7-2-2014

Are gopher tortosies (Gopherus polyphemus Daudin) comaptible with cows?

Thomas William Hentges
University of South Florida, twhentges@comcast.net

Follow this and additional works at: https://scholarcommons.usf.edu/etd

Part of the Other Animal Sciences Commons

Scholar Commons Citation

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.
Are Gopher Tortoises (*Gopherus polyphemus* Daudin) Compatible With Cows?

by

Thomas William Hentges

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

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

Date of Approval:
July 2, 2014

Keywords: Gopher Tortoise, Cattle Grazing, Cattle Ranching, Cow/Calf Farming, Florida, Pasco County, Translocation

Copyright © 2014, Thomas William Hentges
I first want to thank my advisors Dr. Henry Mushinsky, Dr. Earl McCoy, and Dr. Gordon Fox, as well as my family, for their unwavering patients and support through this endeavor. I want to thank all undergrads and graduate students who volunteered to help with the arduous field work and silt fence repair. I know you might not have had as much hands-on experience with the tortoises, but I hope you took something away from it anyway and that you put your experiences to good use in the future. I want to thank the Barthle Brother Ranch for allowing us the opportunity to conduct our research on their property, the Florida Fish and Wildlife Conservation Commission for providing the funding, and the University of South Florida for the opportunity to attend graduate school. A huge thanks goes out to Bill Griffy for all his hard work and coordination to help keep tortoises coming to the recipient site. A very special thanks goes out to Joan Berish at the FWC. Joan, without your support, friendship, or your belief in me, I wouldn’t have had this opportunity. Lastly, and perhaps most importantly, a special thanks goes out to Anna Hathaway. Without you, I wouldn’t have made it through Biometry or even past the first semester of graduate school. I also have to thank you, Anna, for all the interesting conversations, your acceptance of my dry sense of humor, and your patience while sitting through my tirades about the project, politics, and life. Your friendship means the world to me and I hope we have the opportunity to work together in the future.
**TABLE OF CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>ii</td>
</tr>
<tr>
<td>List of Figures</td>
<td>iii</td>
</tr>
<tr>
<td>Abstract</td>
<td>iv</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Site Description, Study Design, and Data Gathering</td>
<td>4</td>
</tr>
<tr>
<td>Hypothesis, Tests, Results</td>
<td>13</td>
</tr>
<tr>
<td>- Burrow Density</td>
<td>13</td>
</tr>
<tr>
<td>- Burrow Spacing</td>
<td>14</td>
</tr>
<tr>
<td>- Burrow Relocation</td>
<td>16</td>
</tr>
<tr>
<td>- Body Condition</td>
<td>17</td>
</tr>
<tr>
<td>- Individual Growth Rates</td>
<td>20</td>
</tr>
<tr>
<td>- Recruitment</td>
<td>22</td>
</tr>
<tr>
<td>- Additional Results: Mortality</td>
<td>23</td>
</tr>
<tr>
<td>Discussion</td>
<td>25</td>
</tr>
<tr>
<td>Literature Cited</td>
<td>31</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 1: Number of Tortoises Released into the Treatment Plots..............................................9
LIST OF FIGURES

Figure 1: Aerial Map of Study Site in Pasco County, Florida ..................................................... 5
Figure 2: Marginal Scute Numbering Scheme Modified from Cagle (1939) ............................... 9
Figure 3: Photo of Alphanumeric Number Clip ........................................................................ 11
Figure 4: Aerial Map Illustrating Cattle Density Over 30 Days of Surveying ............................. 12
Figure 5: Median Distance Between Burrows Inside and Outside Cattle Exclosures ......................... 15
Figure 6: Mean Distance Between Burrows Inside and Outside the Exclosures Versus Burrow Density ................................................................. 15
Figure 7: Mean and Range of BCIInitial of Translocated and Resident Tortoises ....................... 18
Figure 8: Mean and Range of BCIInitial of Translocated Males and Females .............................. 19
Figure 9: Median Growth Rate (mm/year) of Translocated and Resident Female Tortoises ................................................................. 22
Figure 10: Carcass Count, Number of Tortoises Released, and Elapsed Time (Days) ............. 24
ABSTRACT

Many Gopher Tortoise populations are in steep decline throughout Florida, and various measures have been attempted to curb the trend. One such measure is to relocate tortoises to protected recipient sites on private lands. The majority of private lands in Florida are used for cattle, however, production and the effect of cattle production on tortoises is not known. Here, I tested six parameters of tortoise behavior by monitoring 1403 gopher tortoises released at the Barthle Brothers Ranch, Pasco County Florida, between August 2009 and December 2012. The parameters tested were (1) burrow density, (2) burrow spacing, (3) burrow relocation, (4) body condition, (5) individual growth rate, and (6) recruitment (addition of young to the population). I used telemetry techniques to observe movement and burrow placement as it related to cattle activity and burrow impacts, and collected morphological data to determine changes in body condition and growth. I used burrow surveys and analyzed movement patterns to interpret the propensity for tortoises to place burrows where cattle may or may not congregate. Lastly, I investigated recruitment of juveniles into the population and followed the mortality of resident and relocated tortoises in all treatment plots. I found that burrow density, distance moved when relocating to new burrows, and avoidance of cattle were not distinguishably different within or between the plots. Burrow relocation, however, was more frequent outside the exclosures. The change in body condition did not differ between males and females or resident and relocated individuals. Females within the exclosure did not grow at a rate different than those outside the exclosure although translocated females grew faster than resident females. Densities of non-adult burrows inside the exclosures were no different than densities outside the exclosure. Eleven percent of tortoises relocated to the ranch died during the project. Although we have no evidence that cattle and tortoise cannot successfully coexist, a number of circumstances
prevented rigorous testing of our hypotheses, predominately the failure of the silt fence used to enclose the treatment plots. Using a trespass-proof perimeter fence would allow a better assessment of the actual interaction between the cattle and tortoises and may shed new light on the lack of recruitment and the decline of juvenile tortoises relocated to the ranch. Without recruitment of individuals back into a population, or the persistence of reproducing adults within the population, any efforts to curb the downward trend in gopher tortoise numbers by relocating tortoises to actively grazed pasture is futile.
INTRODUCTION

The Gopher Tortoise is the only one of the five living North American tortoise species that is found east of the Mississippi River. Because the Gopher Tortoise digs extensive burrows, it is restricted to upland habitats that are found on deep well-drained soils throughout the southeastern United States (Auffenberg and Franz 1982). Florida remains the stronghold for the Gopher Tortoise, as populations occur in all 67 counties. In many parts of the State, however, populations have become greatly reduced in size and are increasingly isolated as human development continues on land with well-drained soils (Mushinsky et al. 2006). The habitats that occur on these soils are fire-maintained, and in the absence of fire, degrade rapidly; thereby making the habitat less suitable for the tortoise (Mushinsky and Gibson 1991). Frequent fires promote a lush ground cover of the herbaceous plants and grasses consumed by the Gopher Tortoise (Macdonald and Mushinsky 1988), because frequent fires restrict the closure of the tree canopy.

