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Behavioural Adaptations of the Common Slow Worm (*Anguis fragilis)* on Jersey, Channel Islands: Looking at Autotomy, Thermal Conditions, and Vegetation Structure

Student ID: 750066939

Fieldwork Statistics

23 January 2026

Abstract

Island environments often create distinct ecological conditions that influence how animals behave and use their habitats across different life stages. This study explores how life stage relates to behaviour and microhabitat use in the slow worm (*Anguis fragilis*) on the island of Jersey, the Channel Islands. Using previous field data, autotomy, thermal conditions, and vegetation structure were analysed in relation to the life stage and body size of slow worms. Autotomy frequency was analysed using a binomial generalised linear model; air temperature was compared across life stages using a one-way ANOVA; and the relationship between vegetation depth and SVL was assessed using a Pearson correlation. Autotomy frequency differed significantly among life stages ($X^2 = 6.62, p = 0.037$), with adults showing the highest percentage of tail loss. Air temperature also varied among life stages (p < 0.001), and vegetation depth was weakly but significantly positively associated with body size (r = 0.15, p= 0.006). Overall, these findings show that life stage plays an important role in shaping behaviour and habitat use in A. fragilis and emphasise the value of considering ontogeny when studying reptile ecology in island systems.

Introduction

Island characteristics such as area, isolation, and habitat diversity strongly influence not only the island's biodiversity, but also the behavioural strategies that species use to survive. On islands, animals often face unique ecological pressures, such as reduced predator communities, altered microclimates, and spatially constrained resources, all of which can drive striking shifts in behaviour, habitat use, and life-history patterns. Jersey is the largest island in the British Channel Islands, covering around 45 square miles, and sits about 22 kilometres off the coast of France and 250 kilometres from the South Coast of England (Fig. 1). Jersey's position in the midst of overlapping marine and continental weather systems have turned the island into one with unique and distinct environmental conditions, leading to a natural landscape that sharply differentiates itself from that of mainland England (Policy Centre Jersey). Onshore, Jersey supports a rich diversity of introduced and native fauna, including reptiles, amphibians, and mammals within grasslands, coastal heathlands, and dunes. Among these species, the slow worm (*Anguis fragilis*) is one of four reptile species on the island, alongside the green lizard (*Lacerta bilineata*), the wall lizard (*Podarcis muralis*), and the grass snake (*Natrix helvetica*), all of which are important components of Jersey's herpetofauna.

Figure 1: Location of Jersey in comparison to Europe and the United Kingdom. Figure retrieved from the Britannica page “Jersey”.

The common slow worm (*A. fragilis*) is a widespread legless lizard native to most of temperate Europe, inhabiting grasslands, heathlands, woodlands, and gardens (Shortridge, 2019). Slow worms are semi-fossorial, spending much of their time hidden under rocks, logs, or dense vegetation (Shortridge, 2019). Although slow worms are superficially snake-like, they are true lizards with eyelids and reproduce through ovoviviparity. Adult slow worms are usually grey-brown to copper in colour (Fig. 2) and reach a snout-vent length (SVL) of 120-200 mm, with females having dark stripes along their backs and sides (Shortridge, 2019). Juveniles, on the other hand, display a pale gold or silver colour with dark sides and ventral colouration, and develop an average of 100mm SVL within the first year of birth (Shortridge, 2019). This species is a long-lived reptile (often 20-30 years in the wild), meaning individuals have lengthy lifespans across which various ecological pressures (predation, climate, habitat use) can have cumulative effects.

Figure 2: A male European slow worm. The figure was taken by Marc Baldwin.

Slow worms display a defensive mechanism in which their tails are deliberately shed as a strategy to escape predation; this is known as caudal autotomy, the effectiveness of which comes at considerable energetic cost and possible effects on future locomotion, and thus survival (Barr et al., 2021). Juvenile lizards rely on caudal autotomy more frequently than adult lizards due to predation and the amount of energy they require during maturation (Bateman et al., 2009; Bellairs et al., 1985; Webb, 2006; Barr et al., 2019; Pafilis and Valakos, 2008). Because predation pressure and ecological exposure may vary across ontogeny, the frequency of autotomy provides insight into life-stage-specific behavioural ecology.

Slow worms are ectotherms that rely on external heat sources to regulate body temperature and typically maintain relatively low body temperatures around 25-26°C °C (Brown and Roberts, 2008). Slow worms can generally be found in cool, damp habitats, but also near areas where they can bask indirectly, such as under sun-warmed objects or in worm compost, rather than in open sun (Shortridge, 2019; Alderney Wildlife Trust). Adult slow worms tend to bask more frequently to thermoregulate, especially because they need to reach higher body temperatures for activities like foraging and reproduction. Interestingly, adult slow worms are occasionally observed moving or basking in the open during warm conditions, although they usually bask under shelter and are rarely fully exposed (Edgar, 2010). On the other hand, juveniles are more vulnerable to predators, especially avian predators, and tend to remain hidden under cover for safety. Like many reptilian species, slow worms hibernate during the winter months, coming out to forage and reproduce in the spring (Woodland Trust).

