MICROHABITAT SELECTION OF THE WESTERN SKINK (*PLESTIODON SKILTONIANUS*) IN THE OKANAGAN REGION OF BRITISH COLUMBIA

by

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Abstract

Understanding microhabitat features is an important aspect of managing for the persistence of reptile species. The Western skink (*Plestiodon skiltonianus*, formerly *Eumeces skiltonianus*) is an at-risk lizard species in B.C. Very little information on the habitat requirements of this species is known, which hinders federal and provincial management planning efforts. Microhabitat variables were measured at a study site in Vaseux-Bighorn National Wildlife Area, and microsites used by skinks were compared to randomly located microsites within the individual's home range. Principle Components Analysis and paired Logistic Regression models showed that the best microhabitat predictors for skink presence were thickness of rocks and percentage of rock cover within a 1m area of the sighting location. Thermal profile analysis indicated *P. skiltonianus* used rocks that maintained a cooler daily maximum temperature. Future research should focus on further describing habitat selection at several spatial scales and clarifying the distribution of the species in B.C.

Keywords: *Plestiodon skiltonianus*; Western skink; species at risk; microhabitat selection; thermal profile

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First and foremost, this project is dedicated to the Western skink, the species that has fascinated and inspired me throughout this entire process. I have dedicated the past three years of my life to finding you, measuring you, and writing about you. My only wish is that you continue to persist in this country long after I have disappeared.

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Finally, I thank my family and friends. Thank you to my mom Kathy and my sister Charlotte for letting go and being supportive of me moving across the country to pursue my dream of a master's degree on the west coast. You can finally stop asking when my thesis will be finished. Thank you to my entire cohort of REM friends for the wonderful times we have shared during our journey to complete our degree: let's change the world.

"In wildness is the preservation of the world"

– Henry David Thoreau

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GLOSSARY

B.C.	British Columbia
BEC	Biogeoclimatic Ecosystem Classification
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWS	Canadian Wildlife Service
GPS	Global Positioning System
HSM	Habitat Suitability Model
MOE	Ministry of the Environment
NCC	Nature Conservancy of Canada
NWA	National Wildlife Area
PCA	Principle Components Analysis
PIT	Passive Integrated Transponder
RISC	Resources Inventory Standards Committee
SARA	Species At Risk Act
SEI	Sensitive Ecosystems Inventory
SVL	Snout-vent length
TEM	Terrestrial Ecosystem Mapping
TLC	The Land Conservancy
TNT	The Nature Trust
VIE	Visible Implant Elastometer

1: Introduction

The globally increasing number of species classified as being endangered has prompted the creation of policies for protecting those species thought to be most at risk of extinction (Abbitt et al. 2000; Baumgartner 2004). Species protection and recovery is costly (Kerkvliet and Langpap 2007), and limited resources for species protection and conservation have forced scientists, conservationists and governments to identify and prioritize species at risk (Stem et al. 2005; Zhou and Jiang 2005; Gregory et al. 2012). In Canada, species are prioritized and afforded protection at the federal level of government and some provinces have developed complementary provincial protection for species. According to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an organization of experts that assesses the risk status of wildlife species in Canada and makes a recommendation to the federal government for legal listing of species, 15 species of wildlife in Canada have been documented as extinct, and another 635 species are designated as at risk (COSEWIC 2011; COSEWIC 2012).

Globally, amphibians and reptiles represent the highest risk status of terrestrial vertebrates, with more species listed as at risk than both mammals and birds (Gardner et al. 2007; IUCN 2012). Eighty five percent (41 of 48) of Canada's reptile species are classified as Species At Risk by COSEWIC (2012). The majority of published, peer-reviewed literature on habitat fragmentation and biodiversity loss focuses on mammals and birds, yet reptiles represent an important taxonomic group that can be indicative of regional biodiversity (Berry et al. 2005). Lizards are the most diverse group of all reptiles (Russell and Bauer 1993). Canada is home to five extant species of lizard: a sixth species, the Pygmy short-horned lizard (*Phrynosoma douglasii)* is extirpated (COSEWIC 2011). All five extant species are designated as at risk COSEWIC, and four of these five species have been legally listed under the federal *Species at Risk Act* (*SARA*) (Table 1).

Table 1. Risk status of all Canadian lizard species.

Scientific Name	Common Name	Province	SARA status
Elgaria coerulea	Northern Alligator lizard	British Columbia	Not at risk
Plestiodon fasciatus	Five-lined Skink	Ontario	Endangered
Plestiodon septentrionalis	Prairie Skink	Manitoba	Endangered
Plestiodon skiltonianus	Western Skink	British Columbia	Special Concern
Phrynosoma douglasii	Pygmy Short-horned lizard	British Columbia	Extirpated
Phrynosoma hernandesi	Greater short-horned lizard	Alberta Saskatchewan	Endangered

For every extant species of lizard in Canada, the most significant identified threat is habitat loss (Seburn and Seburn 2000; Quirt et al. 2006; Venter et al. 2006). Most lizard species in Canada are limited to the extreme southern portion of the country; therefore their habitat overlaps with the most densely populated and heavily developed areas (Seburn and Seburn 2000). The percentage of species at risk in a specific area shows an increasing trend as the level of human presence and activity increases (McKinney 2002). This correlation occurs because the areas of land which are most suitable for human development are often the same areas that support a high degree of species richness (Lugo 2002).

In British Columbia (B.C.), the interior Thompson-Okanagan region supports one of the highest proportions of nationally, provincially and even globally rare species and ecosystems (Ovaska et al. 2004). This includes the Western skink (*Plestiodon skiltonianus*), one of only two extant lizards native to B.C., the other species being the Northern alligator lizard (*Elgaria coerulea*) (COSEWIC 2002). The Thompson-Okanagan region has the highest rate of rural and urban development in the province (Statistics

Canada 2003). Despite the overlap between diversity and development in the B.C. interior, reptile habitat is not currently afforded any legal protection on private lands, which is where the majority of species occur (Ovaska et al. 2004; BC Ministry of Environment 2011).

In April 2002, *P. skiltonianus* was listed as a species of Special Concern under Schedule 1 of *SARA* (COSEWIC 2002). *P. skiltonianus* is also on the provincial blue list of species at risk in B.C. (BC Ministry of Environment 2007). Under SARA, a Management Plan is required within three years of listing for any species listed as Special Concern. A Management Plan is a document that sets goals and objectives for maintaining sustainable population levels of species that are particularly sensitive to environmental factors, and recommends approaches for the species' conservation (Province of British Columbia 2011). The Management Plan for *P. skiltonianus* is currently being finalized, in accordance with the species being assessed as Special Concern in 2002 by COSEWIC and listed as Special Concern under *SARA* in 2003. In order for the Management Plan to be an effective conservation tool, the most current biological information on the life history and ecological requirements of the species needs to be synthesized and incorporated into the document. The most critical information required for the conservation of the majority of species at risk is detailed knowledge of habitat requirements for different life stages of the species, especially since habitat loss and degradation is the greatest threat (Venter et al. 2006). I therefore studied the habitat selection of *P. skiltonianus* to provide a critical component towards determining the conservation needs and priorities for this species.

1.1 Habitat Selection

Habitat selection is described as the series of decisions an organism makes that leads to its choice to settle in one location over another (George and Zack 2001). Certain habitat types are selected because they provide the microhabitat features which allow the species to meet its biological and physiological requirements (Huey 1991). Habitat selection is one of the most poorly understood ecological processes (Krebs 2001) due to the complex variety of factors that can influence it (Fortin et al. 2008). Despite the lack of solid scientific understanding, habitat selection is a central theme in the fields of ecology and conservation biology (Quirt et al. 2006). Microhabitat selection refers to the choosing of certain sites that are used for activities such as reproduction, basking, nesting, predator avoidance, or other biological needs (George and Zack 2001).

The suitability of a particular habitat is influenced by numerous variables operating at different spatial and temporal scales. Habitat suitability also changes over time in response to both natural and anthropogenic influences (George and Zack 2001). Studies designed to describe habitat use and selection are important contributions towards understanding both the biological requirements of animals and the strategies they use to meet these requirements (Guido and Gainelle 2001; Manly et al. 2002). In order for designated authorities to make informed decisions regarding the management of SAR, effective communication and presentation of the results of habitat selection research is essential (Scott et al. 2002; Guisan and Thuiller 2005; Haan et al. 2007).

Microhabitat features are particularly critical for ectothermic species such as reptiles. Ectotherms use microhabitat features to regulate their body temperature relative to ambient temperatures (Avery 1982; Grover 1996), and the decline of several

species of lizard has been linked to a decline in the availability of key microhabitat features (Howes and Lougheed 2004). For lizard species in particular, thermoregulation through microhabitat features is important at higher latitudes within the species' range (Rosen 1991; Shine and Mason 2004). The northern limit of *P. skiltonianus'* global range occurs in southern B.C. Part of the explanation for this range limit is that relative to more abundant populations of *P. skiltonianus* in the southern United States, the populations in Canada have a shorter seasonal thermal window of activity and therefore must search for suitable hibernation sites earlier in the fall season (Powell and Russell 2007). The availability of suitable retreat sites for hibernation and other life history requirements may limit the distribution and abundance of reptile populations at northern range limits (Gregory 1982; Rutherford and Gregory 2003).

Knowledge of specific physical microhabitat characteristics such as thermal profiles and dimensions of cover objects are lacking for *P. skiltonianus* (COSEWIC 2002). A study on *P. skiltonianus* near Creston, B.C. indicated that some retreat sites appeared to be more important than others, but further study is required to determine whether skinks select rocks nonrandomly at a microhabitat scale (Rutherford and Gregory 2003).

Estimating population abundance of *P. skiltonianus* presents an extremely difficult challenge because skinks are a cryptic species (COSEWIC 2002). This secretive nature makes the study of their behaviours and population dynamics very difficult under natural conditions, i.e. through field programs (Fitch and von Achen 1977). The complete lack of population size and density estimates for *P. skiltonianus* in B.C. reflects this challenge (COSEWIC 2002). There is also a limited understanding of what natural factors and anthropogenic threats limit the distribution of lizard species in Canada (Powell and Russell 2007). The 2002 COSEWIC species assessment for *P. skiltonianus*

identified several key factors which threaten Canadian populations: habitat and microhabitat alteration, illegal collecting for the pet trade, depredation by raccoons and road mortality. Genetic drift from a lack of metapopulations could also be a limiting factor. A metapopulation is a collection of partially breeding habitat patches connected by occasionally dispersing individuals and therefore each patch exists with a significant probability of extinction (Smith and Green 2005). Genetic drift acts strongly in small, fragmented populations to influence the fixation and loss of alleles, which reduces genetic diversity and makes it less likely that a population can adapt to changing conditions (Willi et al. 2006). Without new genes from outside populations, it is possible that the Canadian populations of *P. skiltonianus* will be threatened by genetic drift more than if there were connections between these populations and other populations from the United States.

1.3 Distribution and Habitat

Information on a species distribution is valuable to local governments and private landowners for land-use planning, and helps inform provincial and federal management objectives for the species (Bryn White, pers. comm., Orville Dyer, pers. comm., Courtney Albert, pers. comm.). *P. skiltonianus* is known to live in a variety of habitat types throughout their geographic range, including desert canyons, open woodlands, grasslands, forests and warm dry hillsides of up to 2100m in elevation (Nussbaum et al. 1983). In south-central B.C. the range of the Western skink coincides with the Bunchgrass, Ponderosa Pine, Interior Douglas Fir, Interior Cedar-Hemlock, and Engelmann Spruce-Subalpine Fir Biogeoclimatic Zones (Meidinger and Pojar 1991; COSEWIC 2002). The species appears to be confined to areas of warm, dry, open, sparsely treed habitat with loose soils and abundant cover objects (usually rocks lying

on the substrate) (Dulisse 2004). Cover objects are preferred if they are flat (shale-like) and embedded in the ground on at least one side (Hallock and McAllister 2005; Mike Sarell, pers. comm.).

