Status of Native and Introduced Species of Aquatic Herpetofauna

at San Bernardino National Wildlife Refuge

Philip C. Rosen

Department of Ecology and Evolutionary Biology
University of Arizona, Tucson, AZ 85721

and

Cecil R. Schwalbe

U.S.G.S. Biological Resources Division, Cooperative Park Studies Unit
University of Arizona, Tucson, AZ 85721

FINAL REPORT

to

Arizona Game & Fish Department
Heritage Program
2221 West Greenway Road
Phoenix, AZ 85034

U.S. Fish and Wildlife Service
San Bernardino National Wildlife Refuge
7628 N. Highway 191, P.O. Box 3509
Douglas, AZ 85607

on the challenge cost share project

BULLFROG IMPACTS ON NATIVE WETLAND HERPETOFAUNA

Arizona Game and Fish Department Heritage Grant
IIPAM I95045

December 31, 1997

ARIZONA GAME & FISH HERITAGE FUND
ARIZONA LOTTERY
LOTTERY DOLLARS WORKING FOR WILDLIFE

STATUS OF NATIVE AND INTRODUCED HERPETOFAUNA

AT SAN BERNARDINO NATIONAL WILDLIFE REFUGE

1997

FINAL REPORT

DISCLAIMER

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report summarizes and updates our findings on the impacts of bullfrogs on garter snakes, the effectiveness of ongoing bullfrog control measures, and work toward leopard frog population recovery in the San Bernardino Valley. We discuss the Mexican and checkered garter snakes, Chiricahua leopard frog, Sonoran mud turtle, and other reptiles at and near San Bernardino National Wildlife Refuge (SBNWR), Cochise County, Arizona, for 1985-1996 and 1997. Information on the background of this project is available in the published literature (Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1995) and in previous reports (Rosen and Schwalbe, 1988, 1996a & b).

The focus of the work has been the effect of introduced bullfrogs (*Rana catesbeiana*) on native Mexican garter snakes (*Thamnophis eques*) and on Chiricahua and lowland leopard frogs (*R. chiricahuensis* and *R. yavapaiensis*). Leopard frogs disappeared from the refuge early in this project (1988), persisting in outlying ranch ponds without exotic species. They have been managed with success at and near SBNWR since 1994.

We report a sudden decline in four of the seven managed leopard frog populations, including the possible disappearance of a key population. These declines may share a common cause: all are within 2 miles of the international border, and sick, moribund, or dead frogs were observed in each case before the decline was confirmed. It seems possible that air pollution, a microbial epidemic, or nutritional shortfall could be involved. We are extremely concerned at this time, although frogs apparently remain at 5 or 6 of the 7 localities.

Mexican garter snakes have been declining since before 1985, when we first visited the refuge, but are approaching local extirpation in the late 1990's, as previously predicted. We are collaborating with the refuge to re-establish a viable population in a fenced, native fish and frog refugium at SBNWR, and to this end have established a trial breeding colony in captivity in Tucson. The first breeding attempt is to be fall 1997 and spring 1998. Without this effort, we would anticipate possible extirpation of the Mexican garter snake from Cochise County before active management options are underway.

Bullfrog removal efforts have yielded mixed results. Declines in harvested totals have been seen during 1995 - 1997, but they correlate with relatively small changes in trapping intensity. Our initial efforts in the 1980's were not effective. Intensified trapping in the 1990's produced a decline in bullfrog average size (and presumably age), and a decline in the number of very large bullfrogs. However, it appears that there may now be larger numbers of juvenile, subadult, and small adult bullfrogs than previously. Removals may be responsible for recent recruitment of juvenile Sonoran mud turtles. Temporary successes in bullfrog control in one pond system (Twin Pond) produced a small wave of recruitment of Mexican garter snakes, suggesting that intensive local control efforts produce the best results.

More promising for medium-term species preservation is the refurbishment of various wetlands at SBNWR that has been initiated in 1998 by U.S. Fish and Wildlife Service (USFWS). The main purpose is to eliminate an exotic parasite in the natives fishes on the refuge, the Asian tapeworm *Bothriocephalus achelognathi*. We are assisting planning Refuge Manager Kevin Cobble in the design of the refurbished wetlands. This will allow us to capture bullfrogs at temporary fences around ponds as

they are dried, and prevent bullfrog colonization of new wetlands using permanent fences. Fenced wetlands with native fishes, leopard frogs, and garter snakes are the best current option for sustaining large populations of native aquatic amphibians and reptiles. These may serve as sources for repopulation of surrounding ranch and forest areas with Chiricahua leopard frogs.

Captive propagation of garter snakes is not feasible on a large scale. They are very active snakes requiring frequent feeding with frogs, toads, and fishes. Even our small laboratory colony of 12 - 16 snakes in the genus *Thamnophis* requires considerable attention. A fenced semi-natural wetland at SBNWR would support one or two orders of magnitude more individuals. The fenced populations would be the most reasonable source for re-introduction of Mexican garter snakes in restored habitats.

Leopard frogs at the nearby Magoffin Ranch, at Rosewood Tank and Belency Tank, have been a focus of conservation work by private landowners, federal and state wildlife agencies, and university scientists. Frogs from Rosewood Tank have been established and have bred successfully in a bullfrog exclosure at SBNWR, and at newly constructed Choate Tank on Magoffin Ranch. Progeny have been released at a newly created pond at Douglas High School and one at Magoffin Ranch headquarters, and in a screened-in ranarium (frog breeding facility) at SBNWR. With funding and assistance from Arizona Game and Fish Department (AGFD), Malpai Borderlands Group (MBG), and The Arizona Nature Conservancy (TANC)--not to mention the great efforts of the Magoffins--wells, pumps, water lines, sediment traps at main cattle ponds, and a small cement pond, have been installed or repaired on Magoffin Ranch.

The work on Magoffin Ranch, SBNWR, and Douglas High School is the nucleus for a potentially more encompassing conservation project. It has led toward development of a plan for repatriation of frogs to a number of ranches in the Malpai Borderlands area. Under guidance from AGFD Nongame Branch and USFWS Ecological Services, we are surveying ponds in this area, and speaking with local landowners and land managers to clarify "on-the-ground" realities concerning a conservation plan for the Chiricahua leopard frog in this area. We anticipate that this will assist the development of the apparently imminent proposal to list the Chiricahua leopard frog as a federally threatened species. We also view this plan as a step toward a recovery program for the species based on public-private partnerships and on using our understanding of causes of frog declines to manage habitat for recovery. Development of this conservation plan is becoming an important focus for the ongoing work under this project.

INTRODUCTION AND OVERVIEW

This report presents results of ongoing garter snake monitoring, leopard frog conservation, and bullfrog removal efforts at San Bernardino National Wildlife Refuge for 1996, with available 1997 data included as possible. Project objectives are to (1) evaluate the feasibility of bullfrog removal as a means of control of this introduced species, (2) determine whether control of bullfrogs can assist population recovery of affected species, and (3) develop innovative strategies for management of native wetland herpetofauna (see Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1988, 1995, 1996a & b). In particular, the project aims to (4) assist recovery of Chiricahua leopard frog and Mexican garter snake populations in the Cochise County area.