According to the general IUCN Red List, the slow worm is currently listed as Least Concern (Bowles, 2024; IUCN); however, due to habitat loss and fragmentation associated with agriculture practices and urban development, the slow worm is protected in the UK under the Wildlife and Countryside Act of 1981 (Alderney Wildlife Trust; Trees for Life; Shortridge, 2019). On islands such as Jersey, fine-scale habitat structure and microclimatic conditions likely influence behavioural ecology, yet the relationship between life stage, thermal microhabitat, body size, and fine-scale habitat features remains poorly quantified.

Using ecological field data of slow worms in Jersey taken by Napaul, S., between 2013 and 2015, this study addresses the following three questions central to understanding life-stage-specific behaviour and microhabitat associations:

1. Does autotomy (the presence/absence of tail) frequency differ among life stages (Adult, Subadult, Juvenile) for *Anguis fragilis*?
2. Does air temperature at sighting differ among life stages (Adult, Subadult, Juvenile) for *Anguis fragilis*?
3. Is vegetation depth correlated with *Anguis fragilis* body size (SVL)?

By examining these relationships, this work seeks to illuminate how behavioural ecology and microhabitat associations vary across ontogeny in a widely distributed reptile species.

Methods

The following information for the Study Site and Experimental Design sections has been derived from Napaul's 2023 Thesis.

Study Site

The study was conducted on the island of Jersey in the British Channel Islands. The island's landscape, at the time of the surveys (2021), was dominated by agricultural land (52%) and urban areas (24%), placing considerable anthropogenic pressure on local wildlife (States of Jersey, 2021). 14 survey sites, primarily along the southwestern and western coastal regions, were selected based on historical records indicating high reptile activity (Fig. 3). Each survey location was assigned to one of four habitat categories: amenity grassland, dune grassland, rough grassland, or scrubland. Amenity grassland represented suburban habitats, whereas the remaining three sites represented natural habitats. For the purposes of this paper, the study sites were not of primary concern and were therefore not accounted for. Survey sites varied in size (0.39-33.99 ha) and were separated by physical barriers and geographical distance to maintain spatial independence, following previously reported home-range and movement estimates for slow worms (Smith, 1990; Schmidt et al., 2017).

<u>Figure 3:</u> Map of Jersey, Channel Islands, showing study sites. Figure and modified caption taken from Napaul 2023.

Experimental Design

Slow worms were surveyed between March and September using a combination of visual encounter surveys and checks beneath artificial cover objects (ACOs). At each encounter, individuals were captured by hand using gentle restraint to avoid injury or inducing autotomy. For each slow worm capture, several key measurements and observations were recorded to address the study's behavioural and ecological questions. Only individuals with complete data for the relevant variables (SVL, life stage, temperature, autotomy) were included in this analysis.

Individuals were assigned to one of three life-stage categories (Adult, Subadult, or Juvenile) based on body size and external characteristics commonly used to assess slow-worm maturity (overall length, body proportions, and the presence of mature sexual traits when visible). These classifications were essential for evaluating differences in body size, autotomy frequency, and thermal conditions among life stages. A dorsal and ventral photograph of each individual was taken alongside a 30-cm ruler. SVL (the distance from the snout to the cloaca) was later measured to the nearest millimetre using ImageJ. SVL served as the measure of body size for analysing size variation among life stages and for testing its relationship with vegetation depth. The presence or absence of tail autotomy was recorded for each individual. Ambient air temperature was recorded at each capture location using a handheld thermometer. For the full methodology of the original experimental design, please refer to Napaul 2023.

Statistical Analysis

All statistical analyses were performed on raw observational data, which were pre-organised in Microsoft Excel to remove incomplete entries and to filter for *A. fragilis* before being imported into RStudio. Analyses were conducted using R version 2025.09.0+387 with packages dplyr (Wickham et al., 2014), Tidyverse (Wickham et al., 2019), ggplot2, and readr (Wickham et al., 2015). Packages dplyr and readr were used for data manipulation and cleaning, whilst package ggplot2 was employed for visualisation when creating the graphs and figures. A significance value of $\alpha = 0.05$ was used for each hypothesis test. The following information includes the methods used in RStudio, the study question, and its hypotheses:

1. *Does autotomy (the presence/absence of tail) frequency differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

To test whether autotomy frequency varied among life stages, a fitted binomial Generalised Linear Model (GLM) with autotomy (0= no, 1 = yes) as the response and life stage (adult, subadult, juvenile) as a categorical predictor. Adults were set as the reference category. Records with missing values for tail condition or life stage were excluded prior to analysis using Microsoft Excel. The overall effect of life stage on autotomy frequency was evaluated using a likelihood-ratio chi-square test (analysis of deviance) to compare the full model with a null model that excluded life stage. This test indicated whether including life stage as a predictor significantly improves model fit. The hypotheses are as follows:

H0: Autotomy proportion is independent of life stage (adults, subadults, and juveniles)

H1: Autotomy proportion differs between at least one life stage

2. *Does air temperature at sighting differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

