

Winter Microhabitat Selection and Growth of Jacky Dragons (*Amphibolurus muricatus*)

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Most temperate-climate lizards become inactive during the winter months of each year. As temperatures drop, they must find appropriate overwintering microhabitats to avoid lethal surface temperatures and/or thermoregulate. The environmental variables that characterize such microhabitats and the cues that lizards utilize to assess them are a critical but understudied component of their natural history. While many studies of overwintering site selection focus on temperature, other factors constituting microhabitats (e.g., surface structures, substrate) may play a role in site selection. We used the Jacky Dragon (*Amphibolurus muricatus*), an Australian agamid lizard, to test for preference of using various cover types (leaf litter, open sand, sticks, rocks) for overwintering as well as the consequences of cover type selection. Jacky Dragons preferred overwintering beneath leaves compared to other structures, and this choice was associated with growth during winter, but not with survival. Our study highlights the potential importance of cover structures in overwintering site selection, suggests that midwinter activity may be common in Jacky Dragons, and calls for further study of the winter ecology of temperate-climate lizard species.

MOST lizards that inhabit temperate regions become dormant during winter, and their distribution, abundance, and activity are partially influenced by their ability to withstand winter conditions (Spellerberg, 1976; Strijbosch et al., 1980; Bauwens, 1981; Gregory, 1982; Bredin, 1989). Across high latitudes, species undergo true hibernation (a period of little or no activity) to survive the potentially lethal temperatures of winter and spend as much as two thirds of their life in a state of winter-induced torpor (Etheridge et al., 1983; Powell and Russell, 1998, 2007). These species often select hibernacula for their thermal properties, which serve to buffer individuals against deadly surface temperatures (Legler and Fitch, 1957; Elfström and Zucker, 1999; Grenot et al., 2000). Even so, mass die offs from lethal temperatures occur (Scott and Sheldahl, 1937; Tinkle, 1965; Worthington and Sabath, 1966; Nussbaum and Diller, 1976; but see Wilson and Cooke, 2004), and therefore, the ability to locate appropriate hibernacula is likely under strong selection.

Alternatively, in lower temperate latitudes, some lizard species do not truly hibernate but simply become inactive during the colder months, emerging on warm winter days (Davis, 1967; Weintraub, 1968; Ruby, 1977; Wapstra and Swain, 1996; Bishop and Echternacht, 2004). Because individuals of these species may benefit from episodic winter activity through faster growth and decreased time to maturity (Ballinger and Congdon, 1980; Adolph and Porter, 1993), the selection of overwintering sites that allow for thermoregulation rather than solely for the avoidance of lethal temperatures is likely important. For example, the Green Anole (*Anolis carolinensis*) is a widely distributed North American lizard that does not hibernate. Individuals remain active during warm winter days, occasionally feed, and achieve some growth over winter, even at the northern limit of their range (Bishop and Echternacht, 2003). During winter, individuals of this species are known to utilize thermally stable crevices that allow them to avoid cold temperatures but also provide access to the surface in order to opportunistically raise body temperatures (Bishop and Echternacht, 2004). Because fecundity in females and mating success in males often covary with body size (Ruby, 1984;

Andrews, 1985), overwinter activity that results in growth might be advantageous; therefore, selection of overwintering sites that maximizes the opportunity for growth is likely advantageous.

Whether an individual truly hibernates or merely becomes temporarily inactive, each individual must select an appropriate microhabitat in which to overwinter to survive low temperatures or thermoregulate (Gregory, 1982; Zani et al., 2012). Moreover, to our knowledge, all temperate-climate lizard species experience at least one winter prior to reaching sexual maturity; therefore, selecting an appropriate overwintering site is important for fitness. Clearly, overwintering site choice is a critical component of lizard natural history at higher latitudes, yet it remains poorly understood (Mathies and Martin, 2008). Due to the sparse literature on hibernation ecology in lizards, particularly as it relates to site choice, any new information about this important aspect of their natural history will be an important contribution.