The first phase of the project (1985-9) primarily involved two or three trips a year of 3-4 days each to remove bullfrogs from SBNWR. Results suggested weak positive effects of bullfrog removals on garter snakes (below, and Schwalbe and Rosen 1988); however, bullfrog populations recovered from the removals within less than a year. The second project phase was initiated in 1992 after a two-year hiatus. Effort was intensified beginning May 1993. This involved manual removals of bullfrogs by approximately 14-18 persons from University of Arizona and Arizona Game & Fish Department, plus extended trapping of bullfrogs during much of their active season. Trapping was conducted jointly by USFWS and University of Arizona personnel during June-November 1993, March-October 1994, and May-October 1995, and May-October 1996.

In 1994 we initiated a third phase of the project involving active preservation and management of Chiricahua leopard frog populations at and near the refuge. This was in collaboration with SBNWR, AGFD Nongame Branch, and the MBG, and Magoffin Ranch. 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, as well as at Leslie Canyon, which is under management by SBNWR.

Principal investigators, refuge managers, and AGFD Nongame Branch personnel collaborated in a frog re-establishment project during 1994, in which a portion of the tadpoles and metamorphs from Rosewood Tank were removed before the tank dried, and relocated (total 188) to a pond-enclosure system created for them on the refuge (Rosen and Schwalbe, 1996). The rest were maintained by the Magoffins in a pool dug in the dry floor of Rosewood and supplied by hauled water (about 1000 gallons/week). Rosewood has received scant runoff and has not filled completely since it dried in 1994. The refurbished tank bed has received very scant runoff in the locally extreme drought years since 1994, and has not properly resealed itself yet. A strong population at Belency Tank, on the Mexican border, has been left undisturbed except for installation of a windmill-powered well, cleaning of the sand trap with a bulldozer, and periodic monitoring.

This project has been expanded in cooperation with Douglas High School, University of Arizona, USFWS, and AGFD. In 1995, a small pond was constructed at the Choate Well site on Magoffin Ranch; stunted tadpoles from the Magoffins' pool at

Rosewood were established there in August-September 1995. In fall 1996, a ranarium was completed at SBNWR and stocked with wild Chiricahua leopard frogs from Guadalupe Canyon Road; and eggs from Choate were hatched and reared by students at Douglas High School. Surviving tadpoles from Douglas High School were released in May 1997 in a new pool constructed by SBNWR personnel at Douglas High School (n = 27 tadpoles), in a new small pond at Magoffin Ranch headquarters (n = 41 tadpoles), and at the SBNWR ranarium (n = 6 tadpoles).

BULLFROG REMOVAL AND ABUNDANCE

Review of Removal Program. Ongoing removal methods (detailed in Schwalbe and Rosen, 1988; Rosen and Schwalbe, 1995) consist of hand capture, spearing with a frog gig (as in sport hunting), and trapping using turtle traps (hoop nets) set at the ends of seine drift fences.

Trapping throughout the active season (April or May to September or October) was done 1993-7, with the longest trapping period and most extensive manual removal occurring in 1994 and 1995 (Table 1). Table 1 is the best available index of removal effort, which varied from year to year due to fluctuations in weather, number of skilled frog collectors during the manual removal efforts, and number of traps. Effort is correlated with total numbers and mass of frogs removed from the refuge (Tables 2-5, Fig. 1), making it difficult to statistically test the significance of changes of the magnitude we have seen in the bullfrog population of the refuge.

Bullfrog Egg Mass, Tadpole, and Juvenile Removals. Bullfrog egg mass removals were conducted at SBNWR during 1994-1996 with unknown effect on the population. Based on available records, we removed the following: (May 20-29, 1994, Mesquite Pond, 26 removed, 6 hatched masses observed); (May-June, 1994, House Pond, ca. 6 egg masses removed); (May-June 1995, House Pond, ca. 10 egg masses removed); (May 25, 1996, Astin Spring, 1 mostly hatched egg mass removed); (May 27, 1996, House Pond, 11 egg masses removed; Double PhD., 1 egg mass removed; Twin Pond, no egg masses found); (June 1996, House Pond, ca. 6 egg masses removed); (July 1996, Leopard Frog Enclosure, 1 egg mass transferred to garbage can, eggs infertile); May 24-26, 1997, House Pond, 7 egg masses removed; Twin Pond, 1 egg mass removed); (June-July 1997, Twin Pond, ca. 5 egg masses removed; Oasis Pond, 2 or more egg masses removed). All personnel removing egg masses did not consistently record removals. The annual totals for recorded egg mass removals were approximately as follows: 1994, 32; 1995, 10; 1996, 20; 1997, 14; total 1994-1997, 76 egg masses removed.

Tadpole removals were attempted in 1995 and 1996 using submerged minnow traps and larger wire tadpole traps. Submerged minnow traps, set primarily for fish sampling, captured large numbers of tadpoles, but unfortunately also inadvertently drowned garter snakes, including at least one large adult female Mexican garter snake. On our recommendation, the refuge has discontinued minnow trapping in the warm season. Other types of tadpole traps failed to capture large enough numbers to justify the effort. Dipnetting for tadpoles was frequently carried out to obtain live food for captive garter snakes, yielding 1-4 tadpoles per sweep in Twin Pond during 1996 and 1997. It seems unlikely that dipnetting could have a substantial effect on tadpole populations on the refuge.

Hand capture of juvenile bullfrogs at night from a canoe proved to be highly effective; it requires two persons to be efficient, and is somewhat labor intensive, but is the most promising additional removal technique we have tried. Capture success is about 80%. Under proper conditions, it is also possible to capture approximately 30% of observed juveniles while wading. Two persons can remove 50-100 or more juveniles from certain areas, such as Twin Pond and Double PhD. in a single night.

Refuge Manger Kevin Cobble attempted periodic removals of egg masses in Twin and Oasis Ponds in 1997, and suggested that tadpole densities were reduced as a result. It remains to be seen if these reductions are evident in 1998. Our experience is that bullfrogs may place egg masses in difficult-to-find places, and the intensive search required to remove all egg masses on the refuge during April- or May-August would be impractical. A highly motivated worker could remove much greater numbers of bullfrog egg masses at SBNWR by making regular, careful wading and canoe surveys, and by identifying frequent egg-laying sites for regular re-checking. Current removals should continue, but should be focused on sites where the most intensive removals are recommended for 1998 (below).

Bullfrog Population Trends at SBNWR. Annual variation in mass of large (subadult plus adult) bullfrogs removed (Table 5) roughly reflects total removal effort. At each of the four sites where intensive removals had been ongoing since 1992 (North, Twin, Tule, and House Ponds) there was a slight decrease in total biomass removed in 1996 compared to 1995, and total biomass removal from the refuge area was down markedly for the first time. The 1996 decline may primarily reflect a reduction in trapping carried out by refuge staff in that year (Table 1B) to 1993 levels, which yielded similar levels of biomass removal. The control methods, as currently applied, have reached a point at which further reductions in the bullfrog population will probably not be significant. The average size of the bullfrogs removed declined markedly from 1992 to 1994, but declined only slightly further after that (Fig. 3). A preliminary inspection of 1997 results to September 1 suggests that these trends are holding.

