at Summit Lake in some areas because of the site topography. The drift fence may be placed parallel to the road if it still allows the toads to travel toward their destination (the fence should not be placed perpendicular to the direction of travel).

Amphibian underpass systems should have grated tops (Figures 15 and 26), which helps to maintain temperature, humidity, light levels and air flow conditions within the tunnel (Jackson 2003), important factors for migrating amphibians. Concerns regarding this design have been expressed locally with regard to snow plowing activities and ongoing maintenance. While there will likely be increased maintenance, the concerns regarding compatibility with snow removal may be unfounded given that there are currently many grated amphibian tunnels in place at sites receiving comparable snowfall to our area. Snow plows currently operate without incident over highway surface breaks such as bridge expansion joints.

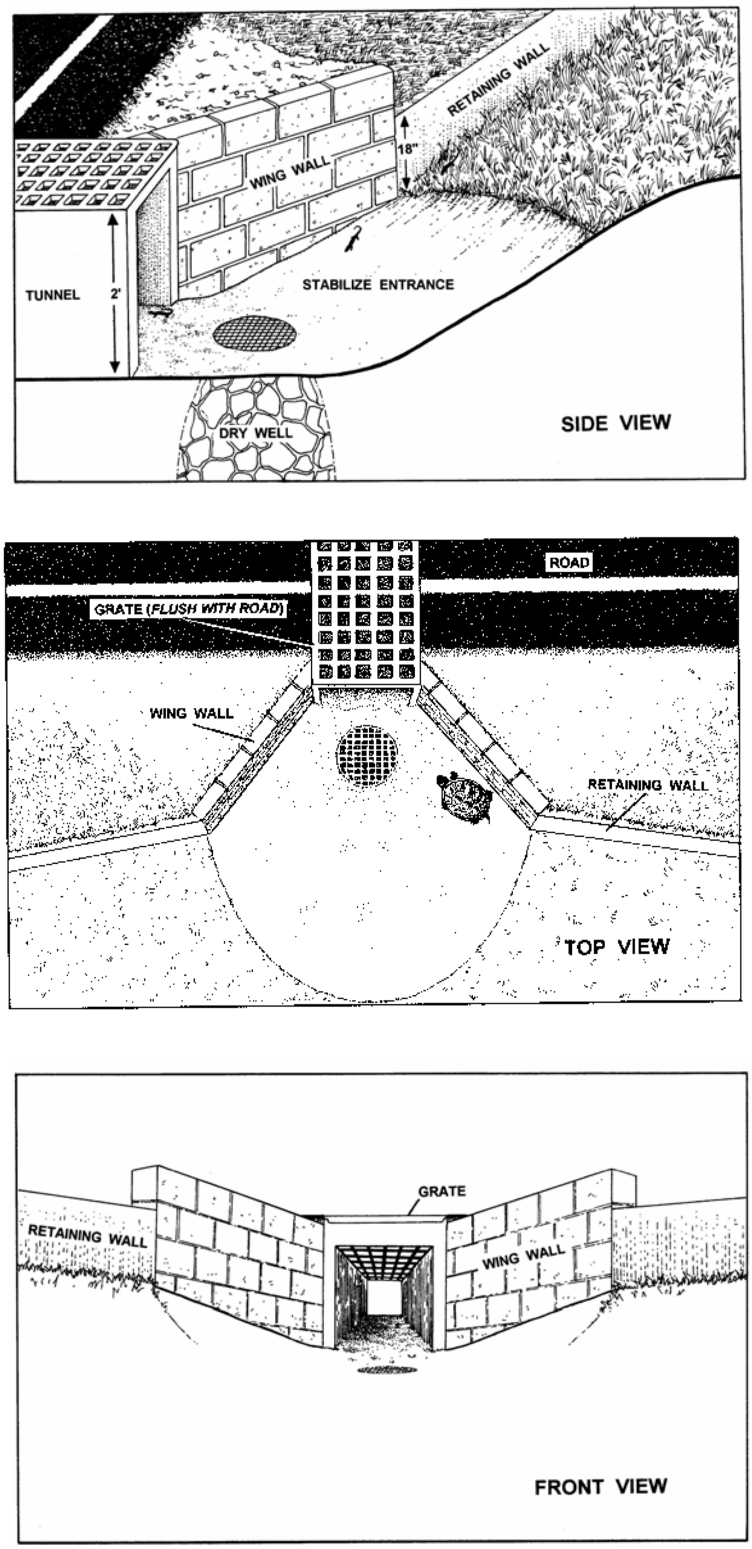


Figure 15. Three views of generalized amphibian underpass design showing the barrier fence (in this case, a retaining wall), wing wall and tunnel entrance. Used with permission from Jackson (2003).

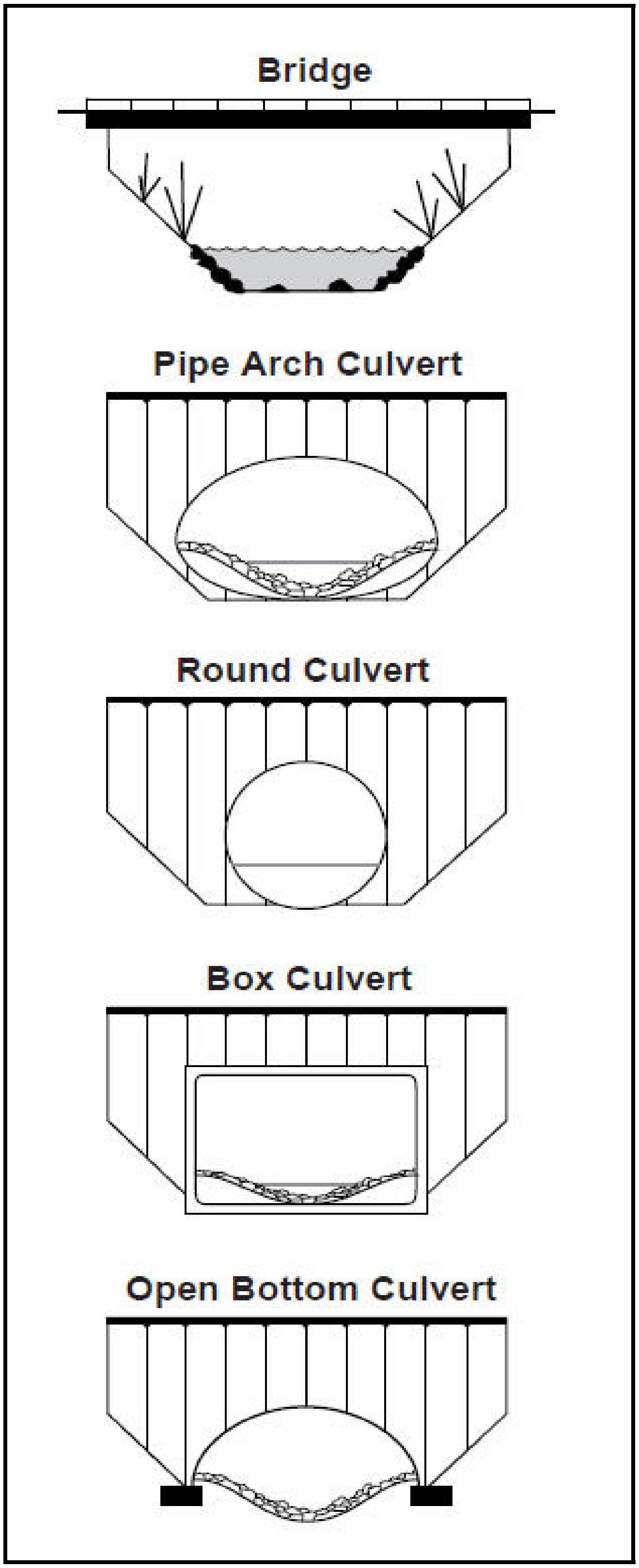


Figure 16. Generalized drawings of five types of amphibian underpass designs to be considered at Summit Lake.

