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REINTRODUCTION OF GOPHER TORTOISES (*GOPHERUS POLYPHEMUS*) TO RECLAIMED PHOSPHATE LAND

Prepared by
Laurie Ann Macdonald

under a grant sponsored by

FIPR
Florida Institute of Phosphate Research

July 1996

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Prepared by

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DISCLAIMER

PERSPECTIVE

Dry ("xeric") upland habitats are critical to the existence of several animal and plant species. Acreages of such lands have shrunk dramatically due to urban, agricultural and industrial development. Although phosphate mining causes a drastic disturbance of the land, it may be possible, with proper reclamation techniques, to restore critical upland habitats and the wildlife populations they support. The major objective of this study was to assess the suitability of reclaimed lands at the Tenoroc State Reserve (now the Tenoroc Fish Management Area) to support viable tortoise populations, and the study has provided important clues as to how site characteristics and relocation tactics can be optimized. The research at Tenoroc has shown that reintroduced gopher tortoises can be successfully reestablished on sandy, open habitat on reclaimed lands.

At Tenoroc, egg production and growth rates of reintroduced tortoises appeared to exceed the reported averages for tortoises in undisturbed habitats. To more thoroughly evaluate this latter finding, Laurie Macdonald and Christine Rucker-Small conducted an additional study, "Growth and Reproduction in Reintroduced and Resident Tortoises, *Gopherus polyphemus*, on Reclaimed Phosphate Lands" (FIPR # 93-03-105R), which compares tortoises at three additional relocation sites (one unmined and two reclaimed). This project is essentially completed as this report goes to press, and we anticipate the final report will be submitted soon.

In related work, Dr. Henry Mushinsky and Dr. Earl McCoy of the University of South Florida have been conducting research, "Studies of Wildlife Usage and Restoration of Upland Habitats on Phosphate Mined Land in Central Florida" (FIPR # 93-03-100), to provide information to guide upland habitat restoration or rehabilitation. They have examined the kinds and numbers of vertebrate species on reclaimed sites as compared to those on unmined scrub, sandhill and scrubby flatwoods in the central Florida mining area. They have also identified those species that have or have not recolonized reclaimed lands. From these results, they are making recommendations for improving restoration of critical xeric upland habitats and for reintroduction of vertebrate species (especially rare species) that may have been unable to recolonize reclaimed lands on their own. The final report has been submitted and reviewed and is being revised in preparation for publication as this report goes to press.

Steven G. Richardson
Research Director, Reclamation

ACKNOWLEDGEMENTS

This project was funded through a grant from the Florida Institute of Phosphate Research. I would like to thank the FIPR Board, Technical Advisory Committee, and staff, especially Dr. Steve Richardson who has shepherded the project through the labyrinth of administrative processes.

Through the years over one hundred volunteers came to work on this project in burning sun and pouring rain with little reward except a unique experience, comraderie, and the gratefulness of myself and the research crew. The project could not have been completed without these wonderful volunteers, some of whom returned year after year to give the gift of their time and dedication to scientific inquiry and to the conservation of gopher tortoises.

Thank you to all who helped on the project, especially:

George Heinrich, a superior field biologist, Jennifer McMurtray, without whom the original proposal would not have been written, and Steve DeCresie, jack of all trades and master of many; the Tenoroc staff, including managers Peter Woodward, Donny Sessions, and Danon Moxley; Janine Callahan, Joan Diemer Berish, Tim King and Henry Mushinsky for advice along the way; crew members Joey Casada, Tim Morton, and Bill Copeland; Nancy Bissett, Mike Drummond and Liz Barker for essential botanical work; Donna Heinrich, Carol Coyner, Bob Brechtel, Lois Caruso, David Dewitt, Gene Trescot and his students, Rosemary Garcia, Jeremy Craft and many more volunteers; statisticians Lorrie Hoffman, Robert Garren, Gerry Bruger, and Tim Scott; Lyon Van Lines for the donation of several hundred boxes which held tortoises during the storm of 1988; Quality X-ray and veterinarian Nola Gedeon, and Bill Suchy for documenting the first years of the project in a video production available from FIPR.

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SUMMARY

This study investigated the suitability of phosphate mined land as reestablishment areas for the gopher tortoise *(Gopherus polyphemus),* a Florida Species of Special Concern, and sought to determine (1) if limited habitat enhancement would increase tortoise reestablishment success, and (2) if translocation had an effect on tortoise reproduction or growth. Associated with this project is FIPR Project #93-03-105R, "Growth and reproduction in reintroduced and resident gopher tortoises on reclaimed phosphate-mined lands," by C. R. Small and L. A. Macdonald (in press), in which growth and reproduction in the study animals following translocation are examined in detail and compared with tortoises from other sites in central Florida.

The research was designed to monitor tortoises for at least four years, 1988-1991, and included an additional field season in 1993, in order to ascertain trends and stabilization in the tortoise population over time.

In 1988, 116 gopher tortoises were transferred from sandhill habitat in Hernando County to old phosphate mined land (mined in the early 1950's) that had been reclaimed to pasture at Tenoroc Fish Management Area in Polk County, FL, USA. Four 3.24ha (8 ac), circular study plots were established as release sites; two served as control plots and two were treatment plots. Two methods of habitat enhancement were used at the treatment plots, one being the addition of a variety of plants known to be tortoise forage. The second treatment was the addition of soil mounds to provide topographic heterogeneity, and thus, more burrowing sites, as tortoises commonly burrow into ridges, berms, and slopes. Twenty 3m long by 1.5m wide by 1.25m high sand mounds were placed within each of the two treatment plots and 37,500 tortoise forage plants of over 20 species were planted around the treatment plots's circular rims. Aside from the long term monitoring, project related expenses roughly approximated the amount of funding that would have been involved in development project gopher tortoise mitigation.

Life history data were collected on all tortoises, including body measurements, weight, and, when determinable, age and sex. All tortoises were individually and permanently marked. Females were x-rayed to determine the number of eggs, if any, each was carrying. The translocated tortoises were maintained in four large enclosures at Tenoroc during the summer of 1988 while the study plots were being prepared. A small resident population of tortoises (n=15) was discovered in the sand tailings area where three of the enclosures were located. The residents were captured in late summer, life history data were collected, and all individuals were

marked: however, these resident females were not x-rayed the first year as egg laying season had passed.

The translocated and resident tortoises were recaptured in 1989, 1990, 1991, and to a limited extent in 1993. Each year the number of hectares covered in the search for translocated and resident tortoises increased as two resident colonies were found and as tortoises dispersed. The area surveyed eventually encompassed over 2025 hectares.

By 1991, 34% (n=40) of the translocated tortoises were recaptured, although most tortoises were no longer in the study plots. Adjusting with data obtained in 1993 indicates that 41% (n=48) of the translocated tortoises were still at Tenoroc. Average site fidelity (tortoises remaining on a recipient site a minimum of one year later) is reported as 39% for relocations in the state of Florida reported between 1991 and 1994. The 41% recovery rate of Tenoroc translocatees is comparable to the average one year relocation project; however, only 16% of the recovered animals were within the study plots where they were released and none were in the reclaimed pasture habitat type.

The tortoises totally vacated the habitat reclaimed to dense grassland and primarily settled in unmined areas and sand tailings areas which had high sand content soil, sparse but more diverse vegetation, and structurally open habitat. These preferred conditions existed in two locations at the release sites, the west side of Treatment Plot 1 and the area north of Control Plot 2. Translocated tortoises did settle at these study plots. Site treatments were inadequate to overcome inhospitable habitat conditions at the release sites which were of high clay and low sand content and dense homogeneous grass cover. A major resident colony into which translocated tortoises immigrated, the planted pine area, also had a wider variety of plant species, but had approximately 75% pine canopy. Few patches of bare ground existed among the planted pines but the vegetation was much sparser than the dense mat of the grassland. With respect to the forage plants in the treatment plot rims, most of the species persisted in Treatment Plot 1, the most prominent being wiregrass *(Aristida spp.),* lopsided Indiangrass *(Sorghastrum secundum)*, prickly pear cactus *(Opuntia humifusa),* twinflower *(Dyschoriste oblongifolia),* and pea vines *(Galactia, Rhynchosia, Tephrosia)*. By 1993 the wiregrass was growing vigorously, had bloomed, and was outcompeting the bahiagrass *(Paspalum notatum).*

Translocated recaptures included 45% of the original males, 67% of the females, and 19% of the subadults and juveniles. The translocated population experienced an initial drop in egg production; however, clutch sizes rose in every subsequent year. Subadult tortoises were exhibiting increased growth rate by 1991. Several resident females had unusually large clutches of 18 - 25 eggs.

Results indicated that reclaimed phosphate mined lands can provide adequate gopher tortoise habitat if sites have been prepared in such a way as to provide sandy soils with adequate soil adhesion and compaction characteristics (sufficient clay or organic content), patches of open ground or sparse vegetative cover, and relatively diverse plant species. The report includes explanations and recommendations with respect to field methodologies. Results of the study contributed to guidelines for gopher tortoise habitat reclamation that are provided in a document appended to the report, entitled "Guidelines for the creation and enhancement of gopher tortoise *(Gopherus polyphemus)* habitat on phosphate mine lands", by J. L. Callahan, L. A. Macdonald, and J. E. Diemer Berish, May 1996.

INTRODUCTION

The gopher tortoise *(Gopherus polyphemus)*, the only tortoise in eastern North America, is a characteristic and integral element of upland habitats in the southeastern coastal plain. Although gopher tortoise colonies were once common, habitat loss, incompatible land use practices, and overhunting have reduced the population size (Taylor 1982, Means 1986, Diemer 1987a) by perhaps 80%, according to early estimates by Auffenberg and Franz (1982). Although the harvest of tortoises was banned in 1988, habitat loss and degradation continue to threaten the tortoise. Furthermore, the longevity of the gopher tortoise, and thus the presence of old animals in some locales for many years, tends to obscure the fact that some of these populations may be in decline, that they may not be reproducing and their habitat may no longer be suitable. Recently, Upper Respiratory Tract Disease (URTD) was discovered in Florida gopher tortoises, which raises additional questions about the general health of the species and proper management strategies. The gopher tortoise is nearly extinct in Louisiana, is listed as a federally threatened species west of the Tombigbee and Mobile Rivers in Alabama, and is considered a threatened, endangered, or protected species throughout its range. The vast majority of remaining gopher tortoises (estimates range around 85%) live in the state of Florida, where they are designated a Species of Special Concern.

The gopher tortoise is considered an ecological keystone species by many scientists (Eisenberg 1983, Dodd 1984). The species has a pivotal role in its native upland community, affecting physical, floral, and fauna1 elements. Aeration through soil movement and the creation of microhabitat patches at the mouth of the excavated burrow are aspects of gopher tortoise autecology. The tortoise is an herbivore that forages on a wide array of plant species and whose foraging behavior includes grazing, pruning and cropping of vegetation (Garner 1981, Macdonald and Mushinsky 1988). The animals disperse and fertilize seeds in their scat (Auffenberg 1969, Kaczor and Hartnett 1990) and they may act as enhancers of seed germination similar to other tortoise species (Morafka 1982, Gibson and Hamilton 1983).

The gopher tortoise is best known for its important ecological role because of the burrows it excavates. The importance of the burrow to the life of the gopher tortoise cannot be overemphasized. The burrows, which can exceed 15 meters in length and 5 meters in depth, provide refuge and a stable temperature and humidity for the tortoise and its burrow associates. Females are known to deposit their clutches in the soil mound at the burrow mouth. Burrow and mound-building activities of gopher tortoises generate significant plant species diversity (Kaczor and Hartnett 1990). Over 360 invertebrate and vertebrate species are known to use gopher tortoise burrows facultatively or opportunistically (Jackson and Milstrey 1989). According to Milstrey (1986) "the diversity in terms of numbers of both vertebrate and invertebrate species found using gopher tortoise burrows is one of the greatest yet studied in North American animal burrows." Burrow associates use gopher tortoise burrows for a wide range of activities including foraging on items within the burrow, such as, dung or other animals, parasitizing burrow inhabitants, maintaining resident side burrows (e.g., gopher frog, Florida mouse), denning and nesting within burrows (e.g., fox, bobcat, burrowing owl, indigo snake) and seeking refuge from harsh weather conditions, predators, or fires (Milstrey 1986).

The gopher tortoise is long-lived (50+ years); is slow to mature (9-21 years depending on latitude) (Landers 1982, Mushinsky 1994); has a very low reproductive rate, with an average of 5 to 12 eggs per clutch in Florida (Diemer 1987b, Linley 1986, Burke 1987, Godley 1989); apparently has just one clutch per year (Iverson 1980, Landers, et al 1980); experiences a mortality rate as high as 92.3% (Witz 1992) in the egg through yearling stages; and is thought to have a successful clutch only once each decade (Landers, et al 1982, Dodd 1984). Because of its slow reproductive rate, recovery of tortoise populations is a slow process. Dodd (1984) states “when all factors are considered, during an extended lifetime . . . tortoises may only produce a small number of successful offspring even under normal conditions, without the influence of human caused mortality and habitat perturbation."

Gopher tortoises generally inhabit areas of well-drained sandy soils but they are found in a wide variety of habitats. According to Diemer (1987b), “In Florida, over 80 individual soil series, ranging from somewhat poorly-drained to excessively-drained, are capable of supporting tortoises. Classified according to the Soil Conservation Services (1981) ecological community map and descriptions, tortoise habitats include the following: north Florida coastal strand, south Florida coastal strand, sand pine scrub (includes oak scrub), longleaf pine and turkey oak hills, mixed hardwood and pine, upland hardwood hammocks, oak hammocks, north Florida flatwoods and south Florida flatwoods (includes dry prairies)." Ruderal or disturbed habitat, such as, pasture, old fields, roadsides, rangeland, open edges of overgrown woodlands, and upland banks along canals and ditches, are also utilized by gopher tortoises.

Habitat loss, directly (e.g., urbanization) and indirectly (e.g., habitat degradation due to exclusion of natural ecological process, such as, fire), continues to pose the greatest threat to tortoise survival. A burgeoning human population and consequent development are the major cause of upland habitat loss: however, in central Florida, phosphate stripmining has also had a major impact on the gopher tortoise and its habitat (Gilbert c1986). From 1880-1980, approximately 750 km^2 were mined in the northern portion of the

Bone Valley phosphate mining area of central Florida (Schnoes and Humphrey 1980). The reserves in southwestern Polk County are becoming depleted and a shift toward mining in the southern and western parts of the district is underway. Mining activity has destroyed many square kilometers of native sandhill and scrub habitat and has created a mosaic of disturbed wetlands and uplands over a vast area. Schnoes and Humphrey (1980) noted tortoise utilization of unreclaimed pits and spoil piles 5-30+ years after mining; however, information regarding tortoise recolonization of mined lands is minimal.

Since 1975, reclamation of mined lands has been required by state law. While much of this land has been converted to pasture and intensive land uses, upland restoration efforts are increasing. IMC-Agrico Company has established several sand pine scrub and oak scrub restoration areas using (1) sand-tailings fill and (2) mulched overburden approaches to xeric habitat reclamation (King and Feirtag 1992).

As native upland habitat continues to be developed, as tortoise populations decline, and as recipient sites for displaced tortoises have become scarce, there has been increasing interest in the use and suitability of reclaimed phosphate lands as gopher tortoise reintroduction sites. Such interest has been prompted by those seeking acceptable relocation sites for tortoises displaced by mining and development, as well as for reestablishment and restocking sites for maintaining the species' genetic heterogeneity and historic range. In her 1986 and 1987 papers on the ecology, management and status of the gopher tortoise, Diemer Berish recommended that potential tortoise restocking sites be identified throughout the state of Florida, citing reclaimed mining sites as possibilities. In 1989 the Department of Natural Resources (now the Department of Environmental Protection), Bureau of Mine Reclamation issued a document entitled "Wildlife Management and Phosphate Mined Lands." This document discusses a Department policy to encourage reclamation of wildlife habitat. It points out that improved pasture constituted a major percentage of the reclaimed vegetation on phosphate mines, but that these areas appeared to have little wildlife habitat value. The document goes on to say "the viability of reclaimed pasture suggests that it may have a high wildlife potential, but this potential can only be realized if wildlife-oriented landuse decisions are made." Clearly a need existed to determine the value of these and other reclaimed lands as potential reestablishment sites for gopher tortoises.

