BULLFROG IMPACTS ON SENSITIVE WETLAND HERPETOFAUNA AND HERPETOLOGY OF SAN BERNARDINO NATIONAL WILDLIFE REFUGE

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FINAL REPORT

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ENHANCEMENT OF EXISTING RANID FROG INVENTORY

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and
Herpetology of the San Bernardino National Wildlife Refuge

1995

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EXECUTIVE SUMMARY

This report summarizes herpetological work at San Bernardino National Wildlife Refuge (SBNWR), Cochise County, Arizona, 1985-1994. The focus of the work has been the apparent negative effect of introduced bullfrogs (*Rana catesbeiana*) on native Mexican garter snakes (*Thamnophis eques*) and Chiricahua and lowland leopard frogs (*R. chiricahuensis*) and (*R. yavapaiensis*). Leopard frogs disappeared from the refuge early in this project, after having persisted marginally for some years of our observation. Chiricahua leopard frogs have not been confirmed breeding on the refuge since the early 1980's. Mexican garter snakes have declined from already-low population densities during the years of the project, despite bullfrog removals. Much of this basic information is summarized in the published literature (Rosen and Schwalbe, 1995).

Early bullfrog removal protocols (1985-1989) were not intensive enough to cause a persistent decline in bullfrog population sizes, although a weak increase in garter snake trapping returns was observed prior to 1990 (Schwalbe and Rosen, 1988). After a two year hiatus, work was resumed in 1992-present. Removals were intensified during 1993 and 1994, using continuous trapping throughout the primary active season to remove bullfrogs. This protocol has produced a persistent reduction in bullfrog populations and especially in biomass. Almost all adults are removed using the traps, and juveniles are removed soon after they mature. Reproduction has been reduced but has not ceased.

Mexican garter snakes reproduced successfully in one of the intensive bullfrog removal areas, apparently in response to an unusually successful bullfrog removal. Although this response was statistically significant, it was not very strong, and the species appears to continue to decline. It appears to be threatened by bullfrogs in southeastern Arizona, and presumably also in central Arizona, where it is uncommon. It is extremely rare in New Mexico, and may be headed for extirpation from the United States. Leopard frogs have not successfully re-colonized the refuge, although isolated records of immigrants exist. The checkered garter snake, less aquatic than the Mexican garter snake, appears to be maintaining large population size and successful reproduction on the refuge. The Sonoran mud turtle population at SBNWR is unusually small, for reason(s) unknown. There has been recruitment during our study, suggesting a possibly increasing population.

Bullfrog diet is being studied by dissecting large numbers of the removed animals at SBNWR. Vertebrates appear to comprise at least half the dietary mass, and frogs, especially small bullfrogs, comprise two-thirds of the vertebrates in the diet. Both the Mexican and checkered garter snake, as well as the Sonoran mud turtle, have been recorded in the diet, along with a number of other remarkably large, noxious, and unexpected items.

Another phase of this project involves direct management of two native Chiricahua leopard frog populations, which are at bullfrog-free stock ponds on a ranch close to SBNWR. In cooperation with AGFD, USFWS, and the Malpai Borderland Group (a rancher association for the San Bernardino-San Simon-Animas valleys region), we have established an enclosed leopard frog population on the refuge (bullfrogs excluded) using frogs from one of the ranch ponds. Also in cooperation with the above entities, we have monitored the naturally existing leopard frogs. The leopard frogs that were re-established on the refuge bred successfully at an age of only 4 mo

post-metamorphosis, in September 1994, and appear to be establishing a small population.

The rancher who owns the two naturally occurring leopard frog population sites has hauled water to one of the frog populations since it went dry, during the severe, ongoing drought, in spring 1994, and has installed a well for the other. Another population, slightly farther east, in Guadalupe Canyon, appears to have disappeared during the drought. We are cooperating with an attempt to provide AGFD Stewardship Funding for the establishment of a well to supply water to one of the two extant population sites. This would promote co-existence of livestock operations with native ranid frog conservation. To date, the naturally-occurring populations have persisted, with little or no successful reproduction since winter 1994. This phase of the project--monitoring and management of leopard frogs--appears to have excellent potential as a model of public-private cooperation in conservation.

In addition to the management-oriented work described above, we have conducted a general mark-recapture study of the snakes and turtles at SBNWR. Recaptures demonstrate that the Mexican garter snake is surprisingly long-lived, reaching at least age 10 yr. We have also had several promising recaptures of terrestrial snake species that may assist a general understanding of their populations. General herpetological work on site has resulted in a draft annotated checklist of the herpetofauna, presented here.

INTRODUCTION AND BACKGROUND

This report summarizes results of ongoing herpetological research and management at San Bernardino National Wildlife Refuge (Fig. 1) for 1985-1994. Project objectives are (1) to determine whether the introduced bullfrog is responsible for declines of native herpetofauna (Hayes and Jennings, 1986), specifically Chiricahua and lowland leopard frogs and Mexican garter snake, and (2) to determine whether control of bullfrogs leads to population recovery of affected native species (Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1995). In addition, the project aims to (3) assist recovery of Chiricahua leopard frog populations in the Cochise County area (Rosen et al., 1995), and (4) produce a general, annotated herpetological checklist for SBNWR and closely surrounding territory.

The first phase of the project was during 1985-9, primarily involving two or three trips a year of 3-4 days duration to remove bullfrogs from SBNWR, while simultaneously monitoring native amphibian and reptile populations. We conducted mark-recapture studies on snakes and turtles, as well as overall herpetofaunal survey. The work consisted of Memorial Day and Labor Day extended weekend efforts, with a July removal trip in 1988. These trips usually involved 7-16 people on site capturing and dissecting bullfrogs. Results of this first phase suggested weak positive effects of bullfrog removals on garter snakes (below, and Schwalbe and Rosen 1998); however, bullfrog populations recovered from the removals within less than a year, as detailed below.

The second project phase was initiated in 1992 after a two-year hiatus. Effort was intensified beginning May 1993 with combined funding from Arizona Game and Fish Department (AGFD) Heritage Program, and U.S. Fish and Wildlife Service (USFWS), and with active support of Refuge Manager Kevin Cobble, Refuge Officer Matt Magoffin, AGFD State Herpetologist Jeff Howland, Ted Cordery (BLM to 1994; currently at USFWS), and numerous other personnel, especially from AGFD Nongame Branch, in particular Mike Sredl and his associates. These intensive removal efforts have involved approximately 14-18 persons on site. Extensive and intensive snake censusing, bullfrog removal, and native frog study at SBNWR and other localities, in addition to the biannual intensive removals, has been carried out by University of Arizona (UA) personnel--Phil Rosen, Shawn Sartorius, Peter Holm, Shawna Nelson, Dave Parizek, Steve Hale, and Brent Martin from UA. Nearly continuous bullfrog trapping was conducted jointly by USFWS and University of Arizona personnel during June-November 1993 and March-October 1994.

In 1994 we initiated a third phase of the project, in which we participated in active preservation and management of Chiricahua leopard frog populations at and near the refuge. This work was in collaboration with Kevin Cobble, Matt Magoffin, AGFD Nongame Branch personnel, particularly Mike Sredl, and the Malpai Borderlands Group (MBG). MBG is an innovative association of local ranchers dedicated to preserving open space, the ranching lifestyle, and species diversity. We assisted in preserving leopard frog populations at Rosewood Tank, 7 mi east of the refuge, and Belency Tank, along the border at 5 mi east of the refuge, both on the Magoffin Ranch. Rosen, Magoffin, and Cobble conducted regular and frequent visual surveys of the leopard frogs, and the Magoffins managed waters to forestall habitat drying. Rosen and other UA personnel additionally surveyed the surrounding region, and monitored Chiricahua leopard frogs in the next nearest known population site, Guadalupe Canyon. Principal investigators, refuge managers, and AGFD Nongame Branch personnel collaborated in a frog re-establishment project

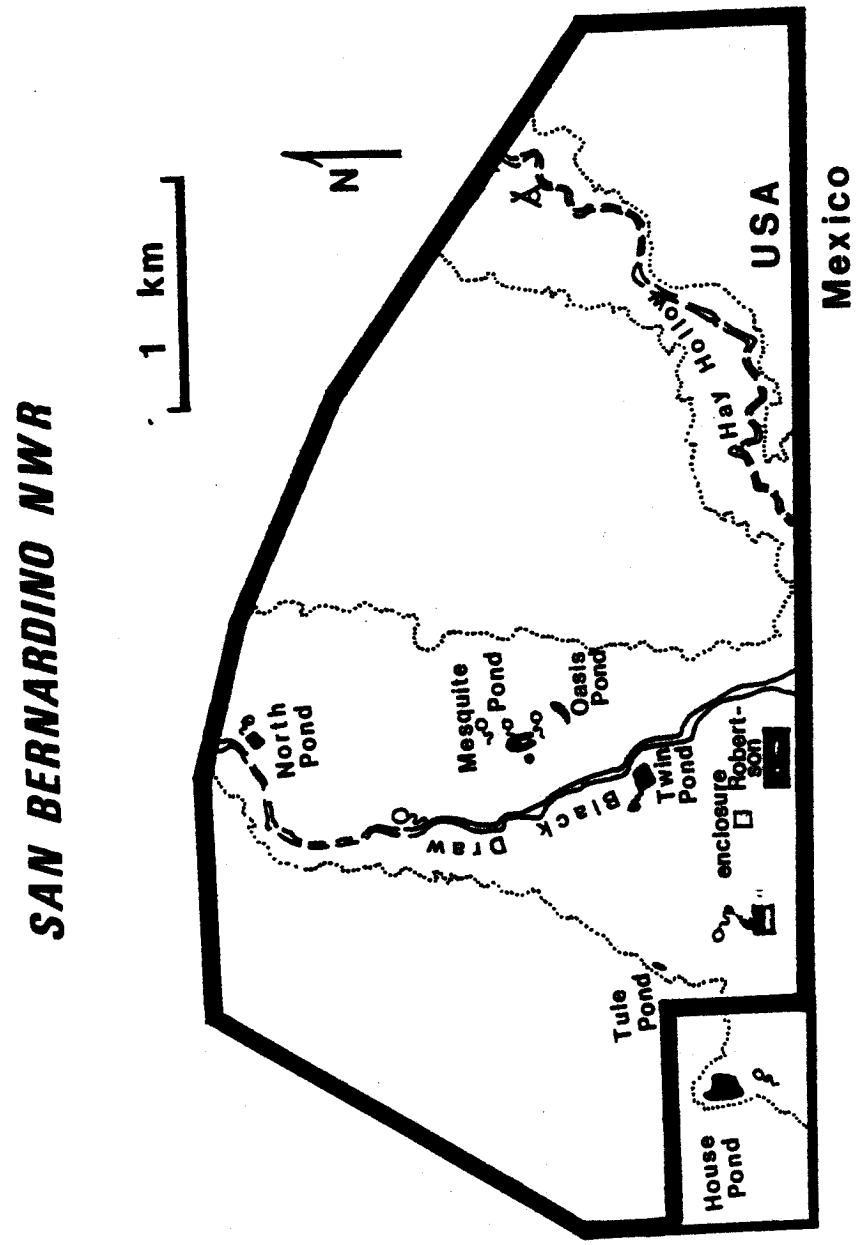


Figure 1. San Bernardino National Wildlife Refuge, Cochise County, Arizona, 1994.

