Conservation and Management Zones and the Role of Earthen Cattle Tanks in Conserving Arizona Leopard Frogs on Large Landscapes

Michael J. Sredl and Loralei S. Saylor

Abstract — Populations of many species of amphibians throughout the world have declined during the past twenty years. In the arid West, Arizona’s leopard frogs, which include five or six native and one introduced species, have also been documented as having declined. Although none are federally listed as Threatened or Endangered, two are Candidate species and, if declines continue, more will be listed or become Candidates. Historically, these frogs occupied a variety of permanent and semi-permanent aquatic habitats, and recent surveys indicate that populations occupying a relatively recent type of aquatic habitat, earthen cattle tanks, may play an important part in the short-term conservation of this group. The role of cattle tanks in long-term conservation planning will be dependent on their manageability and the viability of populations in earthen cattle tanks compared to more natural systems. 1) We examined the current importance of earthen cattle tanks for all native leopard frogs by comparing the frequency of extant and extirpated populations in riverine and cattle tank sites within a historical data set. 2) To evaluate population viability, we developed a simple index of viability for localities of the southeastern Arizona and Mogollon Rim populations of the Chiricahua leopard frog (Rana chiricahuensis) using survey data collected between 1993-1996, then compared this index between riverine and cattle tank sites. 3) To examine the possible management implications of four non-native species on native leopard frog populations, we tabulated the frequency of encounter of non-natives during surveys of riverine and earthen cattle tanks. Our data indicated that for R. pipiens and R. chiricahuensis in southeastern Arizona, there is a significantly higher number of extant populations in cattle tanks; for R. blairi, R. yavapaiensis and Mogollon Rim form of R. chiricahuensis, rates of occupancy between these systems do not differ. Although our data indicate that population viability of R. chiricahuensis in southeastern Arizona cattle tanks and riverine systems did not differ, riverine systems of the Mogollon Rim form of this species were more viable than cattle tanks. Among four non-native species, we found that warm water fish, crayfish and cold water fish were significantly more common in riverine systems than tanks. For bullfrogs our data indicated no significant difference in habitat preference. With adequate precautions and monitoring, we conclude that cattle tanks will play an important role in the short- and long-term conservation of Arizona leopard frogs.

A successful statewide approach to the conservation and management of Arizona leopard frogs will identify entities whose priority for conservation is highest, and apply multiple conservation approaches in an area of sufficient size, while using the best available habitats. We outline such an approach for areas we designate as Conservation and Management Zones (CMZs). CMZs are defined as discreet geographical areas within which conservation and management goals and objectives are set. Once established, activities within a particular CMZ are implemented and their effects monitored. Potential CMZ activities which Arizona Game and Fish Department (AGFD) and cooperators have begun investigating are: 1) ex situ rearing of tadpoles and release of metamorphs, 2)
translocating wild frogs, 3) removing non-native species, 4) renovating habitats, and 5) building captive breeding facilities. CMZs could be used to systematically implement the array of activities required to stabilize portions of the ranges of Arizona's leopard frogs. Using Arizona leopard frogs as models, we will develop the CMZ concept further and discuss advantages of CMZs including: 1) implementation of conservation measures at a time when they may be most effective, 2) streamlined environmental review, and 3) concentration of limited energies on species and areas of high priority.

INTRODUCTION

Since the 1970s, amphibian population declines have been reported from numerous localities throughout the world (Barinaga, 1990; Blaustein and Wake, 1990; Vial and Saylor, 1993). Many factors have been implicated in these declines, including: 1) non-native species (Bradford et al., 1993; Hayes and Jennings, 1986; Rosen et al., 1995); 2) UV radiation (Blaustein et al., 1994); 3) acid precipitation and toxic substances (Berrill et al., 1993; Carey and Bryant, 1995; Dunson et al., 1992; Hale and Jarchow, 1988); 4) disease (Carey, 1993; Laurance et al., 1996; Scott, unpublished data); 5) destruction and fragmentation of habitats and populations (Bradford et al., 1993; Hedges, 1993; Sjögren, 1991); and 6) extreme climate changes, including drought and flooding (Corn, 1994).

