URBAN AMPHIBIAN AND REPTILE BIODIVERSITY:
REPORT TO THE TECHNICAL ADVISORY COMMITTEE (TAC) FOR CITY OF TUCSON HABITAT CONSERVATION PLAN (HCP)

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Executive Summary

This report details a set of interrelated investigations of herpetofaunal (amphibian and reptile) life within and around the urban core and urbanizing periphery of metropolitan Tucson. These are ongoing studies and conservation programs in a novel area of conservation biology that recognizes the increasing predominance of urban environments on planet Earth. Biodiversity is increasingly affected by the presence of urban habitat, and urban habitat often occupies prime environments for humans and other organisms alike. Human beings interaction with biodiversity can be seen to start where most of humanity lives – in the urban environment.

Lizard Status and Ecology Time-constrained search methods revealed consistently high lizard abundance along Tucson's major riparian corridors, especially the Rillito system, during 2005-7. Despite record flooding in 2006, abundance of all species was maintained on the Rillito, including species like the Zebra-tailed Lizard that extensively

used the sandbed in areas where the habitat was tightly confined by residential environments. This indicates that the River Park system can be expected to support persistent, strong lizard populations that can anchor lizard biodiversity within the urban matrix.

A detailed analysis of change in the urban riparian lizard assemblage was performed using modern data compared to a historical profile inferred from museum data. The pattern of change points toward aquifer depletion as the critical factor influencing lizard biodiversity in urbanized Tucson. As bosque environments desiccate and degrade, lizard species will continue contract and disappear. Support for the aquifer, or maintenance of natural bosque vegetation structure via irrigation and runoff capture in residential and open space areas, would allow high lizard biodiversity and abundance to persist near Tucson's major riparian corridors.

High lizard abundance also occurs in some strictly residential areas of Tucson. An experiment was initiated to test whether the increased water supply of residential areas can support enhanced lizard biodiversity analogous to that of the riparian corridors.

Based on the lizard work, a grant proposal to Arizona Game and Fish Department was developed in conjunction with GIS and remote sensing experts at the University of Arizona Department of Arid Lands Studies. Although the proposal was not funded on the first submission, a detailed method was designed for it. This method would be highly suitable for monitoring status and biodiversity of lizards, small mammals, and other animals in the dynamic context of an active metropolis.

A survey for the Giant Spotted Whiptail was conducted along Pantano Wash and the Cienega Creek County Preserve in the Vail region. Habitat was clearly suitable for this large, attractive lizard in parts of the County Preserve, and potentially suitable locally in Pantano Wash, but the species was not observed. The Giant Spotted Whiptail occurs in Chiminea Canyon in Saguaro National Park, and Empire Cienega in Las Cienegas National Conservation Area; historical factors, which are discussed in detail, may be responsible for the absence of the Giant Spotted Whiptail in the Vail region.

Recommendations to support lizard biodiversity in Tucson include preserving key populations at West Branch of Santa Cruz River, support for aquifers in the upper Rillito River basin, irrigation needed to support riparian mesquite bosque environments, and river park plantings that include bosque vegetation structure and a low, sub-shrub vegetation stratum. Little is known about conserving lizard populations in highly urbanized settings.

Distribution, Status, Ecology, and Conservation of the Arthropod-Eating Snakes Optimal conditions for survey of the Western Groundsnake developed during late winter and early spring of 2008. Populations on east side of Avra Valley (near downtown Marana and Red Rock) continue to survive under increasingly marginal circumstances. The population on the west side of Avra Valley was determined to extend at least 23 miles from the confluence of Blanco Wash at its north end with the Brawley-Santa Cruz River system near Silverbell Road up-drainage along the entire length of Blanco Wash and into a part of Brawley Wash in south-central Avra Valley. Several properties belonging to City of Tucson were confirmed to support this snake species, including on some re-vegetating farmland. The species was also confirmed in the Ironwood Forest National Monument portion of Blanco Wash.

The Western Groundsnake is a small, inoffensive, pretty snake that eats insects, spiders, and other arthropods such as scorpions. It is the most visible snake in urban Phoenix, where it is thought to be thriving in urban habitat. Further work warranted for

conservation of the Western Groundsnake in the metropolitan Tucson region would involve a study of the mode of existence of this species in urban Phoenix and additional survey in Three Points and southward into Altar Valley.

This report presents a detailed consideration of ecological restoration possibilities in Avra Valley in context of conservation of the Western Groundsnake and similar, unique desert species, including the Tucson Shovelnosed Snake, which has been petitioned for listing under the Endangered Species Act. Guidelines for preserving snake microhabitat are described. Conservation of mesquite bosque, savannah, and arid grasslands, and restoration of surface flow hydrology in Brawley Wash, which dominates the Avra Valley floor, are identified as key areas for ecological restoration.

Amphibian Distribution, Status, and Conservation Amphibian breeding sites were intensively surveyed in the Pantano Wash-Vail area during August 2006, yielding records for a total of 5 species of anurans (toads and toad-like frogs), plus the Lowland Leopard Frog and the non-native American Bullfrog. Several large, regionally significant populations of the Mexican Spadefoot and Great Plains Toad were found in pools along Pantano Wash and cattle ponds in the Vail area.

Amphibian breeding sites were also surveyed in the Tucson Southlands, which adjoins the Vail area, during 2005-6, yielding evidence of widespread, important breeding sites for 5 species of toads, including the Great Plains Narrow-mouthed Toad and Mexican Spadefoot. This represents the strongest amphibian population center remaining in the metropolitan Tucson region, although two other local areas – West Branch of the Santa Cruz River at Silverlake-Ajo and at San Xavier Mission – also support large populations. Development of a multi-jurisdictional concept for sustaining amphibian biodiversity in the Tucson Southlands should be an important conservation priority.

Amphibian breeding sites were surveyed in Avra Valley during 2004-6 and some further sites were identified during snake surveys in 2008. A total of only 4 species of toads was observed, plus the non-native American Bullfrog. Important breeding sites were identified in the Brawley Wash area near Three Points, with a wide scattering of sites found elsewhere, notably Black Wash Floodway, and Blanco Wash. During 2008, improved access to Blanco Wash revealed potential, high-quality breeding sites that have yet to be surveyed. Further targeted, intensive survey in Blanco Wash and Black Wash Floodway may be warranted.

Infrastructure designed for flood control was examined in detail from the standpoint of incorporating amphibian habitat into urban planning and management. A major report completed in 2008:

- Described the amphibian species of the metropolitan area
- Identified successful use of infrastructure by several toad species
- Outlined potential conflicts between maintaining amphibian breeding habitat and minimizing public health hazards posed by mosquito breeding in amphibian habitat
- Produced initial data showing predation on and control of mosquito breeding by tadpoles, backswimmers, tadpole shrimp, aquatic beetle larvae, and other aquatic insects

- Produced a set of design concepts integrating amphibian breeding habitat needs and biological control of mosquito breeding

The use of infrastructure and urban open space for amphibian conservation may now be explored by the City of Tucson Department of Conservation and Sustainable Development, the Habitat Conservation Plan Technical Advisory Committee, and other locally active agencies, particularly Pima County Flood Control District and Natural Resources Parks and Recreation Department, and U.S. Army Corps of Engineers. Key issues to address are:

- Formally incorporating amphibian conservation into infrastructure and ecological restoration plans, preferably under the HCP

- Establishment of working relationships among jurisdictions to coordinate implementation of such conservation in areas – including almost all regional amphibian population centers – with multiple jurisdictional control.

- Testing the effectiveness of proposed infrastructure designs for
    - Amphibian population success
    - Mosquito biocontrol

Lizard Population Evaluation / Monitoring Design

Background Observations made during 2005 indicated unexpectedly high lizard abundance in Tucson, especially along riparian areas. Lizard observation rates were as high or higher than those observed over many years in other environments in southern Arizona. This suggested that urban populations may be more significant regionally than previously suspected, and thus may merit attention within the HCP context as well as within the Sonoran Desert Conservation Plan (SDCP). Many of the most abundant urban populations are constrained along major riparian corridors closely hemmed in by urbanized landscape. It is not known if these populations can survive the large environmental fluctuations characteristic of the desert – especially powerful flooding.

Objectives (1) Evaluate urban riparian lizard population status in relationship to recent severe flooding of much of the occupied habitat, especially along Rillito, (2) confirm that previously observed high abundance relative to non-urban populations was not a temporary anomaly, (3) seek additional funding (i.e., Urban Wildlife Grant proposal to Arizona Game and Fish Department Heritage Program) to develop a suitable method for quantitatively monitoring abundance of target populations.

Methods Site visits were during 2006-7 to contrast 2005 and earlier 2006 results to those found in the aftermath of heavy midsummer rains and record flooding of the Rillito. Additional site visits were made to various urban sites and environments and to selected comparison sites in southern Arizona thought to support naturally high abundances.

Lizard abundance was recorded using time-constrained search (TCS) within habitat patches, with start and stop times, inactive times (i.e., personal hydration and cooling), and search activity-type recorded using a GPS receiver. Each lizard observed was recorded to species (or as “unidentified”) and age-size class, and results tabulated within habitat search blocks. This permitted rapid assessment of many species in multiple environments over a sizable geographic region.

Other animals and significant plants were also recorded and maintained with the lizard data in an Excel workbook. Digital field notes and images characterizing vegetation, substrate, and habitat features for lizards were also archived.

Results

Abundance and Diversity High Lizard abundance, averaging 45.4 lizards per hour of TCS was recorded throughout the Rillito-Tanque Verde washes system (Table 1) on a consistent basis, and cannot be considered a temporary anomaly. During 2005, I recorded an overall mean of 42.0 lizards/hr, compared to 43.9 in 2006, and 55.6 during limited survey in 2007. Observed lizard abundance in the desert is usually about 10 lizards per hour (reaching a maximum of about 32), for example in Avra Valley, Tucson Southlands, and Organ Pipe Cactus National Monument, which is a fraction of that found in Tucson’s major riparian corridors.

Generally, low diversity and high abundance were found in the downstream portions of Rillito, from 1st Avenue to Dodge Boulevard or Alvernon Way. This is a highly urbanized, constrained reach with narrow xeroriparian habitat in an originally relatively xeric part of Tucson’s major riparian corridors.

Table 1. Time-constrained search results for lizards along the Rillito River system, Tucson, Arizona, from downstream to upstream. Search was confined to diurnal lizards (one gecko was observed incidentally). Repeat surveys between Country Club Road and Dodge Blvd are shown for 2005-7.

			Number of Individuals Observed										
Locality (Reach)	Total Lizards / hr	Total TCS Time (hr)	*A. tigris*	*A. sonorae*	*U. ornatus*	*Uta*	*S. magister*	*S. clarkii*	*Callisaurus*	*P. solare*	*Coleonyx*	unID'ed lizards	All Lizards
Rillito (lower)	34.1	1.35	19	0	1	2	7	0	15	0	0	2	46
Rillito (central)	54.1	5.75	115	0	9	1	29	0	125	0	0	32	311
Rillito (upper)	58.7	5.93	116	1	6	3	36	0	103	1	0	82	348
Ft. Lowell area	75.7	3.77	97	8	11	3	20	2	107	0	0	37	285
Tanque Verde (lower)	49.4	5.17	66	0	45	8	28	4	73	1	0	30	255
Tanque Verde (central)	27.0	5.03	29	0	15	10	12	1	43	0	1	25	136
Tanque Verde (upper)	25.7	7.83	7	55	29	2	19	6	24	0	0	59	201
Overall	45.4	34.83	449	64	116	29	151	13	490	2	1	267	1582
Rillito (central)													
2005	56.3	1.07	17	0	1	0	9	0	29	0	0	4	60
2006	52.6	3.10	66	0	3	1	12	0	56	0	0	25	163
2007	55.6	1.58	32	0	5	0	8	0	40	0	0	3	88

From Columbus Blvd to the confluence of Tanque Verde and Pantano Washes (forming the Rillito) at Craycroft Road, lizard abundance and diversity were both high, with over 100 lizards/hr recorded at the Pima County Search and Rescue property in intact bosque on the north side of Rillito at Craycroft. This is significant for three reasons: (1) it is as high, if not higher, than lizard abundance recorded anywhere else in southern Arizona, if not the American Southwest; (2) it occurs in rich, intact mesquite bosque above the concrete embankment of Rillito, providing a model for lizard conservation in the system; and (3) it is at a site readily accessible by the public adjoining the river park system.

