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Fire-altered Landscapes Influence Locomotor
Performance of Eastern Fence Lizards
(*Sceloporus undulatus*)

Kristoffer H. Wild

Fire-altered Landscapes Influence Locomotor Performance of Eastern Fence Lizards
(*Sceloporus undulatus*)

A Thesis

Presented to

The College of Graduate Studies

Austin Peay State University

In Partial Fulfillment

Of the Requirements for the Degree

M.S. Biology

Kristoffer H. Wild

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To the College of Graduate Studies:

We are submitting a thesis written by Kristoffer H. Wild entitled "Fire-altered Landscapes Influence Locomotor Performance of Eastern Fence Lizards (*Sceloporus undulatus*).” We have examined the final copy of this thesis for form and content. We recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Biology.



Dr. C.M Gienger

Research/Committee Advisor/Chair



Dr. Rebecca Johansen

Committee Member



Dr. Stefan Woltmann

Committee Member



Dr. John H. Roe

Committee Member

Accepted for the Graduate and Research Council



Dr. Raj Dakshinamurthy

Dean, College of Graduate Studies

(Original signatures are on file with official student records.)

Dean, College of Graduate Studies

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Kristoffer H. Wild

April 12, 2016

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DEDICATION

I dedicate this work and give special thanks to my hero and good friend Wade A. Boggs.

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ABSTRACT

Fire-altered Landscapes Influence Locomotor Performance of Eastern Fence Lizards (*Sceloporus undulatus*)

Historically habitat disturbance through fire has played a key role in shaping the biodiversity of forest communities in the Southeastern US. Prescribed burns are an essential management technique used to help maintain the persistence of oak-hickory savanna, an early seral stage vegetative community. *Sceloporus undulatus* is a sexually dimorphic forest lizard that is relatively common throughout the eastern US, which makes it well-suited for studying the effects of fire-altered landscapes on lizard ecology. Our objective was to quantify the effect of fire-altered landscapes on *S. undulatus* locomotor performance. Lizard performance was compared among habitats with three different known fire histories: a control habitat, which had not experienced fire in more than 60 years, a recovering burn habitat that had not experienced fire in four years, and a recent burn habitat that was burned three months prior to the study. There were significant differences in locomotor performance among lizards from the different habitats, and lizards in the recent burn habitat had significantly faster maximum sprint speeds than lizards in recovering and control habitats. Habitats differed both structurally and thermally. Shifts in thermal regimes in burned habitats could be the underlying mechanism leading to change in lizard performance. Understanding how performance of *S. undulatus* is influenced by fire-altered habitats is essential for understanding how ectotherms respond to altered habitats.

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CHAPTER I

INTRODUCTION

Variation in phenotypic traits is common in natural populations and may be due to underlying influences of natural selection among individuals (Price et al., 2003; Piersma and Gils, 2010). Investigating the ecological consequences of how individual variation is maintained requires an understanding of how genotypes and phenotypes interact with the surrounding environment. Phenotypic plasticity is typically thought to be a change in phenotype in response to environmental fluctuations (Agrawl, 2001; Fordyce, 2006; Freeman and Herron, 2007). Plasticity can be induced by biotic effects, such as the presence of predators or competitors (Relyea, 2002; Mondor, 2005) or by abiotic effects such as temperature or habitat structure (Tomkins, 1999; Neufeld and Palmer, 2008). These phenotypic changes can be responsible for differences in behavioral, physiological, morphological, and/or life history traits. For example, Losos et al. (2000) demonstrated morphological plasticity in limb structure within a single generation in *Anolis sagrei*. Hatchlings in that study were raised in different habitat treatments that provided either broad or narrow perches. Lizards reared in the narrow perch treatment had significantly shorter hind-limbs than lizards reared in broad perches, suggesting that modification in hind-limb length allows lizards adapt to differences in the surrounding environment. This suggests that the ability to modify phenotype, in response to changes in the environment, may have potential fitness and evolutionary consequences.