The existing protocol apparently results in removal of a high proportion of the adults, but rapid development and growth, plus the extended reproductive season on the refuge appear sufficient to sustain the bullfrog population at high density and substantial biomass. It is apparent that a tremendous harvest pressure can be withstood by a healthy bullfrog metapopulation such as this one. A re-design of the removal protocol is necessary.

It is possible that the protocol for removing primarily the larger frogs might prove to be self-defeating or counter-productive. Large bullfrogs are a major predator on smaller bullfrogs--quite possibly the more important bullfrog predator at SBNWR. By removing the large bullfrogs, we may be causing ecological release of the younger age-classes, enhancing recruitment and numbers of young adults.

We cannot directly determine absolute age- and size-structure of refuge bullfrog populations. However, two salient facts logically imply that there are indeed, as suggested above, increased numbers of small adult bullfrogs. First, total mass of adult-sized of bullfrogs removed has kept pace with removal effort, and thus bullfrog biomass productivity has declined little. Second, size of adult frogs has declined over the years, especially 1992-1996. For these two things to be true, there must be more small frogs than previously. The only way this logic could fail is if removal effort, as defined above, is not the primary determining factor in the year-to-year trends we observed (i.e., those in Figs. 1 & 2).

There seem to be remarkable "blooms" of juvenile bullfrogs of various sizes in ponds where removals have been intensive, especially House Pond, North Pond, and Twin Pond. We cannot quantify this directly because we did not actively attempt to estimate numbers of juveniles in earlier years of the study. However, earlier observations (1985-1992) were notable for the incredible density of huge bullfrogs, while our observations during the past 4 years seem to be highlighted by (1) the general inconspicuousness of large adults, (2) the surprisingly steady trapping returns of smaller adults, and (3) the above-mentioned blooms of juveniles.

Young adult and subadult bullfrogs in our dissection sample have been found to consume other bullfrogs up to the size of an average adult leopard frog. They also have been found to have eaten small juvenile garter snakes, including one Mexican garter snake (a 107 mm SVL subadult bullfrog had a neonate *T. eques* in its stomach). It is thus possible for removal of adult bullfrogs to be counterproductive, and we should examine this possibility carefully. We cannot draw conclusions now, except to recommend that potential negative effects of low-to-medium intensity bullfrog removal protocols should be examined as part of the new experimental design proposed below.

Modification of Plan for Further Bullfrog Removals. We conclude that the bullfrog removal protocol as currently employed has not been successful. A protocol that "works" should lead to elimination of bullfrogs, or at least to population reduction to consistently low levels. Neither of these criteria have been satisfied or appear likely to be in the near future without changes in the protocol.

There have been some successes of the bullfrog removal project: (1) successful bullfrog control in 1993 at Twin Pond (shortly after it was re-established after being dry for some years) permitted the only recent, significant recruitment of Mexican garter snakes, (2) there have been apparently consistent declines in body size of adult bullfrogs, which appear to reflect decreased survival of adults, and (3) we have seen substantial recruitment of Sonoran mud turtles into the refuge population since bullfrog removals began in 1985 (Rosen and Schwalbe, 1996a).

The garter snake recruitment was part of a statistically significant effect of bullfrogs demonstrated by Rosen and Schwalbe (1996a). However, bullfrog body size trends are still inconclusive, since body size was also low in the 1980's, before intensified removals began (Fig. 3; Tables 6, 7). The recruitment of Sonoran mud turtles is not necessarily related to changing bullfrog populations, although it seems plausible that it may be. Based on our observations at Arivaca (below, and Rosen and Schwalbe, 1996a), Sonoran mud turtle populations may be relatively resistant to bullfrog predation pressure. Moderate reductions in size and abundance of bullfrogs may be sufficient to benefit the mud turtle population. This is an important problem that requires further examination. We should seek comparative data from a variety of localities, and should continue to monitor the turtle population at the refuge.

The key observation remains, however, that there is not a clear trend toward regular and large declines in numbers or biomass of bullfrogs at SBNWR, as would be necessary for successful recovery of leopard frog and Mexican garter snake populations.

We conclude that more intensive removals than currently practiced will be needed to achieve bullfrog control. Other efforts to control bullfrogs, some formal and others undoubtedly opportunistic, are taking place in the name of native species conservation elsewhere in the West. If partial bullfrog removals are unsuccessful or even counterproductive, we should document that so that casual programs could be discouraged if need be.

Based on the above criteria and results, the bullfrog removal protocol at SBNWR should be modified to (1) attempt substantially intensified removals at one set of ponds, (2) contrast these results with the current protocol, which should be retained at a second set of ponds, and (3) contrast this with results in a third set of ponds where removals are not carried out at all. Specifics of this new experimental design are described here and formally specified in the recommendations section. We should utilize existing population structure of checkered and Mexican garter snake and Sonoran mud turtle populations as response variables to these three treatments.

Trapping at North Pond should be discontinued. North Pond is scheduled for drying in spring 1998, and will be replaced by a fenced system nearby. This fenced ecosystem will be designed to provide a fourth treatment, in which bullfrogs are excluded and native frogs, turtles, and snakes are introduced along with native fishes.

Intensified trapping at Twin and Robertson should be combined with bi-monthly removals of juvenile bullfrogs, and bi-weekly egg mass search-and-removal patrols starting in April and continuing through September. The current trapping level should be maintained at Double Ph.D, Tule Pond, and Bathhouse Well, while trapping should be suspended at Mesquite (and Little Mesquite) and Oasis ponds.

The current garter snake trapping protocol is succeeding in creating marked populations of both the Mexican and the checkered garter snake in North Pond, Twin Ponds, and Double Ph.D, where intensive snake trapping has been done, and at Robertson, where lower-intensity trapping has also yielded a modest proportion of recaptures. The garter snake population will be the best available indicator of the effectiveness of various bullfrog removal protocols. Snake censusing in 1998 and 1999 should focus on Twin Ponds, Double Ph.D., and Mesquite Ponds. The immediate response variable to test treatment effect should be proportion of juvenile age classes to adult checkered garter snakes, since this species remains in numbers in each wetland on the refuge. The second response variable, of special interest at Twin and Robertson, will be recruitment of Mexican garter snakes.

Wetland Herpetofauna at Arivaca Ciénega, Buenos Aires NWR. Our work at Buenos Aires National Wildlife Refuge has continued, with observations starting in 1993. Trevor Persons made extensive observations at Arivaca during 1995. He reported checkered garter snakes and bullfrogs only, as we reported earlier. Our visits have failed to give any evidence that leopard frogs or Mexican garter snakes have reappeared at the site. It would be of interest to re-examine Arivaca Ciénega turtle populations as a test of the possibility that Sonoran mud turtles may co-exist successfully with the high bullfrog population density there. However, it now seems unlikely that Mexican garter snakes or any native leopard frog will be found at Arivaca in the foreseeable future.