The plant community here is of interest as well. Bosque trees are mesquite, catclaw acacia, desert hackberry, graythorn, blue paloverde, Mexican paloverde (*P. aculeata*), elderberry, and netleaf hackberry, with cottonwood growing near the building. The understory contains a rich mix of a few shrubs (wolfberry), two species of vine milkweed, and a rich mix of native forbs, including desert tobacco, Gooding's verbena and several other, showy annuals, fiddleneck (*Amsinckia intermedia*) and many others. Raptors, roadrunners, other birds, and snakes are also abundant at this site. However, the site apparently is not recognized as anything special by the government.

Pantano Wash upstream from Wilmot Road, which is not far above the Tanque Verde confluence, becomes a large desert arroyo with substantial, though not unusual

lizard abundance and diversity, like that of Agua Caliente Wash above the influence of Tanque Verde Wash; these sites had an observed TCS abundance of 26.8 lizards/hr. No formal observations have been made, except in the reach between Houghton Road and Vail, where searches for the Giant Spotted Whiptail were conducted (see below).

Upstream from the Rillito, Tanque Verde Wash continues as a rich bosque along most of it length to the base of the Rincon Mountains at Cebadilla Spring and Tanque Verde Guest Ranch. Diversity remains high, as in the upper Rillito; riparian species such as the Sonoran Spotted Whiptail largely replace desert species like the Tiger Whiptail; but abundances generally decrease from the high levels seen in the center of old Fort Lowell Military Reservation, at Craycroft Road.

The richest portions of Tanque Verde Wash currently are at the Agua Caliente Wash confluence near Mariposa County Club and Bonanza Avenue and from near Forty-niners Country Club to Cebadilla Spring. The spring is perhaps the most unique wetland site in the Tucson Basin, with a range of boggy-ground plants, uncommon birds, such as Bell's Vireo, and reptiles such as the Madrean Alligator Lizard, which does not occur elsewhere in this valley. Much of the bosque along this wash is teetering on the brink of collapse due to aquifer depletion.

Post-Flood Sustainability of Lizard Populations There was no evidence to suggest declines in lizard populations related to the record flooding of summer 2006 (Table 1). This is especially encouraging in light of the heavy utilization of the sandbed of the Rillito by one species in particular, the Zebra-tailed Lizard, which presumably escaped the floods by ascending the bank protection concrete to reach the limited available surrounding suitable habitat. Although these observations do not preclude the possibility that winter floods could largely eradicate a population of lizards that was inactive and buried in the sand bed, all species of lizards should be adapted to avoid overwintering in such locations. Therefore, such a catastrophic impact seems unlikely. Conservation of even limited habitat along Tucson's major riparian corridors seems warranted.

Grant Proposal A grant proposal with an advanced monitoring method proposed for lizards was submitted along with the Arid Lands Studies Department, University of Arizona, to Arizona Game and Fish Department, but it was not funded.

Riparian versus Non-Riparian Lizards in Urban Tucson Although this was not the focus of this study, a few comments will provide useful context for the findings reported here and recommendations to follow. Generally, lizard abundance can be moderate to high in Tucson wherever there is suitable cover protecting lizards from cats, dogs, and predatory birds like the Kestrel, Greater Roadrunner, and several smaller birds that readily attack small lizards (e.g., Curve-billed Thrasher, Cactus Wren, and, presumably, Great-tailed Grackle). Backyards may support abundances approaching those of parts of the Rillito, although diversity is far lower (Table 2).

Riparian areas, particularly the major riparian corridors that still have mesquite-dominated woodlands, support most of the original species in Tucson, and consistently high abundances. Certain lizard species seem incapable of persisting in residential areas: ground-running lizards such as the Side-blotched Lizard, Zebra-tailed Lizard, and Long-nosed Leopard Lizard are examples. The Regal Horned Lizard and Western Banded Gecko are also ground-dwelling lizards that are doing very poorly in residential environments of Tucson, though persisting. Thus, major riparian corridors are essential for current conservation of lizard biodiversity in Tucson, although long-term, predictable declines are occurring (Fig. 1).

Current planting patterns in many areas of the river park system in Tucson support high lizard abundances. All these plantings are dominated by creosotebush, saltbushes, brittlebush, and widely spaced blue paloverde, mesquite, and other shrubs such as desert willow. In all cases, only the typical desert lizards, at low biodiversity, are supported. The planting pattern has proven insufficient for riparian biodiversity preservation or enhancement.

It is highly likely that additional lizard species could inhabit residential areas in Tucson. Ordinary-sized backyards with rich native desert plantings in the older parts of central Tucson support populations of the Regal Horned Lizard and Western Banded Gecko. Clark's Spiny Lizard occurs in riparian-like plantings in modern planned housing developments along the Tanque Verde and Rillito; it still occurs in highly urban downtown; and is reported in neighborhoods near the University of Arizona. Other riparian-obligate species such as the Giant Spotted Whiptail could also likely become established. Little effort has been made to determine if ground-dwelling species could live in the city if sufficient cover was present. Thus, although riparian conservation is the focus for lizard biodiversity conservation in the city now, conservation in residential areas is of significant interest.

Recommendations Several points, some of which may find application as the city expands and modernizes, can be drawn from the observations presented here:

- Conservationists should recognize the high value and potential sustainability of lizard biodiversity in Tucson based on the very high abundances recorded
- Biodiversity enhancement for lizards requires two planting schemes not currently in use, which could be employed:
  - Mesoriparian (bosque) vegetation and structure
  - Complex cover with low shrub vegetation (a "sub-shrub" vegetation stratum)
- Aquifer depletion in major parts of Tucson primary riparian corridors should be recognized as a major regional impact on biodiversity
- Research needed on lizard abundance and biodiversity in residential and park environments in Tucson should be supported, with particular reference to evaluation of:
  - Enhancement of biodiversity through adjustments of cover (vegetation, rock, etc.)
  - Establishment of native lizard species into suitable, unoccupied habitat by introduction

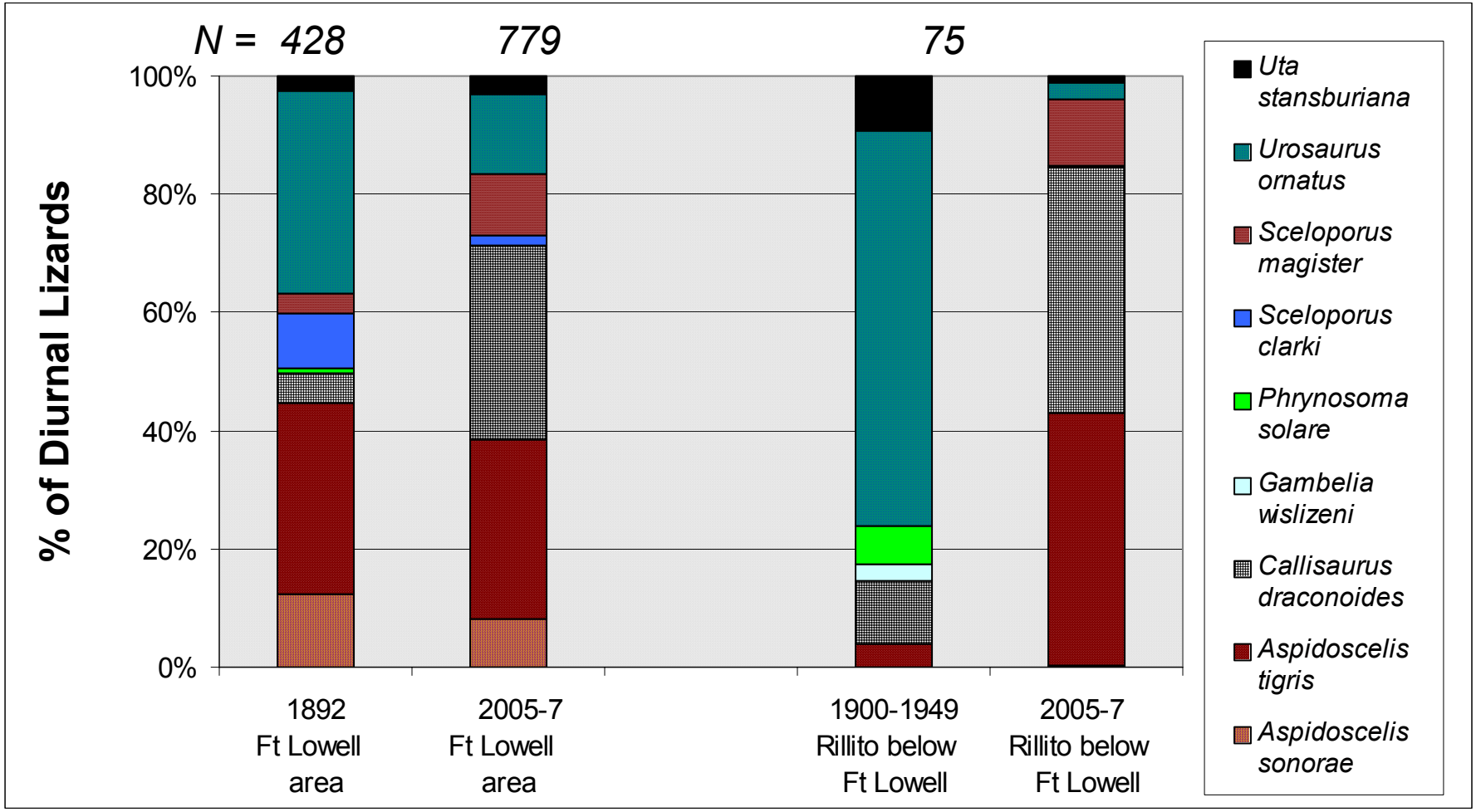

Figure 1. Changes in the lizard assemblage of Rillito River riparian based on museum records (19th and 20th centuries) and recent surveys (21st century).

