Introduced Aquatic Vertebrates in the Chiricahua Region: Effects on Declining Native Ranid Frogs

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Abstract.—The Chiricahua Mountain region offers an outstanding opportunity to manage an aquatic vertebrate fauna that is widely in decline or already threatened or endangered. The fauna is diverse, and potential economic conflicts with recovery of native aquatic species are few and limited. Including Aravaipa Creek, the San Pedro River, and Cajon Bonito in Mexico, there is excellent potential for interagency and international collaboration to the benefit of biodiversity and open space.

Herein we provide data showing the extensive and expanding distribution of non-native vertebrates in southeast Arizona waters. These introduced species are being spread directly by humans, intentionally and accidentally. Our detailed evidence shows that, like most native fishes, native leopard frogs are negatively affected primarily by introduced aquatic predatory vertebrates, especially bullfrogs, largemouth bass, sunfishes, and probably catfishes, trouts, fathead minnows, and mosquitofish. These non-indigenous species appear to be thriving in human-created habitats, and spreading into surrounding habitats where they are destroying indigenous forms. Recovery of the Chiricahua leopard frog and other native leopard frogs in the region is a viable objective given (1) priority within government agencies, and (2) cooperation of conservation professionals with ranchers and other private stakeholders that control or manage most waters in the region.

INTRODUCTION

Introduced predators are known for their strong negative effects on native animals around the world. Examples include mass extinctions of native cichlid fishes in African rift-lakes (Witte, et al. 1992; Ogutu-Ohwayo, 1993) and of native bird and lizard species on Guam (Savidge, 1987; Rodda and Fritts, 1992), as well as ground iguana and solenodont mammal declines in the West Indies (Burghardt and Rand, 1982; Thornback and Jenkins, 1982; Nowak, 1991). In the American Southwest, the native fish fauna is similarly facing extinction due primarily to introduced predators and competitors, which thrive in tandem with human-caused (anthropogenic) habitat modification (Minckley and Deacon, 1991).

Over the course of the present century, modern technological humans have created many lakes, reservoirs, and stock-watering ponds in the American Southwest, where perennial waters originally consisted of cienegas, springs, streams, rivers and riverine marshes (see Hendrickson and Minckley, 1984). In these natural aquatic habitats, flash-flooding frequently favors native over introduced—more characteristically lacustrine — species of fish (Minckley and Meffe, 1987), whereas frequent drying may favor native leopard frogs (*Rana pipiens* complex) over bullfrogs (*Rana catesbeiana*) because of the longer aquatic tadpole stage of the bullfrog. Habitat modifications producing to deep, still perennial waters, lack of scouring flash floods, and reduced fre-

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quency of drying contribute directly to the negative effects of introduced predators on native species. Further, most of the native animals discussed here evolved in isolation from the introduced predators that currently plague them, and thus may be behaviorally unprepared to select habitats, microhabitats, or activity modes that permit avoidance of the introduced species.

The Chiricahua and surrounding mountains have natural perennial surface waters in greater abundance than other Madrean "mountain islands" (Gehlbach, 1981) along the U.S. and Mexican border. Moreover, the Chiricahuas lack the major dammed lakes (which harbor great arrays of non-indigenous fishes, bullfrogs, and crayfishes) that exist in other mountain complexes of southeastern Arizona. Inclusive of Aravaipa Creek to the northwest and Cajon Bonito to the southeast, this local region contains the least altered natural waters remaining in the American Southwest (Minckley and Rinne, 1991), and presents the best opportunity (with most of the adjoining San Pedro River a Bureau of Land Management riparian conservation area) to establish a natural area with (1) great open spaces, (2) natural water conditions, (3) healthy natural aquatic fauna, and (4) overall high biological diversity.

The native "true frogs" (family Ranidae) of western North America are all suffering range contractions, massive population declines, or both (Vial and Saylor, 1993; Leonard et al., 1993; Blaustein et al., 1994; Jennings, 1995; Sredl and Howland, *this volume*). Many species have disappeared from large proportions of their ranges, several are nearing endangered status, and two or three (*Rana tarahumarae* and, depending on the taxonomist consulted, *R. fisheri* and *R. onca*) are extinct in the United States. Decline of the Chiricahua leopard frog *Rana chiricahuensis* was first reported, but not explained, by Clarkson and Rorabaugh (1989).

Many factors apparently contribute to ranid frog declines and disappearances, including habitat loss (Jennings and Hayes, 1994), regional pollution (Hale et al., 1994), and global ozone depletion (Blaustein et al., 1994). Introduced predators including fishes (Hayes and Jennings, 1986; Bradford, 1989, Brönmark and Edenhamn, 1994) and bullfrogs *Rana catesbeiana* (Hayes and Jennings, 1988; Schwalbe and Rosen, 1988; Rosen and Schwalbe, *in prep.*) appear to play a major role in many frog declines.

In this paper, we describe the expanding distribution of introduced fishes and bullfrogs in the Chiricahua region, and we correlate this in detail with the pattern of decline of the native Chiricahua leopard frog. We offer a series of management recommendations to reverse this expansion of non-natives, and possibly to make federal listing of the Chiricahua leopard frog unnecessary or of short duration. We focus on measures that may be advantageous to the major stakeholders in the area, both private and public.