Few studies have been conducted on translocated tortoises other than to determine the number of active burrows or tortoises on a recipient site just one year following relocation. Godley (1989) monitored 134 tortoises relocated from two development sites to one phosphate mine reclamation scrub site by periodic burrow surveys and radiotelemetry to examine tortoise movements and determine relocation success. Burke (1987) conducted a two year follow up of

tortoises moved to a county park and evaluated relocation success, reproduction, and growth. There are no published records of any longterm studies in which all individuals of a population released on a phosphate-mine reclamation site were recaptured to examine the effects of translocation on reproduction and growth.
Most wildlife managers consider relocation a last resort or unacceptable strategy for the conservation of gopher tortoises.[1] Relocation is biologically and logistically problematic; adverse consequences can be suffered by both the relocated population and the resident population at the recipient area. The longterm consequences of moving and mixing animals from differing populations and homelands are not yet known, but certain translocations may contribute to restoring healthy gopher tortoise populations. Transferring tortoises into areas that have a low or no probability of recolonization or where a senescent colony benefits by supplementing the population may aid in the conservation of the species. One of the most oft cited calls for scientific research by those involved in the study of gopher tortoises is the need for more information on the success or failure and the biological and autecological impacts of translocation on gopher tortoises and their native community.

Suitably reclaimed phosphate land may constitute the most significant unoccupied acreage of remaining habitat in the tortoise's range. Reintroduction of gopher tortoises to such lands could result in benefits such as:

* Preservation of an entire tortoise population or a portion thereof that would otherwise be destroyed or displaced.
* Maintenance of the gene pool represented by the population, thus, preserving greater genetic heterogeneity.
* Preservation of the adult females, which are long lived animals whose reproductive value increases with age (under suitable environmental conditions) and who may become especially valuable as time and further population declines continue. Concern for protecting adult females is further warranted by data collected in this study and provided by Mushinsky (pers. comm.), indicating that the number of reproducing females in a population may be far lower than expected. Dodd (1984) considers adults and young equally important since the reproductive rates of adults and survival rates

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[1] Florida state law and Florida Game and Fresh Water Fish Commission guidelines protect all gopher tortoises but offer options that include conservation easements, non-disturbance of the area around the burrows, incidental take permits and relocation. Incidental take permits must be accompanied by payment into a regional habitat mitigation fund which is used to purchase a lesser amount of high quality offsite acreage. Protection of some upland habitat is secured but the outcome is a net loss of gopher tortoises, their habitat, and the other elements of the tortoises' native community.

of young are both quite low.

* Increased acreage and expertise with respect to restoration of upland habitat suitable for gopher tortoises and associated upland species and processes.

* Addressing the public's desire for wildlife protection, which is noticeably apparent with respect to the gopher tortoise, for which more media coverage and public interest is aroused than for nearly any other reptile (or for that matter for many other wildlife species) in the state.

Despite this list of benefits, reintroduction of gopher tortoises to reclaimed phosphate mined lands must not be mistaken for an answer to the need for preservation of gopher tortoise communities in undisturbed upland habitats. Complete restoration of a site's native biological diversity would not be accomplished through gopher tortoise reintroduction alone. However, the gopher tortoise is a relatively adaptable animal that can survive in disturbed areas and may, itself, serve as an instrument of restoration for other plant and animal species.

OBJECTIVES

1. To determine if reclaimed phosphate mined lands can provide suitable gopher tortoise reestablishment sites. The recipient area in this study was an old mine site reclaimed to pasture.

2. To determine if alterations to reclaimed land enhance the success of reestablishment by comparing gopher tortoise site fidelity on treatment and control plots. (Tortoise site fidelity is defined as a tortoise remaining at a recipient site for at least a year). Alterations included an increase in forage plant diversity and creation of topographic heterogeneity. The extent of the treatments was limited by keeping the costs commensurate with the payments one would be required to make into a gopher tortoise habitat mitigation bank.

3. To determine if relocation affects tortoise egg production.

4. To determine if relocation affects tortoise growth.

It was anticipated that the research could lead to recommendations for the growing and evolving effort to restore uplands and create suitable tortoise habitat on mined lands. To that end, the results of this study contributed to a document that is appended to this report entitled "Guidelines for the creation and enhancement of gopher tortoise *(Gopherus polyphemus)* habitat on phosphate mined lands" (May 1966). The guidelines are an independent collaborative effort of J. L. Callahan, L. A. Macdonald, and J. E. Diemer Berish and are not a publication of the Florida Institute of Phosphate Research. Presented within the body of the main report is information on field methodologies for those who may be involved in reestablishment projects. In addition, the reader is referred to Small and Macdonald (in press, FIPR Project #93-03-105R) for the second phase of the research on reproduction and growth of the translocated and resident Tenoroc gopher tortoise populations in addition to other populations and sites.

MATERIALS AND METHODS

DONOR SITE

The population of reintroduced gopher tortoises originally inhabited an area which was to become the Seven Hills subdivision (hereafter "Seven Hills") in Hernando County, Florida. The property encompassed 379ha of sandhill, planted pine, and disturbed upland habitat. Development was underway in 1988 when the capture effort began: a road and powerline dissected the property, housing was under construction in the north, and open sandy areas that had been cleared for golf course fairways were scattered throughout the site. The developer had paid $125,000 into a Gopher Tortoises Habitat Mitigation Fund in exchange for an incidental take permit.

REINTRODUCTION SITE

The reintroduction site, Tenoroc Fish Management Area (originally "Tenoroc State Reserve," hereafter, "Tenoroc") in Polk County, Florida, is a 2430ha parcel managed by the Florida Game and Fresh Water Fish Commission (Figure 1). At the time the project began, Tenoroc was owned and administered by the Florida Department of Natural Resources (DNR), a state land management agency that is now a part of the Florida Department of Environmental Protection (DEP). DNR policy did not allow the relocation of gopher tortoises onto public lands except where tortoises had been extirpated and needed to be reestablished.

Tenoroc historically included sandhill, pine flatwoods, swamp and scrub habitat until mining began by the early 1950's (Becker 1959). Becker described phosphate mining at Tenoroc in his 1959 article "Coronet Wrests Phosphate from Swamps" as follows. New mining areas were first opened up by small draglines which cut drainage canals, then dug a network of ditches leading to the canals. After an area was well drained, bulldozers were dispatched to clear away trees and dense undergrowth. The vegetation was heaped into piles for burning or pushed into nearby mined-out cuts. Muck was often only 30.48cm to 45.72cm deep, with white sea-sand underneath, and the bulldozers or draglines pushed it into adjacent mined-out pits. A path would be cleared for a mining cut 60.96m wide, plus an additional 30.48m for pumping equipment and pipelines. The phosphate extraction phase began by removing the overburden and spoil into adjacent mined-out cuts, and then picking up the matrix and dumping it into earth-made mining wells just in back of the cut line. The mining wells had semi-circular or rectangular dikes four feet high that confined the matrix as it was dumped from the dragline bucket. Historic aerial photographs indicate the semi-circular configuration was used in the field where the gopher tortoise release sites in this study were later located. Pipes

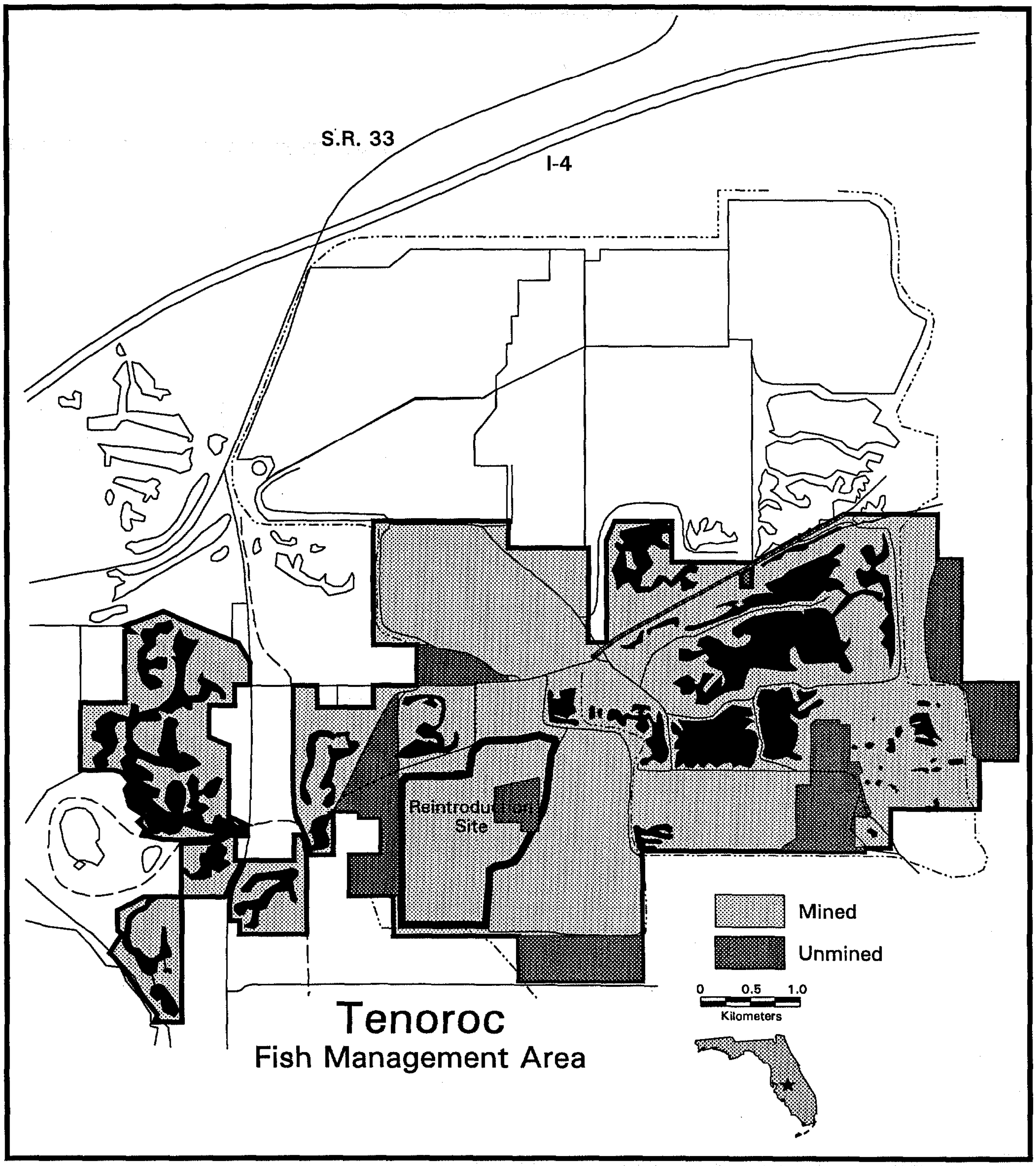

FIGURE 1. Tenoroc Fish Management Area, Polk Co. Florida

and pumps transported the matrix as slurry to the Tenoroc processing plant.

The average overburden in the Tenoroc area was 7.62m deep, the average matrix 2.44m thick. The matrix consisted of approximately 25 to 30 percent phosphate rock, with the rest made up of equal parts of sand and clay. The sand and clay waste material was pumped from the processing plant to large diked areas and confined mined-out cuts. Sand was sometimes used to build or reinforce the dike areas. Slimes were allowed to settle in these area and the water was skimmed off and re-circulated for make-up supply. Apparently, the land was later seeded with grasses and used as a cattle pasture.

In 1988 no resident tortoise burrows existed in the 280ha grassy field that was to become the relocation area. The only tortoises known to exist at Tenoroc at the beginning of the study were situated approximately 3km east of the relocation site near a small cemetery whose ground had been mowed but not cleared during mining operations, and in a native sandhill habitat on the eastern perimeter of the property.

1988 INITIAL CAPTURE, SITE PREPARATION, AND RELEASE

Capture:

From May 15 through June 11, 1988, the project team, assisted by approximately 50 volunteers, surveyed for, captured, transferred to Tenoroc and collected life history data on approximately 140 gopher tortoises from Seven Hills. The starting date was determined by two factors: 1) the need to x-ray females after their eggs had been shelled but before eggs were laid, and 2) only a few weeks were available for capture of the tortoises since development was ongoing in the tortoise habitat.

Active and potentially active gopher tortoise burrows were identified and flagged on 243ha of the donor site. A gopher tortoise “puller" licensed by he Florida Game and Fresh Water Fish Commission, Rufus Stratton, of St Augustine, Florida, used the traditional gopher tortoise pulling technique to hook and extract tortoises from burrows for four work days. Pitfall bucket traps were set at active burrows from which Stratton was unable to pull tortoises and at active and recently active burrows in the areas Stratton was unable to cover during the four days. In addition to pulling and trapping, a few tortoises were hand captured.

Although many tortoises are not recovered by pulling for a variety of reasons, including crooked burrows, soil type, resistance by wedged-in tortoises, and lack of expertise of the puller, pulling would have been the preferred capture technique in a project such as this where a large number of captures must be attempted in an extremely short period of time. At Seven Hills the pulling method of capture was extremely useful, with a success rate approaching 60%. Diemer (1987) reports that pulling success has ranged from 3% - 60%.

Most captures at Seven Hills were made in bucket traps. Properly conducted pitfall bucket trapping during the tortoises' active season is a simple and the least harmful method of tortoise capture. However, bucket trapping is extremely labor intensive, requiring digging in and setting of traps, followed by at least daily trap checking for a standard 28 day period, with resetting of traps as necessary (especially following heavy or frequent rains), and removal of traps at the project's end. Capture rate is high in the initial two weeks but tapers off so that by the end of the fourth week of trapping only the most resistant tortoises remain in their burrows (Godley 1989, Macdonald, unpub.). Capture of all tortoises in a given area can only be assured by excavating all burrows. By first searching the interior of the burrows for tortoises and their associates via camera, the number of burrows to be excavated can be greatly reduced. One hundred percent capture of gopher tortoises in a given area assumes that every tortoise burrow has been identified, all occupied burrows have been excavated and the tortoises removed, and that no tortoise eludes capture unobserved above ground.

Life History Data Collection:

Appendix 1 is an example "Gopher Tortoise Data Sheet" that lists the data that were collected on each individual tortoise. Along with a series of measurements and weight, we attempted to determine the tortoise age and sex. Age was estimated by counting plastral annuli, i.e., the number of complete, concentric growth rings on one plastron scute. Sex was determined by a combined assessment of three measurements: the plastral concavity: the relationship of anal width to anal notch; and the gular length. The size categories used in 1988 to divide the study animals into the four study plot subpopulations were juvenile <l40 mm total length, subadults 140 - 229 mm total length, and adults $\geq$ 230 mm total length. Uncommon characteristics, such as, unusual morphology or marks on the plastron or carapace (e.g., extra scutes, scars), were noted. Many animals in this population exhibited shell damage. The Seven Hills site sustained heavy poaching pressure in the past and this may account for some of the shell abnormalities we observed.

Each tortoise was given an individual, permanent number by drilling holes in the marginal scutes according to a standard marking technique (Appendix 2). Notches were cut into the scutes of the smallest tortoises. The pattern of drill holes unique to each tortoise enabled researchers to track individuals throughout the study and can be used in the future to identify tortoises throughout their life and after death if the marginal scutes remain intact. An exception can occur with very young tortoises as the marginal scutes are too small for drill holes (<10 mm) and because holes and notches fill in as the tortoise grows.

X-rays were taken of all but two tortoises identified as females in the original study population. Several males and tortoises of undetermined sex were also x-rayed to add to the data base. The x-rays were used to show which females had clutches, the number of eggs in the clutch, and the size of each egg. In 1988, Quality X-ray, Inc. from St Petersburg, Florida brought a mobile unit to the study site to x-ray the tortoises. To avoid keeping tortoises captive longer than necessary, in 1989, groups of recently captured females would be transported 80km to the Quality X-Ray, Inc. office in St Petersburg for x-raying, then returned to Tenoroc and released. In 1990 and 1991 tortoises were transported to veterinarian Dr. Nola Gedeon's offices in Lakeland, 8km from the study site. The x-rays at Gedeon's office were taken on a Transworld 360V in-table grid x-ray machine, using Rare Earth cassettes and DuPont Chronix Ultrafast detail film. Settings ranged from 53kv to 65kv for tortoises of 9cm to 15cm body thickness, respectively, at 30 MAS (milliamps x seconds).