In the southern Okanagan region of B.C., skinks inhabit rock (primarily gneiss) outcrops, but they can also be found in lacustrine escarpments and along creek banks (Mike Sarell, pers. comm.). They are also frequently associated with talus slopes (Herrington 1988; Maki Sarell, pers. comm.). Southern aspects and associated warmer temperatures are important macrohabitat features at the northern limit of the species range, as relatively short summers limit the amount of time available for embryonic development and juvenile growth (COSEWIC 2002). Western skinks are known to co-occur with other reptile species in B.C., such as the Northern alligator lizard (*Elgaria coerulea*), the Rubber boa (*Charina bottae*), the Northwestern garter snake (*Thamnophis spp.),* the Western yellow-bellied Racer (*Coluber constrictor mormon*), the Desert nightsnake (*Hypsiglena chlorophaea*) and the Western rattlesnake (*Crotalus oreganus*) (Rutherford and Gregory 2003; Dulisse 2004; Mike Sarell, pers. comm.).

Western skinks are a key prey item for the Desert nightsnake (Weaver 2010), which is listed as Endangered on Schedule 1 of SARA and is red-listed in BC (COSEWIC 2011). Western skinks likely play a key role in the food chain of the ecosystems where the species occurs in the Okanagan, and adverse impacts to populations of Western skinks in BC could have adverse impacts on the fitness of their specialized predators.

1.4 Species Description

P. skiltonianus is a mid-sized lizard (up to 83mm in snout-vent length) with smooth shiny scales, a thick neck, small head and short legs that are characteristic of

skink species (Gregory and Campbell 1984, Tanner 1988). Skinks have a wide brown stripe down the length of their back, and two more longitudinal brown stripes are separated by light cream coloured stripes that extend down the dorsal surface to the base of the tail (Figure 1). The tail is the most distinctive physical feature of *P. skiltonianus*. It is a bright cobalt blue colour in young juveniles and fades slightly in colour to grey or brown as the individual ages. Aside from a faded tail colour, adult skinks have a similar colouration pattern to that of juveniles (Stebbins 1985). Males and females do not exhibit strong sexual dimorphism and are similar in appearance (Rodgers and Fitch 1947), but some males develop a reddish-orange colouration under the neck and chin during the breeding season.

Figure 1. Juvenile Western skink (Photo Credit: E. Vincer, 2010).

Gravid females may be distinguished by a slightly fatter abdomen prior to laying eggs in the late summer. Individuals reach sexual maturity at two years of age, but only actively breed between the ages of three to six years (Rodgers and Fitch 1947). The gender of skinks was determined in the field by the presence of orange colouration under the chin (males). We attempted to determine the age-class of individuals (juvenile or adult) by size and colouration. We classified small individuals with bright blue tails as juveniles and larger individuals with blue or faded tails were classified as adults.

Mating occurs during the spring months of May and June and females lay their eggs in late June and July. Females lay approximately 2-6 eggs per clutch (Stebbins 1985) and lay one clutch per year (Gregory and Campbell 1984). Females create a burrow under cover objects and provide protection from predators by remaining with the eggs until they hatch (Noble and Mason 1933). The eggs hatch in August to early

September. The hatchlings, juveniles and adults all overwinter in hibernacula located in bedrock outcrops, possibly communally with other species of reptiles such as the Western Rattlesnake (*Crotalus oreganus*) (Columbia NWR Files 1989). Skinks emerge from hibernation in the early spring months, usually April and May, depending on the weather conditions of the given year.

1.5 Study Objectives

There is only one published scientific journal article on the habitat selection of *P. skiltonianus* in B.C. (Rutherford and Gregory 2003). In order to contribute to our quantitative understanding of the habitat requirements of this species and to provide information to decision makers and inform conservation actions, I collected field data on the microhabitat of *P. skiltonianus.* My main priority was to focus search effort in areas of *a priori* high habitat suitability in order to increase the likelihood of sightings. This facilitated the highest probability of collecting abundant information on microhabitat selection during the active breeding season, but prior to the nesting season when females are generally more difficult to locate.

The objectives of my study were to:

1. Quantify differences in occupied and occupied microhabitat in order to detect habitat selection by *P. skiltonianus*;
2. Determine whether occupied cover objects have significantly different thermal profiles than unoccupied sites.
3. Clarify the distribution of *P. skiltonianus* in the study area by searching areas where no sightings of skinks have been reported.

2: Materials and Methods

2.1 Study Site Description

The field component of this study was conducted during one field season, between April 19 and June 30, 2010 along the east side of Vaseux Lake (49° 17' N, 119° 33'W) approximately 10km north of the town of Oliver on the east side of Vaseux Lake in the Okanagan region of B.C., Canada (Figure 2). Fieldwork was conducted primarily in the Vaseux-Bighorn National Wildlife Area (NWA) where *P. skiltonianus* has previously been sighted by both professional biologists and members of the public (British Columbia Conservation Data Centre 2012).
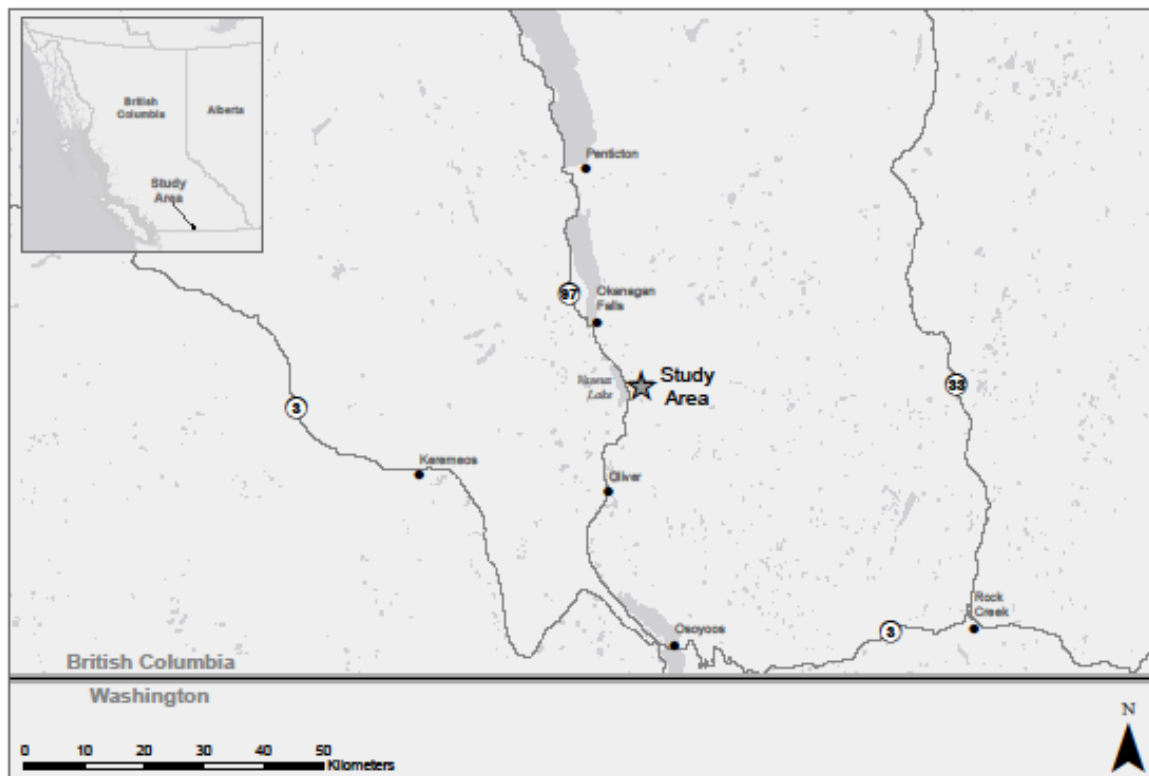
Figure 2. Map showing the general location of the study area in the Okanagan region of British Columbia.

Vaseux-Bighorn NWA consists of a number of different parcels of federal and provincial conservation land. The terrestrial portion of the Vaseux-Bighorn NWA is comprised of three large discontinuous parcels of grasslands and rock outcrops (Environment Canada 2010; Williams et al. 2012). NWAs are created by the federal government for the purposes of wildlife research, conservation and interpretation (Environment Canada 2010). The Vaseux-Bighorn NWA was established in 1979 and is managed by the Canadian Wildlife Service (CWS) primarily to maintain habitat for native species with a focus and priority on species-at-risk. Other parcels dedicated to conservation in this area and which are part of the study site are managed by not-for-profit organizations: The Land Conservancy (TLC) of British Columbia, The Nature Trust of British Columbia (TNT) and the Nature Conservancy of Canada (NCC).

According to the provincial Biogeoclimatic Ecosystem Classification (BEC) system (Meidinger and Pojar 1991), the study site is located within the Bunchgrass (BGxh1) Interior Douglas Fir (IDF) and Ponderosa Pine (PPxh1a) biogeoclimatic zones (Ministry of Forests 2008) and the area is very dry, warm and sparsely treed. These zones typically have very low precipitation (250-450mm per year) and a very long growing season (BC Ministry of Forests 1988).

2.2 Habitat Suitability Model

Habitat suitability models (HSMs) produce landscape-level maps of the distribution of suitable habitat for a species and have been widely employed as a planning tool for field studies (Cianfrani et al. 2010). HSMs arise from an opinion-based modeling process where experts familiar with the habitat requirements of a species assign habitat suitability ratings to mapped ecological units to produce a landscape-level map (RISC 1998).

Habitat suitability was determined by creating a Habitat Suitability Model (HSM) based on Terrestrial Ecosystem Mapping (TEM) and on the expert opinion of Mike Sarell, a biologist familiar with the habitat needs of the species in the Okanagan region. TEM is a provincial mapping standard for classifying the landscape into different polygons that are as similar as possible according to climate, terrain, soils and vegetation communities (Runyan et al. 2008). Existing TEM polygons were used to assign a habitat suitability rating for *P. skiltonianus* to each polygon in the study area.

A four-class rating scheme was used to rate the habitat of *P. skiltonianus*. This scheme is used for species with a moderate knowledge of habitat use and classifies habitat as high, moderate, low or nil (RISC 1998). The criteria used to stratify TEM polygons into suitable habitat polygons are outlined in Table 2.

Table 2. Criteria used to create the habitat suitability model for *P. skiltonianus* in the study area.

Ecotype	Modifiers	Habitat Suitability Rating
Cliff	Warm aspect Cool aspect	Moderate Low
Rugged rock outcrops and talus	Warm aspect or ridge Cool aspect or gentle slope	**High** Low
Low relief, unfractured rock outcrops	N/A	Low
Grassland/ shrub-steppe/dry, open forest – shallow soils	Warm aspect Warm aspect or ridge Cool aspect or gentle slope	**High** Moderate Low
Grassland/ shrub-steppe/dry, open forest – very shallow soils	Warm aspect Cool aspect or gentle slope	**High** Low
Cutbank or exposed soil (including silt cliffs)	Warm aspect	Low
All others (residential/industrial, etc.)	N/A	Nil

I used the HSM to select 35 different TEM polygons in which to search for skinks. My priority was to focus search effort in the high habitat suitability polygons in order to increase the likelihood of sightings; this facilitated the highest probability of collecting abundant information on habitat selection during the active breeding season. My next priority was to search polygons with no previous reported sightings of *P. skiltonianus* in order to further clarify the species' distribution in the Vaseux-Bighorn NWA. In order to ground-truth the HSM for *P. skiltonianus*, I hypothesized that if the HSM was accurate I would document more sightings in the high suitability polygons than in the moderate and low suitability habitat polygons.

