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Translocation of the gopher tortoise: Difficulties associated with assessing success

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Abstract. Gopher tortoises on lands to be developed may be translocated as a conservation measure, sometimes to areas already occupied by the species. We assessed the success of this type of translocation by monitoring the movements, spatial positioning, health, and reproductive activity of translocated and resident individuals at a site in central Florida from 2001 to 2004. By several criteria, the translocation was a success. Most translocated individuals remained on-site for at least one year, home ranges of resident individuals were not significantly different before and after translocation, home ranges of translocated individuals fit within the range of estimates reported in the literature, and neither body condition nor reproduction of either group of individuals could be shown to be affected by the translocation. On the other hand, several resident individuals altered their habitat use after translocation and the spatial positioning of resident individuals was different than that of individuals throughout; so, some potential exists for future off-site movements. The study illustrates two practical problems in assessing translocation success: lack of adequate pre-translocation data for both resident and translocated individuals, which interferes with documentation of translocation effects, and the necessarily small sample sizes, which reduces statistical power.

Key words: Body condition; *Gopherus polyphemus*; home range; radiography; radio telemetry; translocation.

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. We know little of the historical structure and abundance of gopher tortoise populations, but we can speculate that the widespread conversion of upland habitats for human use has resulted in present numbers of gopher tortoises that are only a fraction of historic numbers. More than 80% of the xeric habitat present in the 1960's had disappeared by the 1990's (Mushinsky et al., 2006). As human expansion occupies more and more suitable gopher tortoise habitat, the future of the species becomes

increasingly uncertain (McCoy et al., 2008). In much of its geographic range, the gopher tortoise is restricted to small, isolated patches of habitat, making it susceptible to extinction (Lohoefer and Lohmeier, 1986; Mushinsky and McCoy, 1994; McCoy et al., 2008).

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 occurred historically, to reestablish a population of a species that inhabited an area historically but may not at the present, or to augment a population that already exists (Reinert, 1991). We use the term here to refer to the augmentation of an existing population. Translocation is attractive to biologists because it does not result in the immediate loss of individuals, although it is costly and not all of the potential ramifications are known. A variety of birds (e.g., Wolf et al., 1996; Engelhardt et al., 2000), mammals (e.g., Smith and Clark, 1994; Warren et al., 1996; Wolf et al., 1996; Sigg et al., 2005), and reptiles (e.g., Reinert and Rupert, 1999; Sullivan et al., 2004; Edgar et al., 2005) have been translocated. More than 25,000 gopher tortoise individuals have been translocated in Florida (Mushinsky et al., 2006), with varying degrees of success (e.g., Diemer, 1989; Fucigna and Nickerson, 1989; Stout et al., 1989; Godley, 1989; Layne, 1989; Macdonald, 1996; Small and Macdonald, 2001). The uplisting of the gopher tortoise in Florida from a Species of Special Concern to Threatened by mid-2007 (Enge et al., 2006) and the removal of upper respiratory tract disease testing requirements that had been in place until this year (FFWCC, 2006), portends an increasing shift from incidental take to translocation (McCoy et al., 2008).

Translocation should not be considered a "quick fix"; rather, the goal should be long-term success. Movements of individuals off-site following their release can reduce the success of gopher tortoise translocations. Movements of individuals are strongly influenced by environmental factors, such as habitat quality and density of individuals (McRae et al., 1981b; Mushinsky and McCoy, 1994). Translocated gopher tortoises show lower site fidelity than residents (Bard, 1989). 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 can lead tortoises into unsuitable habitat and high-traffic areas. As suitable recipient sites dwindle in number, the potential deleterious effects of translocated individuals on conspecifics already at the recipient site will be of increasing concern. Translocated individuals could affect the spatial use patterns; the social structure and, consequently, the reproductive activity; and the overall condition of the resident individuals. To assess long-term success, it is essential to monitor translocated and resident individuals (Berry, 1986; Burke, 1989, 1991; Dodd and Siegel, 1991; Tuberville, 2005; McCoy and Berry, 2008). Behavioral and physiological profiles of both groups should be compared pre- and post-translocation. Indicators such as body condition, site fidelity, reproductive activity, home range size, and rate of burrow switching may be used to develop these profiles.