Because many populations of the Gopher Tortoise are in a steep downward spiral in Florida, various measures to protect the remaining populations have been put in motion. One such measure, designed to circumvent the wholesale slaughter (i.e., death by entombment) of individuals in harm’s way, is to translocate them to a safe place. Translocation has become an increasingly popular conservation tool to protect the Gopher Tortoise in Florida, but it is not without controversy. During the last decade or so, researchers have organized a framework for coping with the many questions and dilemmas involved in conservation issues. In particular, Minteer and Collins (2005) developed an “ecological ethics” that recognizes the situational and contextual dimensions of the decision-making process when managing wildlife. They recognized
four ethical domains in which researchers and managers operate: theoretical, research, animal,
and environmental. Other researchers have suggested two modifications to this ecological ethic
framework. The first is to make the ethical reasoning process transparent and user friendly; the
second is to weigh the degree to which humans “care” about the ethical domains or elements
within the domains (McCoy and Berry 2008). Conservation biologists must recognize the
severity associated with moving all organisms out of harm’s way and avoid poorly designed
translocation projects motivated by a need to “dump” unwanted organisms.

Ashton and Ashton (2008) suggested that improved pasture could be used as a recipient site for
tortoises displaced by human development. About half of the 9.2 million acres of land devoted to
agriculture in Florida is pasture land (IFIS Pub. FE 805). The appeal of improved pastures as
suitable recipient sites for displaced tortoises stems from the observation that pastures are
extremely abundant and meet some of the broad criteria included in descriptions of suitable
tortoise habitat (Mushinsky et al. 2006). That is, they have very little, if any, tree canopy,
abundant grasses, and occur mostly on well drained sandy soils. Uncertainty exists, however,
regarding the quality of forage, especially for young individuals; the increased risk of (avian)
predation caused by a lack of protective ground cover; the ability of individuals to thermo
regulate; the adverse effects of the many standard land management practices (e.g., mowing,
fertilizing, herbicide application) needed to maintain productive pastures; and the direct
interaction of cattle with Gopher Tortoises. Previous assessments have indicated that livestock
grazing may not be a major problem for Gopher Tortoises (Diemer 1986, 1987). Also, we know
that the Gopher Tortoise co-existed with cattle on portions of the southern dry prairies and in
pine plantations in northern Florida for centuries with no obvious indication that cattle pose a
significant problem to the species. On occasion, burrow entrances may have become occluded
by cattle activity, but were later reopened by the occupants (Diemer 1992).
One way in which the presence of cattle could harm Gopher Tortoise populations is the use of open sand patches in pastures as a dust source to deal with external parasites. One kind of patch is the aprons surrounding entrances to tortoise burrows. Burrow aprons are created by the spoil that accumulates as tortoises excavate burrows. These open patches of sand at the mouth of the burrows frequently serve as the site of oviposition. The possibility exists that wallowing in, and trampling of burrow aprons, could reduce the viability of eggs deposited in the apron. Additionally, upon hatching, neonate tortoises frequently dig burrows in the vicinity of the burrow apron (Mushinsky et al. 2006) and could be crushed by cow dusting.

The impetus for the current study came from the Florida Fish and Wildlife Conservation Commission’s (FWC) Gopher Tortoise biologists, who oversee the wellbeing of the Gopher Tortoise and must issue permits for translocation. These individuals must make assessments of tortoise stocking densities on FWC-approved tortoise recipient sites. If tortoises can coexist successfully with cattle, then the FWC might use existing cattle ranches as recipient sites for displaced individuals. The carrying capacity of pasture land for the Gopher Tortoise is poorly understood, as are the effects on the Gopher Tortoise of the many ranching practices used to enhance cattle production, including manure management, mowing, and fertilizing the pastures. Thus, the objective of this study was to monitor the biology of translocated tortoises as they were introduced into actively grazed, improved pasture, and to evaluate the potential use of cattle ranches as long-term recipient sites for displaced tortoises.
SITE DESCRIPTION, STUDY DESIGN, AND DATA GATHERING

Our research was conducted on the Barthle Brothers Ranch, a 3,320-hectare ranch located in Pasco County, Central Florida. At any given time, the ranch supports approximately 1,200 head of cattle and 80-100 quarter horses. The primary focus of the ranch is producing beef calves for sale at weaning ("History of the Barthle Brothers Ranch," 2000), as well as, the ranch also provides hunting activities and is host to a wide array of game, non-game, and listed wildlife species. In addition to improved pastures, the ranch supports several other habitats within the ranch boundaries, including turkey-oak sandhill, hardwood oak hammock, pine flatwoods, pine plantation, scrub (all described in Meyers and Ewel 1990), and a variety of wetlands and excavated cattle ponds.

A total of seven adjoining treatment plots spread across 154-hectares were selected based on existing barbed wire fence configurations (Figure 1). The treatment plots were completely contained within actively grazed, improved pasture along the northwestern boundary of the property. Historical aerial imagery shows that by 1967, the land had been converted to improved pasture; conditions have remained virtually the same until the present. Prior to our research, 1,419 gopher tortoises had been translocated to this ranch.

The ground cover within the treatment plots was described in detail by Hathaway (2012). A total of 4,426 one-half meter quadrats were sampled along randomly-placed transects in six of the seven treatment plots, using methods modified from Ashton and Ashton (2008). Plot 21 was not analyzed as that field did not received tortoises during our study. The percent of detritus, manure, and bare soil and the average vegetation height of each plant species were recorded for each quadrat. Maximum vegetation height (to include shoots, stems, and inflorescences) for
each species also was recorded. Bahiagrass (*Paspalum notatum*) was the most common plant in all treatment plots. Broad-leafed, herbaceous species were distributed widely among quadrats, but were recorded only in 23% of the quadrats. Four species occurred substantially more frequently than the other 68 species: Mexican clover (*Richardia brasiliensis*), horseweed (*Conzya canadensis*), three flower ticktrefoil (*Desmodium triflorum*), and Mexican tea (*Chenopodium ambrosioides*).