Captivity:

Four outdoor enclosures a few hundred square meters in size were constructed to hold the tortoises while the release sites were being prepared. Fencing for the enclosures consisted of 60.96cm or 91.44cm (24" or 36") poultry wire secured to wooden stakes all set at least 20.32cm (8") into the ground. Enclosure One was also bounded by the Tenoroc maintenance area chain link fence and the foundation of the maintenance building. Also in Enclosure One, lengths of poultry wire were laid on the grass over the septic tank drainage field to prevent tortoises from burrowing. Heavy metal rods were placed along the edges of the wire to prevent tortoises from getting caught underneath. This arrangement was successful as the drainage field was not penetrated by tortoise burrowing, no tortoises were injured by the wire, and grass continued to grow through the mesh and provide forage.

Starter burrows, plywood shade stations, shallow water dishes, and a “wading pool" were placed in each enclosure. The water dishes and pool were placed near the edge of the enclosure as this was where the tortoises were most likely to encounter the water as they paced the fence line.

The enclosures differed considerably in existing vegetation and exposure. Enclosure One, within the chain link fenced Tenoroc maintenance yard, possessed a thick covering of sod. Enclosure Two backed up to the bottom of a sand tailings hill; the dominant vegetation was cogongrass *(Imperata cylindrica).* This enclosure was relatively well hidden from visitors to Tenoroc. However, its vegetation offered little variety of natural forage and little shade. Enclosure Three was built on a sandy hillside on the tailings area and possessed both grasses and some herbaceous species, primarily asters. Deep sands along its slope made it vulnerable to erosion and breakthroughs at the fence line. The enclosure that was considered the best holding habitat for the tortoises was Enclosure Four. This enclosure was situated at the top of the sandhill and afforded the best drainage during the summer rains, the area had revegetated with a variety of herbaceous species, and provided natural shade due to the presence of an oak tree and tall shrubbery.

The tortoises ate much of the available natural forage; food supply was supplemented by placing pieces of commercial sod in the enclosures. Fresh produce, from artichokes to zucchini, gathered from local grocery stores was offered to the tortoises every other day.

The enclosures were checked every day for the first month and every other day after that. Delays in the preparation of the study plots (release sites) resulted in the tortoises being kept in the enclosures until the beginning of September. The last set of tortoises was released on September 24th, 1988.

Eight young tortoises ranging in size from 5.8 cm to 13.2 cm were cared for at facilities provided by G. Heinrich. The young tortoises were maintained in five gallon plastic buckets cut to a depth of 18cm. A sand based soil was initially used as a substrate. Foods included vegetables and fruits, e.g., apples, kale, spinach, bananas, squash, cucumbers, tomatoes, corn, green beans, watermelon and cantaloupe, as well as native plant food types, e.g., *Opuntia, Baptisia.* Osteoform, a calcium phosphorus vitamin supplement was provided with food on a weekly basis. Light misting of buckets was conducted sporadically. The young gopher tortoises were placed in a container of shallow water at room temperature two to three times weekly for approximately 30 minutes, inducing the animals to drink and defecate.

The juvenile tortoises were maintained indoors due to predators and fluctuating weather conditions. Occasionally they were exposed to natural sunlight outdoors. During this period the tortoises were allowed to exercise at length. Sod was added to each bucket to provide the animal with additional foraging material as well as to provide a variable topography, enabling the animals to exercise in a more natural manner.

Study Plot Selection and Design:

The four study plots were established in the northern portion of the 280ha field (see "Reintroduction Site" on Figures 1 and 2).

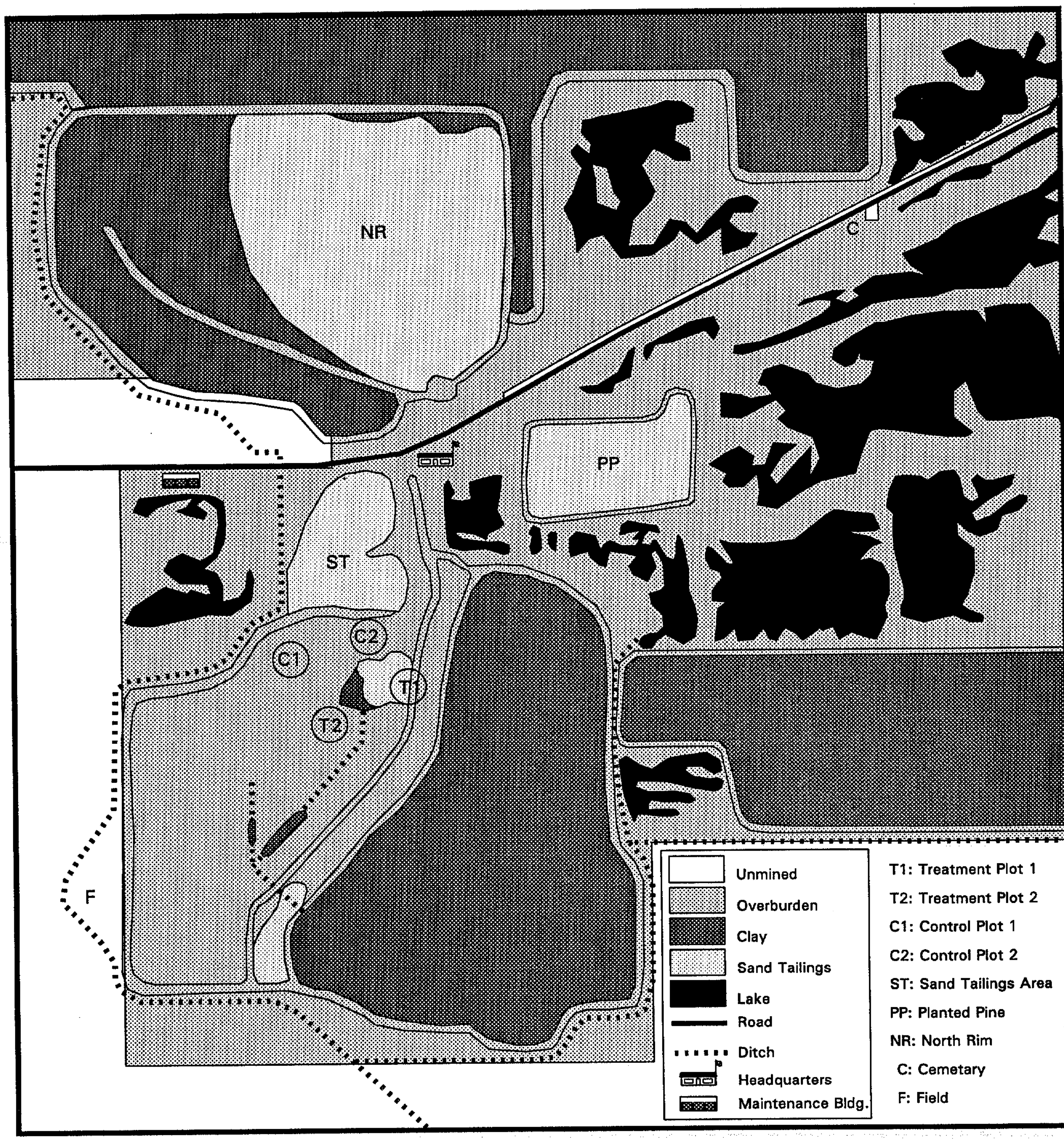

FIGURE 2. Study Area Release and Settled Sites

Botanist Nancy Bissett and soils expert Dr. R.W. Prevatt provided assistance in the selection of the study sites by reviewing historic aerial photographs, examining auger samples, and examining plant species composition. Four areas were chosen that appeared to have at least a 1.25m top layer of sandy soil, had homogenous vegetation and topography, were not inhabited by gopher tortoises, and were situated at least 150m apart. Treatment Plot One (T1) was considered relatively heterogenous compared to the other plots because a portion of the western half was composed of broadleaf (dicot) herbaceous vegetation rather than being dominated by grasses. According to historic aerials the land at T1 was left unmined but covered by overburden. Control Plot Two (C2) lay immediately south and adjacent to the sand tailings hill, therefore, a portion of the sand tailings area was included in the 101.5m wide ring surrounding the C2 rim.

The experimental design called for four 3.24ha (8 ac) circular study plots (101.5m radius) consisting of two treatment and two control plots (Figure 3). The circular shape was selected because the amount of funding available for planting limited the amount of the study plot that could be covered with forage plants. The placement of forage plants in a circular rim around the outside of the treated study plots meant that any tortoise choosing to move away from the treated plots had to encounter the forage plants at least once before dispersing out of the area. The area in a concentric ring 101.5m wide around the study plot was also considered a part of the study plot zone as the planted rim was equally accessible to any tortoise that settled within 101.5m of the rim whether inside or outside the study plot.

Planting:

A strip approximately 2.4m - 3m wide around the rim of each of the two treated study plots was disked and herbicided to eliminate the grass cover in the rims of the circles. The effects of the commercial herbicide “Roundup R," dissipate within 10 days. Bissett conducted the replanting of the study plot rims with 37,500 plants of over 20 species (Table 1) known to be used by tortoises as forage (Garner and Landers 1981, Macdonald and Mushinsky 1988). The number of plants was based on their frequency of occurrence in sandhill habitat and on economical and practical considerations.

Plants were grown from seed at Bissett's native plant nursery. Patches of seedlings or cuttings of the same species were planted in a mixed pattern throughout the treatment plot rims. All plants were set on 0.3m centers in approximately 2.4m wide strips. Planting was conducted in such a manner as to minimize stress from heat and desiccation.

The planting was timed for adequate growth of the plants in the

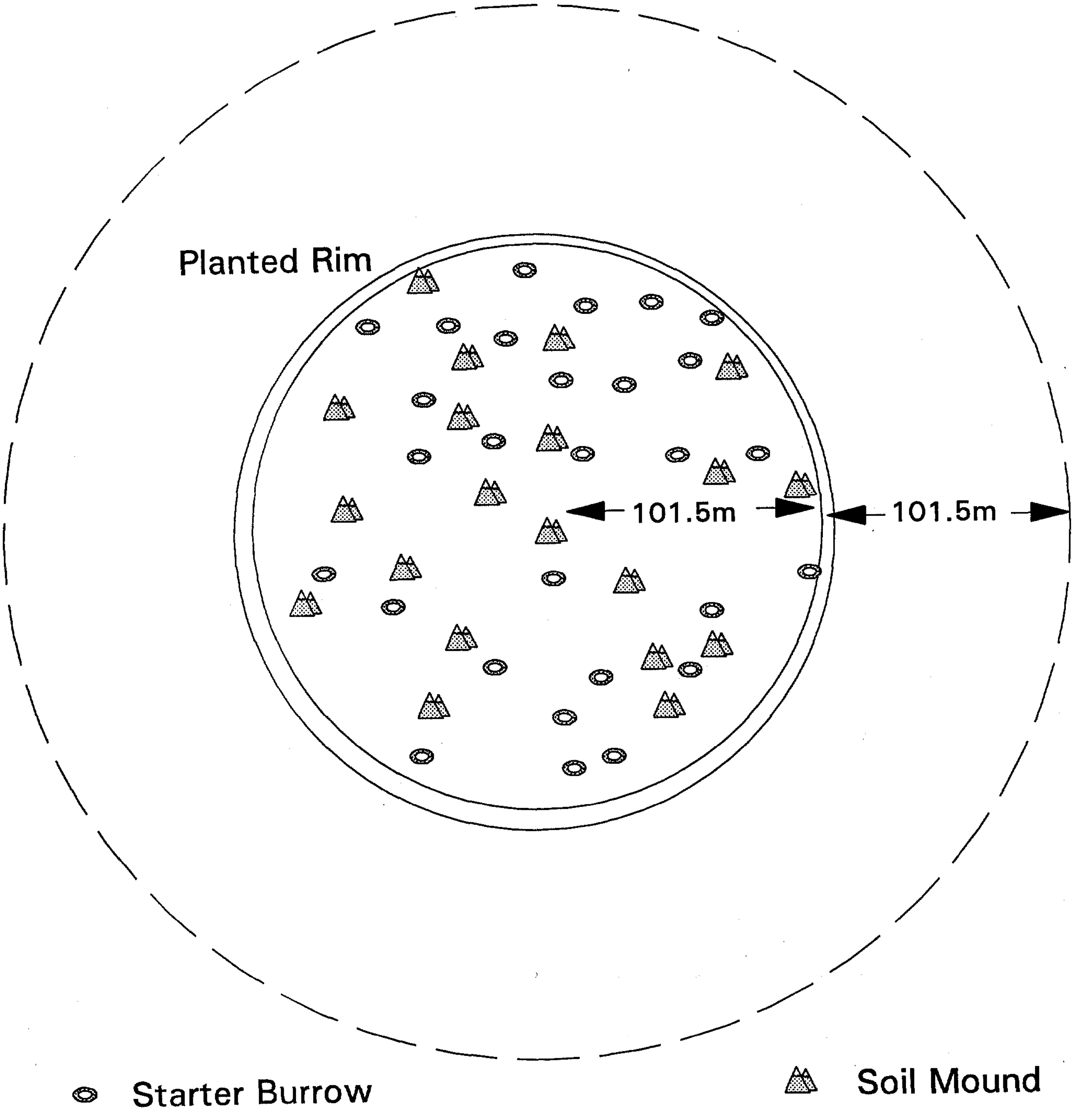

FIGURE 3. Treatment Plot Design

TABLE 1

LIST OF GOPHER TORTOISE FORAGE SPECIES

PLANTED IN TREATMENT PLOT RIMS

SPECIES	COMMON NAME	QUANTITY
Aristida spp	Wiregrass	5296
Asimina obovata	Pawpaw	212
Balduina angustifolia	Yellow buttons	752
Dyschoriste oblongifolia	Twinflower	6873
Galactia, Rhynchosia, Tephrosia	Pea vines	1146
Liatris (3 sp)	Blazing stars	5498
Licania michauxii	Gopher apple	948
Opuntia humifusa	Prickley pear cactus	83
Opuntia humifusa	Prickley pear ears	9875
Phoebanthus grandiflora	Phoebanthus	223
Pinus palustris	Longleaf pine	295
Pityopsis graminifolia	Golden aster	2750
Quercus spp.	Scrub oaks	253
Sorghastrum secundum	Lopsided Indiangrass	3039
Stylisma spp.	Morning glory	196
miscellaneous		43
	Total	37,482

nursery and to take advantage of the rainy season. Mixed sand and clay pockets were encountered on the site. Some areas had to be replanted after the area was supplemented with sand to avoid flooding. Replanting also needed to be done in a few sections where plants were drowned out.

Soil Mounds:

Twenty soil mounds, composed of sand tailings, were placed on each treatment plot to create topographic heterogeneity. Tortoises are known to select burrow sites in ridges, berms, slopes, and soil piles; thus, the simulated mounds were planned as an inducement to tortoises to excavate burrows within the treatment plots.

The locations of the sand mounds/ridges within the treatment plots were determined by randomly generating sets of coordinates (the x and y axes were the north-south and west-east lines), using those coordinates to locate starting points for the soil mounds, randomly choosing a compass direction, and following that compass direction out 3m from the starting point. The same pattern for soil mound locations was used on both treatment study plots.

Phillips and Jordon, Inc. was contracted to move 1,185 cubic yards of sand tailings to the two treatment study plots from the sand tailing area immediately north and within 0.8km of the plots. One front end loader and one moxie dump truck were used on August 16 and 17 to place the 20 sand mounds which were approximately 3m long, 1.5m wide, and 1.25m high on each treatment plot.

The sand tailing deposit from which the material for the mounds/ridges was obtained was chosen because, sandy soils without high clay content were needed. Selecting the nearby sand tailings deposit also minimized the cost and effort needed to move the soil. The thin layer of topsoil in this deposit covered nearly pure sand with minimal clay content.

Release Point Selection and Preparation:

A release point for each tortoise was determined by generating sets of random coordinates as described for the soil mound placement. Twenty-nine locations that fell within or in the rim of an 3.24ha circle constituted the release points. The same pattern was used on all four study plots, thereby providing a starter site for each of the study animals.

The method for determining which tortoises would be released onto each study plot consisted of dividing the tortoises into the three size classes and further dividing the adults by sex. All tortoises within a category were then randomly assigned to a study plot and randomly to a release point within the study plot.

