The effects of gopher tortoise (Gopherus polyphemus) translocation on movements, reproductive activity, and body condition of resident and translocated individuals in Central Florida

Susannah Christina Riedl
University of South Florida

Follow this and additional works at: http://scholarcommons.usf.edu/etd
Part of the American Studies Commons

Scholar Commons Citation
Riedl, Susannah Christina, "The effects of gopher tortoise (Gopherus polyphemus) translocation on movements, reproductive activity, and body condition of resident and translocated individuals in Central Florida" (2006). Graduate Theses and Dissertations. http://scholarcommons.usf.edu/etd/2674

This Thesis is brought to you for free and open access by the Graduate School at Scholar Commons. It has been accepted for inclusion in Graduate Theses and Dissertations by an authorized administrator of Scholar Commons. For more information, please contact scholarcommons@usf.edu.
Effects Of Gopher Tortoise (*Gopherus Polyphemus*) Translocation On Movements, Reproductive Activity, And Body Condition Of Resident And Translocated Individuals In Central Florida

by

Susannah Christina Riedl

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science Department of Biology College of Arts and Sciences University of South Florida

Co-Major Professor: Earl D. McCoy, Ph.D.
Co-Major Professor: Henry R. Mushinsky, Ph.D.
Member: Gordon A. Fox, Ph.D.

Date of Approval July 18, 2006

Keywords: radiotelemetry, home range, site fidelity, radiography, body condition index

© Copyright 2006, Susannah C. Riedl
Acknowledgments

I would like to thank Henry Mushinsky, Earl McCoy, and Gordon Fox for their guidance and encouragement throughout this project. I am sincerely grateful to Dave Sumpter and Kristen Penney Sommers for their help in getting this project off the ground and keeping it going, and to Ray Ashton, Biological Research Associates, and Scheda Ecological Associates for their help in securing gopher tortoises. I give special thanks to Kristan Robbins, Brian Halstead, and Kate Stiles for their field assistance.

Pinellas County Biological Field Station, administered by the Department of Environmental Management, Environmental Lands Division, is gratefully acknowledged for its support of this study. I am similarly grateful for the support of the Hillsborough County Parks, Recreation and Conservation Department.

Finally, I would like to thank my family (including those with four legs) for their unconditional love and encouragement along the way and Nick Popa for his patience and support in this endeavor. This would not have been possible without you.
# Table of Contents

List of Tables ii

List of Figures iii

Abstract iv

Effects of Gopher Tortoise (*Gopherus polyphemus*) Translocation on Movements, Reproductive Activity, and Body Condition of Resident and Translocated Individuals in Central Florida 1

## Introduction

1

## Methods

3

- Study Subjects
- Radio Telemetry
- Home Range Calculations
- Spatial Use
- Habitat Use
- Radiography
- Body Condition
- Statistical Analysis

## Results

13

- Site Fidelity
- Home Range Calculations
- Spatial Use
- Habitat Use
- Radiography
- Body Condition

## Discussion

17

## References

24

## Appendices

38

- Appendix A: List of morphometric measurements taken of all individuals 39
List of Tables

Table 1. Resident and translocated individuals (2001-2004). 33

Table 2. Percentage of females displaying shelled eggs reported in the literature and in this study. 34

Table 3. Home range estimates reported in the literature for natural and translocated populations of gopher tortoises. 35
### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Location map showing Brooker Creek Study Area.</td>
<td>31</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Oak hammock, old field, flatwoods, and sandhill areas at Brooker Creek Study Area.</td>
<td>32</td>
</tr>
<tr>
<td>Figure 3</td>
<td>MCP home ranges of resident (dashed lines) and translocated (solid lines) individuals (2003-2004).</td>
<td>36</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Comparative use of different habitats by resident and translocated individuals.</td>
<td>37</td>
</tr>
</tbody>
</table>
The Effects of Gopher Tortoise (*Gopherus polyphemus*) Translocation on Movements, Reproductive Activity, and Body Condition of Resident and Translocated Individuals in Central Florida

Susannah C. Riedl

ABSTRACT

Human-caused destruction of xeric habitats in Florida that support gopher tortoises (*Gopherus polyphemus* Daudin) is occurring at a rapid rate. One conservation strategy that has been used for numerous taxa is translocation. The effects of translocation on the health, reproductive activity, and movements of translocated and resident telemetered individuals was evaluated for a population of gopher tortoises in central-Florida from 2001 to 2004. Only one of the 13 individuals released left the site during the study. The home range estimates of resident individuals were not significantly different before and after the release of the translocated individuals on the site, and all mean home ranges fit within the range of estimates reported in the literature for natural populations of gopher tortoises. Habitat use of several individual resident gopher tortoises was significantly different after the translocation events. The degree that the home ranges of the residents were overlapped by other individuals in the study was not significantly different. The spatial locations of the home ranges of resident and translocated individuals were significantly different. There was evidence of reproduction for both resident and translocated females a year after the release of the translocates. The body condition of the resident individuals was higher at the end of the study relative to the start, although this may be explained by other factors. This study illustrates some of
the problems associated with studies designed to assess translocation success, namely the lack adequate baseline data for the population and the challenge of balancing the sample sizes necessary for acceptable statistical power with the mechanics of translocation. The results of this study suggest that translocation is a potentially useful conservation strategy, although there are other potential consequences of translocation that need to be considered prior to its implementation.
The Effects of Gopher Tortoise (*Gopherus polyphemus*) Translocation on Movements, Reproductive Activity, and Body Condition of Resident and Translocated Individuals in Central Florida

Introduction

In recent years, the decline of the gopher tortoise (*Gopherus polyphemus* Daudin) in response to human encroachment has been a subject of concern for biologists. Little is known about the historical structure and abundance of gopher tortoise populations. Using deductive reasoning, I note the widespread conversion of upland habitats for agriculture, mining, forestry, and human dwellings, indicates that present numbers of gopher tortoises represent only a fraction of their historic numbers. As human developments consume more and more suitable gopher tortoise habitat, the future of the species becomes increasingly uncertain (Mushinsky et al. 2006). In much of its geographic range, the gopher tortoise is restricted to small, isolated patches of habitat, making it susceptible to extinction (Lohoefener and Lohmeier 1986; Mushinsky and McCoy 1994).