LEOPARD FROGS

All available monitoring data for the Chiricahua leopard frog at Leslie Canyon NWR (LCNWR), SBNWR, Magoffin Ranch, and Douglas High School, are presented in the Appendix (Tables A.1 - A.6; observer abbreviations are given in the Acknowledgements section). In the appended tables, a monitoring "Result" was assigned when a monitoring session was (a) carried out in a consistent way, (b) over a defined area, (c) at a climatically suitable and repeatable censusing time, and (d) a quantitative result was available to us. These quantitative results came from field notebooks, standardized data forms supplied to refuge personnel, and by interviews we conducted with refuge personnel. When a range of values was given by an observer for counts over a period weeks at one site, we selected the midpoint of the range; otherwise, the single value of total frogs plus tadpoles observed was used, unless a concerted effort with dipnets or seines to obtain numerous tadpoles was made.

Leslie Canyon has shown relatively stable fluctuations, with good numbers of various sizes and life stages of frogs: however, the reasons for year to year fluctuations are not clear at this time. John Frost (personal communication) also observed 20 - 100 individual leopard frogs at Leslie Canyon during the mid-1970's, during his intensive leopard frog studies throughout southern Arizona and Sonora.

Our census results indicate that other leopard frog populations we have been monitoring have declined for one reason or another, as detailed below. These declines occurred suddenly, following population growth or stability, in mid-late fall 1996 to winter 1997 (leopard frog enclosure, ranarium, Choate, Belency) or were gradual as an apparent result of limited available water

(Rosewood). We are investigating the causes of the 4 sudden declines at this time, and cannot offer a conclusive explanation for them at this time.

Populations, Habitats, and Monitoring Results.

A. Leslie Canyon. This is the best remaining population of Chiricahua leopard frogs in natural habitat in southern Arizona. It consistently supports substantial numbers of individuals including tadpoles of various sizes and, often, adults as large as young adult bullfrogs. Despite the complex habitat, it is often possible to see over 50 individuals in a single transit across the site. We suspect that more time-intensive monitoring could reveal the presence of much higher numbers, although we suspect that the high population seen in 1986 (Table A.1) was not present in the 1990's.

At this site, the frogs show a distinct preference for the large, deep spring pool at the base of an old CCC (Civilian Conservation Corps) rock dam, which forms the head of the perennial reach supporting a large population of Yaqui chubs (*Gila purpurea*) brought from Astin Spring (adjoining SBNWR) in 1969. Yaqui topminnows (*Poeciliopsis occidentalis sonoriensis*) were also introduced, but have failed, or nearly so, apparently due to the remarkably cold water; a small native population of the longfin dace (*Agosia* [or, *Rhinichthys*] *chrysogaster*) persists primarily in the more downstream portions of the perennial reach. The system is about a kilometer long below the rock dam. Sonoran whipsnakes (*Masticophis bilineatus*) are prominent in and near the shady, dense, ash-dominated riparian gallery forest.

Above the rock dam is a sedimentation-produced flat (filled in level with the top of the dam) dominated by big sacaton (*Sporobolus wrightii*), willows (*Salix goodingii*), and a dense fringe of Arizona ash (*Fraxinus velutina*). Note that this corresponds more closely than any other extant environment to the original vegetation structure described for the San Bernardino Ranch. The leopard frogs have their strongest presence in the semi-permanent (and fish-less), sluggish, muddy pools extending up-drainage for about 1/3 km from the top of the rock dam. Tadpoles may be observed to have survived to large size in the cold, clear, forested reach with the fish, but greater numbers have been found above the dam in 1996 and 1997 by Verma Miera and Eric Wallace using dipnets.

Introduced tiger salamanders (*Ambystoma tigrinum mavortium*), apparently filtering in from ponds on the 99-Bar ("Riggs and Lamberson" on some maps) Ranch, have been seen abundantly but not consistently in these pools, and rarely below the dam. Kevin Cobble found one at the site that had swallowed a leopard frog but gotten it caught in its gill slit and died. Flooding and fish probably make the system marginal for the tiger salamander. Black-necked garter snakes (*Thamnophis cyrtopsis*) are also most prominent where the leopard frogs are most numerous, although they also eat fish (in addition to frogs and salamander larvae) and are very abundant throughout the whole system. Spadefoot toads (*Scaphiopus couchii, S.* [or, *Spea*] *multiplicatus*/*a*) are present but uncommon in the area.

Our available monitoring results suggest a higher population in the mid-1980's than now. Since the frogs probably thrive best when not forced into the core of the fish population, wetter times as in the early 1980's would be expected to expand and enhance the niche space available to them. Our 1994-1997 monitoring results show relative population stability in these later years of a drought that began in the mid-late

1980's. The years 1992 and 1993 had substantial winter rains, and non-quantitative reports of the 1993 survey (Table A.1) were of very large numbers of small frogs.

In 1994, in deep drought, our survey showed a good population of strictly adult frogs that was all but confined to the big pool at the rock dam base. This led to the low population in 1995, when, however, successful reproduction was evident. Apparently the resurgence in 1996 corresponded to this reproductive success, as well as to excellent and early summer rains at the site. Despite a poor winter in 1996-7, we expected to observe a further increase in 1997 following high water in summer 1996, and require further surveys in late summer 1997. At present, we retain some concern that 1997 monitoring results should yield numbers higher than observed.

B. SBNWR Leopard Frog Enclosure (bullfrog exclosure). Four small pools in the center of a 0.8 ha fenced enclosure were constructed by refuge staff in late winter 1994. They are supplied by refuge artesian wells from a medium-depth aquifer (below the one that rises naturally in Slaughter Ranch Spring, Tule Spring, various seeps, and the Black Draw Springs, but not nearly so deep as most wells drilled on surrounding ranches) and regulated by float valves to a constant water level. Vegetation (especially *Typha, Potamogeton, Eleocharis, Paspalum*) is very dense in the pools, and therefore visibility is poor. In June 1994, when green herons and great blue herons descended on the newly-liberated Chiricahua leopard frog metamorphs, the pools were largely covered with predator netting, which remains in place. The site is on a formerly farmed flat, and has supported a luxuriant growth of early successional weeds in 1994-6. In March 1997, a controlled burn went through the area, and much of the terrestrial habitat in the enclosure was barren during 1997.

Recently metamorphosed bullfrogs rapidly invaded the enclosure with the first rains of summer 1994 by climbing the 1/8" mesh hardware cloth fence. These were killed with dust shot. Hardware cloth eaves largely eliminated the problem, but the occasional bullfrog gets over or under and must be removed (33 in 1994; 4 in 1995; 4 in 1996; 2 in 1997). This frequent penetration of the barrier occurs primarily because of the close proximity of Robertson Ciénega, with large numbers of emigrating metamorphs. In addition, a total of 7 checkered garter snakes have entered the exclosure as neonates and been removed prior to reaching the yearling stage (ca. 400 mm SVL). Two king snakes (*Lampropeltis getula splendida*) have entered, presumably through subterranean tunnels of the rodents they prey upon. In the laboratory, these snakes have consumed rodents, while showing no interest in checkered garter snakes or bullfrogs.

