NCOS Hibernacula Study

Garrett Craig

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refugia) were created to assess wildlife usage. This follow-up project, conducted in the spring of 2021, aims to assess not just the frequency of wildlife use of each feature type but also the ecological function that different habitat structures may play in restored landscapes.

For this project, motion-sensor camera traps were installed at 5 boulder locations, 8 log locations, and 14 constructed hibernacula. Generally, 2 camera traps were set at each location for 5 days (though there were a few exceptions to these standards). Images were then uploaded to Wildlife Insights and reviewed manually for the presence of wildlife in and around the habitat features. Reviewers categorized any wildlife present to the lowest possible taxonomic level and counted the number of each taxon present in the image sequence.

39 Data Processing

39.1 Load data downloaded from Wildlife Insights

NCOS Hibernacula Biodiversity Assessment

39.2 Clean and merge data files

39.2.1 Clean Data

Two deployments (L30C9 & H8C11) were set as the incorrect feature type in Wildlife Insights, so I correct them here.

At least a few deployments (H46C2, B2C9, H7C12, H35C6) stopped recording images before their listed end date, so I reset their end dates according to the date of their last recorded sequence. Others (e.g. H2C12), may have also stopped short, though it's not entirely clear.

39.3 Working with February Study Data

40 Statistical Analysis

Since this analysis intended to analyze the effect on wildlife presence of constructed hibernacula relative to natural features like logs and boulders, we performed a two-category analysis comparing wildlife observations at constructed hibernacula against observations at all of the boulder/log sites combined.

40.1 T-Test

A t-test is used here for exploratory purposes to compare mean wildlife visitation rates between two groups—constructed hibernacula and the combined natural feature control (logs and boulders). It's not the primary analysis, but it provides a quick check for differences in means.

Figure 1: Average daily observations per camera trap site across different feature types. Points represent individual sites, black diamonds indicate mean values, and vertical lines show 95% confidence intervals.

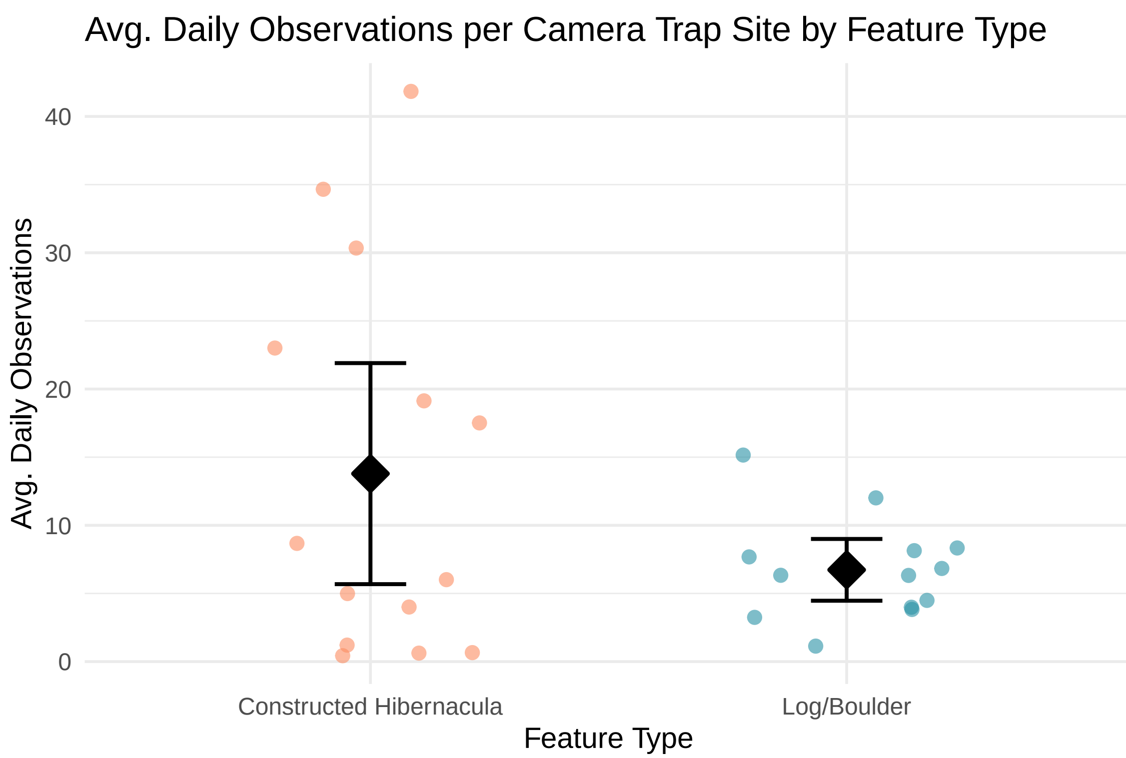

Table 1: Welch two sample T-test comparing average daily observations between feature types