The well-drained upland habitats that gopher tortoises depend upon are fast disappearing. It is estimated that more than 80% of the xeric habitat present in the 1960’s had disappeared by the 1990’s (Mushinsky et al. 2006). With land development increasing at an alarming rate, translocation has emerged as a potential solution to the immediate problem of habitat destruction (Dodd and Siegel 1991; Reinert 1991). ‘Translocation’ is loosely defined as the release of individuals in an attempt to establish a
new population in an area in which the species is not known to have historically occurred, to reestablish a population of a species that historically inhabited an area but may not at the present, or to augment a population that is already in existence (Reinert 1991). I use the term here to describe the augmentation of an existing population. Translocation is attractive to conservationists because it does not result in the immediate loss of individuals, and it has been used for birds (Engelhardt et al. 2000; Wolf et al. 1996), mammals (Smith and Clark 1994; Sigg et al. 2005; Warren et al. 1996; Wolf et al. 1996), and reptiles (Sullivan et al. 2004; Edgar et al. 2005; Reinert and Rupert 1999), including the gopher tortoise (Fucigna and Nickerson 1989; Stout et al. 1989; Layne 1989; Godley 1989). Although translocation is costly and all of the ramifications are not known, translocations of the gopher tortoise will continue. More than 25,000 gopher tortoise individuals were translocated between 1989-1998 (Mushinsky et al. 2006).

Although translocation provides a quick fix in the short term, this may not be the case in the long term. Movements of individuals off-site following their release can reduce the success of gopher tortoise translocation. Movements of individuals are strongly influenced by environmental factors, such as habitat quality and density of individuals (McRae et al. 1981a; Mushinsky and McCoy 1994). Translocated gopher tortoises show lower site fidelity than residents (Bard 1989; Smith et al 1997). In the congeneric desert tortoise, males are especially inclined to make long distance unidirectional journeys away from the sites to which they have been translocated (Berry 1986). These journeys frequently lead tortoises into unsuitable habitat and high-traffic areas. In addition to direct effects to the translocated individuals, translocation can also have deleterious effects on conspecifics already on the recipient site. An increase in
density may affect the spatial use patterns, the social structure and, consequently, reproductive activity, and the overall condition of the residents on the recipient site.

Before translocation can be viewed as a useful conservation strategy for the gopher tortoise, rather than a way to dump excess individuals, costs and benefits of translocation must be weighed. Previous studies have stressed the need for long-term monitoring of translocated individuals (Berry 1986; Burke 1989; Burke 1991; Dodd and Siegel 1991; Tuberville 2005). In particular, the behavioral and physiological profiles of resident and translocated tortoises should be monitored and compared both pre- and post-translocation. Indicators of wellbeing, such as body condition, site fidelity, reproductive activity, and home range size and location patterns, may be used as criteria to assess what effects translocation has on individuals.

This study was designed to monitor the effects of gopher tortoise translocation on both translocated and resident individuals. Body condition, reproductive output, and home range of a resident population of gopher tortoises were documented both before and after other individuals were translocated to the site; and of the translocated individuals from the time they were released onto the study site. I defined success as (1) the presence of the majority of the translocated individuals on the recipient site one year post-translocation and (2) the absence of negative effects on the well-being of both resident and translocated individuals.

**Methods**

*Study Subjects*

The study site was at the Brooker Creek Buffer Tract in Hillsborough and Pinellas Counties in central Florida (Figure 1). The study site consisted of a +/-66.7-hectare
section of old field connected to a +/-9.1-hectare oak hammock (Figure 2). Throughout the study, several individuals maintained burrows in a patch of flatwoods (+/-3.5 hectares), located south of the oak hammock. A small area of sandhill (+/- 3.3 hectares) was located east of the old field (Figure 2). Although none of the resident or translocated tortoises from this study maintained burrows in this area, the area is used by a group of tortoises that was translocated onto the site in the mid 1990’s (Figure 2). The dominant soil type in the oak hammock is Astatula Fine Sand with a moderately deep water table, and in the old field is Zolfo Fine Sands, with a small amount of Candler series, a well-drained soil series, along the western edge. Elevation in the oak hammock was +/- 30 feet and in the old field was +/-30 to +/-40 feet, suggesting the old field was dryer than the oak hammock.

