Cleaning Up the Scrub: Saving the Florida Scrub Lizard

Nicole Hori
Steven Krumholtz
Daniel Lindquist
Olin College of Engineering
Needham, MA

Advisor: Burt Tilley

Introduction

The Florida scrub lizard is a victim of human development and detrimental involvement in the environment. This lizard lives with its "family" of 13 other animals in the Florida scrublands (**Figure 1**). Many lizards have found that their houses of open sand are being invaded by increasing human-aided dominance of flourishing scrub. This dominance has left many lizards homeless.

Our goal is to provide information that can help save the scrub lizards by modeling many different aspects of their life and their environment, and by locating abundant safe places for occupation.

Preserving Scrub Lizard Habitat

Human development of land is the largest factor in the loss of habitat for the Florida scrub lizard (*Sceloporous woodi*). In addition to converting lizard habitat to human habitat in the form of roads, homes, and citrus fields, development prevents natural lightning-sparked fires from sweeping freely across the landscape [Smith 1999]. For decades, fires have been seen by humans as destructive, rather than beneficial, and suppressed. Human prevention of such natural fires has led to overgrowth and increased shading and leaf litter, gradually shrinking the open sandy areas in which Florida scrub lizards live.

Though there are no clear data regarding extinctions and recolonizations of lizards in the scrub, the distribution of the taxa suggests that it is frequent and may be especially common in small patches [Branch et al. 1999, 3, 22]. Human

The UMAP Journal 23 (1) (2002) 37–46.

