



Restoring a Pleistocene Relict: The bolson tortoise recovery project



Adult bolson tortoise that is part of TESSF's captive breeding program in New Mexico

Mike Phillips
Executive Director

Magnus McCaffery
Wildlife Biologist

TURNER ENDANGERED SPECIES FUND
1123 Research Drive
Bozeman, MT 59718

Project summary

The Bolson tortoise reintroduction project aims to ensure that this critically endangered Pleistocene survivor does not vanish, but is restored to security. This will provide an inspiring example of a future in which restoration is an alternative to extinction. The project challenges conventional thinking about restoration ecology and offers a new and exciting answer to the cardinal question: Restore to what?

The reintroduction project will also stand as a flagship initiative that will illustrate the critical importance of private land to the conservation of biological diversity.

Project objective

The Turner Endangered Species Fund (TESF) aims to restore wild populations of the Bolson tortoise to portions of its Pleistocene range in the United States. We are breeding adult Bolson tortoises and rearing juveniles in captivity. We aim to produce offspring with the highest possible genetic diversity, and to release these juvenile tortoises into the wild once they are large enough to withstand predation events (shell length approximately 110 mm).

Project Location

We propose to initially conduct reintroductions on Turner Ranches (Ladder and Armendaris) in New Mexico, USA (Figure 1, all figures follow text). The ranches lie in the Chihuahuan Desert Ecoregion, which has been designated by the World Wildlife Fund as a *Global 200 Priority Ecoregion*, conservation of which would help maintain important aspects of Earth's ecosystems.

Project Background

In Mexico, it is called “Tortuga grande”— the big turtle. The bolson tortoise (*Gopherus flavomarginatus*) is the largest of the four North American tortoise species and was first recognized as a distinct species as recently as 1959 (Legler 1959) (Figure 2). Evidence suggests that this species was distributed throughout the Chihuahuan Desert until the late Pleistocene (about 10,000 years ago). Through anthropogenic exploitation and habitat loss, the species has declined across its historical range. Currently the only extant population teeters on the brink of extinction in the Bolson de Mapimí, a series of enclosed basins in north central Mexico (Figure 1). Their distribution there is estimated to cover less than 6,090 km² (Figure 3), where the Mexican states of Chihuahua, Durango, and Coahuila meet. Following the discovery of this small, relict population (Bury et al. 1988, Morafka 1988, Treviño et al. 1997), subsequent studies have revealed diminishing numbers and range. The Mapimí Biosphere Reserve in northern Durango took form in 1977, and constituted a first step to help protect the last small population of this iconic species.

The decline of the bolson tortoise was likely due to predation by humans from the beginning of the Holocene (Morafka 1988). North American aboriginal groups are known to have consumed other species within the *Gopherus* genera (Schneider 1996). Indeed, present-day harvesting of desert tortoises (*G. agassizii*) by the Seri of northwestern Mexico is a long-standing tradition (Felger et al. 1981), and likely explains why fewer and smaller tortoises are found near Seri settlements compared with those on the more remote Tiburon Island. People still eat bolson tortoises in parts of their current range, leading to low tortoise densities in the vicinity of human settlements and transportation corridors (Bury et al. 1988, Morafka 1988).

The species is listed as federally endangered by the U.S. Fish and Wildlife Service and the Mexican government, and is considered Vulnerable with a high risk of extinction in the wild by the International Union for Conservation of Nature (IUCN) (Aguirre et al. 1997). It has been absent from the United States for over 10,000 years, but without an intervention like our reintroduction program, the bolson tortoise could disappear in our lifetime.

In 2004, the Turner Endangered Species Fund hosted a workshop to consider a startling proposal: prehistoric conditions are sometimes an appropriate ecological template for contemporary restoration projects. The loss of influential Pleistocene fauna from the North American landscape inevitably resulted in the alteration of natural processes that led to cascading changes throughout the ecosystem. By restoring a Pleistocene survivor like the bolson tortoise, we have the possibility of restoring natural processes to the North American landscape that have been absent for thousands of years, but certainly remain essential for ecosystem integrity (Donlan et al. 2005).