Our 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 before and after other individuals were translocated to the study site; and of the translocated individuals from the time they were released onto the study site. We defined success a priori as (1) the presence of the majority of resident and translocated individuals on the recipient site one year post-translocation and (2) the absence of negative effects on the well-being of resident and translocated individuals. Our study also illustrates some of the practical problems that can compromise even the most efficient monitoring schemes.

Methods

Data collection

The study site was the Brooker Creek Buffer Tract in west-central Florida (82°38'55.327"W, 28°7'37.342"N). The study site consisted of a 6.7 ha old field and an adjacent 9 ha oak hammock (fig. 1). The old field is in an early successional stage with abundant grasses and herbaceous plants under a sparse tree canopy; in contrast the oak hammock, which is comprised of mature oaks, scattered upland coniferous species, and saw palmetto (*Serona repens*), is largely overgrown because of fire suppression. Throughout the study, several resident individuals maintained burrows in a 3.5 ha patch of flatwoods immediately south of the oak hammock (fig. 1). A group of individuals translocated in the mid 1990's occupied a 3.5 ha patch of sandhill (a well-drained turkey oak (*Quercus laevis*) -saw palmetto association) immediately east of the old field (fig. 1). 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 old field averaged about 2.5 m higher than in the oak hammock, suggesting that the old field was better drained than the oak hammock. The areas surrounding the study area were generally too wet to provide suitable gopher tortoise habitat, although some suitable habitat did exist, particularly the upland forested areas west of the power line corridor.

In fall 2001, all active burrows encountered in the oak hammock and old field were trapped by placing 24 L buckets at the mouths of the burrows. Nineteen resident tortoises were captured, 11 in the oak hammock and 8 in the old field, and they were penned on-site as captured until trapping was completed. These individuals did not constitute the entire population of gopher tortoises on the study site, as unmarked tortoises ($n = 3$) were encountered during the study. All trapped individuals were determined to be seronegative for *Mycoplasma agassizii* (the principal cause of upper respiratory tract disease). Each individual was uniquely marked by file-notching the marginal carapacial scutes, and measured (carapace length, maximum width, and mass; McRae et al., 1981a). Each individual was fitted

