Western Toad Winter Habitat Requirements in Modified Landscapes on Vancouver Island Summary

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EXECUTIVE SUMMARY

Western Toads (*Anaxyrus boreas*) are listed federally as *Special Concern* (S3/S4). On the south coast of BC, where rural and urban development has been extensive Western Toad breeding populations are relatively rare and patchily distributed and they are believed to be in decline. The *BC Western Toad Provincial Working Group* prepared a *Draft Provincial Management Plan* for this species, citing urban development and transportation corridors as medium and high threats for the species respectively and identified hibernation sites as a knowledge gap needed to assess population viability and improve best management practices. The overall goal of this three-year project (pilot study, Year 1, and Year 2) was to identify important terrestrial habitats on eastern Vancouver Island in order to contribute towards habitat protection and improved connectivity. The objectives of the study were to locate and describe Western Toad hibernation sites, determine whether hibernacula were communal, and determine the distance between important habitat features such as hibernation and breeding sites.

Our study site was located in the Cowichan River Valley west of Duncan, on eastern Vancouver Island within a mosaic of land uses (i.e., forestry, housing developments, agricultural land, etc.). We captured toads via two main methods— night road surveys and incidental captures by volunteers. We fit adult toads with BD-2 radio transmitters with temperature sensors. Toads were re-located every 4 to 7 days throughout the fall and winter. Each winter we set remote cameras at suspected hibernation sites to capture toad emergence, in order to confirm that they were hibernacula and to determine if they were communal. In fall of Year 1 and 2, we re-set remote cameras at some of the previously confirmed hibernation sites to see if they were re-used across years. Lastly, we set microclimate data loggers at hibernation sites to record air temperature and relative humidity and we measured habitat variables at three spatial scales at hibernation sites and random sites. Over the three-year period, we engaged in extensive public outreach to inform the public of our project, garner public support, and to gain permission to access private land.

Of the 61 toads fitted with transmitters in the fall, we confirmed the location of 28 hibernation sites. Toads moved extensive distances in the fall and spring, averaging 496 m between their point of capture and their hibernation site, and 474 m between their hibernation site and their breeding site. Many toads moved in the direction of (closer to) their breeding site in the fall. As a result of these extensive movements, toads crossed at least one public road during their migrations. Each year, the majority of toads entered into hibernation during the month of November, but emergence varied by two months over the three-year study period. Most toads emerged in Feb. during the pilot study year, in Jan. during Year 1, and in March in Year 2. Hibernation and emergence appeared to be temperature related. Toads hibernated on average for 81 days (12 weeks). Some toads did not move towards breeding site in the spring and were suspected of skipping breeding that year.

Most of the toads hibernated in some type of forest edge habitat and / or within a 10-15 year-old clearcut. Hibernacula plots contained more stumps, larger stumps, and more large downed wood compared to random plots. The majority of toads (82%) utilized wood structures (logs, root wads, and stumps) for hibernation. Despite their proximity to, or occasional use of, built structures during fall migrations, none of the toads hibernated near or within a human built structure (e.g., building), although some utilized road banks. Toads were on average 4°C warmer than ambient air temperatures during hibernation. However, 6 toads did experience subzero temperatures at some point during hibernation. The majority of hibernacula were not communal. Wildlife camera data confirmed that one of the hibernation sites was used by more than one toad, and that it was used again the following year. Detailed statistical analyses, and manuscript development, are ongoing.

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1.0 INTRODUCTION

Two populations of Western Toad (*Anaxyrus boreas*) are recognized in Canada, Calling and Non-calling. Both are federally listed as *Special Concern* by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and registered on Schedule 1 of the *Species at Risk Act* (SARA). The majority of Western Toads in BC, including all coastal areas, are within the Non-calling population. Scientists are concerned about the status of Western Toads due to dramatic declines that have occurred within parts of the species' range in the United States and possibly the south coast of BC. The major threats identified for Western Toads include habitat degradation and loss, disease, and road mortality (COSEWIC 2012). Although some aquatic habitats receive a measure of protection through various forms of legislation, we know little of what toads require for hibernation and the availability of these sites within the landscape, which limits our ability to manage for and protect them.

Radio-telemetry studies on Western Toads in various locations investigated breeding sites, summer range movements, and habitat use (see Appendix 1). The few studies describing hibernation sites found that toads move long distances between spring breeding ponds and winter terrestrial hibernation sites, which were often communal (e.g., 146-1936m, Browne and Paszkowski 2010b, AB; 320-1000 m, Palmeri Miles 2012, WA). Loss or disturbance of these terrestrial hibernation sites could have negative effects on toad populations. The only other study that has investigated toad hibernation in BC has taken place in a less urban-developed landscape, where habitat availability is less constrained (Dulisse 2017). Western Toad management and conservation in the intensively developed south coast region of the province requires critical information on the location of hibernation sites and the potential threats that place local populations at risk.

The *BC Western Toad Provincial Working Group* prepared a *Draft Provincial Management Plan* for this species, citing urban development and transportation corridors as medium and high threats for the species respectively (Provincial Western Toad Working Group 2012). The primary goal of the Management Plan is to maintain self-sustaining populations of Western Toads across BC. Two of the knowledge gaps identified in the Management Plan include: 1) Movement distances and dispersal patterns, especially in fragmented landscapes; and 2) Terrestrial habitat use and characteristics of hibernation sites. This information is not well understood but is needed to assess population viability, conservation prioritization, and to improve best management practices.

The Cowichan Valley, near the town of Duncan, has been identified as a "hot spot" for toad occurrence on Vancouver Island (Wind and Willmott 2012a). At least three known breeding sites have been identified within the Valley, two of which occur in the Sahtlam area west of Duncan. The landscape consists largely of rural properties and farms with a combination of forest cover, open areas, and numerous natural and man-made water features (e.g., dug outs). This area is under increasing development pressure and toads appear to be particularly vulnerable to road mortality and development. Toads may be limited in the road density and traffic levels, and / or the ratio of vegetative cover to built environment, they can tolerate before adult road mortality reduces long-term viability. Given their ability and propensity to travel long distances (e.g., more than 7 km from breeding site; Schmetterling and Young 2008), understanding what local terrestrial habitat features they are using outside of the brief breeding season is important for developing management or recovery plans for the species. Improvements in radio-telemetry technology, in combination with the relatively large size of adult Western Toads, make it possible to track individuals for months at a time, and locate them during periods of subsurface inactivity, such as winter hibernation.

1.1 Goals and Objectives

The **goal** of the *Western Toad Habitat Use on Vancouver Island* project, initiated in 2011, was to identify important upland habitats in relation to known breeding sites on eastern Vancouver Island, to contribute towards the protection of hibernation sites and connectivity corridors. This information will contribute to management plans outlined in the provincial *Western Toad Recovery Strategy*. The **objectives of the study were to:**

- Locate Western Toad hibernation sites via the use of radio telemetry
- Describe habitat features at three spatial scales at hibernation versus random sites
- Determine whether toad hibernation sites are communal
- Identify and assess threats to toad hibernation sites

2.0 METHODS

Pilot studies were conducted in 2012 and 2014-15 to assess project feasibility in the study area and develop radio-telemetry and field methods (Wind and Willmott 2012b, Wind 2014, Wind 2015). A Wildlife Research and Animal Care permit was obtained from the Ministry of Environment for this study (Permit #NA14-95430).

2.1 Study Area

This study took place in the Cowichan River valley west of Duncan, on Vancouver Island. It was centred on a known toad breeding site located at Wake Lake, 625 m north of the river. The spatial extent and distribution of the toad population in this geographic locale was unknown. We took an adaptive approach to determining the size of the study area within which to capture and radio-tag toads each autumn. A 2-km radius circle was centred over each confirmed hibernacula from the previous study year and merged into one large polygon (e.g., see Fig. 1 from Year 2 of the study). The radius was based on maximum distances observed between breeding sites and summer ranges and hibernation sites from toad studies conducted in AB and WA (see Appendix 1). The area south of the Cowichan River was excluded from the study for logistical reasons. Though toads are known to use rivers as travel corridors and have been observed along the edges of the Cowichan River in the summer, none of the toads tracked in each of the three years of the study moved across the river from the north side to the south side.

The majority of the study area consists of private land, consisting of homes, undeveloped (largely forested) private land, and private land zoned for industrial logging. Approximately, 90% of the study area is private land, and 10% is public or park land.

2.2 Capturing Adult Western Toads

Survey efforts to capture and radio-tag adult toads were initiated in early September when toads were observed to begin fall migrations, based on capture efforts / toad observations in Year 1 and pilot study results (Wind 2015). Two main methods were used to capture adult Western Toads for this telemetry study: road surveys, and incidental volunteer captures.

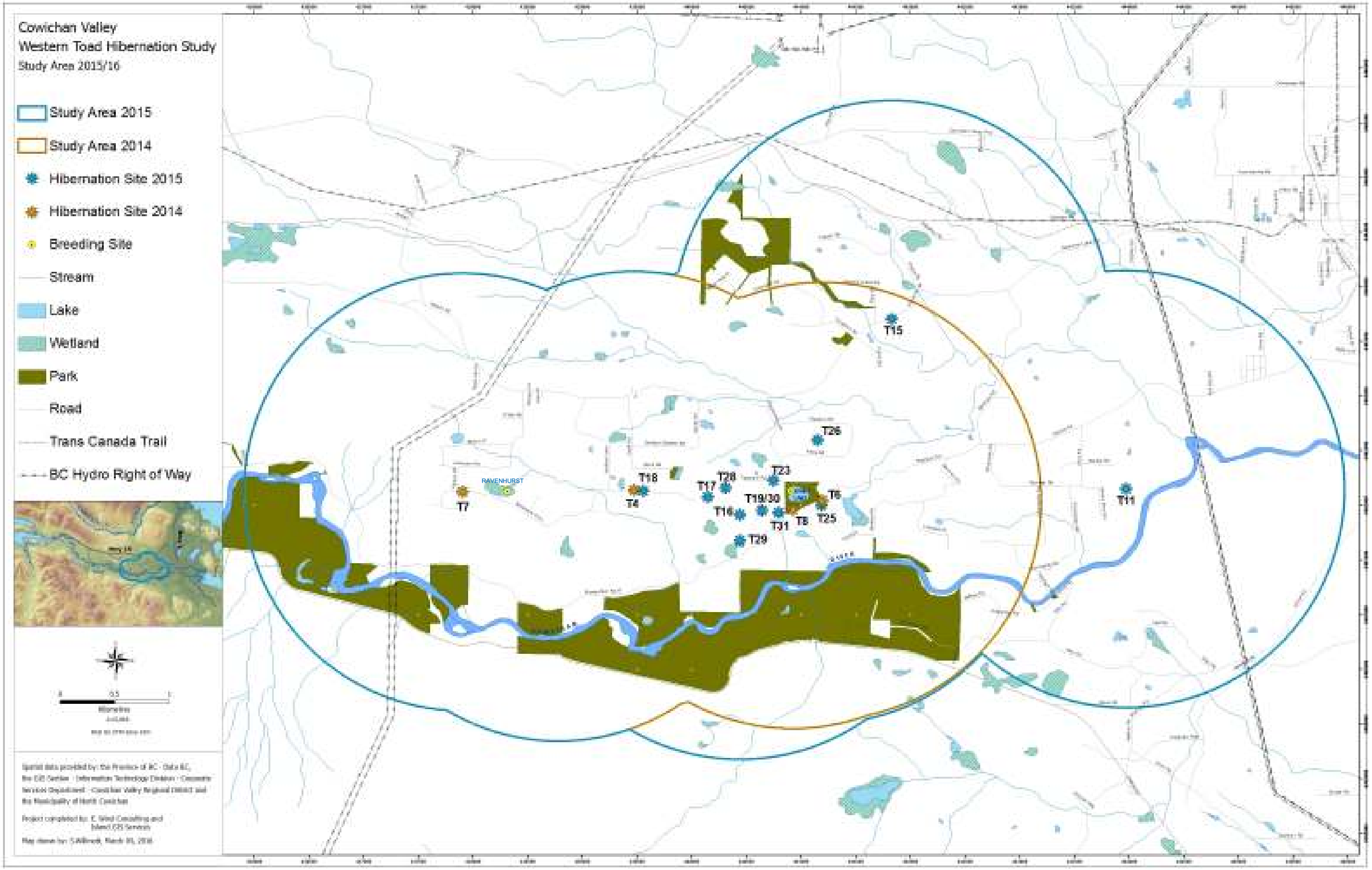


Figure 1. Cowichan Valley, Vancouver Island, Western Toad hibernation Year 2 (2016-17) study area based on 4 suspected / confirmed hibernation sites from the pilot study year (2014-15) and 12 confirmed sites from Year 1 (2015-16).

Rural roads throughout the study were slowly driven on mild, rainy nights, starting at dusk and continuing for approximately 2 hours. In Year 1 and Year 2, five road survey routes were used to distribute effort equally across the study area over time (Fig. 2).

The Cowichan Valley / Wake Lake study area is primarily private land. As such, public / landowner contact, communication, and support was a critical component of the project. Since 2012, a volunteer network of 49 people has been collected and put onto a Western Toad email list for the Sahtlam area west of Duncan. This list includes people willing to report toad locations, allow access to their land to capture and monitor toads, and /or have offered to help in some way with the project. Email, mail out fliers, a blog, local media, “Toadally Awesome Volunteer” magnets (Fig 3), and public presentations were used to engage volunteers and the general public. Laminated “Toads Wanted” project information cards were taped onto 10 community mailboxes in the study area in Year 1 and Year 2.

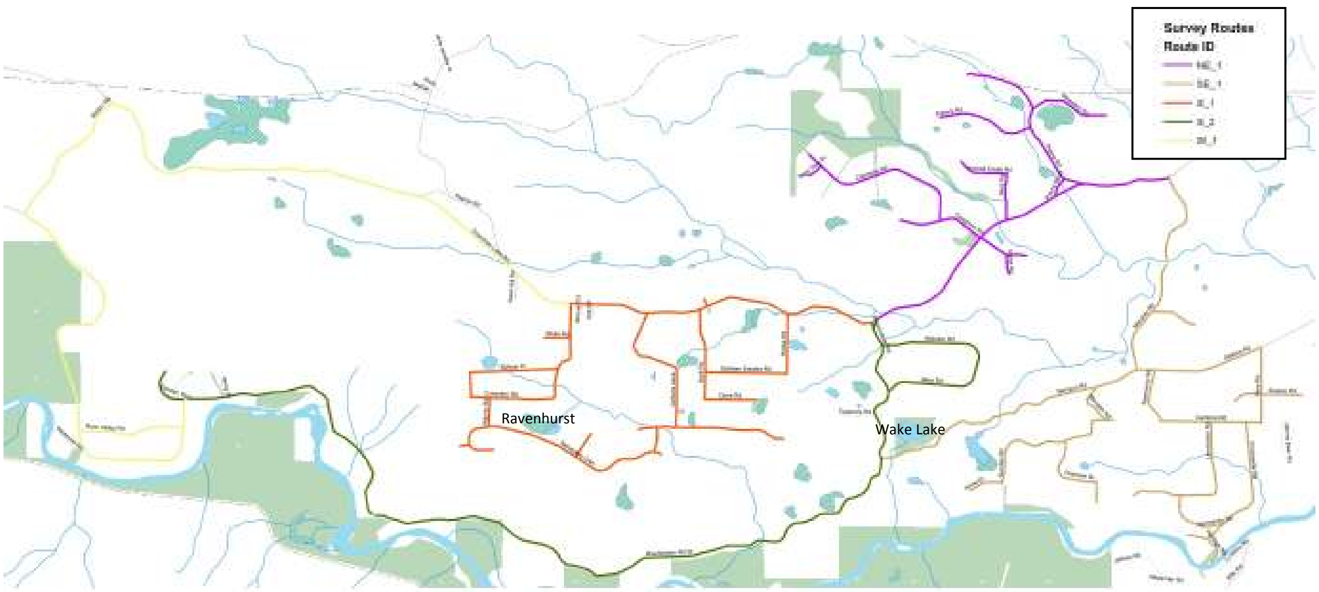


Figure 2. Distribution of five road survey routes used to locate and capture adult Western Toads in fall in relation to the two known breeding sites in the area, Ravenhurst (west) and Wake Lake (east).

Figure 3. “Toadally Awesome Volunteer” magnets were given to volunteers that captured toads for us.

2.3 Fitting Toads with Transmitters

Each toad received either a BD-2 or BD-2T (temperature-sensitive pulse rate) radio-transmitter (Holohil Systems Ltd., Carp, Ontario) attached with a waist belt system. Transmitter size was determined by optimizing the combined target weight of the transmitter and belt (i.e., less than 5% of the toad's body mass; Ministry of Environment 1998, Richards et al. 1994) with battery life (i.e., larger toads received larger transmitters that had longer battery lives). The 'waist' of the toad was measured and a transmitter belt was built by threading the transmitter and surgical tubing (2- or 3-mm outer diameter; MED-RX feeding tube 5 FR x 36" 54-5036, and catheter tube 10 FR x 16" 67-5110) over stretchy jewellery making thread (#2 Opaque CreativeS Gossamer Floss™ 5yd card, B. Toucan Inc.; Fig. 4; Wind 2014). The completed belt was slid over the extended feet and legs of the toad, into position on the waist. The toad was then re-weighed with the belt and transmitter, a photograph taken, and the transmitter pulse checked, before the toad was released at the site of capture. Toads were also individually marked for future identification purposes by inserting an 8 mm (Biomark MiniHPT8™, 8.4mm x 1.4mm, 134.2 kHz; for smaller toads) or 9 mm (Biomark HPT9™, 9mm x 2.12mm, 134.2 kHz; for larger toads) passive integrated transponder (PIT) tag under their dorsal skin. Toads were swabbed following standard practices for Chytrid disease testing (i.e., the fungus *Batrachochytrium dendrobatidis*; Ministry of Environment 2008).

Figure 4. Adult Western Toad fitted with neonatal surgical tubing belt and a BD-2 transmitter.

2.3 Tracking Toads to Hibernation Sites

Within 1 to 2 days of release all toads fitted with transmitters were radio-located to ensure that their belt fit was correct. Toads were then re-located every 3 to 4 days until hibernation, and every 7 days during hibernation (when they were dormant).

During pre-hibernation monitoring, toads were tracked in such a way as to minimize stress that may lead to behavioural modifications. A visual confirmation was obtained at a re-location site if the toad was at or near the surface and relatively easy to find (e.g., not within a thick shrub or debris layer). However, an effort was made to obtain a visual when a toad had not been observed for at least two weeks. Where possible, toads were re-captured every 2 to 3 weeks to check belt fit and to monitor skin condition (i.e., check for irritation or abrasion). During a re-location the spot was flagged and geographic position (UTM) recorded using a handheld GPS, the air temperature and relative humidity were recorded using a handheld microclimate device (Kestrel 3000 Pocket Weather Meter, KestrelMeters.com), and a photograph was taken of the toad microsite habitat. An effort was made to capture all of the toads prior to hibernation to reweigh them, but some could not be captured because they were consistently in holes or under logs during re-locations in late fall. Toads were removed from the study if a weight loss of 10% was observed and / or evidence of a skin irritation.