The Jacky Dragon (*Amphibolurus muricatus*) is a medium sized (~90 cm snout–vent length), wide ranging, and locally abundant Australian agamid lizard (Harlow and Taylor, 2000; Cogger, 2014). Its reproductive period spans from September to March (Spring/Summer), and lizards typically become inactive as temperatures cool in May (Autumn) and remain relatively inactive through July (Winter; Harlow and Taylor, 2000). As with some other temperate-climate lizards, individuals occasionally emerge on warm winter days (D. A. Warner, pers. obs.). Despite its relative abundance and wide geographical distribution (Barquero et al., 2015), many aspects of the Jacky Dragon's ecology are still undescribed (Harlow and Taylor, 2000). Our primary objectives were to: 1) determine if Jacky Dragons exhibit a preference for overwintering microhabitats under controlled conditions; and 2) assess the potential consequences of microhabitat choice on survival and growth during winter months. To address these objectives, we placed 132 juvenile Jacky Dragons into large, outdoor enclosures in June, just prior to winter, and provided them with several choices of overwintering sites that differed in cover material (leaves, sticks, tile). These individuals were later collected just before their natural emergence, and we

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Table 1. Sample sizes of lizards by sex and incubation treatment for each of the 14 enclosures. During summer 2004, prior to this hibernation study, lizards were placed into six outdoor enclosures with equal numbers of each treatment/sex. At the end of summer and beginning of this study, these lizards were moved to these 14 enclosures; however, for logistical reasons associated with another study, we housed lizards overwinter with their summer cage mates. Thus, the total number of lizards, sex ratio, and number of individuals from each treatment vary across enclosures because of mortality that occurred during summer.

Enclosure	Total	Sex		Incubation treatment					
				Control			Fadrozole		
		Males	Females	23°C	27°C	33°C	23°C	27°C	33°C
1	9	2	7	1	2	2	1	1	2
2	7	3	4	3	0	0	3	0	1
3	9	5	4	1	1	1	2	3	1
4	14	5	9	2	3	4	2	3	0
5	12	7	5	1	2	1	3	2	3
6	7	3	4	3	0	0	1	2	1
7	6	3	3	2	1	1	2	0	0
8	8	5	3	0	0	2	2	2	2
9	8	4	4	4	2	0	0	1	1
10	9	3	6	1	2	2	2	2	0
11	11	9	2	3	3	1	2	0	2
12	11	8	3	1	2	3	1	2	2
13	12	9	3	1	2	4	2	3	0
14	9	5	4	3	1	1	2	1	1

noted their final choice of overwintering cover type, measured their growth, and assessed survival.

MATERIALS AND METHODS

The juvenile lizards used in this study were part of another study designed to quantify the long-term effects of egg incubation temperature on survival and reproduction (Warner and Shine, 2005). Thus, specific details concerning collection, incubation, and original housing of animals are published elsewhere (Warner and Shine, 2005). Briefly, from September to December of 2003, gravid females were collected from the field near Sydney, Australia and housed in captivity until oviposition. Eggs were laid from October 2003 to February 2004 and divided into six incubation treatments in a 2x3 factorial design. This experiment contained three incubation temperature regimes (23°C, 27°C, 33°C), and a hormone manipulation (Fadrozole vs. control) used to sex reverse developing embryos. The hormone manipulation had no effects on growth or morphology. Incubation treatment, conversely, influenced growth and morphology: lizards from the warmest incubation treatment (33°C) were shorter and weighed less at hatching than those from the cooler treatments; however, because higher incubation temperatures increase developmental rate in reptiles (Georges et al., 2005), they hatched sooner and had more time to grow prior to winter. Thus, lizards from the warmer incubation treatments were larger at the start of our study than those from cooler treatments (see Warner and Shine, 2005). For reviews of the influence of incubation temperature on reptiles see Andrews (2004) and Booth (2006). At hatching, lizards were each uniquely marked by toe-clipping and briefly maintained (average of six days) under standard laboratory conditions, fed crickets daily, and then transferred into outdoor enclosures at Macquarie University where they were housed over the remainder of the summer (January to June). During this time,

lizards were fed crickets thrice weekly and took natural prey items that fell into the enclosures.