![Figure 1: Aerial map of study site in Pasco County, Florida. The seven treatment plots were selected based on current barbed-wire fence configurations and ranged in area from 15 ha to 32 ha. The smaller quadrates within three plots are the cattle exclosures, each with an area of 3.9 ha.](image)

The canopy, shrub, and groundcover within the hardwood oak hammocks also were sampled using the methods of Stumpf (1993). Canopy closure exceeded 85%, shrub cover ranged from 0-15%, and ground cover from 28-40%. The ground cover was heavily grazed and the soils disturbed. Dominate shrub and ground cover vegetation (when present) included shade tolerant
woody species such as beautyberry (*Callicarpa americana*), greenbrier thickets (*Smilax* spp.), and common pokeweed (*Phytolacca americana*).

The optimal study design would have been one that included numerous replicated experiments evaluating various aspects of the tortoises' biology in the presence and absence of cows; but, such an approach was unrealistic on a large functioning cattle ranch. We had to superimpose our study on normal ranching practices. The sole modification made to the cattle pastures (now called Treatment Plots) was the construction of three 3.9 ha (10 acre) cattle exclosures, created by stringing a high-tensile strength electrified fence (a double strand circuit of wire) on wooden posts about one meter (3 feet) above the ground within three of the treatment plots. Tortoises were free to move into and out of the exclosures by walking under the electrified fence. We asked, and the ranch owners agreed, not to alter any of their normal management practices during our study, so that we could accurately address our overarching question: under normal cattle ranching operations, do gopher tortoises survive, grow, and reproduce in a manner that is sustainable?

To address the question of whether cattle pastures can be considered suitable recipient sites for translocated gopher tortoise, we monitored six aspects of tortoise behavior, ecology, and general health post-translocation. These aspects were: (1) burrow density, (2) burrow spacing, (3) burrow relocation, (4) body condition, (5) individual growth rate, and (6) recruitment (addition of young to the population). The experimental design (within versus without exclosures) permitted us to compare these aspects between places where cattle roamed freely and places from which they were excluded. In most cases, we also could compare these aspects between translocated and resident individuals.

Normal pasture management at the study site typically included mowing, fertilization, herbicide application, manure management, and rotational grazing. Ammonium sulfate fertilizer, which
encourages the growth of a thick monoculture of bahiagrass, was applied to various treatment plots in June 2009 and 2010. Cows were rotated among treatment plots to allow the pasture plots to recover from intense grazing during the winter and spring months. On occasion, certain treatment plots were used for other purposes, such as production of ryegrass as an overwintering crop and production of bahiagrass seed for dispersal to other pastures. Unfortunately, herbicide application and manure management were suspended during our study. Ordinarily, manure management is conducted to redistribute nutrients evenly across pastures and accelerate decomposition (Wells and Dougherty 1997). A common method of manure management involves lashing used car tires to a steel beam and dragging the rig through pastures behind a tractor. Although the management practice would seem potentially detrimental to the Gopher Tortoise, its effect was not included in our study. Additionally, the areas within the three cattle exclosures were not mowed as often as the areas outside the exclosures, which also were grazed by the cattle. Hence, at times, the vegetation inside exclosures was more robust than outside.

All Treatment Plots were enclosed with silt fence (Department of Transportation Type A) that was buried in a trench to a depth of approximately 12 inches. Crews were employed by the ranch owner to install the fence. Because of the type of trenching machine used, the fence had to be placed approximately two feet from the barbed wire fence that surrounded each plot. Consequently, cows were attracted to the relatively lush grasses growing between the silt fence and the barbed wire; and, as a result, they frequently compromised the fence’s integrity. Unfortunately, the fence was not always repaired promptly by ranch personnel, and tortoises were free to move among the treatment plots and off the ranch property while the fence was compromised. In early September 2009, an electrified fence was installed approximately two feet to the interior of the silt fence in Plot 20. Additional electrified fencing was later installed as other plots were opened to receive tortoises. The electrified fence slowed, but did not stop, the
cattle from destroying the silt fence which resulted in a costly and an unmanageable amount of damage to the silt fence. In 2011, Plot 22 was enclosed completely with a wire-backed silt fence stapled to the three-inch wooden barbed-wire fence posts. This wire-backed fence was found to be more durable, but increased the danger to relatively small individuals being trapped when they squeezed between the fabric and the supporting wire.

Our experimental design presupposed that distribution of tortoises into treatment plots would begin with Plot 20 and work westward as each plot reached its capacity. Capacity (density) within each treatment plot was set by the FWC at approximately three tortoises per acre. This part of the design had to be abandoned, however, because the plots were porous. Instead, we attempted to ensure that plots with exclosures were maintained near capacity. Thus, Plots 16, 18 and 19 began receiving translocated tortoises simultaneously. Plots 17 and 22 were added later, and Plot 22 was the last to receive tortoises. Prior to release, each individual was marked permanently by drilling holes in the marginal scutes, in a scheme modified from Cagle (1939) (Figure 2). Individuals were weighed with a Pesola 10 kilogram spring scale. Morphological measurements were taken: straight line carapace length (SCL; anterior edge of the nucal scute to the posterior edge of the caudal scute), midline carapace width (MCW; anterior to the rear leg), and midline shell height (MSH; maximum shell height from the plastron to the peak crown of the carapace), using 50 cm tree calipers (Mushinsky et al. 1994). Adults were considered to be individuals > 230 mm SCL (Goin and Goff 1941, McRae et al. 1981, Mushinsky et al. 1994). A group of 198 tortoises, consisting mostly of adult females, received a Biomark BIO12.BPL 12 mm, 134.2 kHz PL Passive Integrative Transponder (PIT) tag inserted under the skin just below the right knee on the anterior portion of the leg. In total, 1403 translocated tortoises were released into six of the seven treatment plots between August 2009 and December 2012 (Table1).
Figure 2: Marginal scute numbering scheme, modified from Cagle (1939). The modification involved changing the 300’s position to a 400’s position.

Table 1: Number of tortoises released into the treatment plots.