Leopard frogs have been heard calling in the enclosure every year between the last of August and roughly at least to mid-September, with successful reproduction occurring every year. The population increased geometrically in 1995 and 1996 (Table A.2; Fig. 4), but in fall 1996 a dead frog with redleg disease was observed. By the following active season, the population was found to have collapsed, and reproduction had been less successful than in previous years.

Redleg disease is an opportunistic attack of a weakened host by bacteria (usually *Aeromonas hydrophila*) that are generally present in small numbers even on healthy frogs (J. Jarchow, personal communication). The stressor causing the population decline in this case is thus not clear. The large population may have produced a resource shortage, as most enclosure frogs in early September 1996 were not plump, and given the large number of frogs, the chorus was weak. Conversely, some external pollutant or viral epidemic may have impacted the frogs.

C. Rosewood Tank. Rosewood Tank was a large deep tank that gradually filled in with sediment. It has been a known leopard frog site for many years (Rosen and Schwalbe, 1995). It went dry briefly in 1989, eliminating a small, never-thriving bullfrog population brought in by ranchers (M. Magoffin, personal communication); and again briefly in 1993. In 1994, it went dry early, in early April. The area supports a moderate number of checkered garter snakes and Sonoran Desert toads (*Bufo alvarius*). Undoubtedly, several other species of anurans are also present at the site, but have not been documented. A Sonoran whipsnake has been seen there, and western patch-nosed snakes (*Salvadora hexalepis deserticola*) are extremely abundant in Chihuahuan desertscrub immediately surrounding the Rosewood Hollow sacaton-mesquite bottom.

The Chiricahua leopard frog population has clearly declined since 1993 and early 1994. During 1994, after the pond dried and the Magoffins began hauling water from ranch headquarters to the pool dug in the tank bottom, numerous frogs remained in evidence (12 samples, mean = 10.8 $\pm$ 1.87 SE) through the warm season. In 1995, the observed number was 2.4 $\pm$ 0.68 SE for 7 monitoring censuses. In 1996, the result remained 2.4 $\pm$ 0.54 SE (n = 10). Reproduction had been observed each year in the refugium pool.

In March 1997, the frogs were transferred to a new concrete pool at the upper end of the sediment flat created by the original tank but fed by a new well over 4 miles from ranch HQ; although 5 egg masses were laid in the pool, no tadpoles were detected, and at least 3 egg masses have been observed to go bad. On Aug 31, 1997, AGFD Nongame personnel measured a pH of 10.8 in the pool (pH of well water entering the pool was 8.2), suggesting that the concrete had not sufficiently cured (M. Sredl, personal communication). The Magoffins drained the pool and replaced the water on September 1st, finding a few mosquitofish (*Gambusia affinis*) that had been inadvertently introduced with pondweed from ranch HQ in March (two adults had also been removed in June). No tadpoles were found at that time, and two adult frogs were in the pool.

For the year 1997, the monitoring result was 2.9 $\pm$ 0.78 SE (n = 5 censuses) frogs per observation period. However, the current population is probably at a low point, since no successful reproduction occurred at Rosewood in 1997. The decline at this site is remarkable for its slowness--it is surprising that individuals and the population have persisted 3 years without successful filling of the refurbished earthen cattle pond, even with the attention given them.

An interesting phenomenon has been the appearance of leopard frogs at Cockleburr Crossing, in sacaton-bottomland pools where the confluence of Rosewood Hollow and Hay Hollow crosses the Guadalupe Canyon Road. As far as anyone knows or believes, the nearest frogs are at Rosewood Tank (3.5 mi) or further off in different drainages (in Belency and Choate). In 1996, during good rains, at least 28 subadult to medium-sized adult Chiricahua leopard frogs were present in this hollow (25 at the crossing, 3 more 1.5 mi up-drainage at Magoffin Ranch HQ). At the same time, calling aggregations of leopard frogs were found at Belency and Choate (M. Magoffin, personal communication), so the frogs were not likely from those sites. This leaves Rosewood or some nearby, unknown refugium as the source for these frogs.

D. Belency Tank. Belency Tank is described by Matt Magoffin as a "charco tank" (one with a sand trap, which can be cleaned out without disturbing the main tank, that overflows into a main tank). It was built by Matt Magoffin's father around 1968, and has gone dry briefly in some of the recent dry years, although it was neither parched nor dry for long. The site would probably have dried in early 1995, but a well was installed the previous fall, contributing enough water to avoid complete drying. The sediment trap was cleaned out and deepened with a bulldozer in early 1995, but the main tank was not disturbed. In the early 1990's, a number of Yaqui chubs from SBNWR were introduced there, and these have persisted and grown but not apparently reproduced successfully. They are not numerous, according to our seining results (Table A.4). There is a large population of checkered garter snakes, and the site is heavily used by herons at times. No bullfrogs have ever been observed there.

Belency Tank appeared to be the most reliable population of Chiricahua leopard frogs in the region. In 1994, monitoring results averaged 23.5 $\pm$ 6.17 SE (n = 4) individuals/census; in 1995, mean = 13.7 $\pm$ 2.46 SE (n= 6); in 1996, mean = 14.2 $\pm$ 5.40 SE (n=6). Despite the drought, the population appeared fairly stable, with substantial numbers of individuals observed at least once each year (Table A.4). However, very large individuals were not observed, and during our period of observation there was never a large flush of metamorphs, even though egg masses were found in spring 1994 and 1995, and calling aggregations seen in summer 1996. We never observed tadpoles in more than low numbers at the site.

Adult leopard frog survivorship may be limited at Belency by high predation by snakes and herons; it is less clear why reproductive success has been so low. There may be a novel predation pressure at the tank from the recently-introduced chubs, which voraciously eat snail eggs, small invertebrates, and small fishes in the laboratory (personal observations), or the garter snake population might have affected the tadpoles, but neither seems likely.

The leopard frog population became invisible during June through early August 1996, but reappeared with the first floods in mid-August, which filled the trap and half-filled the main tank. In 1997, however, it seems to be gone completely, despite strong runoff on July 31st which completely filled the sediment trap (which had gone dry in late fall 1996), and filled the main tank to overflowing. Further, very few toads were found at Belency in 1997. The last leopard frog seen was a dead adult with redleg in November 1996. The well water might be considered a possible culprit, but strong runoff in 1996 and 1997 dominated the water supply. While the population may reappear yet, we have strong cause for concern that an epidemic or pollution event may have wiped it out.

