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Population Viability Analysis of Sonoyta Mud Turtles at Quitobaquito Springs, Arizona, USA.

A Final Report to Organ Pipe Cactus National Monument

And

Western National Parks Association

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The Rio Sonoyta in southern Arizona and northern Sonora has long been isolated from the Colorado River drainage resulting in its own unique desert riparian fauna. Eruptions within the Sierra Pinacate Volcanic Field diverted the Rio Sonoyta away from its westward course towards the Colorado River Delta southwards towards the Gulf of California ~ 100,000 ybp (Ives 1964; Turner 1983). The resulting diversion and isolation has led to the evolution of two distinct vertebrate taxa: the Quitobaquito Pupfish (*Cyprinodon eremus*; Echelle et al. 2000) and Sonoyta Mud Turtle (*Kinosternon sonoriense longifemorale*; Iverson 1981). Both species only occur within the Rio Sonoyta in northern Sonora and one man-made pond and channel associated with Quitobaquito Springs in Organ Pipe Cactus National Monument, Arizona.

Turtle numbers were probably quite high in the 1950's, but declined because of manipulations of the man-made pond (Rosen and Lowe 1996). These manipulations removed shallow, heavily vegetated habitat typically utilized by juvenile turtles. Over the winter of 1989-1990 substantial shallow water habitat was created and juvenile survivorship and density had markedly increased by the mid-1990's. Throughout this time period, the Quitobaquito Springs population tended to exhibit a heavily male biased sex ratio. While historic population estimates (ranging from 68-143) showed considerable variation in methodology and results, life-table analysis confirmed a stable and possibly increasing population. Variation in juvenile survivorship had the strongest negative effect on female replacement rate (R_0) and in turn population growth rate (λ) (Rosen and Lowe 1996; Organ Pipe Cactus National Monument 2008).

In addition to geographic isolation, major threats to the Sonoyta mud turtle include nutritional stresses based on dietary constraints and water loss. Quitobaquito Springs does exhibit low invertebrate abundances and high abundances of pupfish that could act as competitors for a limited resource (Walters and Legner 1980; Rosen 1987). Turtles at Quitobaquito Springs appear to forage solely on algae and exhibit lower lipid storage rates, slower growth, smaller over sizes, and smaller clutches than other populations of Sonoran mud turtles (Rosen 1987).

In 2007, the man-made pond began losing water at a very rapid rate, possibly because of the combination of a leak and increased evapotransporation from a prolonged drought period. The consequence of temporary water loss on this population is unknown, but is of immediate concern. Ligon and Peterson (2002) demonstrated that Sonoran mud turtles vary in estivation ability depending on whether they originate in permanent or seasonally intermittent streams. As the population at Quitobaquito lives in a permanent water body, they may exhibit a much reduced ability to remain dormant during a prolonged dry period. For this reason 30 adult (17 male:13 female) turtles were placed in temporary holding facilities.

Our specific objectives for this project were to (1) compare demographics between the 2001-05 data with that reported on by Rosen and Lowe (1996), and (2) conduct population viability analyses to determine current population status and likelihood of recovery through the use of a temporary assurance colony.

Methods

Age structured survival was calculated using catch curves or the log frequency distribution of the catch by age (Chapman and Robson 1960). Age frequencies were constructed using data from Rosen and Lowe (1996), because of the larger number of turtles captured and the availability of age data. Annual survivorship was also calculated for 2001-05 samples using Jolly-Seber models in Program MARK (White and Burnam 1999).

Numerous researchers were involved in data collection at Quitobaquito Springs throughout both study periods, leading to some confusion on size at maturity and when secondary sex characteristics become visible (Figure 1a). Rosen and Lowe (1996) state that Sonoyta mud turtles reach sexual maturity at 6 yr, and there were no unknown sex individuals at 7 yr within the age distributions (Figure 1a). The growth curve for this population flattens out and begins to diverge between the sexes at 6-8 yrs of age (Figure 1b). Based on these assumptions, we grouped individuals under 7 yr as unsexable juveniles (Figure 1c). Age structured survival was then calculated for juveniles between 2-7 yr old, and males and females age 7-12. Jolly-Seber estimates were calculated for all juveniles < 7yr and males and females ≥ 7yr. Survivorship values based on Jolly-Seber analysis were 0.95 for males and females ≥ 7 and 0.63 for juveniles < 7. These values were similar to survivorship estimates calculated for the 1982-95 sampling periods (Table 1).