2.3 Field Surveys

The most simple and efficient way to determine the presence of a reptile species in an area is to conduct a systematic survey of microhabitats where the species is likely to be present, during the season of highest activity and when the weather conditions are warm and favourable (Konze and McLaren 1997; Resources Inventory Committee (RIC) 1998; Blomberg and Shine 2006). I conducted field surveys in May and June 2010 with a field assistant, following methods outlined in the British Columbia Inventory Methods for Snakes standards document for determining presence of reptiles in a study area (RIC 1998). We limited all of our surveys to sunny or slightly overcast days with no rain in order to minimize the effects of weather on survey results (Goode et al. 2005; Blomberg and Shine 2006; Du et al. 2006). Skinks are most easily captured in the morning hours of the day when their body temperature is relatively cool (Konze and McLaren 1997). We conducted surveys between the hours of 0800 h and 1600 h, which is the most optimal daily activity period for reptiles to meet their thermal physiological requirements (Heyer et al. 1994; Howes and Lougheed 2004; Goode et al. 2005). Most surveys ended around 1300 h, because the number of skinks sighted after this time

declined to zero on most days. Lizards tend to return to deeper refuge sites to avoid the midday heat (Goode et al. 2005) and detection of *P. skiltonianus* after midday on hot days appears to be compromised compared to morning hours. All field sampling was completed prior to the nesting season which should minimize bias from seasonal, age and sex-specific microhabitat selection (Howes and Lougheed 2004).

We systematically and thoroughly searched each TEM polygon for a total of five hours per polygon per survey day. We searched polygons for skinks by flipping over potential cover rocks that were small enough to be physically lifted by one person (Howes and Lougheed, 2004; Quirt et al. 2006). We recorded the number of rocks that were overturned in each polygon before a skink was found. No polygons were visited more than once per week in order to minimize impacts on microhabitat and reduce disturbance to the skinks (Larkin 2011).

When a skink was sighted, we attempted to hand capture the individual to take body measurements. When possible, we measured snout-vent length (SVL) and total length including the tail. We made a visual determination as to whether it was a juvenile or adult, and classified gender based on the presence of an orange chin during the breeding season. This method was not used to segregate observations into gender classes for statistical analysis, because gender cannot be reliably determined for this species in the field (Germaine and Germaine 2003) without using probing techniques (Rutherford and Gregory 2003). All overturned cover objects were returned to their original position to maintain important microhabitat properties (Pike et al. 2010) and captured individuals were released immediately following microhabitat sampling at the site of capture. *P. skiltonianus* were captured in Vaseux-Bighorn NWA under permission of the permit SARA-PYR-2010-0127.

2.4 Structural Habitat Measurements

We measured structural habitat variables (Table 3) at each capture site of *P. skiltonianus* (Howes and Lougheed 2004; Quirt et al. 2006; Rutherford and Gregory 2003). As a control method, for every measurement at an occupied site we also measured the same habitat variables for a nearby cover object that was not being used by a skink at that time. Any cover objects with no skink observations were potential unoccupied sites, although these sites may have been used, the use was undetected (Block and Morrison 1998). The absence of a *P. skiltonianus* from a site, even after extensive searches on multiple visits, may not necessarily indicate that the species is absent from that location. Since skinks are cryptic and secretive, it is challenging to find them even in the most favourable weather conditions (Block and Morrison 1998). However, when microhabitats are searched during favourable weather conditions and surveys are repeated at least once in a season, the cumulative absence of a species in a given area presents more compelling evidence that the species is in fact absent from that area (RISC 1998).

We measured aspect, percent slope, ground cover and substrate type at the centre of the capture site: for occupied sites, the centre was where the individual was first observed (Larkin 2011). We measured dimensions of the cover element (maximum length $\times$ width $\times$ thickness) to the nearest centimetre. We used a hand-held Garmin GPS unit to record elevation to the nearest metre. We classified the substrate type directly under the cover object as rock, broken rock, bare soil or vegetation (see Figure 2 for examples). We measured slope in degrees with a clinometer, and we used a compass to measure aspect (Block and Morrison 1998). We estimated visually ground cover within a 1m radius around the point of observation to the nearest five percent and

classified ground cover as rock, vegetation or soil (Germaine and Germaine 2003;

Garden et al. 2007).

Table 3. Structural habitat variables measured for occupied and unoccupied cover objects during field surveys for *P. skiltonianus*.

Variable	Description
Elevation	Elevation (m) of location above mean sea level
Length	Length of cover object (cm)
Width	Width of cover object (cm)
Thickness	Thickness of cover object (cm)
Depth	Depth the cover object is embedded in substrate (cm)
Aspect	Slope aspect (degrees) of ground surface under cover object
Slope	Slope angle (degrees) of ground surface under cover object
Substrate	Percentage (%) of substrate that is (a) bare soil (b) broken rock (c) vegetation or (d) unbroken rock
Cover	Coverage (%) of ground cover within 1m radius that is (a) rock (b) vegetation or (c) soil

Defining cover objects as occupied or unoccupied was necessary to meet requirements for statistical analysis. Control, or unoccupied, cover objects were chosen at a random direction and distance between one and five metres from the occupied cover object. The five metre distance limit from the occupied site was chosen based on mark-recapture and radiotelemetry data on skinks from Kansas (Fitch and von Achen 1977) and near Creston, B.C. (Rutherford and Gregory 2003). The average daily movement for skinks in Kansas was approximately 5m, while individuals of *P. skiltonianus* in southern B.C. were recaptured within 10m of a previous capture location. The direction of the control rock relative to the occupied site was randomly chosen by the observer facing north and looking at the second hand of a watch (Howes and Lougheed 2004).

2.5 Thermal Profiles

Information on the thermal biology of *P. skiltonianus* is lacking (Rutherford and Gregory 2003); although many field and laboratory studies have indicated that retreat sites used by lizards have distinct thermal characteristics and this ecological requirement is an important aspect of habitat selection (Huey et al. 1989; Du et al. 2006; Quirt et al. 2006; Andersson et al. 2010). We collected thermal profile data for five occupied rocks and four unoccupied rocks. There are data for one occupied rock with no associated control rock because I had an odd number of temperature loggers available. All temperature loggers were placed under rocks in two different high suitability TEM polygons.

We measured thermal profiles of cover rocks using iButton temperature loggers (DS1921, Dallas Semiconductor, Sunnyvale, CA). Each logger was placed underneath the point of the cover rock as close to the centre as possible (Quirt et al. 2006). We began the thermal profile measurements on May 19, 2012 and we removed the loggers on June 29, 2012 for a total of 45 days of temperature data. The temperature loggers were programmed to record the daily mean temperature, daily high temperature, daily low temperature and daily variance (standard deviation). For the purpose of statistical analyses, I excluded temperature data collected prior to 0800 h and after 1600 h because they were outside of the time frame during which field surveys were conducted; this study did not examine whether *P. skiltonianus* exhibits the same cover object preferences outside of this time frame (Quirt et al. 2006; Du et al. 2006).

2.6 Statistical Analyses

All data were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Bartlett test), and transformed when necessary to achieve conditions for using parametric tests (Du et al 2006). A Principle Components Analysis (PCA) was performed on measured habitat variables in order to interpret the relationship between habitat variables and presence of *P. skiltonianus*. PCA is a multivariate statistical method used when measurements have been obtained on a number of variables and the goal is to develop a smaller set of artificial variables, or principle components, which will account for the majority of the variation present within the original data set (Statistical Analytical Software 2002).

Logistic regression is among the most popular methods to analyze habitat selection (Keating and Cherry 2004). To analyze microhabitat selection of *P. skiltonianus* based on the microhabitat features measured in this study, I used matched-pairs logistic regression to compare each occupied location with its paired unoccupied location (Quirt et al. 2006). This paired design controls for variation in macro-environmental conditions through time and space, and ensures that the unoccupied location was available to a skink within the 1m area of the occupied location (Keating and Cherry 2004).

I used a paired t-test to determine if there was a significant difference between the mean, minimum and maximum temperatures under occupied and unoccupied cover rocks (Quirt et al 2006). Data for one occupied rock was not included due to the logger failing in the field.

All statistical analyses were performed with R version 2.10.1 (R: A Language and Environment for Statistical Computing , R Foundation for Statistical Computing, R Development Core Team, Vienne, Austria, 2004).

3: Results

3.1 Search Effort and Sightings

During the study period, a total of 71 Western skinks were detected in 16 different TEM polygons (Figure 3). Of the 16 polygons where skinks were sighted, 10 polygons were rated as high suitability habitat, 5 were moderate habitat suitability and 1 was rated as low suitability habitat. Another 19 polygons were surveyed where no observations were made with the following suitability ratings: 13 high, 4 moderate and 2 low. The majority of individuals (96%) were observed under cover rocks as opposed to out in the open, which is similar to other findings of field inventories for Western skinks in Canada (Rutherford and Gregory 2003; Dulisse and Boulanger 2006).
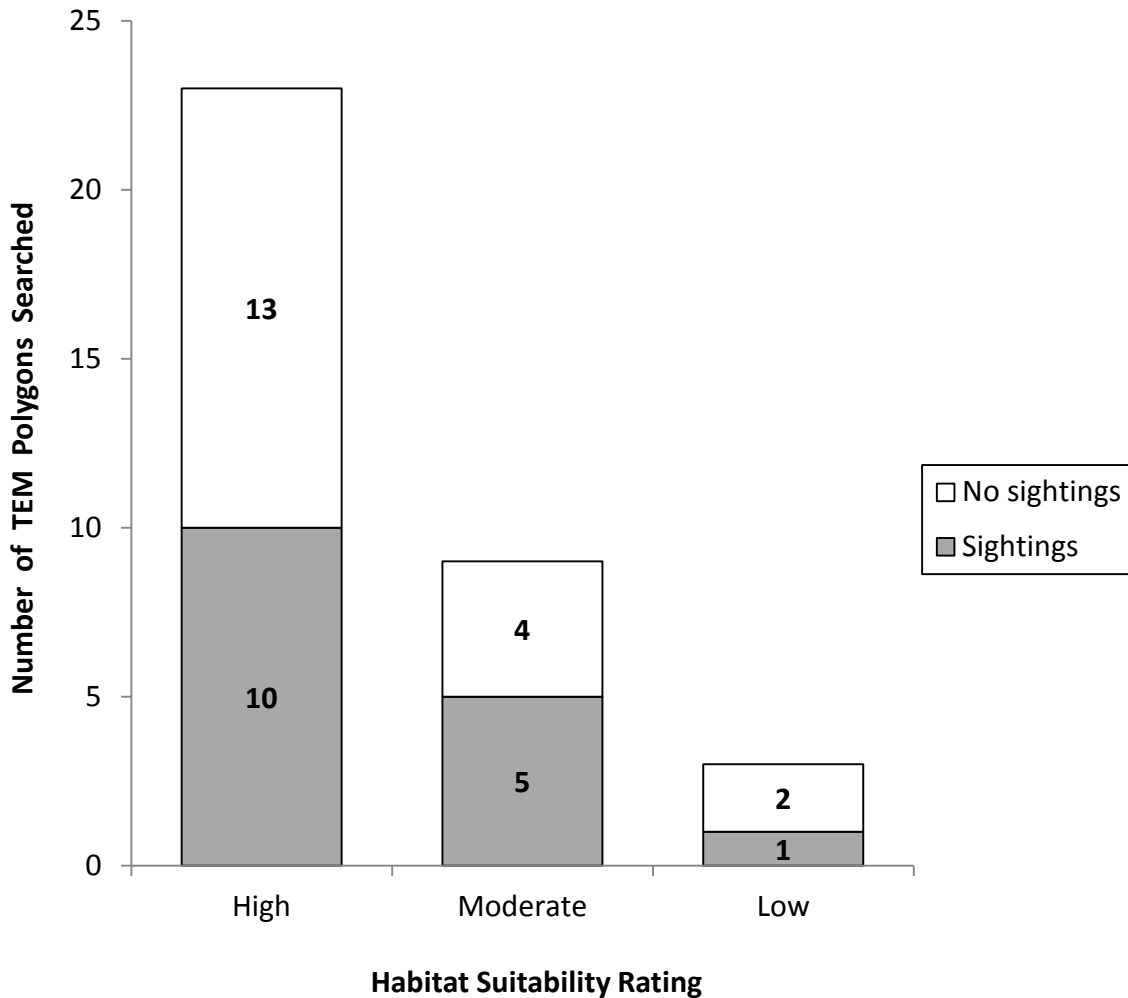
Figure 3. Number of TEM polygons searched for *P. skiltonianus* in the study area. Numbers in boxes indicate the number of polygons in each habitat suitability category.