Table 1. Number of *Rana catesbeiana* removed from San Bernardino NWR, Cochise Co., Arizona.

LOCALITY	YEAR 1985	1986	1987	1988	1989	1992	1993	1994	Site Total
Astin Spring	0	0	0	0	0	0	30	4	34
Bathhouse Well	0	0	2	0	0	0	7	15	24
Cottonwood Well	0	2	0	0	0	0	0	0	2
Black Draw	0	0	71	102	46	11	0	0	230
Evil Twin	0	0	0	0	0	0	26	5	31
House Pond	0	0	110	73	174	147	188	234	926
Mesquite Pond	0	0	0	0	0	0	0	261	261
North Pond	0	85	139	168	290	140	143	247	1212
Oasis Pond	0	0	0	0	0	0	0	9	9
Double PhD	0	0	0	4	0	0	1	6	11
Robertson Cienega	0	0	0	0	0	12	72	78	162
Tule Pond	0	1	6	2	0	1	19	15	44
Twin Pond	4	5	0	3	0	43	110	114	279
ANNUAL TOTAL	4	93	328	352	510	354	596	988	3225

Table 2. Number of adult and subadult *Rana catesbeiana* (≥ 90 mm SVL) removed from San Bernardino NWR, Cochise Co., Arizona.

LOCALITY	YEAR 85	86	87	88	89	92	93	94	Site Total
Astin Spring	0	0	0	0	0	0	22	2	24
Bathhouse Well	0	0	0	0	0	0	6	14	20
Cottonwood Well	0	2	0	0	0	0	0	0	2
Black Draw	0	0	62	101	44	10	0	0	217
Evil Twin	0	0	0	0	0	0	26	5	31
House Pond	0	0	103	50	138	115	184	156	746
Mesquite Pond	0	0	0	0	0	0	0	244	244
North Pond	0	78	116	104	181	135	133	172	919
Oasis Pond	0	0	0	0	0	0	0	8	8
Double PhD	0	0	0	1	0	0	0	6	7
Robertson Cienega	0	0	0	0	0	10	72	75	157
Tule Pond	0	1	5	1	0	1	18	14	40
Twin Pond	4	5	0	2	0	39	105	101	256
ANNUAL TOTAL	4	86	286	259	363	310	566	797	2671

Table 3. Total mass of *Rana catesbeiana* removed (kg) from San Bernardino NWR, Cochise Co., Arizona.

LOCALITY	YEAR 85	86	87	88	89	92	93	94	Site Total
Astin Spring	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.5	4.9
Bathhouse Well	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.0	4.3
Cottonwood Well	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Black Draw	0.0	0.0	15.5	19.7	7.7	2.3	0.0	0.0	45.1
Evil Twin	0.0	0.0	0.0	0.0	0.0	0.0	4.9	1.0	5.9
House Pond	0.0	0.0	26.1	13.0	36.8	48.5	79.7	64.3	268.3
Mesquite Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59.3	59.3
North Pond	0.0	18.4	30.2	28.1	45.8	36.3	31.2	29.0	219.0
Oasis Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6
Double PhD	0.0	0.0	0.0	0.6	0.0	0.0	0.1	1.4	2.0
Robertson Cienega	0.0	0.0	0.0	0.0	0.0	1.9	13.4	15.9	31.2
Tule Pond	0.0	0.2	1.2	0.3	0.0	0.2	5.1	2.3	9.3
Twin Pond	0.8	1.4	0.0	0.4	0.0	9.6	24.2	16.5	53.0
ANNUAL TOTAL	0.8	20.4	73.1	62.0	90.2	98.8	164.4	194.8	704.5

Table 4. Kilograms of large *Rana catesbeiana* (≥ 90 mm SVL) removed, San Bernardino NWR, Cochise Co., AZ.

LOCALITY	YEAR 85	86	87	88	89	92	93	94	Site Total
Astin Spring	0.0	0.0	0.0	0.0	0.0	0.0	3.9	0.4	4.2
Bathhouse Well	0.0	0.0	0.0	0.0	0.0	0.0	1.2	3.0	4.2
Cottonwood Well	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Black Draw	0.0	0.0	15.1	19.6	7.5	2.2	0.0	0.0	44.4
Evil Twin	0.0	0.0	0.0	0.0	0.0	0.0	4.9	1.0	5.9
House Pond	0.0	0.0	25.7	12.2	35.4	47.8	79.5	61.6	261.8
Mesquite Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	58.5	58.5
North Pond	0.0	18.0	28.8	24.9	41.3	36.0	30.6	24.5	204.1
Oasis Pond	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6
Double PhD	0.0	0.0	0.0	0.3	0.0	0.0	0.0	1.4	1.6
Robertson Cienega	0.0	0.0	0.0	0.0	0.0	1.8	13.4	15.7	31.0
Tule Pond	0.0	0.2	1.2	0.2	0.0	0.2	5.1	2.2	9.1
Twin Pond	0.8	1.4	0.0	0.4	0.0	9.5	24.0	16.0	52.0
ANNUAL TOTAL	0.8	20.0	70.7	57.6	84.2	97.5	162.6	185.8	679.2

Table 5A. Manual bullfrog removal work (effort) at San Bernardino National Wildlife Refuge, Cochise Co., Arizona, 1985-1994. Removal trips were Memorial and Labor day weekends, beginning with Labor Day in 1986. An additional intensive manual removal was conducted on Independence Day weekend, 1988.

Year	Days Intensive Manual Removal	Ave. Number of Personnel/Trip
1985	0	2
1986	2	7
1987	6	1
1988	10	10
1989	7	11
1990	0	0
1991	0	0
1992	7	18
1993	6	15
1994	7	16

Table 5B. Trapping effort for bullfrogs (Rana catesbeiana) at San Bernardino National Wildlife Refuge, Cochise Co., Arizona. The number of trap days is followed by (number of traps set).

LOCALITY	YEAR 85	86	87	88	89	92	93	94	Site Total
Astin Spring									
Bathhouse Well							67 (1)	224 (1)	291
Cottonwood Well									
Black Draw				30 (10)	54 (9)	44 (11)		120 (4)	248
Evil Twin							270 (3)	224 (1)	494
House Pond									
Mesquite Pond								674 (5)	674
North Pond	2 (1)			6 (2)	6 (1)		627 (4)	896 (4)	1537
Oasis Pond								76 (1)	76
Double PhD								118 (1)	118
Robertson Cienega							264 (2)	278 (2)	542
Tule Pond							134 (2)	374 (2)	508
Twin Pond	2 (1)						552 (5)	832 (4)	1386
ANNUAL TOTAL	4 (2)	0 (0)	0 (0)	36 (12)	60 (10)	44 (11)	1914 (17)	3816 (25)	5874

during 1994, in which a portion of the tadpoles from Rosewood Tank were removed before the tank dried, and relocated to a pond-enclosure system created for them on the refuge.

During 1994, the present project was integrated with another study, funded primarily by AGFD's Arizona Heritage Program, titled "Southeast Arizona Grassland Herpetofauna", under which Rosen, Schwalbe, Shawn Sartorius, David Parizek, Peter Holm, and Charles Lowe conducted a regional study of leopard frog co-occurrence with native and introduced species. This work indicated that introduced bullfrogs and predatory fishes are primary contributors to leopard frog declines throughout most of the region. Detailed results from that work are presented in another final report (Rosen et al. 1996).

BULLFROG REMOVAL AND ABUNDANCE

Overview of Removal Program. Removal methods, which have been detailed elsewhere (Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1995), basically consist of hand capture, spearing with a frog "gig" (as in sport hunting), and trapping using turtle traps (hoop nets) set at the end of seine leaders. The traps consisted of 4-6' deep, 10-20' long seines attached to metal stakes, with 6-12" of net above water line; hoop nets were attached to the stakes with approximately 3/8 of the funnel out of the water. Seines generally had 1/4 - 1/2" mesh, traps had 1" mesh. Pre-made fyke nets, similar in principle to our design, were used in Robertson Ciénega. The 1" (2.5 cm) mesh of the frog traps begins to capture bullfrogs as they reach about 90 mm snout-vent length (SVL) and about 90 g total mass.

Removals initially focused on North Pond, and secondarily at Black Draw and House Pond (Tables 1-4). North Pond received consistent removal efforts during each visit. Removals 2-3 times per year failed to control bullfrog populations. Between the Memorial Day (28 May-1 June) and Labor Day (1st week of September) removals, and from Labor Day to the following Memorial Day, bullfrog populations generally rebounded to 50-100% or more of their original numbers. There was no downward trend in bullfrog numbers over the Phase I years in any of the ponds, except that bullfrogs became scarce in Twin Pond (Tables 1-4), which was temporarily dried. Although persistent decrease in bullfrog abundance was not achieved, reductions undoubtedly maintained lowered abundance for some part of the year. North Pond usually contained an estimated 5-10 remaining adult frogs after removal of 50 or more, so about 80-90% reduction had been achieved in 3-4 d of work. Bullfrog removal was re-initiated in 1992, and intensified during both 1993 and 1994, with the longest trapping period and most extensive manual removal occurring in 1994 (Table 5).