METHODS

We visited all known localities for the Chiricahua leopard frog and the plains leopard frog *R. blairi* in the Chiricahua Mountains and surrounding Sulphur Springs, San Bernardino, and San Simon valleys, and in the Dragoon and Peloncillo mountains, Cochise and Graham counties, Arizona (fig. 1). These localities were determined from Clarkson and Rorabaugh (1989, and therein),

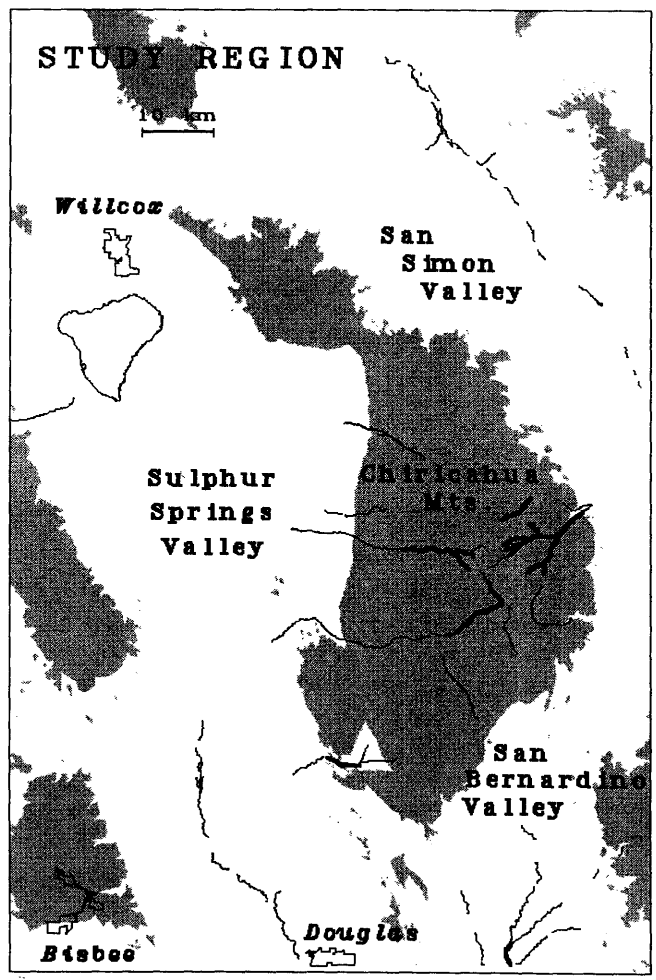

Figure 1.—Footprint of the Chiricahua and surrounding Mule, Dragoon, and Peloncillo mountains, and valley areas, included in this field survey. Major perennial waters are shown as dark lines, major intermittent drainages are light lines.

surveys of museum collection localities, and interviews with herpetologists familiar with the area.

We also sampled other accessible perennial or semi-perennial waters, attempting in sum to visit all potential leopard frog habitat areas; occasionally, site access was denied by private landowners. Whenever possible, we discussed water permanence and faunal observations with landholders, significantly enhancing our ability to locate good sites for frogs. Additional work carried out in the area of the Atascosa Mountains and Altar Valley, in Pima and Santa Cruz counties, Arizona, is reported elsewhere (Rosen and Schwalbe, *in prep.*).

Most of the work reported here was done May-August 1994, a time of drought in southeast Arizona; eleven of the sites were visited only in 1992 or 1993. At each site, we approached slowly, using binoculars for visual observation of frogs or surfacing salamanders and turtles, as well as for fishes. We then walked along the water margin counting frogs or other animals as they moved or were otherwise observed. Finally, we sampled each site with dipnets (6 mm mesh) and seines (3 x 1 m and 8 x 1.8 m; 6 mm mesh) to confirm species identifications and determine relative abundances for tadpoles, salamanders, turtles, and fishes.

Most of the 1994 work was prior to a tardy onset of monsoonal rains, some areas receiving no runoff until at least September—over 2 months late. It was a dry summer following a dry winter in a longer term drought beginning in the mid-1980's. Whereas the aquatic fauna suffered through this drought, we capitalized on the opportunity to determine with some certainty the perenniality for each water source. When we arrived at or near what we estimated to be the drought minimum water level, we recorded the deepest point of each site by wading or diving. These estimates represent 10-20 yr depth minima, based on interviews with resident landholders and land managers. Finally, we revisited a number of sites that were dry in early summer but subsequently filled with runoff, sampling as described above.

Despite our efforts, we may have overlooked some species at some sites, as when fishes may have eluded our small seines or where uncommon species were simply not captured. We think this is a small error, because our results were generally in agreement with interviews with people knowledgeable of the local areas, and with initial visual inspections that revealed the general classes of aquatic animals to be expected. In several areas, we set baited turtle traps and minnow traps to verify species presence.

Reptiles and amphibians were identified in hand using Stebbins (1985) and, for leopard frogs, with Sredl and Howland (1992). Fishes were identified in hand using Minckley (1973) and Page and Burr (1991). Herein we use the term "exotic" to mean exogenous to southwest North American drainage basins, and "introduced species" to be those brought in by man.