During hibernation, when toads were sub-surface, the hibernation sites were flagged based on the location of the strongest pulse at ground level. A hibernation site was defined as "a location where a toad remained subsurface for at least two weeks". Once confirmed to be hibernating, the pulse rate of those toads fitted with temperature sensor transmitters was recorded during weekly relocation visits. Plotted calibration curves that came with the BD-2T transmitters were used to convert the pulse rate to the temperature at the toad (http://www.holohil.com/transmitters/bd-2/).

When toads emerged from hibernation sites, they were tracked from their hibernacula towards their breeding location (re-located every 3-4 days) during late winter (February / March) at which time all transmitters and belts were removed. Belts were removed once a major movement was made towards the breeding site (to avoid losing them at the aquatic breeding site), or if a skin irritation was detected. Toads were weighed and photographed prior to release.

2.4 Camera Monitoring of Hibernation Sites

Remote wildlife cameras (Reconyx, PC900 and HC600) were installed at hibernacula for three main reasons:

1. To confirm that a site was a hibernaculum, versus a dropped transmitter belt
2. To determine whether hibernacula were used by more than one toad (i.e., communal)
3. To determine whether hibernacula were re-used by toads across years

Due to the urban-rural nature of the study area, camera protection from theft and damage was a priority. As such, camera placement optimized monitoring objectives with equipment safety.

To examine potential communal use of hibernacula by toads, cameras were set at 29 confirmed or suspected hibernacula over the 3-year study period. Cameras were set in early February at 5 hibernacula in the pilot study year, and in mid January in both Year 1 and Year 2 (at 11 and 13 hibernacula respectively). Cameras were positioned to focus clearly on the most likely entry / exit way. Some sites had complex / multiple entryways and the camera was aimed at the hole with the most consistent / strongest receiver signal.

To examine potential re-use of hibernacula, cameras were installed in October prior to the onset of hibernation at 9 hibernation sites identified and confirmed during the previous field season [at 3 hibernacula from the pilot study year (2014-15), and 6 hibernacula from Year 1 (2015-16)]. These sites had fairly obvious entry /exit ways and the camera could be set up relatively safely (i.e., locked to a tree or large log; Fig. 5).

All cameras were set to record one image per minute, 24-hours per day, to detect ectotherms, as well as motion triggered to detect endotherms (mammals and birds). All images were manually reviewed and those that contained vertebrates were recorded and evaluated.

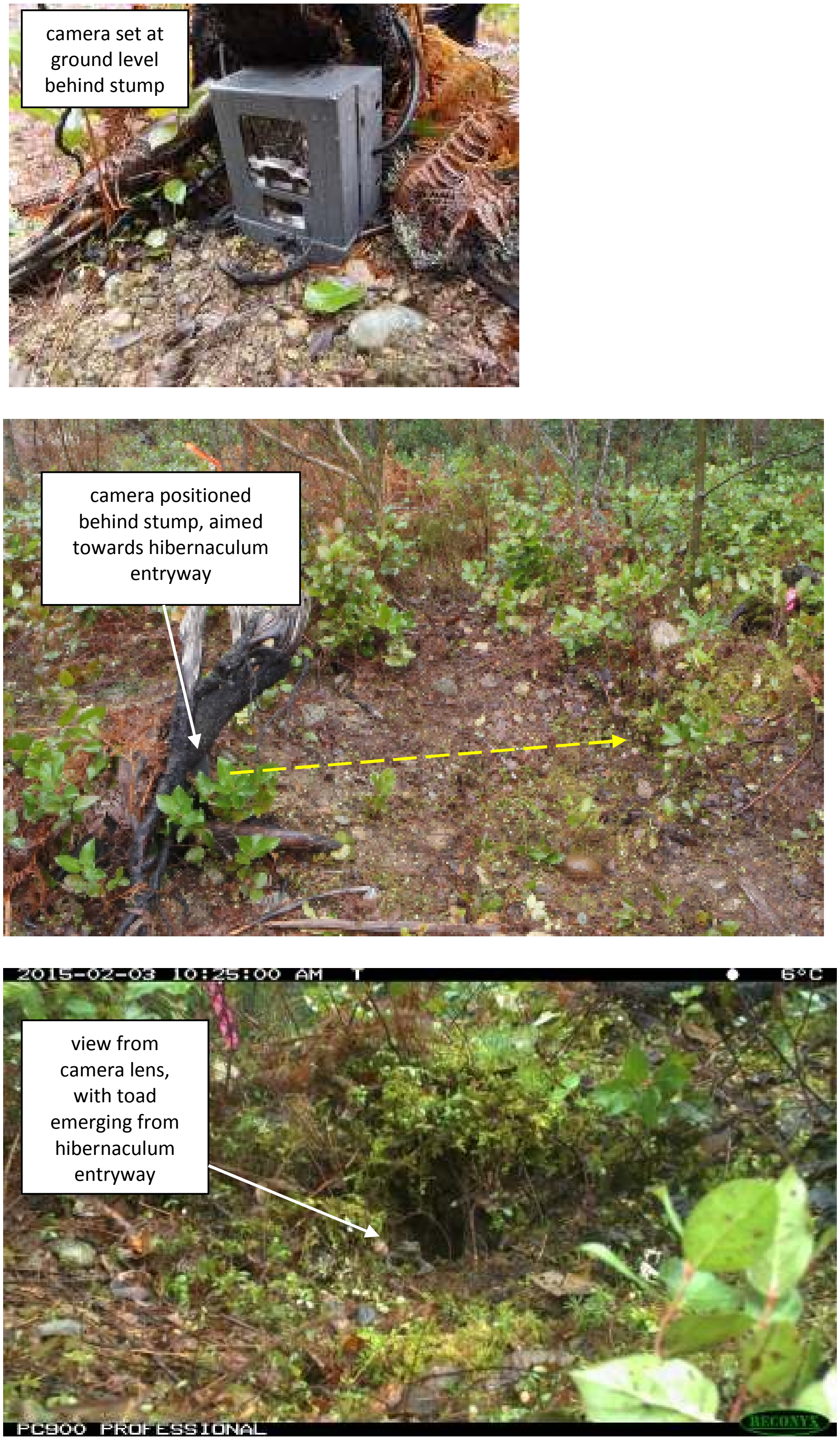


Figure 5. Example of a remote wildlife camera set up at a toad hibernaculum.

2.5 Description of Hibernation Sites and Winter Habitat

To describe hibernation sites, assess selectivity, and characterize threats, environmental and biophysical variables assumed to influence the use of a location were measured at three spatial scales (Fig. 6). Used can be compared to random locations for selection analyses at the scale of the individual, as well as at the scale of the population (Manly et al. 2002). The habitat plots were centred on the hibernation (*used*) sites and replicated at random (*available*) locations. Random locations were generated at two spatial scales to represent available habitat within ecosystems (i.e., sites for hibernation) and landscapes (i.e., ecosystems with qualities suitable for hibernation sites). Habitat variables were measured at three spatial scales: 1) landscape, 2) ecosystem (e.g., forest stand or land-cover type), and 3) microsite (i.e., hibernation site). Used and available habitat data were collected for 28 hibernation sites identified over the 3-year study (4 from the pilot study year, and 12 in both Year 1 and Year 2). Landscape and ecosystem attributes such as road and edge were used to complete a threat assessment for this population. Analyses for habitat selection and threat assessment are ongoing.

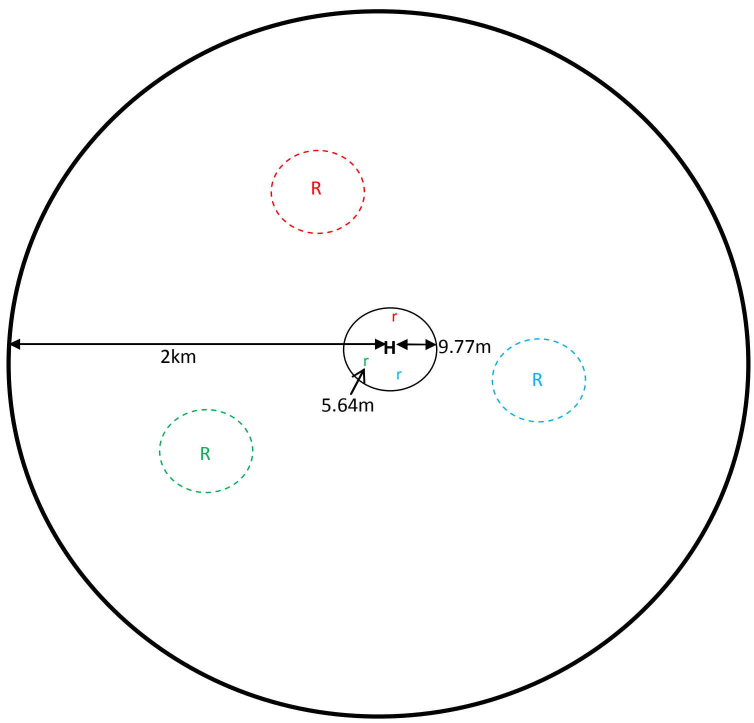


Figure 6. Study design for habitat assessment at three spatial scales (2-km radius landscape, 9.77-m radius ecosystem, and 5.64-m radius microsite). Nested habitat plots are centred over a known hibernation site (H), random locations (n=3) within the ecosystem surrounding that H (r), and random locations (n=3) within the landscape surrounding the H (R).

1) LANDSCAPE SCALE

As described earlier, the spatial extent and distribution of toads in the Cowichan River valley is unknown, therefore the preliminary study area boundary (i.e., area of interest) was defined by linking the outer edges of the 2-km radius (1257 ha) landscape-level plots together for each hibernation location. For habitat and threat assessment, the combined 3-year study area comprised the ‘landscape’ containing the target population of toads from which the sample population of 28 tracked toads with confirmed hibernation locations was drawn.

This scale plot represents the 'landscape' or annual home range within which a toad may make seasonal movements to and from hibernation sites—2 km represents the maximum distances observed between breeding sites and summer ranges and hibernation sites from toad studies conducted in AB (Browne and Paszkowski 2010b) and WA (Palmeri-Miles 2012) respectively. The 1257 ha plot therefore represents the landscape available to the individual toad. A 2-km radius landscape-level plot centred on a hibernation site is assumed to capture all seasonal habitats used by the hibernating toad. We hypothesize that within their annual home range, toads will hibernate within reasonable commuter distances to breeding sites (e.g., 200 to 400 m) to minimize the energetic requirements during migration, given that they have limited to no feeding throughout the winter and during movement to breeding sites.

Within the landscape-scale plots, a series of landscape attributes were generated to characterize habitat availability and quality (e.g., potential breeding ponds) and threats (e.g., roads). A land cover (aka habitat type) classification and spatial coverage was developed in ArcGIS for the study area landscape using a combination of Terrestrial Ecosystem Mapping (EcoCat, 1:10000, 2007), the BC Freshwater Atlas (DataBC; downloaded in Sept. 2015), the Digital Road Atlas (DataBC; downloaded in Sept. 2015), and digitized ortho-photography (Ministry of Environment, digitizing took place at 1:10000, 2014). Habitat was classified within terrestrial (4 habitat sub-types) and aquatic (3 sub-types) land cover types, and distinguished from edges and roads (Appendix 2).

Terrestrial Habitat

The spatial data used to approximate the terrestrial habitat sub-types for this study was Terrestrial Ecosystem Mapping (TEM) for the coastal Douglas-fir (CDFmm) biogeoclimatic zone. Approximately half of the study area (to the east) is captured by TEM. TEM structural stage was used to assign the polygons on the east into one of the 4 terrestrial habitat sub-types (Table 1). The western part of the study area was digitized at 1:10,000 into general polygons and assigned to one of the 4 terrestrial habitat sub-types.

Table 1. TEM structural stages assigned to 4 terrestrial habitat sub-types.

Terrestrial habitat sub-type	**TEM Structural Stage**
Closed vegetation (forested)	4, 5, 6, 7
Open, tall vegetation	3a, 3b
Open, short vegetation	1a, 1b, 2a, 2b, 2c, 2d
Little to no vegetation (built)	Null

Queries were run on the TEM attribute table to calculate the percent of the total polygon area that contained each structural stage using information contained within all three deciles. Polygons were assigned one of the four terrestrial habitat sub-types if the associated structural stages were dominant (i.e. > 50% of the polygon area). For polygons with equal values for two habitat sub-types across deciles (e.g., 50% in one habitat sub-type and 50% in another), the polygon was classified into the sub-type with the greatest amount of vegetative structure [i.e. for a polygon containing 50% closed vegetation (forest) and 50% little to no vegetation (built), the polygon was classified as closed vegetation]. For polygons with no decile containing ≥ 50% of a particular habitat sub-type, the polygon was again classified to the habitat sub-type with the greatest amount of structure (i.e., for a polygon containing 40% closed vegetation, 30% open, tall vegetation, and 30% little to no vegetation, the polygon was assigned to closed vegetation). Given the age of the TEM mapping (i.e., 2007), it was assumed that classifying polygons upwards in structural complexity was justified as vegetation would have grown since that time.

Polygons or deciles which did not contain a TEM structural stage appeared as 'null' in the database and were classified into habitat sub-type little to no vegetation.

After all of the TEM polygons were attributed to the four terrestrial classes, the results were visually compared to 2014 ortho-photography to estimate accuracy. Approximately 6% of the classified TEM polygons (i.e., 30 of 525) had been assigned a habitat sub-type that did not match what was observed in the ortho-photography. In most cases, the inaccuracies were related to the removal of forest cover [i.e., the closed vegetation habitat sub-type (forest) had changed to open, tall vegetation]. Another source of error included 'null' structural stage polygons that had been classified as habitat sub-type little to no vegetation (built), when they were actually aquatic habitat types (which have no structural stage in TEM). These polygons were removed from the terrestrial habitat type cover layer as they are captured by the aquatic layer from the Fresh Water Atlas. The remaining TEM polygons were exported and copied into the habitat land cover feature class.

Aquatic Habitat
The spatial data source for the aquatic habitat was the Fresh Water Atlas (FWA). Four specific datasets were used: FWA Lakes, FWA Wetlands, FWA Rivers and FWA Stream Network. The features in the lake and wetland datasets were classified as either open water wetland / lake or closed water wetland habitat sub-types, using the 2014 ortho-photography for reference. Additional water bodies which were not captured in the FWA, but could be identified in the imagery, were digitized and classified into the two aquatic habitat sub-types. Digitizing was restricted to a mapping scale of 1:10,000 to limit the time spent on generating new spatial data. Once all the open water wetlands and closed water wetlands were classified, the polygons were exported and copied into the habitat land cover feature class.

Data from the FWA Rivers and FWA Stream Network feature class for the river / stream habitat sub-type was not amended (i.e., no new streams were digitized). However, the linear river / stream network was converted into a polygon feature class using the buffer tool in ArcGIS in order to be incorporated into the habitat land cover feature class. The river / stream order was used as means of estimating stream width. A field was added to the river / stream feature class and the river / stream segments were assigned a half width[1], which was then doubled for the creation of the polygon (Table 2).

Table 2. Widths assigned to river / stream features to create habitat sub-type polygons.

Stream Order	River / stream Width (m)
1	2
2	4
3	6
4	8
6	30

The three aquatic habitat sub-types were then cut into the habitat land cover feature class. The aquatic habitat sub-types were cut out of the terrestrial habitat sub-types polygons (i.e., polygons did not overlap).

[1] A half width value is generated as the buffer tool doubles this value when creating the polygon for the feature.

Road Habitat
The Digital Road Atlas (DRA) was used as the input spatial data source for the public road (paved or unpaved) habitat sub-type. A field was added to the DRA feature class using the ArcGIS buffer tool and populated with values that represented the half width[1] of the different road classes, which was then doubled for the creation of the polygon (Table 3). Road width was estimated from the land cover feature class in the Digital Road Atlas.

Table 3. Widths assigned to features to create public road habitat sub-type polygons.

Road Class	Road Width (m)
Highway	25
Collector/ramp	15
Local	10
Restricted/Resource/Service	5
Strata	2.5

An existing spatial dataset could not be found to capture the non-public road habitat sub-type. Using the 2014 ortho-photography provided by the Ministry of Environment, features such as trails, logging roads, and rural driveways were digitized at a scale of 1:10,000. A field was added for this linear habitat sub-type that was populated with half-widths using the buffer tool in ArcGIS, which were then doubled to create habitat sub-type polygon features (see Table 4).

Table 4. Widths assigned to features to create non-public road habitat sub-types polygons.

Non-public Road habitat sub-type Features	Non-public Road Width (m)
Service Road	5.0
Driveway	2.5
Trans Canada Trail	2.0

The public and non-public road habitat sub-type polygon features were then cut out of the habitat land cover feature class (i.e., polygons did not overlap).

Edge Habitat
Once the habitat land cover feature class was created and populated with polygons of all 9 habitat sub-types mentioned above (from the terrestrial, aquatic, and road habitats), a 20 m buffer was applied to all habitat sub-type polygon boundaries (perimeters) to create an edge habitat feature class. The edge habitat feature class was not merged into (i.e., cut out of) the habitat land cover feature class as done for other habitat types, but retained as its own feature class because of its transitional nature between different habitat types (i.e., it consists of / overlaps with two or more habitat types).

Once the edge habitat was completed, the percent area for each of the 9 habitat sub-types, as well as edge, was calculated using the habitat land cover and edge feature classes. Total linear length and density (m / ha) were also calculated for the river / stream, public road, and non-public road habitat sub-types.

2) ECOSYSTEM (STAND / SITE) SCALE

To evaluate habitat selection at the scale of the ecosystem, 3 random points were established within each of the 2-km radius landscape-level plots established for each confirmed hibernation site. Ten random locations were generated using the Create Random Points Tool in ArcGIS. The first 3 random locations generated (out of 10) were selected for field assessment. For those plots which landed on private land for which we had not already obtained landowner access approval, a flyer was mailed to the landowner providing information on the project and requesting permission to access the property. If any of the first 3 random locations fell within an unsuitable location, the next random location generated was selected. Random locations were considered unsuitable if they:

- were located on the south side of the Cowichan River;
- had restricted access (due to land ownership, or logistical constraints); or
- were located less than 20 m away from a known hibernation site or any other random point selected.

A 9.77-m radius circular ecosystem plot (300 m^2) was centred on each of the used (confirmed hibernation site) and 'available' random locations. This scale of plot represents the biophysical area within which the hibernation site is situated, and represents the topographic (e.g., elevation, aspect), geographic (e.g., distance to water, roads), and ecological (e.g., tree and downed wood densities, canopy cover) conditions of the ecosystem within which the hibernation site is located. Plot size is smaller than the standard Ecosystem Plot suggested for terrestrial ecosystems (400 m^2), but still sufficient to describe the anticipated variability in forested ecosystems given the limited number of habitat variables considered in this study, and species-poor ecosystems such as wetlands can have smaller plots due to reduced variability (Province of British Columbia 2010). A plot diameter of approximately 20 m was anticipated to capture the limited pre-hibernation and post-emergence movements of toads, and balance assessment accuracy with logistical feasibility (see Browne and Paszkowski 2010a). The size of the ecosystem plot was based on the observations of movements by 6 toads from the 2014-15 pilot study year, encompassing the area used just prior to and during hibernation, and upon emergence (prior to movement to breeding habitats). Plot size considered the following:

1. The average distance between pre-overwintering radio-locations was 13.2 m (max = 42 m).
2. The average distance toads were observed away from the overwintering site prior to overwintering was 23.8 m (max = 41 m).
3. The average maximum distance across the pre-overwintering radio-location points (polygon) was 26.4 m (max = 47 m).
4. The average overwintering radio-location movements was 0.6 m (max = 4.5 m).