As an alternative to grated tops, underpasses should be large enough to allow light and moisture levels within or under the structure to remain comparable to the environment. Figure 16 depicts five types of underpass designs which could be considered for western toad use at Summit Lake. We recommend (in order of priority and effectiveness) the use of the bridge, open bottomed culvert, box culvert, pipe arch culvert or box culvert. The bridge design is most preferable because is allows the best preservation of surrounding environmental conditions to persist under the structure (light, moisture temperature and vegetation), does not require a grated top, allows for the creation of a riparian travel corridor for use by multiple species (including aquatic organisms) and provides increased flooding protection for the roadway.

Culverts are less expensive than bridges but are also less effective (Jackson and Griffin 2000). If culverts are used, they should be as large in diameter as possible. Amphibian and Reptile Conservation (2009) recommend a minimum round culvert diameter of 1.4m or a minimum box culvert width of 1.5x1m for *Bufo bufo* in Europe (Table 8). They also recommend the placement of tunnels every 50-60m along the roadway if possible.

Table 8. Minimum size requirements for amphibian tunnels (Luell et al. 2003).

Tunnel shape	Tunnel length <20m	20 – 30m	30 – 40m	40m+
Rectangular tunnel (clear width x clear height)	1.0m x 0.75m	1.5m x 1.0m	1.75m x 1.25m	2.0m x 1.5m
Pipe (diameter)	1.0m	1.4m	1.6m	2.0m

Specific underpass design will depend on microsite topography, substrate, potential creek flows and project budget. A combination of designs outlined in Figure 12 could be used along the length of Summit Lake. Figures 17-21 show several preferred underpass designs in place.

Figures 23-28 show different fence designs. The polymer ACO fencing (Figure 25) is currently in use at the east and west tunnels at Summit Lake. It is effective at blocking movement of adults and toadlets but there are several concerns with this product including: a) it is expensive; b) it seems to have durability issues with regard to snow load and possibly human/ungulate foot traffic near the highway; c) the arched design effectively creates a very dry, dark environment on one side of the fence which may not be inviting to toads and d) it requires maintenance (e.g. brushing) which is not occurring with regularity. More permanent materials such as concrete (Figure 24) would likely be more suitable for use at Summit Lake and possible alternative fencing materials such as plastic aquaculture (oyster farm) netting as described by Malt (2012) should be investigated.

Figure 17. Bridge overpass with creek and riparian habitat preserved.

Figure 18. Open-bottom culvert with creek and narrow riparian zone.

Figure 19. Concrete arch bridge with creek and riparian zone intact.

Figure 20. Concrete open-bottom culvert with riparian ledge for animals to pass through.

Figure 21. Concrete open-bottom culvert with wildlife fence.

Figure 22. Concrete box culvert.

Figure 23. Concrete polymer wildlife fence connecting to box culvert underpass.

Figure 24. Concrete amphibian fence during construction.

Figure 25. ACO wildlife fence currently in use at Summit Lake.

Figure 26. Grated top amphibian underpass. This tunnel is likely too small for use at Summit Lake.

Figure 27. Semi-permanent amphibian fence constructed from metal flashing material.

Figure 28. Temporary amphibian drift fence.