Table 5 is the best available index of removal effort, which varied from year to year due to fluctuations in weather and the number of skilled frog collectors during the manual removal efforts. In 1985 and in May 1986, bullfrog removal was incidental to the initial garter snake survey. Intensive removal began in August 1986 at North and Twin Ponds, with seven workers present. All subsequent trips included large enough numbers of frog catchers to effectively cover the major bullfrog population centers on the refuge. Thus, for 1987-1994, days of manual removal is approximately equal to total manual removal effort. This is reflected in the total numbers and mass of frogs removed from the refuge (Tables 1-4, Fig. 2). Annual variation in mass of large (subadult + adult) bullfrogs removed (Table 4) roughly reflects total removal effort. At each of the four sites where intensive removals had been ongoing since 1992, 1994 saw a decline in biomass

removed (Fig. 2). This indicates that at that level of effort, a persistent reduction in bullfrog abundance had occurred. At the same time, average size of the bullfrogs in at least three of these four sites also declined (Fig. 3), reflecting the almost complete removal of adults, except at House Pond. Most frogs removed during late 1994 from North, Twin, and Tule Ponds were subadults that were trapped as they reached trappable size.

Sampling for tadpoles in North Pond and Twin Pond in mid-1994 indicated little successful breeding by bullfrogs under the intensive trapping and manual frog and egg mass removal system. It remains to be seen whether the current removal protocol will produce a continuing reduction of bullfrog numbers, rather than a stabilization at reduced abundance and smaller body size.

Observations and Implications of Abundance. At Mesquite Pond, a 0.2 hectare pond that was created in 1989, but not sampled until 1994, we removed 204 adult bullfrogs totalling 51 kg ($\geq$ 255 kg/ha) during a two month period, June-July 1994. During this dry period of time, there was essentially no terrestrial frog activity, thus no immigration. Therefore, the totals are minima for biomass and density, and probably approach the total non-larval value for biomass. At SBNWR and elsewhere in southeastern Arizona, we have often observed bullfrogs at such remarkable densities, which may appear to be roughly one adult per two meters of shoreline. A hypothetical circular pond of 0.2 ha would have a 158 m shoreline (considerably less than a real 0.2 ha pond with an irregular outline): at 204 frogs (1020/ha) that would be 2.5 frogs per two meters. Thus, our impression of high densities in southeastern Arizona appear accurate. They are considerably in excess of any previously reported for this species (e.g., Currie and Bellis, 1969; Clarkson and deVos, 1986). We attribute the remarkable success of non-indigenous bullfrogs in the area to their presence in the absence of their primary natural enemies. The remarkable numbers that occurred at Mesquite Pond also show how rapidly bullfrog populations can expand into newly-created, optimal habitat in the Southwest.

Following the first major rains of the drought summer 1994, which produced the first floodwaters in Black Draw on September 3rd, Rosen made detailed observations on September 5 of numbers and dispersal of bullfrogs at SBNWR. Adult or subadult-sized bullfrogs moved to approximately 100 m from permanent waters, to newly-flooded or just-filled pools and puddles. Small juveniles ("metamorphs") moved considerably further, and we have seen distances to approximately 1.5 km from known source locations. These long distance movements are over upland territory, not along drainage channels, where longer dispersal is predictable.

On September 5, 1994, juvenile bullfrogs were present throughout Black Draw, which had been almost entirely dry during most of the summer. The frogs were not uniformly distributed, but concentrated within about 0.5 km of North Pond and Twin Pond, the two closest sources of immigration. It was possible to flush and count almost every frog present in the narrow confines of the draw during this census, due to drought-reduced vegetation density. Counts were 236/km in the upper half of the draw (496 frogs in 2.1 stream km), plus approximately 750 observed in the lowermost kilometer, for an estimated total of 1246 *R. catesbeiana* (tadpoles not included) in Black Draw.

This was the only reliable census in Black Draw. Prior to the drought, dense cover caused a substantial underestimate. Therefore, Rosen used the September 1994 opportunity to attempt

an estimate of bullfrog numbers for the entire SBNWR, as follows. Following 2 d intensive removal (totalling 130 adults) at House Pond, 30 adults were counted on September 5, and estimated 50 total plus roughly 300 metamorphs. Similarly estimated numbers for Robertson Marsh (200 frogs), Twin Ponds (200), Tule + Bathhouse Springs (20), Double Phd (100), North Pond (100), Mesquite Pond (200), and Oasis Pond (100) sum to 2516, suggesting that as many as 3000 or more non-larval *R. catesbeiana* could occupy the refuge had we not been intensively removing them during the previous six months.

The observation of over 2,000 ranid frogs in a small area is an indication of the potential numerical importance lowland sites might have for ranid frogs in the Southwest. Although they had a more normal array of effective predators than bullfrogs do in the region, they were still likely found in great numbers. The Chiricahua leopard frog, *Rana chiricahuensis*, is often thought of as a montane stream frog (e.g., Mecham, 1968; Platz, 1976), even though it occurred in major valley-bottom sites in southeastern Arizona prior to the spread of exotic species into these sites. These lowland population sites, many under ciénega-like conditions, could have dominated the regional species population, with montane sites possibly serving primarily as refugia during major episodes of drought.

Large numbers of Chiricahua leopard frogs were probably supported at the key valley bottom ciénegas for each southeast Arizona valley where Chiricahua leopard frogs were formerly known (distribution data from Clarkson and Rorabaugh, 1989; Frost and Bagnara, 1977a; Frost and Platz, 1983; Platz, 1976; Platz and Frost, 1984; Platz and Mecham, 1979; and personal examination of UAZ specimens): they have been recorded at San Bernardino Creek (Black Draw), Whitewater Draw, upper San Pedro River, Santa Cruz River and associated springs in San Raphael Valley, Babacomari Ciénega and its tributaries, upper Ciénega Creek, and Arivaca Ciénega. They almost certainly occurred at San Simon Ciénega and San Simon Creek, which are no longer perennial. The large numbers of frogs presumably supported at these sites probably dominated the gene pool of what is more often thought of as a montane leopard frog.

Major montane streams and occasional meadows in southeastern Arizona may each have supported populations of a few dozen to perhaps 100-200 adult frogs. Recent observers usually found, or still find, *R. chiricahuensis* in abundance in stock ponds or concrete dam ponds in the mountains, rather than in typical natural habitat--clear, usually shaded, and often cool or cold mountain stream. Locally ciénega-like meadows and spring runs are rare in the mountains of southeastern Arizona, and support small numbers of frogs in local areas. The ponds, often concrete (and rock) dam ponds (including the type locality of *R. chiricahuensis*, Herb Martyr Dam) were established in the early decades of this century.

Destruction of ciénega habitat by arroyo-cutting and groundwater drawdown occurred primarily during the late 19th and early 20th century. Meanwhile, construction of stock ponds throughout the Southwest undoubtedly produced an initial boom in leopard frog populations, possibly to levels approaching original abundances in natural valley floor habitat. However, this was followed by exotic species introductions (as in Colorado [Hammerson, 1982]), and by further losses of leopard frog populations as sedimentation filled up many of the artificial ponds in mountain canyons.

In montane situations, where Chiricahua leopard frogs are in streams, they are usually in

still or quiet pools with relatively deep water and stable earth or vegetation root banks. Our impression is that, within any habitat area, Chiricahua leopard frogs in southeastern Arizona, especially adults, select the largest pools with well-developed banks. They are not abundantly observed, and perhaps never were abundant, in carved rock pool and plunge pool habitat, where the now-extirpated Tarahumara frog *Rana tarahumarae* was characteristically found (Hale et al., 1995; personal observations). This might be an ecological difference that is relevant to the apparent divergence of the undescribed, White Mountains stream-and-meadow form (Platz, personal communication) from southeastern Arizona *Rana chiricahuensis*.

We suggest that extensive cienega-stream-pool complexes on the valley floors may have originally supported tens or hundreds of thousands of leopard frogs. These situations, rich in productivity and poor in predatory fishes, may well have made the desert Southwest ideal for leopard frogs, rather than marginal as may sometimes be envisioned. If so, the high species diversity of leopard frogs in this region may reflect enhanced ecological opportunities, rather than marginal conditions and attendant speciation in small, isolated populations.

Bullfrog Population Trends at SBNWR. The great numbers of bullfrogs taken in 1994 at Mesquite Pond, plus those from Robertson Ciénega, Double Phd Ponds, Oasis Pond, and Bathhouse Spring (all first intensively sampled in 1993 or 1994) account for the increase in total numbers of frogs removed that appears in Tables 1-4.

The decline in biomass removal at other sites (North Pond, Twin Pond, Tule Pond, and House Pond) reflects both reduced numbers of frogs and markedly declining size for the largest frogs (Tables 6, 7, Fig. 3). This decline occurred because most adult frogs were being removed, as described above, except in House Pond, where trapping was not carried out, but which was the 1994 focal point for manual removal efforts.

In newly-trapped areas, we have generally observed 1-6 weeks highly successful trapping of large adult frogs, with the variability depending on habitat complexity and trap density. This has been followed by slow attrition of the remaining large adults and steady, continual removal of young as they reach trappable size (Fig. 4). Results in 1995-6 will indicate whether this procedure succeeds in restricting bullfrog reproduction and recruitment.

During 1994, we removed 26 bullfrog egg masses from Mesquite Pond, and observed approximately 6 that had already hatched, May 28-31; approximately 20-30 egg masses were also removed from House Pond May 29-30, although this was a less systematic effort.

Diet. A preliminary summary of bullfrog stomach content data is given in Table 7. This is similar to some but not all dietary reports on this frog (summarized by Bury and Whelan, 1984), which may contain high proportions of vertebrates as well as surprisingly noxious prey (Clarkson and deVos, 1986; Corse and Metter, 1980). At SBNWR, although vertebrates comprised only 9.1% of the food items, the average vertebrate is several fold more massive than average-sized invertebrates. Therefore, vertebrates undoubtedly are a major portion, probably a majority, of the bullfrog diet by weight or volume; and frogs (mostly small bullfrogs) comprise 68% of the vertebrates eaten. This supports the hypotheses that (1) bullfrogs may be expected to affect populations of anurans via predation (Hayes and Jennings, 1986; Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1995), and (2) bullfrog abundance might be sustained by cannibalism at

Figure 2. Bullfrog biomass removals from San Bernardino NWR, Cochise Co., Arizona, 1985-1994. Total includes additional ponds.