Experimental design.—From 13–18 June 2004, just prior to winter, we collected all surviving juvenile lizards that we could find at that time ($n = 71$ males, 61 females) from their outdoor enclosures and recorded their mass to the nearest 0.001 g with a Sartorius B310S balance (Gottingen, Germany) and snout–vent length (SVL) to the nearest 1 mm using a ruler. Each lizard was relocated to one of 14 smaller, open-air enclosures ($n = 6–14$ lizards per enclosure) located on the roof of a building at the University of Sydney (see Table 1 for sample sizes per enclosure). The entire area was caged to exclude predators. Enclosures were of two types: either oval tubs (148 cm long x 95 cm wide x 66 cm deep, $n = 7$) or round tubs (120 cm diameter x 50 cm deep, $n = 7$). Each tub was filled approximately 7 cm deep with sand and divided into four equally sized sections that each represented a potential overwintering site, among which lizards could move freely. Three sections were each filled with a single cover type, either 1) dried leaves, 2) sticks, or 3) tiles that covered the sand. The sticks and dried leaves (*Eucalyptus*) were collected on the campus of the University of Sydney. The sticks were haphazardly arranged in a pile so that they crossed each other. Although stick size and pile depth were not directly measured, sticks roughly ranged in size from about 1–4 cm diameter in a 5–7 cm deep pile. The dried leaves were also piled haphazardly approximately 4–5 layers deep. Tiles were haphazardly stacked to create spaces within which lizards could hide, thus simulating rocky habitat that could be used as overwintering cover. The fourth section of the enclosures contained only sand, which allowed individuals to choose none of the provided cover structures, overwintering buried in the sand or in the open. No food or water was provided to animals during the study, but insects occasionally fell into the enclosures and rainwater and dew provided potential sources of hydration. On 5–6 September, at the end of winter,

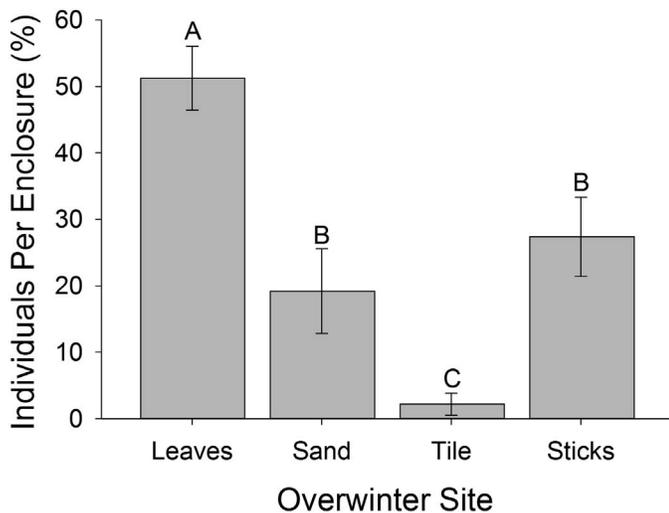


Fig. 1. Average percentage of individuals that chose each overwintering cover type per enclosure ($n = 14$). Bars represent standard error. Letters above bars denote groups that were statistically different from each other.

we removed all animals from their enclosures, measured their mass and SVL, recorded the cover types under which individuals were found, and noted whether each lizard was alive or dead. We did not thoroughly check enclosures through the winter and individuals may have moved between cover structures during the study. Individuals were assigned to the type of cover they were found in at the end of the experiment. We assume this is where they spent the majority of the winter.

Statistical methods.—Preliminary analyses using a generalized linear mixed model with incubation treatment (Warner and Shine, 2005), enclosure type, and sex as independent variables and specific enclosure as a random effect indicated that final cover type choice was not associated with incubation treatment ($F_{5,105} = 1.48$, $P = 0.20$), sex ($F_{1,105} = 0.04$, $P = 0.84$), or enclosure type ($F_{1,105} = 0.11$, $P = 0.74$). Therefore, individuals from all incubation treatments and both sexes were combined for the analysis of cover type preference. To assess preference of overwintering cover type, we tested for nonrandom distribution of individuals among cover materials using a Kruskal-Wallis rank sum test against the null hypothesis that individuals were equally distributed. This analysis compared the ratio of individuals found under a given cover type at the level of the enclosure. A Dunn's test was used to make *post hoc* pairwise comparisons among cover types.