RESULTS AND DISCUSSION

Species Observed and Distribution

A total of 103 sites was sampled in the study region. We observed 30 species of aquatic and semi-aquatic ectothermic vertebrates in the Chiricahua region, including 13 exotic species (table 1, figs. 2-6); there were 74 occurrences of non-native

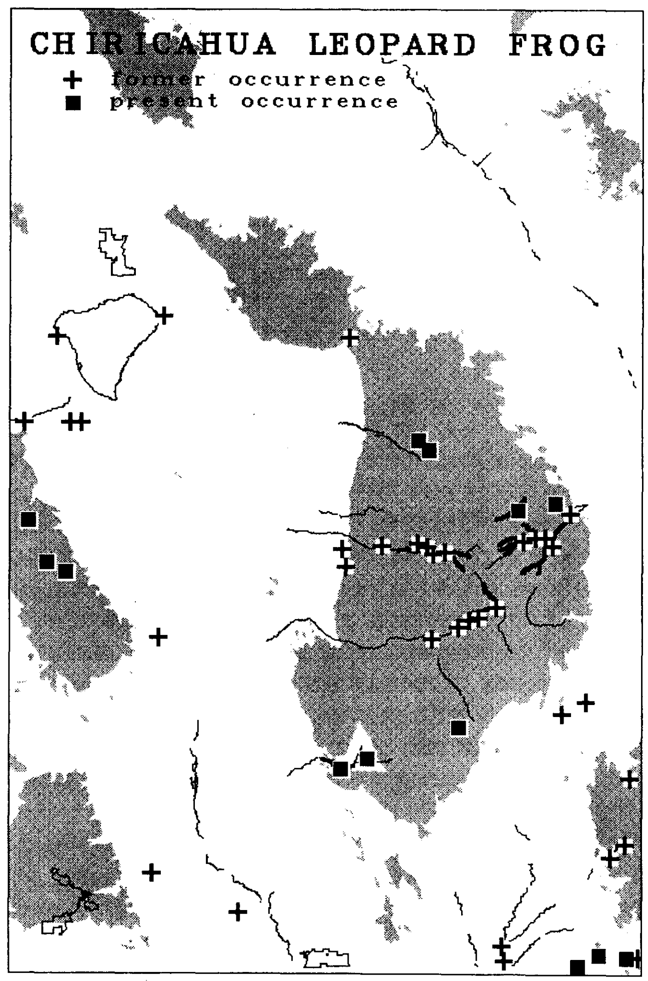

Figure 2.—Present and former known distribution of the Chiricahua leopard frog *Rana chiricahuensis* in the study region as of 1994.

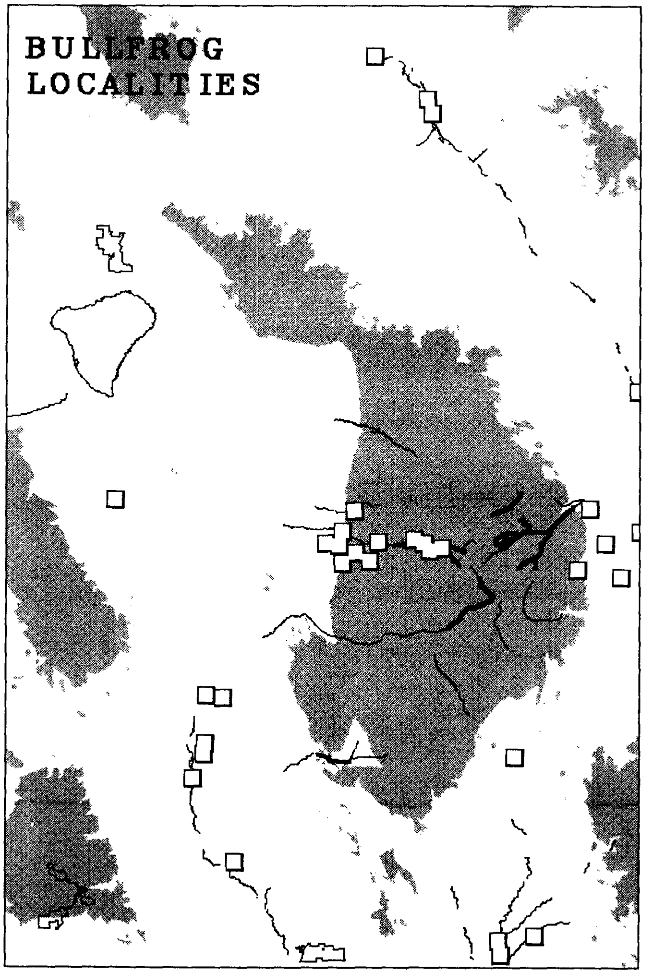

Figure 3.—Known distribution of the introduced bullfrog *Rana catesbeiana* in the study region, 1994.

