DRAFT

Potentially Problematic Species in Pima County:

Ecological Effects and Management Strategies

Sonoran Desert
Conservation Plan

Pima County, Arizona
Board of Supervisors
Mike Boyd, District 1
Dan Eckstrom, District 2
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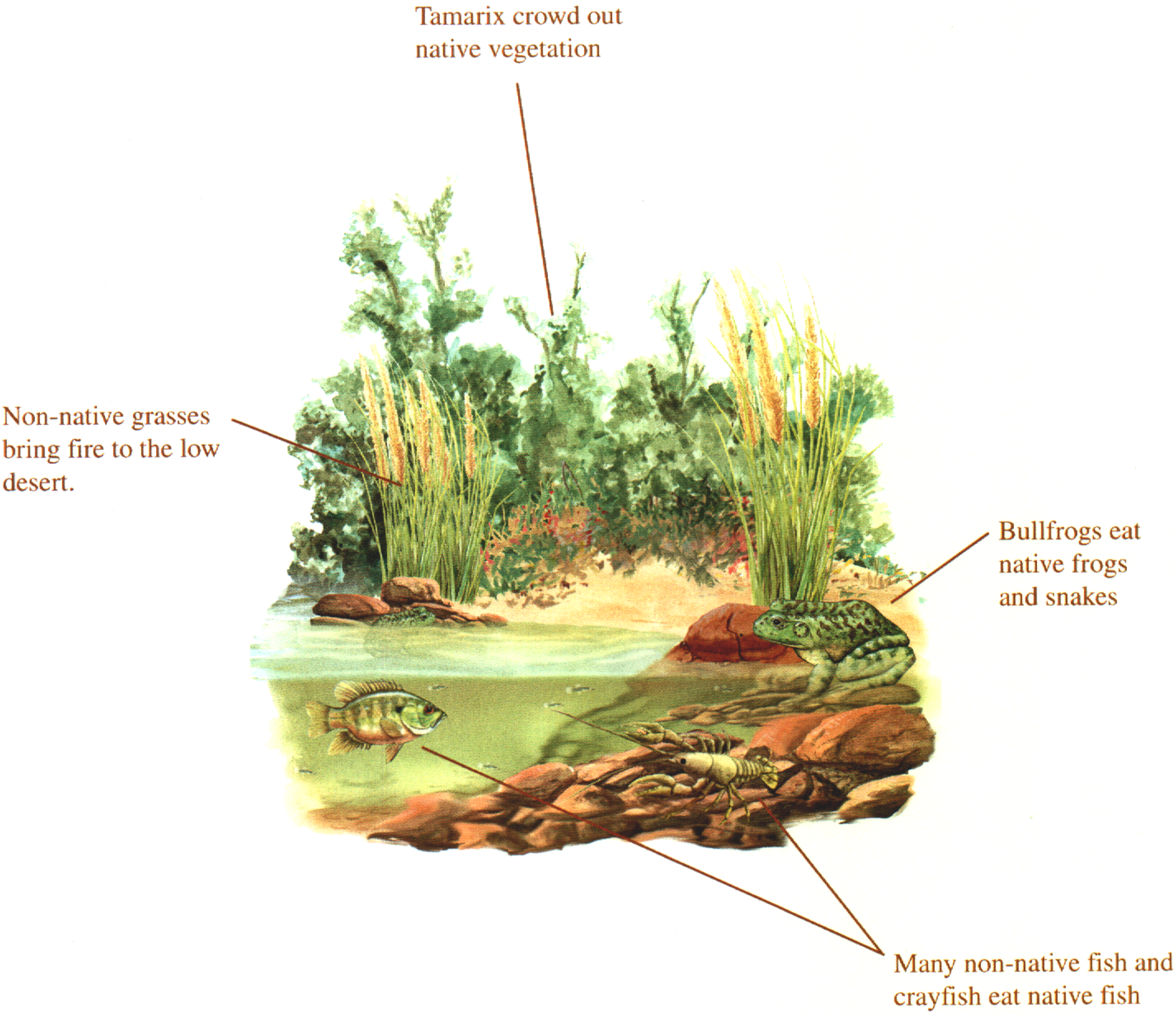
County Administrator
Chuck Huckelberry