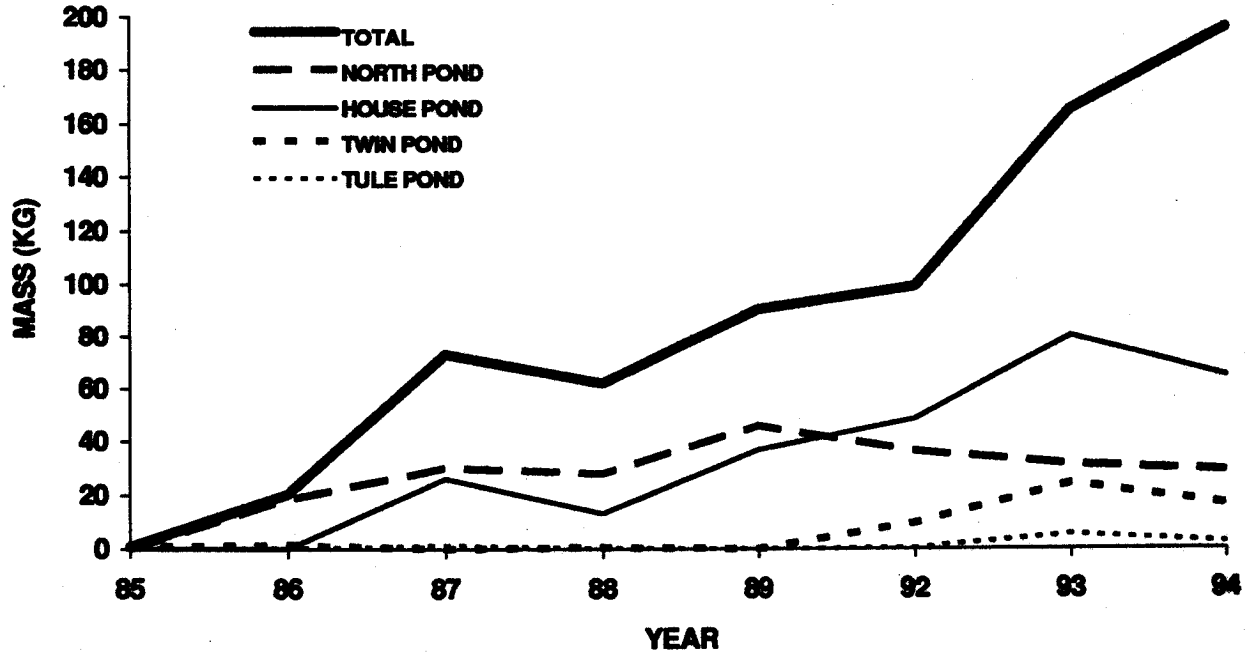


Figure 3. Mean mass of adult and subadult bullfrogs (SVL ≥ 90 mm) at San Bernardino NWR, Cochise Co., Arizona, 1985-1994. Frogs from additional ponds are included in the overall average.

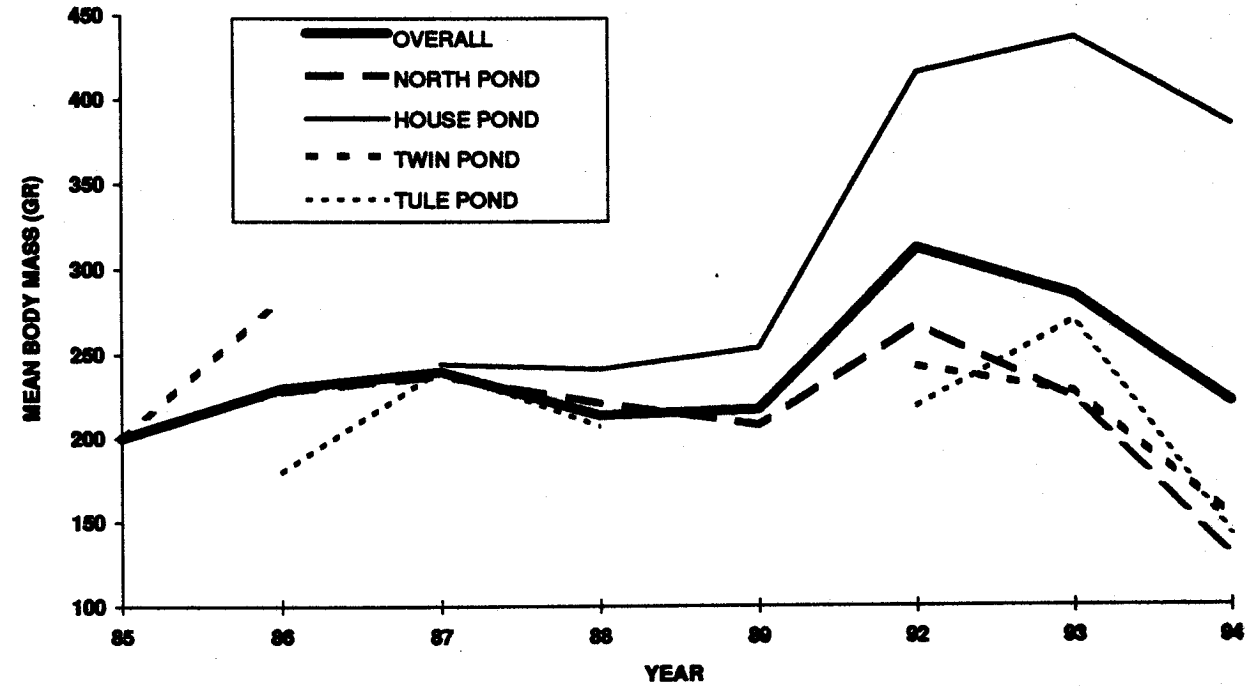


Table 6. Mean SVL of adult and subadult bullfrogs (≥ 90 mm SVL) captured at SBNWR, Arizona, 1985-1994.

	YEAR								site
Locality	85	86	87	88	89	92	93	94	average
Astin Spring							118.2	120.3	118.4
Bathhouse Well							124.0	128.8	128.0
Black Draw			135.4	131.0	124.1	129.4			130.8
House Pond			132.0	136.1	140.5	168.7	164.5	164.6	154.1
Mesquite Pond								146.5	146.5
North Pond		130.5	133.1	132.0	134.1	148.6	139.3	112.5	133.8
Robertson Marsh						133.3	133.6	135.2	134.0
Tule Pond		116.0	137.0	134.0		149.0		134.3	135.1
Twin Pond	135.0	133.6		133.5		145.4	142.6	125.4	138.6
ANNAUL MEAN	135.0	130.7	133.2	132.3	135.3	154.2	148.1	142.9	141.2

Table 7. Mean mass of adult and subadult bullfrogs (≥ 90 mm SVL) captured, SBNWR, Arizona, 1985-1994.

	YEAR								Site
Locality	85	86	87	88	89	92	93	94	average
Astin Spring							161.5	154.7	160.8
Bathhouse Well							200.3	202.6	202.0
Black Draw			237.4	193.1	167.4	204.6			201.1
House Pond			244.4	241.3	254.3	415.5	436.4	384.3	351.4
Mesquite Pond								234.6	234.6
North Pond		228.0	237.5	221.2	207.9	267.5	223.8	129.1	207.8
Robertson Marsh						166.9	186.7	208.0	195.7
Tule Pond		180.0	241.2	207.0		219.0	270.3	142.0	223.9
Twin Pond	200.0	283.2		198.5		242.9	227.7	153.0	200.7
ANNUAL TOTAL	200.0	229.9	240.0	213.9	217.2	312.4	285.1	221.2	245.5

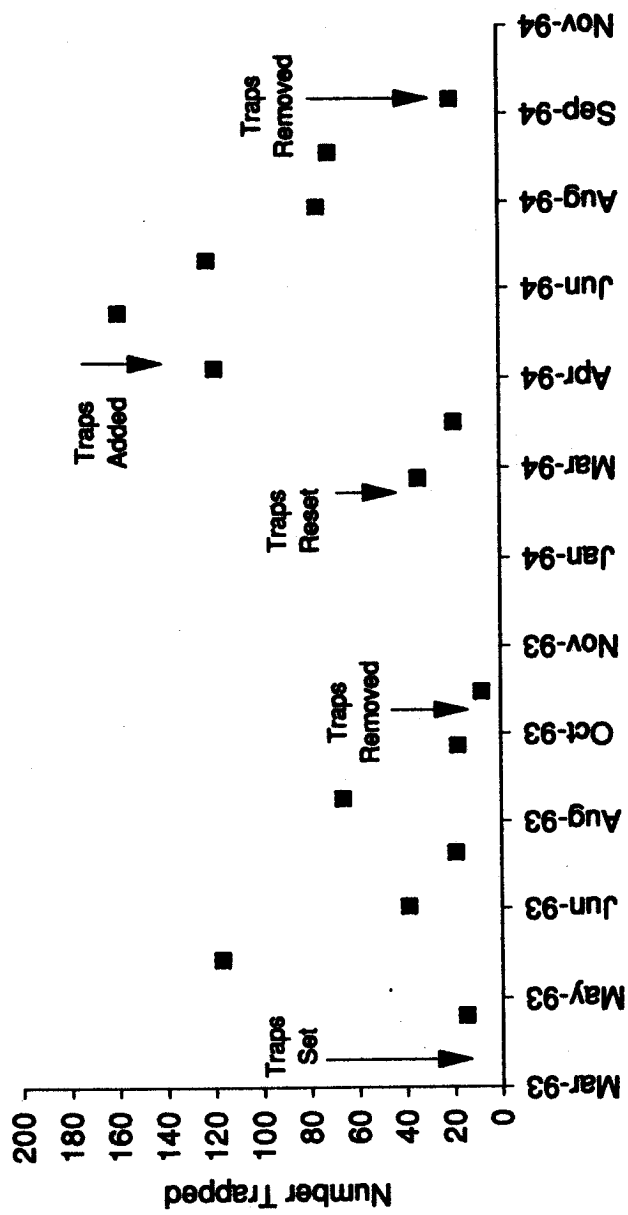


Figure 4. Monthly trapping results for bullfrogs at San Bernardino National Wildlife Refuge, Cochise County, Arizona, 1993-1994.

high population density (Rosen and Schwalbe, 1995), thus increasing the effect bullfrogs may have on populations of other species of prey.

Recommendations for Bullfrog Removal Operations. Additional removal techniques should be employed in 1995 and 1996. Regular and systematic survey for and removal of bullfrog egg masses should be conducted in most or all refuge areas starting April 15 (or earlier, depending on when choruses of calling males are first heard), and continuing to at least June 15. These should be at least once a week until May 1, and twice weekly thereafter.