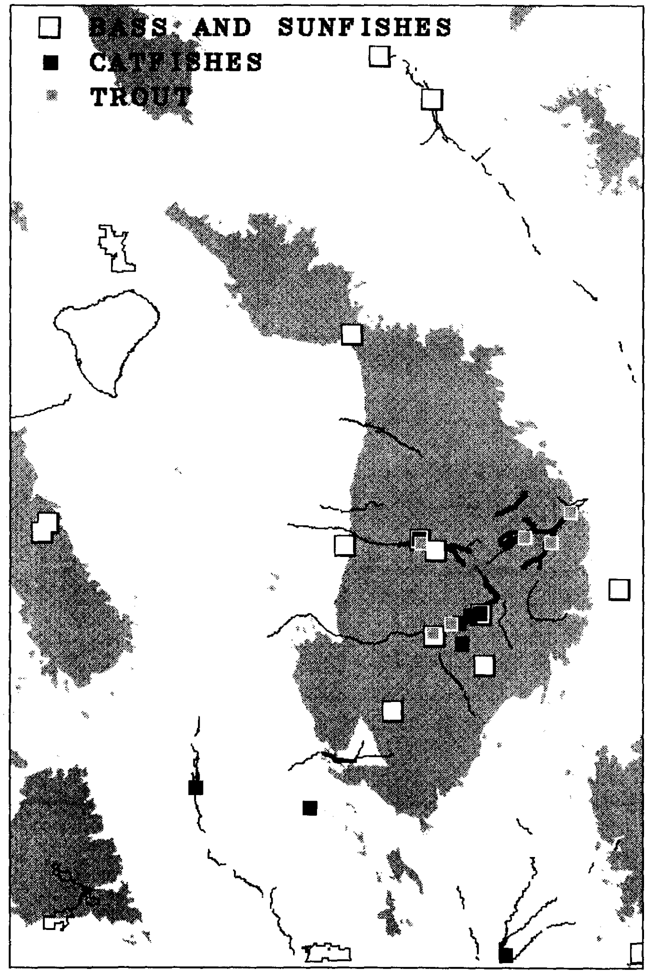

Figure 4.—Distribution of introduced large predatory fishes (largemouth bass *Micropterus salmoides*, green sunfish *Lepomis cyanellus*, bluegill sunfish *L. macrochirus*, black bullhead *Ameiurus melas*, yellow bullhead *A. natalis*, channel catfish *Ictalurus punctatus*, rainbow trout *Onchorhynchus mykiss*, and brook trout *Salvelinus fontinalis*) in the study region in the 1990's.

species at a total of 48 sites and 86 occurrences of native species at 48 sites. Most frequently observed was the introduced bullfrog at 24 localities, double the number of sites for the next most frequently recorded species, the native Sonoran mud turtle (*Kinosternon sonoriense*). Although the Chiricahua leopard frog was observed at 11 sites, this number of occurrences reflects its discovery at some very minor sites, rather than a real abundance of robust populations. This figure is undoubtedly close to the full number of sites at which this species persists in the region.

Introduced fishes were recorded 42 times during our less than two years of sampling with modest collecting gear for this study, compared to a known total of 33 mapped records for the study region as of 1972 (Minckley, 1973). This suggests a recent spread of non-native fishes in the region, despite removal of introduced fishes from two major regional wetland areas—San Bernardino Ranch and Leslie Creek. Available historical records for Rucker Creek also show a marked increase of non-native fishes over the past two decades (fig. 7). In most localities, one or more introduced species had high population densities: for example, effective seine hauls sometimes yielded several dozens or hundreds of adults or subadults of such exotic species as the black bullhead, green sunfish, bluegill sunfish, tiger salamander, and mosquitofish.

Exotic fishes appear to us to have been placed in virtually all reliably perennial waters. Whereas we observed only two partial cases of direct drought-related mortality of these stocked fishes in 1994, heavy, possibly complete, mortality of introduced trout in the Cave Creek drainage followed ash-laden flash floods originating on slopes burned in the 1994 Rattlesnake Fire; similar

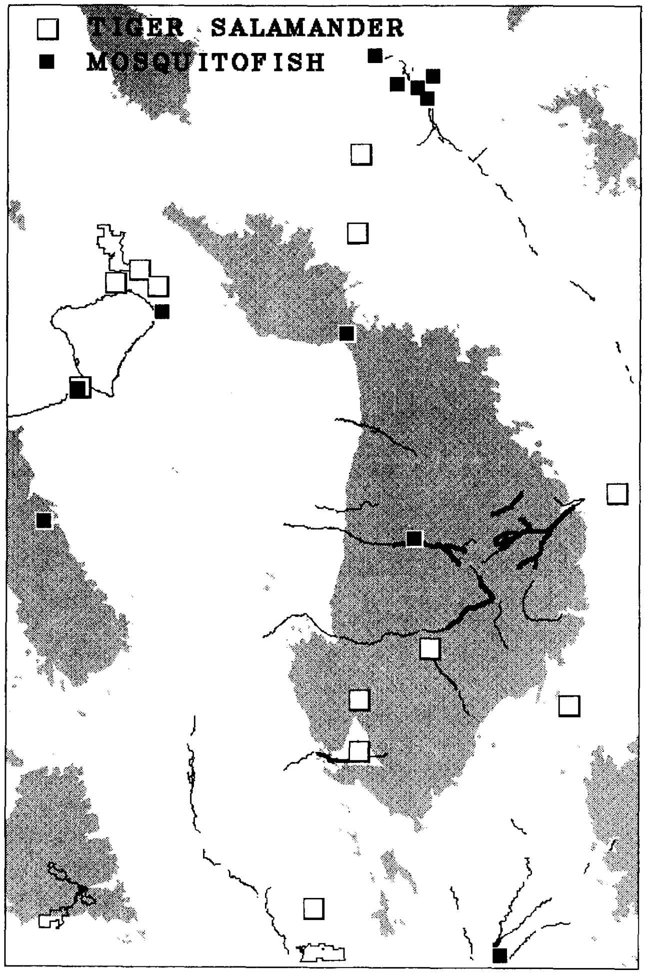

Figure 5.—Distribution of introduced species, mosquitofish *Gambusia affinis* and tiger salamander *Ambystoma tigrinum* in the study region, 1994.