Draft
October 2000

Sonoran Desert Conservation Plan



Potentially Problematic Species

MEMORANDUM

Date: October 18, 2000

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry,
County Administrator

Re: **Ecological Effects of Potentially Problematic Species in Pima County**

I. Overview

The attached report by Dr. Ken Kingsley entitled *Potentially Problematic Species in Pima County: Ecological Effects and Management Strategies* is an assessment of the problems that are presented by non-native and introduced species in maintaining native species and natural systems. Divided into two major sections, the study covers representative ecosystems in Pima County as well as representative species that have a negative impact on native species.

II. Representative Ecosystems in Pima County

Pages two through twenty of the attached study describe the effect of introduced and non-native species on both aquatic / riparian systems and terrestrial systems.

A. Aquatic and Associated Riparian Systems

1. Springs and Stock Ponds – In discussing the relatively small, self-contained ecosystems created by springs or stockponds, a number of species that are proposed for protection under the Sonoran Desert Conservation Plan are identified, alongside a description of the species that occur in these systems and have adverse impacts on native species.

PRIORITY VULNERABLE SPECIES			SPECIES WITH ADVERSE IMPACTS ON PRIORITY SPECIES			
1	Desert pupfish		1	Tamarisk	10	Horses
2	Gila topminnow		2	Giant reed	11	Cattle
3	Bats		3	Bermuda grass	12	Burros
4	Arizona shrew		4	Fountain grass	13	Pigs
5	Chiricahua leopard frog		5	Bullfrog	14	Tiger salamander
6	Lowland leopard frog		6	Green sunfish	15	Non-native snails
7	Merriam's mouse		7	W. mosquitofish	16	Fire ants
8	Huachuca water umbel		8	Crayfish		
			9	honey bee		

The study describes impacts on native species, including:

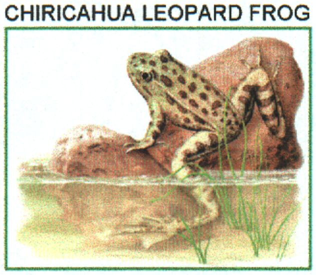
- "Bullfrog, [introduced] fish, tiger salamander, and crayfish are predators and competitors of some native species of concern, particularly fish, garter snake, and frogs."
- "Crayfish may alter and destroy aquatic vegetation and consume water umbel."
- Ungulates may degrade or contaminate resources and alter shading vegetation.
- "Plants may cause water to dry up or become clogged with debris, or change the salinity or other chemical composition of water."

2. <u>Streams and Rivers</u> – The text notes that of 69 fish species listed by the United States Fish and Wildlife Service, habitat alteration is a factor in the decline of the species in 63 cases and introduced species is a factor in 48 of the listings. In discussing the streams and river ecosystems, both aquatic and riparian species that are proposed for protection under the Sonoran Desert Conservation Plan are identified, alongside a description of the species that occur in these systems and have adverse impacts on native species.

- **AQUATIC AND WATER DEPENDENT SPECIES**

PRIORITY VULNERABLE SPECIES			**SPECIES WITH ADVERSE IMPACTS ON PRIORITY SPECIES**			
1	Chiricahua leopard frog		1	Bullfrog	11	Burros
2	Lowland leopard frog		2	Green sunfish	12	Pigs
3	Longfin dace		3	W. mosquitofish		
4	Desert sucker		4	Red shiner		
5	Sonora sucker		5	Black bullhead		
6	Desert pupfish		6	Yellow bullhead		
7	Gila chub		7	Spiny softshell turtle		
8	Gila topminnow		8	Asiatic clam		
9	Huachuca water umbel		9	Horses		
10	Bats		10	Cattle		