An individualized starter burrow was dug at each release point.

Starter burrow width approximated the length of the assigned tortoise; burrow length was one to three times the tortoise length: and a shade was placed over the burrow mouth. At the time of release scat was set inside the burrow to familiarize the tortoise with the burrow. The primary purposes of the starter burrows were 1) to provide shelter at the time of release, and 2) to provide an initial data base point for tracking and comparisons throughout the study. It was hoped, but not necessarily expected, that tortoises would further excavate the starter burrows.

Preparation for release:

In order for the study animals to be released onto the Tenoroc study sites, they first needed to be recaptured from the temporary enclosures. Over the summer the tortoises had enlarged the starter burrows in their enclosures and excavated new burrows. Most of the tortoises were captured by hand; however, it was also necessary to dig out, pull, and bucket trap the remainder. Each tortoise was accounted for, and its measurements and identification number were confirmed against the original data.[2] In addition, a small number of gopher tortoise burrows had been discovered on the sand tailings hill immediately north of the original study area. The hill was surveyed and bucket trapped to obtain data on the newly discovered extant resident population and to recapture Hernando tortoises that had escaped from enclosures over the summer.

Recapture and release of the majority of tortoises and the final planting work were scheduled to be completed over the weekend of September 3rd through 5th. However, during that weekend, a storm occurred that flooded west-central Florida. For 10 days, 130 tortoises were kept in individual boxes in the Tenoroc maintenance building. During their confinement, the tortoises were offered fresh produce daily and placed in a wading pool to drink and rehydrate every few days.

Release:

One hundred sixteen gopher tortoises were released to the 4 study plots (29 per plot) between September 12 and 14, 1988. On September 13 tortoises that were slated for release to Treatment Plot Two (T2) were put into Enclosure One to await the completion of the planting work. The T2 tortoises were released on September 24. Throughout this period as more individuals were recaptured, such as those caught in the bucket traps set in the enclosures, the newly recaptured animals were released to the appropriate study plots. Thus, not all tortoises were placed on a study site on one

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[2] In September Dr. Mark Hayes took standard measurements along with plastral and carapace annuli measurements on the translocatees and residents to obtain data for research on an improved methodology for aging tortoises.

day.

At the time of release scat from the tortoise's box was placed in the starter burrow, the animal was placed at the burrow mouth heading into the burrow and its behavior observed and recorded for 15 minutes. If at the end of 15 minutes the tortoise was away from the starter burrow, the observer returned the tortoise to the burrow entrance. Releases were conducted at various times of the day and evening to determine if timing affected the likelihood that tortoises would remain at the starter burrow when released.

1989, 1990, 1991 RECAPTURE AND DATA COLLECTION

At the end of the second week of May in 1989, 1990, and 1991 a resurvey effort was begun at Tenoroc to locate the 116 original translocated study animals. A thorough search was carried out on the zone within 203m of each study plot center (the circular study plot with 101.5m radius and the outer ring within 101.5m of the study plot). Surveys, capture effort, and data collection expanded to include more Tenoroc property each year and led to an extension of the research project to include a substantial resident[3] tortoise population.

Additional areas surveyed in 1989 (Figures 1 and 2) were the sand tailings area (hereafter referred to as “sand tailings" or "ST"), the vicinity of the study plots, that is, the area between and near the study plots, the planted pine parcel (hereafter referred to as "planted pine" or "PP") approximately 1.5km northeast of the study area, the cemetery and east side of the cemetery (hereafter referred to as “cemetery" or "C") approximately 3km northeast of the study area, the complete boundary of the field in which the study plots were located, and the southern portion of the field (hereafter referred to as "field" or "F"). A rough search by vehicle was conducted in areas adjacent to the field in which the tortoises were released and the sand tailings plateau (hereafter referred to as the "north rim" or "NR") 2 - 3 km away from the study area on the northern side of the Tenoroc lands. The areas listed above were chosen based on proximity to the study site, vegetation, soil, reports that a tortoise had been sighted in the area, and/or the presence of resident tortoises.

In 1990 survey work expanded to include 1) an extension of planted pine, 2) the areas adjacent to the north, south and west sides of the cemetery, and 3) the north rim sand tailings area. In 1991 the north rim received a more extensive survey because tortoises were

[3] The resident population was assumed to be composed primarily of animals born at Tenoroc as well as tortoises brought to Tenoroc by the public from off site, and probably included a few animals from Hernando County that escaped from the temporary enclosures.

colonizing the area.

Pitfall bucket traps were set at all active and inactive burrows identified during surveys. Once a tortoise was captured, that trap was left in place for generally 4-5 days in case the captured animal was a visitor to the burrow and not the burrow “owner." While in captivity, the tortoise's life history data were collected; unidentified animals were permanently marked; and females and probable females were x-rayed. Each tortoise was returned to the burrow from which it was captured: the bucket trap was removed; and the entranceway was restored. Traps at which no tortoises were captured were removed after 28 days.

1993 RECAPTURE AND DATA COLLECTION

In 1993 the Florida Institute of Phosphate Research approved a contract to extend this study to obtain further data on the reproduction and growth of tortoises on phosphate lands, using the translocated study population, the Tenoroc residents, and several additional tortoise populations in west central Florida. At Tenoroc, recapture in May 1993 consisted of 2 days of pulling and 2 weeks of bucket trapping in the study plots, sand tailings, planted pine, and cemetery areas. Primary effort was put into recovering adult animals. All animals were measured, weighed, sexed, and aged: new animals were marked. Annuli measurements for comparison with 1988 data were collected for the aging study. Males, subadults, and juveniles were replaced in their burrows. Adult females were x-rayed to determine presence and number of eggs. All gravid (egg carrying) females were maintained temporarily as subjects of the reproduction research, part of which involved keeping the animals until their eggs were obtained, generally by inducing egg laying through injection of oxytocin. Females were then returned to their original burrows.

STUDY SITE TREATMENT (PLANT AND SOIL MOUND) ANALYSIS

To determine if the study plot treatments had an effect on tortoise burrow site selection, it was necessary to measure the distance from burrows to both the planted rim and the sand mounds. In 1989, 1990, and 1991, the distance between each occupied burrow and the closest sand mound and the distance between each occupied burrow and the closest point along the planted rim were measured at each study plot.

VEGETATION ANALYSIS

Vegetation analysis was performed to quantify any differences between the areas where tortoises were released and the areas, where they selected to settle. Vegetation data collected at the starter burrows where 38 translocated tortoises were originally released (release sites) were pooled and compared to the pooled vegetation data collected at the thirty-eight burrows the tortoises occupied in 1991 (settled sites). Vegetation data were collected in 1990 and 1991; the 1991 data are used for analysis in this paper.

Frequency and cover of plant species, bare ground, and litter were recorded in a 0.61m (2') by 9.14m (30') transect running in a randomly generated compass direction away from the mouth of the burrow. Data were gathered as if the transect was divided into fifteen 0.61m by 0.61m squares. For each 3.05m (10') of 5 squares, the number of squares in which the plant, bare ground, or litter occurred, was recorded. This measure of frequency of occurrence could range from 0 to 5. Ultimately, species were ranked according to relative frequency based on the formula:

$$\text{frequency} = \frac{\text{\# of squares in which species occurs}}{\text{total \# of squares (600)}}$$

Cover by plant species, bare ground, and litter cover was recorded on the basis of 7 categories. Categories 1 through 7 represented percent cover of <1%, 1-10%, 11-30%, 31-50%, 51-70%, 71-90%, and 91-100%. In any one square the measure of percent cover for any one plant species, bare ground, or litter could range from 1-7, *or* <1% through 100%. Species were given a relative rank based on their amount of coverage.

In addition, the plantings in the treatment plot rims were assessed in 1991 by recording the occurrence of species at 30m intervals along a transect running the midline of the complete rim. A cursory assessment was made of rim plants at T1 in 1993.

SOIL ANALYSIS

Initial study plot site selection:

On July 14, 1988 Dr. Rupert Prevatt of Florida Southern College, reviewed historic aerial and ground level photographs, dating from the 1950's to the present and took auger samples in seven areas of the grassland to determine their potential use as the four study plots.

Soils Mapping:

Figure 2 depicts three categories of soil types existing at the study area (overburden, clay, and sand tailings), in addition to showing which areas remained unmined. The boundaries of mined and unmined areas are also depicted on Figure 1. All of the translocated tortoises settled in areas that were either sand tailings or unmined. Unmined areas may have subsequently been covered with a layer of sand tailings or overburden. With respect to the four study plots where tortoises were released, tortoises remained at the west side of T1 which was unmined and covered with sandy overburden and on the north side of C2 which was composed of sand tailings and a transition zone between overburden and sand tailings. As for areas the tortoises selected for settlement, sand tailings, planted pine, and north rim all have a cover of sand tailings, the cemetery and road leading to it was unmined with sandy overburden surrounding it, and the field was unmined.

Penetrometer Analysis of Release and Settled Sites:

Soil analysis was performed to quantify differences in soil resistance or hardness between the areas where tortoises were released and the areas where they selected to settle. On four sampling dates between August 1991 and March 1992 a soil penetrometer approximately one meter in length was used to test soil resistance with pounds per square inch (psi) as the unit of measurement. Readings (3 to 6) were taken at the 1988 starter burrow release sites and the burrows where tortoises were located in 1991 for the 40 study animals recaptured in 1991. The readings were made within approximately 1/3 meter of the right or left side of the burrow mouth, taking care not to take samples through the soft soil of the burrow apron. These data were pooled in two groups 1) the release sites which included readings from all four study plots, and 2) the settled sites which included readings from the two treated study plots, sand tailings, planted pine, north rim, and the field. The control study plots were not included in the latter group because no tortoises settled in either control plot.

Supplemental information: Observations of anomalous burrows were recorded (e.g. diggings in soil mounds, pallets (i.e., short, <1 meter, seemingly abandoned holes) in burned over clay soils, caved in burrows), where the information lent itself to interpreting the influence of soils on tortoise habitat suitability.

RESULTS

CHARACTERIZATION OF THE POPULATIONS

Translocated Study Population

The translocated study population consisted of 116 gopher tortoises from Hernando County which were separated into four groups of 29 tortoises each with similar percentages of juveniles, subadults, and adults and similar percentages of females, males, and undetermined sex tortoises. Table 2A characterizes the study population by sex in 1988 and each subsequent year of recapture. Table 2B presents recapture information by sex for 1993, the year in which a limited recapture effort occurred. Table 2C characterizes the study population in 1991 ("1991/93 combined") by adding the 1993 recapture information to the information obtained in 1991.

Because the population was examined for six years the sex of many of the recaptured animals which were subadults in 1988 could be determined by the end of the study and sex data could be input retroactively. Life history data obtained in 1988 indicated the study population consisted of 27% females (n=33), 43% males (n=47), and 30% animals of unknown sex (n=36). Table 2A categorizes females at 30% (n=35), males at 44% (n=51), and unknowns at 26% (n=30), as determined retroactively.

The literature reflects several ways in which to divide gopher tortoises by size category. The size categories used in 1988 to divide the study animals into the four study plot subpopulations resulted in four groups with approximately 6% juveniles (n=7), 34% subadults, and 59% adults. Recategorization into a size classification scheme based on carapace size at 50 mm increments (Alford 1980) results in a sharply peaked bell curve with 54% of the population in the size category between 200 mm and 249 mm (Table 3A). Records indicate the mean age of the tortoises in this size class is 14.5 years, minimum 7 years, maximum over 25 years of age. Age could not be approximated for 9 of the larger of the 63 tortoises in this category; therefore, the average age was probably somewhat higher than 14.5.

The mean carapace length (CL) for the population was 212 mm, minimum 300 mm, maximum 340 mm. Female and male mean CL for each year is listed in Table 4. The mean CL for adult females was 248 mm, the largest female being 285 mm. Mean adult male carapace length was 230 mm, maximum 300 mm. Mean CL for females exceeded CL for males in all years.

Resident Population

The number of resident gopher tortoises included in the study

Table 2A. Translocated study population by sex and year with annual recapture data.

Year	Females			Males			Undetermined			Total recapt'd
	n =	% of pop	% of orig females recapt'd	n =	% of pop	% of orig males recapt'd	n =	% of pop	% of orig undet recapt'd	
1988	35	30%	-	51	44%	-	30	26%		116 (100%)
1989	14	30%	40%	22	47%	43%	11	23%		47 (41%)
1990	12	32%	34%	21	55%	41%	5	13%		38 (33%)
1991	16	40%	46%	22	55%	43%	2	5%		40 (34%)

Table 2B. Translocated study population recaptured in 1993.

Year	Females		Males		Undet		Total
1993	13		16		1		30

Table 2C. Translocated study population at Tenoroc in 1991 based on combined 1991 and 1993 data.

Year	Females			Males			Undetermined			Total
	n =	% of pop	% of orig females recapt'd	n =	% of pop	% of orig males recapt'd	n =	% of pop		48 (41%)
1991-93 Combined	19	40%	54%	26	54%	51%	3	6%		

Table 3A. Translocated study population by year and size class in 50 mm increments in carapace length. Note that the population is aging thus the small size categories are disappearing.

	Size Class						Total
Year	50-99	100-149	150-199	200-249	250-299	300-349	
1988	4	8	21	63	19	11	116
1989	-	3	14	24	6	-	47
1990	-	-	5	19	14	-	38
1991	-	-	1	19	19	1	40

Table 3B. Translocated study population captured in 1993 by size class in 50 mm increments in carapace length.

	Size Class						Total
Year	50-99	100-149	150-199	200-249	250-299	300-349	
1993	-	-	-	5	25	-	30

Table 4. Carapace length for adult females, females with eggs, and males for translocated and resident tortoises.

Year	Translocated Study GTs			Resident GTs		
	Female	Female with eggs	Male	Female	Female with eggs	Male
1988	24.8	26.1	23.0	29.1	-[1]	26.6
	n=27	n=12	n=50	n=6	-	n=2
1989	25.4	26.5	22.9	27.9	28.9	25.2
	n=9	n=2	n=21	n=15	n=5	n=13
1990	25.2	25.8	24.3	27.3	27.2	23.6
	n=10	n=5	n=20	n=24	n=18	n=18
1991	26.0	26.1	24.7	27.3	27.3	24.5
	n=16	n=10	n=22	n=31	n=19	n=22
1993	27.1	27.2	25.7	27.1	28.2	25.1
	n=13	n=10	n=16	n=15	n=7+1[2]	n=11

[1] Egg information is not available for 1988 as residents were not captured until September.

[2] Measurements not available for one female with eggs.

increased each year as the area subject to search expanded and as additional individuals were released at Tenoroc by the public. Table 5A and 5B categorize the resident population by year and by sex. Of 15 residents captured in 1988, 40% were females, 33% males, and 27% undetermined. By 1993, 112 individuals considered residents had been captured at Tenoroc; 37% female (n=41), 27% male (n=30), and 37% of undetermined sex (n=41).

Tables 6A and 6B categorize the resident population by year and size class. Because new individuals were added to the resident study population each year and tortoise size changes each year, the data from the 112 residents are not pooled to reflect size categories at any one point in time. In 1988, 47% of the residents (7 of the 15) were under 200 mm and another 7 (47%) were between 250 mm and 299 mm. The sample size of tortoises in the latter category for which an age could be determined (n=3) is too small to be a reliable indicator. An approximation of a characterization of the population by size class could be done by analyzing the data from 1991 when data were collected on 84 new and recaptured residents. Based on 50 mm increment size classes in 1991, the number of individuals in each category increased as size increased to a total of 32 individuals, in size class 250 mm to 299 mm (38% of the total number collected). However, there were only 6 individuals in the largest size class (>300 mm) during this period. Age data could be obtained on 18 of the 32 animals. Their mean age was 11.8 years; minimum 8, maximum over 25. The ages of the two tortoises in the size class exceeding 300 mm CL were determined to be 13 and 16.

The overall mean CL for the resident population in 1991 was 220 mm, with a minimum of 58 mm and a maximum 308 mm. Mean adult female CL was 273 mm and mean adult male CL was 245 mm. Female CL exceeded male CL in all years.