4.9.1 Summary of Key Design Features for Western Toad Underpasses

•The best underpass structures serve multiple purposes (e.g. water drainage and population connectivity for multiple species)
•Tunnels should be as large as possible because toads may be reluctant to enter small tunnels
•Tunnels should have a grated top, or be large enough to allow light and moisture into passageway (e.g. bridges or large culverts)
•Tunnel should be lined with natural substrate
•Due to potential electromagnetic and chemical issues, tunnels should be constructed with concrete or plastic
•Tunnels should be placed 60m or less apart, if possible
•Wing walls should be oriented at 45 degrees to tunnel entrance to direct amphibians into tunnel
•Barrier fences should be at least 20cm high and angled at 25-30 degrees to the road edge (or in the direction of travel) to direct amphibians toward the wing walls and tunnel entrances
•The top of the barrier fence should be flush with the road or substrate surface to allow animals that have managed to trespass the barrier to escape from the highway or continue travelling (concrete highway barriers currently in place at Summit Lake are trapping migrating toadlets and adults on the highway)
•Design should prevent tunnels from being flooded with runoff. If a drain is constructed near the tunnel entrance to prevent this problem, it should be designed to prevent amphibians from becoming trapped.
•Regular maintenance of crossing structures and fences is very important and often overlooked
•Effectiveness of structures can only be determined with long-term monitoring

5.0 Literature Cited

Amphibian and Reptile Conservation. 2009. Common toads and roads. Guidance for planners and highways engineers (England). Edited by F. Barker.

Anonymous.1998. Field manual for describing terrestrial ecosystems Resource Inventory Branch, BC Ministry of Environment Lands and Parks & Research Branch, BC Ministry of Forests, Victoria BC.

Barker, R. J., and G. C. White. 2001. Joint analysis of live and dead encounter of marked animals. Pages 361-366 in R. Fields, editor. Intergrating People and Wildlife for a Sustainable Future: Proceedings of the Second International Wildlife Management Congress. The Wildlife Society, Bethesda Md.,Gödölló, Hungary.

Braumandl, T.F. and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. Research Branch, British Columbia Ministry of Forests, Victoria, B.C.

Campbell, J.B. 1970. Life history of *Bufo boreas boreas* on the Colorado Front Range. PhD. Dissertation. University of Colorado, Boulder, CO.

[CDC] B.C. Conservation Data Centre. 2012. BC Species and Ecosystems Explorer. B.C. Minist. of Environ. Victoria, B.C. Available: http://a100.gov.bc.ca/pub/eswp/ (accessed Apr 20, 2012).

Corkran, C.C. and C. Thoms. 1996. Amphibians of Oregon, Washington and British Columbia, A field identification guide. Lone Pine Publishing. Vancouver, B.C.

COSEWIC. 2002. COSEWIC assessment and status report on the western toad *Bufo boreas* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp.

CTC & Associates LLC. 2012. Highway crossings for herptiles (Reptiles and amphibians). Preliminary investigation for Caltrans Division of Research and Innovation.

Davis, T.M. 2000. Ecology of the Western Toad (*Bufo boreas*) in forested areas on Vancouver Island. Final Report. Forest Renewal B.C. Ministry of Forests, Victoria, B.C.

Davis, T.M. 2002. Research Priorities for the Management of the Western Toad, Bufo boreas, in British Columbia. B.C. Minist. Water, Land and Air Protection, Biodiversity Branch, Victoria, BC. Wildlife Working Report No. WR-106.

Dulisse, J. and D. Hausleitner. 2010. 2009 West Kootenay Amphibian Survey. Report prepared for the Fish and Wildlife Compensation Program. Nelson, BC.

Dulisse, J., D. Hausleitner and J. Boulanger. 2011. Western Toads at Summit Lake 2010 Field Season. Report prepared for Fish and Wildlife Compensation Program. Nelson, B.C.

Dulisse, J., D. Hausleitner and J. Boulanger. 2012. Western Toads at Summit Lake 2011 Field Season. Report prepared for Fish and Wildlife Compensation Program. Nelson, B.C.

Ferner, J.W. 2007. A review of marking and individual recognition techniques for amphibians and reptiles. Society for the study of Amphibians and Reptiles. Herpetological Circular 35: 72pp.

Gosner, K.L. 1960. A simplified table for staging anuran embryos and larvae with notes on identification. Herpetologica 16: 183–190.