Locomotor ability is a common metric used to assess whole animal performance (Arnold, 1983; Husak, 2006), and an individual's ability to effectively traverse its environment has been shown to play an important role in overall fitness (Irschick and Losos, 1998; Warner and

Andrews, 2002; Miles, 2004). Studies focusing on ectothermic vertebrates have shown that individuals with high locomotor abilities tend to also have higher success in fitness-related activities including prey acquisition (Ayers and Shine, 1997), predator escape (Lailvaux et al., 2003), social dominance (Husak and Fox, 2006), and reproductive success (Phillips et al., 2006). Because the physiological processes of ectotherms are temperature dependent, including locomotor performance, maintaining body temperatures (T_b) that permit a high level of performance is essential (Dunham et al., 1989; Angilletta et al., 2002). Thermal optimum (T_o) is defined as the temperature (or range of temperatures) at which physiological processes are maximized, and ectotherms maintain body temperatures (T_b) within this optimal range (T_o) by behavioral thermoregulation (Huey and Stevenson, 1979). Thermoregulation varies considerably by species and environment (Adolph, 1990), therefore different scales of environmental thermal heterogeneity may potentially lead to differences in phenotype.

Changes in vegetation cover (e.g., fires, herbicide applications, logging) can affect local microclimates for animals found on the landscape, and improved thermal habitat quality for ectotherms has been documented in landscapes that have recently experienced fire (Radke et al., 2006; Hossack et al., 2009; Greenberg et al., 2010). Fire alters forest communities by reducing canopy cover, leaf litter, and coarse woody debris (Hutchinson et al., 2005), and effectively interrupts natural vegetative community succession (Driscoll et al., 2010). Due to effective fire suppression by resource management agencies, large-scale naturally occurring wildfires have largely been replaced with smaller-scale prescribed burning. Typically, fires burn at different intensities across the landscape (Turner et al., 2003), creating a mosaic of different available habitats which can aid in maintaining biodiversity by providing new opportunities for both plants and animals (Fisher and Wilkinson, 2005). Structural habitat complexity produced by recently

burned landscapes can provide new microhabitat opportunities for species, such as shelter (Mushinsky, 1992), nesting (Bowman et al., 1999), and foraging (Porter et al. 2002). Previous studies have shown that fire disturbance can be beneficial to species that prefer earlier successional forests, such as heliothermic reptiles (Perry et al., 2009), while others have shown that species that rely on leaf litter layers for refuge may be more susceptible to the indirect effects caused by fire, such as injuries or predation (Howey and Roosenburg, 2013).

The eastern fence lizard, *Sceloporus undulatus*, is a forest-dwelling lizard that occurs across the eastern United States (Tinkle and Ballinger, 1972; Angilletta, 2001; Langkilde and Boronow, 2012). Fire is a common landscape disturbance throughout the range of *S. undulatus* and population increases following fire events have been documented (Greenberg et al., 2010). The primary objective of this research is to quantify the phenotypic response of *S. undulatus* to habitat alteration created by fire. Because fire creates physical changes in habitat structure (i.e. changes in prey assemblage and thermal regime), we hypothesize that habitat heterogeneity created by fire would induce a phenotypic response in body condition and/or locomotor performance of *S. undulatus*, both traits that have been used as proxies for measuring fitness (Stevenson and Woods, 2006; Husak et al., 2006). We predict that recently burn sites would provide new foraging opportunities, and an increase thermal opportunities within *S. undulatus*'s thermal optima, which could provide a mechanism for a phenotypic response. The unique relationship between temperature, physiology, and ecology of reptiles may result to flexible phenotypes in response to environmental change created by fire.

CHAPTER II

MATERIALS AND METHODS

Localities Examined

Study sites were located at Land Between the Lakes National Recreation Area (LBL) in Trigg County, Kentucky. Vegetation at LBL is dominated with secondary oak-hickory forest (Close et al. 2002). During Spring and Summers of 2014 and 2015, adult (≥ 1 year of age) Eastern Fence Lizards were captured by hand or by noosing (Fitzgerald, 2012). Sex was determined by morphological characteristics and ventral coloration. Adult males display conspicuous dark blue coloration on their throat and ventral areas, while females show very little to no coloration on their throat or venter (Cooper and Burns 1986; Smith and John-Alder 1999). Reproductive condition of females was noted in the field, and gravid females were not used for locomotor performance trials. Capture locations were recorded with a handheld GPS (Garmin Fēnix® GPS) and percent canopy cover at location of capture was measured for a subset of captured lizards ($n = 34$) with a spherical densiometer. Lizards were placed in cloth bags and transported to Hancock Biological Station (Murray, KY) for laboratory locomotor performance trials. After completion of locomotor trials, lizards were marked with a unique toe clip and released at point of capture.