Search effort across habitat types is summarized in Table 4. Over 20,100 rocks were flipped to search for *P. skiltonianus* throughout the entire field season. A total of 80 hours were spent searching in polygons that eventually yielded a skink sighting, and a total of 95 hours were spent searching in areas where no skinks were found. Most skinks were found singly under a cover object; only twice were two individuals found using the same cover object. *P. skiltonianus* has not been frequently found sharing a

cover rock with another skink or other reptile species such as Northern Alligator Lizards or Western Yellow-Bellied Racers, despite a range overlap with these species (Rutherford and Gregory 2003; Dulisse and Boulanger 2006). I calculated the number of skinks found per hour of search effort in each habitat type and the number of rocks flipped per individual found in each habitat type.

Table 4. Summary of search effort for field surveys for *P. skiltonianus* in the study area.

Variable of Interest	Sites with *P. skiltonianus*			Sites with no *P. skiltonianus* found		
	High	Moderate	Low	High	Moderate	Low
Total number of TEM polygons sampled	10	5	1	13	4	2
Number of skinks found	46	24	1	-	-	-
Number of cover objects investigated	7,364	1,517	302	9,254	1,236	475
Total search effort (hrs/person)	50	25	5	65	20	10
Skinks/hour	0.92	0.96	0.2	-	-	-
Rocks flipped/skink found	160	63	302	-	-	-

3.2 Thermal Profiles

The mean dimensions of all cover rocks used to examine thermal profiles for occupied (n=5) and unoccupied rocks (n=4) are shows in Figure 4. Elevation (range 475

m to 591 m) was also recorded for each rock, but since the rock pairs were located

within 1m of each other this habitat variable was not significantly different.
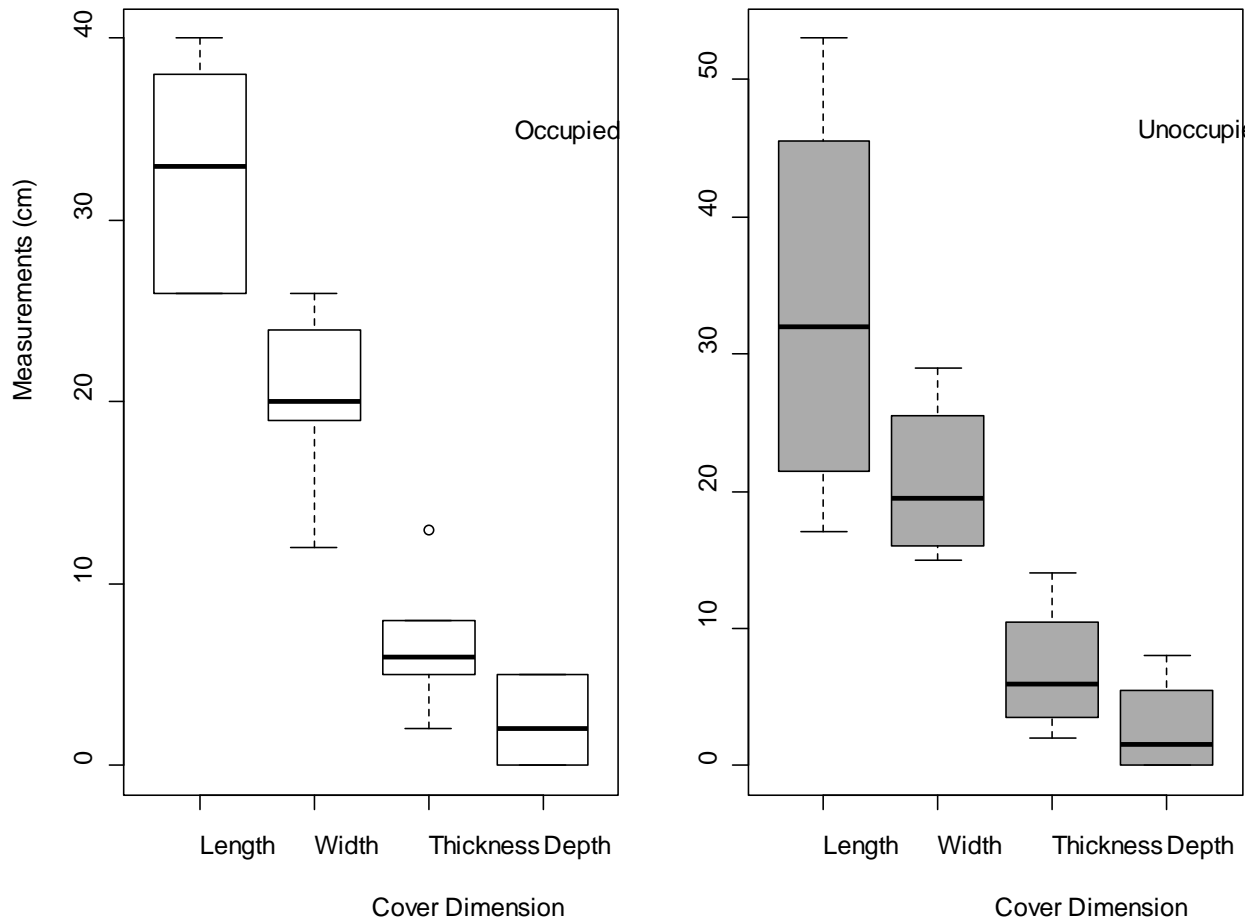
Figure 4. Boxplots illustrating the dimensions of occupied (n=5) and unoccupied (n=4) cover rocks used for thermal profiling. One open circle in the occupied plot shows an outlier. Dimensions of the one occupied rock with the failed datalogger are included in the left graph.

The thermal profiles for four occupied and four unoccupied cover rocks were

recorded and are shown in Figure 5. Maximum temperatures (range for all rocks was

17^{oC} to 41^{oC} during the activity period) occurred for both occupied and unoccupied rocks

at 1300 hr as shown in Figure 5. The smallest rock (length, width and thickness) was a

control rock which had the highest mean temperature (29.1^{oC} at 1300 hr) compared to

all other rocks at this time of the day. This rock also had the highest recorded maximum temperature value (40.7^{oC} at 1400hr). On average, this rock was 3.4^{oC} warmer than its paired occupied rock at 1300 hr.
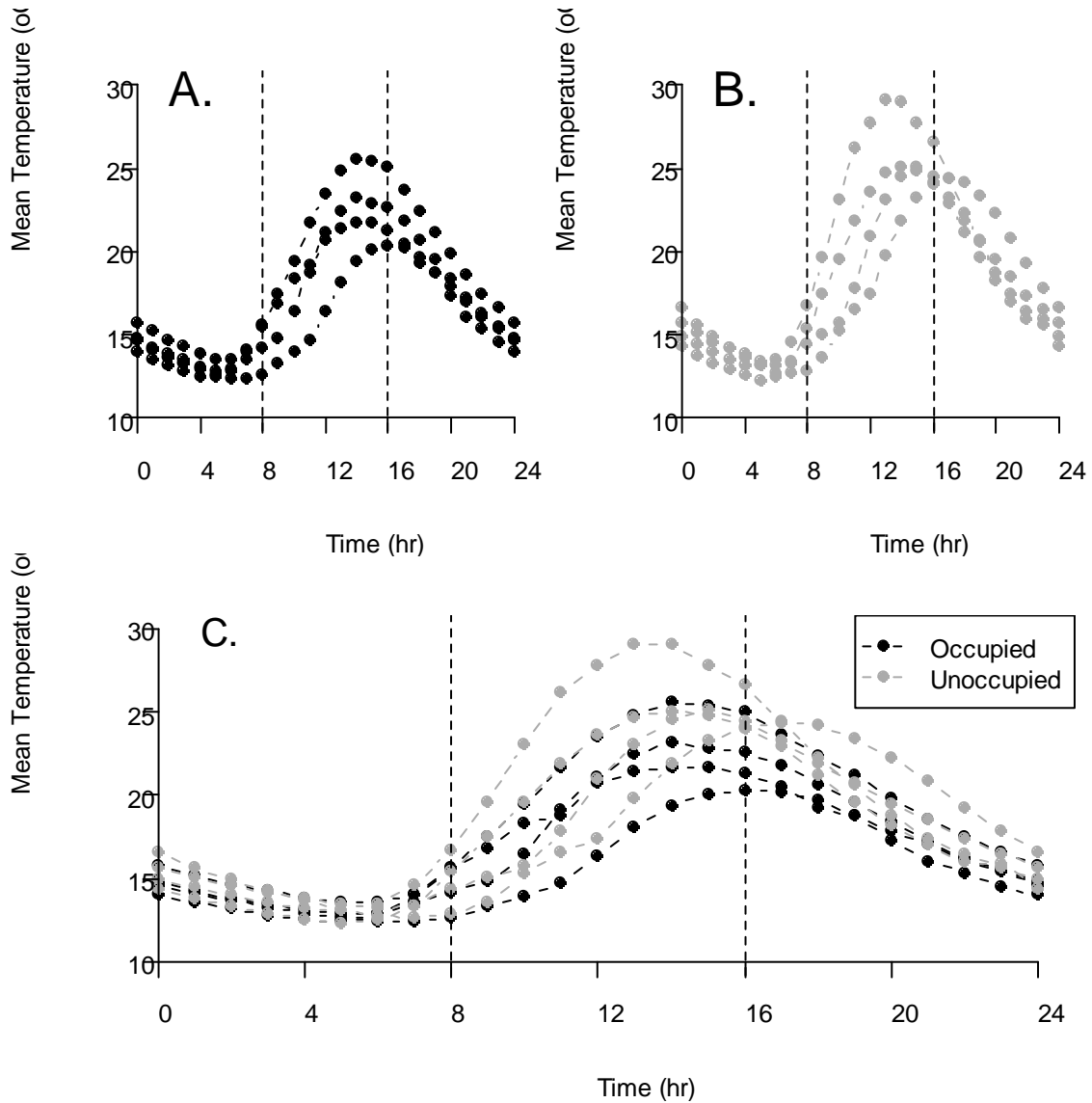
Figure 5. Average 24 hr temperature profiles of each iButton temperature data logger for (A) occupied rocks (B) unoccupied rocks (C) all rocks. The vertical dashed lines show the period during which field surveys took place which represents the estimated diurnal activity period of *P. skiltonianus*. Dashed lines between points show profiles for individual loggers.