E. Choate Tank. The Choate site was originally a windmill-powered well supplying water to a large open concrete storage tank, which in turn supplied a cattle drinker. The storage tank would overflow, creating a moist spot favored by Sonoran Desert toads. The site is in a sacaton-dominated bottom that is part of Belency Hollow, and is about two miles above Belency Tank. Continuing up this drainage, the Rosewood Hills massif is to the north (with Rosewood Hollow on the north base, leading to Hay Hollow and thence to Black Draw in Mexico); the head of the drainage is near Thompson Flat Tank, not far from Guadalupe Canyon Road, a site where leopard frogs have been seen in wetter times in the early 1990's. Below Belency Tank, in Mexico, is a small perennial spring that has not been surveyed for amphibians and reptiles; this is in the Agua Verde drainage, which enters the Black Draw-Hay Hollow-Silver Creek system several miles further downstream, south of Mexican Highway 2.

Choate Tank was constructed by Matt Magoffin in early 1995 by scooping out a 15 m diameter hole and using the earth as a levee. It is filled almost entirely with well water. It was seeded with narrow-leaf pondweed (*Potamogeton pectinata*) and algae (*Cladophora*) from SBNWR. Tadpoles introduced from Rosewood Tank in August-September 1995 transformed and grew rapidly. They appeared to be thriving until mid-May 1996, when the pump broke; the water dropped from 2 m to about 0.7 m deep and emitted a bad odor. At that time, 15 dead frogs were observed floating in the pond, and the two that were retrieved had redleg. Ten frogs are known to have survived, and the pump was repaired immediately.

During summer 1996, at least 10 adult frogs were seen at the site, and in early fall, 3 egg masses were found there. These three were divided at the site by Hans Bodenhamer, a teacher at Douglas High School, leaving half the eggs and taking the rest to the school for rearing in a class project. On December 8, 1996, Anna Magoffin observed a single lethargic leopard frog on the floating vegetation mat at Choate, and the frogs were not seen during numerous visits by the Magoffins until a nighttime survey team found 2 apparently healthy, yearling-sized adults in late August 1997. The population is still being monitored.

F. Additional Sites. Three additional sites in the area have been established for the Chiricahua leopard frog during 1996. The Douglas High School class of Hans Bodenhamer received approximately half of three egg masses from Choate Tank in early fall 1996, yielding approximately 290 hatchling tadpoles. These were raised in a project overseen by AGFD Nongame Branch and by SBNWR, with advisement from University of Arizona, and a reported 82 were distributed to outdoor population sites in May 1997: 6 to a screened ranarium at SBNWR, 27 to a very small pond on the grounds of the high school, and 41 to a small pond at Magoffin Ranch headquarters.

Magoffin Headquarters Pond. The Magoffin HQ Pond was scooped out in Rosewood Hollow, about 2 miles below Rosewood Tank, at a site where water normally pools after strong summer rainfall events. These pools normally support large aggregations of spadefoot toads, especially Couch's spadefoot, and in wet times Chiricahua leopard frogs appear there in small numbers (M. Magoffin, personal communications), almost undoubtedly from Rosewood Tank. A large number of checkered garter snakes are present. The pond is similar in all respects to Choate, and is supplied by water from the ranch house well.

It was completed on about February 20, 1997, stocked with pondweed, and received 41 eight-month-old tadpoles (ca. 10-15 mm SVL with small hind limbs) from the Douglas High School project on May 24, 1997. From about mid-July to early August, Matt Magoffin was able to see 2 metamorph leopard frogs at the pond fairly regularly. Two subsequent visits have revealed a high density of neonate-sized checkered garter snakes. These appear to be growing slowly, if at all. The garter snake population is presumably based on a staple supply of ephemeral-water anurans at the site: in 1997, however, only 4 *S. couchii* were heard after July rains. This decline in toads is unexplained, although the preceding 3 years have had almost negligible rainfall and runoff in Rosewood Hollow. A predator-prey system with predator (garter snake) density set by availability of ephemeral water anurans might be inherently unstable for a newly introduced prey species (leopard frogs), particularly in a dry year. At this point, however, the success or failure of this experimental population is unknown.

Douglas High School Pool. The Douglas High School had a large pond on-site that was constructed by SBNWR for native fishes, but eventually used instead for catfish, bass, and sunfish. In winter 1996-7, this pond was dried and the exotics removed, in preparation for stocking of Yaqui catfish (*Ictalurus pricei*) from the Dexter, N.M., fish hatchery. While the class reared leopard frog tadpoles (in classroom aquaria using an array of temperatures and stocking densities), the refuge prepared a smaller, fenced-in pool near the original one, for leopard frogs. The instructor, Hans Bodenhamer, released 27 tadpoles from the classroom into this pond in May 1997, and reported in August the subsequent observation of very large tadpoles in small numbers (ca. 1 or 2) at the pool. Leopard frogs have been seen at this site subsequently, but the success of this introduction effort remains unknown.

SBNWR Ranarium. During 1995 and 1996, a screened-in ranarium was built near the maintenance building at SBNWR. A concrete pool with water circulating through an external pumphouse to a rock-and-concrete waterfall was built early and allowed to cure for many months pending completion of the enclosure. The ranarium was completed in September 1996, with plantings of sacaton, a small sod bed, and filling of the pool. Ten adult frogs from Cockleburr Crossing (Rosewood/Hay Hollow) were introduced, two of which were found dead with redleg in November, and 6 more similarly found dead in March 1997. The remaining two adults died in the ranarium in October 1997. In May, 1997, 6 Choate (i.e., presumably Rosewood-derived) tadpoles from the Douglas High School project were introduced, at least 2 of which persisted as juveniles in August 1997. Causes of death for the frogs are not yet known: the March specimens appeared to have enough fat to rule out starvation as a proximate cause of death; those from October 1997 had evidence of protozoan parasitism, and one had symptoms suggesting ethylene glycol contamination, but no source for such contamination is known. It is not known if any frogs persist in the ranarium.

<u>Potential Causes of Population Declines</u>

The cause of the die-off in the ranarium in winter 1996-7 is not clear. Problems with the concrete might be suspected; although it was cured for a lengthy period, the pool was apparently not flushed prior to introduction of frogs. In April 1997, an ozone filter was activated in the water line in the pumphouse. An alternative is that the frogs had poor nutrition in the enclosure, and suffered from a variety of opportunistic infections as a result.

However, the most striking aspect of the observed die-offs is the simultaneous appearance of sick or dead frogs at all four sites (ranarium, SBNWR enclosure, Choate, Belency), followed by marked population declines at each. Although each site receives well water from a possibly related aquifer, the wells are spread over a large area that should not have been simultaneously affected by a change in water quality (bullfrogs on the SBNWR are also living in this well water, but a die-off could go un-observed. The Douglas High School project did not involve all these sites. Although the Magoffins and researchers visited each site, frogs were not handled at Belency (except in 1995), Choate, or the enclosure, and at most a trace of dried mud might have been transported from one site to another: a human-borne pathogen seems unlikely. Predatory birds can have had minimal impact in the enclosure and no impact in the ranarium. The common aspects are proximity to the international border, fairly high densities of frogs, and a drought that affected the entire area in varying degrees during 1994-1997. The marked reduction in number of toads heard and seen at Belency and at Magoffin HQ in 1997 is also troubling.