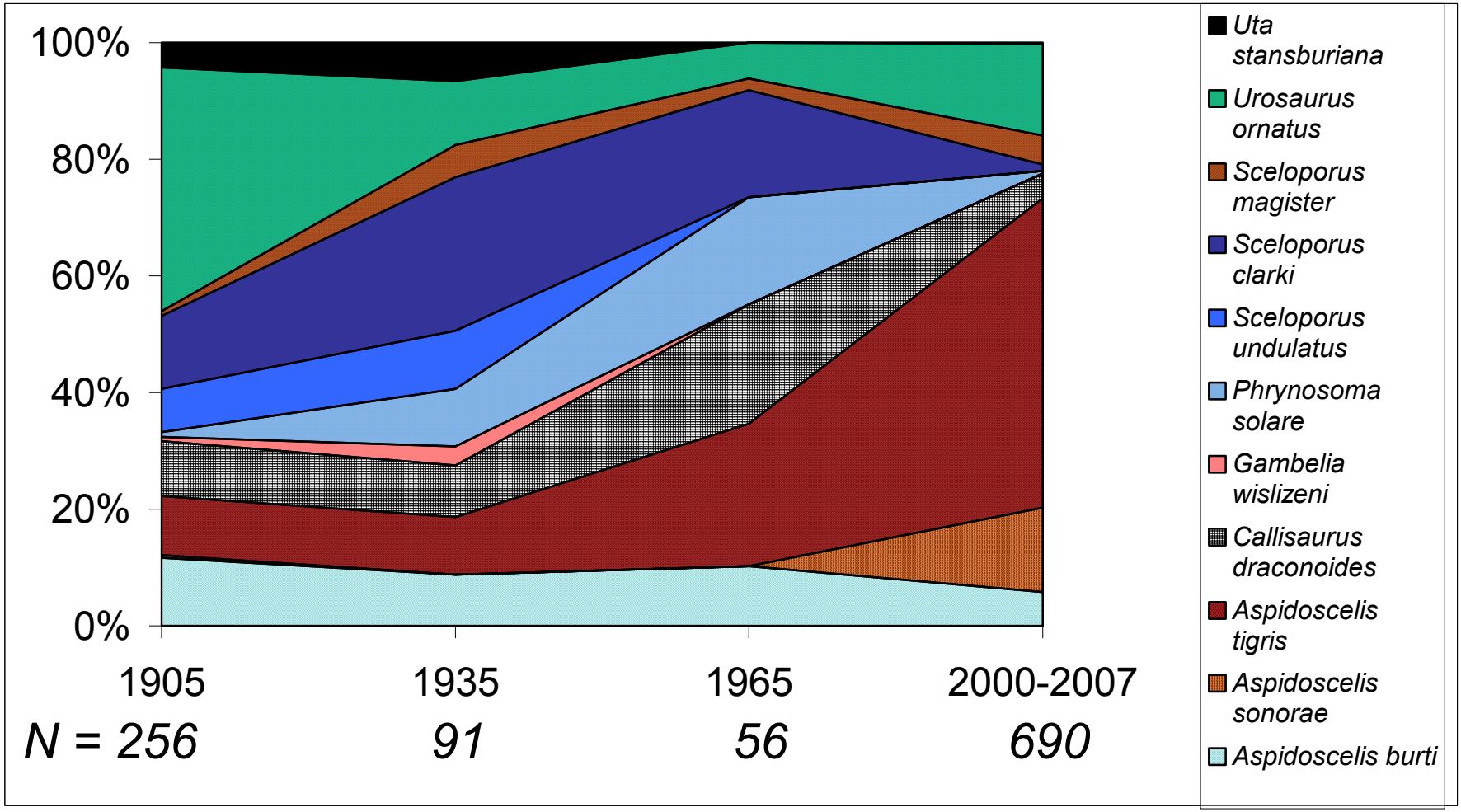

Figure 2. Changes in the lizard assemblage (percentage of records of diurnal species) of the Santa Cruz River riparian based on museum records (19th and 20th centuries) and recent surveys (21st century). The recent surveys were focused primarily on optimal remaining riparian environments, especially at the West Branch of the Santa Cruz River, and the changes indicating decline in riparian taxa are therefore conservatively under-represented.

Table 2. Lizard species (*n* = 19) status in urban metropolitan Tucson. Alternative names are in parentheses. Abundance is ranked in order: A (abundant), C (common), U (uncommon), R (rare), and E (extirpated); "na" indicates taxon would not occur in the indicated environment.

		Abundance				
Taxon	English Common Name	Ripa-rian	Resi-dential	Over-all	Status in Tucson	Annotations
Iguana-like lizards:						
Callisaurus draconoides	Zebra-tailed Lizard	A	E	C	Stable	Riparian obligate in city
Cophosaurus texanus	Greater Earless Lizard	U	U	U	Stable	Catalina Mountains base & bajada
Dipsosaurus dorsalis	Desert Iguana	R	na	R	Declining	Low desert (marginal in Tucson)
Gambelia wislizenii	Long-nosed Leopard Lizard	E	E	E	Extirpated	(Desertscrub)
Holbrookia maculata	Common Lesser Earless Lizard	R	R	R	Unknown	Semi-Desert Grassland
Phrynosoma solare	Regal Horned Lizard	U	R	U	Declining	Rare in alleys and yard
Sceloporus clarkii	Clark's Spiny Lizard	U	R	U	Declining	Meso-riparian; and downtown
S. undulatus cowlesi	Southwestern (Cowles') Fence Lizard	E	na	E	Extirpated	(Santa Cruz riparian obligate)
S. magister	Desert Spiny Lizard	A	C	A	Stable	Abundant in neighborhoods with cover
Urosaurus ornatus	Northern (Ornate) Tree Lizard	C	A	A	Stable	Most abundant lizard in city
Uta stansburiana	Common Side-blotched Lizard	U	R	U	Unknown	Requires low shrub stratum as cover
Whiptails:						
Aspidoscelis sonorae	Sonoran Spotted Whiptail	C	U	C	Increasing	Riparian (common); residential (uncommon)
A. stictogramma burti	Giant Spotted Whiptail	R	E	R	Declining	Santa Cruz riparian obligate
A. tigris	Tiger (Western) Whiptail	A	C	A	Stable	Abundant in neighborhoods with cover
Skinks and Alligator Lizards:						
Elgaria kingii	Arizona (Madrean) Alligator Lizard	R	na	R	Unknown	La Cebadilla Spring and canyons only
Eumeces (Plestiodon) obsoletus	Great Plains Skink	U	na	R	Unknown	Canyons only
Geckos:						
Coleonyx variegatus	Western Banded Gecko	U	R	U	Declining	Rare in yards
Hemidactylus turcicus	Mediterranean House Gecko	R	A	A	Increasing	Exotic species; on buildings only
Beaded Lizards:						
Heloderma suspectum	Gila Monster	U	U	U	Declining	Suburban only

Giant Spotted Whiptail Survey – Pantano Wash-Vail Area

Background The Giant Spotted Whiptail (*Aspidoscelis burti stictogramma*) is a Priority Vulnerable Species (under the Sonoran Desert Conservation Plan) that currently occurs at West Branch of the Santa Cruz River, upper Tanque Verde Creek, and in major canyons including Sabino and Chimenea canyons in the Catalina-Rincon Mountain complex. It has declined in valley riparian settings, but is still found along Cienega Creek in Empire Valley. This is a sizable, attractive, and interesting lizard that would be a significant enhancement of apparent biodiversity in the HCP area.

Objective Determine if this species occurs in the HCP area, with a focus on the area along Pantano Wash and Cienega Creek from Vail to Pantano.

Method This work will involve a brief visual encounter survey before 15 September 2006 targeted at dense riparian and xeroriparian vegetation located using remote imagery. I will attempt to capture and/or photo-document species occurrence.

Results Many lizards of diverse species, but no Giant Spotted Whiptails, were found in the survey area (Table 3). Habitat conditions were too open and desert-like for this species in the Pantano Wash and Vail regions, but suitable habitat (see below) was found along lower Cienega Creek in the Pima County Natural Reserve.

Table. 3. Number of lizards observed during surveys at Pantano Wash and Cienega Creek xeroriparian and hydroriparian environments, Pima Co., Arizona, August-September 2006.

Taxon	Pantano Wash (Vail area)	Cienega Creek County Preserve
Callisaurus draconoides	5	
Cophosaurus texanus		2
Phrynosoma solare	3	
Sceloporus clarkii		4
Sceloporus magister	1	
Urosaurus ornatus		3
Uta stansburiana		1
Aspidoscelis sonorae	1	10
A. tigris	11	4
A. uniparens		3
Heloderma suspectum	3	
All Lizards	24	27

Discussion The absence of the Giant Spotted Whiptail in the survey area is part of a puzzling pattern, and requires further study as well as discussion. The species is also absent from other valley areas with suitable habitat, notably including the Santa Cruz River between its confluence with Potrero Creek/Nogales Wash and Tubac and Sonoita Creek from Patagonia to the Santa Cruz River. All these areas, including the Cienega Creek Natural Preserve, are at suitable elevations, have dense stands of mesquite bosque, as well as significant areas of gallery forest along perennial water, which together define optimal conditions for the Giant Spotted Whiptail in Arizona. The explanation for its absence from such areas likely lies in two interacting arenas – environmental history and ecological landscape.

Environmental history may be primary. The Giant Spotted Whiptail is probably absent from apparently suitable areas because these areas either suffered tremendous degradation during the 20th century, and because of low re-colonization rates compared to sympatric, competing species of all-female, parthenogenetic ("weedy") species of whiptails. The all-female species are at advantage under high disturbance regimes for two principal reasons. First, only a single immigrant is required to found a lineage, since all individuals are female, a 4-fold advantage (probability of one immigrant of a bi-sexual species being a female is 0.5, for two of two is 0.5 X 0.5 = 0.25). Second, the rate of population growth for a unisexual species following disturbances that collapse population size far below carrying capacity, and then permit density-independent, exponential population growth is twice the rate of that for a bi-sexual species for each generation of exponential growth (2X in Gen1; 4X after Gen2, 8X after Gen3, etc.). Thus, stability as well as suitable habitat is both apparently critical. The bi-sexual Giant Spotted Whiptail is advantageously adapted to the subtropical conditions of stable bosque thickets and dense thornscrub. It therefore has advantages when whiptail lizards become abundant, competition and predation become intense, and thus density-dependent conditions predominate. However, whiptails are all rather similar ecologically, and it is possible, or even likely, that the changes toward stability under density dependent conditions occur slowly in context of frequent human-caused habitat alteration. It is even quite possible that established communities dominated by the bi-sexual Tiger Whiptail in desert habitat and the unisexual Sonoran Spotted Whiptail in thornscrub-grassland transition areas as well as in the core habitat of the absent Giant Spotted Whiptail may be very difficult for the Giant Spotted Whiptail to re-invade successfully even when suitable, reproducing migrants do arrive. The presence of the Desert Grassland Whiptail, a grassland-desertscrub transition species, in the grassland margins of Giant Spotted Whiptail habitat may further reduce the expected success of recolonization by the Giant Spotted Whiptail.

While the only apparent evidence in support of these speculative mechanisms is the landscape pattern of presence-absence of the Giant Spotted Whiptail and its congeners, historic data and recent monitoring of the species at West Branch of the Santa Cruz River offer significant insight. At the dawn of the 20th century, the Giant Spotted Whiptail was abundant along the river at Tucson, and was the only whiptail collected in its habitat. As the river degraded, the Tiger Whiptail and Sonoran Spotted Whiptail both invaded and have apparently become overwhelmingly dominant (Fig. 2), as might be expected. It is the waning presence of the Giant Spotted Whiptail that is notable: after nearly 100 years in which it existed in what had become – based on inferred habitat requirements as well as the observed trend of gradual decline – marginal or unsuitable habitat, the species still persists at and near the West Branch. This persistence suggests that the changes we are seeing, while entirely predictable, are considerably slower than we would expect. They are consistent with a concept that whiptail species are similar ecologically, and that, without frequent catastrophic ecological disturbance, changes in a site are slow and observed abundances retain a historic component for many decades.