In the pairwise occupied-unoccupied rock comparisons, all four pairs of loggers show that the average daily temperatures for unoccupied rocks were higher than the occupied rocks (Figure 6), during the time of day when surveys were being conducted (approximately 0700hr to 1600hr). Paired t-tests with a Bonferroni correction applied (α = 0.05/4 = 0.0125) showed that the mean temperature during the diurnal active period differed significantly between the occupied and unoccupied rocks for three of the four pairs of thermal dataloggers (df=10 for all pairs) ($t_{(1)}$=4.0014, $p_{(1)}$ = 0.0031; $t_{(2)}$= 4.1697, $p_{(2)}$ = 0.0024; $t_{(3)}$ = 6.1536, $p_{(3)}$ = 0.00016).
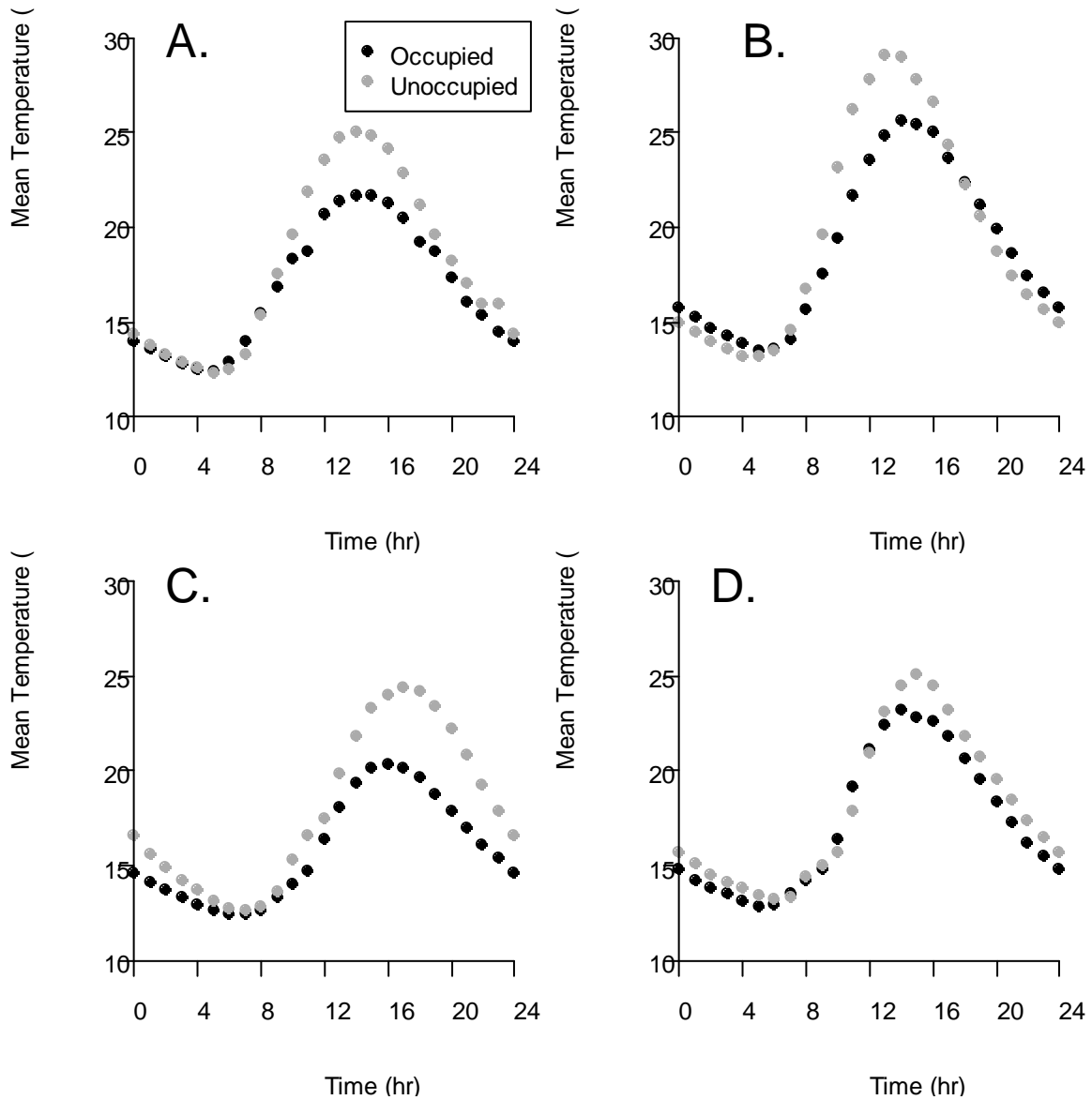
Figure 6. Mean thermal profiles for each occupied and unoccupied cover rock pair of temperature dataloggers.

3.3 Microhabitat Selection

P. skiltonianus was found within a range of elevations (383 – 816m) representing the entire ranges of altitudes searched throughout the field study. The mean dimensions of all occupied and unoccupied cover rocks are shown in Table 4. The mean percent

slope for occupied rocks was 17% ± 11, compared to 13% ± 8 at unoccupied sites.

Occupied sites had a similar slope range (0-40%) as the unoccupied sites (0-35%).

Table 5. Average dimensions of cover rocks selected by *P. skiltonianus* compared to available rocks in the study area.

	N	Cover Rock Dimensions (cm)			
		Length	**Width**	**Thickness**	**Depth**
Occupied rocks	48	40 ± 16	25 ± 10	7 ± 4	3 ± 2
Unoccupied rocks	48	44 ± 15	24 ± 9	5 ± 3	2 ± 2

The PCA reduced the measured habitat variables down to three components which explained 95% of the total sample variance (Table 5). The results of the PCA are also shown graphically in Figure 7. PCA plots the data on a rotated scale, so the horizontal axis labelled Component 1 shows the most most-varying direction of the data. The arrows for the variables thickness and slope account for the most amount of variation in the first component. The first component explained 54% of the total sample variance and was related to a low percentage of vegetative cover and high percentage of rocks in the sample area (Table 5). The second component accounts for 30% of the variance and includes the variables for thickness of the cover rock, embeddedness of the rock (depth), and aspect of the cover rock. The third component accounted for 11% of the variance and described increasing rock length and rock width and increasing percentage of rock cover within a 1m radius of the observation point.

Table 6. Loadings of variables from the Principle Components Analysis

Habitat Variable	Components		
	1	2	3
Elevation	–0.00	0.08	–0.10
Rock Length	–0.20	0.03	0.60
Rock Width	–0.27	0.18	0.54
Rock Thickness	–0.18	–0.51	–0.12
Rock Depth	–0.18	–0.46	–0.09
Slope	–0.30	–0.33	0.27
Aspect	0.27	0.34	–0.08
% Rock cover	0.54	–0.16	0.36
% Vegetation cover	–0.57	–0.32	–0.27
% Soil cover	0.12	–0.33	–0.12
Variance Explained	**54%**	**30%**	**11%**
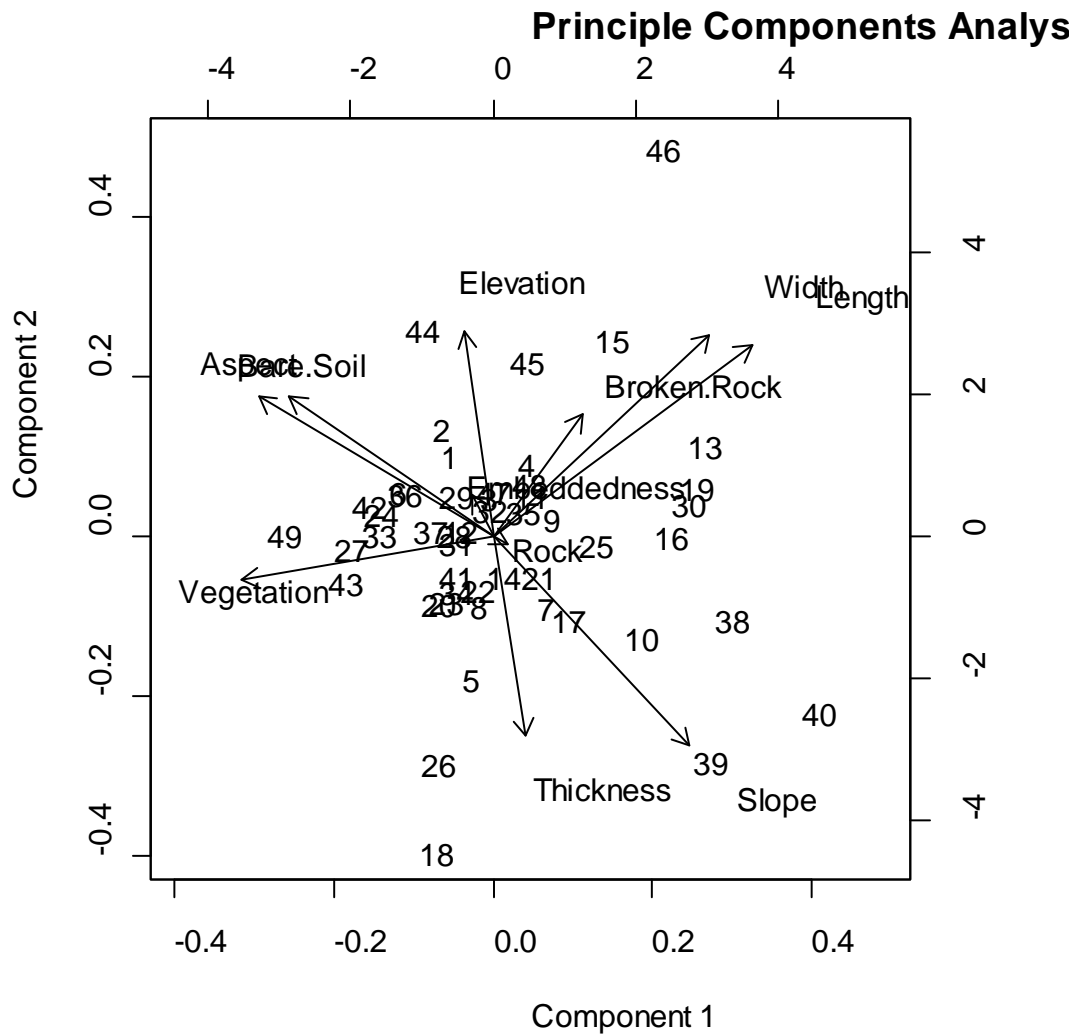
Figure 7. Differences in microhabitat composition of *P. skiltonianus* based on Principle Components Analysis for structural habitat variables at occupied and unoccupied sites. The arrows indicate the direction of each habitat variable, and the numbers in the centre of the graph represent each observation point.

In matched-pairs logistic regression the estimated coefficients are interpreted in the same manner as standard logistic regression. The results of the logistic regression (Table 6) show that the variables for rock thickness, depth, slope angle and aspect were significant at $\alpha = 0.05$.

Table 7. Paired logistic regression model of microhabitat selection for *P. skiltonianus* in the study area. Bolded values show variables that are significant at α=0.05.

Variable	Coefficient	SE	Z value	P value
Elevation	0.002679	0.002598	-0.927	0.354
Length	0.065676	0.091141	0.721	0.471
Width	0.023476	0.028900	0.812	0.417
Thickness	**-0.032977**	**0.019221**	**-1.716**	**0.086**
Depth	**0.239347**	**0.134409**	**1.781**	**0.075**
Slope	**0.073344**	**0.029159**	**2.515**	**0.012**
Aspect	**0.006625**	**0.003569**	**1.856**	**0.063**
% Rock	0.048296	0.082826	0.588	0.556
% Vegetation	0.025297	0.082826	0.305	0.760
% Soil	0.036436	0.082490	0.442	0.659

4: Discussion

4.1 Microhabitat Selection

The importance of cover objects for reptiles is well documented (Shine et al. 1998; Andersson et al. 2010; Pike et al. 2010; Croak et al. 2012). Several studies have shown that Western skinks and other closely related species of skinks in Canada (e.g. *Plestiodon fasciatus*, formerly *Eumeces fasciatus* and *Plestiodon septentrionalis,* formerly *Eumeces septentrionalis*) are associated with different types of cover elements depending on the available microhabitat in the study area (Hecnar 1994; Rutherford and Gregory 2003; Howes and Lougheed 2004; Dulisse and Boulanger 2006; Quirt et al. 2006; Larkin 2011). In my study some structural properties of cover objects differed statistically between occupied and unoccupied objects, which was also reported in other studies on skinks in Canada (Dulisse and Boulanger 2006; Quirt et al. 2006).