Beginning in Fall 2001, active burrows in the oak hammock area and adjacent old field area were trapped by placing a 24-liter bucket at the mouths of the burrows. Nineteen resident tortoises were captured (11 from the oak hammock and 8 from the old field; Table 1), had unique combinations file-notched along the marginal carapacial scutes for identification purposes, and were measured (see Appendix 1 for a complete list of morphometric measurements and refer to McRae et al. 1981 measurement diagrams). All individuals were outfitted with Holohil Al-2 transmitters (each approximately 28.7g). The transmitter was affixed to the rear marginal carapacial scutes of the tortoise and covered with a waterproof epoxy. Individuals were collectively penned on-site until trapping of resident tortoises was concluded to allow for all transmitters to be attached at one time and a final set of measurements to be taken. Individuals were released to the burrow from which they were captured.
In May 2002, four individuals were translocated to Brooker Creek from a site in Pasco County for which development was planned. It was desired that all translocated individuals be released as a group. For this reason, these four individuals were penned in individual stalls in anticipation of the procurement of additional tortoises. Additional tortoises were not obtained in a timely manner and so these individuals (3 females and 1 male) were released in the old field after being penned for 3-4 weeks. Prior to release in the old field, each individual was marked with a unique number file-notched, measured, and outfitted with a transmitter as described for the residents. They were released as a group in the northwest corner of the old field. All resident and translocated tortoises were determined to be seronegative for *Mycoplasma agassizzi*, the agent known Upper Respiratory Tract Disease (URTD).

In the spring of 2003, two additional groups of tortoises from separate donor sites were translocated to Brooker Creek. The first group consisted of three females and one male tortoise that were released as a group in the northwest corner of the old field in March 2003. The second group consisted of four females and one male that were released as a group in the old field in May 2003. Neither the second nor the third group of translocated individuals were penned prior to their release. In all, 13 individuals (10 females and 3 males) were translocated to Brooker Creek.

During September 2004, all tortoises were pitfall-trapped and transmitters were removed. Prior to the release of each tortoise to the burrow from which it was captured, a final set of morphometric measurements were taken.
Radio Telemetry

Resident gopher tortoises were located weekly (late fall through early spring) or twice weekly (late spring and summer) from September 2001 through August 2004. Translocated individuals were located every few days for several months following their release, and then the same radiotracking schedule as followed for the resident tortoises was used to track their movements. The time of day that tortoise locations were tracked varied from 0700 to 1730 h. Tortoises were tracked using a TRX-2000S receiver with a folding 3-element Yagi antenna (Wildlife Materials; Carbondale, Illinois). Each occupied burrow was flagged, given a unique number, and its coordinates were mapped using a Trimble Pathfinder@ Pro XR receiver. In the event that a tortoise was sighted above ground when it was not being radiotracked, the location was flagged and later mapped. The tortoise’s activity at the time of the observation was recorded. Because several translocation events occurred over the course of a year, there was not an obvious point at which to divide the resident tortoise data sets into “before translocation” data sets and “after translocation” data sets. To facilitate evaluation of changes in spatial use patterns related to the addition of individuals onto the study site, I consider resident tortoise data collected before June 2002 as “before translocation data” and data collected for resident tortoises during and after June 2002 as “after translocation data.”

If raw radiolocation data are employed, several biases can result. First, lack of independence among observations can result in home range underestimation. To reduce the effects of autocorrelation during the winter months when individuals are sedentary, radiolocations obtained from mid-November through mid-February were omitted from the home range calculations (see Brito 2003). Second, observations collected during the
first few months following an translocated individual’s release may be more erratic than in the subsequent months, after the individual has had an opportunity to adjust. I omitted the observations for three months following the release of translocated indivuals to allow for a period of adjustment for the translocated tortoises without affecting the home range estimates.

In the event that an individual could not be recovered at the end of the study to verify transmitter attachment, the set of locations used to calculate the home range of that individual was truncated after the first instance the tortoise used its last burrow. The same rule was used when a transmitter was recovered that was not attached to a tortoise and when a tortoise was not recaptured at the end of the study, but a signal was still detected from a burrow. This procedure ensured that the locations used to calculate each tortoise’s home range accurately reflected the tortoise’s position and not the position of an unattached transmitter.

Individuals that remained on the study site for the duration of the study were considered to exhibit site fidelity. On a finer scale, fidelity of translocated individuals to areas within the study site was examined by comparing the distance each individual moved from the start of the study to the end of the study to the distances moved by the residents during the same time period.

*Home Range Calculations*

Several different methods exist to estimate the home range of an individual. One of the most commonly used methods is the minimum convex polygon (MCP) method. This method consists of connecting the outermost observations of an individual to form a convex polygon. The main drawback of this method is that the estimate is positively
correlated with the sample size. Another problem is that outliers in the data set can greatly inflate the home range estimate, even though a large portion of the area contained in the polygon may never be used by the individual. The benefits of this technique are its simplicity and the ease at which inter-study home range comparisons can be made (White and Garrott 1990).

The kernel density estimation technique may be used in place of the MCP method to reduce the issues of sample size dependence and outlier influence. Kernel density estimators use non-parametric techniques to describe an individual’s home range in terms of a probabilistic model (Worton 1989). A probability estimator (the kernel) is placed over each observation point and the set of observations is overlaid with a rectangular grid, enabling a density estimate to be obtained at each grid intersection by averaging the kernel densities at each intersection point (Seaman and Powell 1996). The shape of the kernel (tall in height with short tails or short with long tails) is determined by specifying a bandwidth (smoothing parameter). The least squares cross-validation method is commonly used to select the optimal bandwidth for a given set of observations (Seaman and Powell 1996).

I used the MCP technique to compare the home range estimates of resident individuals following the release of the translocated individuals to those reported in the literature for natural populations of gopher tortoises. Similarly, I used the MCP technique to compare the home ranges of the translocated individuals to those of natural populations of gopher tortoises. Because I wanted to avoid the problems associated with variable sample sizes and potential outliers when comparing home ranges within my study, I used the kernel density estimation technique.
MCP homeranges were computed for each individual using ArcView 8.3 and the Hawth’s Tools extension. HOMERANGER v. 1.5 software (Hovey 1999) was used to calculate the 95% fixed kernel home ranges for each of the individuals in this study. The program allows the user to specify the use of either a fixed kernel density estimator where smoothing is constant over the entire area, or an adaptive kernel density estimator where a higher degree of smoothing is used in areas that have low densities of observations. The decision to use a fixed, rather than adaptive, kernel estimator was based on a published computer simulation that showed the adaptive kernel to overestimate home range size in many instances (Seaman and Powell 1996). The same study also revealed that the least squares cross-validation (LSCV) method of selecting an appropriate bandwidth (h) resulted in the least bias (Seaman and Powell 1996).