Statistic	Value
p-value	0.00788
Confidence Interval (Lower)	1.62180
Confidence Interval (Upper)	10.51530
Mean (Constructed Hibernacula)	12.73120
Mean (Log/Boulder)	6.66270

40.1.1 Calculate Cohen's d

Table 2: Cohen's d - effect size for average daily observations between feature types

Statistic	Value
Cohen's d	0.6751
Effect Size Magnitude	3.0000
Confidence Interval (Lower)	-0.1404
Confidence Interval (Upper)	1.4906

40.1.2 T-Test Assumption Testing

40.1.2.1 Shapiro-Wilk Test for Normality

Table 3: Shapiro-Wilk normality test for average daily observations by feature type

feature_type_methodology_recoded	shapiro_p_value
Constructed Hibernacula	0.0356278
Log/Boulder	0.4442690

The p-values are greater than 0.05, so we do not reject the null hypothesis that the data is normally distributed for Log/Boulder sites nor for hibernacula.

40.1.2.2 Levene's Test for Homogeneity of Variances

Table 4: Levene's Test for Homogeneity of Variance for Average Daily Observations by Feature Type

Statistic	Value
Df (Group)	1.00000
Df (Residual)	25.00000
F value	8.39310
p-value	0.00772

Variances between the two groups are not equal (i.e., there is heteroscedasticity, or unequal variances).

Even given unequal variances, the Welch Two Sample t-test is still appropriate because it does not assume equal variances and is robust to non-normality when sample sizes are not too small.

40.2 Linear Regression

Comparison of Linear Models

	Dependent variable:	
	Daily Total Observations	
	Model 1	Model 2
	(1)	(2)
Feature Type - Boulder/Log)	-6.069**	-8.579***
	(2.341)	(2.629)
Trail - Yes		-6.670**
		(3.289)
Habitat Type - Grassland		
Habitat Type - Scrub		
Constant	12.731***	15.241***
	(1.607)	(2.017)
Observations	176	176
R2	0.037	0.060
Adjusted R2	0.032	0.049
Residual Std. Error	15.501 (df = 174)	15.364 (df = 173)
F Statistic	6.722** (df = 1; 174)	5.478*** (df = 2; 173)

Note: *

Reference levels: Constructed Hibernacula (Feature Type), No (Tra

Model 1: Including only the feature type: Sites with Boulder/Log features have ~6.1 fewer daily observations compared to the reference feature type. This effect is statistically significant at $p < 0.01$.

Model 2: Adds Trail (Yes/No): Boulder/Log effect remains significant and grows stronger (~8.6 fewer observations). The presence of a Trail reduces observations by ~6.7, and this effect is statistically significant.

Model 3: Adds Habitat Type (with Marsh as the reference): Boulder/Log still shows a strong, significant negative effect (~9.0 fewer observations). Trail effect becomes slightly stronger (~9.0 fewer observations) and is still significant. Grassland habitat appears to increase observations by ~7.7, and Scrub by ~3.5, but only grassland's effect is statistically significant.

Model Fit (R^2): Very low R^2 across models (~3–10%), meaning the linear model explains only a small portion of the variance in daily observations.

40.3 Poisson and Quasipoisson GLM

```
Comparison of Poisson GLMs
========================================================================================
                                                   Dependent variable:
                              ----------------------------------------------------------
                                                Daily Total Observations
                                      Model 1                  Model 2
                                        (1)                      (2)
----------------------------------------------------------------------------------------
Feature Type - Boulder/Log           -0.648***                -0.827***
                                      (0.052)                  (0.054)

Trail - Yes                                                   -0.576***
                                                               (0.067)

Habitat Type - Grassland


Habitat Type - Scrub


Baseline                              2.544***                 2.724***
                                      (0.029)                  (0.034)

----------------------------------------------------------------------------------------
Observations                            176                      176
Log Likelihood                      -1,677.997               -1,637.599
Akaike Inf. Crit.                    3,359.994                3,281.197
========================================================================================
Note:                                                                                  *
                     Reference levels: Constructed Hibernacula (Feature Type), No (Tra

Poisson GLM 1's dispersion ratio indicates overdispersion: 16.36991
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Poisson GLM 2's dispersion ratio indicates overdispersion: 15.9975
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Poisson GLM 3's dispersion ratio indicates overdispersion: 15.3268
```

These Poisson models are more appropriate for count data like daily observations. The coefficients are on the log scale, so interpretation requires exponentiation.