Additionally, we propose that experiments be conducted on Buenos Aires National Wildlife Refuge or nearby in Coronado National Forest (at Alamito Tank) to test the effectiveness of underwater explosion in elimination of bullfrogs and other non-indigenous vertebrates from stock ponds. This procedure should be supervised and implemented by personnel from both refuges, with site plans and timing developed in consultation with us, and the work should be observed and biological effects evaluated by us.

Bullfrog trapping should always be initiated by the third week in April, or the fourth during a cool year. Traps may be removed any time beginning in the third week of September, or trapping may continue through October. It is important to initiate trapping in spring prior to initiation of spring breeding in bullfrogs. Manual removals in May should focus also on removing all young bullfrogs that may potentially prey on soon-to be born Mexican garter snakes.

Leopard Frogs

Species Present. All verifiable records available to us (literature records [sources cited above], UAZ and ASU museum records) for the San Bernardino Ranch and Magoffin Ranch represent the Chiricahua leopard frog *Rana chiricahuensis*. Herpetologists passing through the area took 1-2 frogs from the locality generally stated as "San Bernardino Ranch, 15-17 mi E of Douglas", or occasionally, "Astin Spring" (or Tank). Collections were also made at the locality now known as Rosewood Tank.

Our photo voucher of one of the last leopard frogs seen in central Black Draw in the late 1980's is clearly a lowland leopard frog *Rana yavapaiensis*. It has a white lip stripe, reticulations on the posterior surface of the thigh, is brownish and tan in color, and has light cream-colored dorsolateral folds. Chiricahua leopard frogs from this region (Chiricahua and Dragoon Mountains and surrounding valleys), in our experience, have bright green lips, are primarily or entirely green in background color, with dark brown spots, have green dorsolateral folds, and usually have clear salt-and-pepper markings on the thighs. The photo voucher appears to be a juvenile, and in our experience, juvenile *R. chiricahuensis* from the region always have lime-green or neon green dorsolateral folds. Our distinctions are in basic agreement with Platz and Mecham (1979) and Platz and Frost (1984). We do not think the photo voucher could be a Chiricahua leopard frog. We also have a small preserved collection of tadpoles and metamorphs from central Black Draw in May 1987, all of which appear to represent *R. yavapaiensis*. Lowland leopard frogs have been identified in the Peloncillo Mountains (Charles Painter and Norman Scott, personal communications). As such, both species may occur at the refuge when and if regional leopard frog metapopulations ever rebound.

The potential occurrence of two species of leopard frogs in the area has implications for re-establishment work on leopard frogs at the refuge. Early work demonstrating co-occurrence (co-existence) of Chiricahua and lowland leopard frogs was used to support species-level recognition for both taxa (Frost and Platz, 1983; Platz, 1976; Platz and Frost, 1984; Platz and Platz, 1973). Hybridization was uncommon in sympatry, but it did occur, as it regularly is found to do in many, if not most, sympatric species pairs of leopard frogs. Although F_1 hybrids occur in nature and can be created between many taxa in the laboratory, backcrosses are usually sterile, or nearly so; however, backcrosses have been found in nature (see also Frost and Bagnara, 1977a, b; Dunlap, 1979; Green and Delisle, 1985; Kruse and Dunlap, 1976; Platz, 1972). This pattern of hybridization suggests that the leopard frogs may be "semi-species" that, on an evolutionary time scale, may well exchange genetic material. Such exchange would occur despite the existence of several strong pre-mating isolating mechanisms (call, breeding season, and habitat differences; see the above references, especially Frost and Platz, 1983).

For our purposes these facts are important for two reasons. First, limited co-occurrence of *R. chiricahuensis* and *R. yavapaiensis* could occur at the refuge in the future, given a best-case scenario where both species have thriving populations. There could be hybridization, especially if there were booming populations with enough spatial overlap and chaos during breeding to overwhelm pre-mating isolating mechanisms (habitat segregation, temporal segregation of breeding, advertisement call differences). Second, if such hybridization were frequent, for example from housing of two species together, it would presumably cause a substantial depression of fitness (hybrid dysgenesis). It should be 100% clear that it is absolutely imperative that leopard frog species are not mixed in re-establishment operations.

A third factor, currently unexplored, is just how "pure" we should strive to keep source material for leopard frog re-establishment. Inbreeding depression (at the opposite end of the continuum from hybrid dysgenesis) and/or loss of genetic variability could accrue with an extreme purist approach. The genetic arguments are certainly not resolved at present. For the time being, we recommend a consistent, conservative policy of not cross-breeding leopard frogs from different metapopulations within an area--for instance, between Leslie Creek and San bernardino NWR. Genetic analysis and further consideration could alter this recommendation.

Finally, field workers (scientists, managers, biotechnicians) should be alert for the appearance of long-snouted, usually tan-and-brown leopard frogs that may be the lowland species, *R. yavapaiensis*. At Leslie Canyon, where the Chiricahua leopard frog and the plains leopard frog, *Rana blairi*, once co-occurred (Frost and Bagnara, 1977a), there is a possibility that the plains species, which still lives near Whitewater Draw and Willcox Playa, may reappear.

Disappearance and Last Records at SBNWR. There is some confusion regarding historic leopard frog occurrence and abundance at San Bernardino Ranch. Earlier reports suggest that leopard frogs were abundant all over, even when bullfrogs were present. This suggests that bullfrogs and leopard frogs co-existed for much longer than we might have expected. This is true, but only given several specific caveats, as described here.

Bullfrog records in museum collections at San Bernardino Ranch date to at least 1954 (personal observation, UAZ collection); and Wendy Glenn reported that some leading citizens of Douglas proudly brought progress (in the form of the then-novel bullfrog) to Slaughter Ranch in

the mid-1940's. At that time, of course, the ranch was private, and aquatic conditions and biota quite different from that seen toady. For example, Astin Tank was a large pond fed more or less continuously from Astin Spring. Black bullheads, black crappie, largemouth bass, bluegill sunfish, and common carp have all been taken at San Bernardino Ranch (summarized in Hendrickson et al., 1980) prior to creation of the native fish refugium.

Observations near Portal and near San Pedro River indicate that, in open-water ponds, bullfrog tadpoles survive well with exotic fishes, but adults are only moderately abundant. This is expected based on results showing unpalatability of bullfrog tadpoles to fishes (Grubb, 1972; Kats et al., 1988; Kruse and Francis, 1977; see also Sexton and Phillips, 1986), along with the evident palatability of metamorphs to fish. At San Bernardino Ranch, the elimination of exotic fishes, but not bullfrogs, very likely led to a population surge, and possibly a spread, of the bullfrogs, which had been left with only garter snakes (upon which they also prey) and herons as effective predators. It may seem contradictory, but it is not, that elimination of a single class of exotics may not be wholly beneficial. Our observations suggest that bullfrog population densities in central Arizona are also moderate in abundance in the presence of numerous other exotic species, notably fishes (see also Clarkson and deVos, 1986, for similarly moderate abundances seen along the Colorado River).

Nonetheless, statements that we have repeated (Schwalbe and Rosen, 1988, Rosen and Schwalbe, 1995), attributed to earlier investigators, that leopard frogs were everywhere abundant at SBNWR, are not supported by specimens. Tadpoles at the University of Arizona collection, from ponds at the site from 1965 are *R. catesbeiana*. Museum vouchers from 1980 at Arizona State University include large numbers of preserved bullfrogs from Twin Pond and other major ponds, and leopard frogs only from small springs (apparently Cottonwood, Middle, and Ciénega Springs, although we have not yet determined the exact locality). We found leopard frogs in August 1985 in a few shallow-water habitat areas, but mainly in Black Draw where some factor, possibly predation by endothermic predators (hawks, mammals) in the shallower water and more exposed stream banks restricted bullfrog size and abundance severely in the upper spring. Leopard frogs persisted in local abundance in open and shallow habitat, characteristic of central Black Draw in the late 1980's, to July of 1988, but had disappeared by September 1988.

Leopard frogs have not been observed on the Refuge, with the exception of isolated individual occurrences, since 1988. Based on the long term observations of Refuge Manager Kevin Cobble, Assistant Manager Matt Magoffin, and from NBS herpetologist Dr. Norm Scott, we have an emerging understanding of the remaining leopard frogs of this region (comprising the lower San Bernardino Valley in the United States). We here commit the details to prose for the record.

In 1991 Kevin Cobble observed 2 leopard frogs in a two-track road mudpuddle, on the Malpai Ranch access road to the refuge north gate. This is on the Black Draw bottom near North Pond. As there are unlikely to have been breeding leopard frogs in this area at that time, the finding suggests a possibility of a breeding population near Black Draw on Peterson Ranch.

In 1990, Dr. Scott observed a leopard frog at Hay Hollow windmill, on the refuge several km upstream from Black Draw, and Cobble saw one or more there in 1991. We visited this site in May 1992 with Mike Sredl and Jeff Howland (AGFD), but found only a single large bullfrog at

the spot the leopard frogs had been seen. We interpret this as also representing immigration of leopard frogs from a more extensive source--this one probably in Hay Hollow (Magoffin Ranch).

In 1993 Matt Magoffin reported to us leopard frog populations on his ranch 5-11 km east of the refuge, on the Hay Hollow system upstream of the Peterson Ranch portion that intervenes between Magoffin Ranch and SBNWR. On the latter property, the Hay Hollow windmill pond on Peterson Ranch reportedly has bullfrogs, and not leopard frogs. Rosewood Tank, 11 km east of the Refuge on Guadalupe Canyon Road, and Belency Tank just above the Mexican border south of the Magoffin homestead, both have populations of Chiricahua leopard frogs as reported to us, and as verified in March, May, July, September, and October 1994.

Recent records at San Bernardino Ranch, 1980-1988, do not suggest co-existence of leopard frogs with bullfrogs on a stable protracted basis. The Chiricahua leopard frog disappeared early from refugia in heavily-vegetated spring runs, and the lowland leopard frog disappeared less than a decade later, possibly following a recrudescence in a notably sparsely-vegetated local spring run. In the mid-century decades, exotic fishes may have partially mitigated the effect of bullfrogs on leopard frogs by partially controlling the bullfrog population. Nonetheless, leopard frogs clearly were restricted to local population centers. During the wet period, which ended in the late 1980's, leopard frog successfully colonized sites that were semi-perennial and hence marginal. The elimination of exotic fishes appears to have produced a further increase in the bullfrog population, which overwhelmed the landscape and, in combination with worsening drought conditions, led to complete extirpation of the leopard frogs.