Because of their natural history and physiology, many amphibians may be important indicator species of environmental change: 1) The biphasic life cycle of most anurans (aquatic larvae that are usually herbivorous and terrestrial adults that are exclusively carnivorous) exposes them to both air and water borne toxicants that may be concentrated in either plant or animal foods. 2) They occur in habitats ranging from deserts and rain forests to alpine and subpolar tundra, across the globe (only the marine environment lacks a significant amphibian fauna). 3) Amphibians are important components of energy and nutrient cycles of many ecosystems, often comprising a significant fraction of total biomass. 4) Their moist, permeable skin and egg masses leaves amphibians vulnerable to a variety of environmental insults such as air and water borne pollutants (Vitt et al., 1990).

As currently recognized, Arizona's ranid frog fauna includes the Tarahumara frog (*Rana tarahumarae*) and six or seven species of leopard frogs. This leopard frog fauna is surprisingly diverse and is among the largest in North America (Platz et al., 1990). It includes a disjunct population of the plains leopard frog (*R. blairi*), the southwestern end of the distribution of the northern leopard frog (*R. pipiens*), the northern end of the distribution of the Chiricahua leopard frog (*R. chiricahuensis*), the core populations of the lowland leopard frog (*R. yavapaiensis*), the only known populations of the Ramsey Canyon leopard frog (*R. subaquavocalis*), possibly a portion of the small range of the relict leopard frog (*R. onca*), and an expanding population of the non-native Rio Grande leopard frog (*R. berlandieri*).

In Arizona, most recent concern for population declines of native amphibians involves native ranid frogs, for which many populations have been reported to be extirpated or have declined (Clarkson and Rorabaugh, 1989; Hale and Jarchow, 1988; Sredl, 1993a). While it is
unclear exactly when these declines began, they were first noticed during studies of *R. tarahumarae* in the late 1970s (Hale and May, 1983; Hale and Jarchow, 1988; Hale, 1992). Hale and May (1983) suspected concurrent declines of other native leopard frogs, but historical data were unavailable for comparison. However, nearly every native leopard frog species in Arizona has been included as a species of concern at the state or federal level. *R. blairi* is on the list of Wildlife of Special Concern in Arizona (WSCA; Arizona Game and Fish Department, in preparation) and has no federal status. *R. chiricahuensis* is a WSCA listed species and is a federal Candidate. *R. pipiens* and *R. yavapaiensis* are WSCA listed species with no federal status. *R. onca* was previously considered to be extinct, but we now believe that a few populations still exist, and it is now a WSCA listed species. *R. subaquavocalis* is a WSCA listed species with no federal status, but a multi-party Conservation Agreement was recently signed to ensure implementation of a Conservation Strategy aimed at stabilization and recovery of the species. *R. tarahumarae* is a WSCA listed species with no federal status.

Although reasons for declines of Arizona's amphibian populations are not fully understood, factors which have been identified include: 1) negative impacts of non-native species such as bullfrogs, sportfish, and crayfish (Rosen and Schwalbe, 1988; Sredl and Howland, 1992; Fernandez and Rosen, 1996), 2) epidemic disease (Jancovich et al., 1998; Sredl, 1993b), 3) damming, diverting and draining of wetlands (Sredl and Howland, 1995), and heavy metal toxicity (Hale and Jarchow, 1988).