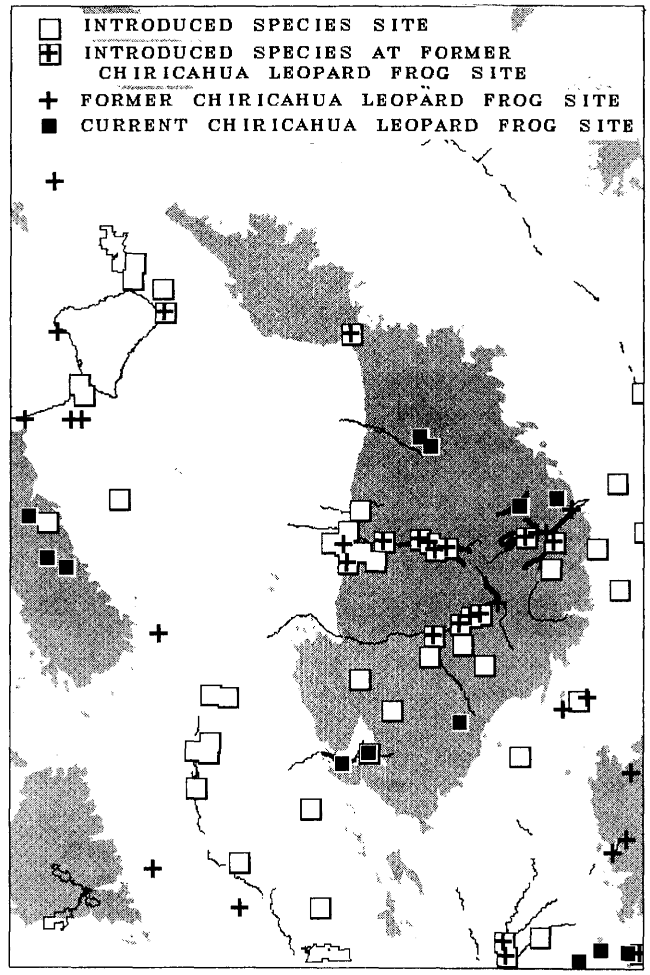

Figure 6.—Occurrence of introduced predatory species at all major perennial waters from which the Chiricahua leopard frog has disappeared. This native frog persists with exotic species in only the single locality shown, as discussed in text.

mortality events occurred in West Turkey Creek; and sediments similarly transported into Rucker Lake largely filled in the lake environment that was a stronghold for introduced fish species.

Regional bullfrog distribution (fig. 3) appears to reflect a limited number of initial introductions, followed by within-drainage dispersal and transplantation. In addition to mapped localities, we observed bullfrogs crossing public roads on five occasions, all within 2 km of known populations. It appears that independent introductions were made at San Bernardino Ranch (1954 or before, personal observations by CHL), lower West Turkey Creek (ca. 1983, J. Austin, personal communication), San Simon Cienega (prior to 1973, R. Zweifel, personal communication), and at Sunsites and near U.S. Rte. 80 and Tex Canyon Road (during the past 10 yr, personal observations by DAP, CRS and PCR). Population groups near Rodeo, New Mexico, Whitewater Draw, and in the Fan region of San Simon Creek are of uncertain origins, possibly involving multiple releases and subsequent dispersal. Possession and intentional spread of bullfrogs continued in 1994, despite its current illegality.

Bullfrogs in southeastern Arizona can be seen at remarkable densities, approaching 1 adult per 2 m of shore at ponds without introduced predatory fishes. In coexistence with largemouth bass (*Micropterus salmoides*) and other centrarchids, yellow bullheads (*Ameiurus natalis*), and other introduced predators (figs. 4, 5), bullfrogs were at far lower abundances, although huge numbers of the unpalatable tadpoles were seen in at least three of these situations (personal observations, PCR).

Minckley (1973) mapped mosquitofish (*Gambusia affinis*) at only three localities within our study region, compared to our 10 sites (fig. 5). Similarly, tiger salamanders (*Ambystoma ti-*

Table 1.—Occurrences of ectothermic aquatic vertebrates in the Chiricahua Mountains region, Arizona, during current survey. The surveyed region included the San Simon, Sulphur Springs, and San Bernardino Valleys and the Chiricahua, Dos Cabezas, Guadalupe, and Dragoon Mountains. An asterisk (*) indicates non-native (introduced) species.

Species	Common Name	Number of Occurrences
*Rana catesbeiana**	Bullfrog	24
Rana chiricahuensis	Chiricahua Leopard Frog	11
Rana blairi	Plains Leopard Frog	4
Hyla arenicolor	Canyon Treefrog	1
Bufo punctatus	Red-spotted Toad	5
Bufo alvarius	Sonoran Desert Toad	4
Scaphiopus spp.	spadefoot toads	8
*Ambystoma tigrinum**	Tiger Salamander	8
Kinosternon sonoriense	Sonoran Mud Turtle	12
Kinosternon flavescens	Yellow Mud Turtle	9
Thamnophis cyrtopsis	Black-necked Garter Snake	10
Thamnophis marcianus	Checkered Garter Snake	7
Thamnophis eques	Mexican Garter Snake	1
*Micropterus salmoides**	Largemouth Bass	7
*Lepomis cyanellus**	Green Sunfish	6
*Lepomis macrochirus**	Bluegill Sunfish	6
*Salvelinus fontinalis**	Brook Trout	1
*Onchorhynchus mykiss**	Rainbow Trout	2
*Ameiurus melas**	Black Bullhead	3
*Ameiurus natalis**	Yellow Bullhead	2
*Ictalurus punctatus**	Channel Catfish	1
*Ctenopharyngodon idellus**	Grass Carp	1
*Pimephales promelas**	Fathead Minnow	3
*Gambusia affinis**	Mosquitofish	10
Poeciliopsis occidentalis	Yaqui Topminnow	2
Gila purpurea	Yaqui Chub	4
Cyprinella formosa	Beautiful Shiner	1
Agosia chrysogaster	Longfin Dace	4
Rhinichthys osculus	Speckled Dace	2
Campostoma ornatum	Mexican Stoneroller	1