At this point, we are still guessing about causes for these declines, as we are for other worldwide amphibian declines except those caused by habitat degradation and exotic species. In our case, the most obvious hypothesis for the 4 sudden population declines (at SBNWR enclosure, SBNWR ranarium, Choate, and Belency) is that airborne pollution simultaneously affected them. Another possibility is that independent effects produced the declines--resource stress at SBNWR; disturbance of eggs, chance fluctuation influenced by small population size, or inbreeding depression at Choate; and chaotic predator-prey dynamics at Belency. However, the consistent timing and symptoms (redleg in winter 1996-7) suggest a coherent epidemiology--one more consistent with disease or air pollution. Matt Magoffin reports that occasionally a pollution plume is visible to the south against the backdrop of the Peloncillo Mountains; this is infrequently apparent once or a most a few times per year. This plume probably comes from a copper smelter in Mexico (at Cananea or Nacozari): the Cananea smelter was previously implicated circumstantially in the 1974-1983 extinction of the Tarahumara frog (*Rana tarahumarae*) in southeastern Arizona. It pollutes heavily, and was supposed to have been closed upon operationalization of the Nacozari smelter, but was not. Pollution effects may accumulate over time, but frog deaths may be synchronized by cold-induced immune or detoxification system depression.

Many ranid frog die-offs throughout the American West, and perhaps also the Middle American declines at higher elevations, have occurred at times of drought. One stressor may be a drought-caused collapse in availability of terrestrial arthropods near pond environs, which are part of the food base for ranid frogs. This is certainly a hypothesis to investigate in Arizona and southwestern New Mexico, where waves of Chiricahua leopard frog population loss have occurred during the post-1984 period of relatively protracted drought.

We urgently need to press forward with epidemiological and toxicological field and laboratory studies. We must also keep ecological landscape processes clearly in mind. For example, the known, widespread effects of exotic species in the American West have fractured frog metapopulations on a massive scale. Disease in North American frogs is well-known at least as far back as 1900, and as today, was usually seen in the cool season. The continuing loss of anuran populations now getting global attention could be a result of normal and natural population pathologic events that are now serious because of the fractured metapopulation structure. This is an important and very difficult research subject. Nevertheless, we can heuristically see that a species that suffers periodic population pathology can only be preserved in the wild if numerous populations, interacting as metapopulations, exist. Ranid frogs in the Southwest, and probably through much of the world, cannot be managed the way we might try to save many other taxa, from parrots to panthers: 500 adult individuals distributed among 10 populations would be an immediate prelude to extinction in a Southwestern ranid frog species.

We stress that this section of the report is based strictly on conjecture and hypothesis at this time. Further monitoring might show that some of the observed declines were more apparent than real, although that seems unlikely. Conversely, the declines might spread from the border sites, suggesting an epidemic. The more likely explanations, however, pollution or disease, will only be understood if we are able to establish proper monitoring of environmental (air and water) quality, and by thorough examination of moribund or dead frogs. This study system is a good one for this sort of study because we have on-site personnel (Kevin Cobble and his staff, the Magoffins, and UA field personnel) that greatly increase the probability that mortality events will be observed, and that moribund or recently dead frogs may be collected in a timely fashion. At this time it seems critical that intensified population monitoring be formalized in the area, and that water and air quality baseline and monitoring be quickly established.

GARTER SNAKES

Intensive aquatic trapping has yielded substantial annual samples of garter snakes in 1993-6 (Tables 8-10), as well as in 1997. Trapping data (Table 8) shows a decline of garter snake capture rate per capture effort of about 39% between the 1980's and 1990's. This suggests a rough stability, with a moderate decline not unexpected, given the long ongoing drought during the study. This relative stability, however, masks a critical, rapid decline in one of the species, the Mexican garter snake (*T. eques*).

The entire wetland herpetofaunal conservation project began with the observation in 1985-6 that the Mexican garter snake population was top-heavy, lacked successful recruitment, and was composed of individuals that had suffered repeated attacks by large bullfrogs (Rosen and Schwalbe, 1988). At that time, we observed that Mexican garter snakes were unusually uncommon at SBNWR, even though they were a major portion of the garter snake sample then. We predicted that their population was in decline, and would continue to decline, under the influence of bullfrog predation, while the checkered garter snake population would probably persist.

The 1988 prediction is unfortunately holding, despite our attempts at bullfrog control (Fig. 5). Mexican garter snakes were apparently the primary species at San Bernardino from 1950 to about the 1970's (16 Mexican, 9 checkered garter snakes in museum records). Our data for the 1980's are 43 captures of Mexican and 41 for checkered garter snakes (Table 8), at a time when we made extensive efforts to sample the species in North Pond, Black Draw, and Twin Pond, where they were doing best: although there was still reproduction going on, the Mexican garter snake population was thus oversampled, relative to that of the checkered garter snake, as represented in Fig. 5. In the 1990's, we trapped in most of the feasibly-worked wetlands at SBNWR (North Pond, Twin Ponds, Bathhouse Well, Robertson Ciénega, Double Ph.D Ponds, and briefly in Little Mesquite Pond. The Black Draw population of Mexican garter snakes disappeared, apparently eliminated by drought (marked individuals from the draw were found in North Pond and Twin Pond). The 1990's samples are a reasonable representation of the population status of garter snakes at SBNWR (Fig. 5).

The Mexican garter snake is clearly nearing extirpation at SBNWR (Fig. 5). Our data for 1997 confirm this trend: only 6 individuals have been captured in intensive trapping as of September 1st, and all were large, old snakes. We are holding three of these (2 females, 1 male) plus four that have been reared as lab-born young since 1995 (3 females, 1 male). We will attempt to breed these successfully in fall 1997 and spring 1998 to obtain neonates to repopulate protected sites at the refuge. If breeding is successful, we plan to take additional snakes next year.

The checkered garter snake population has continued to flourish at SBNWR, although a decline may be imminent. Our records suggests a decline in recruitment during 1995 and 1996, and early returns in 1997 suggest a further drop in the proportion of young snakes. As suggested above, this might be a manifestation of the large numbers of medium-sized and large juvenile bullfrogs present on-site that is favored by our removal of the larger bullfrogs. The complete analysis on this subject will not be available until 1997 trapping is completed and all of the data can be analyzed.

Application of PIT-tagging (Passive Integrated Transponder) in addition to scale clipping ensures that our mark-recapture results will be valid. By the end of 1998 field season we will have a clear understanding of the baseline dynamics of the checkered garter snake population at SBNWR, in addition to the unfortunately too-clear picture of Mexican garter snake population dynamics.

RECOMMENDATIONS

1. Modify the bullfrog removal and garter snake study protocols at SBNWR as follows:

A. Bullfrog trapping should be intensified at Twin Ponds and Robertson Ciénega, and accompanied by bi-monthly night-time hand capture of juveniles by two persons in a canoe or using waders, as well as regular searches to remove bullfrog egg masses. Intensive garter snake trapping and mark-recapture should occur at these sites.