During the past century, cienegas and other wetland habitats within the arid Southwest have greatly decreased (Hendrickson and Minckley, 1984). Damming, draining, and diverting of water have fragmented formerly contiguous aquatic habitats. This loss and reduction has undoubtedly resulted in small, isolated, unstable local populations (Sredl and Howland, 1995). Local populations of leopard frogs in Arizona are prone to extinction (Sredl and Seim, 1993; Sredl and Howland, 1995; Sredl et al., 1997a) and metapopulation dynamics have likely been disrupted. In parts of the West, fragmentation of frog populations has been accentuated by non-native species, leaving potential dispersal corridors between available aquatic habitats impassable (Bradford et al., 1993), a process likely to have occurred in Arizona.

Due to major modification of natural leopard frog habitats in the Southwest, earthen cattle tanks may provide a vital alternative for Arizona's leopard frog populations (Sredl and Howland, 1995; see also Rosen and Schwalbe, this volume). Many of these waters could provide permanent or semi-permanent aquatic habitat for colonization by leopard frogs occurring naturally in riparian habitat lower in the same drainages, adding to regional population stability. In this paper, we address three questions. 1) Are earthen cattle tanks important aquatic habitats for leopard frogs? 2) Are leopard frog populations in earthen cattle tanks viable? 3) How does the presence of non-native species compare between riverine and cattle tank habitats? Finally, we explore how earthen cattle tanks can be used in management plans to conserve Arizona's leopard frog populations.

**METHODS**

Between September 1990 and April 1997, Arizona Game and Fish Department (AGFD)
conducted 2089 statewide surveys at 1274 localities. This overall data set includes records from AGFD surveys and historical records (museum records, published literature, technical reports, and observations of knowledgeable individuals). Information in these records include locality, habitat conditions, source, and herpetofaunal observations (Sredl et al., 1997b). For this analysis, we used all records of native leopard frog localities, their aquatic habitat type, species observations by life stage, and non-native species observed. Because *R. chiricahuensis* will soon be split into two species (J.E. Platz, personal communication), all analyses using sites occupied by this taxon were divided into subsets of the nominate species, *R. chiricahuensis*, and the Mogollon Rim form to detect possible differences between these entities. For all habitat comparisons, we used data from riverine and cattle tank systems which account for 91.6% of the sites in the overall data set.

**Importance of cattle tanks.** Our analyses examine the importance of cattle tank populations utilizing records from all native leopard frog species except *R. onca* and *R. subaquavocalis*. We did not include *R. onca* in our analysis because no verified Arizona records exist. We did not use records for *R. subaquavocalis* because it was only very recently described (Platz, 1993) and is found only in one non-cattle tank system (AGFD, unpublished data). We determined the occupancy status of a site following Sredl et al. (1997b) by comparing presence/absence of pre- and post-1993 survey data. Sites occupied prior to, but not after 1993 were considered extirpated, whereas sites occupied after 1993 were considered extant. We used Fisher's exact test to determine the importance of habitats for each native leopard frog by comparing the number of extant and extirpated cattle tank and riverine systems.

**Population viability.** We developed our index of population viability using data collected between 1993-1996 during statewide surveys of *R. chiricahuensis* and the Mogollon Rim form. For each year, we assigned a reproductive status to sites according to the following criteria: sites without eggs or larvae were categorized as non-reproductive, while sites with eggs or larvae were categorized as reproductive. Some sites were visited more than once in a given year. To make the likelihood of detecting aquatic life stages relatively equal for all sites, our viability index for each site is based on the latest visit prior to mid-October.

We constructed a 2 × 2 contingency table (habitat types × index of viability) for each year, tested for heterogeneity among years, and combined data for all years when we found habitat types × index of viability to be homogenous across years (Zar, 1974). As an overall test of significance of the relationship between habitat and viability, we performed a separate a Fisher’s exact test for *R. chiricahuensis* and the Mogollon Rim form.

**Non-native species.** Using data collected during statewide AGFD surveys (1990-1996), we compared the frequency of encounter of four non-native species (bullfrogs, crayfish, warm water fish and cold water fish) in riverine versus cattle tank systems by constructing 95% confidence intervals (Sokal and Rohlf, 1981).