Management, Monitoring, and Natural History, 1993-1994.

I. Dispersal. During 1993 and earlier, Matt Magoffin made important observations on Chiricahua leopard frogs in the Hay Hollow system. These were reported to us in detail in March 1994, as follows. Bullfrogs occurred briefly in Rosewood Tank, reaching there via human introduction, but disappeared some years ago during dry times, never having achieved large population size. Belency Tank, originally constructed 20-25 yr ago, has only supported leopard frogs. During the foresummer drought in recent years, leopard frogs were seen only at these two tanks, to a distance of 3 or more miles in any direction. During 1993 and also in many previous years, the onset of summer rains produced flooding in Hay Hollow, with persistent large puddles at arroyo crossings of Geronimo Trail and Guadalupe Canyon Road (as well as in the natural sacaton bottoms). Leopard frogs were frequently seen in these pools, and even--along with ephemeral water anurans--in short-lived pools at the Magoffin Ranch headquarters. The specific locations indicate that these leopard frogs disperse during the summer monsoon to at least 3-5 km from dry season refugia ponds. The distance is probably considerably greater, at least on an individual basis.

These observations, along with the remarkable occurrence of *R. yavapaiensis* in Black Draw in 1988, and long-distance movements detected by AGFD in Tule Creek, Yavapai County, Arizona (Mike Sredl, personal communication), all show surprisingly large movements in Southwestern leopard frogs. Similar or even longer movements are evidenced by the rapid spread of the introduced Río Grande leopard frog *R. berlandieri*, both upstream and downstream in the lower Gila River (Platz et al., 1990; J. Platz, J. Rorabaugh, personal communications). These large spatial scales of movement are concordant with metapopulation dynamic processes.

Leopard frogs almost certainly occur in large metapopulations, which have core areas, refugia, and large population fluctuations related to climate and biotic factors.

II. Abundance and Management.

A. Monitoring Results in Natural Populations. We estimated approximately 20 adults in each Magoffin Ranch leopard frog population during early 1994. There were over 400 tadpoles in Rosewood Tank in the arid March of 1994 (probably some thousands in May-June 1993. M. Magoffin, K. Cobble, personal communication), and probably many hundred tadpoles in Belency Tank in May 1994. The counts discussed here are direct observations of adults by Matt Magoffin and Phil Rosen in 1994, and of tadpoles based on seining by Cobble, Magoffin, and Rosen.

In early 1994, counts were 9-18 adults observed at Rosewood, 17-25 at Belency, and 27 in a night of counting at Leslie Creek, June 14, 1994. In early to midsummer, Guadalupe Canyon bottom contained 3 adult plus 9 metamorph *R. chiricahuensis* about 1 mi W of the state line, plus 9-20 metamorphs at Guadalupe Canyon Ranch, lower House Pond. Midsummer counts at Rosewood were generally 3-14 adults with up to 20 metamorphs, but these metamorphs were probably eaten by the adults and by checkered garter snakes. Up to 60 frogs of various sizes were counted at Belency Tank in August. In Guadalupe Canyon, all the metamorphs disappeared, either via predation by adults or other naturally-occurring predators, or when they jumped into the upper ranch-house pond (a 1-2 m distance), which had a high density of centrarchid fishes. By late 1994, numbers of adults were everywhere reduced. Guadalupe Canyon dried and the frogs were not found in September, even after late rains. At Rosewood Tank, counts in September were 4-8 adults, and at Belency Tank we counted 41 during an invasion of herons, and observed (and removed) 21 checkered garter snakes foraging for frogs on September 9, 1994: clearly the number of frogs continued to dwindle in the fall. The higher values in each stated range seem to be approximately the total number of frogs present. In each case, conditions were ideal for frog activity and observer visibility.

Photo vouchers are available for all sites. All frogs were clearly *Rana chiricahuensis*. Contention Spring, just above Guadalupe Canyon Ranch, appeared suitable for leopard frogs, but none were found in our 1994 survey. This is a bedrock stream, apparently not as attractive to Chiricahua leopard frogs as alternate pool and pond habitats. There were no other known leopard frog sites in the lower San Bernardino Valley region in 1994. We surveyed widely in Cottonwood and Sycamore Canyons, in Clanton Draw, as well as in Baker and other canyons tributary to Guadalupe. Frogs may occur at some point higher in the Peloncillos, but we have no evidence for it.

B. Circumventing Drought at Rosewood Tank. Rosewood Tank was historically a major water hole in the region, and appears on USGS 1:250,000 maps. It is now silted in and, due to the current drought, dried completely during spring 1994 for the first time in memory. It had previously gone dry or nearly dry in 1989 and 1994, but wet mud with cattle footprints permitted leopard frogs to survive.

Matt Magoffin and his sons, Chris and Mike, dug a 3 m x 3 m x 1.75 m deep pool in the tank bottom as it dried in early April, and transferred tadpoles (approximately 400 in all) to this water hole from the drying, original pond bottom. They brought water to this site for the frogs

through the unusually warm, dry summer. In June, Matt Magoffin refurbished the main tank's two pools, digging them ca. 1.5 m and 2.5 m deeper than the current, silted-in pond floor. The small water hole with the frogs was left perched between the two excavations. He also re-designed the outflow system of the tank. The pond will be about 4-5 m deep when filled with runoff.

C. Re-Establishing Leopard Frogs at SBNWR. During February-June 1994, in a collaboration involving SBNWR, and AGFD Nongame Branch ranid frog personnel (especially Jeff Howland, Mike Sredl, and Jacques Hill), and us, we initiated a re-establishment project for *Rana chiricahuensis* at SBNWR. In consultation with us and AGFD, SBNWR constructed a complex of four small ponds (each ca. 5 x 8 m) in the center of a 95 yard square (0.75 ha, or 1.9 acre) fenced plot (4' hardware cloth, 1/8" mesh, sunk 8-10" into the ground) to exclude bullfrogs. The ponds are fed by controlled artesian flow, regulated to 1.2 - 2 m depth by float valves, with introduced native aquatic vegetation, rocks, stumps, and branches as cover for frogs. In late spring 1994, we released approximately 1/2 of the tadpoles and metamorphosing froglets saved from Rosewood Tank (188 in all) in this enclosure.

These refuge ponds are designed to (1) allow successful breed-out of leopard frog stock, (2) observe the success rate in refuge water with no bullfrogs, and (3) be sub-divisible in the future for experimental evaluation of leopard frog breeding success with fishes or snakes of various kinds.

Within a week of the leopard frog release, great blue and green herons were regularly present in the leopard frog enclosure. They occurred in unusually high numbers at SBNWR during this drought year. The four pools were covered with "predator netting" (ca. 4" X 4" mesh) 8-15 July, 1994, halting heron use of the area. Following rainstorms, we removed 35 small juvenile bullfrogs that had apparently climbed into the exclosure. Undoubtedly, some of the leopard frogs inside climbed out. During February 1995, SBNWR installed screen eaves on the fence top. No small bullfrogs remained in the exclosure, but at least one checkered garter snake *Thamnophis marcianus* entered (presumably via deep soil tunnels), and was removed.

D. Observed Numbers in the Enclosure. Careful observation at the enclosure by Cobble, Magoffin, and Rosen yielded counts of 1-15 leopard frogs, usually 4-8, throughout the summer and fall of 1994 (Table 9). Dense vegetation makes this an underestimate of total frog number. The counts were generally consistent, and suggest that 15-30 frogs survived into early fall.

E. Observations of Frog Reproduction. Limited breeding occurred in late winter 1994 in both Belency and Rosewood Tanks. Three egg masses were seen in Belency on March 28, 1994, and small tadpoles were seen there in late May. By late May at Rosewood, only larger tadpoles were found, suggesting that rapid drying inhibited reproduction there during late winter and early spring.

Rosen observed 6-10 *R. chiricahuensis* in the enclosure in a chorus aggregation, with at least 4 individual males calling, September 6, 1994. This is at an age no greater than four months post-metamorphosis. Cobble observed single tadpoles in October 1994 and February 1995.

Two egg masses were produced at Rosewood Tank in early to mid September 1994. No eggs were seen in Belency, where water levels continued dropping all summer. Rosewood Tank

Table 8. Stomach contents of bullfrogs from San Bernardino NWR, Cochise Co., Arizona, 1985-1994.

Gila purpurea	13		
Poeciliopsis occidentalis	17		
Fish (unidentified)	32		
total FISH			62
Rana catesbeiana	30		
Rana pipiens complex	6		
Frog (unidentified)	77		
subtotal FROGS		113	
Rana catesbeiana tadpole	11		
Tadpole (unidentiifed)	65		
subtotal TADPOLES		76	
total ANURANS			189
Elgaria kingi	1		
Urosaurus ornatus	1		
Sceloporus sp.	1		
Cnemidophorus uniparens	1		
subtotal LIZARDS		4	
Salvadora hexalepis	1		
Thamnophis marcianus	2		
subtotal SNAKES		3	
Kinosternon sonoriense	1		
total REPTILES			8
total BIRDS	5		5
Peromyscus sp.	3		
Sigmodon sp.	2		
Mammal (unidenitifed)	8		
total MAMMALS			13
unidentified vertebrates	4		4
Grand Total VERTEBRATES			281
Lepidoptera	919		
Coleoptera	510		
Orthoptera	199		
Odonata	215		
Zygoptera (only)		22	
Anisoptera (only)		20	
unidentified Odonata		173	
Hymeoptera	164		
Hemiptera	162		
Diptera	70		
subtotal INSECTA		2239	
subtotal ARACHNIDA		73	
subtotal CRUSTACEA	50		
total ARTHROPODA			2362
total MOLLUSCA	201		201
total INVERTEBRATA			2563
total ANIMALS	2490		2844
PLANT MATERIAL			201
GRAND TOTAL			3045

Taxonomic Summary:	
Pisces	62
Anura	189
Serpentes	3
other Vertebrata	23
Lepidoptera	919
Coleoptera	510
Orthoptera	199
Odonata	215
Hymenoptera	164
Hemiptera	162
Diptera	70
Crustacea (Isopoda)	50
Arachnida	73
Mollusca (snails)	201

Table 9. Monitoring results for Chiricahua leopard frogs in enclosure, SBNWR, Arizona, 1994.