CHIRICAHUA LEOPARD FROG



BULLFROG

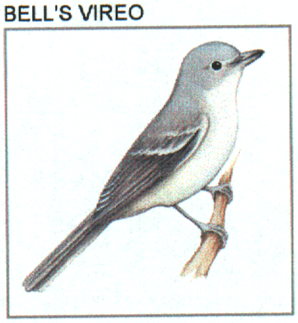
■ **RIPARIAN SPECIES**

PRIORITY VULNERABLE SPECIES			SPECIES W/ ADVERSE IMPACTS -- PRIORITY SPECIES	
1	Arizona shrew		1	Cowbird – brown headed
2	Bell's vireo		2	Cowbird - bronzed
3	Merriam's mouse		3	Tamarisk
4	Western red bat		4	Giant reed
5	Western yellow bat		5	Bermuda grass
6	Western yellow billed cuckoo		6	Cattails
7	Southwestern willow flycatcher		7	Tules
8	Cactus ferruginous pygmy-owl		8	African sumac
9	Mexican garter snake		9	Cattle
10	Abert's Towhee		10	Pig
11	Chiricahua leopard frog		11	Bullfrog
12	Lowland leopard frog		12	Honey bees

ARIZONA SHREW

COWBIRD

BELL'S VIREO



B. Terrestrial Ecosystems

Moving from a water to land based assessment, the study discusses the priority vulnerable species and those species that have a negative impact on them in four terrestrial systems: (1) carbonate terrains; (2) grasslands; (3) desertscrub; and (4) sky islands.

1. Carbonate Terrains – Discussing of limestone outcrops and land that has calcium carbonate as its geological parent material, the report identifies a number of species that are proposed for protection under the Sonoran Desert Conservation Plan, in addition to a description of the species that occur in these systems and have adverse impacts on native species.

PRIORITY VULNERABLE SPECIES			SPECIES W/ADVERSE IMPACTS –PRIORITY SPECIES	
1	Mexican long-tongued bat		1	Fire ants
2	Allen's big-eared bat		2	Honey bees
3	Lesser long-nosed bat			
4	California leaf nosed bat			
5	Pale Townsend's big eared bat			
6	Arkenstone Cave pseudoscorpion			
7	Talus snails			
8	Nichol's Turk's head cactus			
9	Needle-spined pineapple cactus			

LESSER LONG NOSED BAT

PALE TOWNSENDS BIG EARED BAT

CALIFORNIA LEAF-NOSED BAT

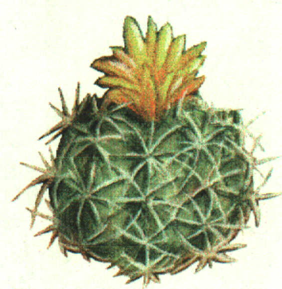
2. Grasslands – Encompassing semidesert grassland, plains grassland, and Sonoran Savanna Grassland classifications, the discussion on pages 15-17 of the study identify species that are proposed for protection under the Sonoran Desert Conservation Plan, along with the species that occur in these systems and have adverse impacts on native species.

PRIORITY VULNERABLE SPECIES			SPECIES W/ADVERSE IMPACTS –PRIORITY SPECIES	
1	Acuna cactus		1	Buffelgrass
2	Needle-spined pineapple cactus		2	Lehmann lovegrass
3	Pima pineapple cactus		3	Red brome
4	Lesser long nosed bat		4	Cheat grass
5	Mexican long tongued bat		5	African daisy
6	Rufous-winged sparrow		6	Filaree
7	Burrowing owl		7	Sweet resin bush
8	Swainson's hawk		8	Honey bees
9	Tucson shovel nosed snake		9	Cattle
10	Organ Pipe shovel nosed snake		10	Horses
11	Ground snake		11	Burros
12	Desert box turtle			
13	Talus snails			