Other historic and landscape factors seem likely to be involved as well. The absence of the Giant Spotted Whiptail from the Tumacacori-Tubac region of the Santa Cruz River could date to early historic or ancient times when the river was not perennial there due to natural, pre-sewage effluent conditions and agricultural diversions that began in Hohokam times or before. This suggests we have recently created suitable conditions for the species but it has been excluded for reasons outlined in the preceding paragraphs. A similar situation may very well exist along the river's effluent-dominated

reach downstream from the Roger Road sewage treatment plant, in Tucson and Marana.

The absence of suitable thornscrub habitat on uplands surrounding suitable Giant Spotted Whiptail habitat on lower Cienega Creek, Babocomari River, and the San Pedro River may also play a historic role in setting the initial state and subsequent development of the lizard communities there. Each of these riparian environments are surround by grassland- or desertscrub-dominated uplands unsuitable for the Giant Spotted Whiptail, whereas Empire Cienega is proximal to thornscrub environments (exemplified by Davidson Canyon, which is occupied by the Giant Spotted Whiptail), where the species could persist when fires and overgrazing damaged its riparian niche severely. A similar explanation may apply to Sonoita Creek, although much more survey is needed to ascertain that the Giant Spotted Whiptail is really absent from that site, where it was previously documented.

An additional landscape-ecological factor may be operating at Cienega Creek Natural Reserve. The deep, steep-walled arroyo cut that developed there in early 20th century abruptly separates semi-arid desertscrub and semi-desert grassland uplands from inundation-prone riparian gallery forest and bosque. Dense, mature bosque thickets occur in a very narrow band along the still mostly vertical arroyo walls and in a few local areas such as Pantano Jungle, the corrals at the middle of the reserve, and near the railroad tracks at the easternmost, upper portion of the reserve. As with habitat for the existing Desert Box Turtle population, the inundation of gallery forest by raging floods confined within steep arroyo walls mitigates against the gallery forest bottomlands being successfully used by terrestrial riparian species.

These considerations need to be verified by research that will likely require a number of decades. They are, however, the best available operative hypothesis available, upon which management decisions should be based. They predict that habitat suitable for the Giant Spotted Whiptail currently exists in several riparian preserves, and that with a suitable effort, it could be established there.

This large whiptail is undoubtedly the most visually spectacular whiptail in the region, and is probably a significant ecological force where it is thriving. Perhaps more feasible and more accessible to our enjoyment would be establishment of the species in human-occupied areas in which we have created suitable habitat. This lizard lives around homes in the West Branch area, and occurs on the grounds of the Ventana Canyon resort. In the context of an urban wildlife conservation plan, the species could likely be established at carefully selected habitat areas. However, the self-establishment or re-establishment of this species in suitable, un-occupied natural riparian areas, such as lower Cienega Creek, will likely be slow, if it occurs at all. Nor will it likely successfully colonize, and thus will not establish itself, without human assistance anywhere in urban or suburban metropolitan Tucson. Furthermore, unless a significant amount of additional water is delivered to the West Branch of the Santa Cruz River, the species is almost certain to be extirpated there very soon, foreclosing the chance that that persisting population could expand into a stable, re-vitalized downtown region, as well as eliminating a unique genotype that may be particularly adapted to valley riparian settings.

Recommendation If the Giant Spotted Whiptail is to be part of the wildlife of the Tucson region, outside of mountain canyons in the Santa Catalina and Rincon Mountains, at least on of two actions must be taken. First, the West Branch population should be secured by provision of water to enhance stable, mesic bosque thicket conditions – at a minimum – or meso-hydro riparian conditions – maximally. Second, an attempt must be made to establish and propagate the species artificially in relatively

mesic, human-dominated environments, such as parks, resorts, around large richly-landscaped buildings, or in residential yards; I have a permit to attempt this, but the effort is more complicated and time-intensive than can be properly attempted on an ad hoc, volunteer basis.

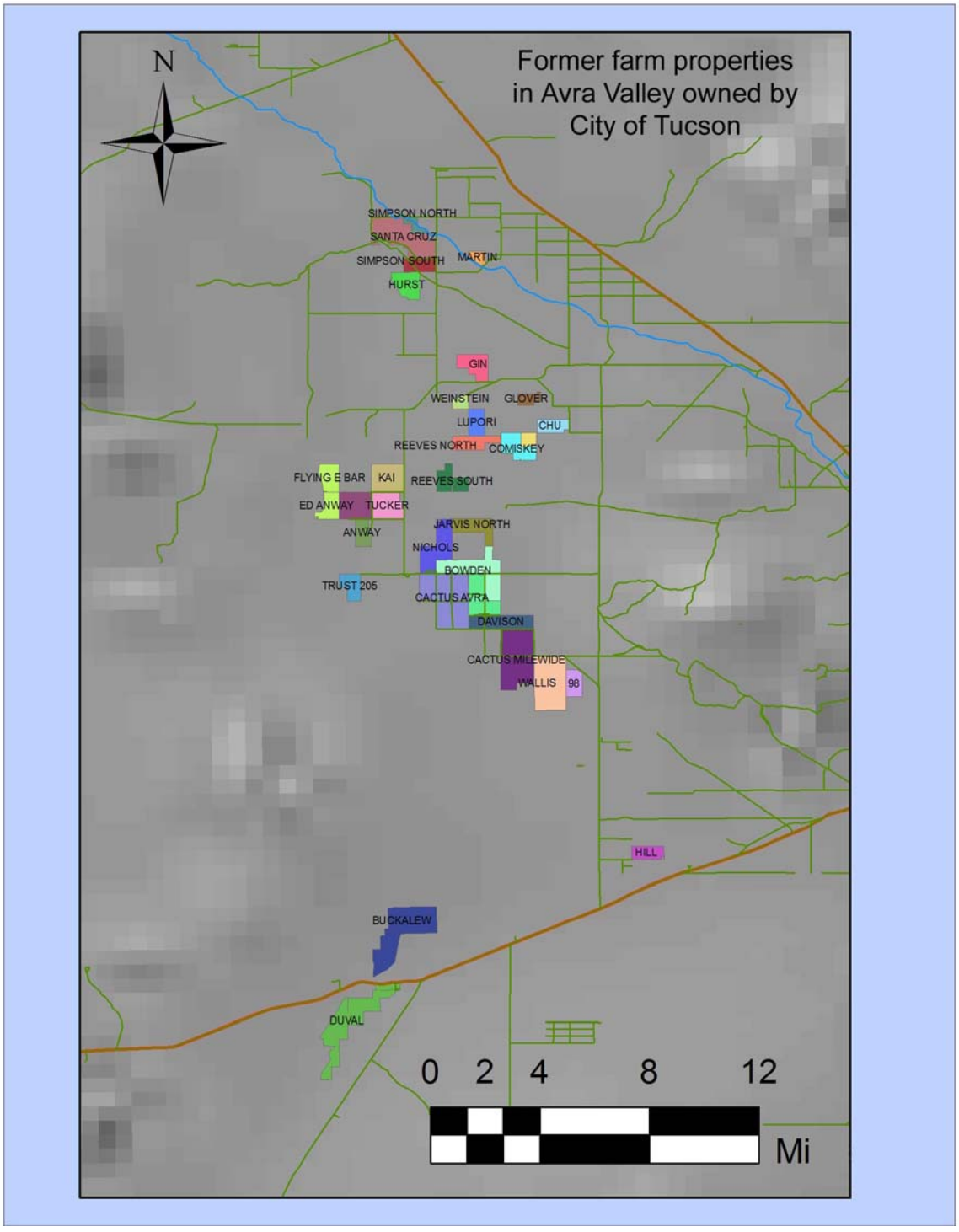

Figure 3. Guide to names of city properties in Avra Valley.

Western Groundsnake Survey in Avra Valley

Background The Western Groundsnake (*Sonora semiannulata*) is a Priority Vulnerable Species and is a focal species in the COT HCP. The interest in protecting this species, which is widespread in southwestern United States, reflects the isolated population that occurs locally on Sonoran Desert valley floors (Fig. 4) Persisting populations have been found in 2003-6 in local areas on the east and west margins of the Avra Valley floor. Good summer rains in 2006 and winter 2007-8 offered the opportunity to significantly enhance existing survey results, focusing on and near COT properties in Avra Valley.

Objective Survey for this species on and near COT property in Avra Valley.

Method Assistance for access will be sought from Tucson Water Co. with the assistance of TAC. The survey will consist primarily of cover turning on mid-valley floodplain sites spanning Avra Valley from Three Points to near the Pinal County line. Time-constrained search (TCS) methods will be followed and results accumulated for other animals encountered during the late September-November sampling period.

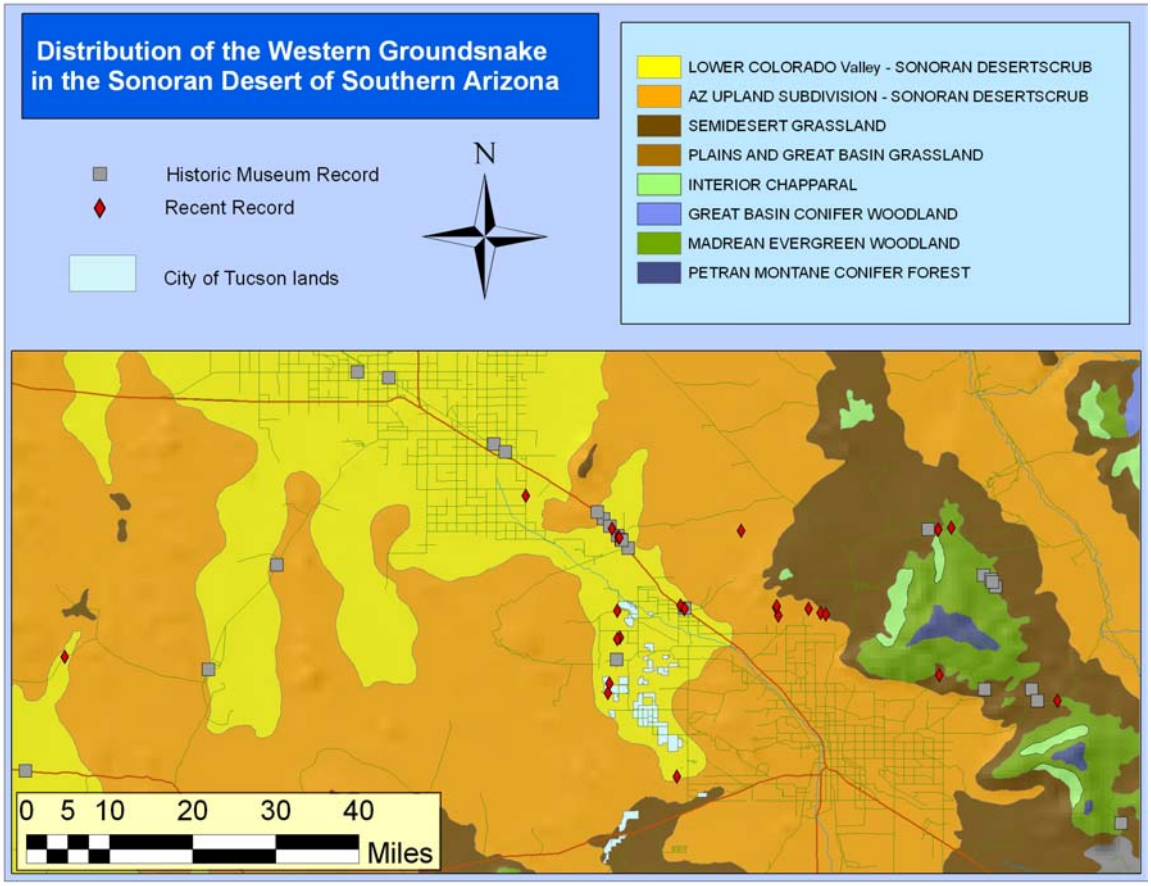

Figure 4. Distribution of the Western Groundsnake on valley floors mapped as part of the Lower Colorado Valley province of the Sonoran Desert in southern Arizona. Records are considered recent if after 1989.