**RESULTS**

Among populations of *R. chiricahuensis* and *R. pipiens*, we found a significantly higher
The proportion of known extant populations in cattle tanks compared to those in riverine habitats (Table 1). *Rana blairi*, *R. yavapaiensis*, and Mogollon Rim form show similar occupancy rates in cattle tanks and riverine habitats.

No significant difference in reproduction was found between riverine and cattle tank systems for *R. chiricahuensis*. However, data from cattle tank populations of the Mogollon Rim form indicate they do not reproduce as successfully riverine populations (Table 2).

Confidence intervals for proportion of riverine or cattle tank habitats occupied by non-native species groups indicate non-random habitat use by warm water fish, crayfish, and cold water fish (Table 1). These non-natives were encountered at a much higher rate in riverine systems. Bullfrogs were encountered as frequently in riverine systems as in tanks. In riverine systems, frequency of encounter of warm water fish was greater than bullfrogs and cold water fish, but not crayfish, and encounter of crayfish was greater than cold water fish, but not bullfrogs. In cattle tanks, frequency of warm water fish and bullfrog encounters did not differ, but both were encountered at a greater rate than crayfish and cold water fish, and encounter of crayfish was greater than cold water fish (Figure 1).

**DISCUSSION**

Recent population declines of Arizona leopard frogs (Clarkson and Rorabaugh, 1989; Sredl et al., 1997b) and the major landscape changes which preceded these declines have had profound effects on their metapopulation dynamics. This change in metapopulation structure will limit available approaches to conservation of this group. One landscape change in the Southwest, the creation of earthen cattle tanks, has the potential to be a beneficial tool to conserve Arizona leopard frog populations.

In the late 1800s and early 1900s, construction of earthen cattle tanks in upland drainages became a common range management practice (U.S. General Accounting Office, 1991), one which continues to this day. While data on historical occupancy of these habitats is lacking, dispersal capabilities of native leopard frogs (Frost and Bagnara, 1977), lead us to suspect many of these waters were colonized by native leopard frogs soon after their creation. During this period natural Southwest riparian systems had not degraded to the extent they have today, so that use of cattle tanks by leopard frogs may not have contributed significantly to metapopulation stability. It is even possible that additional habitat provided by cattle tanks may have actually allowed native frog populations to expand for a time.

Some desert amphibians, such as spadefoot toads and true toads, are able to successfully utilize temporary aquatic systems (Ruibal, 1969). Native leopard frogs require relatively permanent waters due to their inability to survive loss of a high percentage of their body water and their comparatively long larval period (Duellman and Trueb, 1986). While these frogs can survive short periods without standing water by burrowing in mud (AGFD, unpublished data) or taking refuge in mammal burrows, members of the leopard frog complex are not well adapted at withstanding long periods of drought.
Observations of Sredl and Howland (1995) and others lead us to believe that leopard frog populations occupy patches of aquatic habitat, connected by drainages that can be traveled by dispersing individuals. This mosaic forms the microgeographic basis for the development of metapopulations (Harrison, 1991). Furthermore, the life history of Southwest leopard frogs predisposes them to high rates of local extinction and recolonization (Sredl and Howland, 1995). Rates of reproduction and recruitment are highly variable and dependent upon rainfall and other environmental factors (Sredl et al., 1997a). Leopard frogs are strongly aquatic and are therefore vulnerable to desiccation, especially as larvae. Stimuli such as sudden cold snaps may result in devastating disease outbreaks, especially at local sites where overcrowding occurs (Sredl, 1993b). Leopard frogs are mobile, so dispersal should occur between isolated perennial aquatic sites using intermittent or ephemeral aquatic corridors. We suspect that population declines among southwestern leopard frogs can, at least in part, be attributed to disruption of normal metapopulation dynamics. Various human disturbances lead to increased rates of extinction accompanied by decreased rates of recolonization, changing basic metapopulation structure (see Sjögren, 1991 on the importance of connectivity for metapopulations of aquatic frogs).