<table>
<thead>
<tr>
<th>Plot ID</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hatchling (&lt;50 mm)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Juvenile (50-120 mm)</td>
<td>16</td>
<td>22</td>
<td>32</td>
<td>28</td>
<td>11</td>
<td>0</td>
<td>47</td>
<td>156</td>
</tr>
<tr>
<td>Sub-adult (120-230 mm)</td>
<td>38</td>
<td>56</td>
<td>61</td>
<td>49</td>
<td>25</td>
<td>0</td>
<td>90</td>
<td>319</td>
</tr>
<tr>
<td>Adult (&gt;230 mm)</td>
<td>125</td>
<td>79</td>
<td>180</td>
<td>168</td>
<td>85</td>
<td>0</td>
<td>279</td>
<td>916</td>
</tr>
<tr>
<td>UNK</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>180</td>
<td>158</td>
<td>275</td>
<td>245</td>
<td>121</td>
<td>0</td>
<td>424</td>
<td>1403</td>
</tr>
</tbody>
</table>

Each treatment plot was surveyed completely for Gopher Tortoise burrows six times during the course of the study. Burrow surveys were conducted via pedestrian and vehicle transects. Each plot was searched exhaustively for burrows during each survey. Pedestrian transects always were used to search the edges of plots, within the dense understory of forested areas, and within the exclosures when the vegetation was dense. Burrows were classified as Potentially Occupied (Active or Inactive) or Abandoned. Navigation across plots was guided by a Garmin Handheld Global Positioning System (GPS), and all Gopher Tortoise burrow locations were collected using a Trimble GeoXE sub-meter GPS. Burrow locations were converted to point-type shape files via Trimble Pathfinder Office software, Version 4, and exported to ArcMap 10.1 (ESRI, CA, USA). Once imported, the shape files were projected from the Geographic Coordinate System WGS1984, to a Projected Coordinate System WGS-1984-UTM-Zone-17N using ArcCatalogue 10.1 (ESRI, CA, USA). The status of each burrow was assessed and its
diameter measured. We used calipers constructed from two yard sticks affixed at their midpoint to measure burrow width. The calipers were calibrated in the lab using a known width. Burrow measurements were taken with the calipers inserted approximately 50 cm into the burrows for larger burrows (Wilson et al. 1991, Doonan et al. 1994, McCoy et al. 2006), and near the mouths for smaller burrows.

We monitored the movement of 36 adult female tortoises released into three plots (16, 18, and 19). Each tortoise was fitted with a Holohil Systems, Inc. radio transmitter attached to the right-rear marginal scutes of the carapace (Graham 1981). Transmitters were attached using a quick drying dental adhesive (Jet Tooth Shade Powder, Lang Dental Mfg Company, Inc. Wheeling, Illinois 60090-0969) provided by Old Milton Dental (4165 Old Milton Parkway, Suite 270, Atlanta Georgia, 30005). We chose this adhesive over the two-part epoxy used in other research because it dried in less than five minutes, reducing handling and confinement times, and was easily detached without leaving a residue. Transmitters were attached to randomly-selected female tortoises as they arrived on site, and eleven tortoises with transmitters were released into each plot. If a transmitter detached from a tortoise or if a tortoise died, then the transmitter was recovered (if possible), cleaned, and attached to a new female tortoise arriving on site. Similarly, if a transmitter failed and the tortoise could be recaptured, the tortoise was refitted with a fresh transmitter. Movement of each transmitting tortoise was monitored daily for the first three days after release, then once every week thereafter. Not all transmitting tortoises could be found on every occasion. The positions of transmitting tortoises were recorded with the sub-meter Trimble GPS receiver.

We recaptured 158 of the translocated tortoises at least once during the course of the study. We also captured and recaptured 15 resident tortoises. Ten tortoises were recaptured within cattle exclosures. Capture and recapture methods included hand-capture and bucket trapping. Traps were constructed from five-gallon buckets sunk vertically at the mouths of burrows. The
lip of the bucket was positioned a minimum of three inches below the floor of the burrow. Aluminum foil was placed on top of the bucket and covered with a thin layer of sand to conceal the glimmer of the foil. Small holes were punched in the foil to weaken its integrity, and three sticks were placed between the opening of the burrow and the bucket trap to determine whether tortoises were captured while emerging from or entering into burrows. When recaptured, tortoises were identified by the marginal scute drill holes, the number clip (if present), and/or PIT tag (if present). If multiple markings were present, we cross referenced the numbers to ensure accuracy. Morphological measurements were recollected for comparison with values reported at the time of release (or at first encounter). Unmarked residents received a Biomark BIO12.BPL 12 mm, 134.2 kHz PL Passive Integrative Transponder (PIT) inserted under the skin just below the right knee on the anterior portion of the leg and a six digit alpha-numerically numbered clip (1005-3 Fish & Small Animal Tag, SZ. 3 020 M, National Band and Tag Company) fastened to the Number 2 carapace marginal scute (Figure 3). Resident tortoises smaller than 130 mm SCL, but greater than 50 mm, were fitted with the 1005-3 Fish & Small Animal Tag or the 1005-1 Fish & Small Animal Tag, SZ. 1 018 M. Resident tortoises already marked as a result of being released years earlier were not given the number clip or PIT tag. Prior to release, residents also were weighed with a Pesola 10 kilogram spring scale and morphological measurements were taken as previously described for newly translocated tortoises.

**Figure 3:** Photo of alphanumeric number clip. Clip applied to No. 2 marginal scute.
We conducted 30 cattle surveys over the course of the study to determine where cows congregated. Surveys were conducted in the morning and late afternoon on days when cows were free to move between treatment plots and adjacent areas. No surveys were conducted on days when cows were corralled and held in the treatment plots. The locations of individuals were noted on an aerial photograph and later digitized into ArcMap 10.1. We used a kernel density function to place densities of cows into four categories: 0, 1, 2, and 3-5 cows per unit area (Figure 4).

**Figure 4:** Aerial map illustrating cattle density over 30 days of surveying. Variation in cattle densities among common-congregating areas were assessed over 30 days of surveying. Five density categories were derived, the highest being 3 to 5 cows were unit of measure and displayed as a red-filled polygon, was observed in Plot 19.
HYPOTHESES, TESTS, RESULTS

**Burrow Density**

**Hypothesis** – Burrow density inside cattle exclosures cannot be shown to differ from burrow density in plots outside exclosures (where tortoises are exposed to cattle production).