Conservationists in North America have traditionally used historic (i.e., post-Columbian), not prehistoric, conditions as restoration benchmarks (Reid 1996, Simpson 2002, Botkin 2001). However, during the past few decades several imperiled species restoration programs have included releases in regions with no historical record of occurrence. Prominent among these are California condors (*Gymnogyps californianus*), released in northern Arizona (Meretsky et al. 2000), and black-footed ferrets (*Mustela nigripes*) released in northern Chihuahua (Messing 1986, Lockhart et al. 2006). A recent assessment of potential recovery habitat for the critically endangered Mexican wolf (*Canis lupus baileyi*) recommended reintroductions to areas in the southwestern United States without historical records of occurrence (U.S. Fish and Wildlife Service in preparation).

A growing body of evidence suggests a need to refocus our restoration efforts to rethread the intricate network of natural processes that is severed when influential or keystone species are lost. Efforts that seek to restore ecological processes are underway across the planet, and are based on restoring functional ecosystems rather than restoring to an arbitrary date in human history. For instance, proposals to restore wolves (*Canis lupus*) to the Scottish highlands after an absence of almost 300 years, highlight the beneficial effects for bird biodiversity and forest regeneration that would be realized as a result of wolf predation on an overabundant red deer (*Cervus elaphus*) population (Nilsen et al. 2007). Similarly, efforts in Siberia that involve restoring Pleistocene herbivores to the landscape seek to stabilize soils of the northern tundra which could prevent the release of vast quantities of sequestered carbon that is threatening to exacerbate the effects of climate change (Zimov 2005).

For many reasons, most notably its construction of an extensive burrow system that provides refuge from predators and environmental extremes, further study will likely reveal that the bolson tortoise is a keystone or highly interactive species (Soulé, et al. 2003). As such its' absence from desert grasslands for 10,000 years has led to significant changes in important features of that ecosystem. For instance, the gopher tortoise (*Gopherus polyphemus*), a close relative of the bolson tortoise (Auffenberg 1976, Bramble 1982), is considered a keystone species in the southeastern United States. Gopher tortoise burrows provide habitat or refuge for over 360 species, including some, like the eastern indigo snake (*Drymarchon corais couperi*), that are themselves imperiled (Jackson and Milstrey 1989, Guyer and Bailey 1993).

The project we are proposing has been in development for several years (Truett et al. 2005, Truett and Phillips 2009). It is a unique but entirely feasible effort that challenges the original reasons for using historic baselines, advocates adopting more flexible restoration benchmarks, and calls for innovative conservation actions in this direction by using reintroductions to restore a viable population of bolson tortoises to the species' prehistoric range. Such reintroductions will benefit a species teetering on the brink of extinction and serve to restore important natural processes that have been absent from the northern Chihuahuan grasslands for thousands of years. Further benefits will be generated by developing a recovery plan for the species and using the reintroduction project along with other landmark restoration efforts by the Turner Endangered Species Fund as catalysts for broadening the role of private land in the conservation of imperiled species and the habitats on which they depend.

In early fall 2006, TESH biologists transferred 33 captive bolson tortoises (26 adults and 7 hatchlings) from an insecure facility at the Appleton Ranch in southeastern Arizona (Figure 1), where they had lived for around three decades (e.g., see Appleton 1978, 1980, 1983) to secure enclosures at the privately owned Armendaris Ranch in New Mexico. Each enclosure contained soil textures, dominant forage vegetation, and landscape gradients selected to mimic those at the Mapimí Biosphere Reserve as described by Morafka et al. (1981), Lieberman and Morafka (1988), and Traphagen (2006). Additionally, elevation, precipitation, and average summer temperatures in the Armendaris Ranch area (Wainwright 2005) are remarkably similar to those at Mapimí (Morafka et al. 1981). But New Mexico winters are colder—average January temperatures at the Armendaris average ~ 15° C lower than those at Mapimí.