To test whether air temperature at sighting and capture differed among life stages, a one-way Analysis of Variance (ANOVA) was conducted with air temperature (as the continuous response variable and life stage (adult, subadult, juvenile) as the categorical predictor. Adults were set as the reference category. Records with missing values for temperature or life stage were excluded from analysis in Microsoft Excel. ANOVA assumptions of normality and homogeneity of variance were assessed using diagnostic plots (Residuals vs. Fitted and Normal Q-Q plots). If these diagnostics indicated major violations of the model's assumptions, a Kruskal-Wallis test would have been used as a nonparametric alternative. This analysis tested whether including life stage significantly explained variation in air temperature at the time of capture. The hypotheses are as follows:

H0: Mean air temperature at the time of sighting and capture is the same for all three life stages (adult, subadult, and juvenile)

H1: Mean air temperature differs for at least one life stage

3. *Is vegetation depth correlated with Anguis fragilis body size (SVL)?*

Snout-vent length (SVL, mm), and vegetation depth (cm) were utilised as continuous variables in a correlation analysis to test whether vegetation depth at capture location was associated with body size. Records with missing values for SVL or vegetation depth were excluded prior to analysis using Microsoft Excel. The relationship between SVL and vegetation depth was first visualised using a scatterplot with a fitted regression line to assess linearity and identify potential outliers. When the relationship appeared approximately linear, and residuals were roughly normally distributed, Pearson's product-moment correlation was used. If the relationship was strongly non-linear or contained major outliers, Spearman's rank correlation was planned as a non-parametric alternative. This analysis tested whether variation in vegetation depth was significantly associated with variation in slow-worm body size. The hypotheses are as follows:

H0: There is no correlation between vegetation depth and SVL

H1: vegetation depth and SVL are correlated

Results

1. *Does autotomy (the presence/absence of tail) frequency differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

A binomial Generalised Linear Model showed that autotomy frequency differed significantly among life stages in slow worms (likelihood-ratio test: $X^2(2) = 6.62,\ p = 0.037; Fig. 4)$. Adults exhibited the highest proportion of tail autotomy, while subadults were significantly less likely to show evidence of tail loss compared to adults $(\beta = -0.64 \pm 0.28\, SE, p = 0.024)$, corresponding to a 47% reduction in the odds of autotomy (odds ratio = 0.53). Juveniles also showed lower odds of autotomy than adults ($\beta = -1.64 \pm 1.23\, SE,\ odds\ ratio = 0.19$), although this difference was not statistically significant (p = 0.184). The distribution of autotomy across life stages is illustrated in Fig. 4, and raw counts of autotomized and intact individuals are provided in Appendix Table A2. Full model output from the GLM is presented in Appendix Table A3.

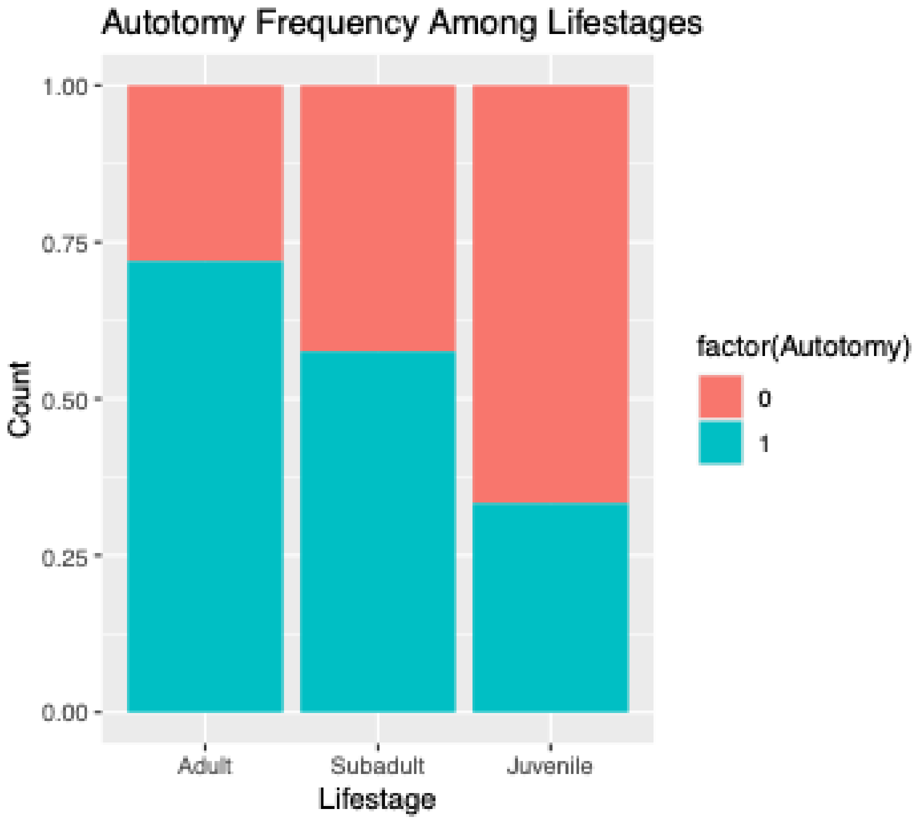

Figure 4: Proportion of slow worms with (1) and without (0) evidence of tail autotomy across life stages.