Translocated Non-study Population

There are sixteen gopher tortoises that were brought to Tenoroc from Hernando County whose life history and recapture data are used in selected analyses in this paper but who were not placed in the study population of 116 animals. In 1988, they ranged in size from 130 mm to 260 mm and included 9 females, 5 males, and 2 of undetermined sex. All tortoises in the translocated non-study population exceeded 200 mm in length by the year of their most recent recapture.

RECAPTURES

Translocated Study Population

The pooled results of attempting to recapture the 116 gopher tortoises translocated to the four Tenoroc study plots in 1989, 1990, 1991, 1993, and adjusted 1991 are presented in Table 7.

Table 5A. Resident population by year and sex. Reading from top to bottom of each column indicates the first year animals were captured and how many of those were recaptured in subsequent years.

Year	1988			1989			1990			1991			1993			TOTAL CAP & RECAP
Sex	F	M	U	F	M	U	F	M	U	F	M	U	F	M	U	
1988	6	5	4													15
1989	5	5	2	14	11	10										47
1990	5	5	2	9	8	7	13	7	11							67
1991	6	5	3	11	9	6	12	5	9	4	5	9				84
1993	5	4	0	5	2	0	2	2	0	0	1	1	4	2	7	35

Table 5B. Summary of resident population by year and sex

Year	Total Residents			
	F	M	U	
1988	6	5	4	15
1989	20	16	14	50
1990	33	23	25	81
1991	37	28	34	99
1993	41	30	41	112

Table 6A. Resident population by year and size class in 50 mm increments in carapace length.

	Size Class						Total Residents
Year	50-99	100-149	150-199	200-249	250-299	300-349	
1988	2	3	2	-	7	1	15
1989	3	9	5	8	21	1	47
1990	-	15	12	12	25	3	67
1991	5	9	15	17	32	6	84

Table 6B. Resident population captured in 1993 by size class in 50 mm increments in carapace length.

	Size Class						Total Residents
Year	50-99	100-149	150-199	200-249	250-299	300-349	
1993	4	2	2	8	16	2	34[1]

[1] Size data missing for adult female GT 1110

Table 7. Recapture of translocated and resident populations by years.

Year	Translocated		Residents: Cumulative		Residents: By Year							
	n =	% Recap	n =	% Recap	1988		1989		1990		1991	1993
					n =							
1988	116	n/a	15	n/a	15	n/a						
1989	47	41%	47	80%	12	80%	35					
1990	38	33%	67	72%	12	80%	24	69%	31			
1991	40	34%	84	81%	14	93%	26	74%	26	84%	18	
1993	30	n/a	35	n/a	9		7		4		2	13
1991-1993 comb'd	48	41%	99									

Tables 2, 3, 4, and 8 are referred to for details of the information summarized in Table 7.

Forty-one percent (n=47) of the 116 study animals were recaptured in 1989 (Table 7): thus, a loss of 59% of the individuals occurred in the first year. A smaller loss occurred in the second year (1990) when 38 individuals were found (33%), and a slight increase to 40 animals occurred in 1991 (34%). Adding the study animals recovered in 1993, but not recovered in 1991, to the 1991 data yields an adjusted 1991 population of 48 tortoises. This means 41% of the original study animals were still at Tenoroc in 1991. Once the initial loss occurred the recapture rate was relatively stable. The number of years or times in which tortoises were recaptured varied. Sixteen tortoises were recovered in all four recapture years, 15 were recaptured three times, 14 were recaptured twice, and 18 were recaptured once.

Three study animals were not seen from the time of release until 1993. Two of these tortoises were female GT 104 (the study animal with the longest carapace length) and male GT 91. These animals were captured from the same general area at the Hernando County property, were kept in the same enclosure during the summer of 1988, were released in relatively close proximity on study plot C2, and by 1993 had moved to the farthest end of the sand tailings area into adjacent burrows. Among the translocated non-study animals was one that was recovered for the first time in 1993. The third gopher tortoise, GT 99, was not in the study population because she had escaped from Enclosure Three in 1988. She was recovered in 1993 from a burrow less than 50 meters from the old enclosure site.

Table 2A contains the results of yearly recapture of the translocated population categorized by sex. In 1991, the recapture percentage for females was 46% (n=16) and 43% (n=22) for males. Over the years recapture rates ranged from 34% to 46% for females and from 41% to 43% for males.

Recapture rates by size category each year for the translocated study population are found in Table 3A. The results in Table 3A provide information about the changing demographics of the population through the years following translocation. Table 8 provides information about differential survival based on sex and the tortoises' initial size class in 1988. Only one tortoise (GT 59) under 140 mm CL (n=7) in 1988, was still in the population in 1991. GT 59 was released at Tl and has been recaptured there every field season. The survival rate in adjusted 1991 is about 40% in the size classes encompassing tortoises from 140 mm to 249 mm, but rises to 53% in size class 250 mm to 299 mm.

Table 8 also presents the results of survival based on the combination of size and sex. Although there is a small degree of variation from year to year, longterm there does not appear to be

Table 8. Recapture success by 1988 size class and sex for translocated study population

Year	Size Class						Total
	50-99	100-149	150-199	200-249	250-299	300-3490	
	U/F/M	U/F/M	U/F/M	U/F/M	U/F/M	U/F/M	
1988	4	8	21	63	19	1	116
	4/0/0	5/2/1	14/4/3	7/18/38	0/11/8	0/0/1	
1991	0 (0%)	3 (37.5%)	7 (33%)	21 (33%)	9 (47%)	0 (0%)	40 (34%)
	0/0/0	0/2/1	2/3/2	0/7/14	0/4/5	0/0/0	
1991-93 Combined	0 (0%)	3 (37.5%)	9 (43%)	26 (41%)	10 (53%)	0 (0%)	48 (41%)
	0/0/0	0/2/1	3/4/2	0/8/18	0/5/5	0/0/0	
Percent GTs recovered by sex and size	0/-/-	0/100/100	7/100/67	0/44/47	-/45/62.5	-/-/0	

a difference in survival rate among males and females (see Tables 2 and 8). Mean CL for surviving adult females was 271 mm and for the males was 257 mm.

Resident Population

Table 7 contains the results of yearly recapture of the resident population. In 1989, 1990, and 1991 the recapture rates for the resident population, progressively including the tortoises added the previous year, were 80%, 72%, and 81%, respectively. Fourteen, or 93%, of the 15 residents captured in 1988 were recaptured in 1991. The only tortoise lost from the 1988 resident group was a 180 mm subadult. Eighty-eight percent of the females and 83% of the males were found in 1991. In 1991 the resident population consisted of 39% females, 29% males, and 32% tortoises of undetermined sex.

SITE FIDELITY AND MOVEMENT

The locations of recaptured translocated and resident gopher tortoises throughout the Tenoroc study area from 1988 through 1993 are recorded in Table 9. During the six years of the study tortoises were found in nine areas (Figure 2): Treatment Plot One (T1), Treatment Plot Two (T2), Control Plot One (C1), Control Plot Two (C2), the sand tailings area (ST), the planted pine area (PP), the north rim (NR), the cemetery (C), and the south and the western edge of the field in which the study plots were established (F). By the final field season tortoise movement had occurred between every site.

One year after translocation, 16 study animals were in the vicinity of T1, generally on the west side. Thirteen study animals had burrows within the study plot zone; seven tortoises were inside the study plot and 6 were within the ring extending 101.5m around the study plot. This included 8, or 28%, of the original 29 tortoises released on T1, 2 tortoises released at C1, 3 tortoises released at C2, and 3 tortoises released at T2. Three, or 10%, of the tortoises released at T2 had remained, two inside the study plot and one within the outer ring.

One year after translocation no tortoises were located in C1 or C2. Sixteen tortoises were located within the northern portion of C2's surrounding ring which constitutes the southern portion of ST. Of the 16 tortoises in the C2 ring, 12 or 41%, had been released at C2, 8 had been released at C1, 3 had been released at T1, and 3 had been released at T2.

Ten additional translocated study animals were recaptured from the ST hill and surrounding plain, and 2 were found within a colony of resident tortoises in the planted pine area approximately 1.5 km northeast of the study plots.

Table 9. The number of translocated (T), resident (R), and translocated non-study (N) tortoises from 1988 through 1993 in the following areas: Treatment Plot 1 (T1), Treatment Plot 2 (T2), Control Plot 1 (C1), Control Plot 2 (C2), Sand Tailings Area (ST), Planted Pine (PP), North Rim (NR), Cemetary (C), and Field (F). (* These data for C2 are included in ST, see text.)

Year	T1			T2			C1			C2			ST			PP			NR			C			F + misc		
	T	R	N	T	R	N	T	R	N	T	R	N	T	R	N	T	R	N	T	R	N	T	R	N	T	R	N
1988	29			29			29			29				15													
1989	16			3						*			26	20	3	2	15	3					9			3	
1990	10		1							*			23	22	3	2	18	3	1	5			22		1		1
1991	9		1	1						*			26	25	4	1	20	3	2	10	1		28		1	1	
1993	8		1							*			20	18	5	1	5?						11		1	1	

Calculating site fidelity as the percentage of tortoises released in the vicinity of a site that remained at that site, in 1989 site fidelity at T1 was 28% (n=8), at T2 18% (n=3), at C1 0%, and at C2 41%. Overall, 41% (n=47) of the study animals were recaptured at Tenoroc.

With respect to the 15 residents captured in 1988, all 12 were still in ST in 1989, indicating site fidelity of 80%.

Three years after release (1991) 9 translocated study animals were recaptured from T1. This included 6 (or 21%) of those originally released at the site and 2 more tortoises that had been at T1 since 1989. One study animal was burrowed into a sand mound at T2; however, it was the first time this tortoise had been noted at this site. There were no tortoises at C1. Seventeen of the 26 translocated tortoises that had been at ST in 1989 were still within the ST area; however, it appears that at most, 7 of the original 12 in the C2 ring remained. Exact data for this later finding are unavailable. One male was recaptured for the second year at PP.

By 1991, translocated tortoises were found in two additional areas at Tenoroc. One female occupied a burrow approximately 1.5 km from the study plots in the southern end of the field. Two males had moved to the NR, the sand tailings plateau that lies 2 to 3 km north northeast of the study plots.

Records of tortoise movement were also evaluated in terms of whether a tortoise had settled at a site. If records indicated an individual had remained at a site for 3 years or more and its last capture was at that site in 1991 or 1993, it was considered settled. Thirty-seven translocated tortoises are known to have been at ST at least one year. Of the 37, at least 25, or 68% are known to have settled at ST once they got there. Among residents there are records for 22 tortoises that go back at least three years and that were in ST at least one of those years. Seventeen, or 77%, of the residents were settled at ST.

INFLUENCE OF TREATMENTS ON SITE FIDELITY

Twenty-eight percent of the tortoises released on T1 remained in and around T1 the first year, 10% remained in and around T2, 0% remained in and around C1, and 24% remained not in but around C2. Although the distribution of burrows on the study plots shows that some tortoises did remain in the treated plots and no tortoises remained in control plots, the sample size was too small to show a statistically significant difference.

The starter burrows of gopher tortoises released and recaptured at the treated sites were an average distance of 28.5 m to the planted rim. The 1989 burrows of those same tortoises averaged 14.5 m from the rim. The distance to the rim was cut in half but there was not enough evidence to show a statistically significant difference. An increasing number of burrows has been observed within the planted rim of T1 each year.

The distance from the starter burrows to the soil mounds averaged 18.5 m. The average distance between the tortoises' 1989 burrows and the soil mounds increased to 34.8 m. When this result is interpreted in the field it appears that the movement was not so much avoidance of the soil mounds as it was movement toward the higher, sandy side of T1 and its outer ring.

VEGETATION ANALYSIS AND HABITAT STRUCTURE

Release and Settled Sites

The release and settled sites of translocated gopher tortoises varied significantly with respect to vegetation and structure. The settled sites had nearly twice as many plant species, five times the bare ground, and 56% of the litter cover (Table 10). The release sites possessed 43 plant species, the settled sites possessed 78 species. The species planted in the rims of the treated study plots are listed in Table 1.

With respect to diversity and frequency of occurrence, only four species *(Paspalum notatum, Indigofera hirsuta, Sporobolus indicus,* and *Aeschynomene americana)* were available on more than 10% of the release site area. *P. notatum* was present on every transect, on 97.2% of the sample unit squares, and covered 132.4 square meters. *I. hirsuta, S. indicus,* and *A. americana were* available on 57.7%, 44.3%, and 21.3% of the sample unit squares, respectively. The next most prevalent plant on the release sites, *Cynodon dactylon* was available on 8.7% of the sample unit squares. In contrast, twelve plants occurred at frequencies greater than 10% on the settled sites; *Heterotheca submaxillaris 56.2%, Indigofera hirsuta 42.3%, Paspalum notatum 41.8%, Rhynchelytrum repens 35.29, Sporobolus indicus 26.8%, Cyndon dactylon 20.3%, Richardia brasiliensis* 19.5, *Ambrosia artemisifolia 18.2%, Conyza canadensis* 16.2%, *Panicum repens 13.79, Ampelopsis arborea 12.8%,* and *Galactia elliottii 12.5%.* The coverage or square meters occupied by the most dominant plants in the settled area were *P. notatum 47* m^2, *H. submaxillaris 24* m^2, *I. hirsuta* 19.4 m^2, *S. indicus* 12.2 m^2, *R. repens* 10.5 m^2. These species also represent a greater diversity of plant families present at the settled sites than the release sites.

Three species were prevalent throughout both sites: two perennial grasses *(P. notatum* and S. *indicus)* and an annual legume (*I. hirsuta).* On the settled sites *H. submaxillaris* was the most frequently encountered plant and ranked second in coverage.

TABLE 10. List of plant species, bare ground, and litter at gopher tortoise release and settled sites with frequency and cover rankings

Plant Species	Release Sites (43 species)		Settled Sites (78 species)	
	Frequency	Cover	Frequency	Cover
Acalypha gracilens			59	56
Aeschynomene americana	4	4	33	30
Ambrosia artemisiifolia			8	4
Ampelopsis arborea	9	13	11	8
Andropogon glomeratus	17	15	55	48
Andropogon virginicus	21	16	53	31
Aristida spiciformis, spp			69	62
Aristida stricta	15	9		
Aster tenuifolius			69	62
Baccharis halimifolia	27	14	30	22
Buchnera americana	36	35		
Bulbostylis ciliatifolia			37	44
Bulbostylis stenophylla			30	43
Carex albolutescens	29	34		
Cassia nictitans	6	8	19	23
Cassia rotundifolia			35	26
Cenchrus incertus	34	35	59	62
Chenopodium ambrosioides			21	23
Cida rombifolia			59	62
Clematis crispa			55	50
Conyza canadensis			9	12
Crotalaria brevidens/mucronata	11	7	42	37
Crotalaria rotundifolia	21	16	69	62
Croton glandulosus			59	62
Cynodon dactylon	5	6	7	9
Cyperus brevifolius	14	31		
Cyperus globulosus	24	30	37	46
Cyperus nashii			49	50
Cyperus polystachyos	36	35	69	62
Cyperus retrorsus	10	21	13	20
Cyperus sp.	24	26		
Cyperus surinamensis	29	31	53	56
Desmodium incanum	24	26		
Desmodium triflorum	12	11		
Dichanthelium sp			23	16
Digitaria ciliaris			37	44
Diodia teres	29	25	21	34
Drymaria cordata			37	40
Dyschoriste oblongifolia			49	62

TABLE 10. Continued

Plant Species	Release Sites Frequency	Release Sites Cover	Settled Sites Frequency	Settled Sites Cover
Eremochloa ophiuroides			14	10
Erigeron strigosus			59	62
Eupatorium capillifolium			46	34
Euphorbiaceae			69	62
Eustachys petraea	36	35	15	25
Euthamia tenuifolia	12	10	18	27
Fimbristylis sp	16	19		
Froelichia floridana			17	36
Galactia elliottii	34	26	12	11
Galactia volubilis			59	62
Gnaphalium sp			69	62
Heterotheca subaxillaris	18	20	1	2
Hyptis mutabilis			28	15
Imperata cylindrica			28	13
Indigofera hirsuta	2	2	2	3
Kummeromia stricta	29	18		
Lactuca graminifolia			59	56
Lantana camara			30	21
Lespedeza sp	36	35		
Liatris chapmanii	29	26		
Linaria canadensis	36	35		
Lippia nodiflora			69	62
moss			69	62
Momordica charantia			55	56
Oenothera laciniata	36	35	37	40
Opuntia humifusa			42	48
Oxalis corniculata	36	35	26	55
Panicum hemitomon			35	47
Panicum repens	27	31	10	19
Paronychia baldwinii			49	56
Parthenocissus quinquefolia	19	23		
Paspalum notatum	1	1	3	1
Paspalum setaceum			33	54
Paspalum urvillei	23	21	46	31
Passiflora incarnata			16	14
Polypremum procumbens			25	29
Quercus geminata			59	50
Rhynchelytrum repens	19	23	4	6
Richardia brasiliensis	8	11	6	7
Richardia scabra			59	62
Rubus argutus			24	17

TABLE 10. Continued

Plant Species	Release Sites Frequency	Release Sites Cover	Settled Sites Frequency	Settled Sites Cover
Rubus cuneifolius			42	31
Rubus trivialis	6	5	42	37
Scoparia dulcis			69	62
Sesbania vesicaria			49	37
Setaria geniculata			46	40
Smilax bona-nox			26	27
Sporobolus indicus	3	3	5	5
Sporobolus junceus			59	62
Urena lobata			69	62
Vitis rotundifolia			20	17
Wahlenbergia marginata	36	35	55	56

Bare Ground:
Frequency - Present in all release and settled quadrats
Coverage - Release sites 9.6 m^2; Settled sites 49.5 m^2

Litter:
Frequency - Present in 100% release & 99.3% settled quadrats
Coverage - Release sites 183.6 m^2; Settled sites 103 m^2

Thirteen of the 43 species on the release site were not found on the settled sites including *Aristida stricta, Buchnera americana, Carex albalutesus, Cyperus brevifolia,* and an additional *Cyperus species, Desmodium incanum, Desmodium triflorum, Fimbristylis sp., Kummeromia stricta, Lespedeza repens, Liatris chapmanii, Linaria canadensis,* and *Parthenocissus quinquefolia.* The wiregrass, *A. stricta,* and the blazing star, *L. chapmanii,* had been planted in the rim of the release site as part of the study plot enhancement (Table 1).