We hypothesize that toads select for areas that offer conditions suitable for pre-hibernation, hibernation, and emergence.

Within ecosystem-scale plots, groups of environmental variables were measured or generated to characterize habitat availability and quality (Appendix 2). Structural vegetation variable measurements adhered to provincial standards (Province of British Columbia 2010) except where noted otherwise. Debris piles, root wads and mounds (mineral and organic) were counted in the plot as potential hibernation features; the bases of live and dead trees, stumps and large pieces of downed wood may also act as hibernation features and were counted as structural attributes. The proportion of the plot area in different habitat sub-types was estimated (Appendix 2). For those habitat sub-types not found within the ecosystem plot the nearest distance (proximity) to each was estimated in the field if these sub-types occurred within 20 m of the plot centre. If the sub-type habitat was beyond 20 m, the nearest distance was estimated from the habitat classification coverage created for the study landscape, using ArcGis. If more than one habitat sub-type occurred within 20 m of the plot centre, the plot was recorded as containing edge habitat (edges were buffered by 20 m), and the percent of edge habitat within the plot was estimated and the habitat sub-types that edge comprised were recorded (e.g., closed vegetation / public road).

3) MICROSITE (HIBERNATION SITE) SCALE

To evaluate selection at the scale of the specific hibernation sites (i.e., microsite selection with an ecosystem), 3 random points were identified within the 300 m^2 ecosystem-scale plot established at a hibernation site using a random number generator app (True Random Generator, version - Nov. 2015). The app was set to generate points between 1 and 360° and between 3 and 9 m away from the centre of the plot in order to keep the centre of the random plots at least 3 m apart from the hibernation plot and each other. Microsite variables thought to reflect hibernation site quality were measured and recorded at both the 'used' hibernation sites and 'available' random points.

The focus of this scale was on the characteristics of the hibernation site itself. We hypothesized that hibernation sites were situated where there is sufficient ground complexity to afford suitable security cover and environmental conditions (i.e., a safe haven with optimal temperature and humidity / moisture). Therefore, variables measured at this scale were both environmental (i.e., microclimate) and biophysical variables assumed to provide suitable microclimate and structure (for security), contributing to the presence of hibernation habitat at that exact spot (i.e., microsite). Biophysical variables were measured directly at the hibernation site or random point, except for shrub cover and ground cover, which were estimated within a 5.64-m radius circular plot (100 m^2) centred on the hibernation site or random point (Appendix 2).

Ambient air and ground surface temperature and relative humidity were monitored using microclimate data loggers (Hygrochron iButtons; D1923-#F5, Maxim Integrated) at hibernation sites through winter in Year 1 and Year 2. Paired hygrochron data loggers were mounted at 1 m above ground and at ground level, protected from rain by white plastic cups with holes to allow for air flow (Fig. 7). In fall of Year 2, hygrochrons were also re-installed at 6 of the Year 1 hibernation sites (where cameras were also installed) in a replicated configuration as that used in winter Year 1. As well, a waterproof data logger (HOBO TidbiT v2 Water Temperature Data Logger UTBI-001) was inserted into the hibernation entryway / hole to record air temperature. A piece of twine was attached to the logger and it was pushed or tossed down into the entryway as far as possible.

A total of 22 toads (9 in Year 1 and 13 in Year 2) were equipped with BD-2T transmitters containing temperature sensors, allowing for a comparison of sub-surface temperature to ground surface and ambient air temperatures at hibernation sites.

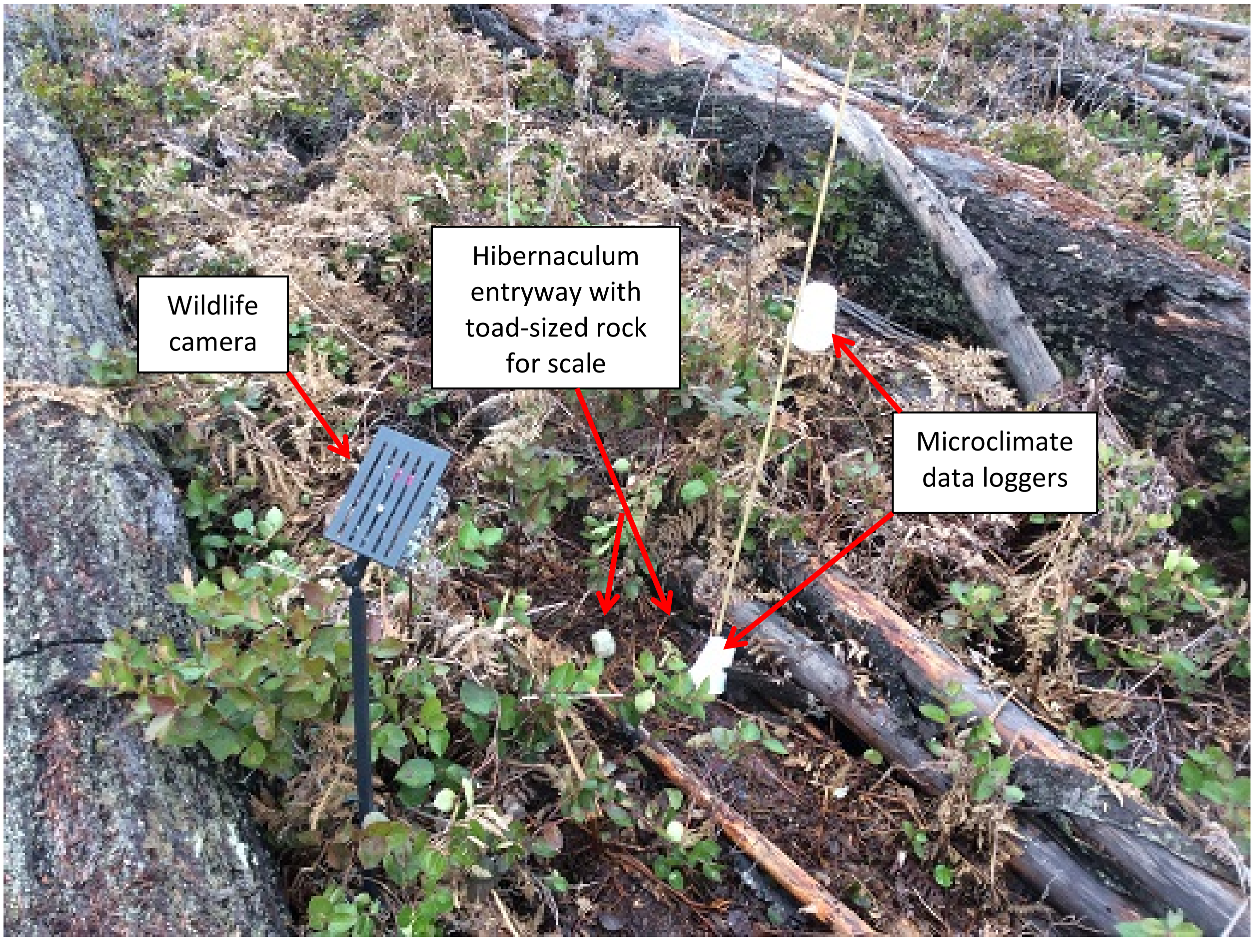


Figure 7. Positioning of wildlife camera, toad-sized rock by hibernaculum entryway, and two Hygrochron iButton microclimate data loggers set at each hibernation site. The data loggers recorded air temperature and relative humidity at ground level and 1 m above the ground every hour during the hibernation period and at 3 random points within the 300 m^2 ecosystem plot.

3.0 RESULTS

3.1 Public Liaison and Support

The toad project was the topic of an article published in a local newspaper in early September in Year 1 and Year 2 (e.g., Fig. 8). Approximately 40 people attended a toad project presentation held in Sept. in Year 1 and Year 2 at the community hall in the Sahtlam area. Project information fliers were mailed to all of the addresses in the study area (e.g., 849 in Year 2; see Appendix 3). Additional fliers were sent to select addresses in the winter seeking permission to access private land to collect habitat data for our random plots (e.g., 12 addresses in Year 2). Our Year 1 and Year 2 efforts to contact private land owners during toad tracking relocations and vegetation plots resulted in 137 addresses / people providing us with permission to access their private property. When members of the public were encountered during field work, the majority were familiar with the study.

A blog for the project (http://cowichanvalleywesterntoadproject.blogspot.ca/) was developed in 2015 that includes a project video shared with the volunteer network describing the objectives of the project, toad natural history, how volunteers have helped obtain toads, how radio-telemetry works, and what habitat data were collected and why.


Cowichan Valley Citizen NEWS

Keep eye out for declining western toads

Bridge repairs to close Crofton Road

Figure 8. An article on the project was published in a local newspaper to generate public support and to utilize volunteer help to capture toads.

3.2 Toad Captures and Disease Testing

In total, 61 adult Western Toads were captured and fitted with BD-2 or BD-2T transmitters over the 3-year study (8 in the pilot study year, 23 in Year 1, and 30 in Year 2). Of the 61 toads, 30 (49%) were captured in the month of Sept., 24 (39%) in Oct., and 7 (11%) in Nov. Ten (16%) were incidentally captured (e.g., during tracking), 15 (25%) came from volunteers (in their yard), 36 (59%) from road surveys.

Unlike the pilot study year and Year 1, toad captures in Year 2 (2016-17) were more evenly distributed throughout the study area. As well, three toad captures occurred in the far west end of the study area, which is less developed and has a lower density of roads. The three toads were captured more than 2.5 km away from the nearest toad captures in previous years. Of 26 toads captured over the three years where Wake Lake was confirmed or suspected to be the breeding site (see Section 3.4 below), 8 (31%) were caught less than 1 km away from the main breeding site (Wake Lake) and 18 (69%) within 1 to 2 km (Fig. 9). Despite efforts to survey roads in the study area relatively evenly (see Fig. 2), toad captures were not evenly distributed across the survey routes. The survey route with the greatest number of captures was S_1, in the centre of the study area and west of Wake Lake, with more than 50% of the road captures.

In total, 25 of the 61 toads captured were female (41%), 34 (56%) were male, and 2 (3%) were unknown. All toads looked healthy at the time of capture. Female toads ranged in size from 86 to 116 mm (average = 102 mm) body length, while males ranged between 53 and 102 mm (average = 88 mm). Females weighed between 95 and 243 g at capture (average = 155 g) and males weighed between 60 and 131 g (average = 90 g). For all toads, the combined mass of the transmitter and belt averaged 4% percent of the toad's body weight (range = 1.3% to 4.0 %; average = 2.5%).

Of the 23 fall 2015 and 42 fall 2016 (n = 65) vials of swab samples submitted for disease testing, no Chytrid disease (i.e., the fungus *Batrachochytrium dendrobatidis*) was detected for any of the adult toads sampled in this population. The 2015 swabs came from toads captured for tracking (i.e., live) while the 2016 samples included toads captured for tracking (n = 30; live) as well as dead toads found on the road during night surveys (n = 12; dead).

3.3 Transmitter Fate and Body Condition

Of the 61 toads, 4 died (e.g., hit by car, predator, 2 were likely due to winter cold), 24 had their belt removed (e.g., tracked through winter), 24 dropped their belt, and 9 were lost (e.g., transmitter battery died). Unlike the pilot study year and Year 1, some study toads died in Year 2. One was hit by a car on a road within a day of capture in the fall (T47). Two toads tracked to hibernacula were found dead on Jan. 18, 2017, after the snow had melted enough to see into the shallow holes they were occupying (T41 and T51). Both toads were found with open wounds. T51 was observed outside of its hibernacula (a hole at the base of a stump) on Dec. 29, 2016, 4.5 weeks after it had become dormant, at a time when minimum air temperatures had been dropping below zero for many weeks. T51 had moved approximately 7 m into a shallow surface depression, where the end of its antenna was visible but not the toad. When T51 was discovered dead in mid Jan. its internal organs were visible outside of the body from a side wound. T41 was one of the later toads to become dormant and appeared to be hibernating relatively shallow. When he was found dead on Jan. 18, 2017 he was only approximately 20 cm deep in a hole in the side of a hill slope when found and he had an open wound on his forelimb with exposed bone and hanging skin.

All toads appeared healthy upon emergence in terms of weight and their skin condition. Of the 12 toads that had their weight recorded immediately post emergence, all but one weighed less compared to their capture weight in the fall (average percent weight change = -15.2%, range = -61.1%-1.3%). It should be noted that weigh scale error under field conditions (e.g., effects of wind and rain) can influence weights, as can capture or re-belting conditions (e.g., if toads are captured in wet environments, and / or urinate during processing).

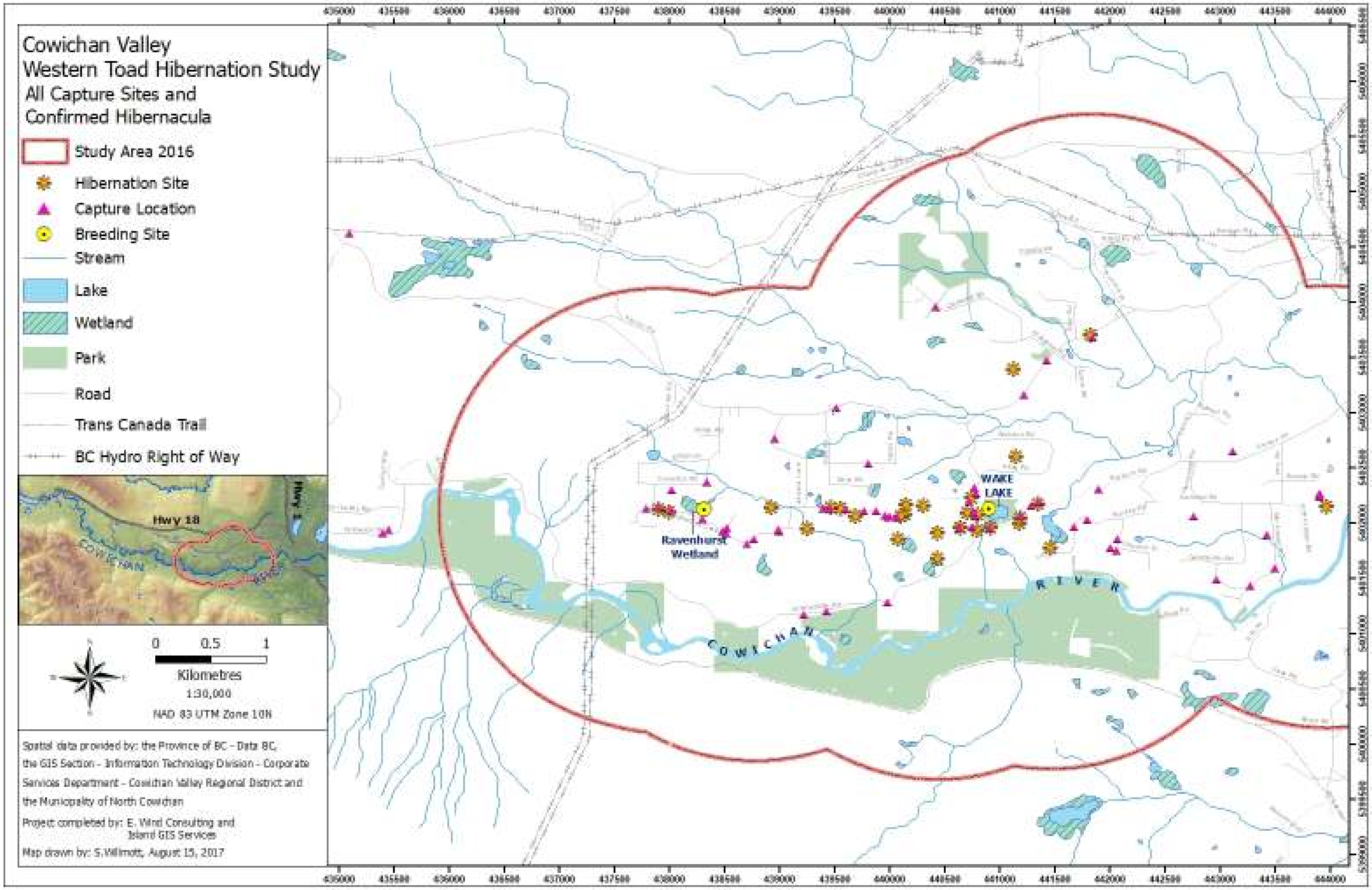


Figure 9. Distribution and location of toads captured in Year 2 (fall 2016), relative to our study area boundary (red line) and the two known breeding sites (yellow circles).

3.4 Toad Movement Patterns and Location of Hibernacula

Of the 61 toads captured and fitted with transmitters over the 3-year period, 28 were tracked to confirmed or suspected (likely) hibernacula. Although a number of toads hibernated relatively close to hibernacula utilized by toads in previous years, none of the tracked toads hibernated in a previously studied hibernacula. For example, T61 (2016) hibernated within 100 m of the site used by T7 (2014), T18 (2015) hibernated within 83 m of the site used by T4 (2014), T55 (2016) hibernated within 60 m of the site used by T17 (2015), and T25 (2015) hibernated within 41 m of the site used by T6 (2014; Fig. 10).

Toads displayed two general movement patterns in the fall and / or spring: 1) they stayed within one general area relatively close to their capture location or 2) they made regular, unidirectional movements towards their hibernacula and /or subsequent breeding site. In both years, the majority of toads tracked to their hibernation sites (15 of 24; 63%) occupied the immediate area close to their hibernation structure for weeks to months before and / or after hibernation (i.e., within 25 m). Wildlife camera observations from the fall suggest that toads may go in and out of hibernacula structure during this time (see Section 3.5 and 3.6 below). For example, T16 was within 22 m of his hibernation structure (i.e., upturned stump / debris pile) by Sept. 28, but did not start to hibernate until Nov. 26, 2015 (Fig. 11a). T17 was within 15 m of her hibernation stump by Oct. 19, but did not hibernate until Nov. 26th. She emerged Jan. 29 and stayed within 10 m of the hibernation stump for at least one month (Feb. 29), utilizing another shallower hole for 2.5 weeks (Jan. 29 to Feb. 10; Fig. 11b). T28 arrived to within 15 m of his hibernation structure (stump) on Nov. 9, 2015 but did not hibernate until Nov. 26, 2015. He emerged around Jan. 29, 2016 and stayed within 15 m of the hibernation structure for three weeks until he left on Feb. 19, 2016 and moved more than 200 m towards the breeding site (Fig. 11c). T15, T18, and T23 stayed within 60 m of their hibernation site for more than 50 days prior to the onset of hibernation (Fig. 11d to f). In Year 1, most toads stayed near hibernacula upon emergence in late winter, but in Year 2 emergence occurred almost a month later (see below) and most toads moved almost immediately towards their breeding sites upon emergence.