Results The unique, tan, unicolored population of the Western Groundsnake that was well-known from near the junction of Park Link Drive and I-10 Frontage Road is

extirpated, or nearly so, by desiccation produced by the interruption of sheet flow from the Tortolita Mountain bajada by the Central Arizona Project canal. However, within 1/3 to 1 mi NNW of this junction, bosque thickets remain in a wash, tank, and flat valley floodplain environment still suitable for this snake. A single hatchling was found at the northern end of this site in 2006. This small area may support the only remaining valley population of this species in the immediate region, and the only remaining representative of the local genotype.

A second population is known along the east side of Avra Valley, and it appears to be even more restricted spatially, possibly be restricted to a narrow band of mesquite along the I-10 Frontage Road occurring approximately 0.15-0.25 mi north of the Marana Road exit intersection of I-10. All six records known to me, spanning five decades, may have been obtained within an area of less than one-tenth of a mile along the frontage road. I identified a spot where ditch drainage and surrounding bosque thicket cross under roadway as the likely source of this local hotspot for the Western Groundsnake in the local region, and I have looked for the species along the much more extensive bosque along I-10 several times. In spring 2008, I found two large males together at precisely the spot I identified (i.e., within 10 meters, on the bed of the ditch near the box culvert) as the likely population hotspot. Although additional search of the long bosque along the east margin of I-10 from Rillito Station to Park Link Drive should be conducted, and the habitat would appear suitable, the existing evidence increasingly supports a hypothesis that the species is confined in a miniscule population that should be protected from catastrophic disturbance or alteration, or that should be salvaged as a genetic resource. All individuals found in this populations were tan with a bright scarlet-orange mid-dorsal stripe the length of the body.

More auspicious results were obtained along Blanco Wash, on the other side of the valley floor. The findings along I-10 are directly relevant to this Avra Valley population of the Western Groundsnake, much of which occurs on City of Tucson lands controlled by the Tucson Water Company, and all of which may be confined within “important Riparian Areas” (or adjoining lands that belong in that category) identified in the Pima County Sonoran Desert Conservation Plan. The I-10 populations are extremely local, as indicated by the tight clustering of the two sets of locality records. The nearest known populations appear to be fairly distant from these, on the north side of Picacho Peak in the narrow band of flats remaining at the margin of Santa Cruz Flats agriculture and possibly in Eloy, and in semi-desert grassland and Arizona Upland desertscrub in the base of the Tortolita Mountains. The hypothesis that the populations near I-10 are small is supported by their lack of polymorphism, which suggests genetic drift and/or natural selection effects that are likely to be most prominently seen in small, isolated populations. Thus, from the standpoint of regional biodiversity, the Blanco Wash population appears to be most significant, while the 1-10 populations, especially the one near Park Link Drive, may hold significant genetic resources.

Intensive sampling was conducted during late winter and early spring 2008, by turning cover in Avra Valley, with a focus along Blanco Wash on and near City of Tucson lands, and using those findings as a guide, contemporaneously in Brawley Wash areas with comparable habitat in central and eastern Avra Valley. Results demonstrate an extensive population along the entire length of Blanco Wash, from its confluence with the Brawley-Santa Cruz floodplain bottoms at northern West Silverbell Road near North Cocio Road southward 23 mi along the drainage to the north edge of the SAVSARP CAP-water infiltration project that is currently under construction.

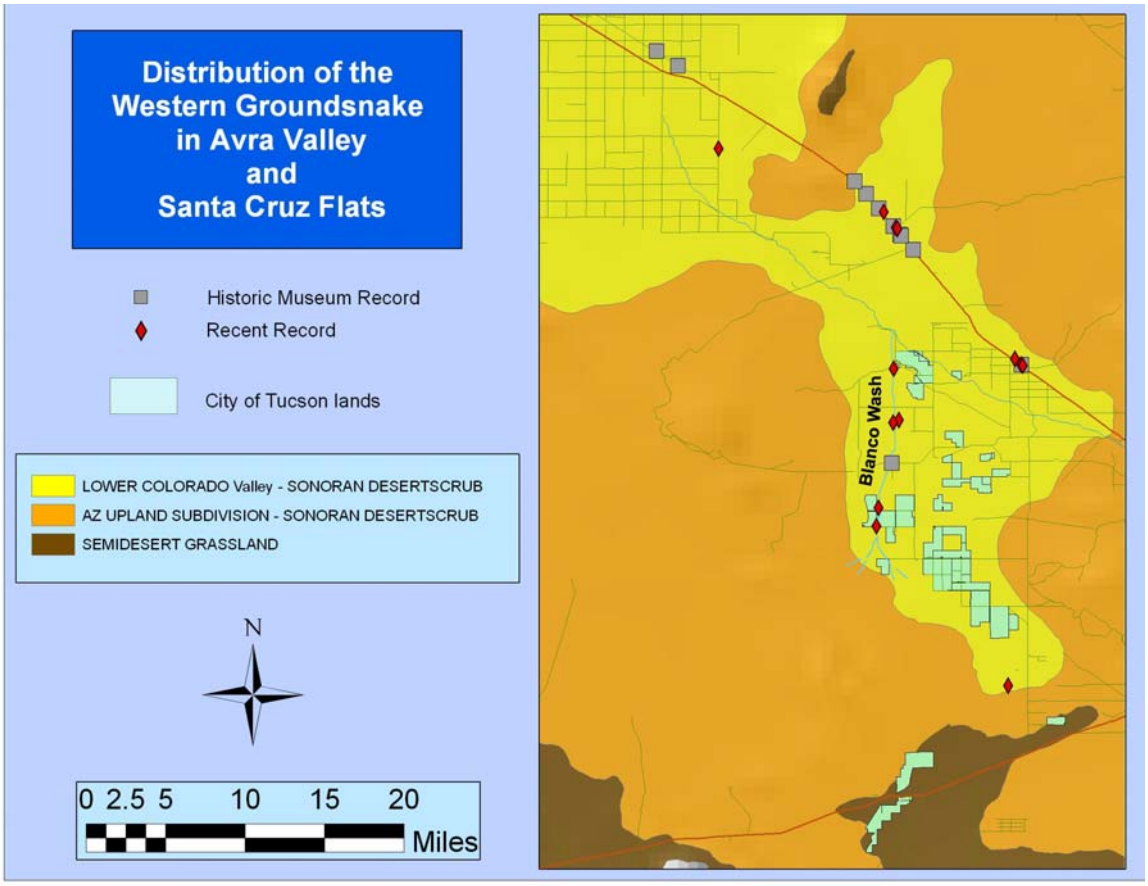

Figure 5. Distribution of the Western Groundsnake in Avra Valley and adjoining Santa Cruz Flats. Records are considered recent if after 1989.

All 6 records that I have obtained, during the 21st century, including 3 during spring 2008, and the original Tom Van Devender record from Avra Valley Road, were in areas with well-developed mesquite stands of medium to medium-tall stature growing on silty and clayey to very fine sandy loam soils. Of the 6 records I obtained, for which exact habitat conditions could be determined, one was at an abandoned residential property in a wildcat housing area adjoining Blanco Wash mesquite thickets, 5 were within major Blanco Wash mesquite thicket or bosque, and the southernmost was in an open mesquite stand in a region where Brawley Wash and the drainage head of Blanco Wash braid together and anastomose in the center of the southern Avra Valley floor. The latter record occurred on ground that had been utilized for agriculture, while all others were in areas with apparently un-plowed soil (Fig. 5).

Two morphs were found in the Blanco Wash sample: 4 individuals were tan with a red to scarlet-orange mid-dorsal stripe and 3 were tan with a bright orange mid-dorsum interrupted by black crossbars. Based on habitat considerations and the limited sample, there are likely a number of local subpopulations along Blanco Wash, Although this population is not likely entirely continuous, it is best regarded as a single metapopulation that has at least occasional genetic interchange by longitudinal dispersal between adjoining population cores, and in which natural colonization of suitable habitat will likely occur within a short, “ecological” time-scale.

Contemporaneous sampling was also conducted during late winter 2008, including at Pan Quemado adjoining an occupied area of Blanco Wash at a time when

moisture conditions were suitable for sampling the Western Groundsnake, but I found none, and there exist no such records from rocky hills and mountains covered with Sonoran Desertscrub in the Arizona Upland province of the Sonoran Desert in southern Arizona. Further, there are no Western Groundsnake records from Three Points, Ajo Way, and Altar Valley, although substantial herpetological data are available in museum catalogs. Likewise, with the exceptions along I-10 discussed in preceding paragraphs, there is no evidence indicating likely populations extending north of the Blanco Wash population. Nonetheless, additional sampling conducted by tracking the population and its habitat southward toward Three Points, and into the Altar Valley if that is successful, as well as north along the Santa Cruz River in southern Pinal County and west into the rocky desert slopes in Ironwood Forest National Monument adjoining Avra Valley might demonstrate the presence of additional populations. At present, the available evidence tells us that the Blanco Wash population most likely represents a largely linear, 22-26 mi long, isolated, but substantial, population of the Western Groundsnake (Fig. 5).

Conclusion Blanco Wash represents the focal area for conservation of the regional population of the Western Groundsnake in the Sonoran Desert. Two other, very local, small populations are known to remain long I-10, at Marana and Red Rock, with an additional, also probably limited population area near Picacho and Eloy. More extensive populations probably exist at low population densities in semi-desert grassland in the base of the Tortolita and Santa Catalina mountains and Redington Pass. All valley populations remain unprotected except for a small area of Blanco Wash that is within Ironwood Forest National Monument.

Recommendations Blanco Wash should be recognized as a unique conservation resource in Avra Valley that has suffered less degradation than most or all of the rest of the Brawley Wash system that occupies the entire central flats of the Valley between Altar Valley and the Santa Cruz River. Existing unplowed habitat along the entire Blanco Wash corridor should be recognized within the category of “Important Riparian Areas”. Within an urbanization context, Blanco Wash deserves consideration as a linear park feature. When construction occurs within the Blanco Wash bottomland, extensive blading, which is often done during the development of “planned communities”, should be minimized.

The City of Tucson could preserve occupied habitat of the Western Groundsnake with suitable management of parcels along Blanco Wash. Regenerating mesquite, desertscrub, and grass environments on the central and eastern valley farms would also likely become occupied by the Western Groundsnake, and some may already be occupied.

The following 28 May 2008 *document, requested by the Department of Conservation and Sustainable Development in context of the HCP, is inserted within this report.*

ECOLOGICAL RESTORATION IN TUCSON-OWNED AVRA VALLEY LANDS IN CONTEXT OF CONSERVATION OF THE WESTERN GROUNDSNAKE AND TUCSON SHOVELNOSED SNAKE

Introduction The Avra Valley – by name an open plain, “La Abra” – is dominated by the braided, anastomosing floodplain of the Brawley Wash system, which spreads across a broad, largely level valley center from Robles Junction north 30 miles to the Santa Cruz River confluence near the Pima-Pinal county line. The level valley-center flats range from 4 to 9 miles across, with a narrow point near and above (south of) Mile Wide Road. At Robles Jct (= Three Points), Brawley Wash emerges from Altar Valley (where it is

called Altar Wash) and broadens as its alluvia merge with sands from the massive Sierrita Mountain bajada, along Ajo Way.