ACUNA CACTUS

NEEDLE SPINE PINEAPPLE CACTUS

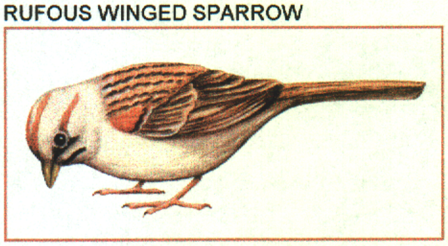
PIMA PINEAPPLE CACTUS



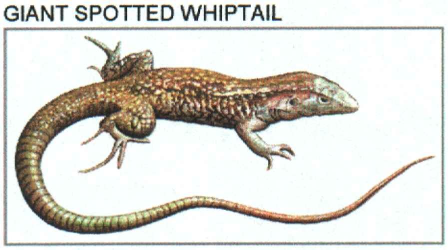
3. <u>Desertscrub</u> – Described as the most extensive and least impacted of Pima County ecosystems, desertscrub is nevertheless home to an estimated 233 species of non-native plants. The discussion on pages 17 through 19 of the study describe species that are proposed for protection under the Sonoran Desert Conservation Plan, and with the species that occur in these systems and have adverse impacts on native species.

PRIORITY VULNERABLE SPECIES			SPECIES W/ADVERSE IMPACTS –PRIORITY SPECIES	
1	Rufous-winged sparrow		1	Cattle
2	Burrowing owl		2	Horses
3	Tucson shovel-nosed snake		3	Burros
4	Organ Pipe shovel nosed snake		4	Buffelgrass
5	California leaf nosed bat		5	Lehmann lovegrass
6	Ground snake		6	Red brome
7	Giant spotted whiptail		7	Cheat grass
8	Talus snails		8	Mediterranean grasses
9	Pima pineapple cactus		9	African daisy
10	Acuna cactus		10	Filaree
11	Needle spined pineapple cactus		11	Sweet resin bush
12	Tumamoc globeberry		12	Sahara mustard
			13	Many other plants
			14	Honey bees

RUFOUS WINGED SPARROW



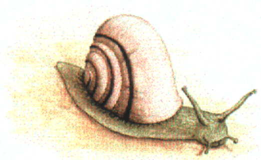
GIANT SPOTTED WHIPTAIL

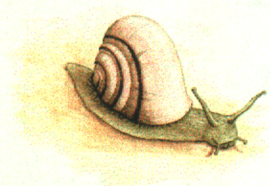


4. Sky Islands – The insular mountains of Pima County, including Forest Service and National Park lands, are discussed in the study on pages 19 and 20. Species that are proposed for protection under the Sonoran Desert Conservation Plan, along with the species that occur in these systems and have adverse impacts on native species, include:

PRIORITY VULNERABLE SPECIES			SPECIES W/ADVERSE IMPACTS –PRIORITY SPECIES	
1	Gentry indigo bush		1	Cattle
2	Talus snails		2	Horses
3	Lesser long nosed bat		3	Burros
4	Mexican long tongued bat		4	Buffelgrass
5	Allen's big-eared bat		5	Fountain grass
6	Pale Townsend's big eared bat		6	Lehmann lovegrass
7	Arizona shrew		7	Red brome
			8	Cheat grass
			9	African daisy
			10	Filaree
			11	Sweet resin bush
			12	Honey bees

TALUS SNAIL





III. Species Accounts

Detailed species accounts are found on pages 20 through 39 of the study. The Science Technical Advisory Team requested a review of species that pose threats to native vulnerable species of concern based on these criteria:

- actual or potential occurrence in the planning area
- level of threat to priority vulnerable species
- management feasibility
- affected resource
- primary habitat

Dr. Kingsley and the Recon team submitted a "top ten list" of species of greatest concern to the Science Team. The following species were researched and accounts are found in the study:

- Bullfrog
- Green Sunfish
- Western Mosquitofish
- Red Shiner
- Northern Crayfish
- Red Swamp Crayfish
- Saltcedar
- Buffelgrass
- Lehmann Lovegrass
- Red Brome

IV. Recommendations

Throughout the study, management concerns and considerations are offered. These include:

- information about the labor and cost of managing invasive plants
- issues to consider in managing livestock
- methods for management of bullfrogs
- methods for management of cowbirds
- use of effluent in riparian restoration
- role of fire in grassland management.