To assess the consequences of cover type choice, we analyzed growth and survival over the study period. We tested the effects of cover material, sex, incubation treatment, and enclosure type on survival using a generalized linear mixed model with a binomial distribution; for growth, we used mixed model ANCOVAs with either final mass or final SVL as the response variable and initial mass or initial SVL as a covariate; specific enclosure was a random effect. Preliminary analyses demonstrated that neither incubation treatment nor enclosure type affected growth or survival (all P -values > 0.20); these variables were excluded from all subsequent analyses and our models only considered cover material and sex. To determine how individuals found beneath each cover material differed in growth, pairwise

comparisons were performed using the lsmeans package in R (R Core Team, 2015). We used t -tests to determine if males and females differed in SVL or mass at the beginning of our study and Wilcoxon Ranked Sum tests to determine if growth in both mass and SVL over winter were positive. Mean growth in SVL was small in comparison to standard error; thus, we calculated change in SVL (final–initial) and mass (final–initial) for each individual and performed a linear regression between these values to determine if individuals that gained mass also grew in SVL; a positive relationship would suggest that measurement error likely contributed little to patterns of growth in SVL.

Our generalized linear model describing the effects of sex, incubation treatment, and enclosure type on cover type choice was performed in SAS 9.3 (SAS Institute, Inc., Cary, NC). All other analyses were performed in R 3.1.3 (R Core Team, 2015). Data collected by the Australian Government Bureau of Meteorology (Observatory Hill; site #066062) showed that the temperatures during this study (average daily high = 19.0°C, average daily low = 9.4°C, absolute high = 24.8°C, absolute low = 5.9°C) were consistent with typical winters in Sydney, Australia. These ambient temperatures likely differed little from those experienced by the lizards in this study because they were recorded only ~4 km from the University of Sydney, and the enclosed roof where the lizards were kept was only 3.5 m off the ground.

RESULTS

In general, lizards found beneath a cover material were curled into a circle, resting between the cover material and the sand. Each was nestled into the substrate and left behind a circular depression in the sand when removed. Most lizards found outside of cover materials were buried in the sand. Choice of overwintering cover material was nonrandom ($\chi^2 = 29.715$, $df = 3$, $P < 0.0001$), with a clear preference for leaves and aversion toward tile. The relative number of individuals per enclosure found in sand did not differ from the number found in sticks, but both of these cover types were less preferred than leaves and more preferred than tile (Fig. 1). Overwinter survival was high and did not differ among cover types ($\chi^2 = 27.54$, $df = 3$, $P = 0.90$) or between sexes ($\chi^2 = 28.12$, $df = 1$, $P = 0.47$; Table 2). Only 3 of the 132 juveniles (2.27%) died over winter, and these individuals were distributed among cover materials (1 beneath each of leaves, sand, sticks).

Initial mean mass and SVL (\pm SE) of females were 3.94 ± 0.24 g and 44.52 ± 0.92 mm; the corresponding statistics for males were 4.73 ± 0.33 g and 46.55 ± 1.09 mm. Males and females did not differ in SVL ($t_{130} = 1.39$, $P = 0.16$) or mass ($t_{130} = 1.86$; $P = 0.065$) at the beginning of winter; however, males were heavier at the end of our study (Table 2). Collectively, mass gain over winter was significantly greater than zero ($V = 7054$, $P < 0.0001$) with a mean gain of 0.25 ± 0.04 g (range: -0.073 to 2.24 g; Fig. 2). Similarly, gain in SVL was also greater than zero ($V = 3566$, $P < 0.0001$) with a mean gain of 0.57 ± 0.18 mm (range: -4.5 to 16.5 mm; Fig. 3), and we found a positive relationship between change in SVL and change in mass (Fig. 4).

Cover type influenced body mass ($F_{3,113} = 5.41$, $P = 0.0016$); individuals found in sand gained more mass than those in leaves and sticks but were not significantly different in mass gain from those in tile (Fig. 2). Sex also influenced mass ($F_{1,113} = 7.03$, $P = 0.0092$) with males ending the winter 0.18 g (± 0.068 SE) heavier than females (Table 2). Snout–

Table 2. Effect of cover type and sex on final mass, final SVL, and survival of overwintering juvenile Jacky Dragons. Initial mass and final mass were used as covariates for appropriate analyses. β s for sex reflect the difference of male minus female. See Table 3 for pairwise comparisons between cover types. Significant probabilities indicated in boldface.