Hammerson, G., Santos-Barrera, G. & Muths, E. 2004. *Bufo boreas*. In: IUCN 2007. 2007 IUCN Red List of Threatened Species. Web site accessed August 2007.

Hestbeck, J. B., J. D. Nichols, and R. A. Malecki. 1991. Estimates of movement and site fidelity using mark-resight data of wintering Canada geese. Ecology 72:523-533.

Hosmer, D. W., and S. Lemeshow. 2000. Applied Logistic Regression Analysis: Second Edition. Wiley and Sons, New York.

Jackson, S. D. and C. R. Griffin. 2000. A Strategy for Mitigating Highway Impacts on Wildlife. Pp. 143-159 In Messmer, T.A. and B. West, (eds) Wildlife and Highways: Seeking Solutions to an Ecological and Socio-economic Dilemma. The Wildlife Society.

Jackson, S.D. 2003. Proposed design and consideration for use of amphibian and reptile tunnels in New England. Unpublished Report. University of Massachusetts Amherst, MA.

Krebs, C.J. 1989. Ecological Methodology. Harper and Row Publishers, New York.

Livo, L.J. 1998. Investigations of boreal toad tadpole ecology. In, Colorado Division of Wildlife Boreal Toad Research Progress Report 1995-1997. Colorado Division of Wildlife, Fort Collins, CO.

Luell, B., G.J. Bekker, R. Cuperus, J. Dufek, G. Fry, C. Hicks, V. Hlavac, V. Keller, C. Rosell, T. Sangwine, N. Torslov, B. Wandall (Eds.) 2003. COST 341 Wildlife and traffic: A European handbook for identifying conflicts and design solutions. KNNNV Publishers, Brussels.

Malt, J. 2012. Assessing the effectiveness of amphibian mitigation on the Sea to Sky Highway: population level effects and best management practices for minimizing highway impacts. Final Report. BC Ministry of Forests, Lands, and Natural Resource Operations, South Coast Region.

Milliken, G. A., and D. E. Johnson. 2002. Analysis of messy data, Volume III: Analysis of covariance. Chapman and Hall, New York, New York, USA.

[MoE] Minsitry of Environment. 2008. Standard Operating Procedures: Interim Hygiene Protocols for Amphibian field staff and researchers. Ecosystem Branch, Ministry of Environment. Victoria, B.C.

Nichols, J. D., and J. E. Hines. 2002. Approaches for the direct estimation of lambda, and demographic contributions to lambda, using capture-recapture data. Journal of Applied Statistics 29:539-568.

Ohanjanian, I. A. (Penny). 1997. Mortality of newly metamorphosed western toads (*Bufo boreas*) on the highway at Summit Park. Report prepared for B.C. Parks. Nelson, BC.

SAS Institute. 2000. The SAS System for Windows. The SAS Institute,Cary NC.

Seaton, P. 2008. Wildlife fence repair, monitoring and the western toad's (*Bufo boreas*) utilization of the fence and tunnel at Summit Lake on Highway 6. Report prepared by Ingersol Mountain Enterprises Ltd for Ministry of Environment, Nelson, BC

Seaton, P., G. Seaton, D. Knopp and A. Knopp. 2005. Options to reduce traffic mortality of western toads (*Bufo boreas*) at Summit Lake. Report prepared by Ingersol Mountain Enterprises Ltd for Ministry of Water Land and Air Protection, Nelson, BC.

Underwood, A. J. 1997. Experiments in Ecology: Their Logical Design and Interpretation Using Analysis of Variance. Cambridge University Press, Cambridge.

White, G. C., W. L. Kendall, and R. Barker. 2006. Multistate models and their extensions in program MARK. Journal of Wildlife Management 70:1521-1529.

Zar, J.H. 1996. Biostatistical Analysis. Prentice-Hall. Englewood Cliffs, NJ.