Spatial Use

Spatial position of resident and translocated individuals relative to one another was examined using several methods. First, the burrow locations comprising the home ranges of the resident and translocated individuals were examined to determine whether the resident and translocated individuals were spatially segregated from each other. The Multiresponse Permutation Procedure (MRPP) was used to test for differences in the spatial distribution of the burrows used by resident and translocated individuals by comparing the average distances between observations within groups (average distance between burrows used by residents and the average distance between burrows used by translocated individuals) to the average distance between observations when groupings are ignored (average distance between all burrows) (White and Garrott 1990). A finding that the overall average distance is significantly greater or less than the average distance
when the burrow location data is grouped into resident burrow and translocated burrow
sets signifies that the burrows used by resident and translocated individuals are not
spatially distributed the same as one another. MRPP analysis was conducted using the
program BLOSSOM (USGS 2005).

Second, the degree of overlap of the home ranges of translocated individuals by
resident individuals and other translocated individuals, was compared. If translocated
individuals were spatially segregated from the resident individuals, it would be expected
that the home ranges of the translocated individuals would be significantly more
overlapped by the home ranges of other translocated individuals than by the home ranges
of resident individuals. The percentage that the home range of each translocated
individual was overlapped by other translocated individuals was calculated, as well as the
percentage that each translocated individual home range was overlapped by resident
individuals.

Habitat Use

Relative use of different habitats by resident and translocated individuals was
documented. Changes in relative use of different habitats (old field, oak hammock,
flatwoods, and power line right-of-way) by resident individuals was evaluated by
examining the number of locations within each habitat type by each individual before and
after the translocation events.

Radiography

In the spring of 2002 and 2004, efforts were made to trap all resident female
tortoises and radiograph them to detect the presence of eggs. Translocated females were
radiographed in the spring of 2002 and 2003 (prior to their release) and again in the
spring of 2004. An INSPECTOR X-Ray Source Model 200 (Golden Engineering, Centerville, IN) with an output of 3 millrads per 60 ns pulse was used. Polaroid 803 8”x10” b/w film was processed using a Polaroid 8” x 10” Radiographic Film Processor, Model 85-12 (Polaroid, Waltham, MA). Exposure time was 45 seconds. Morphometric measurements (as described above) of each female were taken before either releasing it into the old field (newly translocated individuals) or back to the burrow from which it was captured (established resident and translocated individuals).

The earliest eggs were visible in females in the last week of April and the latest eggs were visible in the second week in June. The observed seasonality of egg production is nearly identical to that found at another location in Hillsborough County (Colson-Moon 2003). To decrease the risk of false negatives, females radiographed outside this date range were not considered in the analysis.

Because of small samples and large natural variation in the proportion of females with shelled eggs from one year to the next (Table 2), statistical analysis was not performed on the radiography data. The data were used to document whether there was at least some reproductive activity occurring within the resident and translocated females following the translocation events.

Body Condition

A body condition index (BCI) is a non-destructive and simple method to assess an individual’s well-being indirectly. More well-hydrated and/or more well-fed individuals will display a higher BCI (Moore et al. 2006). A body condition index was calculated for each tortoise each time it was captured in the study. The index used was

\[
BCI = \frac{mass}{(T_{max})(W)(C)},
\]
where $T_{max}$ is the maximum thickness, $W$ is the width, and $C$ is the carapace length (Wallis et al. 1999).

BCI values of gopher tortoises have been shown not to fluctuate with season as strongly as do the BCI values of desert tortoises (Moore et al. 2006), however a severe drought year that affects the availability of herbaceous plants and hydration of gopher tortoises would likely have an affect on BCI values that year. Rainfall data from the Tampa International Airport was obtained from the Southwest Florida Water Management District. Rainfall for July through September of 2001 was summed and compared with that from the same 3 month period in 2004 to see how great a difference existed. The morphometric data used in calculating the BCI values was limited to those collected from males to eliminate any confounding effects of female reproductive state on index values. The final comparison made was between the BCI values of male individuals before the translocation events (data from August and September of 2001) and at the end of the study (July and August of 2004).

**Statistical Analysis**

Shapiro-Wilk Tests for normality revealed that the data were not normally distributed. Data were log-transformed and square root transformed, but neither transformation adequately increased the normality of the data, therefore comparisons were made using non-parametric statistics.

The Mann-Whitney U-test, the non-parametric analogue to the two-sample t-test, was used to compare displacement distances of resident and translocated individuals. The Wilcoxon Paired Sample Test, the non-parametric analogue to the paired sample t-test, was used to compare resident home ranges before and after the translocations.
Overlap of home ranges of translocated individuals by translocated and resident individuals was also compared using the Wilcoxon Paired Sample Test. Changes in relative habitat use by resident individuals were analyzed using Fisher’s Exact Test, a form of contingency table analysis based on the hypergeometric probability model. The difference in BCI values of residents at the start of the study and at the end of the study was evaluated using the Wilcoxon Paired Sample Test. The alpha level was set at 0.05 for all statistical analyses.