Of the 28 toads tracked to hibernacula, 12 (43%) made unidirectional movements in the direction of Wake Lake prior to the onset of the hibernation period in the fall (e.g., see Fig. 12 for fall movements of Year 2 toads, Table 5). Of the remaining 16 toads, 13 (46%) were caught close to their hibernaculum (i.e., within 100 m) and 6 moved towards a known breeding site in the spring (i.e., Wake Lake or Ravenhurst). The remaining 7 toads (6 of which were females) did not give any indication of breeding in terms of directional movement patterns or hibernating near a breeding site. We suspect that these toads may have skipped breeding in the field season that they were being tracked. The average distance these 7 toads hibernated from the closest breeding site was 1438 m (all but 1 toad hibernated more than 1 km away from a breeding site). Unfortunately, we were not able to track any of the three toads captured in the west section of the study area to hibernation sites in Year 2 (Fig. 12). These toads were captured more than 5 km and 2.6-3.9 km away from the Wake Lake and Ravenhurst wetland respectively, and none made movements towards either site. In fact, T42 travelled in a westward direction, away from both known breeding sites. Assuming that these three toads were all sexually mature, they may use alternate breeding sites that we are unaware of (e.g., we suspect that a breeding site occurs near T35 as metamorphs have been observed on the TransCanada Trail in that area).

For the 28 toads tracked to confirmed and suspected (likely) hibernacula, the distance toads moved from their point of capture to hibernation sites ranged from 11 m to 1979 m (average = 496 m; Table 5). Males travelled farther than females to reach hibernacula in the fall (average = 574 m versus 422 m respectively), with 4 males and two females each travelling over 1.2 km to reach hibernation sites. Four toads (T28 in Year 1, and T58, T39, and T52 in Year 2) travelled past or away from one of the two known toad breeding sites (Ravenhurst wetland) to reach their hibernation site closer to the Wake Lake breeding site (e.g., Fig. 12). However, females travelled farther than males from their hibernacula to their breeding site in the spring (average = 738 m versus 342 m respectively).

Numerous dead adult toads were observed on the roads by Wake Lake in late winter in Year 1, but none were confirmed to have PIT tags (e.g., 9 dead adults were observed along approximately 300 m of Barnjum and Riverbottom Roads on March 4, 2016 alone). In Year 2, for the first time during the three years of the study, one of the toads fitted with a transmitter (that had been caught on the road) was struck by a vehicle and killed in the fall close to where it had been captured. Of the 36 toads tracked in fall of Year 1 and 2 for at least two weeks, 19 (53%) encountered at least one public road (paved or unpaved) during their monitoring period (i.e., the straight-line connection between sequential re-location points crossed a mapped public road or ran along it; Table 6). Toads which moved more in the fall were more likely to encounter a road. The potential "risk" associated with movements across or along roads may be higher than presented here. For example, three consecutive re-locations for T28 between Oct. 22 and 29, 2015 were situated along the entire length of Appaloosa Road, with more than 1 km between the first and third re-location. Although some toads did not make large, unidirectional movements, they hibernated relatively close to roads (e.g., < 22 m; T15, T18, T23, T48, T51, T56, and T61), and their smaller, nightly foraging excursions may have put them at risk from vehicular traffic prior to hibernation and post emergence. For 29 toads, where the breeding site was estimated to be either Wake Lake or Ravenhurst, based on their movement patterns, it was estimated that 24 (83%) would have to cross at least 1 road in spring to get to their breeding site.

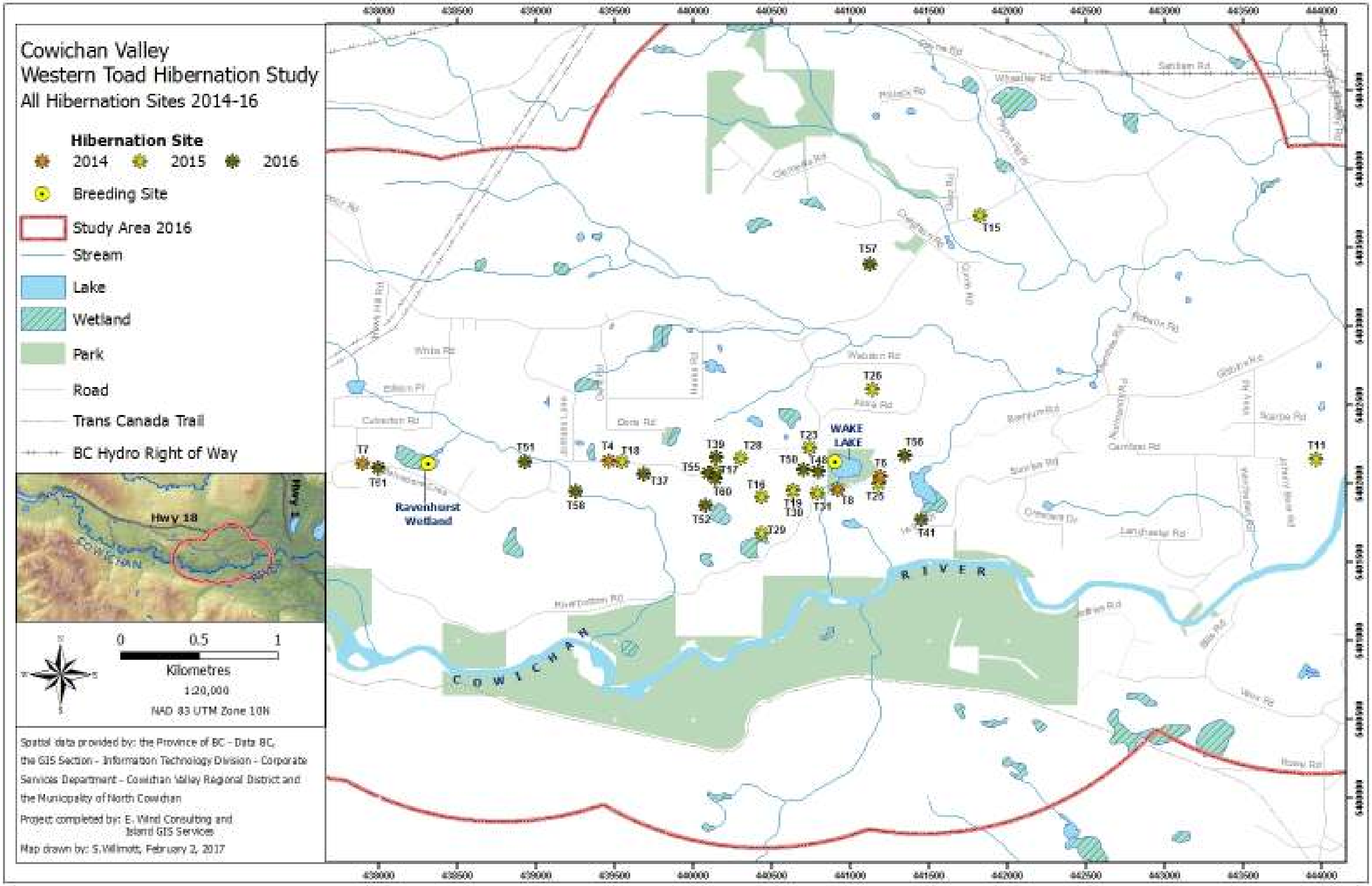
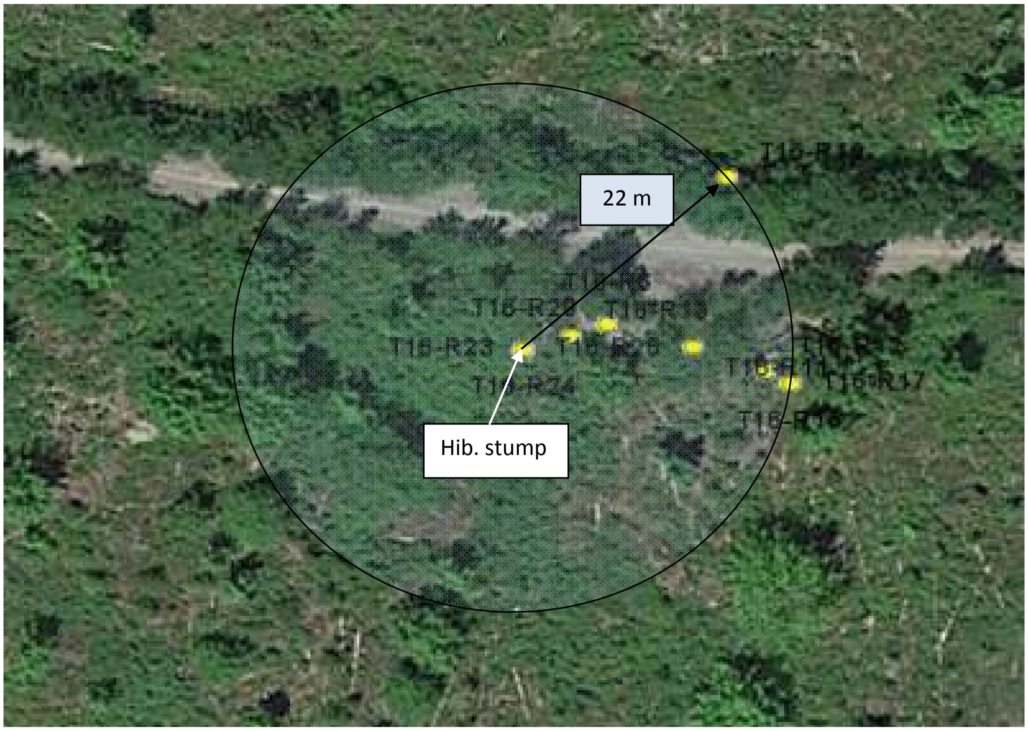
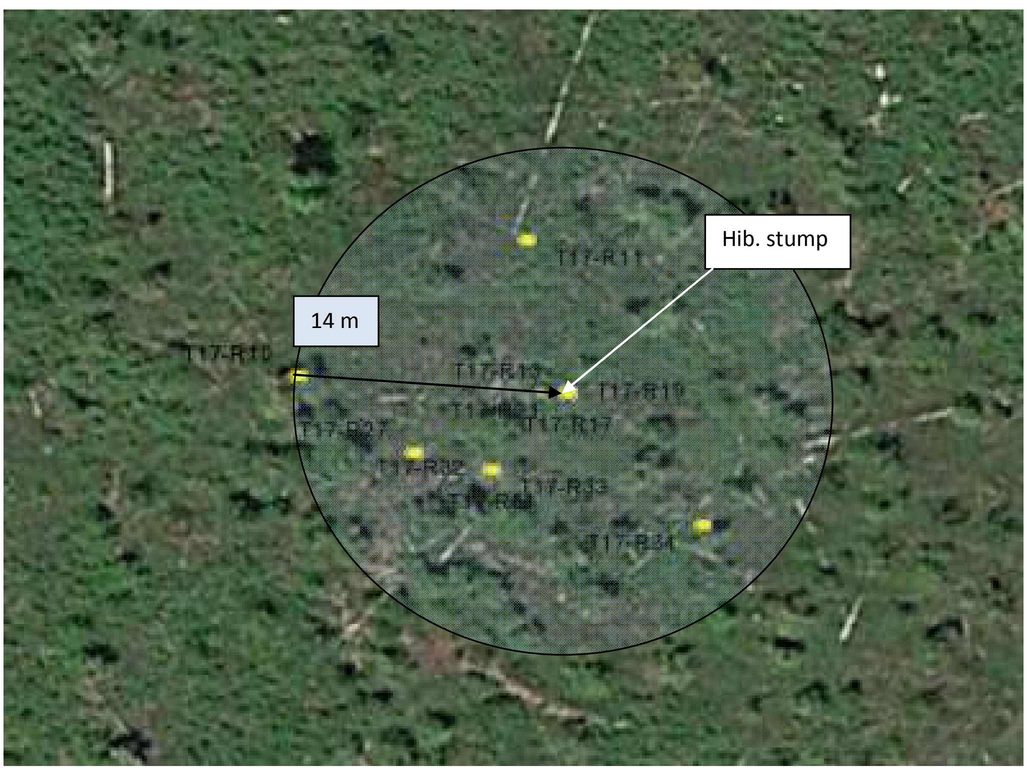


Figure 10. Location of all hibernacula from the pilot year (2014-15), Year 1 (2015-16), and Year 2 (2016-17)

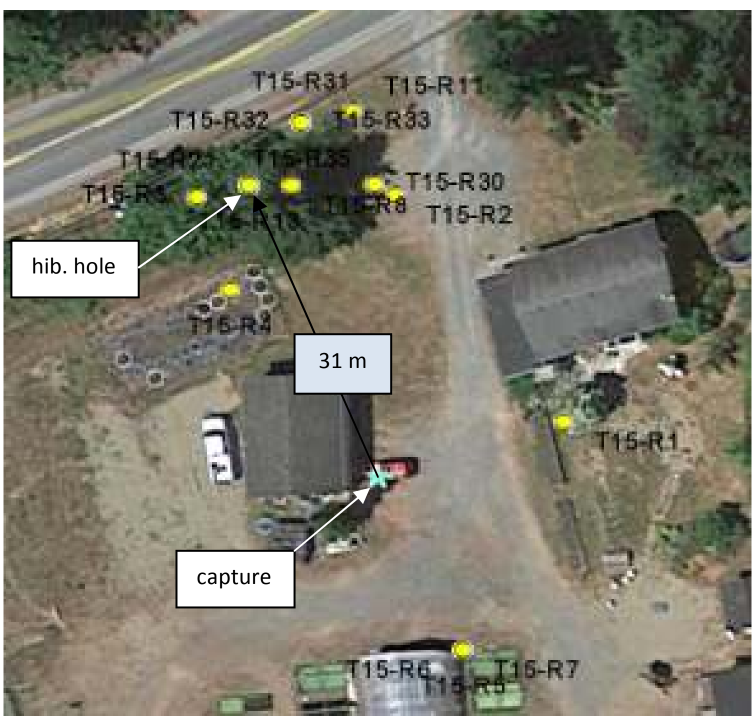


a) Toad 16 – Sep. 28 to Nov. 26 re-locations

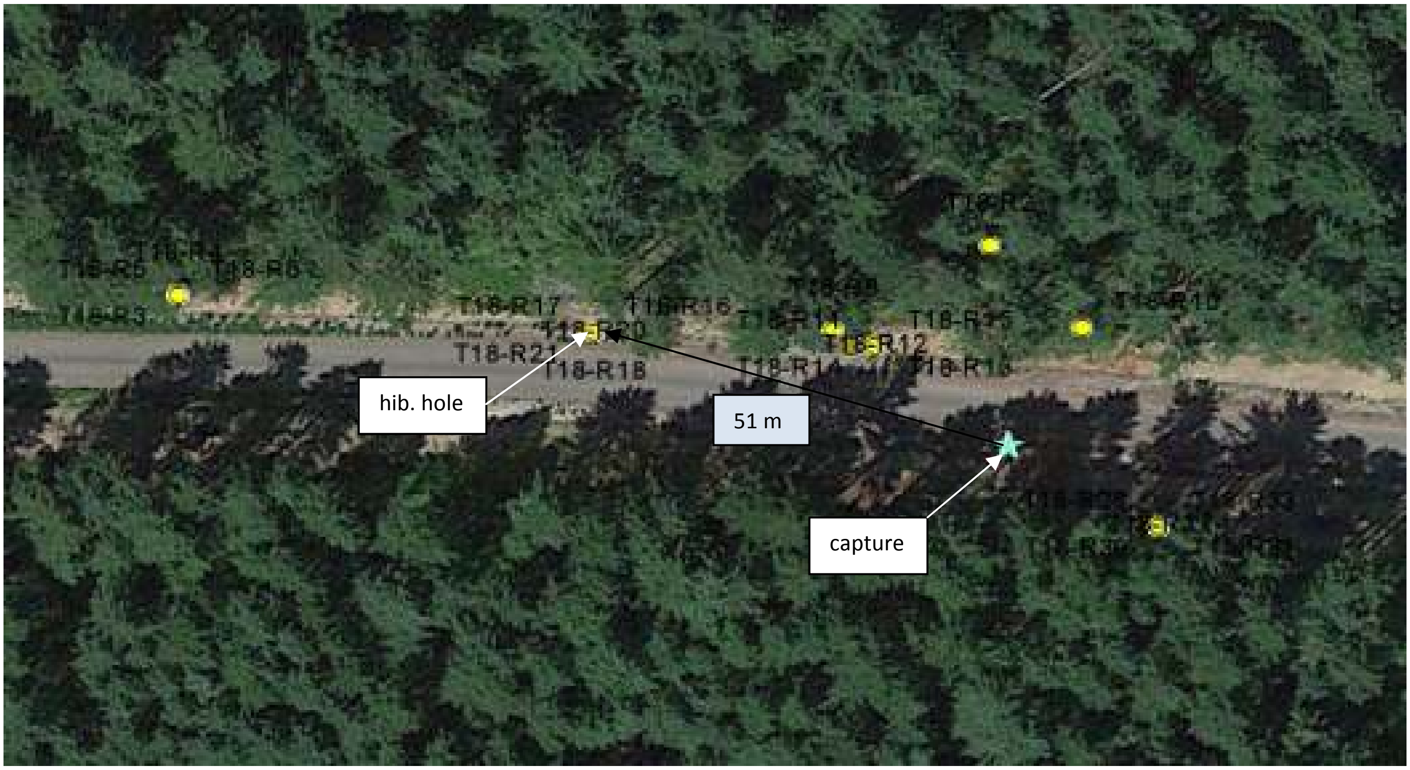


b) Toad 17 – Oct. 19 to Feb. 29 re-locations

c) Toad 28 – Nov. 9 to Feb. 19 re-locations



d) Toad 15 – Sep. 15 to Mar. 7 re-locations



e) Toad 18 – Sep. 18 to Mar. 4 re-locations

f) Toad 23 – Sep. 21 to Feb. 17 re-locations

Figure 11. Movement patterns of toads captured relatively close to their hibernation structures in the fall and tracked post emergence.

