Restoration of the Bolson tortoise in the northern portion of its prehistoric range in the southwestern U.S.A.

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Introduction

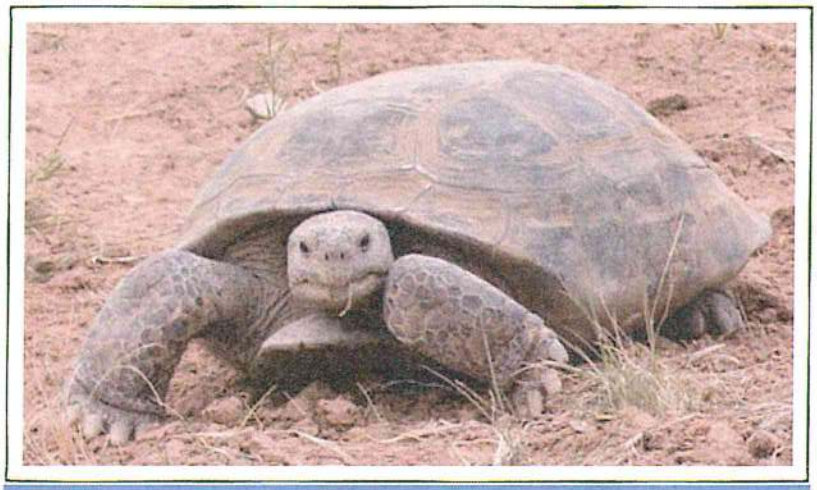
The Bolson tortoise (*Gopherus flavomarginatus*) is the largest and rarest of five species of land tortoise native to North America. Prehistorically, its range extended throughout the Chihuahuan desert, from west Texas to southwestern Arizona and Oklahoma to Aguascalientes, Mexico (Morafka, 1982). Its current range is restricted to discontinuous basins ("Bolsons") in the Mapimi sub-province of north-central Mexico. The species is listed as "Endangered" in the US and Mexico, and it appears on CITES Appendix I. It was listed as "Endangered" on the IUCN Red List in 1982, but was down-listed to "Vulnerable" in 1996 because the previous steep population decline had slowed. There remains considerable uncertainty about the size of the extant wild population. It may consist of fewer than 2,000 individuals. The Bolson tortoise restoration effort on Ted Turner's Armendaris and Ladder Ranches in the species' prehistoric range in southern New Mexico began in 2006 with the acquisition of a private collection of 30 adults. This original group has produced over 500 new hatchlings to date. The captive population will be used to establish two or more wild populations on private and public lands in the northern portion of the species' prehistoric range.

Goals

- Goal 1: Generate large numbers of new Bolson tortoises that can be used to populate two or more assurance colonies on private and public lands.
- Goal 2: Protect the young tortoises from predation until they reach predator-resistant size.
- Goal 3: Release predator-resistant juvenile tortoises to establish new wild populations.
- Goal 4: Monitor released tortoises to ensure adequate survival, growth, and reproduction.

Success Indicators

- Indicator 1: To establish a robust breeding program to produce large numbers of genetically diverse juvenile tortoises during early stages of the project.
- Indicator 2: Find evidence for normal growth and behavior (burrow use, mating, foraging, brumation, estivation, etc.), and sexual maturation of juvenile tortoises (egg production by females of reproductive size and age).