One concern with statistical testing is whether the lack of a significant finding is the result of high variance masking differences between small numbers of individuals. In the framework of applied ecology, however, differences that are significant only at unrealistically large sample sizes become meaningless. In this particular example, sample sizes that would result in final tortoise densities exceeding 3 per acre, or that, given the labor and cost involved with translocation, are not mechanically feasible, are considered unrealistic. To determine the magnitude of the sample sizes needed to obtain significant results for the analyses used in this study that had non-significant results, retrospective power analysis was performed using the observed differences. The results obtained from the power analysis were then put into the context of a translocation study to determine whether or not the required sample size would be meaningful. Required sample size estimates are included following non-significant test results.

Results

Thirteen gopher tortoises were translocated to the recipient site. A summary of the dates each individual was active in the study and their fates is provided in Table 1. I recorded a total of 2320 radiolocations for the resident and translocated study subjects
between 2001 and 2004. Of these 2320 radiolocations, individuals were observed aboveground 13 times (0.56% of the total number of radiolocations). Nine of the aboveground observations consisted of individuals positioned at the mouth of the burrow, three of the individuals were moving, and one was an individual foraging along the edge of a road. In addition to these aboveground observations, on 15 instances two individuals were located to the same burrow at the same time.

**Site Fidelity**

One translocated gopher tortoise is known to have moved off site during the study. This female was translocated to the site in 2003. This individual, which had been using burrows well within the study area boundaries for six months, was tracked to a position outside the study area on 29 September 2003 and on 1 October 2003 subsequently moved outside of signal-range before it could be recaptured. Although possible, it is not likely that the transmitter failed at this time because the transmitter had only been on the tortoise for six months.

The mean displacement of resident individuals (N = 12) from their location at the start of the second half of the study (i.e. the beginning of the post-translocation data set) to their final location at the end of the study was 63.2 m, compared to a mean displacement of 146.1 m for translocated individuals (N = 9) from their location following the 3-month “adjustment” window to their location at the end of the study. The mean displacement of the translocated individuals was significantly greater than that of the resident individuals during this time frame (U= 59; p < 0.05).
Home Range Calculations

The median of the MCP home range values for the translocated individuals (females = 0.34 ha; males = 0.08 ha) and the median of the MCP home range values of resident individuals following the release of the translocated individuals (females = 0.78 ha; males = 0.63 ha) were both within the range of those reported for natural populations in other studies (Table 3). No significant difference was detected in the kernel density estimation home ranges of female resident tortoises before ($\bar{x} = 0.071$ ha) and after the translocations ($\bar{x} = 0.106$ ha, $n = 6$; $T^+ = 6$). Similarly, no significant difference was detected in the kernel density estimation home range sizes of male resident tortoises before ($\bar{x} = 0.175$ ha) and after the translocations ($\bar{x} = 0.201$ ha, $n = 10$; $T^+ = 21$). Sample sizes of 30 and 89 individuals, respectively, would have been needed for these results to be significant at an alpha level of 0.05.

Spatial Use

Visual inspection of the home ranges of the resident and translocated individuals in 2003 and 2004 (Figure 3) suggests that the home ranges of the residents and translocates are spatially segregated from each other. The results of the MRPP analysis support this observation (standardized MRPP test statistic = 14.0855, $p < 0.001$). There was not, however, a significant difference in the percentage of the home ranges of translocated individuals that is overlapped by resident home ranges (54.4%) and the percentage that is overlapped by home ranges of other translocated individuals (41.0%; $N = 9$; $T^- = 18$). More than 100 individuals would have been needed for this difference to be significant at an alpha of 0.05.
Habitat Use

The majority of the radiolocations of the resident individuals both before and after the translocation events were in the oak hammock and old field habitats (Figure 4). The translocated individuals were observed only in the oak hammock and old field habitats. (Figure 4).

Of the 16 resident individuals for which I had data both before and after the release of the translocated individuals, eight were observed to use only one habitat type throughout the study. Of the eight resident individuals that used more than one habitat type, four significantly altered their use of habitat after the release of translocated individuals on the site. Three of these individuals increased their use of the oak hammock relative to the old field and one increased its use of the power line corridor relative to the oak hammock.

Radiography

Efforts were made to capture as many females as possible each spring for the purposes of determining reproductive status. Shelled eggs were observed in 25% of the resident females radiographed in 2002 (N = 4), before any translocated individuals were released on the site and in 66.7% (N= 3) of the females radiographed in 2004, after the release of the translocated individuals. Shelled eggs were observed in 50% of the translocated females radiographed (N = 8) prior to their release in 2002 and 2003. One year after release, none of the translocated females radiographed (N = 3) contained shelled eggs. Two years after their release, 50% of the females radiographed (N = 2) contained shelled eggs.
**Body Condition**

Data from five resident males were used to compare the body condition index values of residents before and after translocated individuals were released on the site. A Wilcoxon Paired Test was used to test the differences in the body condition index values of individuals measured in August and September of 2001, and again in July and August of 2004. The body condition values of these five individuals were significantly higher in 2004 ($\bar{x} = 0.555$) than in 2001 ($\bar{x} = 0.516$; $T^+ = 0$).

A substantial difference in rainfall exists between the summer of 2001 and the summer of 2004. A total rainfall of 20.6 inches was recorded in July through September of 2001. Rainfall within this same 3-month period in 2004 was 33.99 inches.

**Discussion**

The success of this translocation study was inferred through the site fidelity, movements, reproduction, and body condition of the resident and translocated individuals following the translocations. Site fidelity of resident and translocated individuals was high. All resident individuals and 12 of the 13 individuals released on the site remained on the site for the duration of the study. The areal extent of home ranges used by resident and translocated individuals did not appear to be affected by the translocation events, although changes in habitat use of resident individuals were observed. Both resident and translocated females displayed evidence of reproduction post-translocation. The health of resident individuals, as inferred through the BCI values, was not negatively affected by the translocation events.