Model 1: Boulder/Log sites have a log count decrease of 0.648, or about 48% fewer expected daily observations (exp(-0.648)   0.523). Highly significant ($p < 0.01$).

Model 2: Adding Trail: Trail presence decreases expected counts by about 44% (exp(-0.576)   0.562), significant at $p < 0.01$. Boulder/Log effect becomes stronger: 56% decrease (exp(-0.827)   0.437) and remains highly significant.

Model 3: Adding Habitat Type: Grassland: +121% increase (exp(0.791)   2.206), highly significant. Scrub: +48% increase (exp(0.394)   1.483), highly significant. Trail effect strengthens to 56% decrease (exp(-0.832)   0.435), highly significant. Boulder/Log effect remains strong at 58% decrease (exp(-0.873)   0.418), highly significant.

Model Fit: Log-likelihood improves substantially across models (less negative = better fit). AIC decreases markedly across models (lower = better), with Model 3 showing the best fit.

BUT: Overdispersion is present in all Poisson models (dispersion ratios ~15.3-16.4), which violates Poisson assumptions and may lead to underestimated standard errors. Consider using negative binomial regression or quasi-Poisson models to account for overdispersion.

Comparison of Quasi-Poisson GLMs

	Dependent variable:		
	Daily Total Observations		
	Model 1	Model 2	Model 3
	(1)	(2)	(3)
Feature Type - Boulder/Log	-0.648***	-0.827***	-0.873***
	(0.236)	(0.259)	(0.247)
Trail - Yes		-0.576*	-0.832**
		(0.320)	(0.348)
Habitat Type - Grassland			0.791***
			(0.302)
Habitat Type - Scrub			0.394
			(0.265)
Baseline	2.544***	2.724***	2.437***
	(0.133)	(0.161)	(0.218)

```
----------------------------------------------------------
Observations                    176       176       176
==========================================================
Note:                         *p<0.1; **p<0.05; ***p<0.01
```

These Quasi-Poisson models correct for overdispersion by adjusting standard errors (coefficients remain the same as Poisson models, but standard errors are inflated to account for overdispersion).

Model 1: Boulder/Log sites have a log count decrease of 0.648, or about 48% fewer expected daily observations (exp(-0.648) 0.523). Remains highly significant ($p < 0.01$) even with corrected standard errors.

Model 2: Adding Trail: Trail presence decreases expected counts by about 44% (exp(-0.576) 0.562), but now only marginally significant ($p < 0.1$) due to inflated standard errors. Boulder/Log effect remains strong: 56% decrease (exp(-0.827) 0.437) and highly significant ($p < 0.01$).

Model 3: Adding Habitat Type: Grassland: +121% increase (exp(0.791) 2.206), highly significant ($p < 0.01$). Scrub: +48% increase (exp(0.394) 1.483), but now non-significant due to larger standard errors. Trail effect strengthens to 56% decrease (exp(-0.832) 0.435), significant at $p < 0.05$. Boulder/Log effect remains strong at 58% decrease (exp(-0.873) 0.418), highly significant ($p < 0.01$).

40.4 Results

40.4.0.1 Summary of Results

Across all models, Boulder/Log features consistently and significantly reduce daily observations relative to Constructed Hibernacula, suggesting the latter are associated with higher activity or detection.

Trail proximity and Habitat Type effects appear meaningful in the Poisson models. And the Poisson models fit the data better than linear models, but overdispersion must be addressed. Quasi-Poisson corrects for this with corrected standard errors, and the Quasi-Poisson Model 3 that includes all three variables (feature type, trail proximity, and habitat type) shows significance ($p < 0.05$) for all variables except for Scrub habitat type, which is no longer significant due to larger standard errors.