Current information on population size was taken from surveys conducted between 2001 and 2007 (Organ Pipe Cactus National Monument 2008). Population size was calculated using the Chapman modification for small sample sizes of the Lincoln-Peterson population estimator (Seber 1982), and was based on within year mark-recapture periods. Population estimates ranged from 39 to 153 adult Sonoyta mud turtles (Figure 2), although the 2002 estimate may have been somewhat inflated as there was only 1 recapture during the second sampling session. An estimate was not calculated for 2003, as there was only one sampling period that year. The adult sex ratio was slightly biased, although not significantly so ($X^2 = 0.899$, $P = 0.342$, df=1). Juveniles made up 46% of captured individuals.

Our Population Viability Analyses used four, 3-stage models based on female survivorship in RAMAS Metapop (Akcakaya 2002). All simulations were set to run 1000 replications for 50 time steps (50 yr). Model 1 simulated conditions based on 2001-05 data. The population was set at 65 and divided between 3 age classes (0-1yr [n=10], 2-6 yr [n=20], and 7-12 yr [n=35]). Model 2 was a recovery based model with a starting population of only the 13 females (0-1 yr [n=0], 2-6 yr [n=0], and 7-12 yr [n=13]) being held in on offsite assurance colony. In Model 3, we simulated the effects of doubling the number of adult females (0-1 yr [n=0], 2-6 yr [n=0], and 7-12 yr [n=26]). Because Rosen and Lowe (1996) stated that R_0, and in turn λ in this population showed greater fluctuations when survivorship varied within younger age classes, we simulated the effects of adding 10 individuals from younger age classes to animals already held within the assurance colony for our fourth model. Initial stage populations for model 4 were set at 0-1yr (n=5), 2-6 yr (n=5), and 7-12 yr (n=13).

Clutch size and frequency is fairly variable between populations of Sonoran mud turtles (Hulse 1982; Rosen 1987) and very little is known about the reproductive ecology of turtles at Quitobaquito Springs. Fecundity was set low at 2 hatchlings/yr, based on a clutch size of 4 (Rosen and Lowe 1996) to simulate worst case scenarios, assuming nutritional stress might affect egg quality and hatchability. Carrying capacity (K) was set at 70 females, which is loosely based on previous population estimates and is assuming that resources are limiting within Quitobaquito Pond and Springs. Although we did not have survivorship estimates for 0-1 year olds, we used estimates derived for 2-6 yr old turtles. Rosen and Lowe (1996) calculated a replacement rate of 1.6, which was close to the reproductive transition value of 1.79 we calculated for our models within RAMAS. We used the calculated value of 1.79 for Models 1 and 4. Reproductive transition was lowered to 0.64, the value reported by Rosen and Lowe (1996) based on lowest juvenile survival rates in for recovery models 2-3 to simulate missing juveniles in the initial population structure.

Results

Based on the results of model 1, the population of Sonoyta mud turtles at Quitobaquito Springs appears stable (Table 2) if not slightly growing with $\lambda = 1.26$. While Models 2-3 do demonstrate likelihood of recovery by using only adult turtles, total estimated population size remains low (Table 2). Of more concern is the probability of a population halving event occurring when Models 2 and 3 were compiled. With the addition of just five pre-reproductive turtles in both pre-reproductive age classes in Model 4, estimated population sizes doubled and the probability of the population halving was reduced to zero, as compared to those in Model 2 (Table 2). Based on iterations within Model 4, the smallest viable population to return a zero extinction risk was 24 individuals (0-1yr [n=8], 2-6 yr [n=8], and 7-12 yr [n=8]).