2. *Does air temperature at sighting differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

A one-way ANOVA indicated that air temperature at the time of sighting and capture differed significantly among slow-worm life stages ($F_{2348} = 8.78, p < 0.001; Fig\ 5)$. Adults, subadults, and juveniles were recorded under different thermal conditions. Diagnostic plots showed no major violations of normality or homogeneity of variance (Appendix Graph B1), and the ANOVA results were therefore retained. Mean ($\pm SD$) air temperatures were 17.4 ± 4.14 °C for adults (n = 282), 15.2 ± 3.33 °C for subadults (n = 66), and 18.7 ± 1.38 °C for juveniles (n = 3).

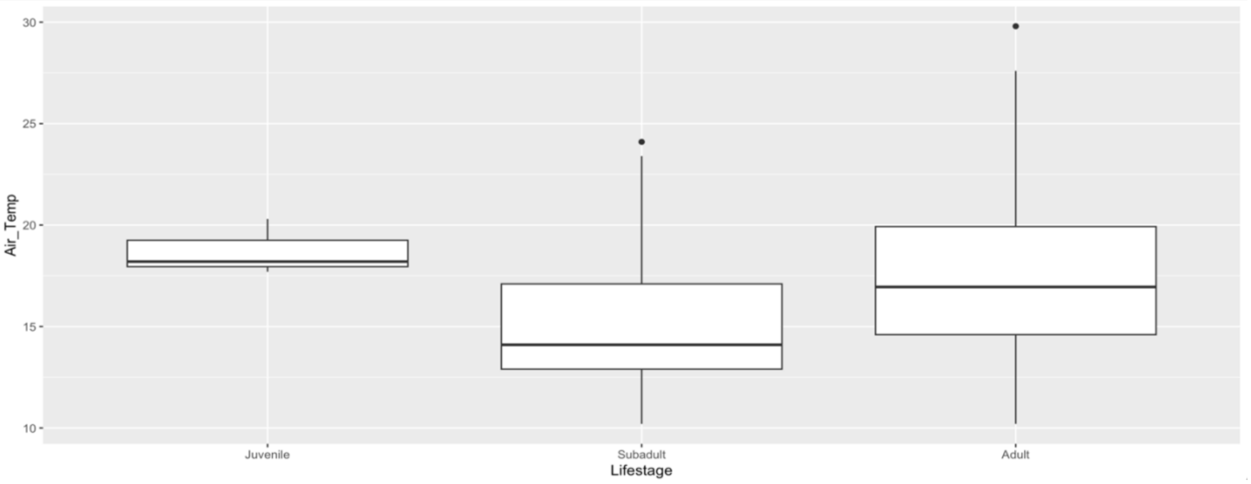

Figure 5: Boxplots showing air temperature (°C) at the time of capture for Juvenile, Subadult, and Adult *Anguis fragilis.*

3. *Is vegetation depth correlated with Anguis fragilis body size (SVL)?*

A Pearson correlation analysis revealed a weak but statistically significant positive relationship between vegetation depth and snout-vent length (SVL) in slow worms $(r = 0.147, t_{349} = 2.77, p = 0.0059; Fig. 6)$. Individuals found in deeper vegetation tended to be slightly larger, though the relationship was weak. The 95% confidence interval for the correlation coefficient ranged from 0.043 to 0.248, indicating considerable variability around this trend. Inspection of histograms and scatterplots suggested that the relationship was approximately linear, supporting the use of Pearson's correlation (Appendix B2, B3, and B4).

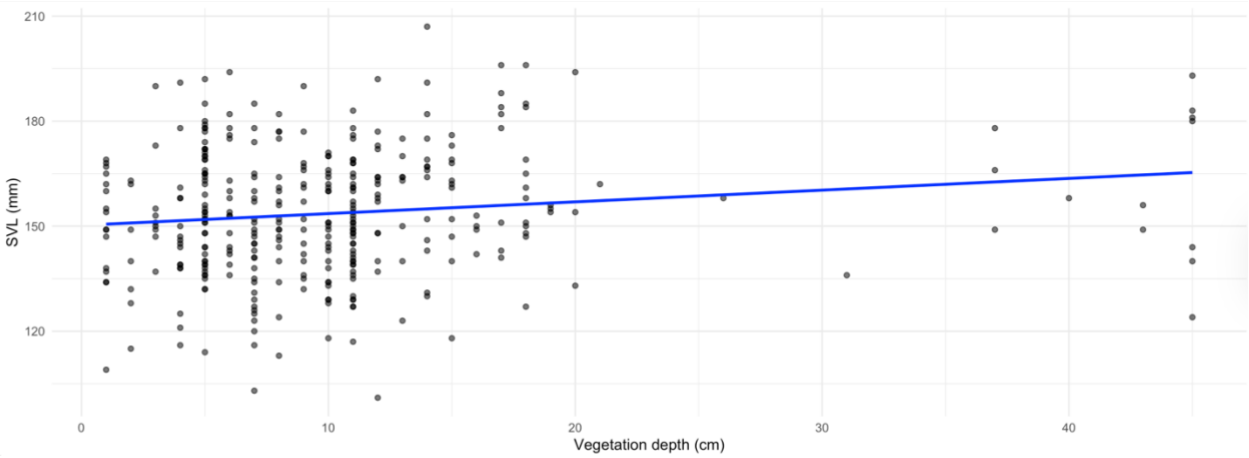

Figure 6: Relationship between vegetation depth (cm) and snout-vent length (SVL, mm) in *Anguis fragilis*, with a fitted linear regression line.