The Science Team in now beginning work with the biological consultant to draft an adaptive management plan which will contain more specific recommendations for managing non-native species in relation to the areas protected under the Sonoran Desert Conservation Plan.

DRAFT
Potentially Problematic Species in Pima County: Ecological Effects and Management Strategies

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APPENDIXES

I. Introduction

The purpose of this document is to examine the role of species that may be potentially problematic in the maintenance of native biodiversity in Pima County, particularly to those species that have been identified as Priority Vulnerable Species. The designation "potentially problematic species" was chosen over a variety of alternatives because the species examined are not necessarily problematic under all circumstances, they are not necessarily species that are considered "pests," and they are not necessarily all "exotic" species. This document is not meant to be an exhaustive compilation and review of the literature on these species, but to specifically address the issue as it relates to the Sonoran Desert Conservation Plan (SDCP).

The number of species of plants and animals, and the relative sizes of populations of those species in Pima County has changed during historical times. Some native species have increased, some have decreased, and several species native to other areas have become established in Pima County over the past 100 years (Brown and Davis 1995). Many of the non-native species have adverse impacts on native species. This is of great concern in the context of the SDCP's goal of maintaining native biodiversity in Pima County and the development of our Multispecies Habitat Conservation Plan. This document examines the issues of the known and speculated effects of potentially problematic species, aspects of the biology of those species, and current and suggested management strategies that may be used to control those species in order to protect native species of conservation concern.

II. Approach

The potentially problematic species of particular concern were initially identified by the SDCP Science Technical Advisory Team (STAT) (Appendix A). The RECON team analyzed the initial list according to the following criteria:

A. Actual or potential occurrence in the planning area
B. Primary habitat
C. Affected resource
D. Level of threat to Priority Vulnerable Species
E. Management feasibility

A matrix table and suggested "Top Ten List" of species of greatest concern were prepared and submitted to the STAT for review (Appendix B). The STAT expressed the desire to follow an ecosystem approach for this document.

That is the approach taken here, followed by a more detailed discussion of certain species that are of particular concern. In this report, the several distinct ecosystems in Pima County are discussed, considering the Priority Vulnerable Species found in each, the potentially problematic species that are known from each or may potentially become established, and the management approaches that are, or might be, used in each ecosystem.

Two additional reports in the Pima County SDCP report series have dealt with aspects of this issue. *Issues of Non-native Species in Public Reserves* by Neva Connolly (Connolly 2000) reviews the current management plans and practices for non-native species on major reserves in Pima County. It lists Federal agencies dealing with non-indigenous species and briefly describes their activities and responsibilities, and also lists Federal laws and Executive Orders dealing with non-indigenous species. It includes as appendices lists of non-indigenous species known from the Cabeza Prieta National Wildlife Refuge, Organ Pipe Cactus National

Monument, Buenos Aires National Wildlife Refuge, Saguaro National Park, Colossal Cave Mountain Park, Cienega Creek Natural Preserve, Bingham Cienega Natural Preserve, Coronado National Forest, Sabino Canyon, and Catalina State Park.

Aquatic Vertebrate Conservation in Pima County: Concepts and Planning Development by Philip C. Rosen (Rosen 2000) very specifically deals with problematic species in aquatic ecosystems in Pima County. He proposes an approach to reduce or eliminate them and create conservation opportunities for native species. Exotic species considered in that document are bullfrog, catfish, sunfish, bass, mosquitofish, and crayfish. A concept for a plan to manage aquatic ecosystems to reduce their suitability for non-native species and enhance suitability for native species is described. Potential challenges in the application of this concept are discussed. A detailed bibliography is included.