**Test** – For surveys conducted within plots containing cattle exclosures, we related the density of burrows found within an exclosure to the total number of tortoises released into the plot surrounding the exclosure and the number released immediately prior to each the survey. Densities were calculated at each survey by dividing the total number of burrows inside and outside cattle exclosures by the respective areas. We determined if the number of burrows observed within cattle exclosure was more than the number expected by chance using randomization. No burrows were observed within the exclosure in Plot 16 during Surveys 1 and 2; so, those two surveys were omitted from our analysis. We used Monte Carlo randomization procedures (Gotelli and Ellison, 2004) for the analysis. The recorded number of potentially occupied burrows in each plot during each survey was randomly redistributed back into the plot 1000 times, and the total number of burrows that fell within the exclosure was tallied after each iteration. Frequency distribution curves were compiled in Statistica 9.1 and Microsoft Excel (Microsoft Corporation, 2010). Each survey was analyzed independently; no comparisons could be made across treatment plots.

**Results** – The results of the randomization suggested that the observed number of burrows within cattle exclosures was not significantly more than the number expected by chance. Rather, fewer burrows than expected by chance often were observed. The relative number of
burrows within exclosures varied over time, however. For instance, in Plot 18, the numbers observed within the exclosure were fewer than expected during the first two surveys, but were more than expected in later surveys, as tortoises continued to be added between surveys. When especially large numbers of tortoises were added to this plot, and densities in the plot spiked, the excess number of burrows within the exclosure became substantial. Prior to Survey 4, 64 tortoises were released into the plot, 25 (39%) more than the total number released prior to Survey 3; and prior to Survey 5, another 58 tortoises were released. For both surveys, the concentration of burrows within the exclosure was strong (p < 0.01).

**Burrow Spacing**

*Hypothesis* – Burrow spacing inside cattle exclosures cannot be shown to differ from burrow spacing outside exclosures.

*Test* – Linear distances between potentially occupied burrows were measured in the Geospatial Modeling Environment (Version 0.7.2.1, Spatial Ecology.com). Within this environment, linear distances were calculated using the point-distance function in the ID format. The ID format calculates a single, average distance between all points (e.g., A to B, A to C, B to C) while omitting back distances (e.g., B to A). Distance between burrows within cattle exclosures was compared to distances within adjacent subsets of the plot, which were derived by bisecting plots at the respective border of the exclosure (e.g., east half and south half). The dataset could not be transformed to meet the assumptions of normality or homogeneity of variance; therefore, we used the non-parametric Mann-Whitney U Test as our test statistic. Burrows within two meters of electric or barbed wire fencing were excluded from the analysis. Because inter-burrow distances might be expected to decline with increasing density, we evaluated the relationship between density and the mean distance between burrows within and outside the cattle exclosure using the Product-Moment Correlation Coefficient.
**Results** – Median distances between burrows inside exclosures were smaller than those outside exclosures (U=34, p<0.01, n_{In} =16, n_{Out} =31; Figure 5). The relationship was true irrespective of density (r=-0.40, p=0.13, within; r=-0.23, p=0.24, without; Fig.6).

**Figure 5:** Median distance between burrows inside and outside cattle exclosures

**Figure 6:** Mean distance between burrows inside and outside cattle exclosures versus burrow density.
Burrow Relocation

**Hypotheses** – The frequency at which tortoises moved to new burrows inside cattle exclosures cannot be shown to differ from the frequency outside exclosures. Tortoises cannot be shown to avoid placing burrows where cows congregate.

**Tests** – We calculated the straight-line distances moved from old burrows to new burrows for female tortoises with transmitters residing inside and outside cattle exclosures. Step lengths were calculated using the Geospatial Modeling Environment. Distances form the point of release to the first burrow location, as well as any observation of tortoises away from a burrow, were omitted from the analysis. We could not transform the step-length data to meet the assumptions of normality and homogeneity of variance (Shapiro-Wilks Test and Brown-Forsyth Test, respectively), so we compared the mean step-length distances within the exclosure against the mean distances outside the exclosure using the non-parametric Mann-Whitney U Test. The frequency with which tortoises relocated to new burrows inside versus outside exclosures was compared with the Mann-Whitney U Test. Frequencies were calculated by dividing the number of relocations observed for each tortoise by the total number of observations conducted within the treatment plot and/or exclosure.

For each cattle survey, we overlaid the locations of tortoise burrows (excluding burrows that fell along the fence lines), and calculated burrow densities within the areas containing the different cattle densities. We used the t-test when assessing the differences between burrow densities in two cattle-density categories and the Kruskal-Wallis Test to assess differences among burrow densities in three or more categories of cattle density.

**Results** – The distances moved when relocating burrows could not be distinguished for tortoises inside and outside exclosures ($U = 779.00$, $p = 0.97$, $n_{inside} = 16$, $n_{outside} = 98$). Burrow
relocations occurred more frequently outside exclosures than inside, however ($U = 96.50$, $p = 0.24$, $n_{inside} = 10$, $n_{outside} = 26$).

Gopher tortoises were not found to avoid placing burrows in areas more frequently used by cows. Within Plot 16, areas with no cows and with one cow could not be distinguished ($t = -0.20$, $df = 10$, $p = 0.84$); within Plot 18, areas with no cows, one cow, and two cows could not be distinguished ($H_{(2, N=18)} = 0.04$, $p = 0.98$); and within Plot 19, areas with no cows, one cow, two cows, and three to five cows could not be distinguished ($H_{(3, N=24)} = 4.36$, $p = 0.23$). Mean burrow densities in areas with no cows ($H_{(2, N=18)} = 1.30$, $p = 0.52$) were similar, but less so in areas with one cow ($H_{(2, N=18)} = 4.56$, $p = 0.10$). Although burrow densities were higher in areas heavily used by cows, they could not be shown to differ strongly between heavily used areas (3 to 5 cows) and areas with no cows ($H_{(3, N=24)} = 5.16$, $p = 0.16$), with one cow ($H_{(3, N=24)} = 6.07$, $p = 0.11$), or with two cows ($H_{(2, N=18)} = 0.99$, $p = 0.61$).

**Body Condition**

**Hypotheses** – The rate of change in body condition of tortoises inside cattle exclosures cannot be shown to differ from the rate outside exclosures. The rate of change in body condition of translocated tortoises cannot be shown to differ from the rate of resident tortoises.