Habitat has been reduced to small pockets that are capable of supporting only small, unstable populations of leopard frogs. Big rivers, with dams and introduced predators and competitors, no longer provide suitable habitat for large populations. Ground water pumping has dried many springs, cienegas, streams, and other wetlands, further reducing habitat availability. Dispersal corridors have suffered the same fate. They are impassable due to lack of water or, in the case of perennially flowing corridors, the presence of large populations of bullfrogs and non-native predatory fishes.

Sredl and Howland (1995) found few large river populations of *R. chiricahuensis* in southeastern Arizona. Further, they hypothesized that as natural aquatic systems became degraded the importance of cattle tank populations increased. Our data lend support to this hypothesis. While leopard frog populations in cattle tanks are important statistically for only two species of Arizona leopard frog, most likely they are important for nearly every species of native leopard frog, except the lowland leopard frog. For two species, *R. blairi*, and *R. subaquavocalis*, earthen cattle tanks are practically the only habitats where they are found. While for other species, these cattle tank populations have been extirpated at a lower frequency than riverine populations, and are likely starting points for short-term conservation planning. In addition to being important demographically, isolated cattle tank populations are likely to be important evolutionarily (i.e. to stabilize populations with unique genetic information), and for long-term conservation.

Earthen stock tanks are generally filled by surface runoff from rainfall or snowmelt. Permanence of water in a given cattle tank is dependent upon factors such as size and depth of basin, permeability of substrate, and size of watershed from which it receives runoff (Cole, 1983). Other factors affect evaporative water loss. Aspect of the basin and surrounding topography may affect exposure to wind and solar radiation. Species composition and density of bank and emergent vegetation affect incidence of solar radiation and wind and also influence evapotranspirational water loss (Cole, 1983).

Permanency of cattle tanks falls along a spectrum (see Sponholtz et al., this volume). At
each end of the spectrum, there are tradeoffs to resident leopard frogs. In temporary cattle tanks, water may not last long enough for dispersing frog to survive and reproduce. On the other end, permanent water may be conducive to maintaining viable leopard frog populations, but it also allows invasion by non-native species, especially warm water fish and bullfrogs (this paper; Rosen et al., 1995). Once introduced into these systems, these species are particularly problematic and difficult to remove (Rosen et al., 1996).

Conservation and Management Zones. There are adequate data to support the contention that *R. tarahumarae* and at least three of five native Arizona leopard frog species (*R. pipiens*, *R. chiricahuensis*, and *R. yavapaiensis*) have declined or been extirpated from Arizona (Hale and Jarchow, 1988; Clarkson and Rorabaugh, 1989; Sredl et al., 1997b). Although reasons for these population declines are not clear, the time is ripe to develop an approach to conservation and management of native amphibians. This approach will need to 1) identify important populations and metapopulations, 2) implement activities aimed at improving the habitat, populations, and metapopulations in those areas, and 3) monitor the effects of applied conservation activities and modify them as necessary to ensure they are effective. Key to the success of this strategy will be the use of an array of conservation and management activities, including those which utilize earthen cattle populations.

One of the first steps in formalizing our approach to conservation and management of Arizona leopard frogs is development of the concept of Conservation and Management Zones (CMZ). We define a CMZ as a discreet geographical area within which conservation and management goals and objectives are set, implemented and monitored. Using our statewide survey results, we will identify areas of critical conservation need. We will first establish criteria for priority, ranking the importance of populations from a statewide conservation perspective. These criteria may include: 1) overall status of the species, both statewide and rangewide (a highly sensitive species endemic to Arizona receives higher conservation priority than a geographically widespread species whose status in Arizona is less critical); 2) geographical context of a population or metapopulation (those in a region of severe decline or in a remote area that is unlikely to be naturally recolonized in the event of a local extinction event receive highest priority); 3) evolutionary context of a population or metapopulation (those that are evolutionarily important due to genetic distinctness or diversity receive highest priority); 4) manageability of the population or area (populations in areas where threats are most likely to be controllable and land owners or managers are more willing and able to cooperate receive highest priority); and 5) complexity and cost (those populations that can be stabilized or recovered through use of the fewest, simplest, and most cost-effective conservation actions receive highest priority).