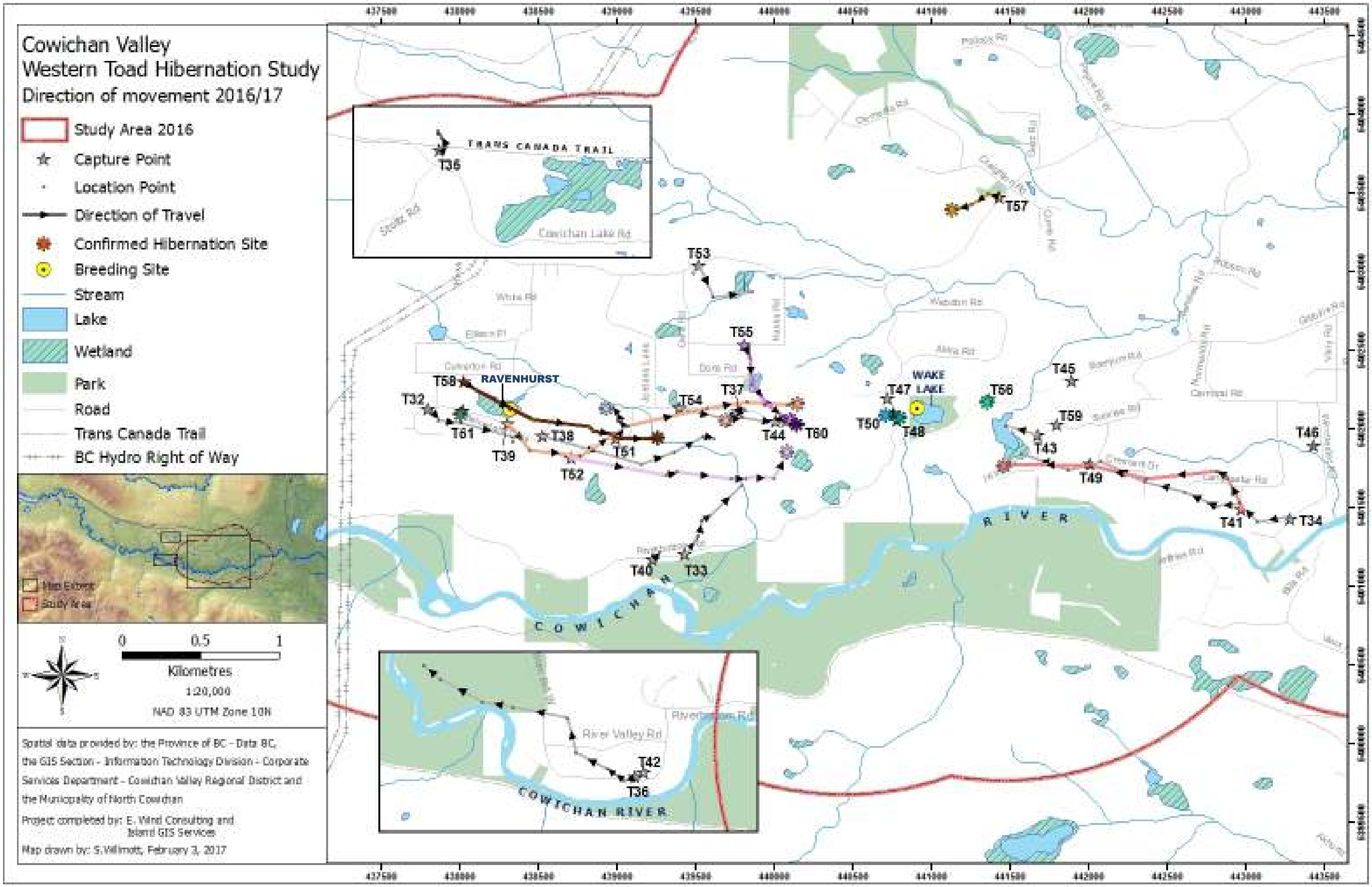


Figure 12. Movement directions of toads fitted with transmitters in fall 2016 that were tracked for at least 2 weeks.

Table 5. Mapped distances between capture points, terrestrial hibernation sites, and two known aquatic breeding sites for 28 toads tracked to hibernacula. For 21 toads where the breeding site is confirmed or suspected, based on fall movement patterns and hibernation locations (see Section 3.4), the mapped distances are highlighted in bold and the average presented in the bottom row.

Toad i.d. - sex	**Mapped** *(straight line)* **distance between capture location and hibernation site** (m)	**Followed a unidirectional movement**(towards breeding site)		**Hibernated within 300 m of a known breeding site***	**Mapped distance** (m) **between hibernacula and:**	
		In fall	**In spring**		**East breeding site** (Wake Lake; WL*)	**West breeding site** (Ravenhurst; RA*)
T4-F	11				1438	1152
T6-M	25			Yes (WL)	**58**	2879
T7-M	20		Yes		3005	**415**
T8-M	16			Yes (WL)	**45**	2610
T11-F	108				3063	5653
T15-M	30				1821	3850
T16-M	588	Yes	Yes		**350**	2133
T17-F	156	Yes	Yes		**764**	1828
T18-F	52				1354	1236
T19-M	686	Yes		Yes (WL)	**165**	2329
T23-M	57			Yes (WL)	**187**	2429
T25-M	1581	Yes	Yes		**308**	2869
T26-F	569	Yes	Yes		**522**	2869
T28-M	1979	Yes	Yes		**599**	1991
T29-M	602	Yes	Yes		**459**	2169
T31-M	58			Yes (WL)	**228**	2484
T37-F	97				1218	1375
T39-F	1850	Yes	N/A		**758**	1832
T41-M	1539	Yes	N/A		**660**	3161
T48-M	24			Yes (WL)	**124**	2482
T50-F	55		N/A	Yes (WL)	**205**	2390
T51-Unk	206		N/A		1974	616
T52-M	1376	Yes	Yes		**870**	1785
T55-F	554	Yes	Yes		**809**	1785
T56-F	18		Yes		**446**	3034
T57-F	314				1280	3083
T58-F	1282	Yes			**1660**	957
T61-M	25		Yes		2904	**316**
Average	**496** (n = 28)	**12** (43%)	**11** (39%)	**7** (25%)	**474** *(for bold values only)* (n = 21)	

Table 6. Number of times a toad movement pathway (straight line connection between subsequent re-locations) encountered a public road (i.e., crossed or ran along a paved or unpaved public road) during fall tracking in Year 1 and Year 2 for toads tracked for at least 2 weeks, and projected road encounters during spring migrations towards breeding site. Toads tracked to confirmed and suspected hibernacula are in bold.

Toad i.d. (those tracked to hibernacula in bold)	**Fall 2016** (pre hibernation)		**# expected road encounters to reach a known breeding site based on toad movement patterns**
	Followed unidirectional movement pattern (towards Wake Lake)	**# of road encounters** (crossed or moved along)	
T11		**0**	
T12		2	
T14	Yes	1	1
T15		**0**	
T16	**Yes**	**1**	**1**
T17	**Yes**	**1**	**1**
T18		**1**	
T19	**Yes**	**1**	**1**
T20		1	
T21		1	
T22		0	
T23		**0**	**0**
T24	Yes	2	1
T25	**Yes**	**1**	**1**
T26	**Yes**	**2**	**1**
T27		1	0
T28	**Yes**	**2**	**1**
T29	**Yes**	**0**	**1**
T30		**0**	**1**
T31		**1**	**0**
T32	Yes	0	1
T33	Yes	0	1
T34	Yes	4	1
T37		**0**	**1**
T39	**Yes**	**4**	**1**
T41	**Yes**	**3**	**1**
T48		**0**	**0**
T50		**0**	**1**
T51		**1**	**0 or 1?**
T52	**Yes**	**0**	**1**
T55	**Yes**	**0**	**1**
T56		**0**	**1**
T57		**0**	**3**
T58	**Yes**	**2**	**1**
T60	Yes	0	1
T61		**0**	**1 or 2?**
Total # (%) of toads with road encounters		19 out of 36 (53%)	24 out of 29 (83%)

3.5 Timing of Hibernation and Emergence

Toads began to enter hibernation sites in late Oct. in Year 1 and 2 (Oct. 22nd and 24th respectively), and mid Nov. (13th) in the pilot study year. Toads started to emerge in early Jan. in the pilot study year (7th) and late Jan. in Year 1 and 2 (Jan. 22nd and 25th respectively; Table 7). The timing of the onset of hibernation occurred over a relatively consistent time period across years compared to the timing of emergence in late winter. The majority of toads went into hibernation in Nov. (24 of 31 toads – 100% of the pilot study toads, 69% Year 1 toads, and 67% of Year 2 toads; Table 7, Fig. 13a), but emergence varied by almost two months across years (pilot study = Feb., Year 1 = Jan., Year 2 = March; Fig. 13b).

Hygrochron data collected in fall of Year 2 (data was not collected in fall of Year 1) suggest that hibernation coincided with a drop in average weekly air temperatures (Fig. 14). The timing of hibernation is consistent with observations from the fall wildlife cameras (see Section 3.6 below). The pattern of entry and exit of a toad(s) into the hibernaculum hole follows the rise and fall of air temperature recorded by the camera during the latter part of November but not earlier in the monitoring period (see Section 3.6 below). Unfortunately, the camera data collection at that site ended on Nov. 23rd so no further activity was recorded (e.g., the actual hibernation date was not determined).

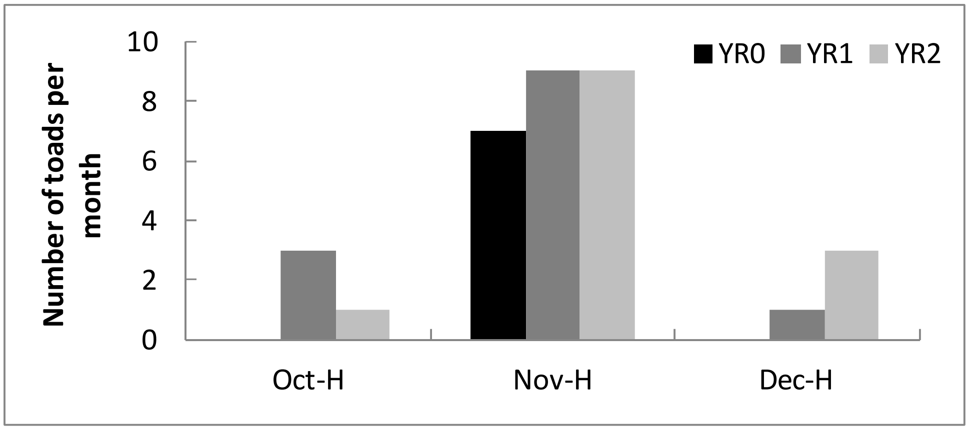
Based on first observations of toads at the surface during re-locations, the amount of time spent in hibernation varied between 40 days (8 weeks) and 119 days (17 weeks), and averaged 81 days (12 weeks). On average, females hibernated longer than males [88 days / 13 weeks (n = 10) versus 78 days / 11 weeks (n = 15) respectively]. The average duration of toad hibernation varied by up to 26 days across the three years; toad hibernation averaged 70 days in the pilot study year, 77 days in Year 1, and 96 days in Year 2. In Year 1, the majority of toads (8 of 12; 67%) emerged from hibernation sites when the average relocation period air temperature was close to 6°C, based on hygrochron data loggers from all sites combined across the study area (Fig. 15a). In Year 2, toad emergence was more temporally dispersed, with most toads emerging once the average relocation period air temperature remained above freezing (Fig. 15b).

Anomalies to the onset of hibernation and / or timing of emergence and were observed in the pilot study year and in Year 2 of the study, where a small number of toads appeared to emerge or shift hibernacula mid winter. In the pilot study year, toad T2 hibernated within / at the edge of a large slash pile on the edge of a small tree patch for 3 weeks (starting November 20th) then moved to another large slash pile / root wad on Dec. 12th approximately 26 m away where he spent another 6 weeks before he slipped his belt. Similarly, in Year 2, T55 was observed at the surface on Jan. 25th and 31st, 2017. She stayed within a couple of metres of her original hibernacula over the next two months. In that same year, T51 went into hibernation around Nov. 17th but was found on the surface on Dec. 29th, during subzero temperatures, about 7 m away from its hibernation stump. It was sitting near the surface, only partially covered with its antenna still visible. It did not move from this position during subsequent relocations and was confirmed to be dead on Jan. 19, 2017 with signs of trauma / predation (intestines hanging out). Given the climatic conditions at the time, combined with the trauma, the toad’s appearance at the surface in late Dec. was likely not a natural “emergence” (e.g., possible predator).

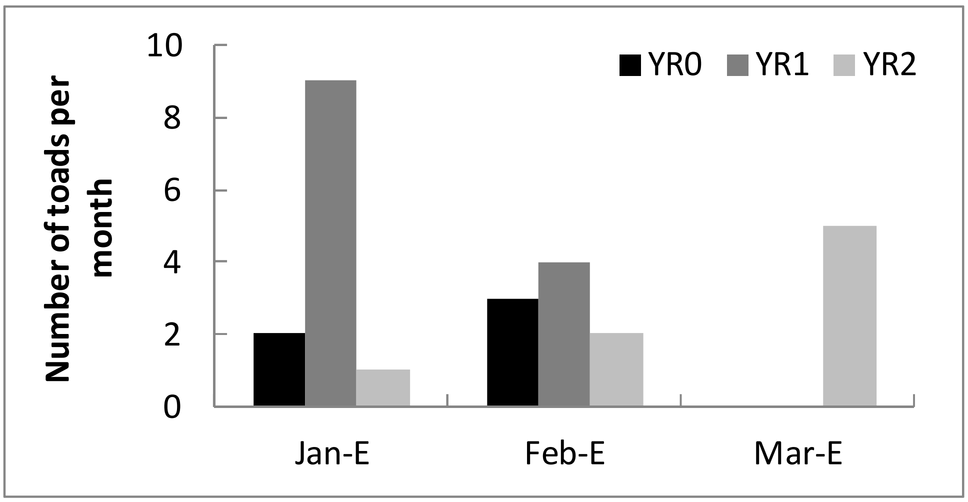
Table 7. Timing of hibernation and emergence for toads fitted with radio transmitters.

Toad i.d.	Approx. date of hibernation	Confirmed (likely) camera emergence	Date 1st observed at surface during relocation	Approx. # days in hib.	Approx. # weeks in hib.
T2-M	13-Nov-14	No	*12-Dec-14 (moved 26 m); 28-Jan-15 (slipped belt)*	*N/A*	*N/A*
T3-F	13-Nov-14	12-Feb-15	*Battery died?*	91	13
T4-M	28-Nov-14	No	07-Jan-15	40	6
T6-M	20-Nov-14	3-Feb-15	5-Feb-15	77	11
T7-M	28-Nov-14	7-Feb-15	8-Feb-15	72	10
T8-M	21-Nov-14	No	28-Jan-15 *(obs. at hibernaculum Feb. 5 & 11)*	68	10
T11-F	29-Oct-15	(11-Feb-16[a])	12-Feb-16	106	15
T15-M	12-Nov-15	27-Jan-16	29-Jan-16	76	11
T16-M	26-Nov-15	(9-Feb-16[b])	*N/A (slipped belt found Feb. 16)*	75	11
T17-F	26-Nov-15	28-Jan-16	29-Jan-16	63	9
T18-F	9-Nov-15	*24 or* 27-Jan-16[c]	29-Jan-16	79	11
T19-M	22-Oct-15	22-Jan-16 & 27-Jan-16[d]	*N/A (battery died)*	95	14
T23-M	18-Nov-15	*N/A – no camera*	22-Jan-16	65	9
T25-M	18-Nov-15	(8-Feb-16[e])	10-Feb-16	84	12
T26-F	29-Oct-15	No	22-Jan-16	85	12
T28-M	26-Nov-15	No	29-Jan-16	64	9
T29-M	5-Nov-15	No	1-Feb-16	88	13
T30-M	12-Nov-15	22-Jan-16 & 27-Jan-16[d]	29-Jan-16	74	11
T31-M	14-Dec-15	No	29-Jan-16	46	7
T37-F	6-Dec-16	21-Feb-17	23-Feb-17	79	11.3
T39-F	14-Nov-16	No	*Slipped belt*	*N/A*	*N/A*
T41-M	6-Dec-16	*N/A*	19-Jan-17 *(dead)*	*N/A*	*N/A*
T48-M	28-Nov-16	No	13-Mar-17	105	15
T50-F	24-Oct-16	No	*N/A – battery died (16-Feb); observed at breeding site 3-Apr-17*	*N/A*	*N/A*
T51-Unk	17-Nov-16	*N/A*	29-Dec-16 *(found dead Jan. 19)*	*N/A*	*N/A*
T52-M	14-Nov-16	16-Feb-17	20-Feb-17	98	14
T55-F	6-Dec-16	No	25-Jan-17	50	7.1
T56-F	28-Nov-16	13-Mar-17	13-Mar-17	105	15
T57-F	10-Nov-16	5-Mar-17	9-Mar-17	119	17
T58-F	24-Nov-16	No	2-Mar-17	98	14
T61-M	10-Nov-16	No	2-Mar-17	112	16
			Maximum	**119**	**17**
			Minimum	**40**	**6**
			Average	**81.3**	**11.4**

[a] Unconfirmed – anuran in photographs looked a little small, but the timing of emergence coincided with when Toad 11 was first observed at the surface.
[b] Slipped transmitter found at entryway on Feb. 16th at same location where an anuran was observed emerging on Feb. 9th.
[c] Toad 18 observed exiting hibernaculum on Jan. 24th, returned to hibernaculum Jan. 25th, and then emerged again on Jan. 27th.
[d] A toad with a transmitter was observed emerging from this hibernaculum on both Jan. 22nd and Jan. 27th. It was impossible to tell from the photographs which was Toad 19 and which was Toad 30.
[e] A toad was observed emerging from this hibernaculum on Feb. 8th. However, a belt and transmitter could not be seen in the photographs.



a) Into hibernation.



b) Emergence from hibernation.

Figure 13. Number of toads that went into (a) and emerged from (b) hibernation per month for each year of the study.