Since then the captive population has flourished, with adults gaining weight, establishing burrows, and producing large numbers of viable eggs largely without managers providing food or water subsidy; only two adults have died. Hatchling and juvenile tortoises have also responded well to captivity, although they have required more intensive management (Figures 4, 5, and 6). By late 2010, our innovative management scheme had led to a 363% increase of the captive population, from 38 animals to 176 individuals (Figure 7).

For the next several years we propose continuing efforts to grow the captive population as a hedge against extinction, thereby ensuring that a sufficient number of high quality animals from various cohorts are available for reintroduction to the wild. An important component of this will entail working collaboratively with the Mexican government to bolster the genetic vigor of our captive population. This would involve temporarily removing select wild adults from the Bolson de Mapimí and breeding them with captive individuals to enhance the genetic health of the captive population. We will begin with reintroductions at Turner Ranches in New Mexico (Figure 1), but ultimately aim to restore bolson tortoise populations throughout the species' prehistoric range in the southwestern United States and Mexico, thereby securing the species from extinction.

Growing the captive population will require continued intensive management that includes augmenting the captive gene pool using wild individuals, encouraging optimal pairings to maintain genetic integrity, monitoring of egg development using X-ray radiography, inducing oviposition using oxytocin, placing eggs in temperature-controlled incubators designed to produce desired numbers of male and female offspring (bolson tortoises have temperature-dependent sex determination), and safeguarding hatchlings and juveniles from predators, diseases, and nutritional stress.

We will continue to use the captive population as the focus of cutting-edge research to clarify the natural history and ecology of the bolson tortoise, a species unknown to science prior to 1959 (Legler 1959). Since 2008 we have supported graduate research studies that improved our understanding of the burrowing habits of captive juvenile tortoises (McCann 2011), and foraging ecology and nutritional requirements of adults (Palomo-Ramos in preparation). We are in the process of designing a study to improve our understanding of behavioral interactions between adults with an emphasis on reproductive behaviors. Given the incredible ability of female bolson tortoises to store sperm for long periods of time, advancing our understanding of mate selection patterns is critical for managing a captive population to ensure genetic health without compromising their opportunity exist in a semi-wild state in the large enclosure at the Armendaris Ranch. We have also formed partnerships that are pushing the research envelope to develop state-of-the-art knowledge and methodologies that will enhance the success of our reintroduction efforts. For example, we are collaborating with one of the world's experts on herpetological endoscopy, Dr. Steven Divers, to determine the influence of incubation temperature and humidity on gender determination. We are also working with the Human Origins Genotyping Laboratory at the University of Arizona to complete molecular genetic analyses to clarify kinship patterns and genetic diversity of our captive population

The continued success of our multi-faceted captive program will require that we promote greater involvement by member institutions from the American Zoological Association (AZA). While our current partners, the Rio Grande Zoo (El Paso, Texas) and the Living Desert Zoo and Gardens State Park (Carlsbad, New Mexico) provide much needed capacity, additional support from AZA institutions will be helpful for adding the physical and human capacity needed for maintaining several hundred tortoises in captivity, completing important research projects, and promoting conservation by advancing public awareness of the species' plight.

For the reintroduction project we will pioneer the use of innovative ecological tools and an adaptive management strategy to guide our effort. Throughout the project, Turner Endangered Species Fund staff will intensively monitor the reintroduced tortoises via conventional VHF and advanced solar powered GPS radio transmitters, and employ powerful analytical tools to promote our understanding of population and life history characteristics that will inform this and future restoration opportunities. Specifically we will:

- Continue to model the growth characteristics of our captive population to confirm our prediction that a sufficient number of tortoises will be available for release by 2013 (Figures 8 and 9).
- Use GIS analyses, satellite imagery, and ground-based reconnaissance of occupied sites in Mexico and potential release sites at the Armendaris to identify those areas at the ranch best suited for tortoises.
- Use advanced population modeling tools to determine optimal release strategies that will allow the reintroduced population to attain maximal growth rates.
- Begin reintroducing juvenile bolson tortoises in 2013 from our captive population using Release Scenario 2 (Figure 10). To gain invaluable information on how best to proceed with the reintroduction program, we will use an adaptive management framework. This will expand our conceptual understanding of ecology, while allowing us to continually refine our methods as the reintroduction proceeds based on up-to-date data (Figure 11 and 12).
- All released tortoises will be implanted with a Passive Integrated Transponder (PIT) tag, and fitted with conventional VHF and advanced solar powered, global positioning (GPS) radio transmitters. We will track tortoise movements, individual growth rates, survival rates, reproduction, and

population growth rates. This information will be used to calculate analytical elasticities for each tortoise stage class, and we will conduct population viability analyses to ascertain the probability of population persistence into the future. These will not only give us a metric of the success of the reintroduction, but will inform future management of the reintroduced population while providing basic life history information for a species largely unknown to science.

As the bolson tortoise recovery effort proceeds, we will publish results in peer-reviewed journals (e.g., *Science*, *Conservation Biology*, *Restoration Ecology*) and popular outlets (e.g., *National Geographic*) showing how the project is a positive, tangible symbol for responding to the extinction crisis. This example is critically important since the extinction crisis is often framed as intractable and as such has become one of humanity's most pressing and least attended problems. Publications from our project will help change that.

We will also produce the first recovery plan for the species in collaboration with other scientists and government officials from the United States and Mexico.