Discussion

Comparing population status between the two principal study periods, Rosen and Lowe (1996) and this study, suggest a population that has remained fairly stable with some minor fluctuations. The population estimates for the 2001-05 sampling period are slightly lower than previous estimates, but are based on within year mark-recapture periods vs. between year mark-recapture periods. However, the male-biased sex ratio at Quitobaquito Springs is constant throughout all sampling periods and a concern. Survivorship estimates based on both Jolly-Seber and age-structured models were very similar, suggesting that differences between estimates of annual survivorship may be more a result of variation in calculations than a real world phenomenon (Koper and Brooks 1998). Based on results in Table 1, survivorship most likely does not contribute to the unequal sex ratios observed at Quitobaquito springs. It may be that other physiological or methodological factors contribute to the observed male biased sex ratio. Sonoran mud turtles do exhibit temperature sex determination (Ewert et al. 2004), which could possibly explain the male biased sex ratios at Quitobaquito Springs, though nothing is known about their nesting ecology at this site. Additionally, the observed sex ratio may simply be a function of sampling technique (Ream and Ream 1966).

What is important to the persistence of this population is maintaining reproduction and juvenile survivorship. Sonoyta mud turtles, in the wild at least, may not exhibit the long life-spans seen in other chelonians, so they must have a higher recruitment rate in order to sustain a stable population. Our Population Viability Models also support the importance of juvenile females to this population, particularly when dealing with assurance colonies and reintroductions. By simply increasing the number of females and age classes represented, the estimated minimum abundance of the Quitobaquito population was doubled.

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Table 1. Annual survivorship of adult (7-12yr) and juvenile (< 7yr) Sonoyta mud turtles at Quitobaquito Springs, Arizona, USA.

	Survival Analysis	Adult Male	Adult Female	Juvenile
Rosen and Lowe (1996)	Jolly-Seber	0.90 ± 0.17	0.85 ± 0.04	0.54, 0.70, 0.85, 0.64[1] 0.84[2]
Riedle et al. (This ms)	Age-Structured	0.83[3]	0.89[3]	0.72[3]
	Jolly-Seber	0.95 ± 0.04[4]	0.95 ± 0.05[4]	0.63 ± 0.08[4]

[1]Survivorship by year for 2yr olds (1984, 1985, 1989, 1992).

[2]Mean survivorship for 3-4 yr olds.

[3]Calculated from 1982-1995 data.

[4]Calculated from 2001-2005 data.

Table 2. Results from Population Viability Models for Sonoyta mud turtles at Quitobaquito Springs, Arizona, USA.

Model	Extinction Risk	Estimated Minimum Abundance	Probability Of Population Halving
1	0	41.1	0.18
2	11%	10.4	0.42
3	3%	16.2	0.50
4	0	32.5	0.00