Performance Measurement Protocol

To measure the effects of habitat alteration on performance, three study areas with different fire histories were selected in LBL during 2014. The first was a control site (CONTROL) which had not experienced fire in more than 60 years (Franklin, 1994) the second site was prescribe burned in March 2010 (RECOVERING; four years since burning), and the

third was prescribed burned in February 2014 (RECENT BURN; < 6 months since burning). Each site was 160 to 1000 hectares in size and surrounded by mixed oak-hickory forest.

Each habitat treatment was visited and searched for lizards at least twice a week, and locomotor performance trials occurred within 24 hours of capture. Before each locomotor trial, lizards were placed individually into copper containers (repurposed autoclave pipette boxes; 4 cm x 6 cm x 25 cm) that were housed inside a lighted incubator. Copper containers were chosen due to their ability to respond rapidly to changes in temperature. Incubator temperature was maintained at 33° C, which is the preferred body temperature (T_p) of *S. undulatus* in a laboratory thermal gradient (Angilletta, 2001). After 30 minutes in the incubator, lizards were placed on a 2.4 x 0.2 m racetrack and encouraged to sprint the length of the racetrack by prodding with a paintbrush. Runs were video-recorded using a Midland XTC 720p High Definition Action Camera that was set to record at 35 frames s⁻¹. The camera was mounted 3 m above the center of the racetrack, such that the entire length of the track was visible on the recording. The racetrack floor was covered by Astroturf, which was marked into 25 cm segments with a white paint pen.

Lizards were raced a three times with trials separated by at least 30 minutes to allow lizards time to recover. The quality of each sprinting trial was classified as “poor” if the lizard paused or reversed direction while sprinting, or “good” where a continuous run was made (Van Berkum and Tsuji 1987). A minimum of two “good” trials were needed for an individual to be included in analyses of maximum sprint speed and maximum total speed. The same researcher (K.W.) conducted all trials and video analysis. Videos were analyzed using Tracker Video Software (version 4.85; www.cabrillo.edu/tracker), following standard video protocols for measuring sprint speed (Tulli et al. 2012). For each video, distance was calibrated by measuring 1-meter of the racetrack distance on-screen using the calibration stick tool. Digitization was

started at the first frame in which the lizard's snout crossed the starting line of the racetrack. Using the manual Point Mass tool, we then proceeded frame by frame to determine when the lizard's snout crossed each of the eight 25 cm segment marks. Maximum sprint speed was defined as the single fastest 25 cm interval of the two best trials. Maximum 2-meter run (2-meter run) was determined by the single fastest total 2 m of the two best trials. After locomotor trials morphological measurements were recorded for each individual including snout-to-vent length (SVL), body mass, and hindlimb length (HLL). Lizards were measured using a ruler to the nearest 0.1 mm for length and a Pesola scale to the nearest 0.25 g for mass.

A general linear model (GLM) was used to compare individual performance measurements (maximum sprint speed and 2-meter run) among the habitats with different fire histories (< 6 months since burn, 4 years since burn, and 60+ years since burn). The main effects for the GLM were sex and site, on both performance measurements, with hindlimb length (HLL) and body condition index (BCI) used as covariates. Hindlimb length was used to remove the potential effects of body size on performance (Tsuji et al. 1989). The Body Condition Index (BCI) was used as an estimate of individual health and to test whether this influenced locomotor performance. The BCI was calculated from the residuals of an ordinary least squares (OLS) linear regression of mass (g) on length (SVL). If main effects of the model were significant they were followed with a Tukey HSD post-hoc test; LS Means are reported to account for differences in body size. An ANOVA was used to compare BCI measurements of *S. undulatus* among recent burn, recovery, and control treatments. Any individuals with missing tails were excluded from BCI analysis.

Habitat Measurements

To determine whether habitats with different burn histories differed in thermal opportunities for lizards, environmental data loggers (Hobo Pendant Loggers) were randomly placed along a 100 m transect at the recent burn, recovering, and control sites (11 loggers at each site). Data loggers recorded temperatures every ten minutes over a three-day period in early July (2015). For analysis, the maximum (max) and minimum (min) temperatures of each site were calculated for each hour of the day. For estimating differences in thermal opportunities among the burn and control habitats, the duration in which environmental temperatures were within the 95% performance breath interval for locomotor performance (B_{95} : 31.3 – 37.0 °C; Angilletta, 2001) were quantified over a 72-hour period. Canopy cover of lizard capture locations was compared among sites with ANOVA and a Tukey HSD post-hoc test for pairwise comparisons between sites.