**Tests** – A total of 58 adult tortoises (34 females and 17 males translocated; and 6 females and 1 male resident) were included in the analysis of body condition. Only 5 of the tortoises, all translocated, were recaptured within exclosures. We used the ratio of mass to volume ($g/mm^3$) (Nagy et al., 2002) to evaluate body condition. Volume was calculated as the product of SCL, CW, and CH (Wallis et al. 1999; Loeher et al. 2004, 2007; Riedl et al. 2008). Body condition of each tortoise was determined at initial release (translocated tortoises) or capture (resident tortoises) and at each subsequent encounter. Change in body condition was calculated as: $BC_{initial} - BC_{final}$, where $BC_{initial}$ is body condition at the time of initial release or capture and $BC_{final}$ is body condition at the time of subsequent encounter.
body condition at the time of final recapture. Elapsed time was recorded as days since initial release or capture and final recapture.

Prior to any analysis, data were tested for normality using Shapiro-Wilk Test, and for homogeneity using the Levene Test or Brown-Forsyth Test (when applicable). We compared the BCI\textsubscript{Initial} between adult resident and relocated individuals and between sexes, to determine if pooling was appropriate. The mean BCI\textsubscript{Initial} values of translocated and resident individuals were different enough (t = 1.61, p = 0.11; Figure 7) that we elected not to pool the two groups. Within groups, the mean BCI\textsubscript{Initial} of relocated males and females also were too different (t = -1.50, p = 0.14; Figure 8) to warrant pooling. The BCI\textsubscript{Initial} of the single resident male was more than two standard deviations larger than the mean BCI\textsubscript{Initial} of the resident females. Between groups, the small difference between relocated and resident females (t = -0.17, p = 0.86) permitted pooling in subsequent analyses.

**Figure 7:** Mean and range of BCI\textsubscript{Initial} of translocated and resident tortoises.
To test the first hypothesis, we used the rate of change (the change in BCI divided by the days since release) calculated for the pooled females. The data could not be transformed to meet the assumptions of normality or homogeneity of variance; therefore, we used the non-parametric Mann-Whitney U-Test. The same procedure was used to test the second hypothesis, but only for females. We were able only to assess the change in body condition of translocated male and non-adult tortoises over time, with the Pearson Correlation Coefficient.

**Results** – The rate of change in body condition over time could not be distinguished very strongly between tortoises (females) inside and outside exclosures ($U = 70.0, p = 0.95, n_{\text{relocated}} = 34, n_{\text{resident}} = 4$). The rate of change differed moderately between translocated and resident tortoises (females) ($U = 58.0, p = 0.10, n_{\text{translocated}} = 34, n_{\text{resident}} = 6$), the rate of positive change being greater for translocated individuals.
**Individual Growth Rate**

*Hypotheses* – The growth rate of tortoises inside cattle exclosures cannot be shown to differ from the rate outside exclosures. The growth rate of translocated tortoises cannot be shown to differ from the rate of resident tortoises.

*Tests* – A total of 158 translocated tortoises (137 adults and 21 non-adults) and 15 resident tortoises (all adults) were captured at least twice during the course of the study. Individuals were excluded from analyses if fewer than 10 days had passed between captures (to reduce the influence of zeroes), if morphological measurements clearly were recorded incorrectly, or if no increase in size could be detected. After these exclusions, 67 adults and 16 non-adults remained. More than 90% of the omitted individuals had been translocated to the ranch. We compared the frequencies with which males and females were excluded with the Chi-squared test, and evaluated the difference in mean SCL\textsubscript{initial} between excluded tortoises and those not excluded with the t-test. Although females were more frequently excluded than males, we could not detect a strong difference in the frequencies ($X^2 = 1.82, p = 0.18$). The mean SCL\textsubscript{initial} of excluded females were substantially larger than that of females that were not excluded ($t = 2.20, p = 0.047$), but the mean SCL\textsubscript{initial} of excluded males could not be distinguished from that of males that were not excluded ($t=1.13, p=0.26$). Larger females grew slower than smaller females ($r=0.34, p=0.04$), which likely accounts for their greater frequency of exclusion.

Because males and females are known to grow at different rates (Alford 1980; McRae et al. 1981; Landers et al. 1982; Mushinsky et al. 1994, 2006), we analyzed growth separately for the two sexes. Growth rate was calculated as: $(SCL\textsubscript{initial} - SCL\textsubscript{final}) / \text{amount of time that had lapsed between observations}.$ We used the Mann-Whitney U Test to assess similarities in the growth rates between females captured inside and outside exclosures, and between resident and
translocated females. We were able only to assess the growth of translocated males and non-adult tortoises with the Pearson Correlation Coefficient.

**Results** – Translocated female tortoises averaged 278 ± 23.8 mm SCL at the time of release, with the largest being 336 mm SCL and the smallest being 244 mm SCL. Translocated females grew at an average rate of 8.73 mm SCL per year, with the slowest being 0.89 mm SCL and the fastest being 36.5 mm SCL per year. Translocated males averaged 284 mm L ± 22.7 mm SCL at the time of release, with the largest being 314 mm SCL and smallest being 234 mm SCL. Translocated males grew at an average rate of 5.15 mm SCL per year, with the slowest being 0.64 mm SCL and the fastest being 20.3 mm SCL per year. Resident female tortoises, all adult, averaged 284 ± 33.30 mm SCL at first encounter, with the largest being 322 mm SCL and smallest being 244 mm SCL. Resident females grew at an average rate of 4.82 mm SCL per year, with the slowest being 0.98 mm SCL and the fastest being 15.27 mm SCL per year. Only one resident adult male recaptured during the study showed measurable growth; at first encounter, it measured 267 mm SCL, and it grew at a rate of 2.79 mm SCL per year.

The median growth rate of females captured inside exclosures could not be shown to differ strongly from that of females captured outside exclosures (U=11.5, p=0.30, n_out=22, n_in=2), although growth rates were higher outside the exclosure. Although translocated females grew faster than resident females (Figure 9), the median growth rates could not be shown to differ strongly (U=30, p=0.23, n_translocated=19, n_resident=6). Growth rate of translocated females increased as they spent more time on-site, but not strongly so (r=0.10, p=0.61); growth rate of translocated males, on the other hand, increased substantially as more time was spent on-site (r = 0.44, p = 0.01). Resident female growth rate increased sharply over time (r = 0.99, p = 0.01), and the single resident male grew at a rate comparable to the relocated males. Although growth rate was greater for smaller non-adults, the relationship was not strong (r=-0.22, p=0.33).
Recruitment

**Hypothesis** – The recruitment (addition of young into the population) cannot be shown to differ between inside and outside cattle exclosures.