FIGURES

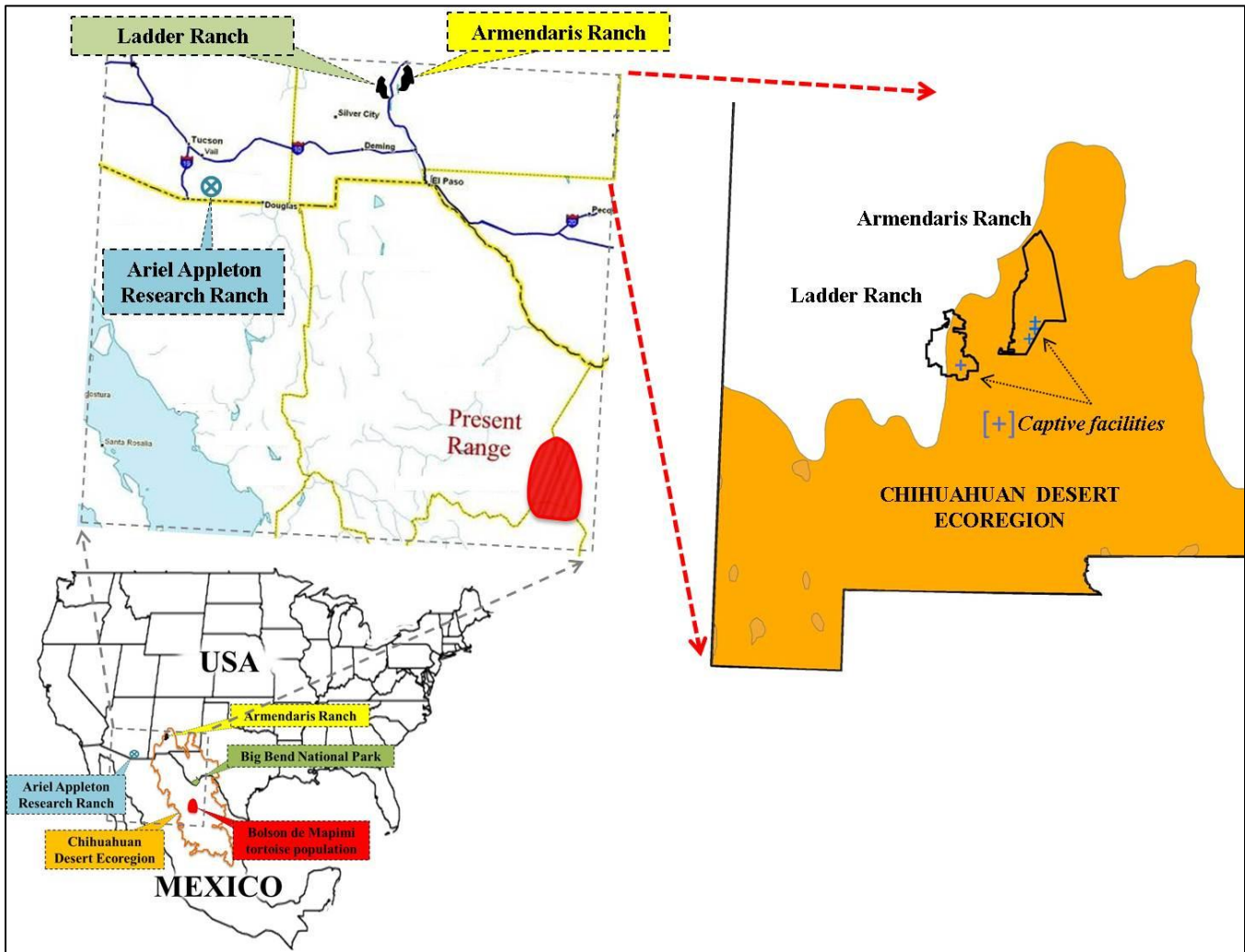


Figure 1. Map showing the bi-national conservation effort aimed at preventing the extinction of the bolson tortoise. Our goal is to breed tortoises originally collected from the dwindling relict population in the Bolson de Mapimí, and to restore viable populations to other parts of the species prehistoric and historical ranges in the Chihuahuan Desert Ecoregion. Potential release sites include the Ladder and Armendaris Ranches in New Mexico and Big Bend National Park in Texas.



Figure 2. Adult bolson tortoises, like this one from the the Bolson de Mapimí, can live for 70 or more years and grow quite large, weighing 15 kilograms or more.



Figure 3. An active bolson tortoise burrow at the Bolson de Mapimí in Mexico.



Figure 4. Intensive management of young tortoises. Some are kept awake during the winter due to poor health, and are allowed to soak three times per week to maintain hydration.



Figure 5. Headstart Pen at the Ladder Ranch where young tortoises are intensively managed to promote high survival rates.



Figure 6. There are terraria tanks at the Armendaris, each one can hold 10 juvenile tortoises (typically hatchlings). These tanks are nearly filled with soil and provisioned with burrows and native plants for food and shade. They can be moved inside overnight and during extreme hot or cold periods.

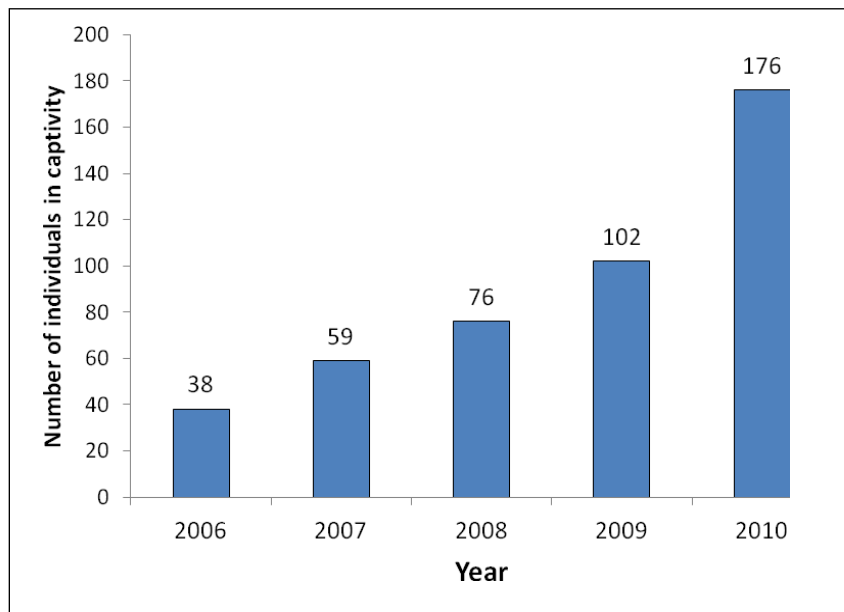


Figure 7. Growth in the captive bolson tortoise population since 2006.