Statewide surveys by AGFD and others have provided, and will continue to provide, most of the information we will need to address the first two criteria. We have begun to develop an identification method using Geographical Information System (GIS) software that will aid us in selecting potential CMZs. Contrasting local status (population or metapopulation) to modal locality status of a river basin, we identified unique populations and metapopulations of each species leopard frog in Arizona.

We have begun to collaborate to collect genetic information necessary to address the third
criterion. We have some information concerning the last two criteria, but they will require additional investigation specific to individual populations, areas, politics, and other factors that may be peculiar to each proposed CMZ. These will largely be addressed through cooperative, site-specific planning and negotiation with appropriate landowners and resource managers, and will culminate in public, academic, and interagency review of proposed actions.

After setting priorities, we will establish a particular CMZ designation through area-specific conservation planning, generation of funding, preparation of any necessary environmental compliance documents, and implementation of measures that are appropriate to each area. Although AGFD can coordinate this process and make significant contributions in funding and implementation, it is essential to have active participation and funding by cooperators, especially the affected public landowners or managers, if we are to have any hope that this approach will be successful on a large landscape level.

We have begun to develop and test management techniques to restore functioning metapopulations to appropriate areas. Techniques include: 1) ex situ captive breeding and/or rearing of eggs and tadpoles for release as metamorphs or adults to the wild; 2) translocating wild eggs, tadpoles, and frogs; 3) removing non-native species where feasible; 4) renovating or creating habitat. Our intent is to use a coordinated mix of these and other techniques, tailored to the needs of particular situations, to reconstitute functioning metapopulations in areas where frogs may be destined for extirpation in the absence of active conservation.

A promising new technique is working with ranchers to manage aquatic habitats for leopard frogs, which are generally compatible with livestock. We have assisted ranchers to renovate or manage two cattle tanks to the benefit of both livestock and leopard frogs. We need to continue to test and evaluate these manipulations, giving special attention to cost-effectiveness because of the tremendous range in cost of different types of habitat renovation or creation.

We recognize that our initial efforts to designate CMZs and implement conservation measures will be test cases. We will evaluate these first efforts and modify our approaches as needed to make them more effective and efficient. We can expect to encounter difficulties and outright failures at the beginning, but by making methodical evaluations and modifications, it should be possible, with adequate commitments from key resource managers and stewards, to successfully orchestrate stabilization and recovery of Arizona’s native ranid frogs.

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Range Experiment Station, Ft. Collins, Colorado.


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Figure 1. Clustered bars show the percent of sites statewide occupied by either warm water fish, bullfrogs, crayfish or cold water fish for each habitat type (riverine [▲] and cattle tank [○]). Bars represent 95% confidence limits.
Table 1. Pre- and post-1993 status relative to riverine and cattle tank habitats for each species of native Arizona for which verified localities exist except *R. subaquavocalis*. Sites occupied prior to, but not after 1993 were considered extirpated, whereas sites occupied after 1993 were considered extant.

<table>
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<th>species</th>
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<td></td>
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<td>cattle tank</td>
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Table 2. Number of sites assigned a reproductive or non-reproductive status, broken down by aquatic habitat type, for *Rana chiricahuensis* and the Mogollon Rim form. Sites without eggs or larvae were considered non-reproductive, while sites with eggs or larvae were considered reproductive.

**Rana chiricahuensis**

<table>
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Fisher's exact, $p=0.435$, $n=64$

**Mogollon Rim form**

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Fisher's exact, $p=0.026$, $n=15$