The Brawley is joined by similar washes, Black Wash from the southeast near Snyder Hill, and it spills into the east head of Blanco Wash near West Mile Wide Road. Although there is a small rise of sand near Anway Road, between Blanco Wash and the Brawley extending up to Avra Valley Road, the 4-9 mile valley center is occupied by the braided system for about 22-23 miles. Near Avra Valley Road, this lowland is separated from the Santa Cruz River by the 8 m high Silverbell Sand rise, which extends north about 6-7 miles to the confluence.

There, at 1 and ½ miles south of the county line, the Brawley system is called Robles Wash. It joins the Santa Cruz floodplain bottom, continuing NNW past La Osa Ranch near Sasco Road, where the combined system produces the Santa Cruz Flats – the large "sediment plug" that has isolated the Santa Cruz Basin from the Gila River for many millennia, or eons.

Two major habitat-creating resources are input to the Avra Valley as a result of the unique characteristics of this system – water and sediment. While rainfall may be only about 12 inches in Avra Valley, water flowing down the Brawley system and into it from surrounding mountain bajadas jacks up the effective plant-available moisture to levels capable of supporting mesquite bosque and semi-desert grasslands. Sediments transported by the system may be deposited or exported. Deposits provide the raw material for wind sorting, which produces sands, while export of sands leaves behind dense, hard adobe soils.

The two snake species given special consideration here have correspondingly different habitat soil type requirements. The Tucson Shovelnosed Snake requires sandy soils in which to dig and "sand-swim", while the Western Groundsnake is confined in this region to dense, fine, floodplain soils, presumably by ecological interactions with specialized sand-swimming species. In the Avra Valley region, the shovelnosed snake population has contracted or disappeared, while that of another sand-swimmer, the Banded Sand Snake, has expanded. Although the reasons for this change remain poorly understood, here the focus is on the sand snake habitat niche, and assumes for these purposes that the Tucson Shovelnosed Snake population might be restored via management or natural processes. Their habitat requirements and management options for them will be considered in turn.

Western Groundsnake This relatively unspecialized species, with an ordinary-shaped head not well suited to digging or sand-swimming, is nonetheless an arthropod-eating specialist like both the Tucson Shovelnosed Snake and Banded Sand Snake. All these species eat beetle larvae (i.e., mealworm-like grubs), crickets and sand-burrowing cockroaches, centipedes, spiders, and scorpions. In all cases, abundant food is required for habitat to be suitable.

The groundsnake lives in relatively mesic floodplain bottoms in Avra Valley and Santa Cruz Flats, chiefly in areas that now support mesquite bosque or, more rarely, open stands of mesquite. It occurs along at least a 23-mile long line composed of the entire length of Blanco Wash on the western margin of Avra Valley and into the western side of Brawley Wash in the southern part of the valley where is connects to Blanco Wash. So far as known, this population does not extend further south into Altar Valley or the Sierrita Mountains, nor east or west into the Tucson Mountains or Roskruge Mountains.

It is isolated, with the nearest known population occupying a tiny area at Marana just east of I-10 (also in valley floor mesquite bosque).

Sheet flow across the silty-sandy, braided bed of Blanco Wash produces suitable habitat for the Western Groundsnake, and all records except the southernmost are from this specific zone, in open to dense, moderate-stature mesquite bosque. On City of Tucson lands in Avra Valley, even those formerly devoted to agriculture, the re-establishment of mesquite woodlands has created habitat occupied by, and probably required by, the Western Groundsnake.

In contrast, Brawley Wash lands, which have been stripped of sand and silt by channelization and drainage, leaving behind hard adobe soils, are, insofar as has been determined, un-occupied by this species. There appears to be too much erosion, and not enough pooling to provide suitable habitat. The mowing and removal of woody vegetation on former farmlands may, further, be restricting the re-establishment of mesquite woodlands and desertscrub, also preventing the re-establishment of suitable habitat for the Western Groundsnake.

The conservation requirements for the Western Groundsnake on City of Tucson lands in the Avra-Altar Valley can be summarized in three categories:

1) Preserve existing mesquite woodlands – both natural and re-growing – along west side of Avra Valley in Blanco Wash and its connecting area to Brawley Wash, and permit or encourage mesquite and other native plants to thrive on re-vegetating farmlands where drainage patterns are suitable.

   The key conservation areas are Trust No. 205 (natural, unplowed habitat), and several former farmland properties, in particular the Flying E-Bar, Edward Anway, and Anway farms, which together form a cohesive conservation unit, particularly if combined with small adjoining State Trust lands on which part of Blanco Wash flows and with the adjoining Ironwood Forest National Monument.

   On these lands, a thorough survey of habitat use by the Western Groundsnake would provide guidance for suitable habitat management. To begin with, little should be done that might disturb existing drainage patterns that support dense growth of mesquite. Once the situation is more clearly understood, the land may be de-fragmented by selectively breaking up concrete irrigation channel remains that cut off sheet flow and prevent the development of braided wash patterns.

   Non-toxic debris, such as the dead trees, irrigation concrete, boards, and pieces of sheet metal should not be removed, as they provide and enhance habitat for this snake, its prey, and many other native species. Existing high ground, such as levees, should also be left where they may serve as flood refugia and to supply habitat heterogeneity.

2) The creation and maintenance of habitat in the SAVSARP water infiltration plant near Sandario Road south of the Tohono O'odham Farms, near Donaldson Road, would likely permit the Western Groundsnake to persist or become established there, as it exists on the property's northwest margin.

   Mesquite woodlands, mesquite savannah, and semi-desert grassland environments would be expected to produce suitable habitat for this, and many other, species.

A similar consideration likely applies to the CAVSARP project area south of Mile Wide Road.

3) Restoration of natural sheet-flooding regimes in the main part of Brawley Wash in the Avra Valley center north of Mile Wide Road would likely produce suitable habitat for the Western Groundsnake as well as other species occupying floodplain bottomlands. This ecological restoration would apply both to unplowed ground, with widespread entrenchment and channelization of Brawley flow paths, and former farmlands, with similar channelization along with flow interruption by the grid of concrete irrigation ditches.

   Repairing the entrenchment and flow obstruction would produce natural irrigation of the desiccated floodplain surfaces and permit the deposition of sandy and silty sediments on them, also increasing vegetation diversity and productivity. In some areas, the addition of sandy sediments may allow wind-sorting to re-create lenses of sand suitable for sand-adapted snakes such as the Tucson Shovelnosed Snake and Banded Sand Snake (see below).

   As described in (1), above, removal of suitable cover and high ground should be avoided.

Additionally, some further survey of the distribution and habitat occupancy of the Western Groundsnake can be recommended:

4) Survey of Black Wash on the east end of SAVSARP site is needed, as is additional survey between SAVSARP and Robles Junction. Monitoring to understand the habitat use and the response of the Western Groundsnake to continuing recovery of farmlands will provide needed feedback for adaptive management, and will also be suitable to provide information on other species benefiting from the process.

Tucson Shovel-nosed Snake This relatively specialized snake occupies sandier, more open habitat than the Western Groundsnake, and probably helps exclude it from productive, sandy sites on the Sonoran Desert floor.

Although we lack a full, clear understanding of its habitat requirements in its range on the transition of Arizona Upland to Lower Colorado Valley Sonoran Desertscrub from Florence to Casa Grande to Marana, there is enough evidence to indicate that productive, mesquite-, catclaw acacia-, blue paloverde-, and creosotebush-dominated areas with sandy loam to very sandy soils are optimal. Productive swales and stabilized former dunes or sand lenses are characteristic formations that appear to enhance habitat suitability for the Tucson Shovelnosed Snake.

The homogenization of sandy-loamy tracts by leveling and mixing for farming operations may have contributed to habitat degradation that will persist beyond agricultural operations, although this remains a novel inference only at this time. Entrenchment of the Brawley Wash system has apparently led to massive erosion and export of sandy-silty soil components in many areas, leaving behind hard abode soils poorly suited to sand-adapted snakes and largely unsuitable for most other species of many ecological types.

Remaining sandy habitat in the Avra Valley portion of the originally known distribution of the Tucson Shovelnosed Snake occurs in just a few limited areas that I have seen:

- Locally as thin veneers and lenses I have found in central Brawley Wash in and near the City properties of Reeves Farm South and Reeves Farm North.
- On the slightly higher ground occupied by natural creosotebush-dominated desertscrub between Blanco Wash and Brawly Wash: in Reeves Farm South and adjoining State Trust and private lands north and south; and to the north of Gin Farm southwest of Brawley Wash.
- In parts of Cactus Avra Farm, especially the southwest portion, where creosotebush and blue paloverde are invading the extreme southwest corner near the corner of Transmission Line Road and Ft. Lowell Road.
- Throughout the Silverbell Rise from the Sanders Road-Avra Valley Road corner extending northwest across Trico Road to the Aguirre Road-Silverbell Road junction. Parts of the Hurst Farm and Simpson Farm South lie on this sandy rise, although much early work during the 1990's showed the presence of only the Banded Sand Snake in this area.
- On the lowermost bajada near Twin Peaks and the desert terrace above the Santa Cruz River northeast of Marana Regional Airport.

Other areas may support suitable sandy environments, but I have not fully investigated all of them. The Simpson Farm North site is very sandy, but probably unoccupied by sand-swimming snake species due to a history of flood inundation. The possibility that the Tucson Shovelnosed Snake could be established there could be investigated, and some further survey should be done there. However, my limited knowledge suggests there are several variables that could preclude this as an optimal area for recovering the Tucson Shovelnosed Snake.

Conservation action for the Tucson Shovelnosed Snake on City of Tucson lands in Avra Valley can be summarized in four parts:

1) Reeves Farm South is an obvious choice for a potential desertscrub reserve in intact habitat for the Tucson Shovelnosed Snake.

A focus for restoration on City of Tucson Lands in Avra Valley would involve three broad approaches:

2) Monitoring recovery of natural vegetation and fauna on Cactus Avra Farm and Lupori Farm, and any other farms in this general part of the valley's landscape where woody vegetation other additional to mesquite and desert broom may be re-growing on loamy soils.

This will provide information needed to evaluate how farmlands recover, which is presently not understood:

- Do they achieve something like the original desert condition?
- Do they reach a new state and, if so, is it a desirable state for the Tucson Shovelnosed Snake and associated components of biodiversity?
- Should and, if so, how should drainage patterns be re-engineered with respect to their current interruption by the grid of concrete irrigation channels?

3) Restoration of sheet-flow, braiding, and sediment deposition by Brawley Wash especially in the areas of Reeves Farm North, Comiskey Farm, and Reeves Farm south. Over time, enrichment of the vegetation and accumulation of sand and fine sandy loam may enhance or create habitat for the Tucson Shovelnosed Snake and other sand-adapted organisms.

   Other City of Tucson-owned former farmlands between Avra Valley Road and Mile Wide Road (especially Lefkowitz Farm, Jarvis Farm North, Bowden Farm, Jarvis Farm South, and part of Davison Farm) might also be treated in this way, particularly assuming recovery in initial site trials is evaluated as successful. The development of natural species of woody vegetation on these farms, as contrasted with continued mowing (e.g., on Bowden Farm and Chu Farm), should be encouraged.