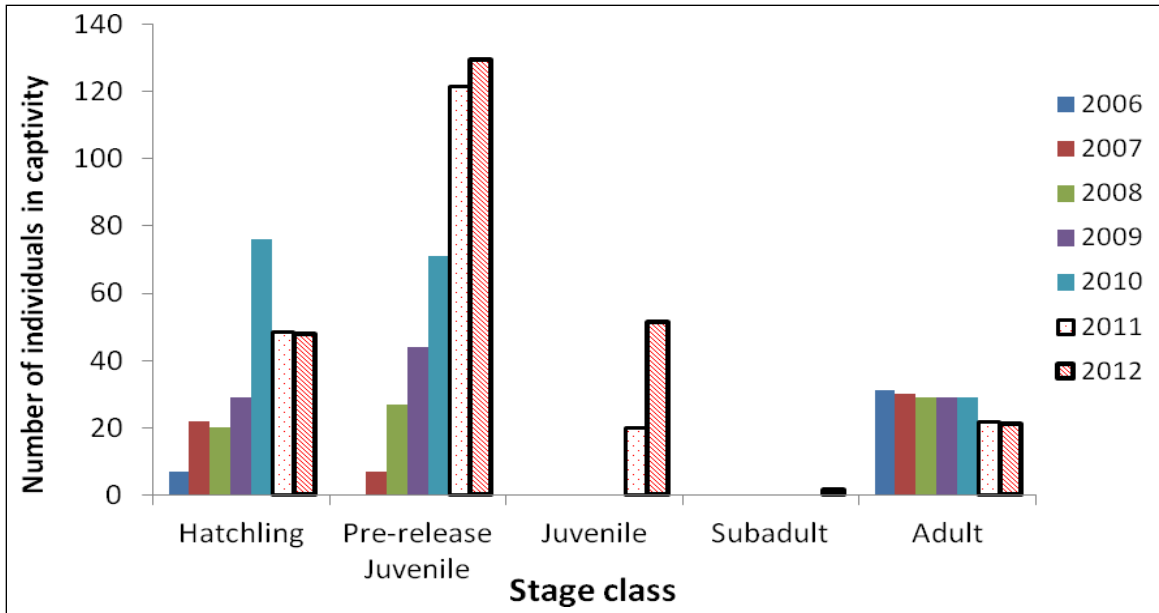


Figure 8. The stage-class composition of the captive bolson tortoise population. Numbers in 2011 and 2012 are predicted based on mathematical projection models. 2011 is the first year that we expect to have tortoises of a releasable size (juvenile stage class).

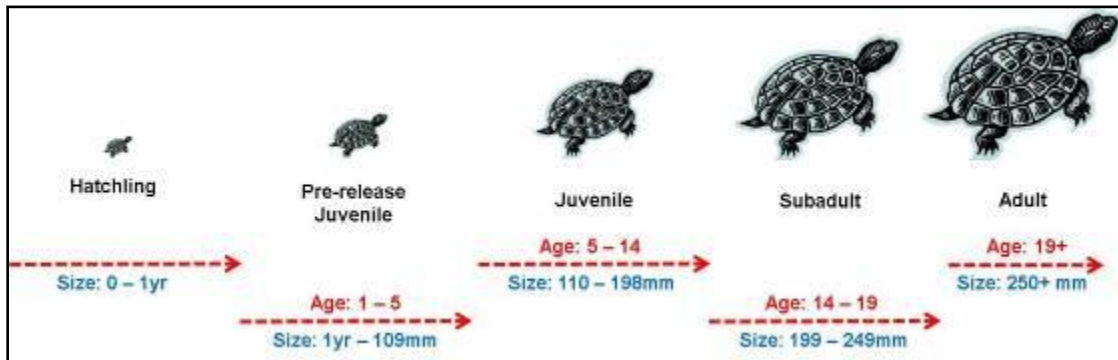


Figure 9. Theoretically important life stages of bolson tortoises that exhibit similar survival and reproductive rates. The juvenile stage class is the minimum sized individual that can withstand predation events and is therefore the threshold size eligible for release into the wild.