**Tests** – Because we measured the widths of all burrows encountered during burrow survey, and the width of a burrow tends to be proportional to the SCL of its resident tortoise (Alford 1980, Wilson et al. 1991), we could relate relatively small burrows to small (young) individuals (Doonan et al. 1994). For this exercise, we assumed that each burrow was occupied by only one tortoise and that each tortoise was using only one burrow.

We could not test the hypothesis with burrows of hatchling size (< 50 mm; Doonan et al. 1994), because none were encountered during burrow surveys. Instead, we tested the hypothesis with burrows smaller than adult size (< 230 mm). We used the non-parametric Mann-Whitney U-Test
to assess differences in non-adult burrow densities (burrows/ha) observed within the exclosures versus densities observed outside the exclosures. We assessed whether burrow densities within exclosures were correlated with burrow densities outside exclosures and the numbers of tortoises released prior to initiation of surveys and between surveys, with the Product Moment Correlation. We compared the number of non-adult burrows observed during each survey against the number expected, with the Chi-squared Test. We calculated the expected number of burrows by summing the number of non-adults released into the treatment plot prior to a survey and the number of non-adult burrows (residents) observed during the first survey.

**Results** – We found no difference in the density of non-adult tortoise burrows observed within and outside exclosures (U = 151.5, p = 0.75, n_{out}= 18, n_{in}= 18). Densities within and outside the exclosures were strongly correlated with the total number of tortoises released prior to initiation of surveys (r = 0.76, p < 0.01) and between surveys (r = 0.74, p < 0.01), however. Overall, fewer non-adult burrows than expected were observed during surveys conducted in each treatment plot (Plot 16 - \(X^2 = 11.03, p = 0.05\); Plot 18 - \(X^2 = 45.30, p < 0.01\); Plot 19 - \(X^2 = 32.34, p < 0.01\)).

**Additional Results: Mortality**

Long term adult survivorship estimates for natural populations are uncertain because of the lack of long-term mark-recapture studies. Survival of translocated tortoises has been reported to be as high as 98% (Ashton and Burke 2007, Tuberville et al. 2008). Tuberville et al. (2009) used reported survivorship data from various studies to determine stage-specific mortality rates for hatchlings, yearling, juveniles, subadults, and adults through modeling. They reported annual mortality rates of 1.5% for adults from maturity to 60 years, 3% for subadults from four years to maturity, 25-50% for juveniles from two years to four years and yearlings from one year to two years, and 96% for hatchlings. We assessed minimum levels of mortality by counting carcasses found within our treatment plots during the course of the study. Carcasses were identified by
using any distinguishable markings still visible: marginal-scute markings, alphanumeric number clip, or PIT tag; and measurements (SCL, MCW, MSH). Once examinations were completed, carcasses were buried on site to prevent their being recounted and for sanitary reasons.

One hundred and ninety four carcasses were found. Of these, 159 were translocated (about 11% percent of all tortoises translocated to the ranch) and 31 were residents. The remaining four individuals could not be identified. Most of the carcasses (69%) were of adult size (>230 mm SCL). Plot 22 had the highest mortality of all treatment plots (38%) (Figure 10).

![Figure 10: Carcass count, number of tortoises released and elapsed time (days).]
DISCUSSION

Burrow densities could not be shown to differ inside and outside cattle exclosures. In most instances, burrow densities within exclosures were lower than expected, based on random chance. Burrow densities within exclosures increased following the release of large numbers of tortoises between burrow surveys, however. This temporary increase suggests that tortoises used the exclosures as short-term refugia, rather than to avoid cows. The exclosures became overgrown from lack of mowing, and the relatively tall vegetation may have proved to be an attraction for the tortoises. Over time, the tortoises gradually moved out of the exclosures and often toward the edges of the plots. Burrow surveys showed that many of these tortoises escaped through holes in the silt fence created by cows. The almost constant loss of tortoises meant that the target density of three individuals per acre could not be met.

Burrows were spaced more closely inside exclosures than outside, suggesting that tortoises were clumped. The closer spacing of burrows within exclosures was independent of density. Individuals were clumped near specific habitat features, such as open sandy areas that made burrowing easier and areas covered with herbaceous plants that were surrounded by taller grasses and shrubby vegetation.

Tortoises inside exclosures moved approximately the same distance when relocating burrows as tortoises outside exclosures. Tortoises inside exclosures also were less likely to relocate burrows than tortoises outside exclosures. Over time, however, most individuals wandered away from their burrows and attempted to leave the treatment plots. The average distance tortoises moved from burrow-to-burrow was approximately the same whether inside or outside exclosures. We found no indication that tortoises attempted to avoid areas used by cows when
choosing a location to place a burrow; in fact, the density of burrows in areas often was greater in areas frequently used by cows.

Upon arrival at the ranch, translocated individuals displayed body conditions (i.e., Mass/Volume) that were slightly less, on average, than those of tortoises already residing in the experimental plots. Because body condition in chelonians are mostly an indicator of hydration and gut content (McCoy et al., 2011), dehydration, urination and defecation during translocation may have contributed to this difference. Because resident and relocated females were more similar initially than males, we focus on these two groups for further analyses. Although more females exhibiting relatively small – or even slightly negative – changes in body condition over time were outside exclosures, change in body condition of females generally was similar inside and outside exclosures. Interestingly, translocated females tended to increase in body condition over time, while resident females tended to decrease. We speculate that translocated females exhibited recovery from the weight losses during translocation, and that resident females may have been stressed by the addition of large numbers of new individuals. One of the possible proximal causes for stress is competition with translocated individuals. Translocated individuals tended not to dig new burrows after release, and smaller resident individuals could be displaced by larger, translocated individuals. Also, confinement within treatment plots when the silt fence barriers were maintained properly may have prevented residents from accessing foraging locations in the surrounding landscape which they had learned previously. When captured in the open, resident tortoises often appeared to be wandering without direction. Fresh carcasses of residents sometimes were observed immediately after large releases of translocated individuals. If individuals indeed were stressed, then these deaths may have been the result of reduced immune capacity to deal with upper respiratory tract disease or other diseases.

When arriving at the ranch, translocated adults (>230 mm SCL) displayed, on average, similar SCL’s to those of resident adults. Among the individuals that did exhibit subsequent growth,
translocated and resident females increased in SCL at similar rates. Likewise, growth rates of females inside and outside exclosures were similar. The growth rate of non-adults was lower than those at a nearby well-maintained sandhill site (Mushinsky et al. 1994). Hathaway (2012) concluded that, although the improved pastures that comprised our experimental plots were capable of supporting adults, including reproductive females, they may not provide the nitrogen and crude protein needed for early growth and development. Gopher Tortoise growth has been well documented across its range (Goin and Goff 1941, Landers’ et al, 1982, Godley 1989, Mushinsky et al 1994, Aresco and Guyer 1999) and is strongly dependent on the quality and type of forage available.