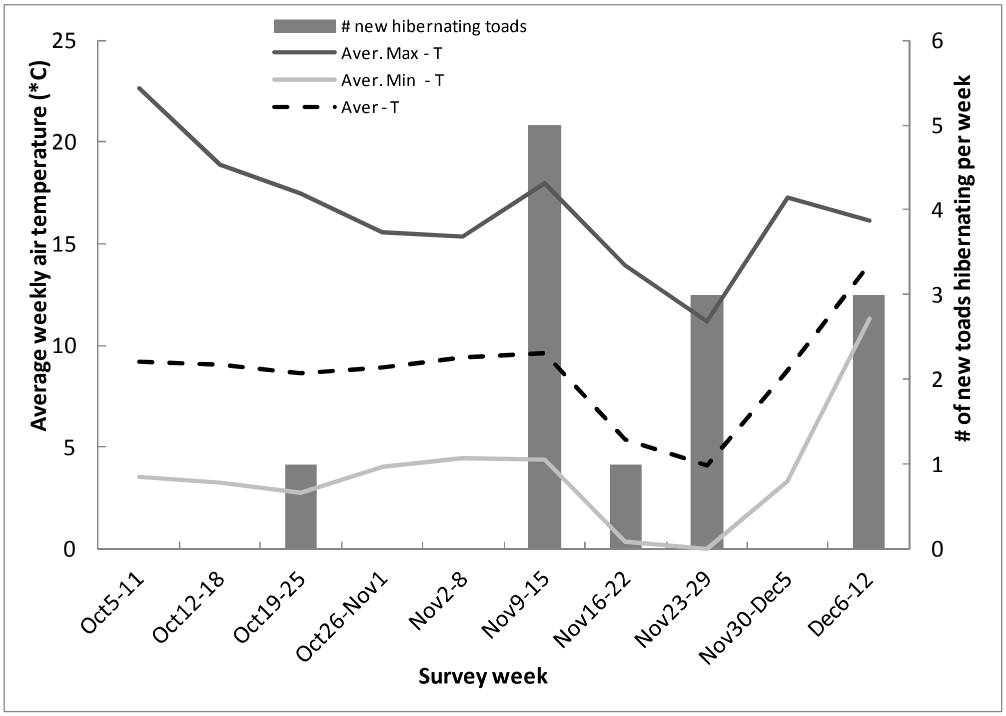
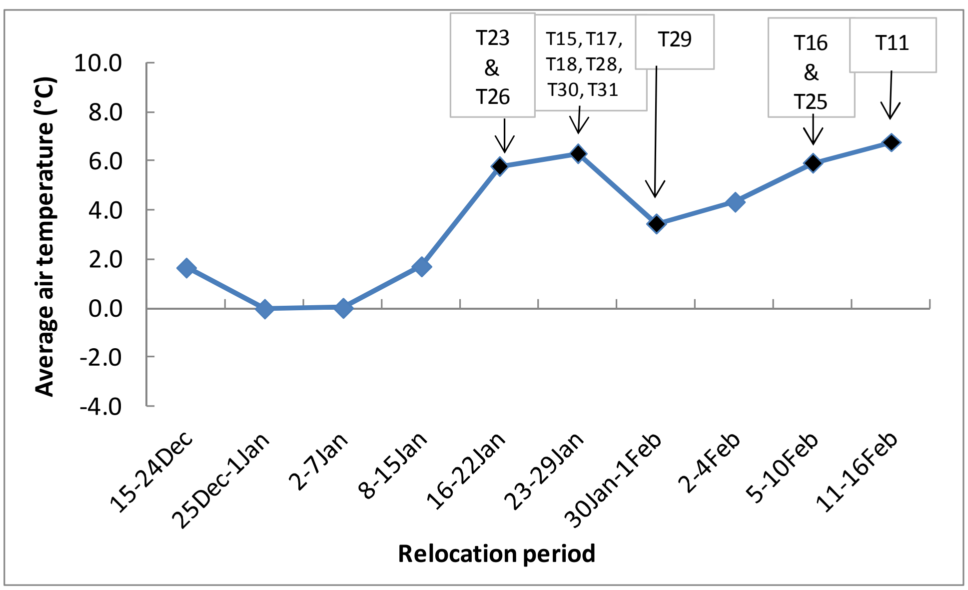
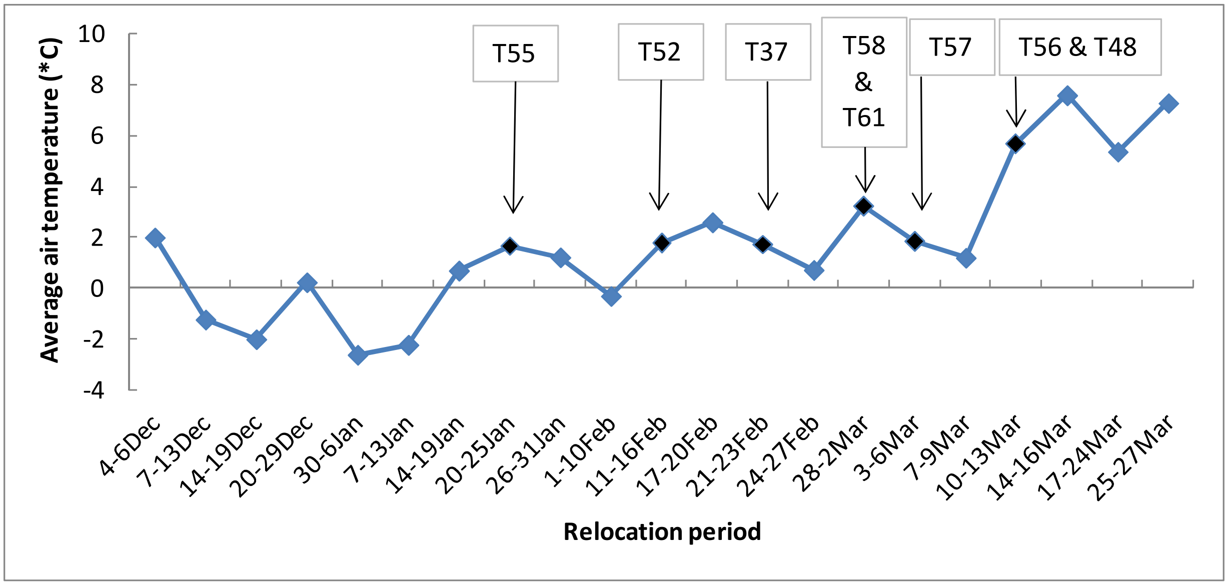


Figure 14. Timing of hibernation in relation to average weekly air temperatures in fall of Year 2.



a) Average air temperature per relocation period as recorded by 96 Hygrochron data loggers and the date of emergence of 12 toads from hibernation in Year 1.



b) Average air temperature per relocation period as recorded by 104 Hygrochron data loggers and the date of emergence of 8 toads from hibernation in Year 2.

Figure 15. Timing of emergence in relation to air temperature in Year 1 (a) and Year 2 (b).

3.6 Camera Monitoring

Hibernation Site Confirmation and Emergence Monitoring

In total, cameras were set at 31 of 32 confirmed or suspected hibernacula in winter over the 3-year study. Cameras were set in mid Jan. (13^{th} to 17^{th}) and removed in late March. One site in Year 1 was not monitored due to theft concerns and the complex nature of the site (T23). Toads were not captured on film at a number of sites due to camera issues (e.g., camera failure for T48 and T58), or the relatively complex nature of the hibernacula (e.g., numerous, hidden entryways likely existed).

In total, tracked toads were observed emerging from 13 hibernacula via wildlife cameras based on confirmation of transmitters seen in the photographs (Table 7). The emergence dates from the cameras were consistent with the toad observations at the surface during re-locations.

In Year 2, the signal for T50 was lost in Jan. (battery failure) and she was not captured emerging via a wildlife camera. However, a pit tag scan of breeding toads at Wake Lake on March 3, 2017 confirmed that she was still alive. T50 was in amplexus with a male and was not wearing the belt and transmitter at the time.

Communal Use of Hibernacula

Of the 13 hibernacula where tracked toads were observed emerging via wildlife cameras, the images from 2 of the sites (T3 and T7) were deemed of relatively poor quality and not reliable for assessments of potential communal use. Of the 11 sites with suitable image quality, communal use by toads was observed at 3 of the hibernacula (27%). In Year 1, T30 was captured and fitted with a transmitter in the fall at the hibernation site of T19 (i.e., an old, rotted out stump). T30 remained at that hibernation site throughout the winter. During the winter, the transmitter battery for T19 died (Jan. 15, 2016) so its emergence and subsequent surface activity could not be confirmed via tracking. Slight changes in the location of the strongest signal prior to battery failure suggested underground movements and hibernation. Table 8 summarizes the movements of toads with and without transmitters into and out of the hibernacula over a 10-day period in Jan. 2016. On Jan. 28, 2 toads were observed going into the hibernacula at the same time, one with a transmitter and one without. If the hibernacula had multiple entryways, it is impossible to say how many toads may have been in the hibernacula. However, if the hole monitored by camera was the only entryway, the images of toads exiting the site suggest at least 4 toads used the hibernacula. Unfortunately, the camera was removed on Jan. 29, according to the methods protocol (i.e., T30 was observed on the surface and assumed to be 'emerged' from hibernation on Jan. 22) so no further camera images were available for assessment. Results from surface tracking indicate that T30 moved into and out of its hibernacula a number of times before the end of Feb. (Table 9), after which it moved towards the breeding site.

In addition to the site above, an adult toad was observed emerging from T25's hibernacula on Feb. 8, 2016. No transmitter was visible on the toad. During tracking, T25 was located on the surface approximately 8 m away from the hibernacula two days later on Feb. 10 (i.e., emerged from hibernation), confirming that it had not slipped its belt. It appears that T25 exited the hibernation site from an alternate hole and the toad observed on camera was an untagged toad, providing evidence of communal hibernation by toads at this site. Lastly, 2 toads were observed at the hibernation site for T17. On Jan. 28, 2016, T17 was observed emerging from the hibernacula via wildlife camera. During surface tracking on Feb. 16, T17 was observed on the surface approximately 7 m away from the hibernation structure. At this time, another untagged adult toad was observed sitting at the hibernation stump entryway. The untagged toad jumped down into the hibernacula hole as surveyors approached and was observed down the hole through the use of a flashlight.

The wildlife camera data confirmed that 7 of the 11 Western Toad hibernacula were used by other amphibian and mammal species, and one site was also used by a reptile species. Other amphibian species observed going into or out of Western Toad hibernation sites via the wildlife cameras included Red-legged Frogs (*Rana aurora*), Pacific Treefrogs (*Pseudacris regilla*), Northwestern Salamanders (*Ambystoma gracile*), and Roughskin Newts (*Taricha granulosa*; Table 10). An adult Western Red-backed Salamander (*Plethodon vehiculum*) came out of T15's hibernation entryway hole on Jan. 15, 2016, followed by a gartersnake (*Thamnophis sp.*) on Jan. 31, 2016 at 10:26 am when the air temperature was only 6°C (based on the average air temperature recorded by 4 ground-level Hygrochron data loggers at the site). Rodents were commonly observed at hibernation sites, especially mice who appeared almost nightly at some hibernation sites suggesting ongoing use by these vertebrates (Table 11). Two mammals were observed going into or out T50's hibernacula in Feb. 2016—American Mink (*Mustela vison*; February 24) and Red Squirrel (*Tamiasciurus hudsonicus*; Feb. 12, 14, 18, 19, 20, and 27). The mink was only observed on one occasion and it appeared that the animal was foraging / hunting (i.e., it went to the hole, partially inside, and then it left). The Red Squirrel entered and left the hole many times suggesting that it was utilizing the site in some way on a regular basis.

Re-use of Hibernacula across Years

Cameras were installed between early Nov. and early Dec. of Year 1 (4 weeks), and between mid Oct. and early Dec. in Year 2 (4.5 weeks). Three pilot study year hibernation sites were monitored in the fall of Year 1 (T4, T6, and T8), and six Year 1 hibernation sites in the fall of Year 2 (i.e., at T11, T16, T17, T18, T19/T30, T25). Of the 9 hibernacula monitored in the fall, re-use by adult Western Toads was only observed at 1 site—the hibernacula for T19/T30. If this hibernaculum has multiple entryways it is impossible to determine how many toads used the site based on the camera images. However, if the hole in the camera images is the main / only entryway, it appears that at least 2 toads entered and left the hole between Oct. 22 and Nov. 23, 2016 (Fig. 16). Toads were observed at three other sites during fall monitoring, but potential re-use of the site for hibernation was not confirmed. One juvenile toad was observed at T6 in fall 2015, coming down slope toward the hibernation hole. It sat near the entryway for a few minutes, but then it exited the image frame away from the hole. An adult toad was observed walking past the T17 hibernacula in fall 2016; an upper entrance hole (outside of the camera view) may have been associated with this hibernation structure. A juvenile toad(s) was observed on multiple images going into and out of T25's hibernacula between Nov. 4 and 23, 2016.

A relatively large salamander (e.g., *A. gracile*) was observed on numerous occasions near and at entryway of the T6 hibernation site in Nov. and Dec. 2015. Small unidentified anurans (e.g., juvenile toads and / or *P. regilla*) were observed moving up and / or down the slope left of the T8 entryway (i.e., near a large adjacent stump) on at least 6 occasions but none were observed going near or into the hibernacula entryway.

In Year 1 and Year 2, the majority of tagged adult Western Toads went into hibernation in Nov. Cameras were installed between mid Oct. and early Nov. each year. As such, toads that went into hibernation earlier in the season (e.g., in early Oct.) would not have been captured by our wildlife cameras (approximately 15% of adult toads may have gone into hibernation by Oct. based on Year 1 and Year 2 tracking results).

Table 8. Movements captured on a wildlife camera of toads going into and out of an hibernaculum occupied by T19 and T30 in Year 1.

		Toad with a transmitter		**Toad without a transmitter**		
Date	**Time**	Enters hole	Exits hole	Enters hole	Exits hole	**Comments regarding wildlife camera images for T30**
18-Jan-16	4:08 PM					Toad with transmitter observed inside entryway
21-Jan-16	8:15 PM					Toad eyes observed in entryway
22-Jan-16	6:56 PM		X*			
27-Jan-16	5:27 PM		X			
	10:00 PM				X	
28-Jan-16	4:37 AM				X	
	5:26 PM	X		X		Two toads appear to go into entryway at the same time

* During surface re-locations, T30 was on the surface on 22-Jan-16 approximately 2.5 m away from hibernaculum and considered “emerged” from hibernation.

Table 9. Re-locations of T30 upon “emergence” from hibernation in 2016.

Date	**Visual of toad?**	**Approx. distance moved** (m)	**On surface or in hibernaculum**
22-Jan-16	Yes	2.5	Surface
29-Jan-16	No	0	Surface
4-Feb-16	No	1.5	Hibernaculum
10-Feb-16	No	0	Hibernaculum
16- Feb-16	Yes	0	Hibernaculum
19- Feb-16	No	9	Surface
22- Feb-16	No	5	Hibernaculum
25-Feb-16	No	0	Hibernaculum
29-Feb-16	No	>10	Surface

Table 10. Amphibian species observed on wildlife camera images that appeared to go in or out of known Western Toad hibernacula.

Toad Hibernacula	Western Toad	Red-legged Frog	Pacific Treefrog	Unknown Anuran species	Northwestern Salamander	Roughskin Newt	Terrestrial Salamander	Unknown Caudate species
T6	X							X
T11		X					X	X
T15	X	X					X	
T16	X		X					
T17	X							
T18	X	X		X				
T19&T30	X							X
T25	X					X		
T26								X
T28								X
T31								X
T37	X							
T52	X				X			X
T56	X							
T57	X							
Total	10	3	1	1	1	1	2	7

Table 11. Other vertebrates observed on wildlife camera images that appeared to go in or out of known Western Toad hibernacula.

Toad Hibernacula	Rodents		Red Squirrel	American Mink	Gartersnake	Unkn. species
	Mouse	Rat				
T6	X					X
T11	X					
T15	X				X	
T16						X
T17	X					
T18	X					
T19&T30	X					
T25	X					
T26	X	X				
T31						X
T50			X	X		
T52	X					
Total	25	2			1	2

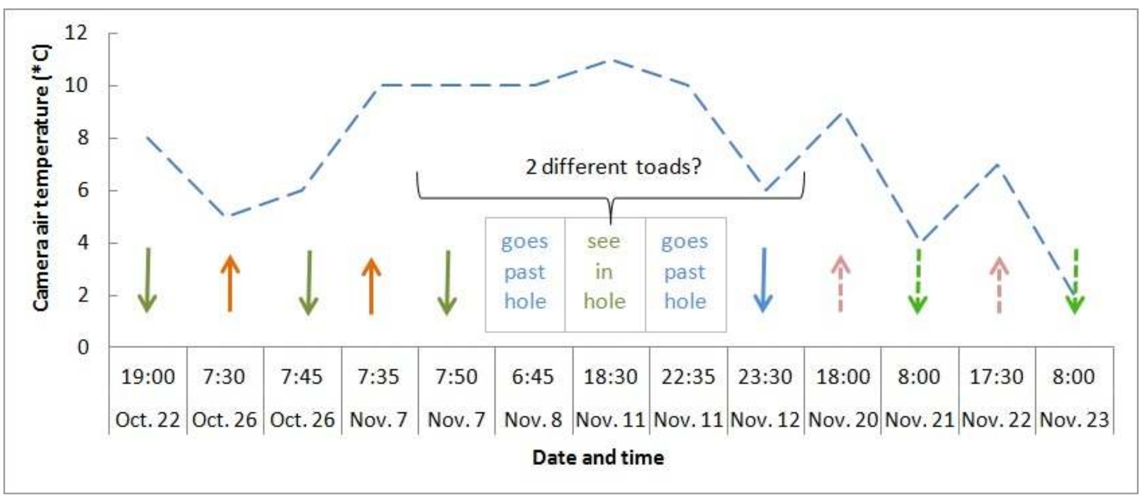


Figure 16. Toad activity at a hibernaculum confirmed in Year 1 (fall 2016) during camera monitoring in Year 2 (fall 2017). The date and time a toad was observed going into (down arrows), out of (up arrows), or past the entrance hole are presented in relation to air temperature (°C) recorded by the Reconyx camera.

3.7 Habitat Characteristics of Hibernation Sites

In total, 28 confirmed and suspected (likely) hibernation sites and 81 random sites were assessed for habitat characteristics at both the ecosystem (9.77-m radius plot; n = 33) and microsite level (5.64-m radius plot; n = 36). The 2-km landscape-level plots were also assessed, centred over each of the 28 hibernation sites.

Observational summary analyses indicate that the dominant habitat type within the 2-km landscape level plots around a Western Toad hibernaculum is forest cover (average = 65%), with an average percent cover of hard edge habitat of 33% (e.g., forest cover + another type of habitat category). At the ecosystem level, hibernacula plots had more deciduous canopy cover (average = 20%) compared to random plots (13%).

None of the toad ecosystem-level plots (0%) contained habitat defined as "built" and the median distance of the plot to built habitat was 171 m, compared to 7% of the random plots containing built habitat and averaging only 95 m away from this habitat type. However, the toad hibernacula plots were on average closer to a public road than random plots (85 m versus 178 m away) and hibernacula plots averaged 48% cover of road edge habitat compared to 33% for the random plots. Hibernacula plots were also closer to lentic habitats than random plots (277 m compared to 430 m respectively), including being closer to known breeding sites (average = 732 m compared to 1287 m respectively).

At the microsite level, hibernacula plots contained more stumps, larger stumps, and more large downed wood compared to random sites (average number of stumps = 8 compared to 6 at random plots; average diameter of stumps = 45 cm versus 39 cm respectively; average number of large downed wood = 9 versus 7 at random plots). A higher percentage of hibernacula microsite plots contained root wads (11% of plots) and stumps (50% of plots) compared to random plots (1% and 16% of plots respectively). The majority (82%) of the 28 hibernation structures used by toads contained a woody component, such as stumps, large downed wood, and root wads (Table 12). Three of the 5 remaining hibernacula were in mineral or organic mounds that appeared to include a woody component. For example, we dug into the hibernacula of T7, which was a mound with ferns growing on it and discovered a large underground cavity with a woody roof. The diameter of stumps and downed wood associated with hibernacula ranged from 0.12 to 1.25 m (average = 0.67 m) and 0.20 m to 1.50 m (average = 0.73 m) respectively. Only one toad (T41) used an indiscernible structure, hibernating in what appeared to be a shallow hole near the crest of a south-facing mineral slope (the toad was visible at the surface). However, on January 19th it was determined that T41 was dead. He had an open, gaping wound on his right forelimb but it was unclear exactly what caused the death as he was exposed at the surface throughout hibernation and temperatures had dropped below freezing.

Microclimate

For all but one of the hibernation sites, the average air temperature by the hibernaculum versus the three random sites within the ecosystem-level plot varied by less than 1 degree from Dec. through Feb. in Year 1 and through March in Year 2 (i.e., the period when most toads were hibernating; Fig. 17). Only 1 site had more than a 1°C difference between the hibernaculum and the random sites (T16). This site, situated on a south-facing slope within a clearcut, had the warmest recorded temperatures during the winter months of all sites across the two years. The average air temperature was warmer across the 11 hibernacula in Year 1 (3.4°C; range = 2.69 to 5.21°C) compared to the 12 hibernacula in Year 2 (1.2°C; range = 0.46 to 1.98°C) during the winter monitoring period.

On average, the temperatures recorded at the toads during relocations, based on the temperature-sensor BD-2T transmitters and a handheld device to record air temperature (Kestrel 3000 Pocket Weather Meter, KestrelMeters.com) indicated that toads were on average approximately 3.9°C warmer (range = -4.0 to 7.1°C, n = 16) than ambient air temperature during hibernation. However, 6 of the toads did experience subzero temperatures within the hibernacula (Fig. 18). Transmitter temperature sensors detected subzero temperatures for 4 toads in Year 1 and 2 toads in Year 2, dropping as low as -4.5°C for T25 on Jan. 1, 2016. There was no clear relationship between average toad or air temperature during hibernation and distance to open habitat / forest edge along a SE-S-SW aspect (Fig. 19).

Table 12. General characteristics of 28 Western Toad hibernacula.