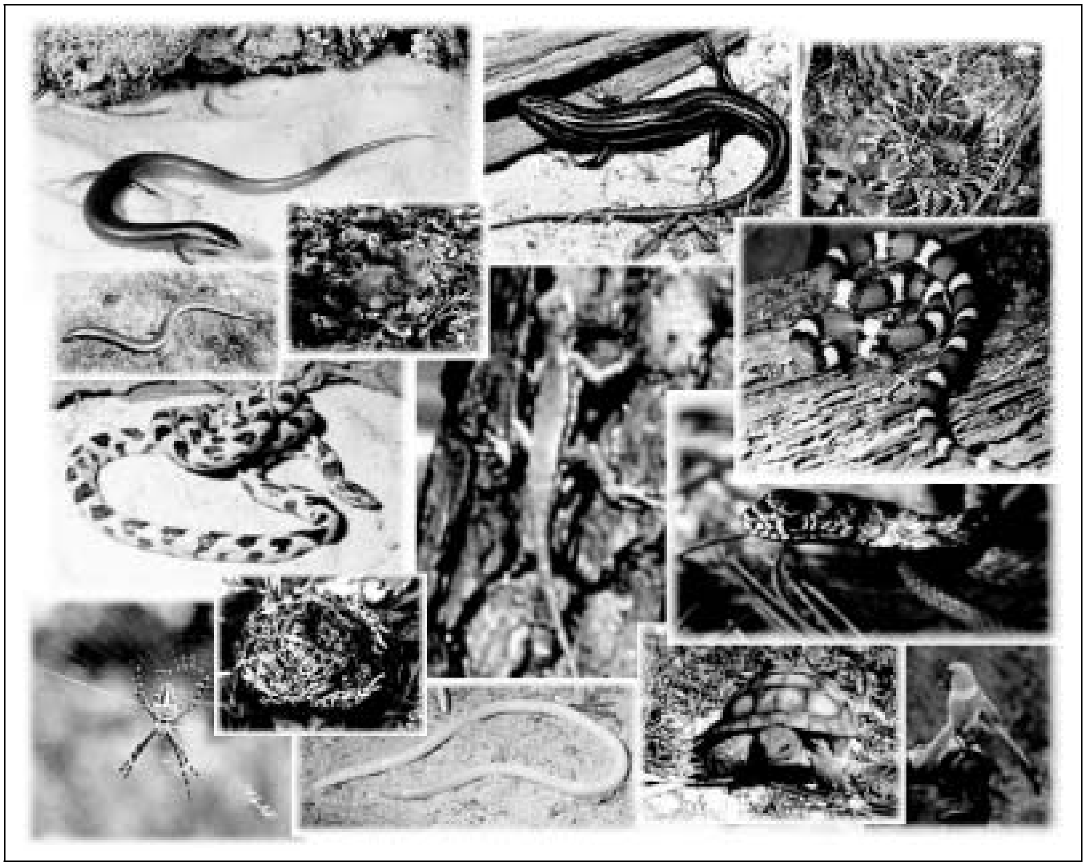

Figure 1. The Florida scrub family. From top left to bottom right: blue-tailed mole skink, southeastern five-lined skink, eastern diamondback rattlesnake, sand skink, Chuck-Will's-Widow, scarlet kingsnake, short-tailed snake, **Florida scrub lizard**, eastern coachwhip, silver-backed argiope, gopher frog, Florida worm lizard, Florida gopher tortoise, Florida scrub jay.

development has resulted in fragmentation, which creates barriers between patches of scrub that prevent lizards from migrating to repopulate areas and exchange genetic information [Branch and Hokit 2000]. Lizards in small scrub patches in urban areas in Titusville and Naples were far less genetically diverse than those in the Jonathan Dickinson State Park, which has about 1,900 ha of continuous scrub [Branch et al. 1999, 52].

Fires are an integral component of the natural scrub ecosystem and without human intervention would occur in a given area approximately once every 6–20 years. In their absence, shrubs and trees become overgrown and many species are displaced, including scrub lizards. Alterations made to the environment make the stoppage of fire-fighting insufficient for full scrubland recovery. Instead of burning thousands of acres, naturally started fires run into concrete or asphalt "firebreaks" or are extinguished to prevent damage to property, and controlled fires must take their place. Controlled burning allows the amount of fuel to be lowered to safe levels [Smith 1999] and can create areas of scrub in different stages of growth alongside one another so that there will be refuges to which small animals and insects may return [Fire in the Florida scrub 2000].

Controlled burning must be done carefully, as accumulation of fuel may cause fires to become uncontrollable. Furthermore, scrub oaks grown to the size of trees will survive if they are not cut back first. Under natural conditions, scrub oaks would be killed before full growth by above-ground fire and sprout up again from their root systems.

The fragmentation of scrub patches has caused even more problems for scrub lizards. Lizards are much more vulnerable to local extinction in small patches; while these patches may provide good stepping stones for lizard movement between preserves, larger patches must be kept intact to sustain a stable population. The precise reasons for different survivorship, density, and recruitment rates in small and large patches are unclear [Branch et al. 1999, 71]. Some of the vulnerability experienced by small patches may be attributable to stochastic demographic processes: In the smallest patches, there are fewer than a dozen individual lizards, and they may be more susceptible to predation since there is a higher ratio of perimeter to sandy area.

In addition to controlled burning, conservation measures should include habitat preserves whose spatial distribution corresponds to the characteristics of the scrub lizards. Although an assortment of small reserves may protect as many vertebrate species as a single large reserve, the distribution of these small reserves will have a tremendous impact on individual species. The most stable populations of scrub lizards occur in patches with large amounts of bare sand that are close to other stable patches. Scrub lizards are more vulnerable than race-runners, a similar species of lizard, because they have a lower ability to disperse and are more habitat-specific, being unable to live in areas with dense grass cover, mesic flatwoods, old fields, dry depression marshes, and very barren areas [Branch et al. 1999, 24]. While race-runners have a home range of up to 13,000 m^2, home ranges for scrub lizards are 800 m^2 and 400 m^2 for males and females, respectively.

Genetic diversity correlates strongly to geographic distribution, since scrub lizards have extremely limited ranges and tend to stay in the patches in which they hatch (only 10% migrate). Lizards from the five largest scrub ridges have distinct mtDNA (mitochondrial DNA), and a representation of each should be preserved for the sake of genetic diversity. The portion of total genetic diversity observed among populations within ridges was 17.5%, and the portion that occurred within local populations is 10.4% [Branch et al. 1999, 53].