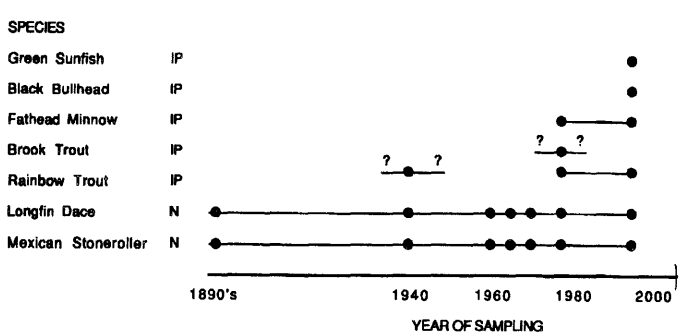

Figure 7.—Time line showing appearance of introduced fishes in Rucker Canyon, Chiricahua Mountains, Arizona. Introduced (non-native) fishes are indicated with an (I), natives with an (N). Species likely to prey on leopard frog tadpoles are indicated with a (P). Occurrence records (dots) 1890-1977 are as summarized by Hendrickson et al. (1980); 1994 records are original here. Question marks on the time lines indicate that stocked game fishes may not have been continuously present.

grinum) were apparently absent prior to the early 1970's (Zweifel, personal communication), but are now widespread in the region (fig. 5). Tiger salamanders are normally eradicated by introduced fishes (Collins et al., 1988), and we found them only once with mosquitofish, in the complex of power plant settling ponds near Cochise. Remarkable abundances were observed for both tiger salamanders (over 40 adults per seine haul) and mosquitofish (several hundred per haul) where they occurred in ponds without additional introduced predators.

During this study, we found tiger salamanders crossing roads four times, all at unknown distances from breeding ponds, and we think they are considerably more widespread than indicated on the map. Branchiate (larval-form) salamanders were found at several sites that nearly dried during 1994, differing from introduced fishes in this regard, and transformed individuals readily live a terrestrial, subterranean existence. Moreover, the animals observed were all probably introduced barred tiger salamanders *A. tigrinum mavortium*, which have been found alive after several months buried over 1 m deep in a dry pond bottom (K. Cobble, personal communication). Thus, we cannot expect to have located a majority of existing population sites in our brief survey focused on perennial waters.

Distribution and Decline of the Chiricahua Leopard Frog

Almost all apparently perennial waters in the Chiricahua region investigated during this study that lacked introduced predatory vertebrates supported moderately sizable populations of Chiricahua leopard frogs (18-ca. 300 observed adult and subadult individuals). All waters having introduced aquatic vertebrates lacked Chiricahua leopard frogs, with a single exception. At Tom Ketchum Tank, Pedregosa Mountains, we found two adult Chiricahua leopard frogs, and 4 large cannibalistic tiger salamanders; the number of both frogs and salamanders was low, and the frogs were within possible dispersal range of a larger population. Thus, we found a nearly perfect pattern of distributional complementarity of Chiricahua leopard frogs and introduced predators in this region.

There were two other probable exceptions to the complementary distribution of Chiricahua leopard frogs with introduced species. Horseshoe Pothole Canyon in the Chiricahua Mountains, a bedrock stream, supported only black-necked garter snakes, red-spotted toads, and canyon treefrogs; a second perennial bedrock stream, Contention Spring in the Peloncillo Mountains, also had black-necked garter snakes, as well as Sonoran mud turtles, but had no ranid frogs. This is also the habitat type from which the Tarahumara frog was extirpated in the 1970's and 1980's (Hale, et al., 1995 *in press)*, suggesting a continuing toxicity problem unique to, or most clearly presenting in, waters that lack mud or other extensive sediment beds.

The consistent pattern of Chiricahua leopard frog absence at sites with introduced species is strong evidence of a negative effect of exotic species on indigenous frogs. The presence of Chiricahua leopard frogs at almost all perennial water sites that lacked introduced predators is strong evidence that these frogs could, in spite of other possible problems including pollution, thrive in most of southeast Arizona if introduced aquatic species are eliminated.

Further evidence for the effect of non-native species on Chiricahua leopard frogs is the presence of introduced predators at all historical, perennial water localities from which Chiricahua leopard frogs have disappeared (fig. 6). All known recent disappearances of these frogs from historically known localities are at (1) perennial waters now supporting introduced predators, or (2) ephemeral waters on valley floors that were dry in 1989 and 1994, and probably in other years of the current drought period.