Repeatability

We estimated the repeatability of locomotor performance across years using lizards captured and measured for locomotor performance in 2014 and again in 2015. Lizards were individually marked with toe clippings after the first measurement in 2014, and in 2015 recaptured lizards were identified by unique toe clippings, and were rerun for performance measurements. For both years, lizards were subjected to the same performance measurement protocol mentioned above. To test for repeatability of locomotor performance, a linear regression of individual performance speeds in 2014 was compared to individual performance speeds in 2015 (Pearson's correlation coefficient). Due to the difficulty in capturing the same animals across years, samples from the three habitat treatments were pooled for repeatability analysis.

CHAPTER III

RESULTS

A total of 80 lizards were captured and tested for locomotor performance during the 2014 field season, 28 in control habitat (mean SVL of 63 ± 1.34 mm), 26 in recovering habitat (mean SVL of 65 ± 1.29 mm), and 26 lizards in the burn habitat. Snout-to-vent length did not vary among the three treatments (mean SVL of 67 ± 1.34 mm; $F_{2,77} = 2.92$; $P = 0.06$) and there was no significant difference in body condition indices of lizards among the habitat types ($F_{2,76} = 0.16$; $P = 0.86$). In comparing maximum sprint speeds of all lizards captured at the three habitats, there was no significant difference speeds between males (LS mean = 2.80 m/sec) and females (LS mean = 2.59 m/sec; $F_{1,73} = 0.28$; $P = 0.60$). The model covariate of body condition (BCI) had no significant effect on maximum sprint speed ($F_{1,73} = 0.05$; $P = 0.82$), however hindlimb length covariate (HLL) had a significant effect on maximum sprint speed ($F_{1,73} = 6.37$; $P = 0.01$). Once the effects of sex, BCI, and HLL were accounted for, habitat type had a significant effect on maximum sprint speed ($F_{2,73} = 24.59$; $P < 0.01$; Table 1; Figure 1). Pairwise comparisons of lizards captured at the different habitats showed lizards in the recent burn habitat had a significantly higher maximum sprint speed (LS mean = 3.14 m/sec) than those captured in control habitat ($P < 0.01$; LS mean = 2.31 m/sec) or recovering habitat ($P < 0.01$; LS mean = 2.58 m/sec). There was no significant difference between the maximum sprint speeds of lizards captured at recovering and control habitats ($P = 0.09$).

Comparing 2-meter run of all lizards at all three habitats, there was no significant difference in 2-meter run speeds between males (LS mean = 1.76 m/sec) and females (LS mean = 1.95 m/sec; $F_{1,73} = 0.21$; $P = 0.65$). The model covariate of body condition (BCI) had no significant effect on 2-meter run speed ($F_{1,73} = 0.08$; $P = 0.78$), but the hindlimb length covariate

(HLL) had a significant effect on 2-meter run speed ($F_{1,73} = 5.40$; $P < 0.05$). Once the effect of sex, BCI, and HLL were accounted for, habitat type had a significant effect on 2-meter run speed ($F_{2,73} = 24.59$; $P < 0.01$; Table 1; Figure 1). Pairwise comparisons of lizards captured at the different habitats showed lizards in the recent burn habitat had a significantly faster 2-meter run speed (LS mean = 2.26 m/sec) than those captured in control habitat (LS mean = 1.73 m/sec; $P < 0.01$) or recovering habitat (LS mean = 1.86 m/sec; $P < 0.01$). There was no significant difference between the 2-meter run speeds of lizards at recovering and control habitats ($P = 0.53$).

Thermal opportunities for lizards to maintain body temperatures within the B_{95} (optimal sprint performance range; $31.3 - 37.0$ °C) varied among the three habitats (Figure 2). Over the 3-day temperature measurement period, the recent burn habitat offered more opportunities to maintain T_b within B_{95} (9.3 ± 1.2 hours per day) than recovery habitats (7.0 ± 1.5 hours per day), or control habitats (6.7 ± 1.3 hours per day). Vegetative canopy cover for lizard capture locations differed significantly among habitats ($F_{2,31} = 20.42$; $P < 0.01$). Pairwise comparison of canopy measurements among the three habitats showed that recent burn habitats had a significantly lower percent canopy cover (56 ± 3.13 %) than recovering (79 ± 3.56 %; $P < 0.01$), and control habitats (82 ± 3.40 %; $P < 0.01$). There was no significant difference in percent canopy cover between control and recovering habitats ($P = 0.74$).