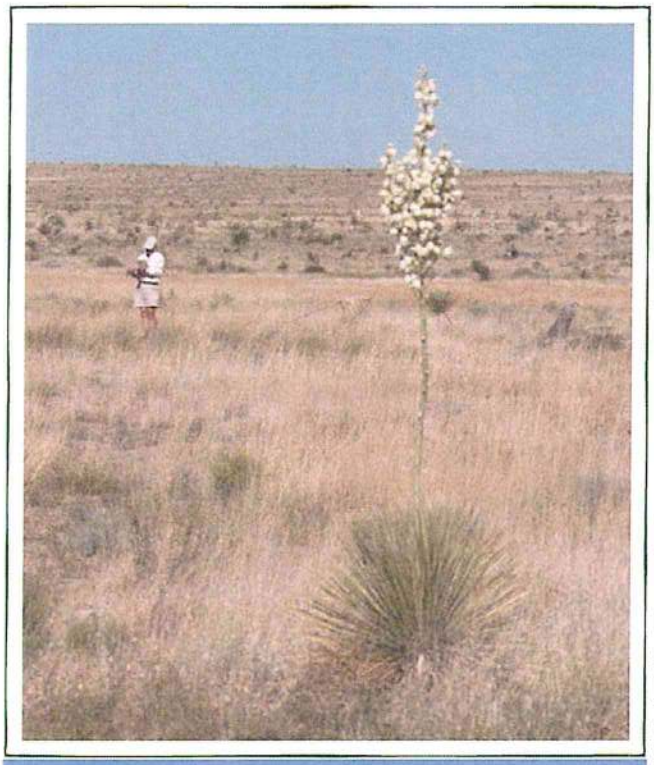
Bolson tortoise

- Indicator 3: Successfully release large juveniles into suitable habitat and observe high survivorship of released tortoises.
- Indicator 4: Find evidence of successful breeding in the restored population, including a documented presence of hatchlings and juveniles.
- Indicator 5: Document new adults, including gravid females that are not from the initial released population, showing that tortoises hatched from natural nests and matured to adulthood. Find evidence for a population structure that consists of all age and size classes.

Project Summary

Feasibility: Fossil records establish the presence of large chelonians in the northern Chihuahuan desert as recently as 12,000 years ago. Their disappearance from this range coincides with human arrival (Zylstra, 2007). Another steep decline in Bolson tortoise numbers during the middle of the 20th century was caused by collection for food, and by habitat degradation (Bury *et al.*, 1988). Today, the only extant wild population is subdivided into clusters within isolated basins in the Bolson de Mapimi, comprising ~6,000 km^2 in north-central Mexico where the provinces of Coahuila, Durango, and Chihuahua meet (Bury *et al.*, 1988). One sub-population is protected within the Mapimi Biosphere Reserve (established in the mid-1970s), but protection for the other subpopulations is minimal or non-existent. Consequently, these sub-populations may be mostly extirpated today (van Dijk & Flores-Villela, 2007). In their current range, the Bolson tortoise continues to be threatened by habitat degradation due to human activities, and by collection for consumption. In 1989, the total tortoise population was estimated at 7,000 - 10,000 (Bury *et al.*, 1988), but the Instituto de Ecologia more recently estimated numbers to be as low as 1,600. Conservation efforts have been stifled by political unrest, cultural concerns, and dangerous conditions where the tortoises live.

Concerned over the species' long-term survival, the Turner Endangered Species Fund (TESF) and its partners initiated a recovery effort (Truett & Phillips, 2009) based on captive-breeding programs located at the Armendaris and Ladder Ranches, and at the Living Desert Zoo and Gardens State Park (LDZG) in Carlsbad, NM and the El Paso Zoo in El Paso, Texas, USA. Breeding programs at all locations are coordinated under the Bolson Tortoise Recovery Project



Bolson tortoise habitat

(BTRP), overseen by TESF. The goal of captive-breeding is to create a source of individuals to establish wild populations in the species' pre-historic range on private and public lands in the US (Truett & Phillips, 2009). Initial research to understand whether Bolson tortoises can thrive in northern Chihuahuan ecosystems has been taking place on both ranches. A robust breeding program has resulted in an expanding population of over 400 juveniles up to 8 years old.

Implementation:

Captive breeding and husbandry: The adult breeding colony on the Armendaris Ranch is housed in a large (~16.5 acre) enclosure surrounded by a 0.61 m perimeter fence that is designed to keep tortoises from leaving but does not protect them from predators. Their diet consists entirely of native forage plants within the enclosure. Regular monitoring and twice-yearly health evaluations since 2006 provide evidence that adult Bolson tortoises can thrive in New Mexico. Moreover, reproduction has been robust with females producing up to three clutches of eggs annually. Thus, we feel that re-introducing Bolson tortoises is a valid approach for restoring a viable population in the species' prehistoric range. To ensure a high degree of hatching success, we chose to place eggs in temperature-controlled incubators. Upon emergence from the egg and yolk-sac absorption, hatchlings are placed in outdoor predator-proof enclosures. We occasionally supplement hatchling diet with fast growing, non-native forbs and grasses (e.g. clover and Bermuda grass), but prefer to raise tortoises mainly on native forage (e.g. globe mallow). In 2013, we began keeping hatchlings "up" during their first winter to encourage robust growth during their first year (resulting in less time in pre-release enclosures). They are returned to outdoor enclosures as soon as spring weather allows.