41 Data Visualization

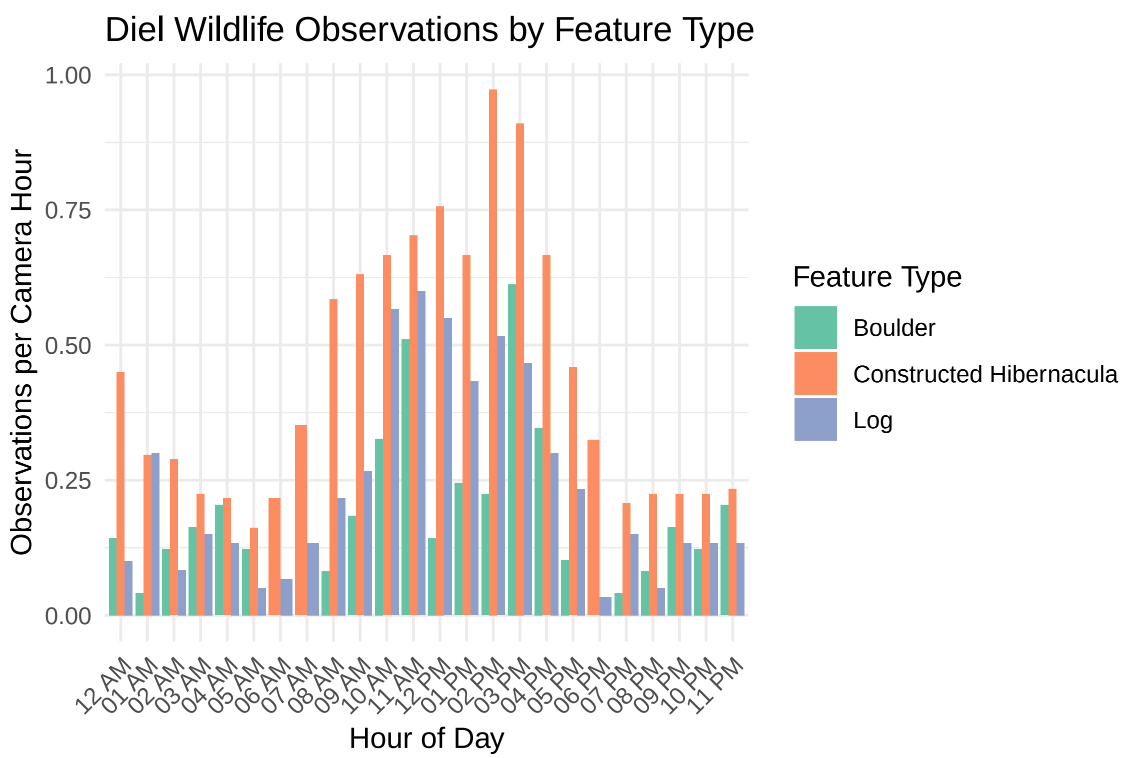
41.1 Taxonomic Class Observations by Feature Type