Discussion

1. *Does autotomy (the presence/absence of tail) frequency differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

According to the binomial Generalised Linear Model results, adult slow worms showed the highest prevalence of autotomy, which may have been significantly influenced by sample sizes per life-stage category (see Appendix Table A1). On the other hand, the pattern could be explained by cumulative exposure to predation, as adult slow worms may encounter more predators over their lifetimes. As mentioned in the introduction of this paper, tail autotomy is an anti-predator strategy in lizards, allowing escape from predators at the cost of stored energy, reduced locomotor performance, and potential impacts on future survival or reproduction (Barr et al., 2021; Arnold, 1984; Bateman and Fleming, 2009). In long-lived species like *Anguis fragilis*, evidence of tail loss may therefore accumulate with age even if predator pressure is similar across life stages. Males typically reach sexual maturity at 3-4 years, and females at 4-5 years, indicating that the juvenile and subadult stages may span several years of growth before full maturity is reached (Baldwin, 2024). Therefore, the lower autotomy frequencies observed in juveniles and subadults may reflect fewer predator encounters due to shorter lifespans or the possibility of tail regeneration. Tail regeneration is known to occur in slow worms and other anguids, potentially reducing detectable evidence of prior autotomy in intermediate life stages (Arnold, 1988; Bryant et al., 1967). Furthermore, juveniles and subadults spend less time out in the open, therefore reducing the chance of detection by predators.

Future analysis and research in slow worm behaviour might consider location sites as a factor. Although included in the original dataset, this analysis did not examine predator abundance, which can vary across locations and include large mammalian and avian predators, both of which can influence autotomy risk. If possible, longitudinal tracking of individuals may also indicate autotomy risk and tail regeneration across life stages.

2. *Does air temperature at sighting differ among life stages (Adult, Subadult, Juvenile) for Anguis fragilis?*

Air temperature at the time of capture between each life stage differed significantly, with juveniles being recorded in slightly warmer conditions than adults and subadults (Appendix Table A4). Due to the small sample size of juveniles, n = 3, not accounting for the sample site, and the consideration of Jersey's unpredictable maritime climate, these results should be interpreted with caution. Rather than interpreting this pattern by differences in thermal preference, this may indicate ontogenetic variation in thermoregulatory behaviour or microhabitat use. Slow worms are semi-fossorial and frequently use surface cover and vegetation to maintain body contact with warm substrates while remaining hidden from predators. This behaviour allows individuals to thermoregulate without prolonged exposure in open habitats (Brown and Roberts, 2008). Juvenile and adult slow worms were recorded at higher air temperatures, possibly because juveniles remain sheltered in thermally buffered microsites to reduce predation risk, whereas adults emerge more frequently to support digestion, growth, and reproductive processes. Subadults, however, were recorded at slightly cooler temperatures, suggesting intermediate behaviour between the life stages. Additionally, juvenile slow worms are the least frequently encountered life stage during field surveys, potentially biasing observed temperature patterns towards individuals detected under favourable conditions (Harrison, 2018).

Future analysis and research on slow worm behaviour might consider site location, substrate temperature, and solar exposure as factors. Increasing the sample size of juvenile and subadult slow worms would improve the reliability of conclusions about behavioural thermoregulation across life stages.

3. *Is vegetation depth correlated with Anguis fragilis body size (SVL)?*

Vegetation depth showed a weak but statistically significant positive relationship with slow worm body size (SVL), suggesting that body size may play a role in microhabitat selection. Larger slow worms may rely on deeper vegetation to remain hidden from predators, while smaller individuals may utilise narrow crevices, shallower vegetation, and surface debris to hide, rather than deep vegetation. Size-dependent use of cover has been documented in reptilian species and is often linked to predator avoidance and the availability of refuges (Downes and Shine, 1998; Recknagel et al., 2023). Additionally, deep vegetation provides buffered microhabitats that reduce a slow worm's exposure to extreme temperatures, which may help larger individuals thermoregulate. However, the weak relationships in this study of slow worms on Jersey suggest that vegetation depth alone may not be a strong determinant of body size distribution, and that factors such as temperature, predation risk, and habitat complexity may interact.

Future analysis and research on slow worm behaviour might consider site location, substrate temperature at depth, predation risk, and more detailed measures of vegetation structure to accurately identify the main contributors that influence size-dependent microhabitat use in slow worms.