Toad ID	Hibernacula Feature	Height / length (m)	Width / diam. (m)	% edge habitat	Canopy cover (%)	Aspect	Private or Public land	General habitat description
T4	Stump	0.2	0.5	95	76	10 (NW)	Private - Undeveloped	Top of road bank / forest edge along public road
T6	Mineral mound	3.5	1.5	100	62	none *(top of hill)*	Private - Undeveloped	Mature forest / trail edge
T7	Organic mound (old stump?)	5.0	5.0	100	67	154 (SE)	Private - Home	Mature forest / short open veg. edge
T8	Downed log (and stump?)	2.3	0.6	100	69	240 (SW)	Public - CVRD parkland	Mature forest / public road edge
T11	Stump	1.1	1.3	100	43	200 (SSW)	Private - Home	Mature / old forest patch opening
T15	Bank / stump / downed wood in bank?	0.5	0.1	100	21	163 (SSE)	Private/Public – MoTI road edge	Bottom of public road bank slope
T16	Stump / bank	0.6	0.2	100	0	185 (S)	Private - Industry	10-15 yr old clearcut
T17	Stump	0.4	1.3	0	0	188 (S)	Private - Industry	10-15 yr old clearcut
T18	Stump	0.3	0.7	100	38	356 (N)	Private - Undeveloped	Top of road bank / forest edge along public road
T19/30	Stump	0.1	0.5	100	16	19 (SSE)	Private - Industry	10-15 yr old clearcut
T23	Mineral mound / cwd in mound?	10.0	3.5	100	38	267 (W)	Private - Home	Young / mature forest opening (near public road and grassy lawn edges)
T25	Downed log	2.3	0.7	100	34	0 (N)	Private - Undeveloped	Young forest / trail edge (near public road edge)
T26	Downed log	20.0	1.5	0	48	2 (N)	Private - Home	Mature / old forest
T28	Stump	0.9	0.9	100	67	0 (N)	Private - Industry	Remnant patch of young, dense conifers within 10-15 yr old clearcut
T29	Stump	0 (holes in ground)	0.9	100	92	224 (SW)	Private - Industry	Remnant riparian mature forest patch within 10-15 yr old clearcut
T31	Stump	0.3	1.0	0	52	55 (ENE)	Private - Industry	Mature / old forest (near riparian and road edge)

Toad ID	Hibernacula Feature	Height / length (m)	Width / diam. (m)	% edge habitat	Canopy cover (%)	Aspect	Private or Public land	General habitat description
T37	Root wad	0.70	0.60	0	65	134 (SE)	Private	Mature Forest
T39	Root wad	1.25	0.35	100	7	220 (SW)	Private	Clearcut
T41	No discernible structure (shallow hole on mineral slope)	N/A	N/A	100	45	165 (SSE)	Private	Forest / dirt road edge
T48	Downed log	4.00	0.70	100	36	98 (E)	Public	Forest / road / wetland edge
T50	Downed log	25.00	0.66	100	67	21 (NNE)	Private	Forest patch / clearcut / wetland edge
T51	Stump	0.60	0.47	75	72	340 (NNW)	Private	Road / forest edge
T52	Stump	0.28	0.95	0	21	113 (ESE)	Private	Clearcut
T55	Stump	0.28	0.30	0	5	188 (S)	Private	Clearcut
T56	Mineral mound + snag	2.20	4.00	100	18	185 (S)	Private	Road / forest / small wetland edge
T57	Large snag	20.00	73.50	95	46	102 (E)	Private	Mixed forest / riparian / farm edge
T58	Stump	0.88	0.66	100	65	330 (NW)	Private	Mature forest / wetland edge
T61	Root wad	0.97	1.20	100	20	207 (SSW)	Private	Young forest / dirt road / wetland edge
	Average	Stumps	0.7	77.3	42.5	154.3 (SSE)	Private = 25	
		CWD	0.8	22 of 28 plots contained ≥ 75% edge habitat			Public = 3	

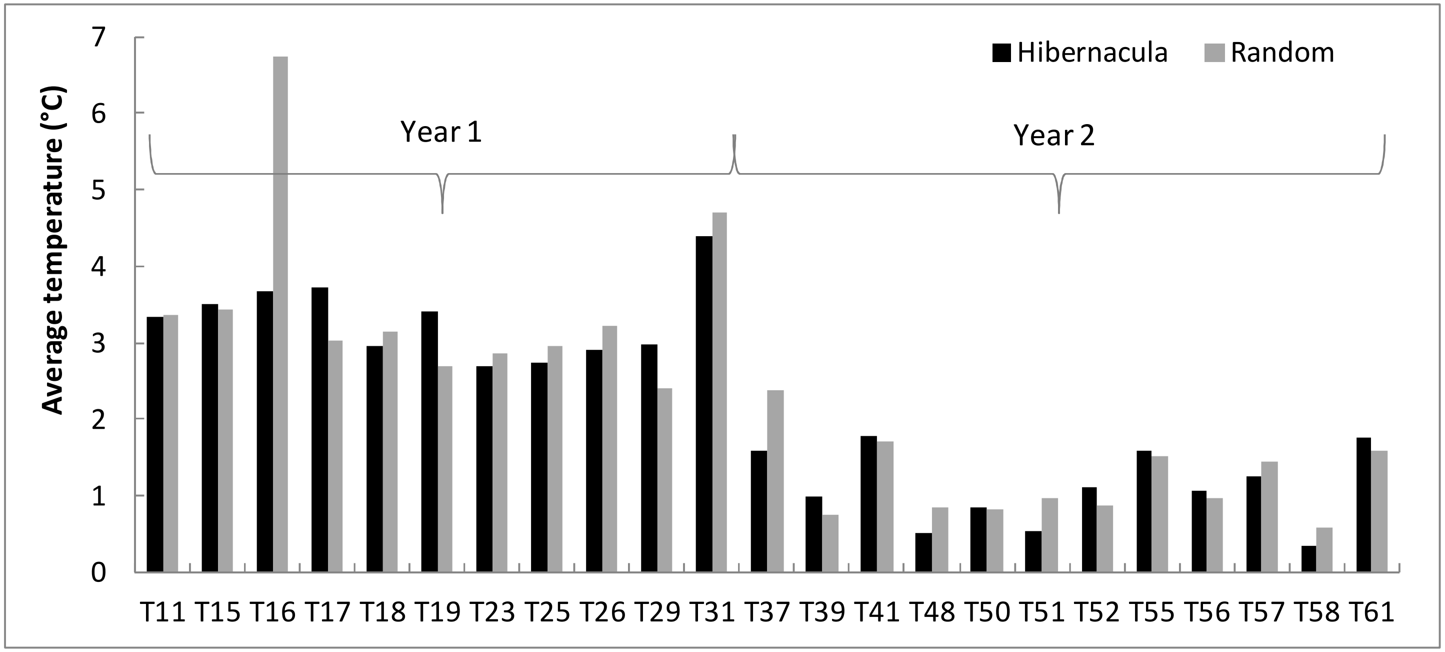
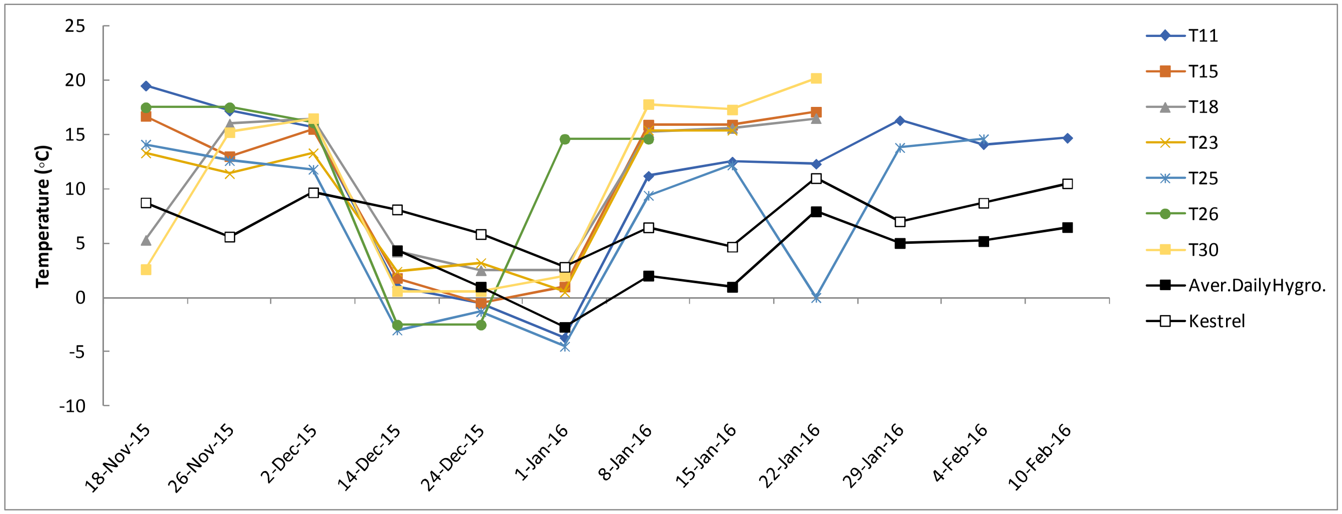
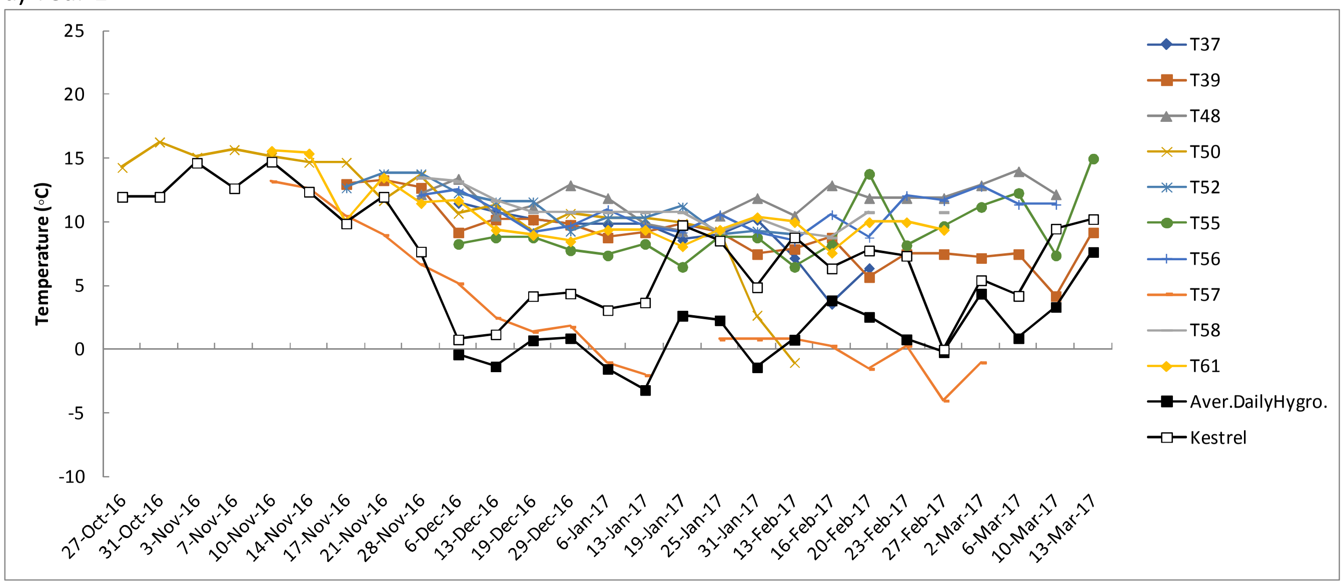


Figure 17. Comparison of average air temperature from hygrochrons for hibernacula (HIB) versus random (Random) sites for each hibernation site ecosystem-level plot for toads in Year 1 (T11 to T31) and Year 2 (T37 to T61) recorded from December to March.



a) Year 1



b) Year 2

Figure 18. Temperature at toads versus surface air temperature during the hibernation period in Year 1 and Year 2.

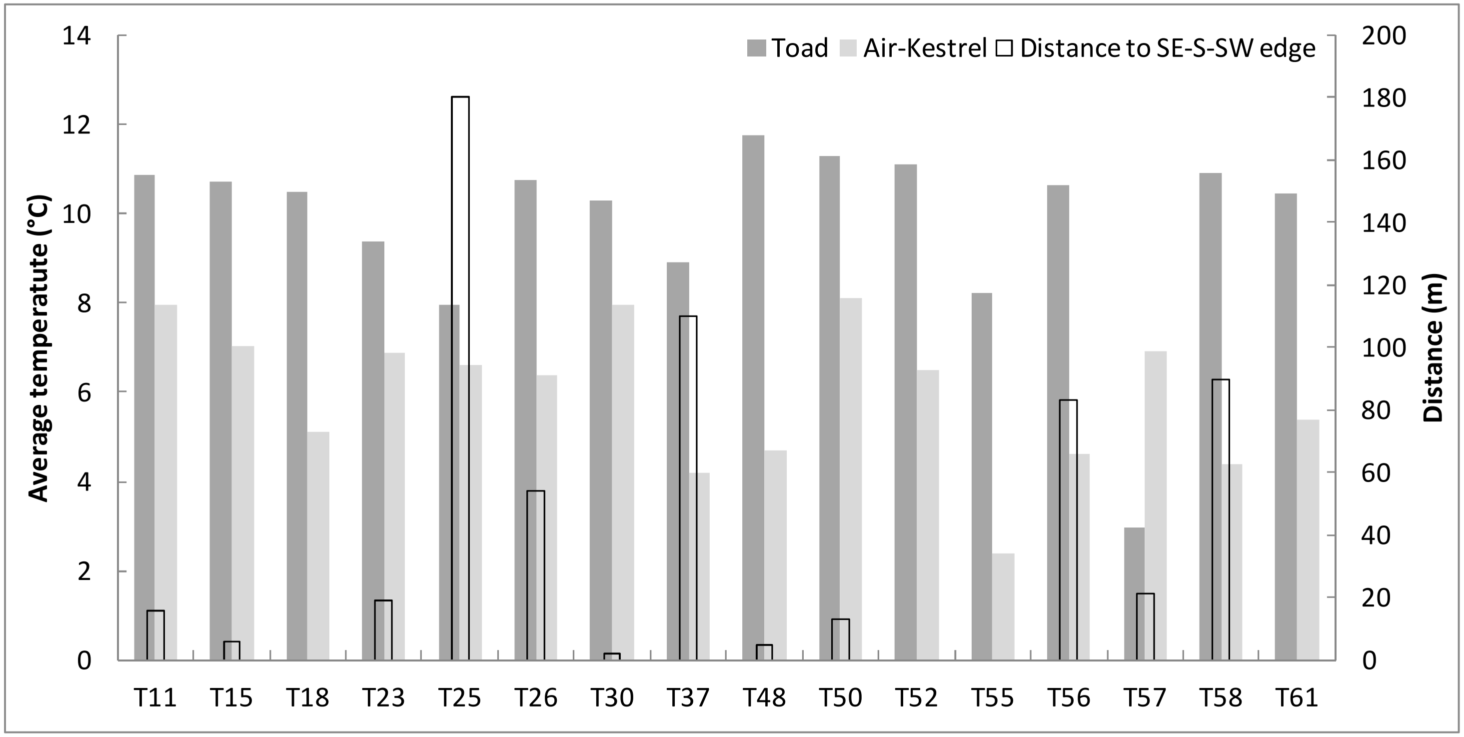


Figure 19. Average toad (fitted with temperature sensor transmitters) and air temperature (recorded with handheld microclimate device - Kestrel 3000) during hibernation in relation to proximity to open habitat / forest edge along a SE-S-SW aspect.

4.0 DISCUSSION

The Western Toad population we studied west of Duncan on Vancouver Island displayed similar behaviour patterns to populations observed elsewhere within the species' Pacific Northwest range in relation to hibernation. Toads in the Duncan area moved relatively far to reach their hibernation sites in the fall and to breeding sites in the spring, they selected hibernation sites that provided thermal cover, and some hibernacula were communal.

The toads within our study area displayed two types of movement patterns in the fall: a) unidirectional movements towards a known, primary breeding site (Wake Lake), and b) small movements relatively close to their point of capture / hibernation site. Dulisse (2017) also observed that Western Toads near Nakusp, BC move towards a primary breeding site in the fall prior to hibernation. Some of our toads displayed similar movement distances as observed elsewhere within their range when migrating between important habitat features. Most notable were two males and a female that travelled over 1.3 km from their point of capture to their hibernation site in the fall, followed by another 600+ m to reach their suspected breeding site in late winter. The distance between hibernation sites and breeding sites in Duncan ranged from 45 to 1660 m. In AB (Browne and Paszowski, 2010a&b) and WA (Palmeri Miles 2012) the distance between hibernation and breeding sites ranged from 146 to 1936 m and 320 to 1000 m respectively. In contrast, toads in OR travelled between 180 and 6230 m, with females moving farther than males (23 out of 27 females moved more than 1600 m between sites; Bull 2006). Interestingly, in both years of our study, some toads travelled past a known toad breeding site after capture in the fall (i.e., the Ravenhurst wetland) en route to their hibernation site, closer to the Wake Lake breeding site. This suggests that Wake Lake may be the main (or source) breeding site within the area and toads are faithful to the breeding site of their origin. The instinct to make unidirectional movements towards the breeding site in the fall after the summer foraging season, versus in the late winter post emergence from hibernation, likely ensures that toads retain suitable energy stores for the spring breeding season.

In contrast to the unidirectional, long-distance movement patterns we observed, some toads in our study moved relatively little throughout the tracking period (through fall and / or spring). For example, T11 and T57 (both females) moved 108 m and 314 m respectively from their point of capture to their hibernation sites in the fall, but neither showed any sign of moving towards a breeding site post emergence in late winter; these toads hibernated 3063 m and 1280 m respectively from Wake Lake (the closest known breeding site). This suggests that some individuals within this Duncan population, like other populations, may skip years between breeding cycles (e.g., most females breed every second year at a site in Nanaimo, H. Kimura, pers. comm.; BC Dulisse 2017; OR Olson 1988). Seven toads (6 of which were females) that gave no indication of their breeding site via fall or spring movement patterns hibernated on average 1438 m from the closest known breeding site compared to an average for all toads of 474 m. Given the relative importance of reproductively mature females to the ongoing persistence of a population, landscape management for Western Toads needs to take into account, and prioritize, the location and protection of hibernacula of all females.

Given the urban-rural landscape context of our study, the extensive migration distances of toads in the Duncan area inevitably result in toads encountering roads—ether crossing over roads or moving along them. Dead adults have been observed on the roads around Wake Lake during fall and late winter migrations for years (Wind and Willmott 2014). Wake Lake has roads on three sides so that even if a toad hibernates within 100 m of the lake it will have to cross a road prior to breeding. One of our study toads (T47) was struck and killed by a car shortly after being fitted with a transmitter in fall 2016. We estimated that all of the toads we tracked would have to cross at least one road in order to reach their breeding site in 2017. The level of risk associated with roads is also a factor for toads that do not make large, unidirectional movements. Western Toads have been found to use roads for movements more frequently than they would at random (Deguise and Richardson 2009). Like other wildlife, Western Toads are attracted to roads and roadside habitats, for their thermal properties, foraging opportunities, and as potential hibernation habitat—5 of our toads hibernated immediately adjacent to roads (e.g., within 10 m of the edge), one of which utilized the ditch / road bank itself as a hibernaculum. T56 was captured on a road and hibernated within 10 m of the roadside near its point of capture. The location of the hibernaculum along Barnjum Road, which leads directly to Wake Lake, could result in T56 taking advantage of the road as a travel corridor towards the breeding site. Effective habitat management for Western Toads includes avoiding the construction of new roads, especially where migration corridors exist and in and around breeding sites (i.e., within 1 km), taking measures to reduce traffic volume on roads in and around breeding sites (e.g., improved public transit), seasonal road closures (where possible; e.g., Riverbottom Road during the summer toadlet migration), identifying potential migration corridors that intersect with existing roads and installing suitable underpasses and directive fencing at those locations, and educating the local homeowners and drivers about toad movement patterns and road issues (e.g., the use of signs near migration corridors, discouraging night driving during migration periods).