Estimating F_a, S_j, and S_a

To determine fecundity, we use the data provided, as well as additional background information on scrub lizards. Measuring fecundity—the number of hatchlings one female lizard can produce in one year—first requires knowing how many clutches of eggs a female can lay. Female lizards are capable of 3–5 clutches per year. Furthermore, mature lizards become sexually active and able earlier in the season than the younger females. Therefore, we estimate that young females (age 1) lay an average of 3.5 clutches per season, while mature females (age 2 and 3) lay an average of 4 clutches per season.

We determine the number of eggs per female per age group by using the equation provided in the problem statement (clutch size $= 0.21l - 7.5$) to determine clutch size, then multiplying clutch size by the estimate of number of clutches per season (**Table 1**).

Table 1.
Number of eggs laid per female, every season, divided by age group.

Age (years)	Number of Eggs
1–2	7.4
2–3	16.9
3–4	17.0

To determine how many total eggs are laid per season, we multiply the values for eggs per female per age group by the number of females in that age group and add over age groups. The sum (901.7) is divided by the total number of females (105) to get the number of eggs laid per female (8.6).

On average, 95% of eggs survive into hatchlings. Therefore, to determine fecundity, the eggs/female ratio is multiplied by 0.95, resulting in a fecundity of 8.2 eggs/female.

To determine the survival rate of juvenile lizards, the number of age-1 lizards (180) is divided by the number of age-0 lizards (972). The resulting quotient is $180 \div 972 = .185$, or 18.5% of lizards survive their first year.

Determining the survival rate of adult lizards is similar. By dividing the number of age-2 lizards (20) by the number of age-1 lizards (180), we find that the survival rate of young adult lizards is 11.1%. For the survival rate of older "senior" lizards, the number of age-3 lizards (2) is divided by the number of age 2 lizards (20), resulting in a survival rate of 10%. We assume that no age-3 lizard lives to be 4 years of age.

To determine the overall survival rate of adults for this sample, the survival rate of young adults and the survival rate of senior adults are weighted and then averaged. To weight the survival rates, the rate for each age group is multiplied by the number of members of that age group, as in **Table 2**; the resulting average adult survival rate is 11%.

Table 2.
Calculation of overall survival rate.

	Survival rate	No. of members	Weight	
young adults	0.111	20	2.22	
senior adults	0.100	2	0.20	Weighted survival rate
	Total	22	2.42	2.42/22 = 0.11

Developing Functions for F_a, S_j,S_a, and C

Fecundity and survivorship appear to depend both on patch size A and on area h of sandy habitat. But patch size and sandy habitat are related via

$$h = .3165A + 2.31, \tag{1}$$

with correlation .986. We use area of sandy habitat as the better predictor; it makes more sense to model the lizard population by the area in which it lives instead of by the area that surrounds its living space.

Since density is measured by lizards/hectare, we must consider patch size and use **(1)** to convert to area of sandy habitat.

Since fecundity, survivorship of juveniles, and survivorship of adults all have upper bounds (levels at which physical biology presents limits), we model these quantities by logistic regressions:

$$F_a = \frac{10.33}{1 + 1.421e^{-0.0957h}}, \qquad S_j = \frac{0.179}{1 + .89e^{-0.169h}}, \qquad S_a = \frac{0.139}{1 + 1.93e^{-0.123h}}, \tag{2}$$

where F_a is the fecundity, S_j is the survival rate of juveniles (aged 0–1), S_a is the survival rate of adults (aged 1–3), and h is the sandy habitat area in hectares.

We also regress the carrying capacity of a scrub patch on the desired category and the area of sandy habitat. To do so, we make three assumptions:

- The measured of density D is in terms of lizards/hectare of scrub, not in terms of lizards/hectare of open sandy habitat.
- Since the scrub patches have existed for multiple years, each scrub patch is currently at its carrying capacity, as demonstrated by the provided density data.
- There is an upper bound to density.