Dependent variable	Final mass				Final SVL				Survival			
	df	$\beta \pm SE$	<i>F</i> value	<i>P</i> value	df	$\beta \pm SE$	<i>F</i> value	<i>P</i> value	df	$\beta \pm SE$	χ^2	<i>P</i> value
Cover type	3,113	—	5.41	0.0016	3,113	—	4.62	0.0043	3,127	—	27.54	0.9
Sex	1,113	0.179 \pm 0.068	7.028	0.0092	1,113	0.522 \pm 0.35	2.18	0.14	1,130	0.869 \pm 1.24	28.12	0.47
Initial mass	1,113	1.074 \pm 0.014	6530.4	<0.0001	—	—	—	—	—	—	—	—
Initial SVL	—	—	—	—	1,113	0.971 \pm 0.022	2279.5	<0.0001	—	—	—	—

vent length at the end of winter was influenced by cover material ($F_{3,113} = 4.62$, $P = 0.0043$), but the effect differed from that on body mass; individuals found under tile grew more in SVL than those from all other groups (Fig. 3). Final SVL was 0.52 mm (± 0.35) greater for males than females, but this was not statistically significant ($F_{1,113} = 2.18$, $P = 0.14$; Table 2).

DISCUSSION

Most studies of lizard winter ecology focus on temperature as the primary variable that influences overwintering site choice (Etheridge et al., 1983; Grenot et al., 2000; El-Masry and Hussein, 2001; Bishop and Echternacht, 2004), yet other aspects of microhabitats comprising overwintering sites (e.g., surface structures, substrate, moisture) may also play an important role (Mathies and Martin, 2008). Here, we provide evidence that overwintering site choice by juvenile Jacky Dragons is non-random with respect to cover materials. Jacky Dragons exhibited a preference for overwintering beneath leaves versus other cover types. This choice, however, provided no apparent benefit for survival or growth.

Collectively, Jacky Dragons tended to gain mass over winter; only 27% of individuals lost mass during the study. Most gains in mass and SVL were slight, but many individuals still exhibited measurable growth. When data were pooled from all cover types, 23% of lizards increased

their mass by 10% or more, and 20% increased their SVL by at least 3%. These gains in SVL are small and could be due to measurement error. Although we did not quantify measurement error for SVL, our regression analysis (Fig. 4) demonstrates a positive relationship between gain in mass and gain in SVL; thus, the mean increase in SVL is likely not wholly attributable to measurement error: individuals that increased in SVL also tended to be the individuals that gained mass.

Jacky Dragons are sexually dimorphic in body size, with adult males attaining a larger size than females (Harlow and Taylor, 2000). We observed that males gained more mass than females over the course of our study (Table 2) and were, thus, heavier at the end of winter than females. Although growth rates over the first six months of life varied among individuals, males and females did not differ in size at the start of winter nor did they show a difference in growth rates (Warner and Shine, 2005). Furthermore, Radder et al. (2007) report no differences in size or growth between sexes of Jacky Dragons during the first six months after hatching. Similarly, our data suggest that a difference in growth leading to sexual size dimorphism might begin during winter months. Past studies in other species of sexually dimorphic lizards show that winter growth can differ between sexes (Davis, 1967; Ruby, 1977; Bishop and Echternacht, 2003).

The resources used for overwinter growth are not apparent because we did not feed or water lizards during the study;