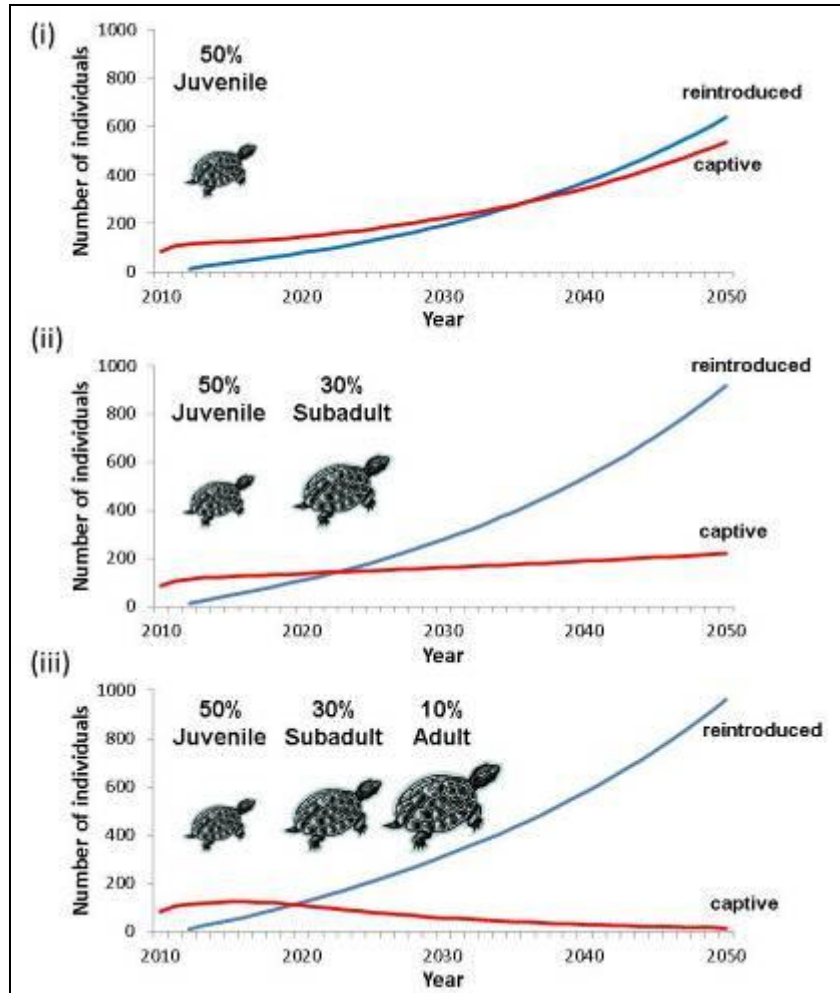


Figure 10. Hypothetical release strategies informed by modeling population dynamics of captive and reintroduced bolson tortoises. The three strategies entail reintroduction work beginning in 2013, where scenario (i) involves releasing 50% of juveniles produced in captivity each year, (ii) releasing 50% of the juveniles (starting 2013) and 30% of the subadults (starting 2016) produced in captivity each year, and (iii) releasing 50% of the juveniles (starting 2013), 30% of the subadults (starting 2016), and 10% of the adults (starting 2016) produced in captivity each year. From these simple scenarios, it appears that scenario (ii) would be most efficacious as it would promote high growth rates in the reintroduced population while maintaining the captive population at a manageable level.