41.2 Number of Species Observed per Feature Type

41.3 Avg. Daily Observations per Camera Trap Site

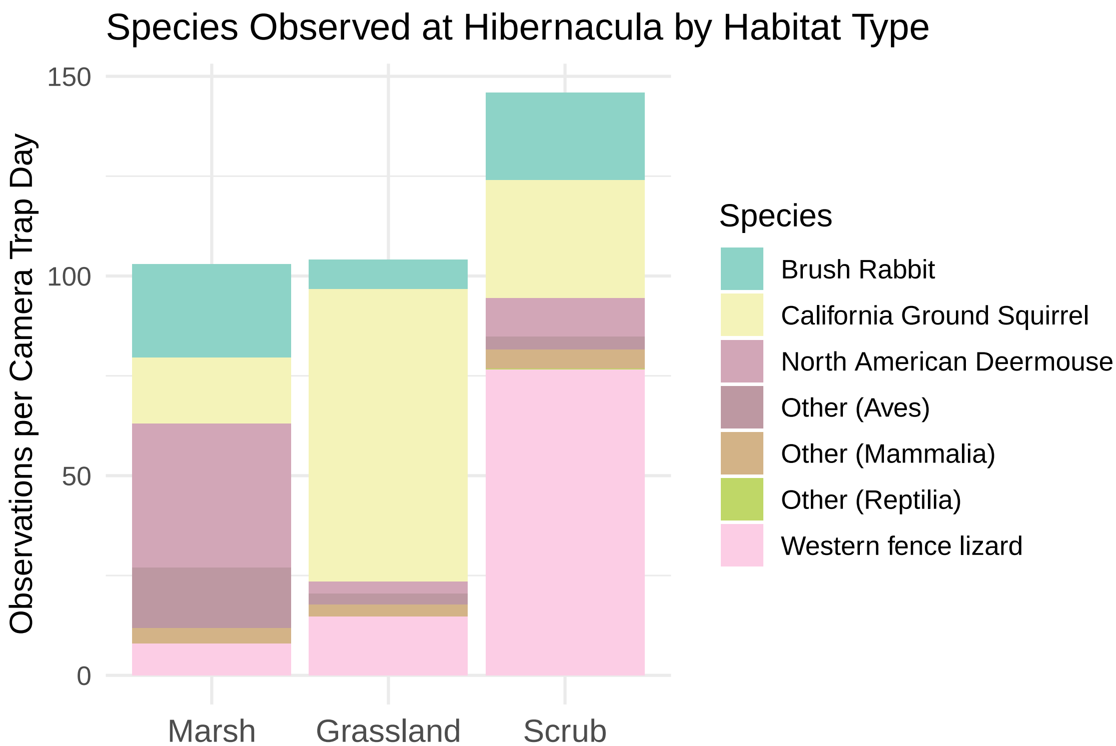
41.4 Hourly Breakdown by Feature Type

Figure 2: Temporal distribution of wildlife observations throughout the day by feature type. This visualization demonstrates potential differences in when animals use each feature type. Each bar represents the total number of animals observed at a given feature type divided by the total number of camera days at each feature type.



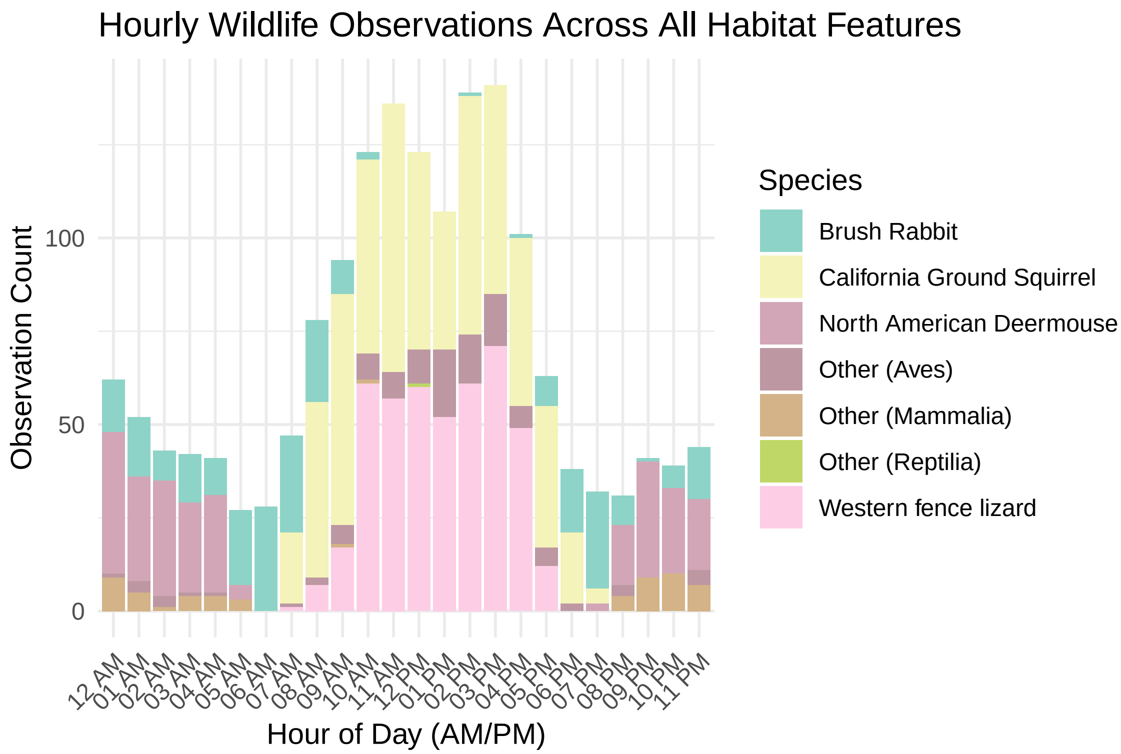
41.5 Species by Habitat Type

Figure 3: Species observed at hibernacula by habitat type, normalized by camera days.