Within my study area, individuals of *P. skiltonianus* selected rocks that are thicker and more deeply embedded in the substrate than the subset of available rocks, and selected rocks on steeper slopes on a southwestern aspect. Microsite elevation did not play a significant role in microhabitat selection. Since the cover rock pairs were located within 1m of each other, it is logical that elevation was not significantly different at a microhabitat scale. Presence of *P. skiltonianus* was also associated with a higher percentage of rock cover and a lower percentage of vegetative cover (Santos et al. 2008) within a 1m radius of the sighting location.

In my study area, TEM mapping shows that talus slopes with loose cover rocks are abundant. However, in other areas of the Okanagan, removal of talus for construction and landscaping purposes may pose a threat to the Western skink and other reptile species such as the Desert nightsnake that rely on talus slopes for habitat

(COSEWIC 2002; Southern Interior Reptile and Amphibian Recovery Team 2008).
Removal of cover objects has been cited as detrimental to *P. skiltonianus* in all parts of
its Canadian range (COSEWIC 2002; Rutherford and Gregory 2003; Dulisse 2004).

4.2 Detection and Limitations of the HSM

More individuals of *P. skiltonianus* were found in the high suitability habitat
polygons than in moderate and low suitability habitat polygons. However, the number of
skinks found per hour of search time was roughly equal in the high and moderate
suitability habitats, and the number of rocks flipped per skink found was the lowest in the
moderate suitability habitats. This likely indicates that the HSM was not highly accurate
at predicting the suitability of habitat types for *P. skiltonianus* in TEM polygons.

For my results I report the number of sightings I made in each polygon rather
than making assumptions of presence or absence of *P. skiltonianus* in each polygon.
Nondetection of a species at a site does not mean that the species is absent from the
site (Sewell et al. 2012), especially for cryptic species like *P. skiltonianus*. Detection
probability of *P. skiltonianus* in the Kootenay region was estimated at 0.2 to 0.25 over
three sampling sessions at 48 sites (Dulisse and Boulanger 2008). Once the detection
probability of a species is estimated it is possible to determine the number of survey
visits required at an occupied site for the species to be detected to a given level of
certainty (Kery 2002). This is useful information for managers and biologists who are
trying to determine how to allocate limited resources for survey efforts that will yield the
most useful information on species presence and abundance (Sewell et al. 2012).

Over the course of my field study, skinks were detected at 16 of the 35 sites
sampled and therefore occupancy was at least 0.49 (17/35), but most likely higher
because detection probabilities are not close to 1 (Dulisse and Boulanger 2008). *P.*

skiltonianus was detected at 7 of 10 sites in Creston over the course of three field seasons which yields a higher occupancy value of 0.7 (Rutherford and Gregory 2003). In my study, high habitat suitability polygons were on average much larger than moderate and low suitability polygons. With consistent search effort across all suitability types, this meant that our field searches tended to be more intensive within moderate and low suitability polygons because they were smaller, and often only had a few patches of good skink habitat within the entire polygon. Search effort was more diffuse in high suitability habitat because the polygons were larger and we attempted to search the entire polygon within 5 hours.

We used a survey method for determining species presence that allowed for us to concentrate survey effort in smaller patches of suitable microhabitat (visual encounter surveys) rather than using a method that results in consistent survey effort across the entire sample area (e.g. transects). This may partially explain why we had 13 high suitability habitat polygons with no sightings, because we attempted to cover the entire polygon in 5 hours instead of intensively focusing search effort on suitable microsites within each polygon. If we had stratified polygons into size classes and applied a proportionate amount of search effort hours for each size class, this may have resulted in a more consistent level of effort across habitat suitability types.

There are several limitations with the HSM used to guide fieldwork in this study. The four-class rating scheme for the HSM is best used when there is an intermediate amount of knowledge available about the species' habitat use, and is most useful at medium map scales (1:50,000 to 1:100,000) (RISC 1998). However, my results indicate that habitat selection of *P. skiltonianus* occurs at the microsite scale, which cannot be captured using a HSM for medium map scales. The HSM classified some TEM polygons as Nil habitat; that is, polygons that contained no suitable habitat for *P. skiltonianus.*

These polygons included residential and industrial land uses, and were completely excluded from my field surveys. However, it is possible that portions of the Nil polygons may have contained a small percentage of low, moderate or even high rated habitat for *P. skiltonianus*, according to the percentages in the TEM mapping. The mapping technique used by TEM classifies polygons according to the highest percentage of ecosystem type in a given polygon, which will in some cases cause the HSM to rate a polygon as low habitat even though there may be a small portion of that polygon with excellent skink habitat. Detecting skink presence in residential and industrial polygons would provide important inventory data that could be used to refine management objectives. According to the personal observation database of M. Sarrell, skinks have previously been detected in some polygons classified as Nil. Collection of inventory data from Nil polygons would need to occur in accordance with the permission of the private landowner(s).

4.3 Thermal Characteristics of Cover Rocks

Cover objects are important components of microhabitat for ectotherms because cover modifies the thermal characteristics of refuge sites. I found that three out of four average daily thermal profiles were significantly different between the cover rock pairs during the daily activity period of *P. skiltonianus*. In all four pairs of logger profile pairs, the unoccupied rocks showed greater variation and higher average daily temperatures in their thermal profiles than did the occupied rocks. This was true for occupied rocks as a group and for each occupied-unoccupied rock pair.

Results of this study indicate that there appears to be non-random selection of cover rocks used by *P. skiltonianus*, which could be partially driven by the thermal properties of the cover rocks. Repeated use of particular cover objects is thermally

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driven for some lizard species (Croak et al. 2012) and Western skinks appear to be selecting rocks that maintain thermal profiles with lower daily maximum temperatures throughout the day compared to other available cover rocks in the same area. Other species of skinks select a lower body temperature in order to reduce their energy consumption, especially in cooler climates (Patterson and Davies 1978; Shu et al. 2010). Western skinks may be choosing rocks with less extreme thermal profiles because these rocks allow them to maintain a cooler body temperature throughout the day and therefore reduce their energy consumption. However, without comparing how the thermal profiles of occupied and unoccupied rocks overlap with the preferred body temperature (T_{sel}) for the species (Quirt et al. 2006; Andersson et al. 2010), which has not yet been determined for *P. skiltonianus*, the results of my study cannot be used as evidence that *P. skiltonianus* selects thicker rocks that are more deeply embedded in the soil because these rocks have a more ideal thermal profile for the species.

Quantifying the thermal properties of occupied microsites for *P. skiltonianus* can provide information regarding ecological variables that influence microhabitat selection in all parts of the species range. Based on observations in this study *P. skiltonianus* appears to prefer using rocks for cover elements in the Okanagan region, but in other parts of their Canadian range (e.g. the Kootenays), *P. skiltonianus* has been found using other types of cover such as shrubs and coarse woody debris (Dulisse and Boulanger 2006) which may afford optimal thermal ranges over other available retreat sites.

Other studies on microsite thermal preferences in skink species have used the preferred body temperature range (T_{sel}) of the species to examine the overlap between the thermal profile of the cover object and preferred temperature range (Du et al. 2006; Quirt et al. 2006; Vickers et al. 2011). T_{sel} is the body temperature that an organism tries to achieve under ideal environmental conditions with no physical or biological

constraints (Du et al. 2006). While the preferred body temperature range of several other species of the genus Plestiodon are known (Youssef et al. 2008), this information has not been acquired for *P. skiltonianus*. The range of preferred body temperatures (T_b) for other members of the family Scincidae (n=210) is wide ($20.3 - 38.0^oC$) (Vickers et al. 2011) and applying a conservative range to compare the thermal profiles of rocks for *P. skiltonianus* would not yield useful information. Therefore, without this information I could not test whether the thermal profile of occupied cover rocks overlapped more significantly with the preferred body temperature range of *P. skiltonianus* than the thermal profile of unoccupied rocks.

Spatial placement of thermal dataloggers under the rock also has an influence on the thermal profile; temperatures under the edges of rocks are not the same as the temperatures under the centre of rocks, and edge temperatures tend to vary more and change more quickly throughout a 24 h period (Huey et al. 1989; Quirt et al. 2006). This means skinks may have several different thermal gradients available to them even under a single rock, and may select rocks based on whether they offer a range of temperatures throughout the day. However, my results show that *P. skiltonianus* selects rocks that are thicker and more deeply embedded in the substrate than other available rocks. This result, coupled with the result that skinks appear to select rocks that maintain a lower daily mean temperature and less daily variation in temperature could indicate that thicker rocks embedded on the substrate are a priority for conservation because they may help skinks achieve optimal body temperatures.

Phenology is particularly influential for *P. skiltonianus* and phenological responses to weather conditions may be critical for small SAR, especially as global climate changes progresses (Gienapp et al. 2005). Lizards cannot evolve rapidly enough to keep pace with current climate change rates due to genetic constraints

regarding thermal preferences (Huey et al. 2003). Although climate change was not identified as a direct threat to this species (COSEWIC 2002) *P. skiltonianus* may be susceptible to local extinction driven by climate change impacts on thermal characteristics of microhabitat. As development of lowland habitat for urban and residential development proceeds, *P. skiltonianus* will most likely continue to be driven to higher elevations in the Okanagan region, which could result in local extinctions of populations as maximum daily temperatures increase.

4.4 Movement Patterns and Home Range Size

There is currently little understanding of the seasonal patterns of habitat use in small lizard species (Rutherford and Gregory 2003). I attempted to determine movement patterns and home range size of adult Western skinks during the breeding season by using mark recapture techniques with Passive Integrative Transponder (PIT) tag technology implanted in individuals to collect movement data. PIT tagging can be an effective method for permanently marking individuals to document their locations at close proximity (Blomberg and Shine 2006). The movement pattern component of this study was not successful, and data on home range size was not collected in the field. The PIT tags were too large to safely implant into juvenile skinks, and the majority of skinks found during my study were juveniles or small adults: this was a similar problem with using implants to mark juvenile skinks in the Kootenays (Dulisse and Boulanger 2006)

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5: Recommendations

Developing monitoring programs that provide statistically valid trends for reptiles is challenging because many such species are secretive, have wide population fluctuations and exhibit strong behavioural responses to weather conditions (Konze and McLaren 1997). All three of these challenges apply to the study and therefore management of *P. skiltonianus*. Future research for this species should focus on developing field techniques that lead to successfully estimating abundance, detection, home range size and eventually population trends of *P. skiltonianus* in all parts of its Canadian range. Revision of the HSM to help guide management planning for this species on public and private land will also benefit the species, and increased sample size to assess changes in thermal attributes of important microsites should also be priorities for future studies on *P. skiltonianus*.

5.1 Estimating Home Range and Population Size

Determining population trends and understanding seasonal habitat use and movement patterns in small lizards is central to the applied management of the species (Rutherford and Gregory 2003). Clarifying the home range size and daily and seasonal movement patterns, as well as determining the dispersal ability, for *P. skiltonianus* is identified as a beneficial management action in the species' provincial draft Management Plan (BC Western Skink Working Group 2010). Although other studies on *P. skiltonianus* in B.C. have tested various methods of marking individuals such as PIT tagging, visible implant elastometer (VIE) implants and photo recognition marking, these techniques have limitations and varying degrees of success in the field (Rutherford and Gregory 2003; Dulisse and Boulanger 2006). Establishing field techniques that yield robust statistical power for population size estimates for the Western skink should be explored in future studies.