Although the findings of this translocation study appear encouraging, caution should be used in the interpretation of the results. Although the majority of the
translocated individuals remained on the study site, the displacement distances of these individuals within the site were greater relative to those of the resident individuals during the same time period, even after translocates were allowed to settle on the site for 3 months. This finding suggests that the translocated individuals had not settled into the area where they were released and may continue to move further from the release area in the future until they are no longer on the study site.

Translocated individuals have been documented to maintain home ranges that are larger than those of individuals in natural populations (Tuberville et al. 2005). The home ranges of the translocated individuals in this study were within the range of what has been reported in other studies for natural populations of gopher tortoises. Similarly, the translocation of conspecifics to the Brooker Creek site did not result in a change in the areal extent of the home ranges used by the resident individuals. It is possible, particularly in the case of the female individuals, that the sample size used in this study was insufficient to detect a relevant difference. Home ranges of the translocated individuals appear to be spatially segregated from those of the residents. This visual observation is supported by the MRPP analysis, which found the spatial distribution of burrows used by translocated individuals to be different from the spatial distribution of resident burrows during the same period. This suggests that the residents and translocated individuals differed in their aggregate burrow placements. This does not confirm that the home ranges of the residents and translocated individuals were segregated. The point patterns of resident and translocated individuals may have been different (more clumped or dispersed) within a common area. This possibility is likely given the overlap patterns of the home ranges of translocated and resident individuals did
not support my visual assessment that the translocated and resident individuals were isolated from each other.

The oak hammock and old field habitats were the most frequently used by the resident individuals before and after the translocations. Two habitats (the flatwoods and the power line right-of-way) used by the resident individuals were not utilized by the translocated individuals. Four of the resident individuals significantly altered their relative use of different habitats following the translocation events, however these individuals had maintained home ranges before the translocations that were directly adjacent to the areas they eventually moved into. Interestingly, most of the shifts in habitat use involved an increase in use of the old field, where the translocated individuals were released and where a majority of the translocated individuals maintained home ranges. In this regard, it does not appear that the release of the translocates repelled the resident individuals. It is possible that these resident shifts into the old field were due to the prescribed burning that occurred in the old field during the study. Herbaceous plant material following the burn would have been more abundant and this may have attracted individuals into the area. It is also possible that resident individuals were able to maintain burrows in the oak hammock, which is at a lower elevation and is presumably wetter than the old field, at the start of the study because it was a dry year. Conditions were wetter in the second half of the study and individuals may have moved into higher ground in the old field.

Physiologically, the resident individuals did not appear to be negatively affected by the translocations. The body condition of the male resident tortoises, as measured by the BCI, significantly increased after the translocated individuals were moved on site.
The difference in rainfall between the two years, although substantial, is not likely to have had an appreciable effect on plant health or gopher tortoise hydration (i.e. the observed increase in BCI is not likely an artifact of differential rainfall between the two years). This increase in body condition may be a result of an increase in available herbaceous plant material following prescribed burning that took place between the two years.

Post-translocation reproductive activity was evidenced by the presence of eggs in several females. While this is encouraging, it is imperative to note that this finding says nothing of reproductive activity among translocated males and translocation success can be influenced by the mating strategy of the species. Sigg et al. (2005) studied paternity in subsequent generations following the translocation of bridled nailtail wallabies (*Onychogalea fraenata*), a polygynous species, and observed that larger males had a much greater probability of siring young than did smaller males. The researchers found that below a certain threshold size, a male, although sexually mature, has only a fraction of the reproductive success of a male at or above the threshold size level. This result led to the conclusion that translocation programs involving polygynous individuals should release higher numbers of females than males and that the males released should be of adequate size to ensure mating opportunity. An alternative conclusion is that it may be less disruptive to the existing reproductive population in species in which large males exhibit preferential siring to translocate smaller males because they gradually assimilate into the reproductive population (Colson-Moon 2003).

A related consequence to the mating system of the gopher tortoise is the potential for the disruption of the existing social structure when new individuals are translocated
onto the site. A similar size-based hierarchy is observed in the desert tortoise (Gopherus agassizi) and it has been suggested that the introduction of new individuals into a system with a pre-existing hierarchy might severely upset any existing hierarchy (Berry 1986). It was also suggested that tortoises maintained territories at low densities and hierarchies could form when density increased. The increase in density may also lead to an increase in aggressive interactions. (Berry 1986). Recent evidence has shown that gopher tortoises in large areas of high-quality habitat may use a mating system that resembles scramble-competition polygyny, although in smaller, more highly-disturbed areas, males may be able to defend female burrows and the mating system switches to the system of harem-defense polygyny that has been proposed by researchers in the past (Boglioli et al. 2003).

Several studies have addressed problems inherent to translocation efforts that are beyond the scope of this study. One major concern with wildlife translocations is the spread of disease (Cunningham 1996). Upper respiratory tract disease (URTD) has been a major concern in recent years. This disease, caused by a bacterial mycoplasm (Mycoplasma agassizi), is spread when tortoises are in contact with one another (Mushinsky et al. 2006). Individuals infected by this disease, which causes damage to the respiratory tract cilia, are unable to pass the mucous produced by the bacteria, which then migrates into the eyes (Smith et al. 1998; Berish et al. 2000). Individual tortoises may be carriers for the mycoplasm that causes URTD but may not become symptomatic until they are subjected to stress (Berish 2000, but see McCoy et al 2005). With the increasing frequency of gopher tortoise translocations, diseases, such as URTD, could be spread among these social animals. Because of the potential to spread disease, the
Florida Fish and Wildlife Conservation Commission has requirements for the testing of individuals prior to the issuing of a permit to translocated tortoises. Populations that support tortoises that test positive for the presence of antibodies to this disease cannot be translocated off-site (FFWCC 2001). The high potential for the spread of disease among social animals is one reason that larger recipient sites are preferable to smaller ones.