Pre-release conditioning: Juveniles are housed in outdoor enclosures with native vegetation until they are large enough for release. We provide starter burrows, but tortoises also dig their own. The large outdoor space allows young tortoises to build muscle strength through foraging, dispersing, and building burrows, and allows them to find the best food sources and micro-environments. Moreover, juveniles learn to respond and adjust to daily and seasonal thermal changes.

Release: We began releasing juveniles that were large enough to resist most predator attacks (~110 mm shell length) into the predator-accessible adult enclosures in the fall of 2012. To date (fall of 2014), we have released a total of 87 juveniles. Each one carries a transmitter that allows us to locate them, study their behavior, monitor growth, and assess survival. Once we obtain the proper state and federal permits, we will release juveniles to unfenced ranch locations as well.

Post-release monitoring: This consists of regularly locating each tortoise by telemetry. Monitoring frequency decreases as tortoises settle in, and during winter brumation. As of the fall of 2014, 75 of 87 released juvenile tortoises were known to be alive (>75% survivorship). In general, juveniles settled within 100 m of their initial release site, suggesting that perimeter fencing may not be necessary. Most juvenile tortoises either dug burrows or modified existing rodent burrows. The cause of death for 11 juveniles that died following their release varied from probable kills by coyotes to other natural causes.

Major difficulties faced

- Bolson tortoises grow very slowly, requiring protection in predator-proof enclosures for up to 7 years or more; the time to release can be shortened by intense management during the first year or two of the tortoise's life, but the (potentially negative) long-term effects of this management are not yet known.
- Releasing tortoises from predator-proof enclosures to predator-accessible sites not only exposes tortoises to predators, but also to perils of translocation. Thus, it is important to provision tortoises well while they are still inside the head-start enclosures.
- Ensuring good tortoise growth rates (>10% shell length per year) requires intensive forage plant management inside head-start enclosures. During good years, this might mean daily harvest and delivery of wild-grown forage plants. In drought years, this might mean growing forage plants in a greenhouse and providing regular waterings inside head-starting enclosures. Both strategies can be labor intensive.
- Predators, such as coyotes and ravens, are abundant and will prey on tortoises once they are released outside of the predator-proof enclosures.
- Adequate monitoring of released populations is a long-term effort that requires long-term stable financial support.

Bolson tortoise hatchling

- The final success of the project cannot be assessed until the first generation of wild-born tortoises begin to reproduce, which may take 40 years or more from the initiation of the project.

Major lessons learned

- Projects involving slow-growing animals with a generation time of 25 years require a level of patience that often outlasts the attention span of managers and caretakers. Developing a long-term plan early on that provides benchmarks to be reached along the way can help to establish long-term commitments, refresh memories, and measure success along the way. This is particularly important when a species is introduced into an area in which it has not lived in thousands of years. Establishing independent populations in un-tested areas requires research to ensure that the chosen location can support the species.
- It is important to develop an understanding of the minimum number of adults required to establish a robust and viable population; in turn, it is important to take survivorship rates into account when planning breeding strategies that affect final population size many years in the future. Success requires the generation of large numbers of genetically diverse juveniles early during the project, and sufficient infrastructure to safely house such juveniles until they are large enough to withstand predation attempts after being released.
- Species that exhibit temperature-dependent sex determination (most, if not all, tortoise species) may require breeding support (in the form of incubators) for some years to build strong release cohorts and manipulate sex ratios to ensure adequate numbers of females for establishing independent populations.
- Managing cold-blooded herbivores like tortoises can be relatively easy if done correctly, but it is also relatively easy to make mistakes that may go unnoticed for a long time. Best management practices should include keeping the tortoises in spaces large enough to maximize the number of possible foraging choices as well as nesting sites. Translocations (including between enclosures) should be kept to a minimum, as complex social structures are easily disturbed.

Success of project

Highly Successful	**Successful**	Partially Successful	Failure
	√		

Reason(s) for success:

- The involvement of people passionate about the Bolson tortoise and dedicated to its conservation.
- The willingness of a private land owner (Ted Turner), who owns large tracts of minimally disturbed land, to share this land with endangered species and thus increase biodiversity.
- Finding and maintaining a large enough group of breeding adult tortoises that can serve as the founder population.

- The development of a robust breeding program that produces at least 50 new Bolson tortoises per year.
- The long-term nature of the project precludes labeling it as highly successful until the next generation of tortoises can be documented. However, with the current expansion of the US Bolson tortoise population from 30 to over 400, we hope to have ensured the persistence of our breeding group for at least another generation, which in the case of the Bolson tortoise means more than 50 years.

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