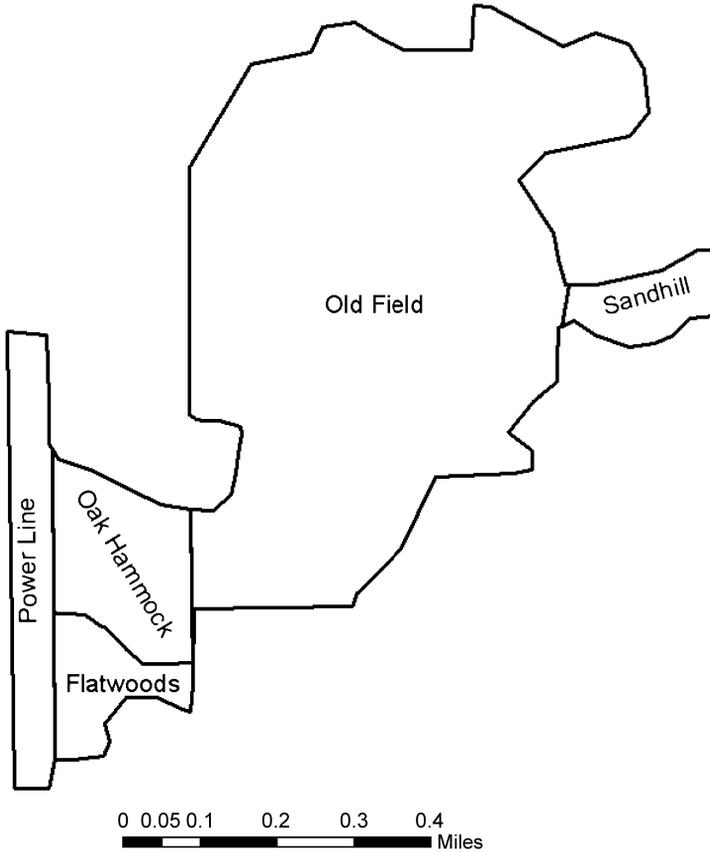


Figure 1. Spatial relationships of study area habitats.

with a Holohil AI-2 transmitter with a mass of approximately 28.7 g. The transmitter was affixed to the rear marginal carapacial scutes of the tortoise and then covered with a waterproof epoxy resin. Individuals were returned to the burrows from which they were captured.

Three groups of translocated individuals were released at the study site. In May 2002, three females and one male were translocated to Brooker Creek from a site a few miles to the north. They were penned individually awaiting procurement of additional individuals, so that all translocated individuals could be released simultaneously. Additional individuals were not obtained expeditiously, however, and the four individuals were released together in the southwest corner of the old field after 3 wks. No starter burrows were provided; animals were released in an area containing both active and inactive resident gopher tortoise burrows. In spring 2003, two additional groups of individuals from other donor sites were translocated to the study site. The first group (three females and one male) was released in the old field in March, and the second group (four females and one male) was released in the old field in May. Both groups were released in the same location as the first

group of translocated individuals. Neither of these two groups was penned prior to release. Prior to release, each individual was marked, measured, and fitted with a transmitter, as described for the resident individuals. All translocated individuals were determined to be seronegative for *M. agassizi*.

After release, both resident and translocated individuals were located using radio telemetry. Each individual was located with a TRX-2000S receiver and a folding 3-element Yagi antenna (Wildlife Materials; Carbondale, Illinois). Resident individuals 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 on the same schedule as resident individuals. Locations were determined once daily, between 0700 and 1730 h. Tortoises usually were found to be in burrows, and coordinates of occupied burrows were mapped with a Trimble Pathfinder@ Pro XR receiver (Trimble Navigation, Sunnyvale, California). When an individual was sighted above ground, its location was flagged and later mapped. If a tortoise was located outside a burrow we recorded the individual's activity.

Egg production of females was determined by X-radiography, using an Inspector X-Ray Source Model 200 (Golden Engineering, Centerville, IN) with an output of 3 millrads per 60 ns pulse. Resident females were trapped and radiographed in spring 2002 and 2004, and translocated females were radiographed in spring 2002 or 2003, prior to release, and then trapped and again in spring 2004. The majority of individuals were radiographed once in a given season, therefore the possibility for false negatives exists. For this reason, the radiography data were only used qualitatively to document whether reproductive activity was occurring, rather than to make inferences regarding relative percentages of reproductively active females or pre-post-translocation comparisons (see Data analysis). Polaroid 803 8" × 10" b/w film was processed using a Polaroid 8" × 10" Radiographic Film Processor, Model 85-12 (Polaroid, Waltham, MA). Additional size measurements of each individual (as described above) were taken before release.

At the completion of the study, in September 2004, all tortoises were pitfall-trapped. The transmitters were removed and another set of measurements was taken. Each individual was then released to the burrow from which it was captured.

Data analysis

The radio telemetry data were used to estimate home range and patterns of spatial dispersion. Before estimating home range, we censored the data to avoid several potential biases that can result from use of raw data. To reduce the effects of autocorrelation — which can result in home range underestimation — we omitted locations obtained from mid-November through mid-February, a period when individuals typically are sedentary (see Brito, 2003). To reduce the effects of erratic movements following translocation — which can result in home range overestimation — we omitted locations obtained for translocated individuals during the first 3 months following release from our home range analysis, as well as from

the other spatial use analyses. Translocated individuals seemed to have “settled-in” after three months. In the event that an individual could not be recovered at the end of the study to verify transmitter attachment ($n = 8$), the set of locations used to calculate the home range of that individual was truncated after the first instance the tortoise used its last known burrow. The same rule was applied when a transmitter was recovered that was not attached to a tortoise ($n = 5$). 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.