Decline of the Chiricahua leopard frog was under way by the mid-1980's (Clarkson and Rorabaugh, 1989), whereas numerous healthy, reproducing populations were seen in the Chiricahua region from the late 1950's (Zweifel, personal communication) to the early 1970's (e.g., Frost and Bagnara, 1977). Thus, timing of decline is synchronous with burgeoning of introduced species populations. The simplest hypothesis is that introduced predators eliminated Chiricahua leopard frogs and are currently preventing their re-establishment.

Other hypotheses are possible. Other native ranid frogs, in California, may be strongly affected by tadpole competition from introduced bullfrogs (S. Kupferberg, personal communication), so an assumption that predation is the main or only force remains to be evaluated. Also, during 1974-1984 in the Santa Rita and Atascosa mountains and adjacent regions of Mexico, ranid frogs were found dying, most probably from chemical toxicity derived from smelter-produced air pollution (Hale et al., *in press*). Similar dieoffs, involving leopard frogs in at least one previously-affected locality, have recurred occasionally in the present decade (J. Carpenter, personal communication). We might postulate that initial declines or disappearances were pollution-mediated, and that pollution currently affects native frogs more than exotics, thus perpetuating exclusion of the native. Even if this proves correct, removal of introduced fishes and bullfrogs will still help effect recovery of the Chiricahua leopard frog. While delay in acting to save the Chiricahua leopard frog from extinction could risk its extirpation, we would nonetheless be well advised to develop experimental and observational studies on causes and mechanisms of decline, and more appropriately, of survival.

During the mid-1980's there was a temporary resurgence of these native frogs, apparently because wet conditions allowed them to colonize predator-free localities that usually become seasonally dry (personal observations, PCR). This phenomenon offers little hope for the species' survival, as shown by niche occupancy during the drought summer of 1994 (fig. 8). Current niche occupancy shows that Chiricahua leopard frogs are restricted primarily to sites that came close to drying in 1994. Tanks that dried in 1994 were not found to contain leopard frogs if they filled late in the summer. Thus, these frogs have been excluded from optimal habitat by exotics and are thus vulnerable to extinction due to environmental stochasticity, i.e. drought. The habitat occupancy pattern supports a prediction that continuing drought will continue to eliminate populations, and more severe drought might extirpate the species from southern Arizona and southwestern New Mexico.

Almost all current populations of the Chiricahua leopard frog in the Madrean region are in stock ponds that have a significant risk of drying, making the current situation unstable for this species. Only two populations are currently established at better sites. One of these has an anoxic bottom that may wipe out the frogs during a warm, dry winter (R. Jennings, M. Sredl, personal communications). The other is a small perennial stream (Leslie Creek) managed for native fishes by U.S. Fish and Wildlife Service, that may be the only remaining natural population center for the species in southern Arizona: however, at 20-30 adults in 1994, this is inadequate for a boom-bust species that almost certainly requires a metapopulation structure for long term persistence (Gilpin and Hanski, 1991; Sjögren, 1991; Bradford et al., 1993; Sredl and Howland, *this volume*).

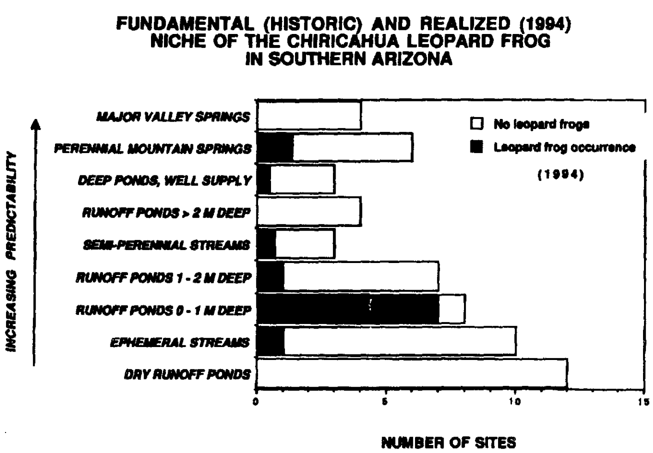

Figure 8.—Habitat occurrence of the Chiricahua leopard frog in southern Arizona, showing 1994 occurrences (shaded) contrasted to existing habitat.

It is clear that introduced predators (in this region bullfrogs, largemouth bass, sunfish, and probably trout and catfish, and possibly mosquitofish and fathead minnows), are the primary causes of decline—and potential listing as a Federally threatened species—of the Chiricahua leopard frog. These frogs may be found to be affected by pollution (Hale et al., *in press*), ultra-violet radiation (Blaustein et al., 1994), or other undetermined factors (Fellers and Drost, 1993) that apparently affect native ranid frogs. In light of our findings in 1994, however, removal of non-native aquatic vertebrates is the most sensible, immediate management action. In concert with control of such exotics, refurbishment of pond habitats to maintain or control water depth is likely to assist recovery of the Chiricahua leopard frog directly.

CONCLUSIONS

1. Introduced predatory vertebrates of at least 13 species now occur widely in the Chiricahua Mountain region. In order of frequency of observed occurrence, these introduced species were the bullfrog, mosquitofish, tiger salamander, largemouth bass, green sunfish, bluegill sunfish, and several species of catfishes and trout.
2. Expansion of these non-native aquatic vertebrates to new localities in this region has been ongoing at an alarming rate for the last 2 decades.
3. Recent decline of the Chiricahua leopard frog, possibly leading to listing as a Federally threatened species, is in this region directly related to interactions (especially predation) with introduced aquatic vertebrates.
4. Remaining populations of the Chiricahua leopard frog exist mainly in habitats subject to drought-related stress, particularly drying or near-drying, where conditions have discouraged the introduction and establishment of non-native aquatic vertebrates.
5. Without corrective action, specifically removal of introduced predatory vertebrates and maintenance of pond and pool environments in predator-free areas, the Chiricahua leopard frog will probably become extinct in this region.