The degree to which the recipient site is managed will affect the success of a translocation. The Brooker Creek Preserve Tract, onto which the gopher tortoises in this study were moved, is an actively managed parcel of land. County personnel routinely use prescribed burns to manage the lands, ensuring that herbaceous groundcover, which gopher tortoises depend upon for forage, is abundant. The presence of land managers also affords the gopher tortoises greater protection from poachers. Unfortunately, not all recipient sites have been managed with prescribed burns and invasive plant removals. Lack of management on the recipient land can result in degradation of habitat quality to the degree that gopher tortoises will abandon the site in search of higher-quality habitat. As these individuals journey off of the site, they may fall victim to automobiles or they may wander aimlessly, not finding suitable habitat or conspecifics. The absence of land managers on recipient sites also puts the gopher tortoises at a higher risk for poaching.

My study highlights some of the key problems associated with monitoring translocation success. The retrospective power analysis performed on several statistical analyses used in this study yielded necessary sample sizes upward of 90 individuals to achieve significant results. Sample sizes that large are impractical when working within most gopher tortoise translocations. The size and carrying capacity of the recipient site,
and the costs of transmitters and labor in obtaining large numbers of fossorial organisms, limit such studies.

Another limitation is the lack of adequate and appropriate controls. Because of the nature of translocation, advance knowledge of donor sites is not available to allow the collection of baseline data for the translocated population. In my study, for example, I was unable to make comparisons regarding changes in the movements of translocated individuals after their release on the study site. I had to rely instead on published data to determine whether the areal extent of the home ranges used by translocated individuals in my study fit within the realm of what has been observed for natural populations. Even with years of post-translocation monitoring, which many studies stress the need for, proper before and after comparisons cannot be made because of the absence of a control.

The lack of significant behavioral and physiological alterations by gopher tortoises in response to translocation events in this study is not synonymous with giving gopher tortoise translocation a “green light.” Numerous potentially negative effects of translocation exist that are beyond the scope of this study, but still must be considered before deciding to implement a translocation program. Gopher tortoise translocation does not replace the habitat that is lost to the development and the future of the gopher tortoise depends upon suitable land being available. The incidental take permit is the current alternative to moving individuals when development is certain and sufficient on-site land cannot be set aside for relocation. Incidental take permits generate funds to purchase private lands that can support the gopher tortoise and other upland species. Although this option preserves valuable habitat, the take of healthy individuals is a long way from a sustainable solution. At present, there is no perfect solution. In the future,
removal of the incidental take option and requiring developers to fund not only the
relocation of displaced individuals, but also the maintenance of the mitigation area, may
be an option that results in exhausting the available recipient sites and potentially slowing
down urbanization (McCoy et al. 2006). Until then, development continues and we need
to do our best with the available conservation tools.

References


respiratory tract disease in gopher tortoises in Florida. Journal of Herpetology
34(1):5-12.

Berry, KH. 1986. Desert tortoise (Gopherus agassizi) relocation: Implications of social
behavior and movements. Herpetologica 42(1); 113-125.

Blankenship, EL, TW Bryan, and SP Jacobson. 1990. A method for tracking tortoises

Boglioli, MD, C Guyer, and MK Michener. 2003. Mating opportunities of female gopher
 tortoises, Gopherus polyphemus, in relation to spatial isolation of females and
Brito, JC. 2003. Seasonal variation in movements, home range, and habitat use by male
Vipera latastei in Northern Portugal. Journal of Herpetology 37(1); 155-160.

Burke, RL. 1989. Florida gopher tortoise relocation: overview and case study. Biological

Burke, RL. 1991. Relocations, repatriations, and translocations of amphibians and

Colson-Moon, JC. 2003. Reproductive characteristics, multiple paternity, and mating
system in a central-Florida population of the gopher tortoise Gopherus

Cunningham, AA. 1996. Disease risks of wildlife translocations. Conservation Biology
10(2):349-353.

Dodd, CK and RA Siegel. 1991. Relocation, repatriation, and translocation of amphibians

mitigating development threats to great crested newts (Triturus cristatus) in


Moore, RD, ED McCoy, HR Mushinsky, and SC Riedl. In review. Body condition of gopher tortoises (Gopherus polyphemus) in Florida, and a comparison with desert tortoises (G. agassizii) in California.


Figure 1. Location map showing Brooker Creek Study Area.
Figure 2. Oak hammock, old field, flatwoods, and sandhill areas at Brooker Creek Study Area.
Table 1. Resident and translocated individuals (2001-2004).