Two methods were used to estimate home range. The first, the minimum convex polygon (MCP) method, is simple to calculate and is easily compared with other published studies. Problems with MCP are the positive correlation of home range estimates with the sample size and the presence of outliers in the data set that can inflate home range estimates when a large portion of the area contained in the polygon is never used (White and Garrott, 1990). We computed MCP home range for each individual with ArcView 8.3 and the Hawth’s Tools extension. We used MCP only to compare the home ranges of translocated individuals and of resident individuals following the release of translocated individuals to home ranges reported in the literature. Because several translocation events occurred over the course of a year, no obvious point existed at which to divide the resident tortoise data into “before translocation” and “after translocation” sets. To make the comparison of home ranges of resident individuals following the release of translocated individuals to literature values, we adopted the convention that data on resident individuals collected before June 2002 are “before translocation” data and those collected subsequently are “after translocation” data. We employed the same convention for additional analyses.

The second method used to estimate home range was the kernel density (KD) method. This method uses non-parametric techniques to describe an individual’s home range in terms of a probabilistic model (Worton, 1989), and its use reduces the problems of sample size dependence and outlier influence that accompany MCP. HOMERANGER v. 1.5 (Hovey, 1999) was used to calculate a 95% fixed kernel home range for each individual. The program permits user specification 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. We used a fixed, rather than an adaptive, kernel density estimator because of the tendency of an adaptive kernel density estimator to overestimate home range size (Seaman and Powell, 1996). We used the least squares cross-validation (LSCV) method of selecting an appropriate bandwidth (h) (Seaman and Powell, 1996). We used KD to compare home ranges of resident individuals before and after translocation. The Wilcoxon Paired Sample Test was used to judge the significance of the comparison. Shapiro-Wilk Tests for normality revealed that the data were not normally distributed, and they could not be made so by any standard transformation; therefore, we used non-parametric tests for this, and additional analyses. We were concerned that the necessarily small

sample sizes could account for any non-significant results that we might obtain, and determined the sample sizes that would have been needed to obtain significant results with retrospective power analysis using the observed differences. Sample sizes needed for significance follow non-significant test results.

Individuals that remained on the study site for the duration of the study were considered to exhibit large-scale site fidelity. On a finer scale, fidelity of translocated individuals to areas within the study site was examined by comparing the distances moved from the start of the study to the end of the study to the distances moved by resident individuals during the same time period. The Mann-Whitney U -test was used to judge the significance of the comparison.

Three methods were used to examine spatial dispersion patterns. The first was to test for spatial segregation of resident and translocated individuals. 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 mean distances between individuals — actually burrows — within groups to the mean distance between individuals ignoring group membership (White and Garrott, 1990). A mean overall distance that is significantly greater or lesser than the mean within-group distances indicates spatial segregation of the groups. The MRPP was conducted with Blossom (USGS, 2005).

The second method used to examine spatial dispersion patterns was to test for significant overlap or non-overlap of the home ranges of resident and translocated individuals. If translocated individuals were spatially segregated from resident individuals, then one would expect the home ranges of the translocated individuals to be overlapped more by the home ranges of other translocated individuals than by the home ranges of resident individuals. We calculated the percent that each translocated individual's home range was overlapped by other translocated individuals and by resident individuals, and compared the percentages across individuals. The Wilcoxon Paired Sample Test was used to judge the significance of the comparison.