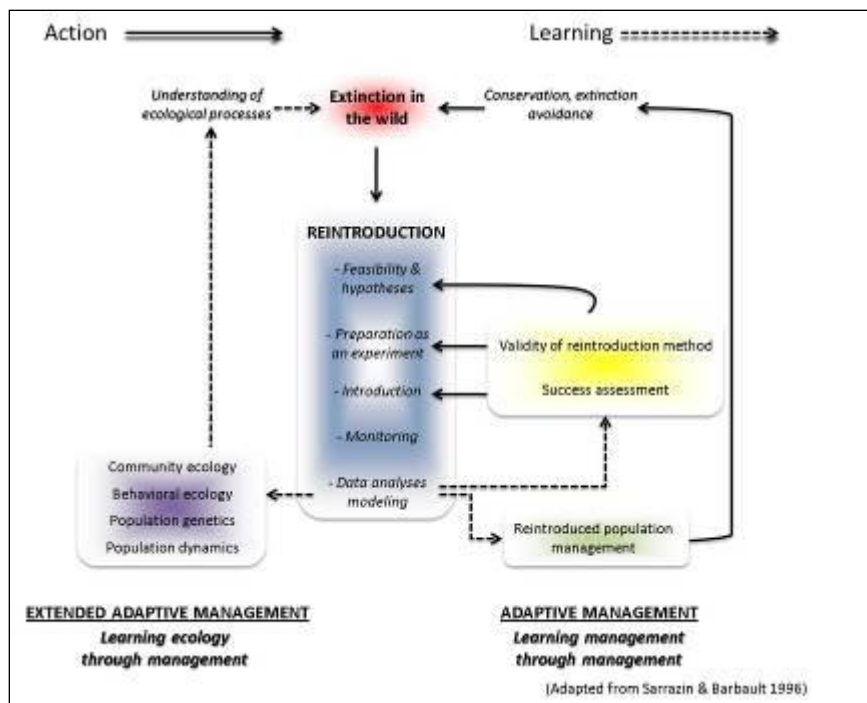


Figure 11. Use of an adaptive management framework in this reintroduction will expand our conceptual understanding of ecology while allowing us to refine our methods based on up-to-date data as the reintroduction program proceeds. Solid arrow indicate a step where *action* is taken, and dashed arrows indicate a step where we *learn* something new. For example, when presented with a species at risk of extinction in the wild, we take *action* in the form of initiating a reintroduction program (which has a series of components). Under Extended Adaptive Management, our data analysis that is part of our reintroduction strategy allows us to *learn* and increase our conceptual understanding of various aspects of ecology, which increases our conceptual understanding of ecological processes and informs future strategies for ameliorating extinctions in the wild.

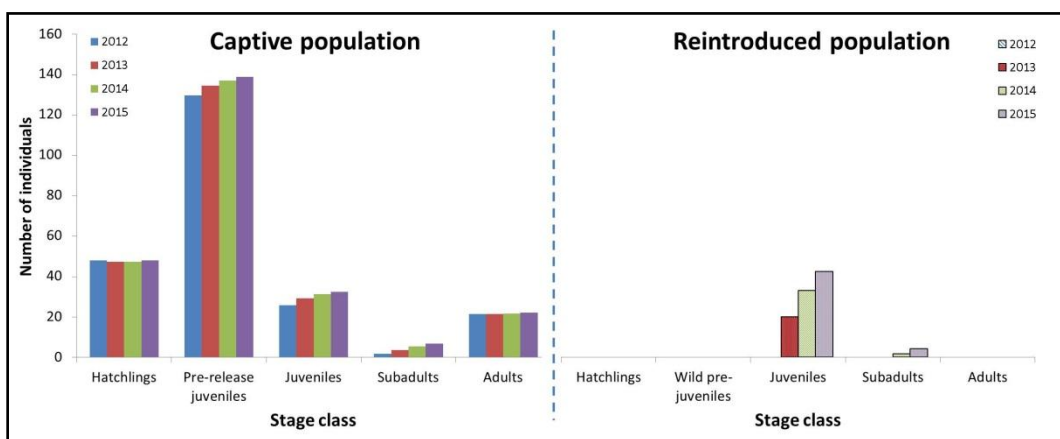


Figure 12. The projected number of tortoises in each stage class in both the captive and reintroduced populations, with releases commencing in 2013. This is based on Release Scenario 2 (Figure 10).

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