In comparing the annual repeatability of maximum sprint speed and 2-meter run, 14 individuals were measured during both 2014 and 2015 (8 males and 6 females). Maximum sprint speeds were significantly repeatable between 2014 (2.54 ± 0.43 m/sec) and 2015 (2.44 ± 0.47 m/sec; $r = 0.74$; $t_{1,12} = 34.96$; $P < 0.01$). Also, 2-meter run speeds were significantly repeatable between 2014 (1.79 ± 0.54 m/sec) and 2015 (1.79 ± 0.47 m/sec; $r = 0.41$; $t_{1,12} = 8.20$; $P = 0.01$).

CHAPTER IV

DISCUSSION

This study demonstrates an example of plasticity in locomotor performance traits in *S. undulatus* and how they vary in response to different thermal environments following habitat alteration created by prescribed fire. Lizards captured in recently burned habitats (burned 3-6 months previous) exhibited significantly higher maximum sprint speeds and higher two-meter run speeds than lizards inhabiting recovery or control habitats (Figure 1). The increased habitat structural heterogeneity and open vegetative canopy created by prescribed fire lead to an increased range of environmental temperatures and thus increased thermoregulatory opportunities available to lizards in recently burned habitats. This shift in thermal regimes in burned habitats is likely the underlying mechanism leading to plasticity in lizard performance. When testing the effect of sex on locomotor performance, there was no difference between males and females in maximum sprint speed or two meter run speed (Table 2). These results, coupled with lizards in burn habitats having significantly faster locomotor performance speeds, shows that the thermal environment in burn habitats is acting on this phenotype the same way on both males and females.

Our data shows that the occurrence of low-intensity prescribed fire led to pronounced structural and thermal differences among habitats, and this in-turn led to phenotypic differences in lizard populations inhabiting those habitats. Vegetative canopy cover was significantly lower at lizard capture sites in the burned habitat than recovery or control habitats. This structural heterogeneity in recently burned habitats provides an increased opportunity of around 2.3 hours per day more for lizards to maintain body temperatures within the B_{95} than recovery or control habitats (Figure 2). This additional opportunity for maintaining body temperatures within the B_{95}

may provide lizards in the burn habitat with the ability to achieve body temperatures that are closer to their thermal optimum for sprinting for longer periods of time than lizards captured in recovery or control habitats. Lizard muscle power output has shown to have a strong thermal dependence (Putnam and Bennett, 1982), thus lizards in burn habitats have the ability to maintain temperatures that increase muscle power output for longer periods of time. Hossack et al. (2009), found differences in the opportunities for toads (*Bufo boreas*) living in habitats with different burn severities (unburned, partial, and high severity), and *B. boreas* preferred landscapes that were more thermally optimal by selecting micro-habitats that maintained their B_{95} . These results further support our finding that burn habitats can provide habitat thermal heterogeneity that is beneficial to ectotherms.

Recently burned habitats that yield wider temperature ranges over longer periods could also provide the ability to maintain body temperatures that favor higher rates of energy assimilation. Angilletta (2001), found that *S. undulatus* populations from South Carolina and New Jersey differed in metabolizable energy intake (MEI) because populations in South Carolina had more opportunities to maintain temperature within their preferred temperature range. These results suggest that there is variation in physiology among populations that is driven by differences in thermal quality of the habitat. On a more localized scale, we observed similar results regarding the relationship between thermal opportunities and phenotypic response. In having habitats that permit lizards to achieve preferred body temperatures for longer periods of time (e.g. burn sites) lizards may reduce time and energy spent on thermoregulation and could therefore allocate more time to foraging and acquiring energy (Huey, 1991). The opportunities for lizards in burn sites to more easily maintain temperatures near their thermal preference for

longer periods could result in higher performance speeds when held at a constant temperature in laboratory settings.

The most likely explanation for the observed phenotypic differences in lizard locomotor performance is thermal acclimatization. A class of phenotypic plasticity known as acclimatization can be defined as a rapid change (typically within days or months) of a physiological trait in response to an environmental cue (Schulte et al., 2001). Angilletta (2009) defines reversible thermal acclimatization as reversible responses to diel or seasonal changes in temperature during an adult's lifetime. Rather than demonstrating seasonal changes in performance due to changes in temperature, our study provides an example of acclimatization as a function of changes in environmental temperatures brought about by habitat alteration caused by fire.