4) Processes that enhance the accumulation of patches of sand and soft soil should be favored:

   - ❑ Creosotebush, mesquite-shrub complexes, and other shrubs that trap accumulations of wind-blown sand around themselves should be encouraged, and seeding of creosotebush in suitable areas of re-vegetating farmland could be considered.
   - ❑ Digging animals that have significant effects on soil should also be conserved, particularly large ones like the Bannertail Kangaroo Rat (which apparently occurs on Cactus Avra Farm), Merriam's Kangaroo Rat, and several smaller species of pocket mice in the kangaroo rat family (Heteromyidae).

Additionally, with respect to the possibility of recovery of the Tucson Shovelnosed Snake, there is a great deficit of information and understanding regarding the reasons for its decline and replacement by the Banded Sand Snake, and support for continuing research and survey can be recommended:

5) Study of habitat utilization, animal community structure in occupied habitat, and population trends of the Tucson Shovelnosed snake in the regions of Santa Cruz Flats and Florence is needed. This research should yield hypotheses of the mechanism(s) producing ongoing declines and offer avenues by which these declines may be reversed or re-established populations successfully managed.

Coda With regard to mitigation, attempts to save individual animals in areas undergoing residential or commercial construction remain infeasible for small, secretive animals like snakes. If populations are to be saved *in situ*, use of heavy equipment must be carefully regulated and monitored.

However, if attitudes or priorities change, or, more importantly, if it is decided that animal stocks of various kinds are needed for establishment elsewhere, intensive pre-blading and pre-construction collecting of animals (and plants) should be considered. Such salvage operations could be attempted with city and county direction to evaluate cost and feasibility. Many ecological restoration areas appear to lack whole suites of species, such as heteromyid rodents, that may be considered desirable.

Generally, salvage operations would be pre-construction, rather than during construction, and would involve intensive trapping (i.e., Sherman live-traps for mammals,

drift fence traps for reptiles and many other terrestrial species) and visual/auditory search and manual capture (e.g., for amphibians and some reptiles). For some larger animals, burrow surveys could prove useful (e.g., tortoises, badgers, etc.).

In this context, pre-construction surveys, as a precursor to salvage to supplement or establish new populations elsewhere, may be called for.

Literature The following, mostly unpublished, documents provide background and supporting material for the discussion and recommendations on snakes here:

Rosen. P.C. 2008. 2007 survey results for the Tucson Shovel-Nosed Snake (*Chionactis occipitalis klauberi*), with evidence for ecological change in south-central Arizona. Final report to Town of Marana and Arizona Game and Fish Department.

Rosen, P.C. 2006. Nocturnal rodents and ground-dwelling arthropods as habitat quality indicators on former agricultural lands in Avra Valley, Pima County, Arizona. Report to City of Tucson, Habitat Conservation Plan, Technical Advisory Committee.

Rosen, P.C. 2006. The amphibians and reptiles of the dry borderlands of northwestern Sonora and southwestern Arizona. Pp 310-337 in R. S. Felger and B. Broyles (eds.), Dry Borders: Great Natural Reserves of the Sonoran Desert. University of Utah Press, Logan, UT.

Rosen, P.C. Un-dated, ca. 2006. Survey question answers to City of Tucson regarding salvage of animals at construction sites.

Rosen, P.C. 2005. Preliminary findings for Avra Valley with focus on Tucson Water Company lands: a preliminary interim report. Report to City of Tucson HCP Technical Advisory Committee, 9 October 2005. 6 pp.

Rosen, P. C. 2004. Avra Valley snakes: Marana survey report for the Ground Snake (*Sonora semiannulata*). Final Report to Town of Marana on Ground Snake. 17 pp.

Rosen, P. C. 2004. Ecological opportunities in the lower Santa Cruz Valley of Avra Valley and the Santa Cruz Flats, with a focus on reconnaissance of Pima County Flood Control District properties. Report to Pima County Flood Control District and Board of Supervisors. 16 pp. http://www.pima.gov/cmo/sdcp/reports/d50/Avra_Lower%20Santa%20Cruz.pdf

Rosen, P. C. 2003. Avra Valley snakes: Marana survey report for Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*). Final Report to Town of Marana on Shovel-Nosed Snake. 23 pp.

Rosen, P. C. 2003. Black wash floodway and floodplain, Avra Valley: site visit and report, with discussion of restoration possibilities. Unpublished memo to Pima County Flood Control District. 7 pp.

Harris Environmental Group (HEG). 2002. Black Wash Conservation Review: Task 2. Preliminary Conservation Targets and Research Recommendations. Unpublished report prepared for Pima County Flood Control District. 15 pp. + maps.

Rosen, P. C. and C. H. Lowe, Jr. 1996. Ecology of the amphibians and reptiles at Organ Pipe Cactus National Monument, Arizona. Cooperative Park Studies Unit, National Biological Service, University of Arizona, Tucson. Tech. Rep. 53. 136 pp.

Rosen, P. C., P. A. Holm, and C. H. Lowe. 1995. Ecology and status of shovelnosed snakes (*Chionactis*) and leafnosed snakes (*Phyllorhynchus*) at and near Organ Pipe Cactus National Monument, Arizona. Final Report to Heritage Program, Arizona Game and Fish Dept., Phoenix. 65 pp.

Lowe, C. H. and P. C. Rosen. 1992. Ecology and conservation of the amphibians and reptiles at Organ Pipe Cactus National Monument. Final Report to National Park Service, Cooperative National Park Resources Studies Unit, University of Arizona. 497 pp.

Amphibian Population Survey in the Vail Area and Avra Valley

Background An option for the City of Tucson (COT) HCP is to add a strong focus on urban biodiversity conservation and enhancement to the more traditional approach of non-urban land set-asides. Although amphibian biodiversity is being lost over much of the globe, several species remain abundant within the city. They have persisted even within the urban core, and in some cases appear to be thriving by utilizing modern flood control infrastructure as well as remaining semi-natural open space. COT could contribute significantly to biodiversity conservation by considering urban amphibians within the HCP context.

Objective Identify important biological diversity sites especially for amphibians in the western and southeast parts of the HCP area. A survey of the central city is nearly complete and a survey of the Southlands is already underway. Limited work has already been done in Avra Valley, as well.

Methods Using the great survey opportunities presented by recent strong rainfall, site visits will be made this summer to find and identify tadpoles and young frogs and toads in the Pantano Wash-Cienega Creek corridor and selected sites Avra Valley.

Tadpoles will be identified in the field and some may be collected and raised to confirm identities as needed. Small metamorphs (newly transformed young) will be identified in the field. Digital field notes and images will be collected, and a GIS-georeferenced database will be maintained using Excel spreadsheets.

Results

The Vail area (see Fig. 6) has five species of native aridlands anurans (toads and toad-like frogs), as well as the native Lowland Leopard Frog (*Rana yavapaiensis*), confined to the perennial streams, and the non-native American Bullfrog (*R. catesbeiana*), which I found in gravel pit ponds along Pantano Wash, and which has also appeared in Cienega Creek and the Rancho del Lago golf course ponds. The leopard frog populations near Vail appear to be little impacted by predation or competition from the bullfrog because bullfrogs fare poorly in flood-prone streams.

However, the bullfrog is likely a reservoir and vector of the emerging amphibian disease chytridiomycosis, caused by a chytrid fungus pathogen, *Batrachochytrium dendrobatidis*. It appears that this disease has kept leopard frog populations in the Cienega Creek basin – including that of the threatened Chiricahua Leopard Frog in upper reaches on Empire Ranch – at 1-2 orders of magnitude below original abundances. The presence of the bullfrog also preempts all pond habitat for the leopard frogs. These impacts are contributing to a marked decline of the population of the Mexican Gartersnake (a candidate for federal listing) in the Cienega Creek basin, which is one of its last strongholds in the United States.

City of Tucson could contribute substantially to amphibian and reptile conservation by establishing a program to eliminate bullfrogs from the Tucson Basin. Bullfrog metapopulations in the basin are generally isolated and would potentially be manageable if a plan for population elimination were developed.

Not including canyons, which support amphibian breeding in rock pools, the aridlands anuran assemblage in the Vail area exists in two principal breeding habitat types – actively used cattle watering ponds (stock tanks), and pools and gravel pits along Pantano Wash. The rolling terrain of the uplands is unsuitable for the formation of

summer rains pools for these anurans, and the sandy bed of Pantano Wash is too porous to naturally maintain standing water for anuran breeding in most areas.

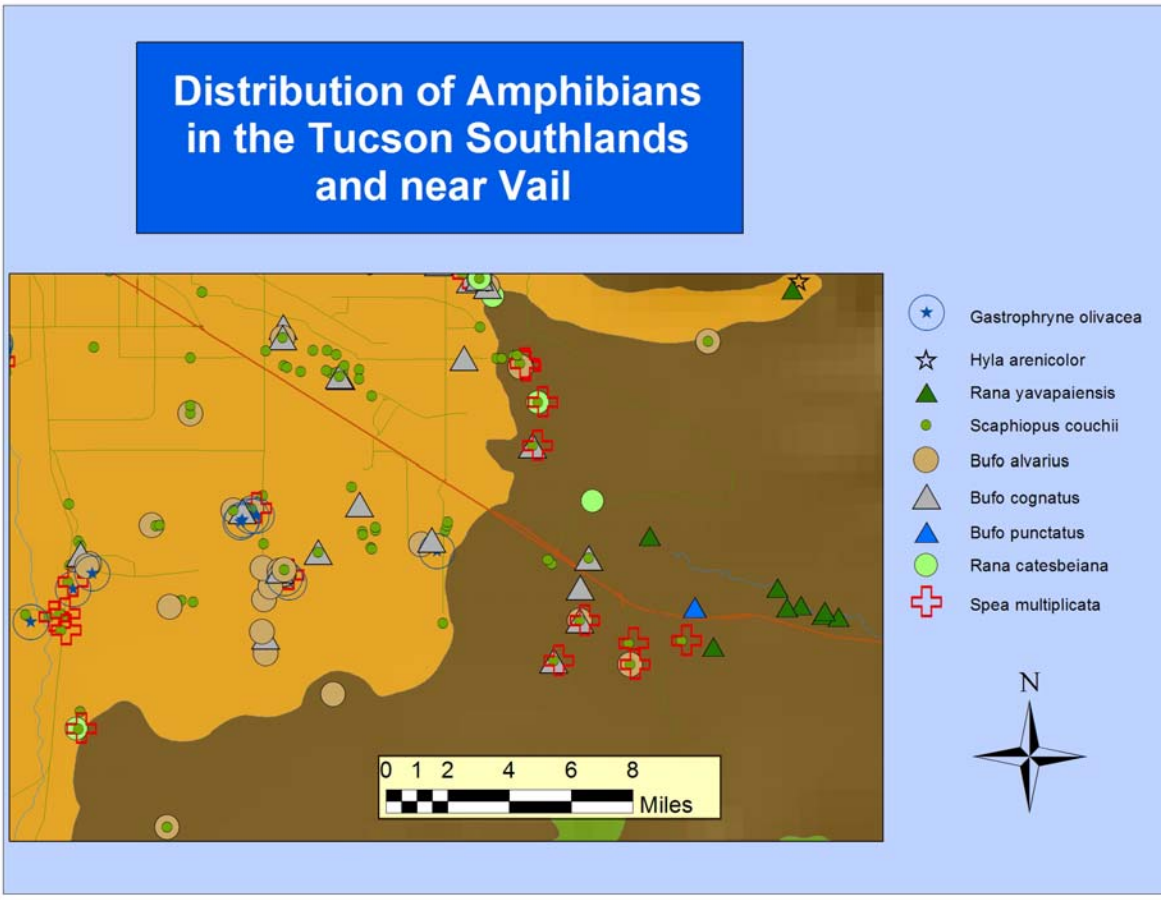

Figure 6. Distribution of anuran amphibians in the Vail area and Tucson Southlands based on surveys during 2004-2006.