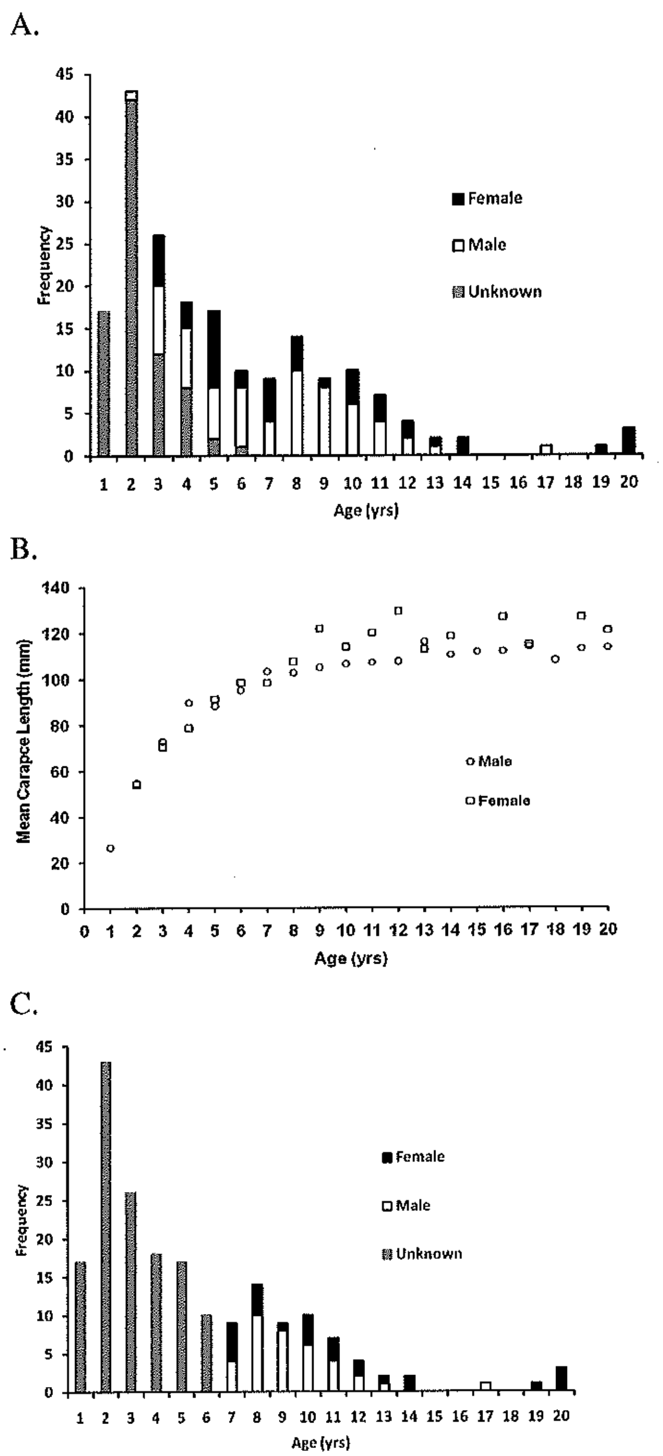

Figure 1. Age frequency distributions from raw data (A), growth curves (B), and adjusted sex frequency classifying all turtles < 7 yr of age being considered juveniles (C) for Sonoyta mud turtles at Quitobaquito Springs, Arizona, USA. Based on the 1982-1995 sampling periods.

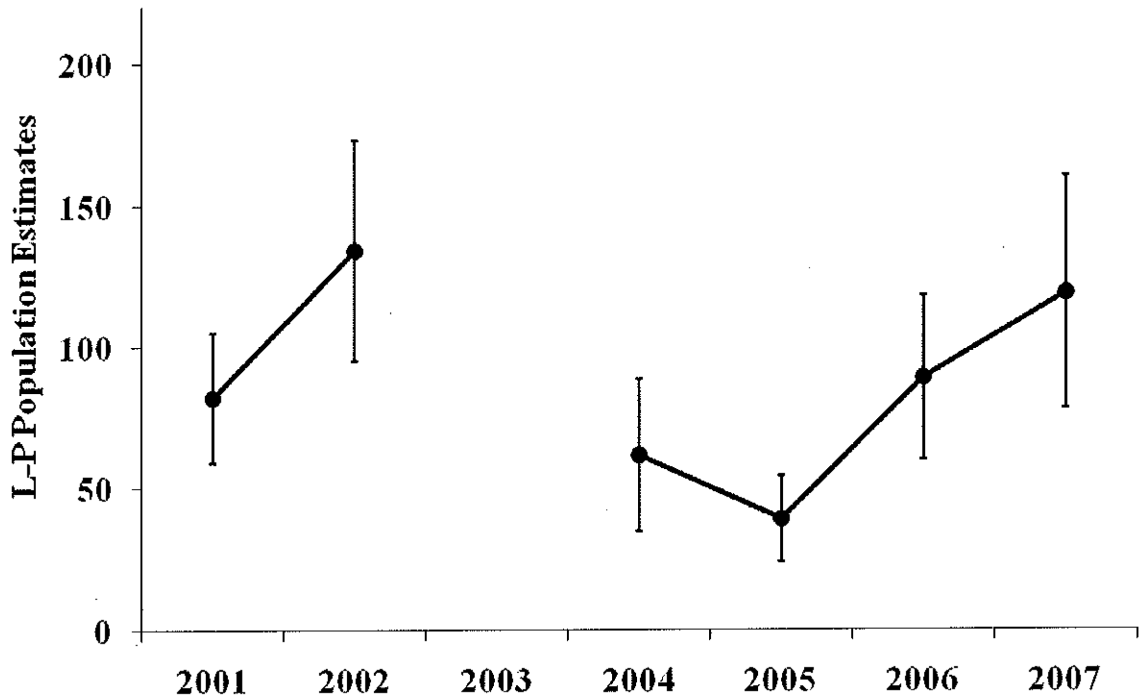

Figure 2. Lincoln-Peterson population estimates for Sonoyta Mud Turtles, Quitobaquito Springs, Arizona, USA, from 2001-2005 sampling periods.