Because of the third assumption, a logistic model would be the best; unfortunately, there is no way of calculating or extrapolating from the information provided the order of magnitude of such an upper bound. Unlike the vital statistics, where there are clear limits to how many eggs a female can lay and how long lizards can live, density has no clear limit. A logistic model of the given data would create an upper bound of about 80 lizards/hectare, a figure that could certainly be higher.

Therefore, for a better model we use power regression, getting for the density D of the scrub patch, in lizards/hectare,

$$D = 36.93h^{0.221}.$$

This regression has a high correlation (.937). Since carrying capacity is measured in total number of lizards, the scrub patch area of each patch must be multiplied by the density equation to determine the carrying capacity C for each patch:

$$C = DA = 36.93Ah^{0.221}.$$

This model can help determine if certain patches of scrub are suitable for lizard "transplantation," or if these patches are already over their capacity and should not have new lizards introduced.

Probability of Surviving During Migration

The data include a probability distribution of distances traveled by surviving lizards. That histogram gives the probability of a lizard going d meters, given that it survived, or $P(d \mid S)$. Then

$$P(d \text{ and } S) = P(S) \times P(d \mid S), \qquad \textbf{(3)}$$

where $P(S)$ is the probability of a lizard surviving and d is distance in meters.

Using release/recapture data from the Florida Game and Fresh Water Fish Commission, we calculate the overall survival rate of the 10% of lizards who migrate:

$$P(S) = \frac{\text{lizards released}}{\text{lizards recovered}} = \frac{227}{71} = .3128 = 31.3\%.$$

Using this probability in **(3)**, we arrive at the entries in **Table 3**.

Table 3.

Probability of survival as a function of distance traveled.

Distance traveled (m)	$P(d \text{ and } S)$
50	0.1314
100	0.0782
150	0.0563
200	0.0376
250	0.0063
300	0
350	0.0031

We can now use regression to model the probability of a lizard surviving a journey of d meters. Since lizards cannot have a negative survival rate, a logistic regression seems best. We obtain

$$S = \frac{0.341}{1 + 0.873e^{0.0125d}}. \qquad \textbf{(4)}$$

We can find the probability of a lizard surviving the migration between patch i and patch j by calculating the distance d between the two patches and substituting that value into **(4)**.

Determining Total Landscape Population and Suitability of Patches for Inhabitation

The landscape at the Avon Park Air Force Range contains a wide range of different-sized patches, not all of which can sustain lizards. Before making the distinction, however, we first create a model to estimate the landscape's current population.

We assume that each patch is at its carrying capacity. We find the density for each patch by determining D in the equation

$$D = 36.93h^{0.221},$$

where h is the size of the sandy area (in hectares). To determine population, we multiply this density by the total patch size: $P = DA$, where P is the population and A is the area.

Using this approach on each patch, we estimate the total population to be 25,200 individuals.

We estimate the fecundity F_a, the survival rate of juveniles S_j, and the survival rate of adults S_a using the earlier regression equations **(2)**.

To determine if a scrub patch is suitable for occupation by lizards, it is important to know if the population of the patch is either increasing or decreasing. A patch that has a decaying population is most likely not a good place to which lizards should relocate, while a patch with an increasing population shows that it is flourishing and that the environment is suited to lizards.

With the fecundity (birthrate) and the survival rates of each generation of lizards, we can create a Leslie matrix for each of the 29 patches:

$$\mathcal{L} \quad = \quad \begin{bmatrix} 0 & F_a & F_a & F_a \\ s_j & 0 & 0 & 0 \\ 0 & s_a & 0 & 0 \\ 0 & 0 & s_a & 0 \end{bmatrix}.$$

In this matrix, the birthrates are in the top row, with each column representing one year of age. Going diagonally down to the right are the survival rates. Using MATLAB, we determined the eigenvalues for each of the individual matrices.

The eigenvalues serve as projections of change of the population. An eigenvalue greater than one indicates an increasing population, whereas an eigenvalue of less than one shows a decreasing population that without external influences would eventually die off. Most of the patches have eigenvalues of less than one and will thus eventually have no lizards. However, we must also take into account immigration.