Recruitment was, in essence, nonexistent. No translocated hatchlings were recaptured, and little evidence of subsequent reproduction was detected during burrow surveys. Hathaway (2012) found that resident and relocated females she radiographed produced shelled eggs, and that clutch sizes were larger than those typically observed in central Florida (Deimer and Moore 1994, Mushinsky 2004). So, the potential to see hatchlings emerging on-site was high. Only one hatchling tortoise was observed, however, emerging from a nest located under a barbed-wire fence surrounding an experimental plot, where it was protected from cows. Typical clutch size for tortoises in central Florida is 5-9 eggs (Diemer and Moore 1994), however, we know that clutch size can be influenced by nutrients including phosphates (Godley 1989) and we speculate that tortoises residing on the ranch had larger than average clutch size in response to the fertilizer added to encourage growth of forage for the cows. Gopher tortoises on reclaimed phosphate-mined land in central Florida had clutches containing more than 13 eggs and exhibited an atypical growth spurt as adults (Small and Macdonald 1999).

We acknowledge that detection of small burrows is extremely difficult, especially in thick vegetation; and that successful reproduction need not occur annually for a population to maintain itself or grow. With that said, the extremely low recruitment that we documented seems
remarkable, however. Among older non-adults, densities were similar inside and outside enclosures, suggesting the enclosures failed to provide any advantage to them. If recruitment indeed is extremely low, and the low rate is being caused by conditions at the ranch, then we suggest that factors such as nutrition – discussed previously – predation, cattle activities, and ranch management activities may be at play. A large variety of predators had more-or-less open access to the experimental plots. Coyotes and crows frequently were observed patrolling the plots. Burrow aprons, which typically support tortoise nests, frequently were trampled or otherwise disturbed – such as by wallowing – by cows. Typical pasture management practices, such as mowing and dragging manure spreaders, could disturb nests and kill unprotected hatchlings. Manure spreaders, in particular, have the potential to be lethal to all but the largest tortoises, although we cannot directly attribute the death of any tortoise to the manure spreading practice.

About 11% of the translocated tortoises were found dead (159 out of 194 carcasses) within our experimental plots as were an additional 31 resident individuals. We observed additional carcasses at varying distances outside the study site; so, we think that 11% mortality is a significant underestimate. We view this level of mortality as excessive based on the levels of mortality we have observed at the dozens of other sites at which we documented the numbers of gopher tortoises known to be present. In fact, it is unusual to find any dead tortoises at a site except for those uncommon instances where an active disease was present and even under those circumstances the observed level of mortality at the ranch stands out. Above we discussed the body condition and growth of individuals at the ranch, so we do know that some percent of the resident and translocated individuals do survive and seemingly can attain a relatively healthy status, but they seem to be the relatively few fortunate ones. We can suggest several factors that may have contributed to this excessive mortality. Tortoises released into a large pasture with a resident tortoise population are confronted with a hostile environment. A
lucky few may find thermal refugia and foraging opportunities by chance, but many may be forced to wander – without knowledge of locations of burrows or shade cover – and could quickly overheat. The environment would be particularly hostile for small individuals. We observed what appeared to be overheated individuals several times during the study. The individuals were frothing at the mouth and eyes, were extremely warm to the touch, and were in the middle of a plot and well away from burrows. Stress, with concomitant emergence of disease, and predation may have contributed to the high mortality, but we have no direct evidence.

We do know that gopher tortoises and cattle can coexist, but the ranch supports a small population of what we called resident tortoises (some, in fact, could have been survivors from a previous translocation effort at the ranch.) Yet, we encountered numerous circumstances that prevented us from testing our hypotheses rigorously. During a typical translocation effort the fencing used to create a soft release is sufficiently durable to last long enough to contain the translocated individuals as they become familiar with the area and establish burrows. The circumstances at the ranch were not typical however; the curiosity of the cattle was constantly being displayed and because we had to position the silt fencing inside of the existing barbed wire fencing, the cows were attracted to the forage that grew between the two fences thereby trampling the silt fence to create an easy escape route for tortoises exiting the ranch. To adequately test the general question regarding the compatibility of cattle and tortoises, it is essential that the tortoise be forced to remain on the ranch for an extended period of time, perhaps an entire year before the silt fencing is removed. The extreme effort needed to maintain a closed population requires near constant vigilance and action to repair the damage caused by cattle. Providing a trespass-proof perimeter barrier would allow a better assessment of the actual interaction between the cattle and tortoises and may shed more light on the lack of recruitment we observed as well. Not only did we not find evidence of successful reproduction
(i.e. hatchlings) but we also documented a precipitous decline in the numbers of non-adults that were translocated to the ranch, although they too could have simply walked away through the damaged fencing.

In summary, we faced numerous challenges as we attempted to test six critical aspects of the planned translocation. So, what would be needed to overcome the challenges we encountered? The simple answer is more people power. At no time did we achieve or maintain a closed population of tortoises. Cattle damaged or destroyed the silt fence, almost as quickly as it was repaired, making easy escape routes for tortoises. Had we been able to maintain the desired density of tortoises our ability to rigorously test the six hypotheses would have been improved greatly. Our efforts to maintain the perimeter fence became so time consuming that we had to decide to either collect data on the cows and tortoises or put all of our time into maintain the fencing. The ranch owners provided some assistance but their priority was to maintain the ranch to grow cattle. Likewise we see a much greater need for the active involvement of FWC biologists to oversee translocations. We, as researchers, did not have authority over the ranchers to gain their greater support of the research effort. If there is a chance for a successful translocation of the Gopher Tortoise to an active cattle ranch, then the major players must play a more definitive role to make it happen. Direct and frequent oversight by FWC biologists is imperative; ranchers are interested in cattle first and foremost and they must be held responsible for their commitment to accept tortoise onto their ranch. With that said, we also understand the extreme workload FWC biologists are experiencing and the limited people power within the agency. Considering the challenges one would face if another research project was proposed to assess the efficacy of cattle ranches as recipient sites for displaced tortoise, we highly recommend no such effort be made unless, and until, the needed people power were present to overcome the many challenges presented by such an effort. We suggest the oversight extend for at least two years post translocation.
LITERATURE CITED