Bare ground and litter occurred in all quadrats (80 of 80) and nearly every sample unit (2396 of 2400); however their prevalence varied. The release sites had one fifth of the bare ground of the settled sites by square meter, 9.6 m^2 as opposed to 49.5 m^2. Litter covered only 56% of the area in the settled sites that it did in the release sites. Both of these aspects of vegetative cover led to structural differences in the habitat. The release sites were more densely covered at surface level while the settled sites, with more sparse vegetation and larger areas of open ground, constituted more open habitats.

Success of Original Treatment Plot Plantings

Botanist's general observations from December 1991:

Most of the species were seen but the most persistent were wiregrass *(Aristida),* lopsided Indiangrass *(Sorghastrum secundum),* prickly pear *(Opuntia humifusa),* twinflower *(Dyschoriste oblongifolia),* and the pea vines *(Galactia, Rhynchosia, Tephrosia).* Species with small numbers planted were difficult to evaluate since planting was patchy and no plant monitoring was planned in the research. Yellow buttons *(Balduina angustifolia)* is a biennial and dependant on reseeding. Golden aster *(Pityopsis graminifolia)* and *Liatris spp.* seemed to not be as frequent relative to the percentages in which they were planted. Blazing star *(Liatris)* persisted the best in open areas. More plants persisted on T1, the unmined site which was higher and better drained than T2. In both plots where the soil was heavier with clays or wetter, there was a heavier weed cover and fewer plants persisting.

The major weed cover on T1 was on the eastern and southern side and was dominated by bahia grass *(Paspalum notatum),* hairy indigo *Indigofera hirsuta),* and bermuda grass *(Cynodon dactylon).* The weeds in sandier areas also tended to include Brazil pusley *(Richardia scabra)* and dogfennel *(Eupatorium* sp.). Other natives, ruderal and also seeded in, were broomsedge *(Andropogon sp.),* saltbush *(Baccharis halimifolia),* Elliott lovegrass *(Eragrostis elliottii),* pepper-vine *(Ampelopsis arborea),* rabbit-bells *(Crotalaria rotundifolia),* passion vine *(Passiflora incarnata),* blackberry *(Rubus sp.),* wax myrtle *(Myrica cerifera)* and flat-topped goldenrod *(Euthamia minor).*

Additional dominant weeds in T2 were Peruvian primrose *(Ludwigia peruviana),* various sedges, more broomsedge, soft rush *(Juncus effusus),* Caesar weed *(Urena lobata),* Johnsongrass *(Sorghum halepense),* and *Aeschynomene viscidula.* Both cogongrass and natal grass were rare on both plots.

Botanist's general observations from April 1996

In April 1996 a site visit was made to the northwestern part of T1, which is the sandiest, best drained portion of the planted areas. The wiregrass was vigorously growing and had bloomed the previous winter, even though the most recent burn was in 1992. Tough bahia grass had grown back into the plowed planted rim, the wiregrass was successfully outcompeting the bahia grass. Twinflower was present and spreading. Blazing star had seeded beyond the planted rim. The greatest spreader was the prickly pear, which was abundant even around 30m beyond the rim. The longleaf pine were declining, reportedly from the pine borer.

SOILS ANALYSIS

A precise history of reclamation and soil deposition at the Tenoroc study area is not known; however, a description of general operations was presented in the "Introduction."

The auger samples taken in July 1988 at seven potential study plot sites in the Tenoroc grassy field area indicated several plots had sandy soil to a depth of 1 to 1.75 meters, while some had approximately 0.3 meter of overburden above the sandy soil. However, it was later discovered that the clay content was much higher than originally indicated. The presence of clay in the granular soil was noted but not measured. The western half and ring of T1 and the northern portion of the C2 ring consisted of primarily sandy soils (T1 unmined with overburden, C2 sand tailings)

Soil penetrometer readings taken adjacent to the burrows occupied by the 40 study animals recaptured in 1991 and adjacent to the original starter burrows (1988 release sites) of these 40 recaptured tortoises, showed that at depths of 10, 20, 30, and 40 cm there were significant differences in release and settled site soil resistance at the 99% confidence interval. Soil penetration resistance was greater at the release sites than at the settled sites. The release site soils had greater clay content than the soils of the settled sites. Constraints in the sampling method led to a conservative statistical. analysis; the results would have been even more significant if actual readings had been obtainable in highly resistant soils. Simply put, the ground was so hard at deeper levels that it was not possible to obtain a complete penetrometer reading. The additional information would have emphasized the difference between the areas where the tortoises were released and the areas where the tortoises chose to settle.

Tortoises chose habitat where the soil resistance was in the 1.1 to 18.0 psi range at the surface (10 cm) over habitat where surface soil resistance ranged from 19.0 to 39.8 psi. After reaching a depth exceeding 40 cm and psi of 45, some overlap in the amount of soil resistance acceptable to the tortoises occurred. In many instances, once tortoises had begun burrows with low surface resistance, they would continue digging in soils with high resistance levels.

Each field season when surveys were conducted to find the locations of the gopher tortoise burrows, signs of digging into the soil mounds on the treatment plots were observed. Such diggings appeared to be aborted attempts to excavate burrows in sand that caved in before a burrow could be completed. Collapsed burrows were noted in areas of deep sand at T1 and in ST.

In 1989 tortoise diggings were found in an area adjacent to C1 that had been burned by a wildfire two months following the 1988 release of tortoises. Several holes one-third to one meter in length, but no completed burrows, were found in this area of hard clay soils.

REPRODUCTION

Data obtained from x-rays of translocated and resident females between mid-May and mid-June of each year are summarized in Tables 11A and 11B. At the time the Hernando County tortoises were first captured, 44% of the adult female population (n=27) were gravid. Resident tortoises were discovered and captured in September of 1988, thus no egg data exist for the residents for that year. The number of gravid females in the recaptured translocated population dropped in 1989 to 22% (n=2). The percent of gravid females in the resident population was 33% in 1989, the lowest percentage of gravid resident females during the four years reproduction data were obtained. The translocated females continued to exhibit an increase in percent gravid from 1990 through 1993, when the highest percentage (77%) was reached. The resident females have fluctuated from 75% to 60% during that same period.

Mean clutch size increased each year for both the translocated and resident females. Mean clutch size for translocated females went from 4.8 in 1988 to 9.9 in 1993. Mean clutch size for residents moved from 8.6 in 1989 to 12.6 in 1993. Although the mean clutch size was larger for the resident than for the translocated population every year, it was not a statistically significant difference. Clutch size ranged from 2 to 13 eggs in the translocated females and from 1 to 25 eggs in the residents. Six of the resident females had clutches containing over 13 eggs.

Table 11A. Gravid females and clutch size in translocated GTs.

	Gravid translocated females				
Year	# of gravid females	# With Eggs	% With Eggs	Mean clutch size	Clutch size range
1988	27	12	44%	4.8	2 - 8
1989	9	2	22%	6.5	6 - 7
1990	10	5	50%	7.4	6 - 9
1991	16	10	63%	7.8	4 - 13
1993	13	10	77%	9.9	2 - 13

Table 11B. Gravid females and clutch size in resident GTs.

	Gravid resident females				
Year	# of gravid females	# With Eggs	% With Eggs	Mean clutch size	Clutch size range
1988	6	-	-	-	-
1989	15	5	33%	8.6	1 - 12
1990	24	18	75%	10.3	1 - 20
1991	31	19	61%	11.5	4 - 25
1993	15	9	60%	12.6	5 - 22

Clutch size increased for all translocated females that showed eggs in more than one year of the study. Among the 15 resident females that showed eggs in more than one year, 7 increased clutch size, 4 decreased clutch size, 3 maintained the same clutch size, and one fluctuated. (Resident female GT 318, whose clutch size fluctuated from 20 eggs in 1990 to 25 eggs in 1991, and 19 eggs in 1993, had a CL of 293 mm and TL of 324 mm in 1991.)

The mean CL for gravid females was consistently higher, but within 1 cm, of the mean CL for the general population of adult females in both the translocated and resident populations. The smallest female with eggs was 234 mm in the translocated population and 228 mm among the residents. The translocated females had a smaller mean CL each year.

Further results of data obtained on tortoise reproduction and on egg viability for the translocated and resident populations at Tenoroc are examined in detail in the extended research project by Small and Macdonald (in press).

GROWTH

All size classes of translocated tortoises showed continued growth as determined by measurements of the shell, annuli and weight. Preliminary results indicated that many of the tortoises were exhibiting an accelerated rate of growth. The increase in growth rate appeared to be prevalent among subadults and young adults and is examined in detail in the extended study by Small and Macdonald (in press).

DISCUSSION

FINDINGS

Forty-one percent (n=48) of the 116 gopher tortoises moved from Hernando County, Florida in 1988 to reclaimed phosphate mined lands at Tenoroc Fish Management Area in Polk County were still in the area in 1991 and probably in 1993. Approximately 16% of the translocated animals remained at study plot release sites; however, the animals *were* non-randomly distributed. The animals settled into areas that had remained unmined or that had a cover of sand tailings. The tortoises totally vacated the habitat reclaimed to dense grassland (0% site fidelity) and primarily settled in the sand based, more vegetatively diverse and more sparsely covered portions of Treatment Plot One and Control Plot Two, along with the sand tailings area which overlapped with Control Plot Two. A major resident colony into which translocated tortoises immigrated, the planted pine area, also had a wider variety of plant species, but had approximately 75% pine canopy. There were few patches of bare ground but the vegetation was much sparser than the dense mat of the grassland.

Diemer Berish calculated that average site fidelity (defined as percent of relocated tortoises remaining on the recipient site a minimum of one year later) for relocation projects reported between 1991 and 1994 was 39% (1994). Interpretation of recipient site boundaries varied among projects. The 41% recovery rate of Tenoroc translocatees is comparable to the average relocation project; however, only 16% of the recovered animals were within the study plots where they were released and none were in the reclaimed pasture habitat type.

One paper exists for comparison to the Tenoroc reintroduction study. In 1985, Godley (1989) relocated 83 tortoises to a reclaimed sand tailings area planted in bahiagrass *(Paspalum notatum)* and used as pasture. Site treatments included placement of logs and brush piles, 5 x 5 m clearings scraped to provide burrowing and feeding sites. Tortoises were released into starter burrows at the scraped sites. Fences were temporarily placed around the release sites for a portion of the population. Only *2.4%* of the tortoises remained in the pasture; apparently[4] approximately 30% of the translocated tortoises were found within 0.5 km of the recipient area 2 years following release.

Despite habitat enhancement at the two treatment plots (whose cost approximated the amount paid by the developer into the habitat

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[4] Calculation based on Macdonald's interpretation of data in Godley's 1989 paper.

mitigation fund), including planting of tortoise forage species, creation of a more heterogeneous terrain, and excavation of starter burrows, the treatments were ineffective for maintaining a high level of site fidelity. There are indications that the site treatments influenced burrow site selection once an animal chose the general habitat for settlement. Tortoises burrowed in the planted rim at a greater frequency than would occur by chance. Tortoises may have selected burrowing sites in the rim due to the presence of bare ground rather than the presence of forage plants. However, most of the rim burrows were situated on the west side of treatment plot one which already had substantial coverage by open, sandy soil.

Tortoises attempted to burrow into the soil mounds: however, only one completed burrow in a soil mound was identified. As with several burrows in deep sand areas at the study site, the burrows caved in due to too low a clay content in the sand tailings soil used to create the soil mounds. In addition, compaction and the rooting of plants may be important factors in making these areas more suitable for gopher tortoises.

Results of soil analysis on two pools of data, one from the tortoises' starter burrow release sites and one from the tortoises' burrows at settled sites, showed that a significant difference exists between the areas with respect to soil resistance. Tortoises did not excavate burrows in soil that exceeded a resistance factor of 18.0 psi at the surface. It appears that once a depth of about 40 cm is reached the tortoises may continue digging even in higher resistance soils.

Soil resistance would be a major factor in habitat suitability for gopher tortoises because of the animals' dependance on their burrows. It could also be a factor in nest site selection as the tortoise buries its clutch of eggs, relying on soil to insulate the eggs during incubation. Dense, hard packed soils may be difficult for the adult female to dig through in order to create a chamber for her eggs and may be impossible for the hatchlings to dig back out of. Soil resistance is also a factor in soil porosity. The gopher tortoise will live in mesic conditions (Breininger, et al 1988) but it is foremost an animal of the porous xeric upland habitats.

Some clay content is necessary if sand tailings are to be used as the base of suitable gopher tortoise habitat. The structural strength and integrity of the arched burrows disintegrate in a nearly pure sandy substrate since such soils lack the adhesion capacity present with the addition of clays.

Vegetation analyses showed a significant difference between release and settled sites based on at least three factors. First, with respect to plant composition, the settled sites had 2.5 times the species of the typified release habitat. The sand tailings habitat included a variety of Asteraceae (asters), Fabaceae (legumes), Cyperaceae (sandspurs), Rubiaceae, and Poaceae (grasses). A very dense cover of grasses, primarily *Paspalum notatum* (Bahiagrass), resulted in a relatively homogeneous release site habitat.

The results of the planting of gopher tortoise forage species in the rims of the treatment plots indicates that many upland plant species may be successful if appropriate conditions and management are provided. The initial workpower required to grow, plant and to provide water if rains are not sufficient, can be extensive. In addition, site preparation and subsequent removal of undesired encroaching vegetation, would probably be necessary. In this study no supplemental water, nor any subsequent care (such as, removal of invasive grasses), was provided for the plants, although the area was burned in 1992, yet the plants in the well drained, sandy soils in the higher elevations *are* surviving.

Second, the structure of the release and settled sites differed significantly. The smaller tortoises experienced noticeable difficulty moving about in the dense grasses and litter of the pasture. It is possible that dense ground cover inhibits the initiation of burrow excavation. It has been speculated that it would not be beneficial for tortoises to bury clutches in areas of thick grass: onset of the rainy season soon after egg laying could lead to regrowth of the grasses over the egg chamber during the up to 100 days of incubation, making it nearly impossible for hatchlings to dig through to the surface.