Date	Time	Observer	No. leopard frogs	Method; Annotations
31-May	0843 - 0943	Rosen	18	Binoculars. (all metamorphs)
15-Jun	1025 - 1035	Rosen	8	Splash count
17-Jun	1000 - 1100	Rosen	9	Binoculars; 1 green heron
18-Jun	0830 - 0840	Rosen	3	Splash count; 1 green heron
6-Jul	0840 - 0910	Rosen	4	Binoculars + Splash Count; 2 green herons
7-Jul	1203 - 1216	Rosen	2	Splash count; 1 green + 2 great blue herons
7-Jul	2230 - 2330	Rosen	15	Head lamp. (11 juvenile, 3 metamorph, 1 tadpole)
8-Jul	0934 - 0954	Rosen	6	Splash count
19-Jul	1847 - 1909	Rosen	12	Splash count; just after sunset
2-Sep	2305 - 2335	Rosen	7	Head lamp; males calling; 2 juvenile bullfrogs shot
6-Sep	1740 - 1804	Rosen	7	Binoculars; 3 juvenile bullfrogs seen
6-Sep	1530 - 1550	Cobble	4	Binocs; 1 checkered garter, 11 juv bullfrogs seen
6-Sep	2103 - 2309	Rosen	7	Head lamp; garter sn removed, 13 bullfrogs shot
9-Sep	1040 - 1055	Rosen	4	Splash count
12-Sep	1530 - 1550	Cobble	2	Binoculars; 2 juvenile bullfrogs seen
16-Sep	1510 - 1525	Cobble	7	Binoculars; 4 juvenile bullfrogs seen
28-Sep	0800 - 0900	Cobble	7	Binoculars; 9 juvenile bullfrogs shot
28-Sep	1500 - 1600	Cobble	several	Binoculars; 9 juvenile bullfrogs shot
29-Sep	NA	Cobble	NA	1 checkered garter snake seen
5-Oct	1400 - 1500	Cobble	8	Binoculars; 3 juvenile bullfrogs seen
11-Oct	1445 - 1505	Cobble	1	Binoculars, 3 juvenile bullfrogs seen

eggs hatched, but tadpoles were not found growing at expected rapid rates, and all may have failed. Monitoring in 1995-1996 will be required to track these populations.

F. Additional Progress in Collaboration with Ranchers. Also during summer 1994, Magoffin refurbished a small tank and windmill (Shoat Tank) on his ranch between headquarters and Belency, to set the stage for re-colonization by leopard frogs. During winter 1994-95, he established a well for Belency, which had been dry in 1989, and threatened to dry in late 1994. Water levels were rising in February 1994 despite a lack of storm runoff, as is typical even of wet winters in this area (Matt Magoffin, personal communication). The Malpai Borderlands Group is working with Magoffin, AGFD Stewardship Program, and Rosen and Schwalbe (as advisors) to establish a well and water pipe system for Rosewood. This system could supply water for both leopard frogs and cattle. The project is currently planned for spring 1996.

This set of project operations is part of a program in which private, academic, state, and federal parties are cooperating to prevent the extinction of native Southwestern ranid frogs. We argue that cooperation with local ranchers, including assisting them with managing waters beneficial both to cattle and to leopard frogs, may be of great assistance for both short-term and long-term preservation of leopard frog populations that are faced with introduced predators and competitors.

Most desirable would be waters we can control, in order to eliminate the introduced species, and to manage regional metapopulations of frogs. "Manageable waters" would be those that we can dry out, if needed, and regulate water level as desired. We may wish to maintain water levels during drought, or to rapidly raise water levels to stimulate reproduction or dilute predaceous insect population density. Thus, wells would be very useful features of frog conservation ponds. The early successes of the program described here suggest that re-introductions may be successful, and that management of existing populations has some chance of success. We recommend support for these efforts in the Malpai Borderlands region. In addition, we emphasize that a leopard frog metapopulation project could be highly informative and potentially successful at Buenos Aires National Wildlife Refuge, Pima County, Arizona.

Garter Snakes

We have made 15 recaptures of marked Mexican garter snakes, *Thamnophis eques*, and 26 of checkered garter snakes, *T. marcianus*, among 249 garter snake capture records through 1994 (Table 10). The relative frequency of *T. eques* to *T. marcianus* has fallen steadily. This trend is probably a response to selectively heavy bullfrog predation on the more aquatic Mexican garter snake. The declines for both species in 1994 (Table 10) probably reflect population reductions at the culmination of a protracted drought.

Recapture data indicate that adult *T. eques* are long-lived, with known ages of 6, 7, 7, and 10 yr confirmed by long-term recaptures of individuals marked as juveniles or young adults in the 1980's on the refuge. Our data for *T. marcianus* suggest lower survivorship is likely, as expected for garter snakes. The Mexican garter snake has persisted on the refuge most likely because high adult survivorship slows the decline of a decreasing species. However, *T. marcianus* shows an ability to heal marking scars and other injuries that surpasses that of other snakes in Arizona, and some marked individuals on the refuge may have lost their marks. This species has been

Table 10. Numbers of captures of two species of garter snakes (genus *Thamnophis*) at San Bernardino NWR, Cochise County, Arizona, 1985-1994.

YEAR	*T. eques*	*T. marcianus*
1985	2	3
1986	8	5
1987	9	7
1988	12	6
1989	12	21
1992	10	10
1993	20	63
1994	14	47
TOTAL	87	162

Table 11. *Thamnophis eques* age structure at San Bernardino NWR

	Bullfrog Removal Sites:		Bullfrogs Not Removed:		Adult Bullfrog-Free Spring:	
YEAR	JUV + YRLING	OLDER (Larger) Snakes	JUV + YRLING	OLDER (Larger) Snakes	JUV + YRLING	OLDER (Larger) Snakes
1985-6	-	4	-	3	2	-
1987	-	2	-	1	4	2
1988	-	1	1	2	5	-
1989	3	1	-	-	4	-
	- -- -- -- -- -- - no removals / no sampling - -- -- -- -- -- -					
1992	-	8	-	-	1 Dried	-
1993	6	10	-	-	- Dry	-
1994	5	6	-	2	- Dry	-

Table 12. Records of snakes at and near San Bernardino NWR, Arizona, 1985-1994. All records from Geronimo Trail and Guadalupe Canyon Road vicinities are included between Douglas and Peloncillo Mountains.

Species	No. Marked	No. Rcpt.	Other	Total
Crotalus atrox	13		20	33
Crotalus scutulatus	1			1
Micruroides euryxanthus			1	1
Masticophis flagellum	19	4	16	39
Masticophis bilineatus			1	1
Pituophis melanoleucus	9	5	4	18
Lampropeltis getula	11	1	4	16
Rhinocheilus lecontei	4			4
Hypsiglena torquata	3		1	4
Salvadora hexalepis	2		3	5
Tantilla hobartsmithi	1		1	2
Diadophis punctatus	2		1	3
Thamnophis sp.			17	17
Thamnophis eques	62	15	10	87
Thamnophis marcianus	118	26	34	178
TOTALS	245	51	113	409

TABLE 13. Snakes observed at SBNWR, Arziona, 1985-1994.

SPECIES	NPOND	TWIN	EVILTW	LDRAW	CDRAW	UDRAW	MAINRD	2PHD	ROBERT	HOUSE	BATHH	TULE	COTTONW	MESQ	F-POOLS	ASTIN	MESA	% of fauna	Total
Crotalus atrox	7	7		1	1	2	4			1			1	1		1	2	7.69	28
Crotalus scutulatus	1																	0.27	1
Diadophis punctatus	2							1										0.82	3
Hypsiglena torquata	1		1		1												1	1.10	4
Lampropeltis getula	5	1		1	4	1	1	1			1		1					4.40	16
Masticophis flagellum	13	6		6	4	2	1		1		2		2			1		10.44	38
Pituophis melanoleucus	5	2			1	2	3				1		1					4.12	15
Rhinocheilus lecontei	1		1							1							1	1.10	4
Salvadora hexalepis	1	2			1													1.10	4
Thamnophis eques	27	22	7	11	18				1					1				23.90	87
Tantilla hobartsmithi	1												1					0.55	2
Thamnophis marcianus	49	23	46	8	3	1		11	6	7	2	1	2	1	1	1		44.51	162
Thamnophis sp.	3	6	3	2					1		1		1						17
TOTAL	116	69	58	29	33	8	9	13	9	9	7	1	9	3	1	3	4		381

reproducing with regularity and success on the refuge.

We have evidence that bullfrog removal has allowed statistically significant levels of recruitment in the Mexican garter snake at SBNWR (Table 11). There was recruitment of juveniles into the Twin Pond population, co-incident with low bullfrog densities there in the late 1980's, and again following an extremely successful bullfrog removal in 1992 and early 1993. Twin Pond was drained for refurbishment during 1987, which probably contributed to the low numbers of bullfrogs there in 1988-1992. No males Mexican garter snakes have been found at North Pond since May 1992, and no young or gravid females were observed there during 1985-1994. At North Pond, we have yet to observe any indication of positive effect of bullfrog removal on the Mexican garter snake.

The North Pond population of Mexican garter snakes may be failing due in part to lack of males (which may not readily outgrow bullfrog predation size). At Twin pond and elsewhere, the quantitative response in numbers of Mexican garter snakes to bullfrog removal was 1-2 orders of magnitude less than we might expect based on healthy populations elsewhere in southeastern Arizona (Rosen and Schwalbe, 1988). If bullfrog removal is successful, and drought conditions are broken, we should detect an upswing on the order of 25-50 recruits in 1995 and 50-200 in 1996 or 1997.

Drying of the central spring in Black Draw (see Table 11) presents a serious problem for the Mexican garter snake population on the refuge, unless continued and stronger recruitment occurs at Twin Pond and other bullfrog removal sites. The species may occur in adjacent Mexico, but if so it may be affected by the same population decline, in spite of the border. The nearest known U.S. populations are at and near Lewis Springs, San Pedro River (Rosen and Schwalbe, 1988), at a distance of 98 km from SBNWR. This species is threatened with extirpation in the area, and probably throughout its U.S. range.