Conclusion

This study suggests that life stage plays an important role in shaping microhabitat use and behaviour in slow worms on the island of Jersey. Autotomy frequency, air temperature, and vegetation depth all showed statistically significant relationships with their respective factors. Although the results indicate differences linked to life stage and body size, the relatively small number of juvenile and subadult individuals limits the confidence with which these patterns can be interpreted. Increasing the representation of these life stages would strengthen future analyses. Despite this, the results highlight the importance of considering life stage for behavioural analyses in the common slow worm. Additionally, comparing results from mainland populations with those from island populations, specifically on Jersey, could identify adaptations in island reptile species.

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Appendix – Tables

Adult	Subadult	Juvenile
282	66	3

Table A1: Sample sizes (n) of slow worms by life stage

	0 (no)	1 (yes)
Adult	79	203
Subadult	28	38
Juvenile	2	1

Table A2: Counts of autonomy (0 = no, 1 = yes) across slow-worm life stages.

	Estimate	Std. Error	Z value	Pr (>|z|)
Adult	0.9438	0.1326	7.117	1.1e-12***
Subadult	-0.6384	0.2822	-2.262	0.0237 *
Juvenile	-1.6369	1.2319	-1.329	0.1839

Table A3: Summary output of the binomial GLM testing the effect of life stage on autotomy frequency.

Life stage	Mean Temperature	SD Temperature	n
Juvenile	18.7	1.38	3
Subadult	15.2	3.33	66

Adult	17.4	4.14	282

Table A4: Mean ($\pm SD$) air temperature ($°C$) at capture for slow worms by life stage.

Appendix – Figures

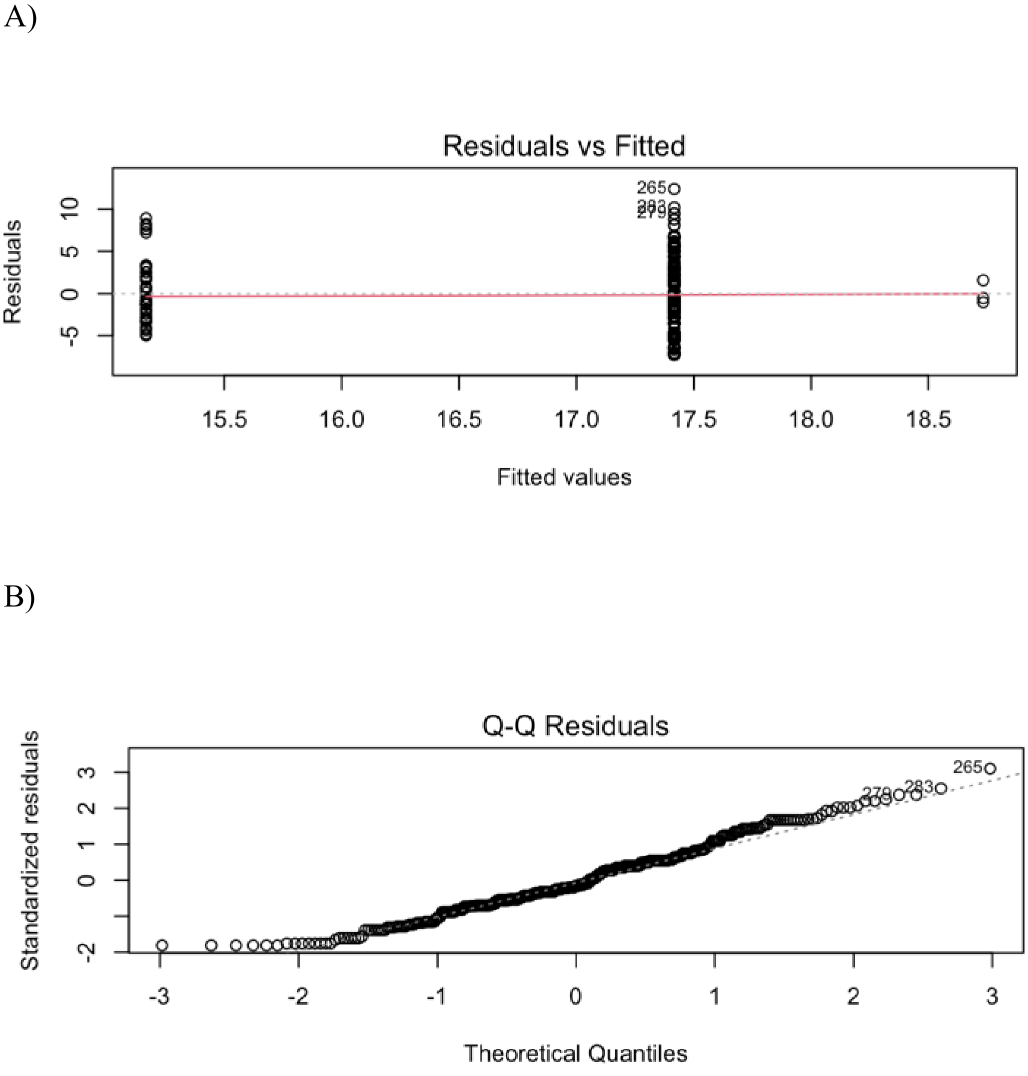


Figure B1: Diagnostic plots for the one-way ANOVA examining differences in air temperature among life stages of *Anguis fragilis*. (A) Residuals versus fitted values show no strong patterns, indicating homogeneity of variance. (B) A normal Q-Q plot shows residuals that closely follow the theoretical distribution, indicating approximate normality.