The third method used to examine spatial dispersion was to test for changes in habitat use. Change in the proportion of use of old field, oak hammock, flatwoods, and power line right-of-way (fig. 1) by resident individuals was determined by comparing the cumulative number of observations within each of the four habitats before and after translocation. The two-tailed Fisher Exact Test was used to judge the significance of the comparison.

The measurement data were used to determine body condition. Body condition was employed as a non-invasive and simple method of assessing an individual's well-being. We calculated a body condition index (BCI) for each individual, which relates the individual's mass to its volume. The index used was

$$BCI = \frac{mass}{(T_{max})(W)(C)},$$

where T_{max} is the maximum thickness of the body, W is the width, and C is the carapace length (Wallis et al., 1999). More well-hydrated and/or more well-fed

individuals will display a higher BCI (Moore et al., in review). A decline in BCI value for resident or translocated individuals during the course of the study would suggest that post-translocation conditions were less favorable for the tortoises at either the donor site or pre-translocation recipient site, respectively. A BCI was calculated for each individual each time it was captured, and initial BCI values were compared to final BCI values. The Wilcoxon Paired Sample Test was used to judge the significance of the comparison. Only measurement data for males were used in calculating the BCI values, to eliminate any potentially confounding effects of female reproductive state. Although 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., in review), a severe drought could affect BCI values that year. To examine rainfall rates during the study, we obtained rainfall data from the Tampa International Airport, and compared cumulative rainfall for July-September 2001 with that from the same 3-month period in 2004.

The radiography data were used to establish reproduction. Eggs were visible from the last week of April to the second week in June, much the same as in a well-studied location nearby (Moon et al., 2006). To decrease the risk of false negatives, data collected outside this time period were not included in the analysis. Because of small sample sizes, large natural variation in the proportion of females with shelled eggs from year to year (fig. 2), and the possibility of false negatives within the datasets, we did not perform a statistical analysis of the radiography data. The radiography data were used simply to document the presence or absence of reproductive activity following translocation.

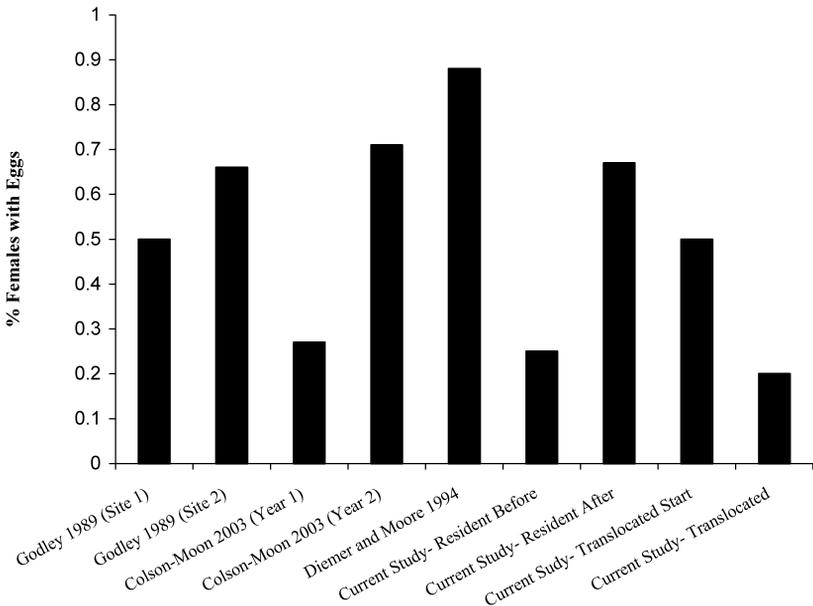


Figure 2. Percentage of females displaying shelled eggs in the literature and in this study.