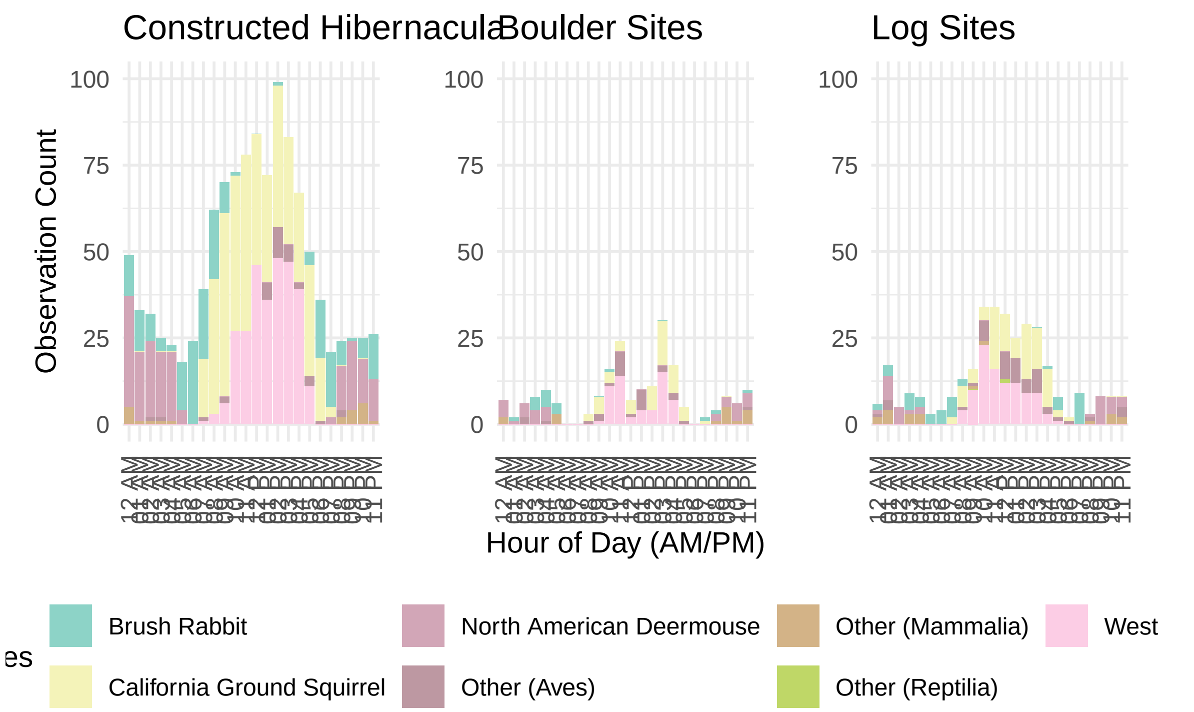
41.6 Hourly Breakdown by Common Name

Figure 4: Hourly wildlife observations across all habitat features, stacked by species. This view highlights daily activity patterns regardless of feature type.



41.7 Hourly Breakdown per Feature Type

Figure 5: Hourly wildlife observations by species across three habitat features. These plots highlight differences in diel activity patterns across Boulder, Log, and Constructed Hibernacula sites.



41.8 Species counts for Each Taxonomic Class

Figure 6: Distribution of bird species observations across different feature types. Each bar represents a unique bird taxon with coloring indicating the feature type where it was observed.