With respect to egg production in 1989, the year following transfer to Tenoroc, the percentage of gravid females dropped by 50%. Resident females had their lowest percentage of gravid females in 1989 also. There are no 1988 baseline data for the resident population; therefore, it is unknown if the percentage differed from the following year. The initial percentage drop for translocated females might be interpreted as the result of transfer from their home site but it does not appear to have had a lasting effect. The percentage of gravid translocated females rose each subsequent year reaching a high of 77% in 1993. In addition, the number of eggs produced by each female increased or remained constant each year and the average clutch size for the translocatees rose from the original average of 4.8 in 1988 to 9.9 in 1993. The results would be consistent with an aging population as female gopher tortoises generally continue to increase their reproductive value with age and size.

CONCLUSIONS

As native habitat continues to be developed and altered, interest in wildlife use of the substantial acreage of reclaimed lands increases. The findings presented here and the findings of the extended study on relocated and resident tortoise reproduction and growth (Small and Macdonald, in press), indicate that while some forms of upland reclamation are unacceptable to gopher tortoises, phosphate mined lands can be suitable gopher tortoise reestablishment sites if appropriate reclamation methodology is implemented. Recommendations regarding reclamation are in the "Guidelines for the creation and enhancement of gopher tortoise *(Gopherus polyphemus)* habitat on phosphate mined lands" that is appended to this report. Suggestions for the most effective capture methods, data collection, and care during captivity of translocated tortoises have been presented throughout this report.

The reclaimed grasslands with primarily clay based soils at Tenoroc were rejected by gopher tortoises despite treatments to enhance the habitat and increase tortoise site fidelity. Many of the translocated tortoises moved to and stayed in the closest acceptable habitat to the release site[5] whether that was unmined uplands or sand tailings areas. Consistent with previous studies of gopher tortoise habitat and disturbed areas, relatively stable colonies emerged in areas of higher elevation with deep sand based soil, sparser yet more diverse vegetation at ground level, with patches of bare ground. The soil, the vegetation, and the structure of the habitat all appeared to be key factors in gopher tortoise habitat selection. Gopher tortoises may also select particular sites because a tortoise colony exists in the area, however, in the study this social factor could not be distinguished from other site characteristics.

Over the years the study expanded to include resident Tenoroc tortoises and colony sites up to 4 km away from the study plot release sites. Natural colonization of a previously uninhabited area in the north-central section of Tenoroc was monitored and by the final year of field work (1993) translocated or resident tortoises had been documented to have moved between and among all colony sites. A small core population has remained at Treatment Plot One which continues to experience immigration and emigration. Successful reproduction (hatchlings) by translocated females was documented in 1993.

Caution is urged with respect to generalizing the findings of this research to species other than the gopher tortoise. The gopher tortoise adapts more readily to disturbed situations than many other animals. It is recommended that projects to reclaim habitat and reintroduce tortoises be consistent with, and in fact, enhance restoration for the array of species and processes that are a part

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[5] Movement away from the study plot release sites appears to have been random. Thirty-four percent of the tortoises were recaptured within 118 degrees or 33% of the potential 360 degrees of compass headings. Observations recorded at the time of release of all 116 tortoises indicate random dispersal.

of the tortoises' native upland ecosystem. Gopher tortoises, themselves, may serve as agents of natural community restoration.

Examining and understanding the translocated tortoises in terms of habitat suitability, site fidelity, dispersal, and the effects of translocation on tortoise reproduction and growth was greatly aided by comparison with the resident Tenoroc gopher tortoise population and relatively longterm funding that carried the project through 6 years of field work.

Although it appears that public lands may afford the gopher tortoise adequate habitat for survival into the near future (Cox, et al 1994), there is a great deal of pressure for encroachment, fragmentation, and intensive uses of public lands. Furthermore, without proper monitoring and management, "...residence on 'protected' land cannot be assumed to assure the continued existence of a [gopher tortoise] population" according to studies on federally protected areas by McCoy and Mushinsky (1992). The contribution by private landowners to wildlife habitat protection by permanently designating conservation areas, by implementing best management and compatible land use practices, and by efforts to restore habitat are critical to the preservation of Florida's biological diversity. The results of this research indicate that not only will areas of unmined lands be of importance to gopher tortoise survival, but that tortoises can be successfully reestablished on reclaimed phosphate land if the foundation for suitable habitat - the soils, vegetation, and structure - are reestablished first. Reclaimed phosphate lands have the potential to play an important role in the conservation of gopher tortoises.

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APPENDICES

APPENDIX 1. Gopher Tortoise Data Sheet

GOPHER TORTOISE DATA SHEET

#	DATE COLLECTED	BURROW	AREA	SEX	AGE	WEIGHT	TOTAL LENGTH	CARAPACE LENGTH	PLASTRON LENGTH	GULAR LENGTH	BODY WIDTH	BODY THICKNESS	PLASTRAL CONCAVITY	ANAL WIDTH	ANAL NOTCH	ANAL THICKNESS	BLOOD SAMPLE	X-RAY	RELEASE DATE	COMMENTS

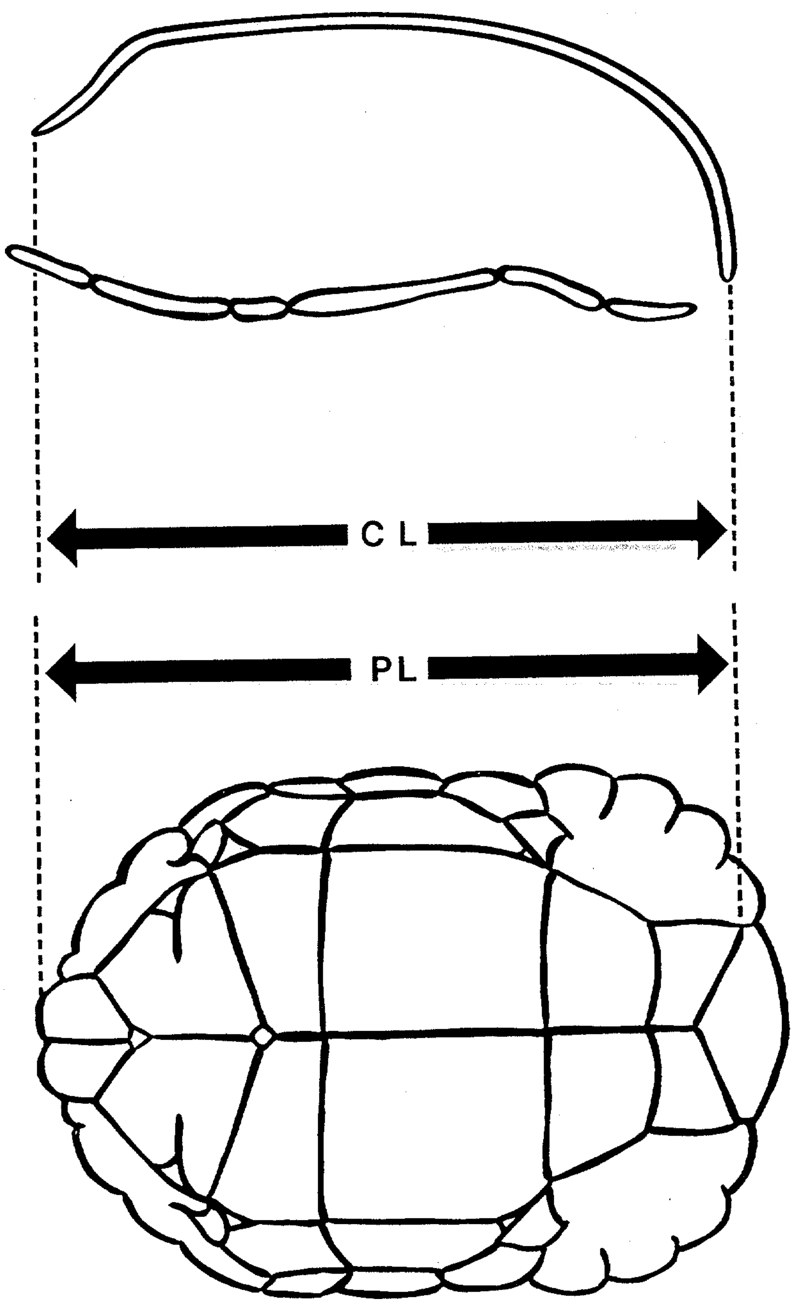
SHEET
OF

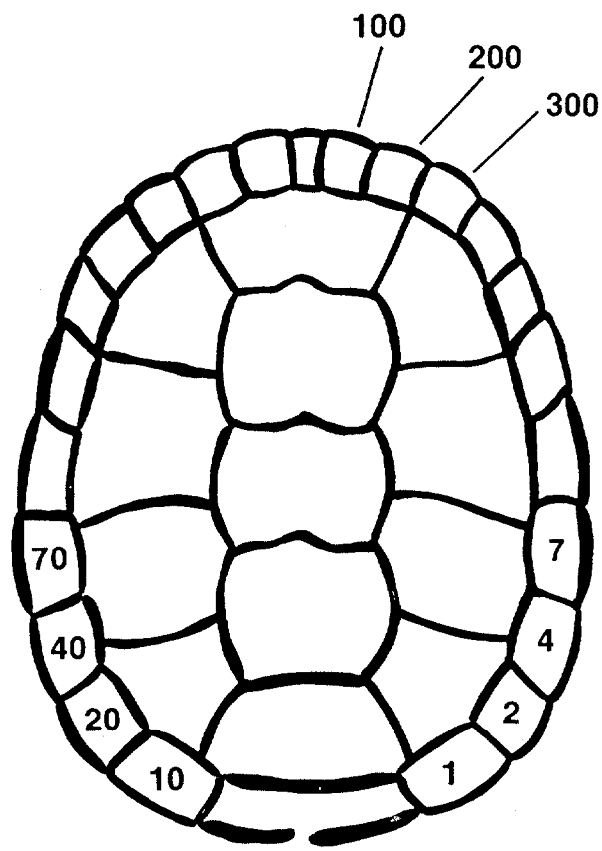
APPENDIX 2. Gopher Tortoise Standard Marking Technique (From Diemer, et al. 1989. Nongame Wildlife Program Technical Report #5)

Marking and Measuring Relocated Gopher Tortoises

Marking: Tortoises are to be marked by notching or drilling holes in one or a combination of the eight rearmost scutes - the four right ones and the four left ones - and the three right-front ones. Each scute is assigned a numerical value per the scheme devised by Cagle (1939), as illustrated below. The scheme is additive; e.g. tortoise #5 would require the drilling or notching of the first and third scutes right of the rear marginal, tortoise #14 the first scute left of the rear marginal and the third scute right of the rear marginal, etc.

Measuring: Straight-line carapace length (CL) and plastron length (PL) should be recorded in millimeters (see below). Forestry tree callipers are useful in making those measurements.





CARAPACE (Upper Shell)

APPENDIX 3

GUIDELINES FOR THE CREATION AND ENHANCEMENT OF GOPHER TORTOISE (*Gopherus polyphemus*) HABITAT ON PHOSPHATE MINED LANDS

by

J. L. Callahan, L. A. Macdonald, J. E. Berish

May 1996

GUIDELINES FOR THE CREATION AND ENHANCEMENT OF GOPHER TORTOISE (Gopherus polyphemus) HABITAT ON PHOSPHATE MINED LANDS

J.L. Callahan[1], L.A. Macdonald[2], J.E. Berish[3]

I. INTRODUCTION

Due to the loss of native Florida upland habitat to phosphate mining and mining operations, there is a high level of interest in the use and suitability of reclaimed phosphate lands as gopher tortoise (GT) reintroduction sites. Industry personnel and natural resource managers are interested in maximizing the survival and viability of the translocated GT populations; however, there is still much to learn about this process. The following guidelines are geared primarily to central Florida phosphate lands and those instances where mining or mining operations were about to occur and translocation was determined to be the appropriate choice. These guidelines were compiled from a variety of studies, publications, experiences and observations in the field, and discussions with several persons involved in gopher tortoise research and relocation.

Translocation of gopher tortoises can involve stocking or restocking GTs into existing colonies that are below carrying capacity as well as introducing or reintroducing GTs into areas where they currently do not exist due to extirpation or habitat change. The first consideration with respect to tortoise translocation is to determine if translocation is an appropriate choice with respect to the conservation of GT populations, their habitat and thus, the tortoises' native community.

The conservation of biological diversity through ecological restoration is a complex and evolving science. Hopefully, the recommendations in this paper will prove to be successful strategies for providing suitable habitat, not only for the relatively adaptable gopher tortoise, but for other members of the tortoises' upland community as well. Continued research and experimentation, monitoring, and sharing of project results are necessary for the improvement of our resource conservation and management capabilities.

II. GENERAL CONSIDERATIONS FOR TRANSLOCATIONS

The Florida Game and Fresh Water Fish Commission (FGFWFC) must be contacted for permits to translocate GTs prior to any handling of tortoises or disturbance of burrows. This agency will also be able to provide pertinent guidelines, such as those in Cox et al. (1987) and Diemer et al. (1989). Detailed translocation plans should be submitted to the Florida Department of Environmental Protection (FDEP) for review in conjunction with the conceptual plan applications and notices to initiate a major disturbance.

When GTs occur in an area to be mined or cleared for mining, an approved burrow survey based on information provided in Diemer et al. (1989) and Cox et al. (1987) should be conducted to estimate the number of GTs present. A tortoise population estimate, based on these burrow surveys, will be needed at both the donor and recipient sites.

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[1] Cargill Fertilizer, Inc., 3900 Peeples Rd., Ft. Meade, FL 33841, 941-285-8125
[2] 103 Wildwood Lane, St. Petersburg, Florida 33705, 813-821-9585
[3] Florida Game and Fresh Water Fish Comm., 4005 South Main St., Gainesville, FL 32601

The habitat quality of the recipient site should be determined using approved methods described in the literature. The FGFWFC is currently recommending the stocking of no more than 5 GTs per hectare of suitable habitat. A burrow:tortoise conversion factor, using approved methodology available in the literature, should be determined for the particular area if there is any doubt as to the accuracy of the standard 0.614 conversion factor (see Cox et al., 1987; Berish, unpublished data).

Recipient sites, which can be located on natural or reclaimed lands, should (1) have sufficient habitat to sustain viable GT populations, (2) be reasonably protected in perpetuity from human disturbances, and (3) not already have GT populations at or near carrying capacity. Greater consideration should be given to those areas from which GTs have been extirpated and for which the potential for recolonization is low due to barriers or distance from other GT colonies. It is preferable to preserve adequate. areas of suitable GT habitat rather than mine and translocate GTs. It is also better to keep relocated populations as intact as possible and to minimize disruption of resident populations when relocating GTs into areas that are already occupied. Examination of the two GT populations should be made to ensure the absence of URTD (Upper Respiratory Tract Disease) in both prior to any relocation effort.

No clearing or other preparatory work should occur within 15 meters of the burrows until after the GTs have been relocated, since GTs are attracted to disturbed, early successional lands and any clearing, disking, or other earthmoving activities near the GT burrows may result in the GTs burrowing in the recently cleared areas. Clearing too far in advance of mining will require resurveying to ensure that no new burrows have been dug. In addition, the extra effort required by the heavy equipment operators to clear immediately adjacent to the burrows without destroying them renders this action inefficient. Therefore, clearing and mining of donor sites should occur as soon as possible after the GTs are removed to the recipient site to prevent ingress of other GTs into the donor area.

After the GTs have been removed to the recipient site, the topsoil from the donor site should be collected and used on reclamation areas as a cap at least 30 centimeters deep over sand tailings or overburden to create similar habitats and possible future GT recipient areas. Translocation efforts involving a reclaimed mine area have a much better chance of success if the recipient site vegetation has been allowed to establish itself first.

GT translocation projects should be consistent with maintenance and/or restoration of native biological diversity. That is, activities undertaken to transfer and/or restore the tortoises should be compatible with and preferably enhance the reestablishment of other components of the native ecosystem. The tortoise itself will be providing habitat with the excavation of its burrow and dispersal of seed as it forages.

III. GOPHER TORTOISES AND TRANSLOCATIONS

A population of approximately 40 to 50 individuals (depending on sex ratio and size structure of the GT population and the quality of the recipient site) is generally the minimum number that should be established on uninhabited recipient sites. Larger populations of GTs moved to larger sites with extensive GT habitat, even under less than ideal conditions, have better long- term survival potential. Populations of less than 40 to 50 GTs require high-quality, intensively managed habitat to have reasonable long-term survival prospects. It should be determined if other tortoises in the vicinity of the project have been relocated and if so, whether these tortoises can utilize that same recipient site.