5.2 Management Planning

As outlined in the draft provincial Management Plan for the species, important habitat sites for *P. skiltonianus* should be identified and protected (BC Western Skink Working Group 2010). According to the results of my field study, *P. skiltonianus* does not select microsites randomly which indicates habitat modelling and field assessment should inform prioritization of sites to be protected. Disturbance to cover rocks from recreation, quarrying, or any other methods of disturbance has detrimental effects on reptile populations (Schlesigner and Shine 1994; Goode et al. 1995) which suggests that preventing the deterioration of important rocky habitats should be a management priority for *P. skiltonianus* that depends almost exclusively on rocks for cover. Protection should consider all activities, from urban and agricultural development to talus extraction and quarrying to disturbance from the actions of researchers who are surveying the habitat by flipping rocks and failing to return the objects to the exact original position which preserves important microhabitat qualities.

The draft Management Plan suggests developing a HSM for *P. skiltonianus* that considers a range of climate change scenarios throughout the entire range of the species in B.C (BC Western Skink Working Group 2010). Refining and validating the HSM model will include more ground-truthing, and gathering data on thermal profiles of cover elements at different sites should be a component in this aspect of the Management Plan implementation. Refinement of the HSM should include, at a minimum, inclusion of a more robust occurrence dataset from the BC Conservation Data Centre to evaluate the model's performance.

Establishing and monitoring thermal attributes of retreat sites at several long-term locations will facilitate understanding of what drives thermal habitat selection and may provide insight into how *P. skiltonianus* may display ecological adaptation by shifting habitat preferences in response to long-term threats such as climate change (Shu et al. 2010; Croak et al. 2012).

Lizards cannot evolve rapidly enough to keep pace with current climate change rates due to genetic constraints regarding thermal preferences (Huey et al. 2003). Although climate change was not identified as a direct threat to this species in the species status report (COSEWIC 2002), *P. skiltonianus* may be susceptible to local extinction driven by climate change impacts on thermal characteristics of microhabitat. If preferred microsites lose their thermal quality as development of lowland habitat for urban and residential development proceeds, populations of *P. skiltonianus* will most likely be driven to higher elevations in the Okanagan region. Preferred body temperature of lizards varies seasonally, with T_{sel} tending to be higher in the summer than in other months (Shu et al. 2010), and as such monitoring should attempt to capture not only spatial variation of *P. skiltonianus*' T_{sel}, but also temporal variation across the active season.

There are several useful planning tools available to developers and municipal planners in the Okanagan region to incorporate the needs of SAR into land-use planning. The Green Bylaws Toolkit (University of Victoria 2007), Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia (Ovaska et al. 2004) and the Sensitive Ecosystem Inventory (SEI) mapping all provide guidelines, recommendations and summarize geospatial information on SAR in the Okanagan Region of B.C. However, I strongly recommend that these tools be used in conjunction with the opinion and input of a regional or local expert familiar with the needs of the particular species in a proposed development area. As evident from the SEI mapping and the HSM mapping used in this project, even areas mapped as low or nil suitability habitat for a particular species like the Western skink does not mean that the species is definitely absent from that patch of habitat. My results indicated that less search effort in terms of rocks flipped per skink found was required in moderate than high suitability habitat, which emphasizes that the HSM is not highly accurate. Future work could build on ground-truthing a HSM model to refine habitat mapping for the Western skink which will be a valuable conservation tool for both private landowners and management planners.

5.3 Future Research and Establishment of Long-term Monitoring Sites

Future research should increase sample size in this study, and examine if the patterns found here are consistent over a broader geographic area and larger sample of cover objects. I found that sightings of *P. skiltonianus* tended to be patchily distributed at a polygon level, which has also been reported in the Kootenays (Dulisse 2006). Whether this observation is driven by habitat selection of the species or detection probability in challenging terrain such as steep talus slopes and rock outcrops should be determined. Future inventory work should focus on identifying whether *P. skiltonianus* is isolated to particular patches of habitat or whether they are more contiguous on the landscape, both within protected habitat areas such as VBNWA and on private lands. This information would be very useful for management planning to help guide the scale of habitat protection initiatives for the Western skink. Identifying patterns of the species' occurrence on the landscape and habitat requirements is essential to integrate the needs of the species into provincial and municipal management planning and into best management practice guidelines for developers (Howes and Lougheed 2004; Stem et al. 2005).

Future research should examine thermal preferences between juveniles and adults, to determine whether thermal attributes of microsites differ at various stages of the skink's lifecycle. Some lizard species exhibit differences in thermal preferences of cover objects between both juveniles and adults (Du et al. 2006; Vasconselos et al. 2012) and males and females (Du et al. 2006), where juveniles and adult males tend to prefer higher temperatures than adult females. Differences in thermal properties between different types of cover (e.g shrubs, woody debris) used by skinks in other parts of their range such as the Kootenays should also be examined (Dulisse and Boulanger 2006) to determine relative importance of different cover types in order to make informed management recommendations.

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Disturbance from field surveys can bias both future survey estimates and permanently disturb the habitat both for the target species and other species (Blomberg and Shine 2006). Future studies that require permanent study sites to determine ecological needs for *P. skiltonianus* such as movement patterns and home range size of should be carefully designed to minimize disturbance to individuals and their microhabitat. The Vaseux-Bighorn NWA is an ideal location to conduct future research projects on *P. skiltonianus*, due to the existing species inventory data in this area and its status as a protected wildlife area. The Creston Valley Wildlife Management Area may also be a suitable long-term monitoring site as this was the location of a habitat use study for *P. skiltonianus* (Rutherford and Gregory 2003).

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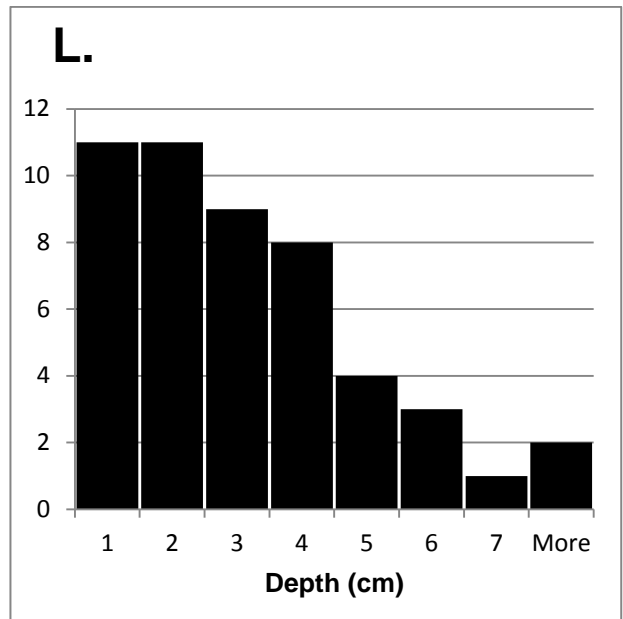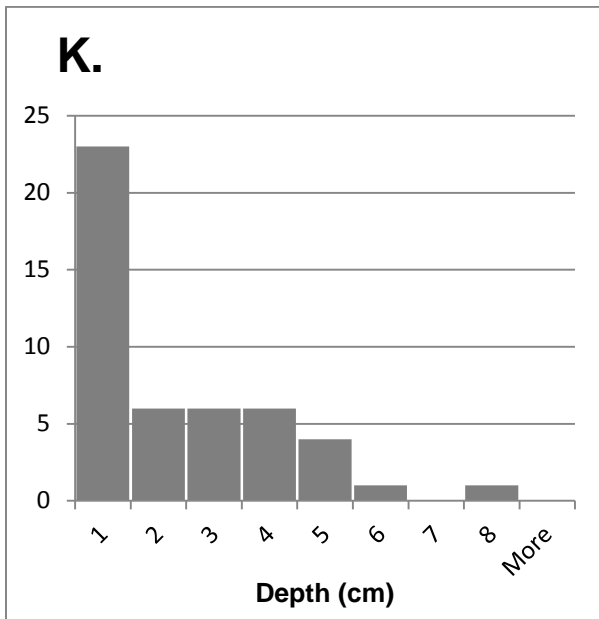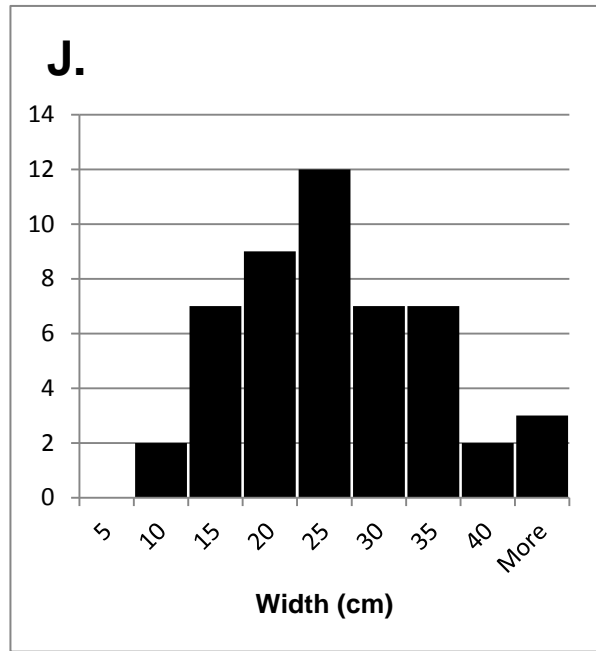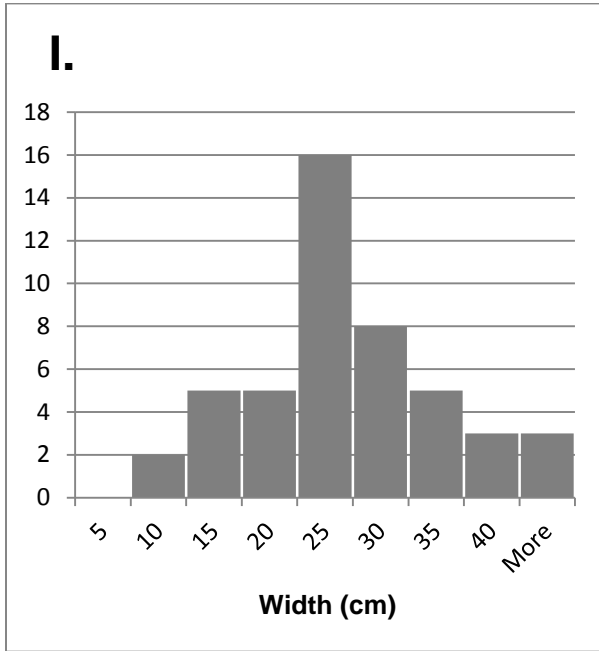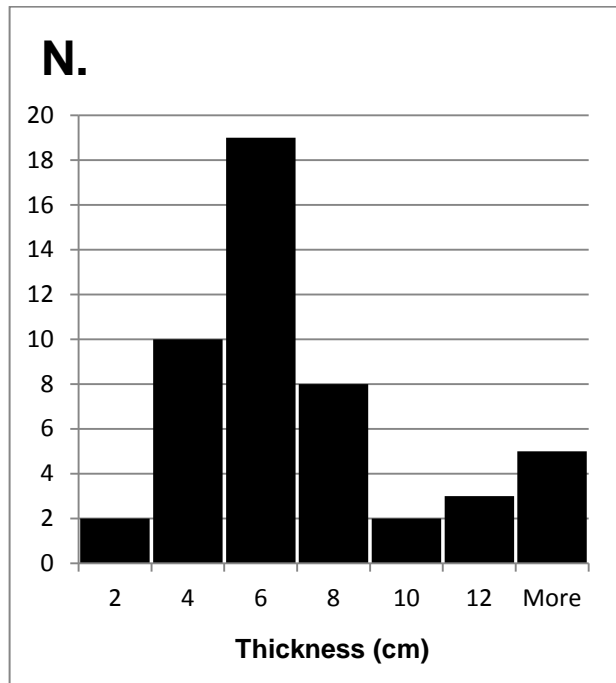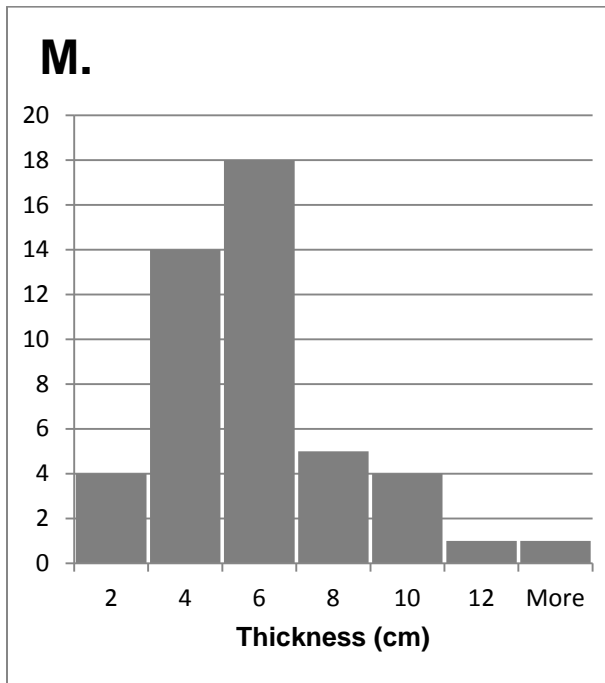
Appendix.