Results

Resident females and resident males were in the study for an average of 785.13 days ($n = 8$, range = 296-1082) and 816.55 days ($n = 11$, range = 445-1082), respectively. Translocated females and translocated males were in the study for an average of 458.60 days ($n = 10$, range = 135-760) and 425.67 days ($n = 3$, range = 383-454), respectively. We recorded a total of 2320 locations for the resident and translocated individuals between 2001 and 2004 via radio telemetry. Individuals were observed aboveground only 13 times (0.56%). Nine of the individuals observed aboveground were positioned at the mouths of their burrows, three were moving, and one was foraging along the edge of a road. Two individuals occupied the same burrow simultaneously 15 times (0.65%).

Translocation could not be shown to affect home range sizes. The MCP home range estimates for translocated individuals (medians = 0.34 ha for females and 0.08 ha for males) and for resident individuals following translocation (median = 0.78 ha for females and 0.63 ha for males) both were similar to home range estimates from the literature (table 1). No significant difference was detected in the KD home range estimates for female resident tortoises before ($\bar{x} = 0.071$ ha) and after ($\bar{x} = 0.106$ ha) translocation ($T+ = 6$, $n = 6$, $p > 0.5$) or for male resident tortoises before ($\bar{x} = 0.175$ ha) and after ($\bar{x} = 0.201$ ha) translocation ($T+ = 21$, $n = 10$, $p > 0.5$). Sample sizes of 30 and 89 individuals, respectively, would have been needed for these results to be significant at $\alpha = 0.05$. In contrast to many other gopher tortoise home range studies (table 1), the home ranges of males in this study were not larger than those of the females.

Table 1. Home range estimates reported in the literature for natural and translocated populations of gopher tortoises.

Population	Study	Location	Male home range (ha) mean (range)	Female home range (ha) mean (range)
Natural	Smith et al., 1997	Central FL, east coast	1.92 (0.3-5.3, $n = 10$)	0.65 (0.3-1.1, $n = 4$)
	McRae et al., 1981	Southwest GA	0.45 (0.06-1.44, $n = 6$)	0.08 (0.04-0.14, $n = 5$)
	Mc Laughlin, 1990	Sanibel Island FL	1.05 (0.28-2.17, $n = 7$)	0.085 (0.0122-0.0935, $n = 6$)
	Stout and Doonan, 1989	Central FL	1.1 (0.29-2.94, $n = 4$)	0.56 (.02-1.19, $n = 4$)
Translocated	Eubanks et al., 2003	Southwest GA	1.1 (0-4.8, $n = 68$)	0.4 (0-3.4, $n = 51$)
	Tuberville et al., 2006 – no pen	Southwest SC	17.5 (0.7-34.2, $n = 2$)	5.0 (5.0-5.0, $n = 1$)
	Stout and Doonan, 1989	Central FL	3.19 (0.25-11.58, $n = 5$)	6.96 (3.83-10.09, $n = 2$)

Individuals exhibited varying degrees of site fidelity. No resident individual and only one translocated individual moved off site during the study. The individual that moved off-site, a female translocated in 2003, used burrows well within the study area for six months, moved outside the study area temporarily on 29 September 2003 and again on 1 October 2003, and then moved outside of signal-range before it could be recaptured. Transmitter failure is possible, but unlikely, because the transmitter had only been attached for a relatively short time and all other transmitters performed at expected levels. The mean displacement of individuals from their positions immediately post-translocation to their positions at the end of the study was 63.2 m ($n = 12$) for resident individuals and 146.1 m ($n = 9$) for translocated individuals ($U = 59$; $p < 0.05$).

The relative positions of the home ranges of resident and translocated individuals suggest that they were spatially segregated (fig. 3). The results of the MRPP analysis support this suggestion (standardized MRPP test statistic = 14.0855, $n = 113$, $p < 0.001$). No significant difference in the mean percent overlap of the home ranges of resident (54.4%) and translocated (41.0%) individuals on the home ranges of translocated individuals could be detected ($T- = 18$, $n = 9$, $p > 0.5$). Sample sizes exceeding 100 would have been needed for this result to have been significant at $\alpha = 0.05$. Most resident individuals and all translocated individuals were located in the old field and oak hammock habitats (fig. 4) throughout the study. Of the 16 resident individuals for whom we had data both before and after



Figure 3. MCP home ranges of resident (dashed lines) and translocated (solid lines) individuals (2003-2004).