Several examples from the literature support the contention that thermal acclimatization or acclimation enhances various performance abilities across taxa, such as filtration in mollusks (Newell et al. 1997), fighting success in crustaceans (Seebacher and Wilson, 2006), swimming in fishes (Temple et al., 2000), jumping in amphibians (Renaud and Stevens, 1983), and swimming performance in reptiles (Glanville and Seebacher, 2006). The time scale over which acclimatization or acclimation occurred in these particular studies was from days to months, suggesting that organisms can rapidly adjust physiology to new thermal environments. When exposed to altered thermal regimes, *S. undulatus* measured in this study seem to take advantage of these new thermal opportunities that provide benefits through increased locomotor performance.

Measurements for individual maximum sprint speed and two-meter run speed were significantly repeatable among years (2014 and 2015). Repeatability of a particular phenotype

through time has been used to understand heritability of performance traits of ectotherms such as speed and endurance (Putnam and Bennett, 1981; Van Berkum et al., 1989; Austin and Shaffer 1992). Though we had limited sample sizes between sex (8 males and 6 females), these significant repeatabilities of maximum sprint speed and 2-meter run speed suggest that performance may have genetic component (Husak et al., 2006b). Between-year repeatability in locomotor performance has been documented in other *Sceloporus* species (Van Berkum et al., 1989 *S. occidentalis*; Huey et al., 1990 *S. merriami*), however these studies compared the repeatability of locomotor performance of populations or repeatability of lizards reared in a captive setting. Our results are noteworthy due to the difficulty of capturing the same individuals over the course of two study seasons, and to our knowledge is the first study to observe individual between-year repeatability in performance in free-ranging *S. undulatus*. Repeatability of expression of a phenotypic trait may show how effective natural selection is on that trait over time, and if an individual measurement is consistent over time then this would suggest that such a trait is likely under strong selection (Brodie and Garland, 2007). Thus, our results on significant repeatability of performance measurements validates the use of this measurement and its importance on *S. undulatus*.

We failed to detect differences in body condition among habitat types in our study. The use of body condition indices as a surrogate measure for energetic state and nutritional status of an organism has been subject to recent debate (Peig and Green, 2010; Schulte-Hostedde, et al., 2005; Barnett et al. 2015). It is assumed that an animal in good condition would have more energy reserves than an animal in poor condition, potentially resulting in important survival and fitness-related benefits. Studies investigating how habitat disturbance influences body condition of reptiles have produced mixed results (Howey and Roosenburg 2013; Amo et al., 2007).

Griffiths and Christian (1996) found significantly higher body condition for frilled-neck lizards (*Chlamydosaurus kingii*) in recently burned habitats than those in control habitats. They attributed the differences to increased prey abundance and to better foraging habitat created by opening up the vegetative community (tropical savannah) after fire disturbance. Although the mixed-hardwood forest habitats in our study showed pronounced structural differences due to fire history, we found no distinguishable differences in body condition among lizard in the three habitats.

If body condition is related to fitness, then there should be a link between other proxies of fitness, such as locomotor performance. We tested whether body condition indices predicted locomotor performance, and our results indicate strong evidence that body condition was not a informative covariate for either of our performance measurements (Table 1). These results are consistent with other studies in the literature that tested this functional relationship between condition indices, generated from morphological measurements, and their relation to various performance measurements (Amo et al., 2007; Vervust et al., 2008). Vervust et al. (2008) tested six commonly used morphological condition indices to predict locomotor performance abilities (maximum sprint speed and maximum exertion) in *Podarcis sicula*, and found that no condition index consistently predicted locomotor performance ability.

Understanding how performance of *S. undulatus* is influenced by fire-altered habitats is essential for understanding the unique relationship between temperature, physiology, and ecology of reptiles and how changing habitats may result to flexible phenotypes. Our data show how a fitness-related measurement, locomotor performance, can change rapidly in response to environmental alteration. We suggest that structural changes in the environment due to fire have created new thermal opportunities, where *S. undulatus* have demonstrated the ability to acclimate

to different thermal regimes resulting in measurable differences in locomotor performance. Our results suggest that there are physiological and, possibly, fitness related benefits for reversible acclimatization. However, more research is needed to explain the underlying mechanisms, and the costs associated with phenotypic plasticity.