<table>
<thead>
<tr>
<th>GROUP</th>
<th>SEX</th>
<th>INCORPORATED INTO STUDY</th>
<th>DATE OF LAST CONFIRMED LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RESIDENT</td>
<td>M</td>
<td>09/01/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>09/01/2001</td>
<td>04/07/2004&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>09/01/2001</td>
<td>06/06/2004&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>09/01/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>09/01/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>09/01/2001</td>
<td>03/23/2003&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>09/01/2001</td>
<td>05/09/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>09/01/2001</td>
<td>07/15/2002&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>09/01/2001</td>
<td>06/21/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>09/01/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>09/01/2001</td>
<td>11/19/2002&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10/16/2001</td>
<td>04/06/2003&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10/16/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10/16/2001</td>
<td>08/08/2003&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10/16/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10/16/2001</td>
<td>10/17/2001&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>10/16/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10/16/2001</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10/16/2001</td>
<td>08/08/2002&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>TRANSLOCATION GROUP ONE</td>
<td>F</td>
<td>05/01/2002</td>
<td>05/30/2004&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>06/07/2002</td>
<td>06/06/2004&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>06/08/2002</td>
<td>10/21/2002&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>06/12/2002</td>
<td>06/30/2003&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>TRANSLOCATION GROUP TWO</td>
<td>F</td>
<td>03/19/2003</td>
<td>09/29/2003&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>03/19/2003</td>
<td>04/19/2004&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>03/19/2003</td>
<td>06/15/2004&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>03/19/2003</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>04/30/2003</td>
<td>08/10/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>04/30/2003</td>
<td>08/14/2004</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>04/30/2003</td>
<td>08/18/2004</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>04/30/2003</td>
<td>07/13/2004&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>04/30/2003</td>
<td>07/09/2004&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> = transmitter presumed to have fallen off tortoise; <sup>b</sup> = transmitter found off of tortoise or tortoise captured without transmitter; <sup>c</sup> = individual moved off-site; <sup>d</sup> = transmitter failed
Table 2. Percentage of females displaying shelled eggs reported in the literature and in this study.

<table>
<thead>
<tr>
<th>STUDY</th>
<th>LOCATION</th>
<th>% FEMALES WITH EGGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Godley 1989 (Site 1)</td>
<td>Central FL</td>
<td>0.5</td>
</tr>
<tr>
<td>Godley 1989 (Site 2)</td>
<td>Central FL</td>
<td>0.66</td>
</tr>
<tr>
<td>Colson-Moon 2003</td>
<td>Central FL</td>
<td>0.27-0.71</td>
</tr>
<tr>
<td>Diemer and Moore 1994</td>
<td>North-Central FL</td>
<td>0.85-0.89</td>
</tr>
<tr>
<td>THIS STUDY - RESIDENT BEFORE</td>
<td>CENTRAL FLORIDA</td>
<td>0.25</td>
</tr>
<tr>
<td>THIS STUDY - RESIDENT AFTER</td>
<td>CENTRAL FLORIDA</td>
<td>0.67</td>
</tr>
<tr>
<td>THIS STUDY - TRANSLOCATED AT</td>
<td>CENTRAL FLORIDA</td>
<td>0.5</td>
</tr>
<tr>
<td>START</td>
<td>CENTRAL FLORIDA</td>
<td>0.2</td>
</tr>
<tr>
<td>(1 and 2 years after release combined)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3. Home range estimates reported in the literature for natural and translocated populations of gopher tortoises.

<table>
<thead>
<tr>
<th>Population</th>
<th>Study</th>
<th>Location</th>
<th>Male Home Range (ha)</th>
<th>Female Home Range (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural</td>
<td>Smith et al 1997</td>
<td>Central FL, east coast</td>
<td>1.92 (0.3-5.3, n= 10)</td>
<td>0.65 (0.3-1.1, n= 4)</td>
</tr>
<tr>
<td></td>
<td>McRae et al. 1981</td>
<td>Southwest GA</td>
<td>0.45 (0.06-1.44, n= 6)</td>
<td>0.08 (0.04-0.14, n= 5)</td>
</tr>
<tr>
<td></td>
<td>Mc Laughlin 1990</td>
<td>Sanibel Island FL</td>
<td>1.05 (0.28-2.17, n=7)</td>
<td>0.085 (0.0122-0.0935, n=6)</td>
</tr>
<tr>
<td></td>
<td>Stout and Doonan 1989</td>
<td>Central FL</td>
<td>1.1 (0.29-2.94, n=4)</td>
<td>0.56 (.02-1.19, n=4)</td>
</tr>
<tr>
<td></td>
<td>Eubanks et al. 2003</td>
<td>Southwest GA</td>
<td>1.1 (0-4.8, n= 68)</td>
<td>0.4 (0-3.4, n= 51)</td>
</tr>
<tr>
<td>Trans.</td>
<td>Tuberville et al. 2006- no pen</td>
<td>Southwest SC</td>
<td>17.5 (0.7-34.2, n=2)</td>
<td>5.0 (5.0-5.0, n=1)</td>
</tr>
<tr>
<td></td>
<td>Stout and Doonan 1989</td>
<td>Central FL</td>
<td>3.19 (0.25-11.58, n=5)</td>
<td>6.96 (3.83-10.09, n=2)</td>
</tr>
</tbody>
</table>
Figure 3. MCP home ranges of resident (dashed lines) and translocated (solid lines) individuals (2003-2004).
Figure 4. Comparative use of different habitats by resident and translocated individuals.
Appendices
Appendix A. List of morphometric measurements taken of all individuals

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length (TL)</td>
</tr>
<tr>
<td>Carapace Length (CL)</td>
</tr>
<tr>
<td>Plastron Length (PL)</td>
</tr>
<tr>
<td>Width (W)</td>
</tr>
<tr>
<td>Maximum Thickness (MT)</td>
</tr>
<tr>
<td>Anal Width (AW)</td>
</tr>
<tr>
<td>Anal Length (AL)</td>
</tr>
<tr>
<td>Anal Shield Thickness (AT)</td>
</tr>
<tr>
<td>Depth of Plastral Concavity (PC)</td>
</tr>
<tr>
<td>Mass</td>
</tr>
</tbody>
</table>