Overall Snake Marking Project

During 1993-4, we rapidly expanded our sample size for snakes by using extensive live trapping of garter snakes. We have marked a total of 245 snakes on the refuge and obtained 51 recaptures (Table 12). The recaptures of gopher snakes, *Pituophis melanoleucus*, despite the few individuals marked are consistent with data from Avra Valley and Organ Pipe Cactus National Monument, Pima County, Arizona: the abundance of gopher snakes is more apparent than real, and full-sized adults are surprisingly few in number. Table 12 includes all 409 snake captures (358 individuals) recorded in lower San Bernardino Valley (defined here as extending from the east outskirts of Douglas (Airport Drive and 15th Street) to the entrance of Guadalupe Canyon riparian habitat), including records from Geronimo Trail and Magoffin Ranch. All marked and recaptured animals in Table 12 are from the refuge.

The Mexican garter snake, *Thamnophis eques*, is known only from the refuge, although individuals probably are present infrequently at Astin Spring. Table 13 summarizes the 381 snake records for the refuge area (including associated Astin Spring on the Glenn's neighboring Malpai Ranch). The numerous records at North Pond and Twin Ponds (including Evil Twin) reflect trapping operations and heavy investigator presence there. Mexican garter snakes were more frequent than checkered garter snakes only in Black Draw, particularly prior to 1992. Table 13

also illustrates the infrequency of snake sightings on the mesa uplands, where reptiles are relatively few, with the exceptions of saxicolous lizards on the old fort walls and terrestrial lizards along road margins.

During 1992-4, we observed numerous dead snakes, not seen in previous, less severe years of the current drought. Among cases where a cause of death could potentially be determined, most were attributable to predation. The records are as follows: [1992] (1) coachwhip at hawk roost base at Ciénega Spring, (2) ringneck snake at North Pond with raptor-type injuries; [1993] (3) western diamondback rattlesnake dead under cover in Black Draw possibly starved or desiccated [1993], (4) gravid female kingsnake being eaten by great horned owl in Black Draw [1993], (5,6) two garter snake skeletons (possibly eaten by predators at North Pond) [1993], (7) large 10 yr old Mexican garter snake found dying of bullfrog-bite-induced tail infection at North Pond; [1994] (8) checkered garter snake partially eaten by small- to medium-sized mammalian predator at North Pond [1994], (9) coachwhip under redtail hawk nest in Black Draw [1994].

Additionally, for the record, two diamondback rattlesnakes have been run over, one kingsnake was accidentally bladed during construction of the leopard frog enclosure, one Mexican garter snake was caught in a cattail cutting machine and a second was drowned in a fish-census minnow trap. These are not considered significant at the population level, but we emphasize the need to avoid accidental mortality of Mexican garter snakes at the present critical time. Overall, the mortality observations suggest that the drought is a time of natural population decline for the snakes, mediated by intense predation, as well as by probably weak recruitment.

We recommend a system of cover and drift fence traps be established on the refuge to enhance the catchability of snakes to continue these observations.

TURTLES

We have 120 recorded observations of Sonoran mud turtles at SBNWR during the work connected with this project, including a number of turtles observed by refuge personnel and us during trap-checking operations 1993-4 (Table 14). The increase in 1993-4 can be ascribed to intensified frog trapping activity, although age structure (Fig. 5) suggests that there has recently been good recruitment. All aquatic turtles we have seen are Sonoran mud turtles, *Kinosternon sonoriense*, although it is conceivable that the yellow mud turtle, *K. flavescens*, may appear on or near the refuge at some point.

Mud turtles have been recorded in North Pond, Tule Pond, Black Draw, Twin Pond, Evil Twin, House Pond, and Bathhouse Spring (Table 14). Most turtles handled were marked by notching marginal scutes, for a total of 35 individuals, mostly in the 1990's (Table 15). The majority of 1994 captures have been recaptures, and several recaptures were obtained in the early years of work in Black Draw. Based on simple Lincoln Index computations, with samples lumped to avoid high variance associated with low numbers of recaptures, and with elimination of redundant records from obviously trap-happy turtles, there are about 34 individuals on the refuge (Table 16), probably approaching 40 or 50 if House Pond (no recaptures available for computation) is included.

Table 14. Sonoran mud turtle captures at San Bernardino National Wildlife Refuge, Cochise Co., Arizona.

	YEAR								
Location	1985	1986	1987	1988	1989	1992	1993	1994	All Years
Double Phd Ponds	0	0	0	0	0	0	0	15	15
Bathhouse Well	0	0	0	0	0	0	7	0	7
House Pond	0	0	0	0	0	1	0	0	1
lower Black Draw	0	0	1	4	1	1	0	1	8
North Pond	2	0	0	0	0	1	26	17	46
Tule Pond	0	0	0	0	0	0	8	28	36
Twin Ponds	0	3	0	0	0	0	1	3	7
ANNUAL TOTAL	2	3	1	4	1	3	42	64	120

Table 15. Number of Sonoran mud turtles marked at San Bernardino NWR Cochise Co., Arizona.

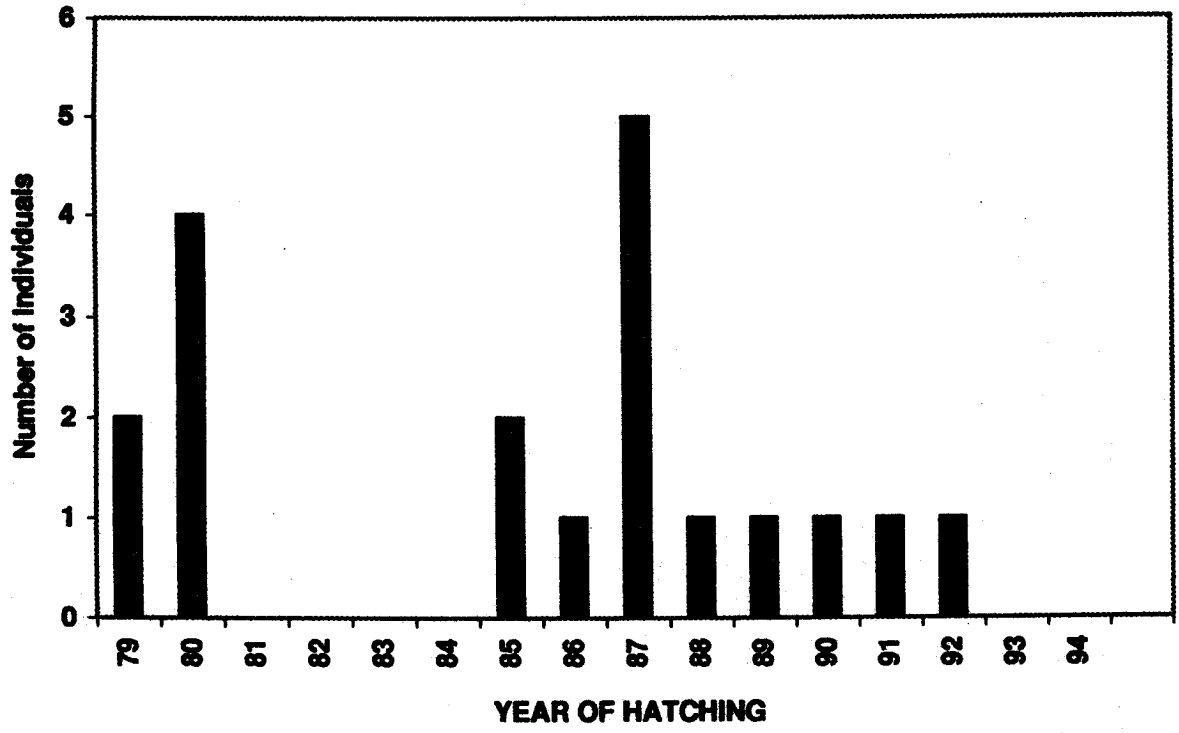
	YEAR								
Location	1985	1986	1987	1988	1989	1992	1993	1994	All Years
Double Phd Ponds	0	0	0	0	0	0	0	9	9
House Pond	0	0	0	0	0	1	0	0	1
lower Black Draw	0	0	1	2	1	1	0	1	6
North Pond	2	0	0	0	0	1	4	6	13
Tule Pond	0	0	0	0	0	0	0	4	4
Twin Ponds	0	3	0	0	0	0	0	2	5
ANNUAL TOTAL	2	3	1	2	1	3	4	22	38

Table 16. Population estimates for Sonoran mud turtles at San Bernardino NWR, Cochise Co., Arizona, 1985-1994.

LOCALITY	Lincoln Index value
Double Ph.D	14
Black Draw	2
North Pond	10
Tule Pond	4
Twin Pond	4
House Pond*	-
TOTAL	34

* no recptures available.

Figure 5. Natality of Sonoran mud turtles observed 1985-1994 at San Bernardino NWR, Cochise Co., Arizona, inferred from growth rings.



These population numbers are small compared to those observed in similar turtle habitat elsewhere in Arizona, and bullfrog predation on young turtles is a possible explanation. The first confirmation of such predation was in May 1994. However, in 1993 we found a healthy population of Sonoran mud turtles at Arivaca Ciénega, Buenos Aires National Wildlife Refuge, also with a high density of bullfrogs. There may be habitat features at Arivaca reducing the impact of bullfrogs, or earlier extensive digging and pond drying at SBNWR may have reduced turtle populations, or there may be some other factor of which we are ignorant. Many of the turtles at SBNWR are young enough to have recruited in the mid-late 1980's, indicating a healthy population nucleus that may expand to the much higher population densities observed elsewhere in comparable habitat in southeastern Arizona.

Box turtles were occasionally observed in the 1980's on the refuge, but we did not see them during 1992-1994 despite our frequent presence on site. We recommend a regular record-keeping for box turtles seen by refuge and project personnel on SBNWR.

RECOMMENDATIONS

1. Continue intensive bullfrog removals at SBNWR via manual capture and continuous trapping for another two years to track results. Trapping should be initiated during the 3rd to 4th week on April, and continued to at least mid-September.

2. Develop additional methods of bullfrog control at SBNWR, including removal of egg masses and hand collection of metamorphs and juveniles.

3. Experiment with increasing the bullfrog trap density at one or more ponds, starting with North Pond.

4. Support the Magoffin Ranch frog conservation project via Stewardship funding, advisement, and assistance with frog population monitoring.

5. Continue monitoring leopard frogs in the enclosure at SBNWR.

6. Continue monitoring garter snake and mud turtle populations at SBNWR, and initiate monitoring at the level of record-keeping by all personnel for the western box turtle.

7. Establish system of cover and drift fence traps be established on the refuge to enhance the catchability of snakes to continue ongoing population study.

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Sensitive information removed from report.

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