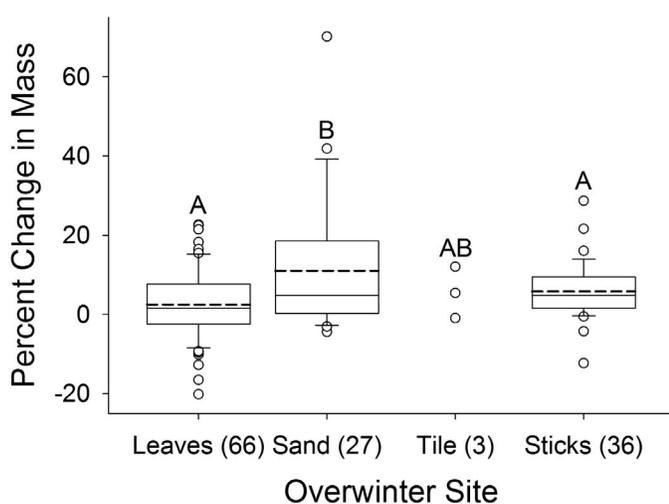


Fig. 2. Percent change in mass across cover materials. Sample sizes for each cover are given in parentheses beneath the x-axis. Boxes and whiskers show quartiles, solid horizontal lines show the median, dashed horizontal lines show the mean, and open circles show raw data points that are above, below the upper, lower quartiles. For tile, only raw data points are shown. Letters denote groups that were statistically different from each other.

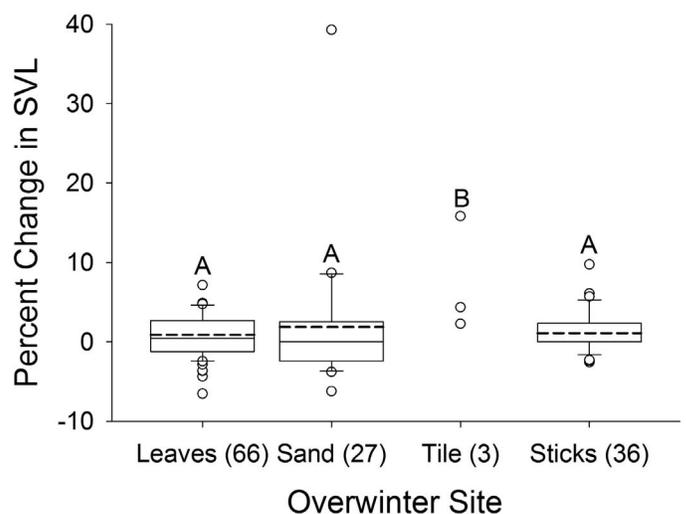


Fig. 3. Percent change in snout–vent length (SVL) across cover materials. Sample sizes for each cover are given in parentheses beneath the x-axis. Boxes and whiskers show quartiles, solid horizontal lines show the median, dashed horizontal lines show the mean, and open circles show raw data points that are above, below the upper, lower quartiles. For tile, only raw data points are shown. Letters above bars denote groups that were statistically different from each other.