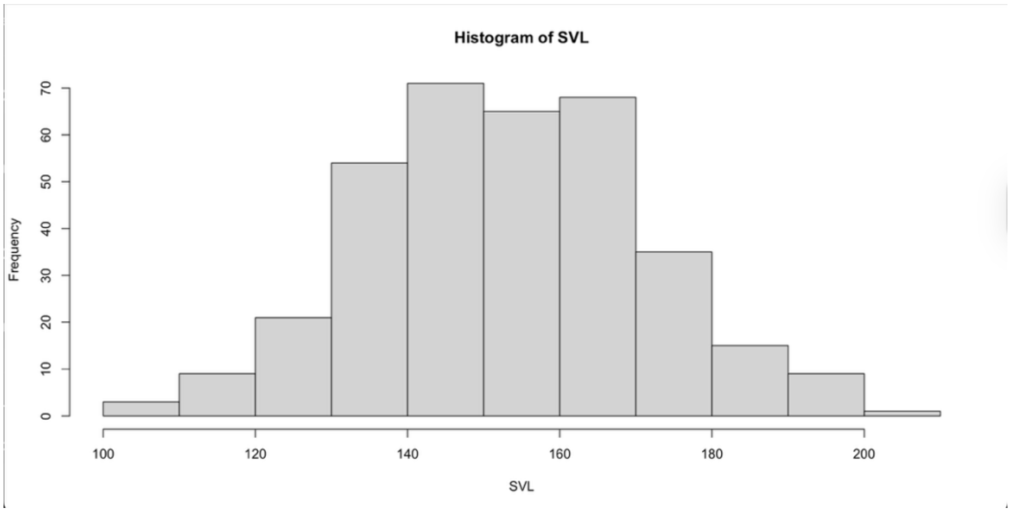


Figure B2: Histogram showing the distribution of snout-vent length (SVL; mm) for *Anguis fragilis*

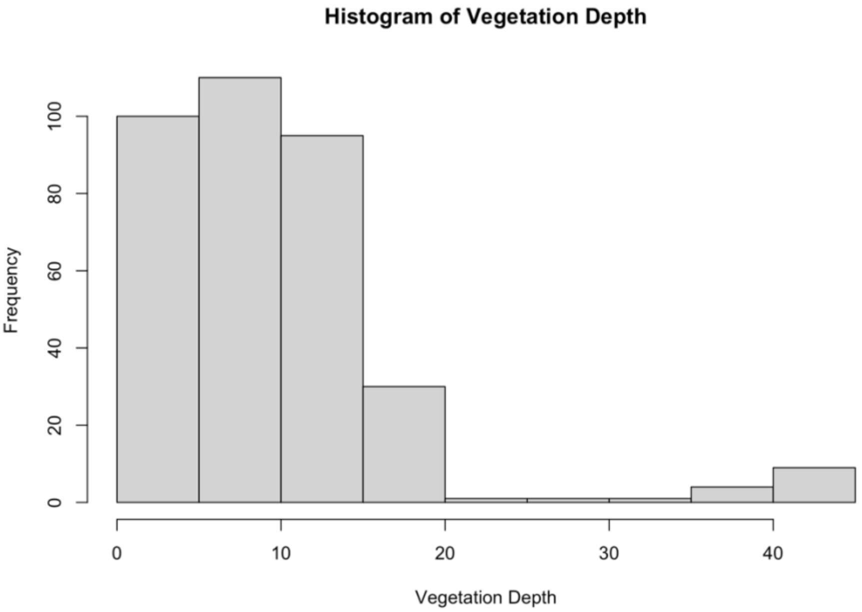
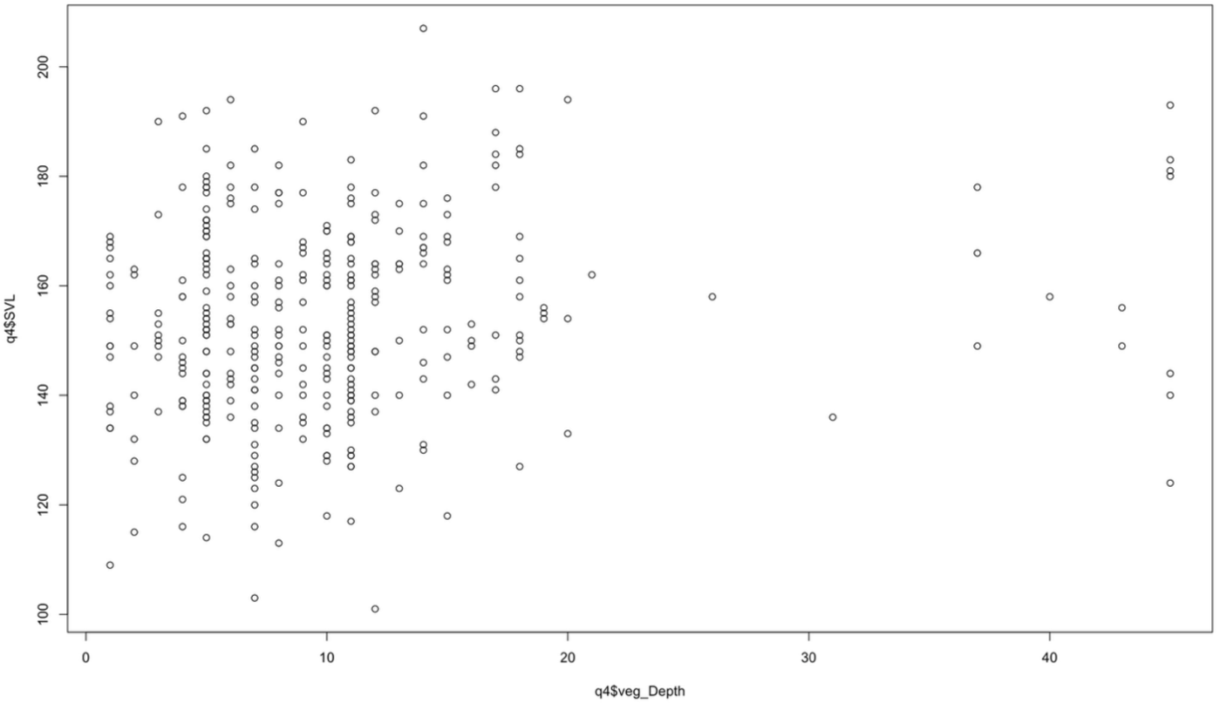