B. Bullfrog trapping should be continued as now at Double Ph.D and Tule Ponds and at Bathhouse Spring. Intensive garter snake census should continue at Double Ph.D. At Tule Pond, further observation and hand collecting of garter snakes should be carried out.

C. Bullfrog trapping and removal should be discontinued at Mesquite, Little Mesquite, and Oasis Ponds, with intensive garter snake trapping and marking there to monitor population dynamics of both species under a regime of no bullfrog removal.

D. Bullfrog trapping should be discontinued at North Pond (which is to be dried and replaced by a fenced wetland in spring 1998). Mexican garter snakes, Chiricahua leopard frogs, and Sonoran mud turtles should be introduced into the new wetland as soon as feasible.

E. Intensive manual removals of bullfrogs (gigging) and their eggs should continue at House Pond, as now, and should also occur at Twin Ponds and Robertson Ciénega.

F. Marking and measuring of Sonoran mud turtles should be continued at the refuge. A training session for refuge personnel should be held to demonstrate the use of growth rings for age-estimation of younger, recruiting juveniles. The possibility of using turtles as an indicator of bullfrog removal effectiveness should be evaluated.

2. Develop and implement plans to utilize drift fence encirclement of ponds, with drying of the encircled pond that may be undertaken as part of native fish management:

A. North Pond should be encircled with a temporary fence as it dries in spring 1998 to remove the bullfrogs, census garter snakes, and obtain mud turtles and Mexican garter snakes for release into the new wetland. The checkered garter snake population can be translocated to House Pond, where they may eat bullfrogs. This translocation will also eliminate possible interspecific competition for resources or "enemy-free niche space" between checkered and Mexican garter snakes in the new enclosure; we may vary this experimentally in future enclosures.

B. The new wetland near North Pond should be fenced to prevent colonization by bullfrogs **before** starting to fill it with water.

C. Robertson Ciénega should be fenced and refurbished to make it suitable for topminnow, leopard frog, and garter snake management when this becomes feasible. This marsh habitat is currently being overgrown by cattails, and has little water in it. This situation is temporarily conducive to garter snakes, including resident Mexican garter snakes and will also allow persistence of native topminnows, until time permits refurbishment of the wetland. At that time, care will be required to save the remaining Mexican garter snakes. If circumstances favoring bulrush ("tule", *Scirpes americanus*) can be recreated, favorable habitat for garter snakes would exist without the choking of the open water by cattail. The system could be readily encircled with a drift fence standing on or near the levee to minimize immigration by bullfrogs. This wetland could readily be re-designed to provide a series of linear pools that would (a) be accessible for management from the banks as well as by boat, and (b) be useful for replicated field experiments with native species assemblages.

D. The effectiveness and desirability of the fencing approach should be evaluated using the experience at North Pond, Robertson Ciénega, and the Leopard Frog Enclosure.

3. An aquatic survey of the Mexican portion of the original San Bernardino land grant lowlands, and surrounding country is sorely needed to properly understand wetland vertebrate status and landscape dynamics at and near SBNWR.

ACKNOWLEDGEMENTS

We are most grateful to the many people who contributed to the field work throughout this project. We have acknowledged most of them in Rosen and Schwalbe (1996a & b). Here we specifically acknowledge contributions to this project in 1996 and 1997. For assistance in the field we thank Hans Bodenhamer (HB); Bruce Christman; Kevin Cobble (KC); Andrew, Cindy and Ted Cordery; Amanda Gaide; Steve Hale; Trevor, Troy, Janet, Cassidy, and Delany Hare; Jeff Howland; Robin Llewellyn; Matt (MM), Anna (AM), Chris and Mike Magoffin; Verma Miera (VM); Mike Pruss; Julia Rosen; Shawn Sartorius (SS); Adam Schwalbe; Mike Sredl (MS); Dennis Suhre; Marty Teugel; Travis Tuchak; Eric Wallace (EW); and Bridget Watts. Again, we apologize profusely to those whose names we may have inadvertently omitted. Arizona Game and Fish Department has also been instrumental in all phases of the work, including consistently funding the work through the Heritage Program. USFWS has been equally instrumental, both through funding and through the longtime collaboration of Refuge Manager Kevin Cobble and Officer Matt Magoffin. Their direct participation, and that of Tony Velasco and Myles Traphagen under refuge direction has been an integral and essential part of this project. The continuing advice, participation, and collaboration by AGFD Nongame personnel, particularly Jeff Howland, Mike Sredl, and Eric Wallace, has been instrumental to the guidance and conduct of the work. Residents of the lower San Bernardino Valley area who have assisted importantly and generously with information and access to lands are Warner and Wendy Glenn, Drummond Hadley, Seth Hadley, Anna and Matt Magoffin, and Bill and Mary McDonald. Their assistance, in part through the Malpai Borderlands Group, is gratefully acknowledged. We are grateful to Joan Ford, Mary Greene, Richard Maze, Guillermina Sumpter, and Carol Wakely for administrative and clerical assistance on the project.

LITERATURE CITED

Rosen, P.C. and C. R. Schwalbe. 1988. Status of the Mexican and narrow-headed garter snake (*Thamnophis eques megalops* and *Thamnophis rufipunctatus rufipunctatus*) in Arizona. Unpubl. report from Arizona Game and Fish Dept. (Phoenix, Arizona) to U.S. Fish and Wildlife Service, Albuquerque, New Mexico. iv + 50 pp + appendices.

Rosen, P.C. and C.R. Schwalbe. 1995. Bullfrogs: introduced predators in southwestern wetlands. Pp. 542-454 *in* Laroe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac (*eds*.), Our Living Resources: A Report on the Distribution, Abundance, and Health of U.S. Plants, Animals, and Ecosystems. U.S. Dept. of Interior, National Biological Service, Washington, D.C. 530 pp.

Rosen, P.C. and C.R. Schwalbe. 1996a. Bullfrog Impacts on Sensitive Wetland Herpetofauna, and Herpetology of the San Bernardino National Wildlife Refuge. Final Report to Arizona Game and Fish Department Heritage Fund and U.S. Fish and Wildlife Service, June 6, 1996. 47 pp. + Appendices.

Rosen, P.C. and C.R. Schwalbe. 1996b. A critical interim evaluation of the effectiveness of bullfrog removal methods at San Bernardino National Wildlife Refuge. Final Report to Arizona Game and Fish Department Heritage Fund and U.S. Fish and Wildlife Service, October 30, 1996. 21 pp.

Schwalbe, C.R. and P.C. Rosen. 1988. Preliminary report on effects of bullfrogs on wetland herpetofauna in southeastern in Arizona. Pp. 166-173 *in* R.C. Szaro, K.E. Severson, and D.R. Patton (editors), Management of Amphibians, Reptiles, and Small Mammals in North America. U.S. Forest Service, General Technical Report RM-166, Fort Collins, CO.

Appendix. Monitoring Data for Chiricahua Leopard Frog Populations.

Data on file at Arizona Game and Fish Department, Heritage Data Management System (602-789-3618).