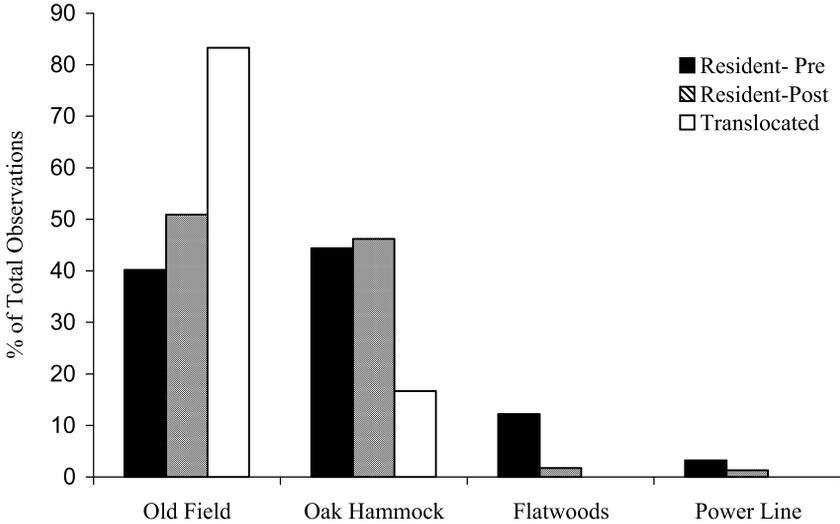


Figure 4. Comparative use of different habitats by resident and translocated individuals.

translocation, eight were observed to use only one habitat type throughout the study. Of the eight other resident individuals, four significantly altered their habitat use after the release of translocation (p values of significant individuals ranged from 0.0001 to 0.086): three 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.

Body condition of resident individuals did not decline after translocation. Mean body condition of five resident males actually could be shown to be better in 2004 ($\bar{x} = 0.555$) than in 2001 ($\bar{x} = 0.516$) ($T + = 0, n = 5, p < 0.10$). Total rainfall in July-September 2001 was 52.3 cm, but in the same time period in 2004 was 86.4 cm.

Reproduction of both resident and translocated individuals was observed after translocation. We observed eggs in two of three resident females X-rayed in 2004, after translocation; and, although we did not observe eggs in any of three translocated females X-rayed in 2004, we observed eggs in one of two translocated females a year later. Prior to translocation, we had observed eggs in one of four resident females and four of eight translocated females. Results of all analyses performed are summarized in table 2.

Discussion

By both of the measures we employed, the translocation was a success. First, the majority of resident and translocated individuals remained on the recipient site one year post-translocation. All resident individuals and 12 of the 13 translocated individuals remained on the site for the duration of the study, although displacement distances of translocated individuals were greater than those of resident individuals,

Table 2. Parameters studied, criteria for success, and outcome

Parameter	Criteria for translocation success	Achieved
Resident		
Fidelity	Majority of individuals remained on study site for duration of the study	Yes
Home range	(1) MCP home ranges similar to those of “natural” populations reported in literature following the translocation; (2) KD home range of resident individuals before and after translocation not significantly different	1: Yes 2: Yes
Spatial segregation	No significant difference in the dispersion of burrows used by resident and translocated individuals (MRPP)	No
Habitat Use	No unexplained shift to usage of marginal habitats by resident individuals following the translocation	Yes
Radiography	Observed reproductive activity following translocation	Yes
Body condition	BCI values not significantly lower for residents following the translocation	Yes
Translocated		
Fidelity	(1) Majority of individuals remained on site for the duration of the study; (2) No significant difference between translocated and resident individuals in the mean distance moved by individuals from the time of the translocation until the end of the study	1: Yes 2: No
Home range	Home ranges similar to those of “natural” populations reported in literature	Yes
Spatial segregation	(1) Home ranges of translocated individuals not significantly more overlapped by the home ranges of other translocated individuals than by the home ranges of residents; (2) No significant difference in the dispersion of burrows used by resident and translocated individuals (MRPP)	1: Yes 2: No
Radiography	Observed reproductive activity following translocation	Yes

even after a 3-month acclimation period. The latter result suggests that translocated individuals had some difficulty in acclimating to the area in which they had been released and, if they continued relatively-long distance movements, might eventually move off-site.