Histograms of Measured Cover Rock Variables
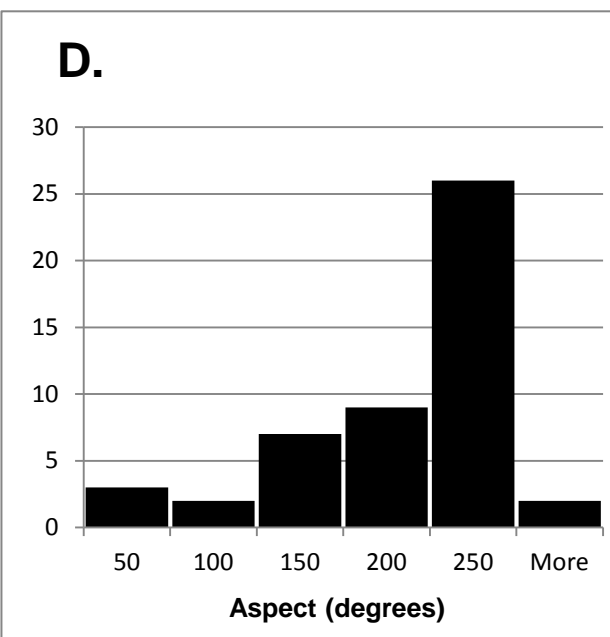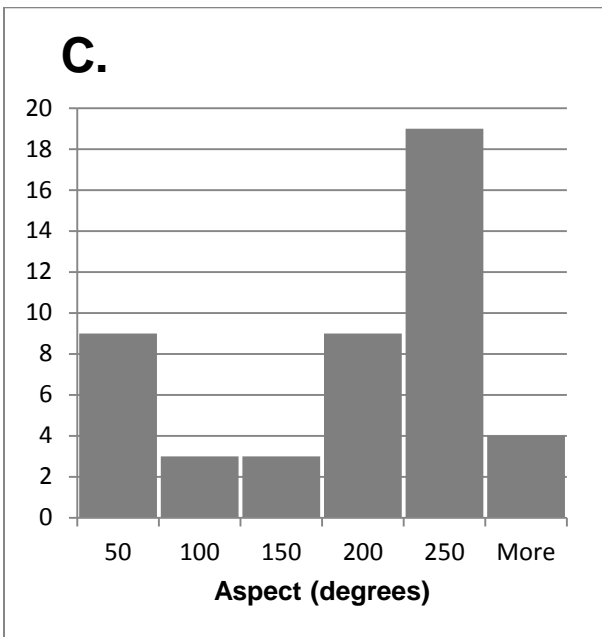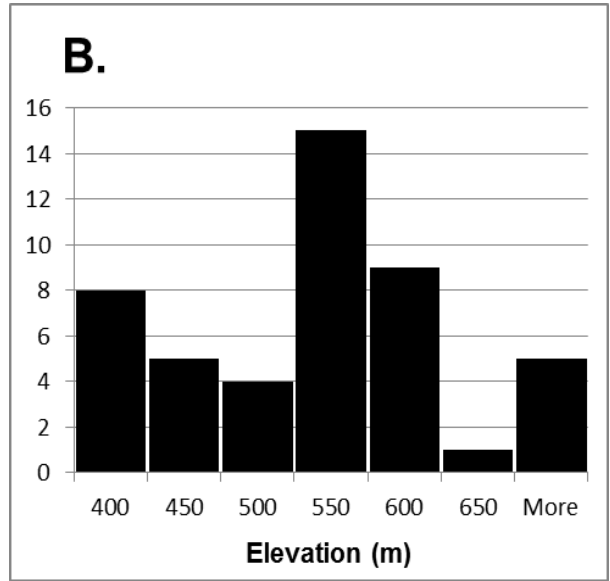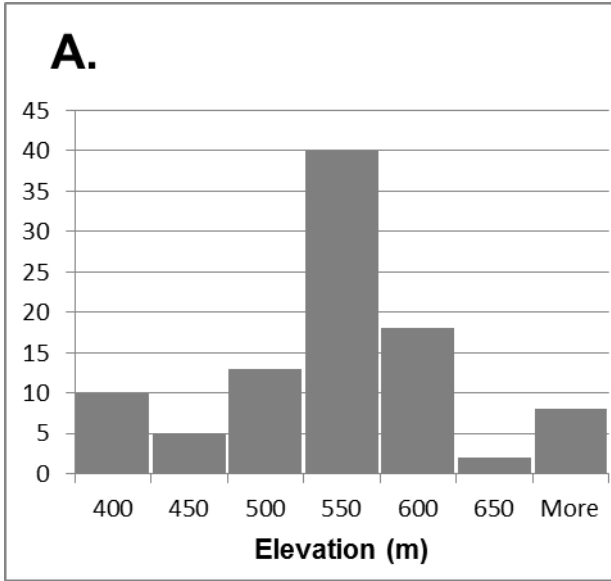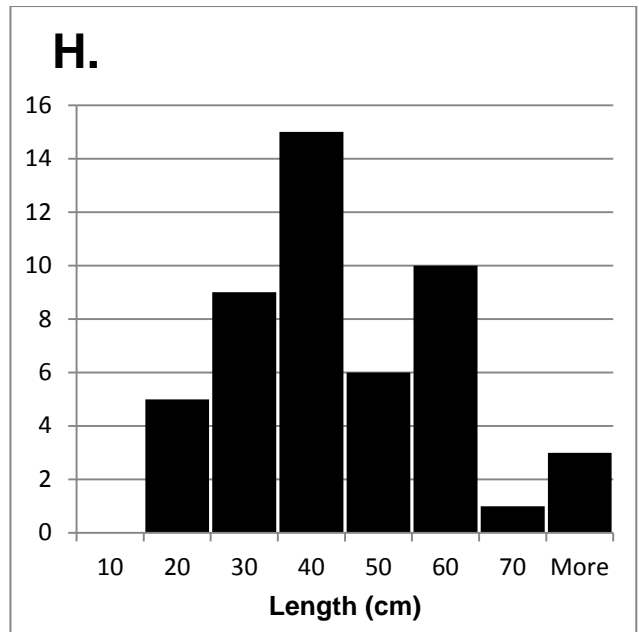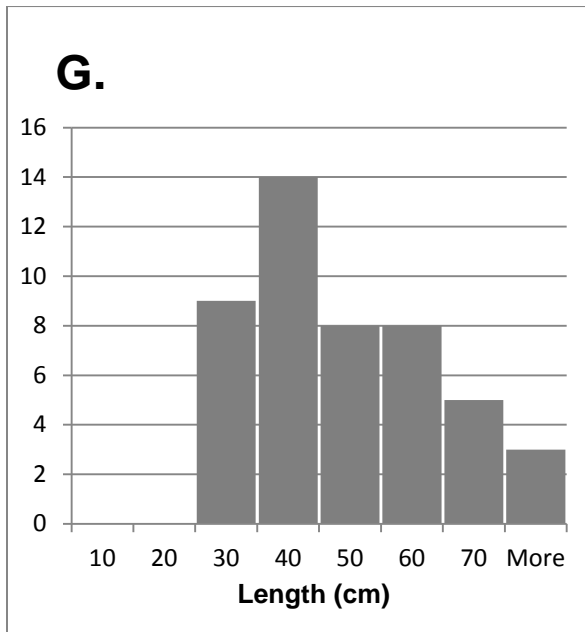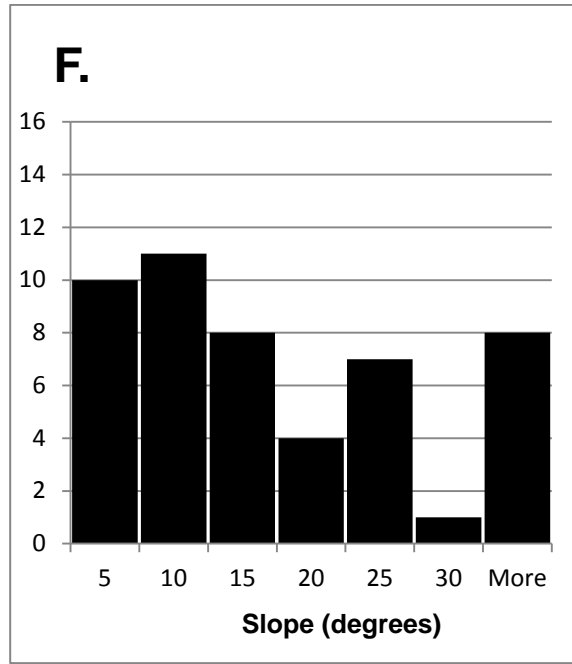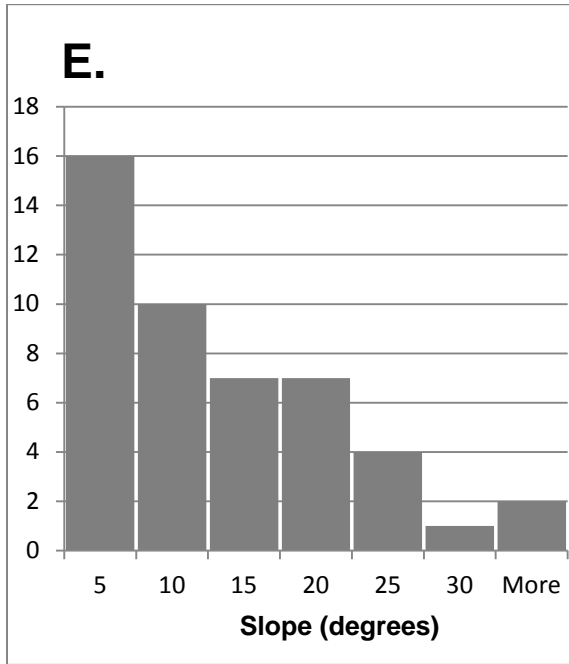
Figure A. Frequency histograms for measured habitat variables of control and occupied cover rocks. Grey plots are control rocks and black plots are occupied rocks. Graphs show (A and B) elevation, (C and D) aspect, (E and F) slope, (G and H) length, (I and J) width, (K and L) depth and (M and N) thickness of the cover rocks.