Although, natural scour pools in areas of silt and clay support anuran breeding naturally, a few of the larger temporary ponds in former gravel pit areas have huge populations of Couch's Spadefoot (Scaphiopus couchii) and the Great Plains Toad *Bufo cognatus). The cattle tanks also generally support very large populations of one or the other of these two species as well as some solid populations of the Mexican Spadefoot, which is becoming increasingly scarce in the Tucson region except in the Vail, Southlands, and San Xavier Mission regions. Two of the populations of the Great Plains Toad near Vail – one on Pantano Wash and one in a Cattle Tank, may be the largest of this species in the Tucson region.

Generally, anuran populations in the Vail region are important within the Tucson Basin context, but most will likely require some planning to prevent urbanization from eliminating them. For Cienega Creek leopard frogs, groundwater threats and bullfrog impacts may require management to ensure long-term persistence. For all the aridlands anurans except Couch's Spadefoot – whose rapid tadpole development permits utilization ephemeral pools and puddles of 8-d or longer duration – urbanization and lack of management will almost certainly lead to loss of both the cattle ponds and abandoned

gravel pit ponds along Pantano Wash. To date, potential conservation of these aridlands anuran populations has not been considered or evaluated.

The Tucson Southlands, though not a survey focus under this particular project, deserve mention, both for their rich anuran assemblage and the connection of these populations to those categorized as in the Vail area. The Southlands also has five species, all native, and has only a single bullfrog population – near the Santa Cruz River. The area also supports a rich aridlands anuran fauna, with several important populations of the mosquito-eating Mexican Spadefoot (*Spea multiplicata*) and several populations of the Great Plains Narrow-mouthed Toad (*Gastrophryne olivacea*), which was previously thought to be absent from the Tucson region (Fig. 6) and is not known in the Vail area. The strongest regional populations of the giant Sonoran Desert Toad (*Bufo alvarius*) are in the Southlands.

The aridlands anurans in the Southlands breed on desert floodplains in natural scours pools and in cattle tanks. The floodplain scour pool setting is of interest in representing the original ecological situation for breeding in these taxa. Floristically, the floodplains these amphibians depend upon are quite rich in grasses and summer forbs.

Conservation of these populations was discussed by me elsewhere (Rosen 2008a), and seems possible within contexts of regional flood control, preservation of some key areas of the low-lying floodplains within the region, and alignment of road and other infrastructure and construction in ways that avoid destroying the populations. The feasibility of such conservation depends upon establishing suitable biological control of mosquitoes in breeding pools that would be close to people, which remains a research topic (see Rosen 2008a&b). Planning and design for such conservation has not formally begun.

Avra Valley currently has a less abundant anuran fauna than the Southlands and Vail regions (Fig. 7). Although in the past the Lowland Leopard Frog occurred in the valley in numerous localities associated with agriculture and stock ponds, have been replaced by bullfrogs. The Great Plains Narrow-mouthed Toad was found in Black Wash and at Three Points, but is apparently absent there – and elsewhere – in the valley now. This may reflect degradation of stock pond environments, climatic fluctuations and chance in small populations, or lack of adequate sampling. The Mexican Spadefoot occurs in few places in the valley, and although it may be expected to persist on City of Tucson lands near Three Points. The most recent record of Woodhouse's Toad (*Bufo woodhousii*) in the Tucson region is from Avra Valley (1992), but whether it persists there is unknown.

The four prominent anurans in Avra Valley are Couch's Spadefoot, Sonoran Desert Toad, Great Plains Toad, and American Bullfrog. The only large populations exist in the City of Tucson Duval Farm lands south of Three Points, in the Black Wash Floodway and the county's wastewater treatment plant, and in stock ponds in the headwaters of Blanco Wash in Ironwood Forest National Monument. The wastewater treatment plant at Black Wash also has a large population of the introduced Tiger Salamander (*Ambystoma tigrinum mavortium*); it is the only population currently known in the Tucson region, although the species may still occur in Redington Pass.

Access into potential breeding habitat for anurans in Avra Valley during wet weather when surveys are effective was limited by the difficulty of traveling on the slippery muds of the valleys floodplains, as well as by time during this study. There may be additional breeding sites in the Black Wash Floodway that I have not been able to detect. During winter surveys for the Western Groundsnake, several excellent breeding areas for toads were discovered in the Edward Anway and other former farms owned by the City in the Blanco Wash area. These are distant from access points achieved during

summertime surveys, and species with relatively quiet calls, such as the Great Plains Narrow-mouthed Toad and Mexican Spadefoot could have gone undetected. In the Three Points area, the surveys cannot be considered exhaustive or certainly complete, and other species could be present.

Regardless of what is there now, Avra Valley breeding habitat and potential habitat could support additional species at some future time, including possibly the Great Plains Narrow-mouthed Toad, Sonoran Green Toad (*Bufo retiformis*, which occurred or occurs at a pond on the San Xavier District of Tohono O'odham Nation and at a single population miles upstream from the Duval Farm), and Woodhouse's Toad.

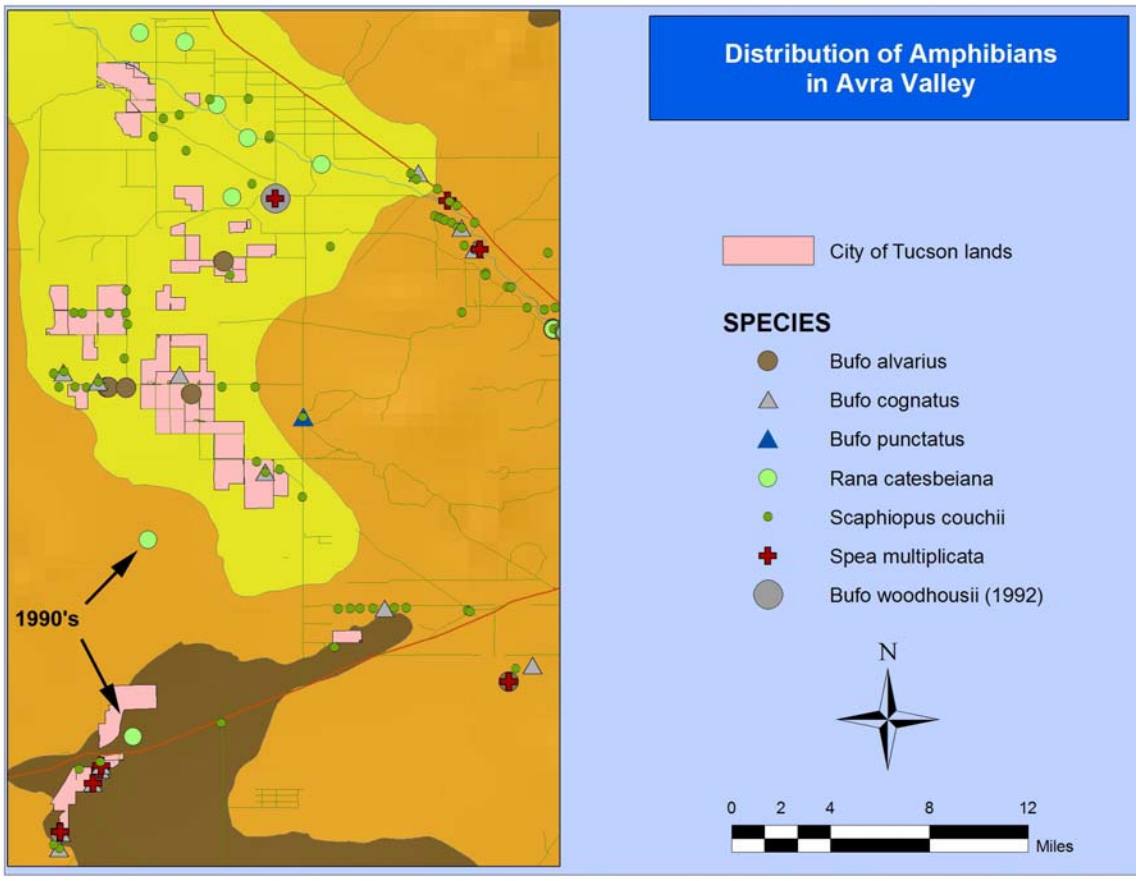

Figure 7. Distribution of anuran amphibians in Avra Valley based on surveys during 2004-2006, except as otherwise indicated on the map and legend.

Recommendations With regard to the future of amphibian life within metropolitan Tucson, and its accessibility to people as a recreational and educational resource, the overriding concern at present is to advance conceptual planning, prioritization, and research needed to integrate breeding habitat into urban design:

1) Flood control and road infrastructure and building construction planning should include explicit consideration for natural biodiversity as a long-term feature of newly urbanizing areas of the Tucson Southlands. Two little-recognized elements are highlighted in this report:
    - Breeding habitat for aridlands toads and toad-like frogs
    - Bottomland floodplain environments and associated flora

2) Consideration should be extended to how amphibian conservation might be effected in the Black Wash Floodway, Brawley Wash bottomlands, at Three Points, and Blanco Wash in Avra Valley.

3) Some additional survey is needed in the above-mentioned Avra Valley areas, particularly if and when conservation concepts are to be evaluated. An important survey element would involve re-locating the documented population of the Sonoran Green Toad in Altar Valley south of Three Points, determining if other populations persist nearby, and learning the conditions that allow this attractive species to flourish.

4) Consideration should be extended to how amphibian conservation might be effected in the ranchlands and along Pantano Wash near Vail

5) Planning for aridlands anuran breeding habitat in an urban context requires:
    - Design of habitat features compatible with flood control infrastructure
    - Allocation of sufficient bottomland floodplain space to support foraging activity for core populations
    - Location of roadways to minimize bisection of core habitat
    - Design of roadway crossing structures to permit amphibian movement under the road
    - Design and location of breeding habitat to eliminate public health concerns related to mosquito breeding
    - Decision regarding which species of amphibians should be supported

Research into:

- Modes of biological and other control of mosquitoes
- Road location features that minimize amphibian mortality
- Community ecology permitting coexistence of desired amphibian species in designed habitat
- Requirements for the size and kind of foraging habitat
- Trial establishment of species in new locations

Amphibian Infrastructure Survey and Design

Objectives (1) Examine existing infrastructure in the HCP area, (2) evaluate its current and potential usefulness for conservation, (3) identify ways infrastructure and amphibian (and co-occurring) biodiversity can be adapted to one another, and (4) initiate discussions with TAC and COT about feasibility of and methods for implementation of this kind of conservation.

Methods Field survey examining infrastructure in the Tucson metro area has been started in 2005-6 and is partly supported by other sources. Additional field survey is needed and will occur during the late summer of 2006. Infrastructure will be evaluated to determine if breeding habitat for amphibians is available, the interaction between primary purpose of the infrastructure and its functionality for biodiversity, and problems (such as mosquito breeding) that may arise in utilizing infrastructure for biodiversity. Golf courses and urban parks will be considered.

Deliverables This subject has been treated in detail in Rosen (2008a&b).

Literature The following reports treat this subject in the context of flood control infrastructure and mosquito issues:

Rosen, P.C. 2008a. Conservation of urban amphibians in Tucson: salvage project report and discussion of habitat issues. Report to Pima County Flood Control District and Board of Supervisors.

Rosen, P.C. 2008b. Conservation of Tucson's riparian herpetofauna. Final Report to Arizona Game and Fish Department, Heritage Grants Program, Phoenix, AZ.