CHAPTER V

LIST OF TABLES

Table 1. Results of General Linear Model using sex and site (habitats with contrasting fire histories) as main effects, and hindlimb length (HLL) and body condition index (regression residuals for BCI) using as model covariates. Data are reported as least squared means (LS Mean) in meters per second with 95% confidence intervals for both maximum sprint speed and 2 meter run speed. If letters above sex or site effect share a letter, then LS means are not significantly different on a pairwise base

Table 1. Results of General Linear Model using sex and site (habitats with contrasting fire histories) as main effects, and hindlimb length (HLL) and body condition index (regression residuals for BCI) using as model covariates. Data are reported as least squared means (LS Mean) in meters per second with 95% confidence intervals for both maximum sprint speed and 2 meter run speed. If letters above sex or site effect share a letter, then LS means are not significantly different on a pairwise bases.

Performance Metric	Sex		Site			Covariate		
	Male	Female	Sex	Burn	Recovery	Control	HLL	BCI
Maximum sprint speed (m s ⁻¹)	2.70 (2.58-2.82) ^A	2.65 (2.50-2.79) ^A	p = 0.60	3.12 (2.96-3.28) ^A	2.57 (2.42-2.72) ^B	2.32 (2.16-2.49) ^B	p < 0.01	p = 0.82
2 Meter run speed (m s ⁻¹)	1.86 (1.73-1.98) ^A	1.81 (1.66-1.96) ^A	p = 0.65	2.24 (2.07-2.40) ^A	1.70 (1.54-1.86) ^B	1.56 (1.39-1.73) ^B	p = 0.02	p = 0.78