Second, few negative consequences of translocation for either the resident or translocated individuals were noted. The sizes and locations of home ranges used by resident and translocated individuals did not appear to be affected by translocation. Home range sizes of resident and translocated individuals in this study were similar to those reported in the literature, although translocated individuals elsewhere have been shown to maintain relatively large home ranges (e.g., Tuberville et al., 2005). We note that within both resident and translocated groups, the home ranges of the female individuals in this study were greater than those of the males, whereas most studies of natural populations note the opposite phenomena. Furthermore, overlap of home ranges did not indicate that resident and translocated individuals were segregated in space, despite their different point patterns. Most of the observed

shifts in habitat use by resident individuals were from the oak hammock to the old field, where translocated individuals were released and where a majority of them remained throughout the study. These shifts may have been prompted by the prescribed burning in the old field during the study or by the relatively wet conditions in the oak hammock during the latter stages of the study. Effective management of translocation sites, such as by prescribed burning, is crucial to the success of translocation efforts (McCoy et al., 2008, and included references).

The health of resident individuals, as inferred from body condition, did not decline following translocation, and both resident and translocated females displayed evidence of reproduction post-translocation. The body condition of male resident tortoises actually improved after the translocation. Again, the prescribed burning, which caused a flush of herbaceous vegetation, or the increased rainfall, or both, may have been responsible for this improvement in body condition. Although females continued to reproduce after translocation, our results do not indicate whether hatching and nesting success were comparable to other populations. Our results also do not address questions about the consequences of translocation for paternity. For example, what sex ratio and size distribution of translocated individuals would be the best to employ, given the mating strategy of the gopher tortoise (see Berry, 1986; Boglioli et al., 2003; Sigg et al., 2005; Moon et al., 2006)?

The general lack of significant test results raises some important concerns about studies of translocation success. One such concern involves the nature of pre- and post-translocation comparisons. In particular, relevant information about the translocated population at the donor site(s) typically is completely lacking. One can only infer patterns indirectly. Even if some pre-translocation information were available, it likely would not be enough to capture all of the possible variation that, for example, substantial differences in rainfall might engender. Another concern about studies of translocation success is the necessarily small sample sizes that often must be employed. Small sample sizes could cause acceptance of an incorrect null hypothesis, with a consequent high cost (Shrader-Frechette and McCoy, 1992; Di Stefano, 2001). Within the framework of applied ecology, however, differences that are significant only at unrealistically large sample sizes become meaningless. The retrospective power analyses that we employed revealed that sample sizes of 30-100+ individuals were required to achieve significant results at $\alpha = 0.05$; yet, sample sizes that large are impractical for most individual translocations of gopher tortoises. The carrying capacity of recipient sites, at about 2-3 individuals per acre (FFWCC, 2006), the small numbers of individuals typically available for translocation, and the costs of transmitters and labor typically limit the numbers of individuals that can be monitored to assess success.

It is important to note that, even when translocation appears to be a successful conservation technique, it is not a replacement for the retention and acquisition of high-quality habitat for the gopher tortoise. If development occurs at such a pace that land for both the protection of existing populations and the reception of populations displaced by development is consumed, then conservation efforts will quickly reach

an impasse. Imminent changes in the listing status of the gopher tortoise in Florida and in disease testing requirements will encourage on- and off-site translocation. We may quickly exhaust the remaining available recipient sites (McCoy et al., 2008).

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