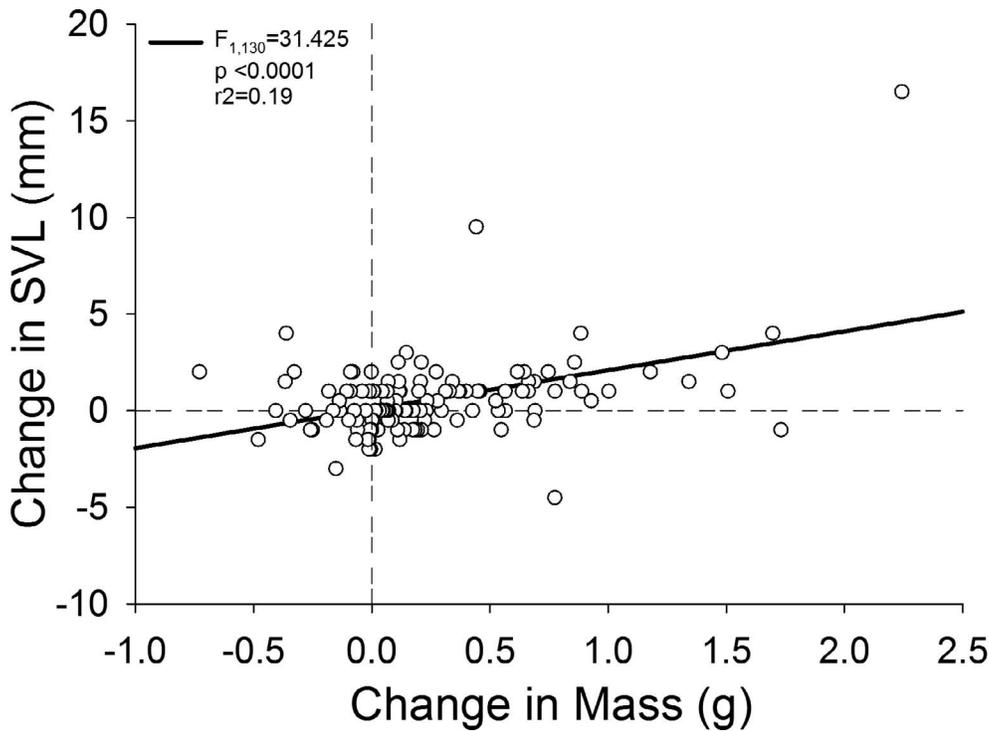


Fig. 4. Regression between change in snout-vent length (SVL) and change in mass. Dark, solid line shows the trendline for x and y values. Dashed lines provide a reference of zero.

however, occasional emergence on warm days may have allowed for foraging on insects that fell into the enclosures as well as hydration from dew or rainwater. Other research on Jacky Dragons in outdoor cages shows that mass can increase by about 160% and SVL by about 40% during the first six months of life when food is continuously provided (Radder et al., 2007). Our study period was half (three months) that of Radder et al. (2007) and the mean growth rate was substantially slower, probably due to a lack of supplementary feeding. Our results and those of Radder et al. (2007; both outdoor studies) suggest that consuming food and water during winter may be common for Jacky Dragons and possibly an important contributor to overwinter growth.

Given several potential benefits of overwinter growth (e.g., more rapid achievement of adult size, and thus increased reproductive success; Warner and Shine, 2008), the relationship between cover type choice and growth in our study does not support the prediction that individuals choose sites that maximize growth. On the contrary, the cover type most commonly selected by Jacky Dragons (leaves) was associated with the lowest mass increase (2.49% of original size) over the winter, and the cover material selected by the fewest individuals (tile) was associated with the highest growth in SVL (Fig. 2). Although these findings suggest that Jacky Dragons choose relatively poor cover materials for overwintering, several other considerations must be taken into account. For example, leaf litter might provide a more stable hydric and thermal environment during winter compared to the other cover materials available, and thus may buffer individuals from unpredictable environmental extremes. We did not measure temperature and humidity in our study, and it is possible that Jacky Dragons were selecting sites based upon these factors rather than the materials themselves. Additionally, natural selection may have shaped individual behavior to select sites that reduce the risk of predation which may be a greater threat to survival than abiotic winter conditions (Wilson and Cooke, 2004).

Incubation temperature is likely important for overwinter growth and survival of temperate-climate lizards (Strijbosch et al., 1980; Qualls and Shine, 1998; Civantos et al., 1999). Developmental rate, and thus seasonal timing of hatching, correspond with temperature. For example, individuals that hatch earlier in the season have more time to grow prior to winter, and this can confer a fitness benefit (Olsson and Shine, 1997; Warner and Shine, 2007). Though Jacky Dragons incubated at warmer temperatures grew at a faster rate leading up to winter and were larger at the start of our study (Warner and Shine, 2005), we observed no difference in overwinter growth or survival due to incubation treatment. This suggests that body size differences that result from seasonal timing of hatching may not influence overwinter survival of Jacky Dragons; however, Civantos et al. (1999) demonstrated that for hatchlings of *Psammotromus algirus*, larger individuals are more likely to survive winter. Our Jacky Dragons were studied for the remainder of their lives, and those incubated at warmer temperatures were always larger than those incubated at cooler temperatures (Warner and Shine, 2008); this difference in size was not due to growth over winter. Body size has been correlated with winter survival in snakes (Shine et al., 2001; Kissner and Weatherhead, 2005) and turtles (Mitchell et al., 2015), and many authors speculate that larger lizards have a survival advantage during winter due to greater energy reserves (e.g., Congdon et al., 1979; Civantos et al., 1999), but more studies across multiple taxa are required to determine the influence of body size on overwinter survival in lizards.