RECOMMENDATIONS

Without doubt, the decline and threatened extinction of native aquatic vertebrates, including fishes, is by far the greatest immediate threat to biodiversity of the Madrean region in the United States. As demonstrated here and elsewhere, this aquatic fauna is being eliminated from historic habitats primarily by non-indigenous sport fishes and bullfrogs. These species, purposefully introduced into lakes created originally for them, are also being spread intentionally and unintentionally into other aquatic environments. If the native aquatic vertebrates are to continue living in southeastern Arizona, wetlands free of these introduced predators must be provided for them.

Below we offer long-term recommendations to aid in recovery of the Chiricahua leopard frog in southeastern Arizona. The survival of this frog in Cochise County is now so tenuous that we also offer shorter term, stop gap measures to maintain the species while longer-term measures are being developed and implemented. Several or all of these long and short-term management recommendations may apply as well to some native fishes of the region, a faunal group even more imperiled than the frogs.

A principal philosophy behind some of the recommendations is that resource managers, conservationists, and private landholders can work together in a spirit of cooperation, with benefits accruing to all parties. Working out this partnership is a challenge that must be met, if the native leopard frogs and fishes are to remain a part of the biodiversity of this unique region.

Many property owners are suspicious of government intentions, especially relating to management of potential threatened or endangered species. Recently, however, several long-time Arizona ranchers have begun working with State and Federal resource management agencies and conservation groups such as The Nature Conservancy to try to insure that the region does retain its biotic as well as cultural components. It is critical that some successes come out of these early efforts—that the landowners, resource managers and, especially, the native wetland ecosystems benefit. Only by demonstrating gains to all sides will we recruit additional participants. Without cooperation of private landowners, efforts to conserve these native aquatic vertebrates in southeastern Arizona are likely to fail.

General Management and Research Recommendations

A management team composed of scientists and resource managers should be created to develop a plan to recover the Chiricahua leopard frog in southeastern Arizona. Such a team should be assembled, regardless of Federal listing status or lack thereof. Actions to be considered in such a recovery plan include:

- Hold off new stocking of sport fishes in the Chiricahua region for at least a decade. The sport fishery in the Chiricahua Mountains is relatively small, yet almost every drainage has a variety of introduced sport fishes.
- Develop standing plans to remove non-native aquatic vertebrates in select areas during severe drought, when such elimination is most likely to succeed.
- Forego the costly and forseeably recurrent dredging of silt from Rucker Lake, permitting Rucker Canyon to exist without the lake habitat that favors introduced species. This "inaction" could save the Coronado National Forest considerable amounts of money in the short and long term. Clear non-natives from the few stock tanks in the Rucker Canyon drainage where they currently occur.
- Maintain the Cave Creek and Portal, Arizona, area free of non-native frogs and fishes for a decade-long experimental period to determine effect on native species. It is timely to begin such a program now, since run-off from the 1994 Rattlesnake Fire seems to have eliminated the non-native fishes. Refurbish key breeding sites for the Chiricahua leopard frog (Herb Martyr and John Hands Dams) by digging out the sediment.
- Cooperate in an attempt to replace non-native with native species of fishes and frogs in West Turkey Creek, Chiricahua Mountains.
- Regularly monitor native and introduced fishes as well as frogs in the Rucker Canyon basin, Cave Creek and South Fork, and West Turkey Creek.
- Initiate research on natural and captive populations of Chiricahua leopard frogs to aid in management decisions affecting recovery.

Recommendations for Landholder Cooperation

- Resource managers and scientists can collaborate with ranchers and other landholders such that all benefit from the frog's need for reliable, clean, perennial waters. Applicable programs available through U.S. Fish and Wildlife Service and Arizona Game and Fish Department should be pursued, wherever clear benefits will accrue to both the resource and the landholder. One such example might be assisting a landholder with the expense or work in installing a new windmill if the landholder agrees (1) to use some of the water produced by the windmill to ensure that leopard frog habitat in the pond is maintained as needed, and (2) to allow and/or assist in keeping his or her ponds free of introduced fishes and frogs.

- Favor management of stock, house, and farm ponds by resident personnel who will help prevent contamination of habitats with introduced species. This could be effected by incorporating inducements to holders of Federal grazing leases into resource management plans in return for commitment to keep ponds predator-free.

We cannot overstate the importance of enlisting cooperative private landholders in this particular effort. Removal of all introduced aquatic predators/competitors from some perennial waters in the area (San Bernardino National Wildlife Refuge, Rucker Canyon, West Turkey Creek, for example) will be a difficult, time-consuming task. Management of stock ponds as leopard frog or native fish habitat may be a relatively simple, cost-effective method of perpetuating the native wetland fauna, while major habitat restoration is in progress elsewhere. Maintaining these man-made wetlands for native species is in keeping with the recent Federal mandate for ecosystem management; even though these wetlands are not the original stream, spring and cienega ecosystems, in most cases they support the only remaining leopard frogs.

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