CHAPTER VI

LIST OF FIGURES

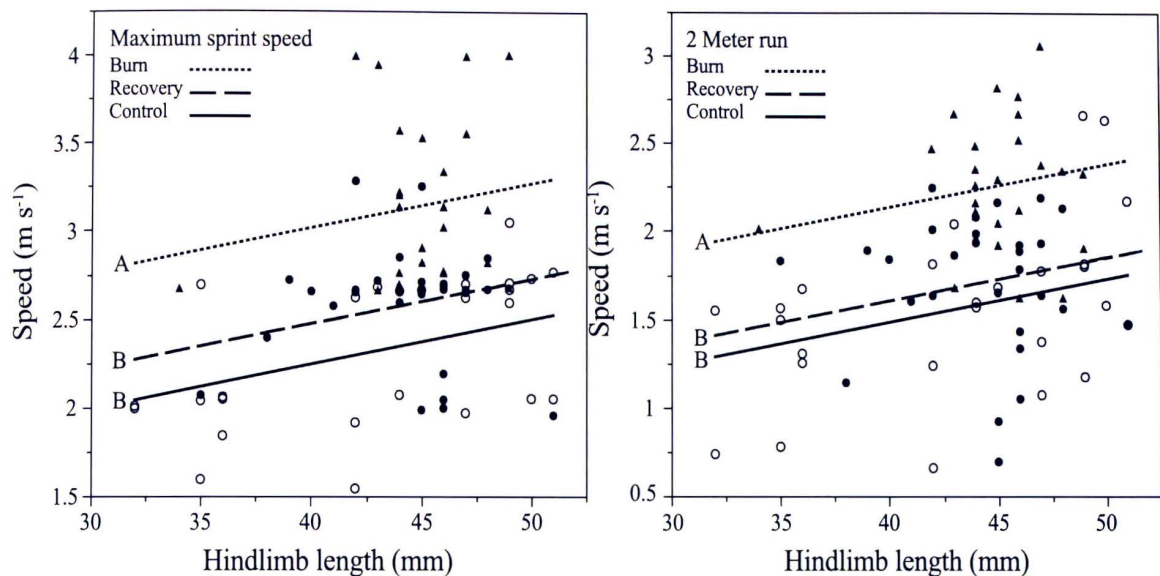
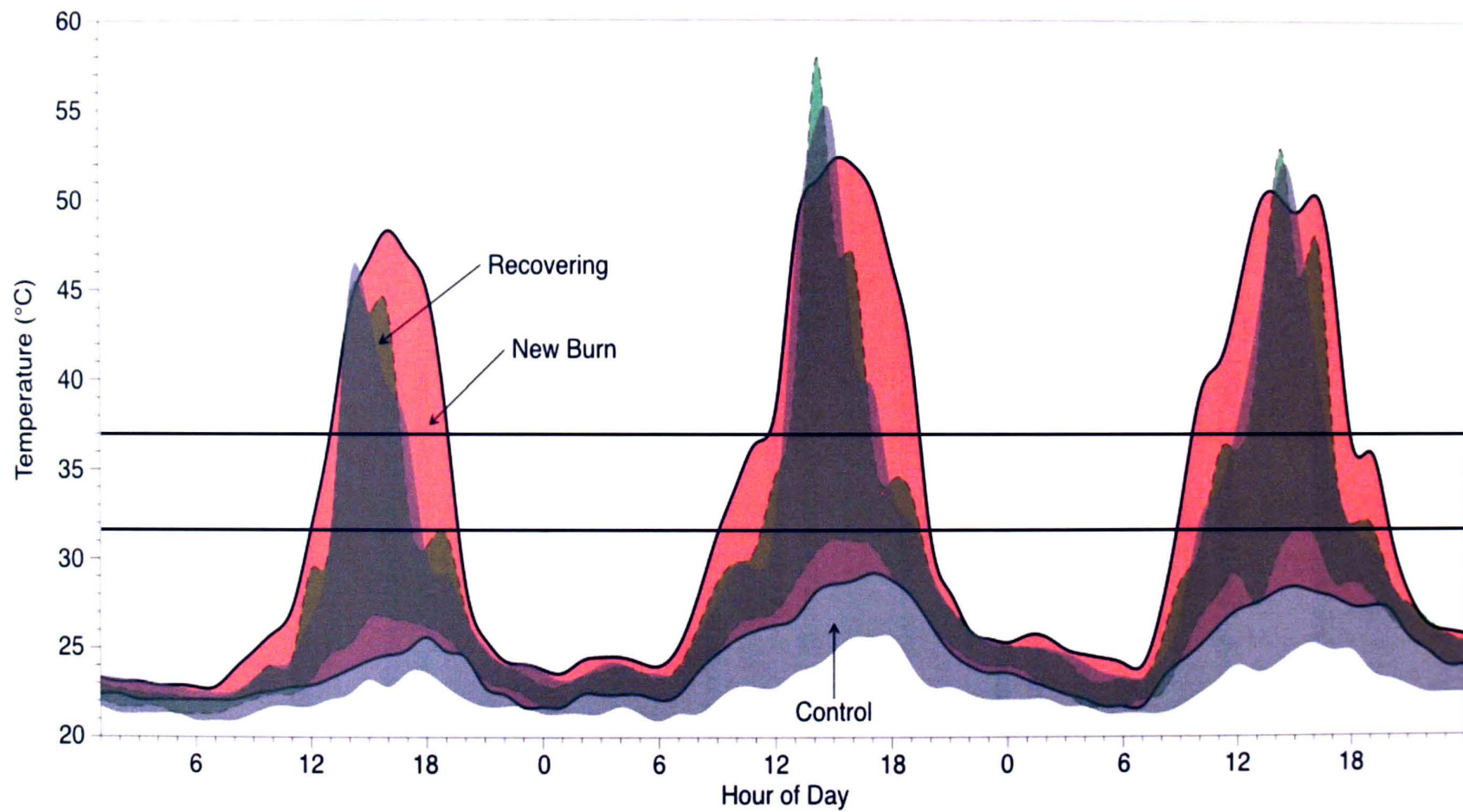


Figure 1. Maximum sprint speed (left) and 2 meter run (right) of lizards captured at three habitats with contrasting fire histories during 2014 (ANCOVA, hindlimb length as covariate). Triangles represent lizards captured at burn habitat (< 6 months since burned). Solid circles represent lizards captured at recovery habitat (4 years since burn). Open circles represent lizards captured at control habitat (60 \geq years since burn). Lines sharing a letter, then LS means are not significantly different from each other ($P > 0.05$). Lizards captured in the recently burned habitat had both significantly higher maximum sprint speed or 2 meter run speed than lizards captured in recovery or control habitats.

Figure 2. To compare environmental thermal opportunities among the three sites, min/max temperature envelope of hourly environmental temperatures ($^{\circ}\text{C}$) were recorded at each habitat over a 72-hour period in June, 2014. Red represents temperatures in recent burn habitat, green represents temperatures in recovery habitat and grey represents temperatures in control habitat. Solid black line represents 95% performance breadth interval (B_{95} : $31.3 - 37.0^{\circ}\text{C}$) of *Sceloporus undulatus* (Angilletta et al., 2002). Over a 72-hour period the recent burn habitat had a higher daily mean within B_{95} (9.3 ± 1.2 hours) than recovery (7.0 ± 1.5 hours) and control (6.7 ± 1.3 hours) habitats.



CHAPTER VII

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