We know that 10% of all juveniles in a given patch tend to migrate, though our results show that no lizards survive past 400 m of travel. For simplicity, we assume that the lizards emigrating from each patch distribute evenly among all patches within 400 m of the original patch. To find the number of lizards emigrating, we use the equation for the juvenile population j in terms of the total population P:

$$j = \frac{P - j}{2} F_a,$$

which when solved for j yields

$$j = \frac{PF_a}{2 + F_a}.$$

Since the number of lizards that emigrate is one-tenth the total juvenile population, the total number E of emigrants from a patch is

$$E = \frac{PF_a}{10(2 + F_a)}.$$

To determine whither these lizards emigrate, we need to determine what patches are within 400 m of another patch; how many survive en route depends on the distance to the other patch. The results of our measurements between patches are shown in **Figure 2**.

Figure 2 also gives a rough model of how the population distribution would play out. The green (gray) patches have an increasing population, based on the eigenvalue; they need no immigrants to sustain a population. The yellow (white) patches are less than 400 m away from one or more green patches and thus have a steady influx of immigrants from those patches. The red (dark) patches are not less than 400 m from a green patch and thus receive few immigrants. Thus, the lizard population will become concentrated almost entirely in the patches on the west side of the landscape.

Recommendation: Controlled Burning

We recommend controlled burning. Fires are an integral component of the natural scrub ecosystem and would occur in a given area approximately once every 6–20 years if allowed to spread. When an open area has been restored through controlled burning, lizards from nearby patches can migrate to the freshly burned area and repopulate it; then the highest densities of scrub lizards would be found in areas in the early stages of recovery from fire or other disturbances. As each patch of scrub matures, scrub lizards are expected to migrate to more open and sandy areas [Branch et al. 1999, 71].

Excess vegetation growth can be controlled with a combination of mechanical cutting (where the scrub oaks or other shrubs have grown too large to burn safely) and controlled burning. Some risk is involved, but millions of acres are intentionally burned each year in the United States [Cannell 1999] and the protocol is well developed.

Not only would prescribed burning increase the amount of habitat suitable for native species, it would reduce the possibility of a wild fire like the one that swept through 500,000 acres in Florida in the summer of 1998.

Figure 2. Landscape at Avon Park Air Force Range, with distances between patches (in hundreds of meters).

References

Antonio, A.L. 2000. *Sceloporous woodi* species account. Animal Diversity Web. http://animaldiversity.ummz.umich.edu/accounts/sceloporus/s._woodi$narrative.html .

Branch, L., et al. 1999. *Effects of Landscape Dynamics on Endemic Scrub Lizards: An Assessment with Molecular Genetics and GIS Modeling*. Tallahassee: Florida Game and Freshwater Fish Comission.

Branch, L., and Grant Hokit. 2000. Scrub Lizard Fact Sheet WEC 139. Florida Cooperative Extension Service. Gainesville: Institute of Food and Agricultural Sciences, University of Florida.

Breininger, D., et al. 1995. *Landscape Patterns of Florida Scrub Jay Habitat Use and Demographic Success*. Kennedy Space Center: Dynamac.

Cannell, Michael. 1999. Fighting fire with fire: Prescribed burning can prevent wildfires. *Science World* (22 February 1999).

Christman, S. 1997–2000. Animals of the Florida scrub. http://216.203.152.232/main_fr.cfm?state=Track&viewsrc=tracks/scrub/fs_1.htm .

Florida Natural Areas Inventory. 2001. *Field Guide to the Rare Animals of Florida*. http://www.fnai.org/fieldguide/ .

Fire in the Florida Scrub. 2000. http://www.archbold-station.org/discoveringflscrub/fire/fire.html .

Fire and Forest Protection. 2000. http://flame.fl-dof.com/Env/fire.html . State of Florida Division of Forestry.

Schmalzer, Paul A. 2001. Scrub habitat. Kennedy Space Center: Dynamac. http://www.nbbd.com/godo/ef/scrub/ . Last updated 5 May 2001.

Smith, R.B. 1999. Gopher tortoises. Kennedy Space Center: Dynamac. http://www.nbbd.com/godo/ef/gtortoise/index.html .