Figure B3: Histogram showing the distribution of vegetation depth (cm) at capture locations for *Anguis fragilis*



<u>Figure B4:</u> Raw scatterplot showing snout-vent length (SVL; mm) plotted against vegetation depth (cm) for individual *Anguis fragilis*, without a fitted regression line.

R Studio Code

```
library(dplyr)

citation ("dplyr")

library(tidyverse)

citation("tidyverse")

library(ggplot2)

citation ("ggplot2")

library(readr)

citation ("readr")

df <- read_csv ("~/Desktop/Field Work Statistics/Book3.csv")



table(df$Lifestage)



#Autotomy vs. Lifestage

q2_glm <- df %>%

  filter(!is.na(Autotomy),

         Lifestage %in% c("Adult", "Subadult", "Juvenile"))
```

```
q2_glm$Lifestage <- factor(q2_glm$Lifestage,
                           levels = c("Adult", "Subadult", "Juvenile"))


glm2 <- glm(Autotomy ~ Lifestage,
            data = q2_glm,
            family = binomial)


summary(glm2)
anova(glm2, test = "Chisq")
exp(coef(glm2))


q2_glm_edit <- q2_glm %>%
  mutate(Autotomy2=if_else(Autotomy==0, "No", "Yes"))


ggplot(q2_glm_edit, aes(Lifestage, fill = factor(Autotomy2))) +
  geom_bar(position = "fill") +
  labs(y="Count", x="Lifestage",
       title="Autotomy Frequency Among Lifestages", )
```

```
table2 <- table (q2_glm$Lifestage, q2_glm$Autotomy)

table2



#Airtemp vs. Lifestage

q3 <- df%>%

  filter(Lifestage %in% c("Juvenile","Subadult","Adult"),

         !is.na(Air_Temp)) %>%

  mutate(Lifestage = factor(Lifestage,

                            levels = c("Juvenile","Subadult","Adult")))



anova_q3 <- aov(Air_Temp ~ Lifestage, data = q3)

summary(anova_q3)



plot(anova_q3)

ggplot(q3, aes(Lifestage, Air_Temp)) +

  geom_boxplot()
```

```
q3 %>%
  group_by(Lifestage) %>%
  summarise(
    mean_temp = mean(Air_Temp, na.rm = TRUE),
    sd_temp   = sd(Air_Temp, na.rm = TRUE),
    n = n()
  )


q4 <- subset(df, !is.na(SVL) & !is.na(veg_Depth))



ggplot(q4, aes(veg_Depth, SVL)) +
  geom_point() +
  geom_smooth(method = "lm", se = FALSE)



ggplot(q4, aes(veg_Depth, SVL)) +
  geom_point(alpha = 0.6) +
  geom_smooth(method = "lm", se = FALSE, colour = "blue") +
  labs(x = "Vegetation depth (cm)", y = "SVL (mm)") +
```

```
  theme_minimal()



cor.test(q4$SVL, q4$veg_Depth)



hist(q4$SVL, main = "Histogram of SVL", xlab = "SVL")

hist(q4$veg_Depth, main = "Histogram of Vegetation Depth", xlab = "Vegetation Depth")



plot(q4$veg_Depth, q4$SVL)
```