Invasive Exotic Species In the Sonoran Region edited by Barbara Tellman (Tellman in prep.) is a book in the final stages of preparation. It is a compilation of review articles by the leading experts in the field, and presents a thorough current review of the issue, a compilation of applicable international agreements, State and Federal laws and Executive Orders, and Federal and Arizona Noxious and Prohibited Weed Lists, an exhaustive bibliography, and a table of naturalized exotic species in the Sonoran region. Ms. Tellman provided a draft copy of the book for reference in preparing this report, with the understanding that it was a draft and the final product will differ from this version.

III. Representative Ecosystems of Pima County

For the purposes of this discussion, ecosystems have been grouped as Aquatic and Associated Riparian Systems (including springs, stock ponds, and streams and rivers) or Terrestrial Systems (including carbonate terrains, grasslands, desert scrub, and "sky islands").

A. Aquatic and Associated Riparian Systems

1. Springs

Springs are defined as places where water that is traveling in rocks or soil naturally rises to the surface (Fonseca et al. 2000). They typically contain both aquatic and riparian species. Because they are small, discrete, self-contained ecosystems, it is probably not appropriate to separate aquatic and riparian species in considering them. A recent report on springs in Pima County has been prepared (Fonseca et al. 2000). A symposium on spring ecosystems was held on 6 May 2000 by the Arizona-Sonora Desert Museum. The proceedings are expected to be published in 2001 and may have useful information that will deal with potentially problematic species and management at springs. Rosen's report (Rosen 2000) discusses conditions and management suggestions for some of the important springs in Pima County.

Priority Vulnerable Species that depend upon or utilize springs include desert pupfish (*Cyprinodon macularius*), Gila topminnow (*Poeciliopsis occidentalis occidentalis*), bats (all species), Arizona shrew (*Sorex arizonae*), Chiricahua leopard frog (*Rana chiricahuaensis*), lowland leopard frog (*Rana yavapaiensis*), Merriam's mouse (*Peromyscus merriami*), and Huachuca water umbel (*Lilaopsis schaffneriana recurvata*).

Potentially problematic species that are known to occur at springs and have adverse impacts on native species of concern include tamarisk (*Tamarix ramossissima*), giant reed (*Arundo donax*), Bermuda grass (*Cynodon dactylon*), fountain grass (*Pennisetum setaceum*), bullfrog (*Rana *catesbeiana*), green sunfish (*Lepomis cyanellus*), western mosquitofish (*Gambusia affinis*), crayfish (*Orconectes virilis*), honey bee (*Apis mellifera*), cattle (*Bos taurus*), horses (*Equus caballus*), burros (*Equus asinus*), pigs (*Sus scrofa*), tiger salamander (*Ambystoma tigrinum*), and nonnative snails of several genera. Introduced fire ants (*Solenopsis invicta*) are likely to survive and possibly become established at springs and may be especially problematic there. The ways in which potentially problematic species are known to affect springs, or may affect them, include the following.

Plants may cause water to dry up or become clogged with debris, and may change salinity or other chemical composition of water. The effect depends greatly on the density of the plants, size of the springs, and the development (or absence) of a community of native plants that can resist invasion by potentially problematic species.

Bullfrog, fish, tiger salamander, and crayfish are predators and competitors of some native species of concern, particularly fish, garter snake, and frogs (as adults and tadpoles).

Crayfish may alter and destroy aquatic vegetation and consume water umbel.

Honey bees and introduced fire ants may sting other native species (e.g., mule deer and desert bighorn sheep) that come to drink. They may have an adverse impact on native insects associated with plants (e.g., bees compete with pollinators, fire ants consume herbivores) and may precipitate a cascade effect that results in damage to the resource. They also can make monitoring studies and maintenance work difficult by stinging workers.

Nonnative snails may alter aquatic vegetation and vector fish diseases and parasites.

Ungulates (horses, burros, cattle, pigs) may consume and/or contaminate water and alter shading vegetation.