It is not advisable to mix several populations of GTs on one recipient site. Information on the incidence of tortoise Upper Respiratory Tract Disease (URTD) indicates URTD occurs more frequently in mixed, relocated tortoise populations than in other populations. At this time, testing for URTD prior to GT translocation is not required; however, it is recommended. The test should be performed on approximately 10 percent or at least 5 individuals from the population to be translocated, as well as on the resident population, if present on the recipient area. If the resident population shows no sign of exposure while the population to be relocated does, or the opposite situation exists, it would not be prudent to combine the populations as URTD is a highly communicable and potentially lethal disease.

It is estimated that typical female GTs can produce a successful clutch only once every 10 years and predation on the eggs and hatchlings can eliminate approximately 94 percent of the young. Most nests are lost to predation within the first week following egg deposition. Protection of translocated nests may minimize predation. Enclosing clutches to a depth of approximately 45 centimeters with a wire mesh screen cover large enough to allow hatchlings to emerge will prevent access to predators. Hatchling GTs display opportunistic sheltering by utilizing leaf litter, fallen branches, depressions shielded by live and dead vegetation, or other cover. Maintaining or creating these habitat features for hatchlings may help increase their survival, Control of known GT predators, such as raccoons or armadillos, is also an important and effective means of increasing the survival of young GTs.

Relocating GTs to a new area does not insure that they will remain on the site, because movements of individual GTs vary considerably. Although more research is needed on tortoise response to translocations, the following manipulations of GTs and their habitats have been partially successful in increasing site fidelity. GT manipulations include: (1) temporary penning; (2) relocating females first and then relocating males; (3) relocating twice as many GTs as desired, assuming that a certain percentage will emigrate; (4) relocating equal numbers of females and males; and, (5) retaining colony integrity by releasing groups of GTs originally captured near one another. Habitat manipulations include: (1) prescribed burning; (2) mechanical selective clearing of understory or canopy layers; (3) seeding and planting with GT forage species; (4) creating low mounds, berms, and brush piles; and, (5) providing starter burrows. Note that while GTs are relatively adaptable animals, these treatments will not suffice if overall the habitat is unsuitable.

Daily feeding ranges for adult GTs are usually less than 50 meters from the burrow, generally in a circular or elliptical pattern (unless roads or food strips are near the burrows). The size of the feeding range differs throughout the year with the increasing/decreasing presence of food species. Adult males searching for mates, adult females searching for suitable nest sites, and subadult males dispersing from a colony may move hundreds or thousands of meters. In good habitat, most annual movements of the colony group (e.g., 10 adults) occur in an area less than 4 hectares (10 acres).

Frequent burrow exchange and maximum male movements occur in the spring (during mating season) and late summer. Fall migrations to winter burrows are undertaken by some adults in some areas. Thus, late summer/early fall translocations may incur a higher rate of post-translocation dispersal. Translocations in the cooler winter months would probably result in less dispersal because the tortoises experience an over-wintering season of reduced activity, cessation of mating forays, and reduced foraging needs. GT relocation permits are not issued during the winter months for north Florida because of the potential danger to GTs from exposure and hypothermia. In south central and south Florida the risk is usually not as great and translocations are possible during the winter season, preferably during periods in which daytime temperatures reach at least 70 degrees Fahrenheit for several days. Special precautions should be taken during extremes of temperature, either high or low. The preferred season for surveying is generally the non-winter months unless cameras used in the burrows are the main survey technique for ascertaining presence or absence of GTs within the burrows. Inactivity and litter fall can mask the presence of a tortoise inside a burrow during the winter.

If any commensals are collected during the GT translocation efforts, they should be transferred along with the GTs. Commensals may be collected by setting funnel traps at the active, inactive, and abandoned GT burrows approximately 1 to 2 hours before sunset and collecting the individuals 1 to 2 hours after sunrise. The creation of starter burrows on the recipient site could be beneficial for commensals. Including ephemeral or permanent wetlands near GT habitats would provide habitat necessary to many GT commensals, such as breeding sites for gopher frogs *(Rana capito)* and foraging areas for indigo snakes *(Drymarchon corais).*

IV. SITE ENHANCEMENTS FOR RECLAMATION AREAS

The best efforts at reclaiming mined lands for GT translocations may include: using a layer of sand or sandy overburden from 3 to 7 meters deep (the minimum depth of a gopher tortoise burrow) with a suitable soil cover; making the area as elevated as possible; creating gently mounded, rolling, ridged or bermed topography; planting or seeding pines and oaks and as much wiregrass, wide-blade grasses, legumes, asters, and a diversity of fruiting plants as feasible. These efforts are an attempt to mimic the natural conditions preferred by GTs: well-drained sandy soils; soil density conducive to burrowing; abundant, diverse herbaceous ground cover, with a generally open canopy and sparse shrub layer so that sunlit nesting and burrowing sites are available; and ground cover that is not so dense as to impede movement. The preserved or reclaimed recipient area should have a buffer constructed or preserved around it to reduce adverse impacts. The buffer may not be suitable GT habitat itself, but should consist of land use(s) that afford some degree of protection to the GT colony and in addition, may serve as habitat through which dispersing GTs can move relatively safely.

Soils

At the surface, soil should be of such a density and depth as to afford suitable digging sites for GTs. Soil penetration resistance at the surface should not exceed 18.0 pounds per square inch. At a depth of 40 centimeters it appears that tortoises will continue burrow excavation in soils of greater resistance. Some clay and organic content is necessary for soil adhesion as pure sands result in unstable conditions and collapsed burrows. Using topsoil from an appropriate habitat in the reclamation of a mined area may introduce a portion of the seed bank and the root material needed for vegetative growth. Sand tailings without topsoiling is better than no sand tailings.

In mine cuts, the overburden should be (1) pushed into the cuts, with sand tailings added to the design level (rather than filling the cuts with sand tailings and topping with overburden) and preferably capped with topsoil from a habitat similar to the type being reclaimed, or (2) left as is, with the overburden in spoils and the sand tailings placed in the cuts between piles and then capped with an appropriate topsoil. Any excess overburden can be transported to other reclamation areas for use there. Past reclamation practices in a particular locale may not reflect conditions as they currently exist at the site (e.g., a lower sand content than expected may exist after years of weathering); therefore, soils should be tested to assure suitable conditions are present.

In dewatered clay settling areas with excellent drainage, sand tailings should be put to a depth of 3 to 7 meters on top of the clays and then capped with topsoil, if available and appropriate for that type of reclaimed habitat.

Burrow depth and placement are a function of many factors including GT behavior, soil type, soil resistance, ground water levels, hardpan depth, proximity to foraging areas and to other tortoise burrows, and other environmental conditions. Tortoises may well cue on other factors of which we are unaware.

Berms, ridges, and soil mounds that are created as potential burrowing sites should be constructed in such a manner and far enough in advance of the release of tortoises that these areas are stabilized through an appropriate degree of compaction and revegetation. Soils used in the creation of these habitat features must consist of a mix of primarily sand and a smaller amount of clay to prevent high soil resistance but provide adequate soil adhesion to hold the burrow structure.

The burrow is a critical aspect of tortoise survival, providing stable temperature and humidity, safe shelter, a possible nesting site, winter sunning site, and refuge from disturbances such as fire. In addition, burrows excavated by GTs may become habitat for other upland species. Although GTs have been observed using flooded burrows in somewhat poorly drained soils, especially in the winter, this is not the typical situation. GTs are generally found in areas with well-drained, sandy soils and their burrows frequently extend to the water table or to a depth of at least 3 meters. Unless GTs being translocated are from a mesophytic habitat, GT recipient sites should be xerophytic uplands.

Site Structure

Similarity between the donor and recipient sites may be important. Unless future studies of tortoise physiology, behavior, or ecology suggest otherwise, an attempt should be made to assure recipient sites are similar in composition and structure to the donor sites. For example, GTs from areas with dense, shrubby vegetation such as saw palmettos or scrub oaks should be relocated to habitats with similar appearance, while GTs from open areas should be relocated to rangelands, native prairies, or other similar habitats.

Reclaimed recipient sites should be created in circular, rectangular or oval shapes, at a minimum size of 10 hectares (25 acres). GTs relocated to narrow, linear areas have a greater tendency to emigrate, although GTs are found in linear configurations along certain land features, such as ridges, forest edges, and roadways. A linear preserve may be acceptable if the site is wide enough to provide adequate foraging area. The recipient site should have a buffer zone of a low- or non-human use area (such as a golf course or forested greenbelt) surrounding it to reduce human impacts on the recipient area. The appropriate width of linear habitat and buffers will be dependent upon surrounding land uses.

Larger recipient sites are preferred, but smaller ones are better than none. Connections can be made between the smaller sites with corridors of sufficient size and quality to permit the movement of GTs between the areas, while offsetting the problems of linear habitats. Small populations of GTs on small areas may be important because of their genetic composition, but these areas will require intensive management. To avoid the loss over time of genetic diversity in an isolated population, it may become necessary to periodically introduce individuals from other populations, but only after taking precautions to avoid the introduction of problems such as the spread of Upper Respiratory Tract Disease.

Fragmenting the habitat by creating roads, ditches, pipelines, rights-of-way, etc. should be avoided or reduced whenever possible. Although these man-made features may attract GTs, they increase the potential for GT mortality and degradation of the ecological system.

Security from human interference needs to be provided for the tortoises, Recipient sites should not be placed in areas of such intensive human use that tortoises would be vulnerable to problems such as harassment or collection. Locations of recipient sites should not be publicized.

Vegetation

GTs naturally occur in many Florida habitats; the types most commonly used in interior central Florida include sandhills, scrubs, flatwoods, upland hammocks and ruderal (or disturbed) habitats. Tortoise densities are highest in grassy, open canopy associations. Numerous plants are eaten by GTs and can consequently be used in revegetating recipient sites.

GTs are "habitual feeders", usually pruning and grazing along the same paths and in the same selected areas. While GTs exhibit some selective foraging and food differences occur between young and adults, they are generally opportunistic, feeding on a wide array of the herbs, grasses, and low shrubby vegetation available in their habitat, including:

Poaceae: *Andropogon, Aristida, Dicanthelium, Paspalum, Panicum, Sorghastrum, Sporobolus;*
Asteraceae: numerous genera, including *Pityopsis;*
Fabaceae: numerous genera, including *Galactia, Tephrosia, Schrankia, Clitoria;*
Pinaceae: *Pinus (palustris, elliottii,* and/or *clausa);*
Fagaceae: *Quercus (laevis, incana, virginiana, pumila, minima, geminata, laurifolia, myrtifolia, chapmanii,* and/or *inopina);* and,
Rubiaceae: *Diodia, Hedyotis, Richardia.*

Other plants consumed less frequently, but which are often used in reclamation projects and are generally available at local nurseries, include: *Vaccinium, Cyperus, Rubus, Licania, Opuntia, Serenoa repens, Liatris, Lyonia ferruginea, Cyperus* spp,, *Asimina,* and *Cnidoscolus.*

Exotics, such as many of the pasture grasses, cogongrass, and hairy indigo, are consumed by GTs, but their value in the GT diet has not yet been determined. More importantly, many exotics can outcompete native vegetation, causing problems in the restoration and maintenance of suitable habitat and natural systems.

GT densities are highest where the herbaceous cover is highest; grasses, grass-like plants, and legumes are the most important forage plants for GTs. Ground cover density ranging from 60 to 80 percent is preferred.

GT densities are lower when the shrub cover, shrub height, and/or canopy cover is high. Widely spaced trees are more beneficial to GTs than dense stands. The densest GT populations occur when the tree cover is 60 percent or less. Longleaf pines are better than slash or sand pines since they more easily carry the fires needed to maintain good GT habitat. Well spaced pines of any type, together with the proper burning frequency and seasonality, are beneficial to GTs. Limiting the midstory scrub oaks is also important in maintaining open, sunlit areas.

GT densities are often higher in disturbed areas, probably due to an increase in food availability. Because GTs also prefer ecotones, reclaiming sites so that several habitat types are created in an area will benefit relocated GTs and other wildlife. Areas with sparse cover or bare ground also need to be incorporated into reclaimed GT habitat.

V. MANAGEMENT AND RESEARCH

A management plan should be developed, funded, and implemented for each site. A reclaimed or preserved area that has been set aside as GT habitat should be maintained in perpetuity to eliminate the highly disruptive influences caused by successive translocations of the same GTs. These benefits will extend to burrow commensals and other wildlife.

Fires are a natural and necessary occurrence in many of Florida's native communities, but wildfires and even prescribed burns can have unpredictable and adverse effects on reclaimed as well as natural areas containing GTs. Burning of disturbed sites should be considered experimental and undertaken cautiously. Be aware that it may not be advisable under some site conditions (e.g., causes proliferation of cogongrass). Documenting the pre- and post-burn conditions and monitoring the effects over time will add greatly to our expertise in land management and restoration.

As a rule, a fill fire prescription needs to be developed for each local situation and used as a guideline for burning natural habitats or well-established reclamation areas. Burning frequency for a recipient site is based on habitat and many other factors such as burn history and fuel load. However, growing season burns (which may be from March through September) are generally the most beneficial because they promote flowering and growth of a diversity of species, remove litter, thin dense scrub oak stands, and create open areas for burrows and nests. Natural fires, especially in sandhills, create mosaics of open habitat rather than uniformly destroy the entire area; this is the same goal in burning a reclaimed area. Fire periodicity also influences both herpetological species diversity and abundance.

If an area has not been burned for many years, cool growing season burns (at night or after rains) or dormant season fires should be used initially, followed by growing season fires simulating natural fire regimens. The natural fire frequency in native sandhill sites is every 1 to 7 years with burns typically occurring in the growing season. Depending upon the type of pine flatwoods, the habitat may have experienced a fire frequency of 1 to 7 years; in scrubby flatwoods, the burn frequency may be as long as 25 years. If growing season burns are not possible in an area, dormant season burns and/or mechanical control methods will be necessary. In older stands of created pine forests (plantations), burning needs to be frequent enough to keep the fuel load down and avoid damaging trees due to overly intensive fires. Burn times should be rotated on small patches in the GT habitat at the frequency which will produce the most benefits for GTs and other wildlife by creating a natural mosaic.

Periodic disturbances, either from fire, mowing, disking, chopping, thinning, etc., are important in maintaining open conditions. Chemical control of nuisance vegetation with herbicides is not recommended because of the possibility of injury to tortoises and other wildlife, although it has been used safely during habitat reclamation prior to GT release. The use of other pesticides in GT habitat is also not recommended and such substances should not be used when tortoises are on the site.

Management practices that may increase the habitability for GTs of an established reclamation area include: (1) leaving or creating brushpiles in the reclamation site, especially if the GTs have been moved from an area with a fairly dense shrub layer; (2) creating small berms, ripping the soil to create open areas, or otherwise mechanically disturbing the soil surface; (3) mowing strips or small sections of the reclamation site; (4) thinning the tree canopy and midstory (especially oaks) when necessary; (5) encouraging proper burning regimen by planting fire tolerant pines, such as longleaf pine, and ground cover, such as wiregrass, to help carry the fire; and, (6) minimizing intensive site preparation techniques such as shearing, windrowing, root raking, or bedding, because GT response to these methods is variable and the health of the GT population cannot be guaranteed. Large scale clearcutting, intensive site preparation, and closed canopy plantation management may negatively affect GTs, but selective cutting and prescribed burning are generally beneficial.

Measures taken to enhance habitat for GTs should be compatible with and preferably enhance the value for other native wildlife. It is not necessary nor desirable to create "single species, GT only" habitat. Managed rangeland and forestry practices can be compatible with and beneficial to GTs and "mixed use" lands can be suitable GT habitat.

Research and experimentation in GT habitat reclamation and translocation efforts should be encouraged. Post-translocation monitoring (with aerial or ground observation of burrow distribution, recaptures, etc.) and reporting are necessary to determine the success of the translocation and to collect information that may be useful in future translocations. Attempting to artificially establish or reestablish gopher tortoises in an area involves creating the soils, hydrology, vegetative cover, fauna., and ecological processes that are conducive to the presence of GTs. While much has been learned, there is still much to learn about the factors involved in a successful translocation effort of GTs. It is possible that the gopher tortoise itself may be an agent of change and restoration in Florida's upland communities and further research into the biology, behavior, and autoecology of the gopher tortoise and the creation and management of upland habitats is strongly encouraged.

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