One caveat in our study is that we did not periodically check the lizards' locations throughout winter, and individuals may have shuttled between cover types; however, when found, each Jacky Dragon was curled into a circle, depressed in the sand, and unmoving so that we could simply lift it from the enclosure. We believe this indicates they were too cool to move and had been resting beneath this cover type for some time, but we cannot say exactly how long. Moreover, we cannot rule out the possibility that cover type

Table 3. Mean and standard error of overwinter site selection, change in mass, and change in SVL for each cover type. For cover type choice, the mean is the mean percentage of individuals in each enclosure ($n = 14$) that selected each cover type. For mass (g) and SVL (mm), the mean is the average percentage increase (final–initial/initial \times 100) of all individuals that selected each cover type.

Cover type	Choice		Mass (g)		SVL (mm)	
	Mean (%)	SE	Mean (%)	SE	Mean (%)	SE
Leaves	51.24	4.83	2.49	1.07	0.89	0.34
Sand	19.22	6.37	10.99	3.18	1.88	1.59
Tile	2.18	1.65	5.48	3.74	7.48	4.22
Sticks	27.36	5.96	5.77	1.21	1.1	0.43

preference is condition-dependent: during relatively warmer winter periods, lizards might aggregate beneath different cover materials than when conditions are relatively colder. Yet to be determined is the extent to which Jacky Dragons demonstrate overwintering site fidelity both in our study design and in the wild. Like some other temperate-climate lizard species, Jacky Dragons may exhibit high fidelity to overwintering sites during and across seasons (Gregory, 1982). For example, Bishop and Echternacht (2004) found that 69% of Green Anoles at their study site returned to the same crevice to overwinter for two consecutive winters; however, they also note that most individuals in their study alternated between the same few crevices throughout each winter. It is possible that the lizards in our study cycled through multiple or even all potential cover types through the winter. A future study could greatly expand upon ours by periodically monitoring the locations of lizards throughout winter and collecting environmental data (i.e., ambient temperature, rainfall, sky conditions) to determine if individuals exhibit condition-dependent preference for overwintering sites.

Further study is needed to better understand the behavioral choice of overwinter microhabitat and its consequences. For example, future research is needed to demonstrate 1) where Jacky Dragons overwinter in the wild, 2) the effects these locations have on winter growth and survival, and 3) the tradeoffs that may exist between opportunistic winter feeding and predation or exposure. Our data imply that relatively few individuals choose to overwinter in rocky areas (tile), but these individuals may be rewarded by increased growth over winter due to midwinter activity. Because rocky microhabitats achieve and maintain relatively warm temperatures (Ribeiro et al., 2008), individuals that choose these sites may have increased metabolism, or achieve a temperature that stimulates them to emerge and forage during winter.

Midwinter emergence and activity have been studied across most groups of non-avian reptiles (e.g., Green Anoles [Bishop and Echternacht, 2004], juvenile Gopher Tortoises [*Gopherus polyphemus*; Harris et al., 2015], and Timber Rattlesnakes [*Crotalus horridus*; Nordberg and Cobb, 2016]), and though winter growth has been documented in several temperate-climate lizard species (Davis, 1967; Ruby, 1977; Bishop and Echternacht, 2003), the extent to which midwinter activity is intended for foraging is not yet well established. Foraging is unlikely to explain snake emergence since the time required for digestion is much greater than that allowed by a few hours of activity (Nordberg and Cobb, 2016), but it is possible that small-bodied lizards are capable

of maintaining body temperatures appropriate for digestion even during winter months (Miller, 1951; Congdon et al., 1979; Goldberg and Bursey, 1990). Moreover, some studies suggest midwinter feeding is a requirement for younger or relatively smaller lizards since they might not have enough fat reserves to survive winter without supplemental feeding (Weintraub, 1969; Goldberg, 1972; Derickson, 1976; Congdon et al., 1979). Our study can be added to the list of those that demonstrate some reptiles remain relatively active during the cooler months, but more data are required across multiple taxa to determine the extent to which temperate-climate reptiles in general remain active during winter.

In conclusion, we provide evidence that juvenile Jacky Dragons display preference for overwintering microhabitats that feature cover materials, and these preferences under controlled conditions have consequences for growth but not survival. Though gains in SVL and mass were slight, our data suggest that, like some other temperate-climate species, Jacky Dragons maintain some activity over winter to forage and rehydrate. The extent to which this behavior occurs in the field and to which it correlates to fitness should be the focus of future research.

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