Western Toads are considered to be a generalist species occurring in a mosaic of landscape types across their broad geographic range. They have been found to readily utilize clearcuts (BC; Deguise and Richardson 2009) or areas with no trees or seedlings (OR; Bull 2006), and recently burned areas (MO; Guscio et al. 2007) compared to forest stands. However, these patterns may be less applicable during hot, dry conditions (e.g., in summer) or in warmer climates (e.g., ID, UT, MO; Bartelt and Peterson 2000, Goates 2006, Schmetterling and Young 2008). Many of our toad hibernation sites were situated within forested edges, containing some overstorey tree cover and relatively large woody structures such as stumps and logs. Most toads utilized wood structures for hibernation, going below the surface and away from subzero temperatures. Tracking in the fall showed that toads frequent private properties near buildings, taking refuge under scrap wood, tires, garden stones, etc. at that time. However, despite the availability of those microsites within the landscape, none of the toads over the three-year study hibernated under, in, or near an urban structure such as a building or shed. This suggests that toads have either not adapted to taking advantage of these novel structures as potential hibernation sites, or these man-made features do not provide suitable conditions for hibernation (e.g., moderate temperatures in winter).

In the study area, land development poses a threat to the forest-edge ecosystems occupied by hibernating toads. Seventeen (61%) the toad hibernation sites within our study occurred on land that is being developed, is for sale, or has been surveyed for the development of new homes. Nine of 28 toads tracked in Year 1 and 2 hibernated within a relatively large parcel of private land previously used for timber harvesting (a clearcut), that is immediately west of the Wake Lake breeding site and is for sale for a housing development. The plans may include extending Barnjum Road through this development area as an alternate connector road into Duncan (versus Cowichan Lake Road). This would likely significantly increase the traffic along Barnjum Road, immediately adjacent to Wake Lake. The parcel of land contains a number of old logging roads and trails and small wetland habitats, and a mixture of young clearcut (10-15 years old) and remnant tree patches. It is unclear whether the toads were attracted to this parcel of land for hibernation because it offered suitable microsites (e.g., stumps) and / or if it was mainly due to its proximity to the main breeding site.

The majority of hibernating toads selected subsurface sites that were warmer than conditions at the surface for the majority of the hibernation period. Temperatures recorded at the toads were on average 5°C warmer than surface air temperatures, but we did not find any difference between the surface air temperature of the hibernacula versus our reference sites. Western Toads are considered freeze intolerant (die at -1.5 to -5.2°C), but the temperature at which tissue crystallization occurs depends on substrate moisture, with wetter conditions leading to freezing at higher temperatures (Swanson et al. 1996). The suggests that toads should select hibernation sites that are relatively dry, or they should be in contact with water that stays above freezing. We recorded subzero temperatures for some of the study toads at some point during hibernation (as low as -4.5°C) and temperature loggers inserted into hibernation and reference sites in central AB recorded subzero temperatures on average for 24 weeks during the hibernation period (Browne and Paszkowski 2010b). As with our study, the authors did not find a difference in temperature between hibernation and reference sites in AB, and they suggested that factors other than temperature influenced toad hibernation site selection (e.g., presence of tunnels, cavity moisture and size). The majority of our toad hibernacula were situated in what appeared to be relatively dry areas (i.e., no obvious standing or running water nearby); toads hibernated on average within 61 m of standing or flowing water. In contrast, many Western Toad hibernation sites in OR and WA were in and around water [e.g., 7 of 26 hibernacula in OR were within 1 m of water (Bull 2006) and all of the hibernation sites of toads in WA had water flowing through or adjacent to them (Palmeri Miles 2012)].

In addition to potential thermal properties, clearcuts offer an abundance of stumps and woody debris. The majority of the toads we tracked utilized wood structures such as stumps and large downed logs as hibernation sites. All of our toad hibernation sites contained at least one stump, they usually included at least one large stump (more than 50 cm diam.), and most contained large downed logs in an advanced state of decay compared to random sites. In addition to woody features, Western Toads in eastern BC and OR also used small mammal or rodent burrows, talus slopes or large rocks, and squirrel middens as hibernation sites (Dulisse 2017, Bull 2006). Differences in available terrain and the absence of certain types of mammal species (e.g., burrowing species) across study sites (e.g., mainland versus Vancouver Island) may lead toads in the Duncan area to primarily select for woody structures as hibernation sites, especially rotted stumps that provide access to subsurface microhabitats.

The hibernation site for T19 and T30 was the first confirmed evidence of communal hibernation by Western Toads in the study area, as well as re-use by toads across years. Communal hibernation has also been observed for Western Toads in WA (2 sites; Palmeri Miles 2012), AB (68% of sites; Browne and Paszowski 2010a&b), and CO (Jones and Goettl 1998). In AB, the authors hypothesized that a relatively high proportion of communal hibernation use combined with the distance from breeding sites (1+ km) suggested that suitable hibernacula were limited in the study area. In contrast, most hibernation sites located in the Cowichan Valley were less than 1 km away from known or suspected breeding sites and most did not appear to be communally used by toads, although we saw evidence of communal use between toads and other amphibian and mammal species. Multi species, cross taxonomic communal use of hibernacula has been observed elsewhere (e.g., Carpenter 1953).

5.0 CONCLUSIONS AND RECOMMENDATIONS

This study was the first to investigate Western Toad hibernation sites on the south coast of BC where development pressure and road density are relatively high, forest habitats are significantly fragmented, winters are mild, and where toad population declines are suspected (COSEWIC 2012). As such, information specific to toad populations in this area is critical for management and conservation purposes in order to avoid placing local populations at further risk.

From our study we have learned that:

- Western Toads travel extensively in the fall from summer foraging areas towards hibernation sites, and in later winter, towards breeding sites.
- During these migrations, Western Toads encounter roads.
- Road mortality of adult toads was observed throughout the study area in spring and fall.
- Toads are attracted to road and roadside habitats for thermal conditions, foraging, and as potential hibernation sites.
- Toads hibernate on average within 500 m of breeding sites.
- Wake Lake appears to be the main breeding site in the area
- Some toads skip breeding in some years (e.g., females). These toads may hibernate farther from breeding sites during these off-breeding years (average = 1400 m away).
- Many toads utilized forest edge habitats for hibernation.
- Most toads hibernated in /under stumps and large downed wood.
- Many toads utilized the area around the hibernation structure (e.g., within 25 m) prior to hibernation in the fall and / or post emergence in late winter for weeks to months. This time period represents a relatively large proportion of the toad's annual life cycle. The average maximum distance of toad re-location points away from the hibernation structure during this time could be used as a basis for recommended buffer widths to protect hibernation sites. Buffered hibernation sites would protect the hibernation structure itself, as well as other surrounding habitat features that may be important, such as holes and tunnels, downed wood, vegetative cover, and small water bodies and streams that are used during this time.
- The toad population in the area does not appear to be exposed to the chytrid fungus (*Batrachochytrium dendrobatidis*; Bd).
- There is a relatively large volunteer network interested in Western Toads in the study area, many private land owners in the area are supportive of the project, and local government is interested in using the information that we have collected in their land management practices and planning decisions.

Future work includes:

- *Habitat Selectivity Analyses* – Ongoing.
- *Threat Assessment* – Ongoing.
- *Manuscript Production* – We will be producing manuscripts for publication in peer-reviewed journals on topics such as Communal Hibernation Use, Habitat Selection for Hibernation, and Threats once analyses are completed.

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7.0 APPENDICES

Appendix 1 - Summary of results of Western Toad radio-telemetry studies from across the Pacific Northwest.

Study location	Objectives (e.g., translocated or tracked from br. site)	Home range	Maximum distance from br. site	Aver. distance from br. site	Hibernation / Overwintering	Other	Source
BC (LM)	Spring movements of males post breeding (translocated into clearcut and forest)					Toads released in forest oriented towards clearcut (from at least 150 m); more than 60% released in forest chose to enter clearcut; toads used roads for movements more frequently than random	Deguise and Richardson 2009
BC (VI)	Characterize habitat use and home range post breeding	Most had HR of about 0.1 ha; with occasional long-distance movements (1 to several km)				Toads moved between forest and clearcut did not seem to avoid CC Relocated toads homed from up to 1 km away 2 toads at Spider Lake – one moved 400 m to a marsh (radio was removed) the other toad signal was lost and the radio was found 1.3 km away	Davis and Gregory 2000
AB	Habitat use and distance moved post breeding (to overwintering)				Distance from br site: range = 146–1936 m; 68% of overwintering sites were communal; for the 3 study sites - all hibernacula were within vegetated buffers at one site, but beyond buffer at remaining two sites		Browne and Paszkowski 2010a&b
WA	Movement patterns and overwintering	2 to 4300 m^2			Breeding site to hibernacula = 320 m, 600 m, 1000 m Summer range to hibernacula = range: 74-2139 m	Water was observed to be flowing through or adjacent to 7 hibernacula; 2 sites were communal	Palmeri Miles 2012
OR	Habitat use and distance moved post breeding (to overwintering)		F = 6230 m	F = 2543 m M = 997 m	Mean distance from br. site = 1968 m (range 180-6230 m); rodent burrows; large rocks, logs or root wads; banks adjacent to streams or lakes (7 of 26 were within 1 m of water); no communal hibernation obs.	23 of 27 F travelled > 1600 m from br. site, while only 8 of 28 M moved > 1000 m; it took toads 16-83 days to reach summer range; no toads returned to br. site in summer Areas with no trees or seedlings were used more than older stands; saw some movement after snow on ground	Bull 2006
ID	Habitat / riparian use post breeding		2500 m (significantly linear)		Underground cavities adjacent to intermittent streams; under slash pile in old clearcut	Data suggest that toads may have avoided macro habitats with little to no cover (e.g., clearcut)	Bartelt and Peterson 1994

Study location	Objectives (e.g., translocated or tracked from br. site)	Home range	Maximum distance from br. site	Aver. distance from br. site	Hibernation / Overwintering	Other	Source
UT	Habitat use post breeding in relation to buffer widths	Median = 17,435 m^2 Range: F = 1180-350,510 m^2 M = 380-172,120 m^2				Toads stayed relatively close to water (most stayed within 35 m of water); larger toads moved farther from water	Goates 2006
MO	Use of streams for movement and distances travelled		Straight line distance between 1st and last location Max = 7400 m (24 d) Min = 30 m (12 d) Aver = 2000 m	Sum of straight line distances Max = 1200 m (23 d) Min = 30 m (12 d) Aver = 4400 m		More captures and movements on days with rain; suspect toads use streams as movement corridors (this habitat may be under sampled) Suggest movements for a multi-year breeding species may need to look at more than 1 year to understand the full picture	Schmetterling and Young 2008
MO	Habitat use post wildfire					Toads used severely burned habitats more, and partially burned habitats less, than expected (this shifted later in summer). No toads were relocated in unburned habitat (which was rare in the study area).	Guscio et al. 2007
CO	Habitat / riparian use post breeding	Mean HR 4x larger for F vs. M (F=246,000 m2; M=58,300 m2)	Mean max: F = 905 m; M = 462 m Mean min: F = 392 m; M = 131 m	F = 721 m M = 218 m			Muths 2003

Appendix 2. Landscape-, Ecosystem-, and Microsite-scale variables collected for habitat analyses.

Landscape-scale variables:

Land Cover Habitat Type	Habitat Sub-type	Description	Measurement	GIS data / measures
Terrestrial Habitat	**Closed vegetation**	Forested	% of plot area	TEM structural stages 4-7
	Open, tall vegetation	Shrub dominated (e.g., young clearcuts, right of ways)		TEM structural stage 3
	Open, short vegetation	Herb / forb dominated (e.g., lawns, cultivated fields)		TEM structural stage 2
	Little to no vegetation	Sparse vegetation or bare ground (e.g., built)		TEM structural stage 1
Aquatic Habitat	**Open water wetland / lake**	> 50% open water	% of plot area	BC Freshwater Atlas; digitized from Google Earth imagery
	Closed wetland	< 50% open water		
	River / stream	Mapped rivers and streams	% of plot area, linear length (m), and density (m/km^2)	BC Freshwater Atlas
Roads	**Non-public**	Includes logging roads, driveways, and ATV trails (limited access / traffic)	% of plot area, linear length (m), and density (m/km^2)	Digitized from Google Earth imagery
	Public	Paved or unpaved public road (regular traffic)		Digital Road Atlas (width based on land cover feature class)
Edge Habitat	**All habitat types listed above** (terrestrial, aquatic, roads)	20-m buffer along boundary between habitat cover sub-types (polygons) listed above	% of plot area	Calculated in ArcGIS (buffers calculated from the land cover classes listed above)

Ecosystem-scale Variables:

Variable Type	Variable	Description / Measurement
Site Variables	Elevation	Recorded in metres at centre of plot using GIS KIT (Apple ipad) and then derived from map layer in Arc
	Slope	Dominant percent slope of plot at centre of plot using clinometer
	Aspect	Dominant aspect of plot recorded in degrees at centre of plot using GIS KIT (Apple ipad)
	Moisture regime	Dominant moisture of the site based on the edatopic grid (Green and Klinka 1994)
Structural Vegetation Variables	Canopy closure	Taken at centre using CanopyApp (Apple ipad, Version 1.0.2) and recorded at waist height (approx. 1 m above ground level)
	% Deciduous tree cover	% cover (drip line) of live deciduous tree species (> 10 m tall)
	% Coniferous tree cover	% cover (drip line) of live coniferous tree species (> 10 m tall)
	Number of Live Trees	Live tree density / stems per hectare – number of trees > 10 m tall within the plot (more than 50% of stem is within the plot)
	Dominant Tree Species	Dominant tree species > 10 m tall within the plot (most numerous)
	Live Tree Diameter	Average dbh of up to 5 randomly selected trees within the plot (recorded at 1.3 m above high point on ground at base of tree)
	Number of Stumps	Number of dead trees < 1.3 m tall within the plot
	Stump Diameter	Average diameter of up to 5 randomly selected stumps (< 1.3 m tall) within the plot (measured from root collar – start of flare)
	Number of Snags	Number of dead trees > 1.3 m tall within the plot
	Number of Large Downed Logs	Number of large downed logs > 20 cm diameter (at any point within the plot) and in contact with the ground
Number of potential hibernation features	# of Debris piles	Number within the plot (> 50% in the plot)
	# of Root wads	Number within the plot (> 50 % in the plot)
	# of Mounds (organic versus mineral / manmade)	Number of mounds (organic and mineral / manmade) counted along 20 m line intercept (plot diameter); mounds are elevated from the dominant ground level by at least 20 cm; organic mounds were distinguished from mineral by soil type (consistency and colour)
Proportion of Plot in Habitat Type and Sub-type	% Road	Non public road (e.g., logging road, trail, driveway)
		Public road (e.g., paved or unpaved public road)
	% Little to no vegetation	e.g., buildings
	% Edge habitat	20-m buffer along boundary between 9 habitat sub-types listed under Landscape above; visually estimated how much of the plot was comprised of edge habitat
Proximity to different habitat sub-types	9 habitat sub-types listed under Landscape scale above	Measured from the centre of the plot for those habitat sub-types occurring within 20 m; beyond 20 m, distances to habitat sub-types were estimated using ArcGis and Google Earth imagery

Microsite-scale Variables:

Variable	Assessment Area	Description / Measurement
Shrub cover	5.64-m radius circular plot (100 m^2)	Percent cover (drip line) - 2 to 10 m tall (B1 layer, Province of British Columbia 2010) - deciduous and coniferous tree species and shrub species kept separate
		< 2 m tall (B2 layer, Province of British Columbia 2010) – deciduous and coniferous tree seedlings and shrub species combined
Ground cover	5.64-m radius circular plot (100 m^2)	Percent cover - Litter / debris (sticks, dead foliage)
		Percent cover - Bare /exposed ground
Leaf Litter Depth	Measured at the hibernation site and random points	Depth (cm) to mineral soil.
Microsite aspect	Measured at hibernation site and random points	Degrees; this may differ from the dominant aspect of the ecosystem plot
Moisture class	Classified at hibernation site and random points	xeric (dry), mesic (moist), sub-hygric (wet just below surface), hygric (surface water)
Size of hibernaculum (m^2)	Measured at hibernation site and random points	The size of the structure itself (e.g., diameter and height of feature) - If a random location landed on / included a structure (see below), the size was also recorded and it was characterized by type.
Type of hibernation structure	Classified at hibernation site and random points	Categories included – live and dead tree root/base, root wad, stump, large downed log, woody debris pile, mineral or organic mound (elevated from the dominant ground level by at least 20 cm), no discernible type of structure within a 1 m of the plot centre
Microclimate	Monitored at hibernation site and random points	Ambient air temperature (°C) & relative humidity (%) were measured at ground level and 1 m above ground every hour from immediately upon hibernation to emergence.

Appendix 3. Toad project information signs and fliers were distributed throughout the study area.

Western Toads on Your Land?

WHY?

Western Toads are listed as *Special Concern* provincially and federally. Populations have declined drastically in some areas, and numbers are relatively low on Vancouver Island. Researchers and volunteers in the Cowichan Valley are currently conducting a study of Western Toad habitat use to identify hibernation locations and habitat characteristics.

Amphibian populations have declined in many parts of the world. Frogs, toads, and salamanders are sensitive to climatic conditions and pollution, and populations act like a 'canary in a coalmine' reflecting the state of our environment. Amphibians are a food source for many animals, such as birds, reptiles, and mammals, and they eat millions of bugs each year.

Western Toads lay their eggs in water, but spend the majority of the year on land. Understanding what toads need for hibernation (i.e., the places where they sleep through the winter) is important for future protection of the species. Hibernation sites may be more than 1 km away from wetland breeding sites.

WHAT?

Adult Western Toads can be large (up to 12 cm / 4.5 inches long), light to dark brown or olive coloured, and they often have a stripe running down the middle of their back. They have wart-like bumps on their skin. Baby toadlets (about the size of your thumbnail) disperse away from wetlands in mid summer, often in very large numbers (by the thousands).

HOW?

We will be searching for adult toads in the Duncan area this fall and fitting them with small, temporary, external radio transmitters in order to track them to hibernation sites. Toads hibernate on land, in holes and crevices, away from the threat of winter frosts.

Project support provided by the: Habitat Conservation Trust Fund, Ministry of Forests, Lands and Natural Resource Operations, and the Ministry of Transportation and Infrastructure.

WHEN?

Starting in mid September and running through February, crews of two to three people wearing high visibility safety vests will be driving and walking through the local neighbourhood tracking toads. We would appreciate your support and cooperation as our crews follow toads through the landscape.

If you have any questions or concerns, or
***if you see an adult toad*,**
please email:

duncantoads@gmail.com