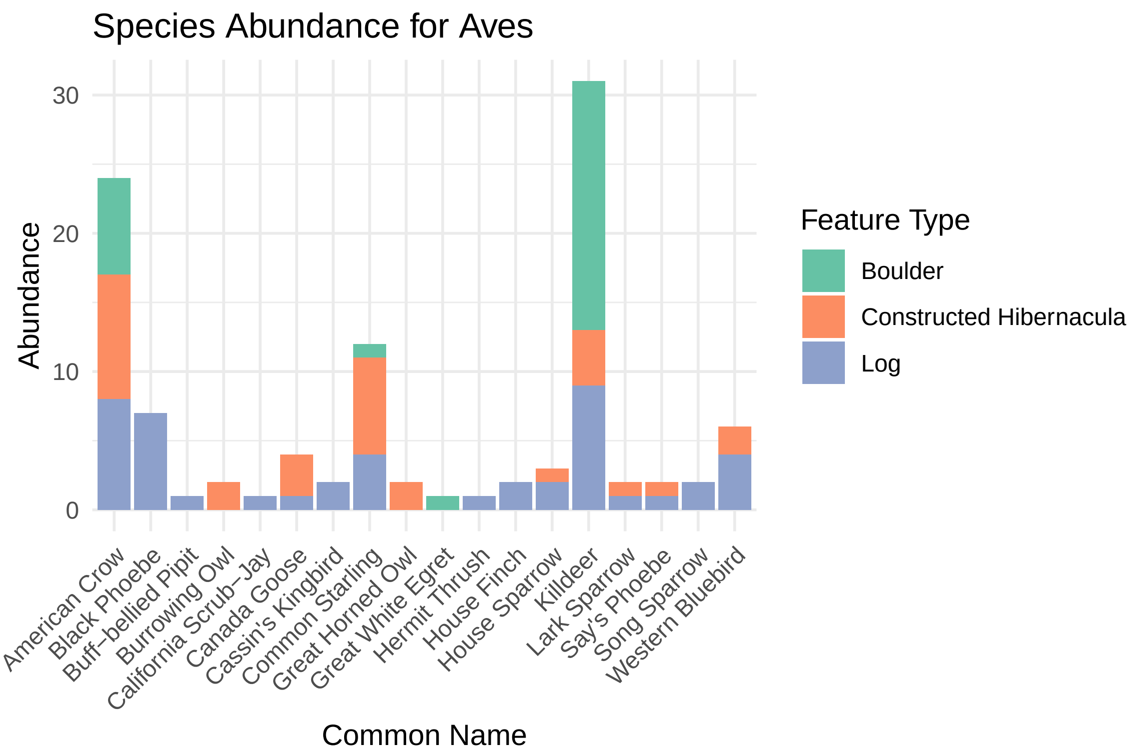


Figure 7: Distribution of mammal species observations across different feature types. The visualization highlights which mammal taxa were most frequently observed at each feature type.

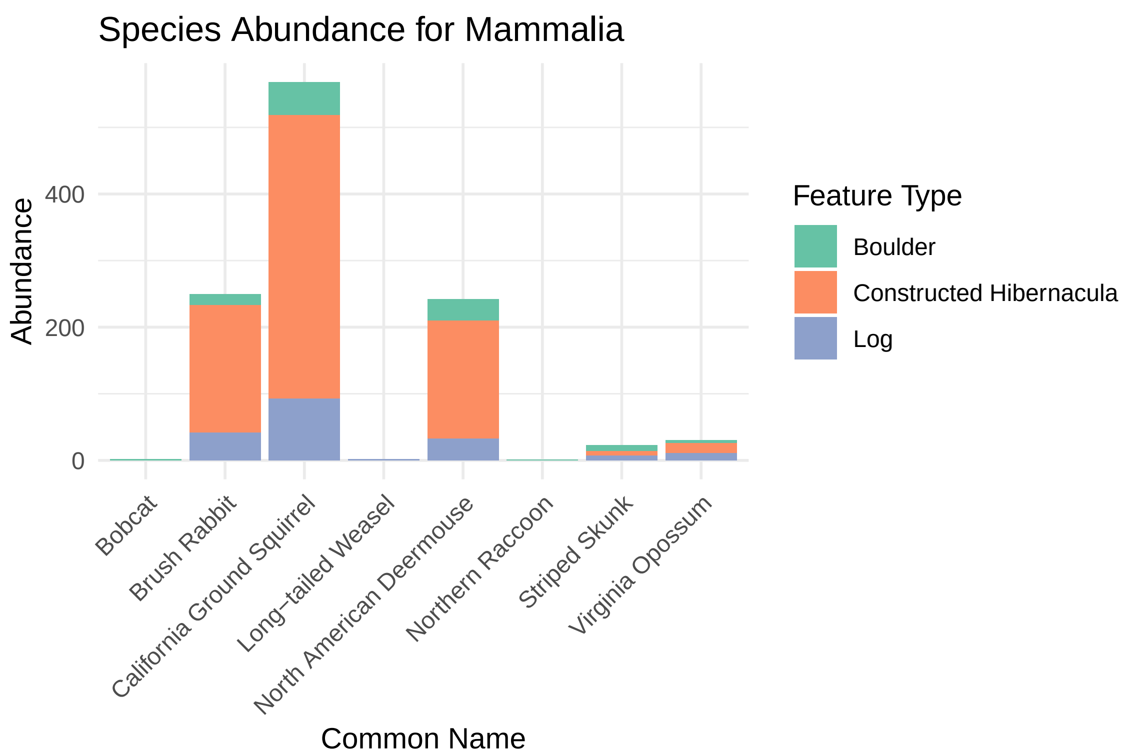
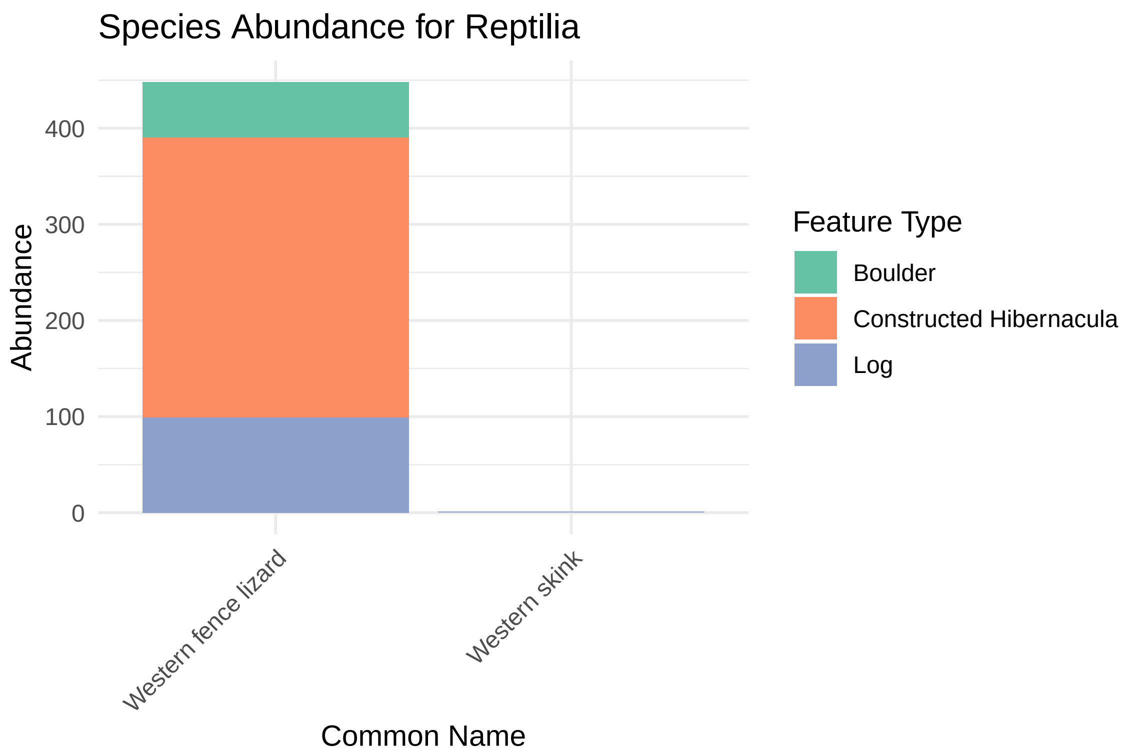


Figure 8: Distribution of reptile species observations across different feature types. The chart shows which reptile taxa utilized each feature type and their relative abundance.



41.9 Map of Deployments and Observations

42 Conclusion

This study provides evidence that wildlife visitation rates differ significantly between Constructed Hibernacula and Log/Boulder features at NCOS. Camera trap data revealed that Constructed Hibernacula supported higher average daily observations compared to Log/Boulder features, with a statistically significant effect shown through Quasi-Poisson regression models.

Beyond the statistics, the ecological implications of these findings are particularly informative. The increased frequency of observations at constructed hibernacula appears to be driven by species such as squirrels and mice that establish semi-permanent residency in these structures. In contrast, logs and boulders seem to serve as transient or opportunistic shelters used by a broader variety of taxa but with less frequent returns.

This suggests that constructed hibernacula may function more like microhabitat "core areas" or refugia—providing thermal stability, protection from predators, and consistent cover—particularly attractive to small mammals. The presence of crows at these same sites may further support this idea, as they may be drawn to hibernacula to hunt small vertebrates or scavenge, indicating a potentially complex trophic interaction centered around these features.

As such, different habitat enhancements serve different ecological roles, and a one-size-fits-all approach may not maximize biodiversity benefits. While logs and boulders contribute to structural

Figure 9: **Spatial distribution of camera trap deployments at the study site.** Circle color indicates feature type and size reflects the average daily number of wildlife observations. Inset map shows the location within California.

heterogeneity and attract a wider diversity of species, hibernacula appear to offer sustained ecological value as shelter and possibly breeding or feeding grounds.

These findings advocate for the intentional inclusion of varied habitat structures in restoration planning, especially those that provide below-ground complexity. Hibernacula in particular may fill a niche that is otherwise underrepresented in restoration design.

43 Limitations and Future Directions

I want to acknowledge several caveats that should be considered when interpreting these results.

- Some camera trap deployments (e.g. H4C12, H8C12) had limited visibility due to vegetation overgrowth, reducing the likelihood of recording observations.
- Variation in camera setup also introduced potential bias, as some sites had only one camera while most had two, affecting the chances of detecting wildlife.
- Furthermore, camera misfirings were not uncommon, which may have led to gaps in data collection or inflated detection counts in certain instances (e.g. if the movement of vegetation triggered an image capture but a stationary organism happened to be present).

Future studies with larger sample sizes and longer monitoring periods could refine these findings, further clarifying the ecological value of different habitat structures.