The most crucial management need for springs is protection from diversion or depletion of the water supply (Fonseca et al. 2000). However, the potential for complete shut down or diversion of water flow may be useful for management of problematic species (Rosen 2000). The inherent isolated nature of springs offers opportunities for the elimination of problematic species, followed by regular monitoring and follow-up treatment. Most springs have been significantly altered from their natural state, either by diversion, construction of "improvements," or invasion by exotic species (or both). Many have dried up, either as a result of drought or lowering of the water table. Inventory, evaluation, and monitoring of all springs in Pima County are important components of management that have not been done. Very few of the springs in Pima County have had current or recent examination. A specific management plan for each spring should be developed based on current conditions.

2. Stock Ponds

Stock ponds are artificial aquatic ecosystems that may sometimes also have associated riparian habitat. They are known to be important habitat for Chiricahua leopard frogs, Mexican garter snakes, and are often used by bats and other native wildlife species. They may be occupied by bullfrogs, non-native fish, tiger salamanders and crayfish. They do not quite fit the concept of native ecosystems, but should be considered as potentially important resources in managing the landscape for biodiversity. Because they are usually isolated from other aquatic resources and have unique design characteristics, management may be facilitated. Rosen (2000) gave a detailed discussion of the potential value of stock ponds. Stock ponds provide a critically important water source for livestock, and many are frequently and closely monitored by ranchers. This high level of on-the-ground observation and monitoring can also facilitate management *against* problematic species, such as bullfrogs, and *for* native species such as leopard frogs. Because of the similarities between stock ponds and springs, the discussion of springs is applicable to stock ponds, and will not be repeated here.

3. Streams and Rivers

Streams and rivers provide habitat for aquatic species, species using water for drinking, and riparian plant and animal species. To facilitate consideration and management, this discussion separates the aquatic from the riparian components.

a. Aquatic and Water-dependent Species

Priority Vulnerable Species that are aquatic and occur in streams and rivers are Chiricahua leopard frog, lowland leopard frog, longfin dace (*Agosia chrysogaster*), desert sucker (*Catostomus clarki*), Sonora sucker (*Catostomus insignis*), desert pupfish, Gila chub (*Gila intermedia*), Gila topminnow, and Huachuca water umbel. Also, all species of bats may use and depend on the water in streams and rivers for their survival in specific areas.

Potentially problematic species that are aquatic and occur in streams and rivers are bullfrog, green sunfish, western mosquitofish, red shiner (*Cyprinella lutrensis*), black bullhead (*Ameiurus melas*), yellow bullhead (*Ameiurus natalis*), spiny softshell turtle (*Trionyx spiniferus*), and Asiatic clam (*Corbicula manilensis*, aka *C. fluminea*). Also, ungulates (cattle, horses, burros, and pigs), both domestic and feral, may affect aquatic resources.

Table 1 summarizes known distribution information on aquatic species, both native species of concern and potentially problematic species. Note that the indicated presence or absence of a species may be historical only, as conditions may have changed since the last available report. Some areas of uncertainty are not included in this table, because specific information is not available at this time. A thorough investigation of the current conditions of aquatic habitats of Pima County has not been completed and should be an important part of the Sonoran Desert Conservation Plan.

Bullfrogs are predators on many species of animals, including leopard frogs, Mexican garter snakes, bats, and fish. They are known to move into and over-run areas and are very difficult to eradicate. Rosen (2000) provides an approach concept to dealing with this species, and reviews the literature on it. Bullfrogs are known to occur in Sabino and Arivaca creeks, the Santa Cruz and San Pedro rivers, Agua Caliente Springs, and Cienega Creek. The Arizona Game and Fish Department relaxed bag limits in many areas to promote bullfrog harvest (Howland 1992), and more recently, removed limits. However, it is unlikely that hunting pressure itself would be sufficient to have an impact on bullfrog populations. Intensive efforts to remove bullfrogs, including hunting and trapping, from the relatively limited area of the San Bernardino National Wildlife Refuge over a period of years was not successful (Rosen and Schwalbe 1996). A species account for this species is included in another section of this document.

Green sunfish become established in most locations where they are introduced (Fuller et al. 1999), and are predators on and competitors with native fishes and leopard frogs (Rosen et al. 1995). Green sunfish are known from Sabino Creek, the Santa Cruz and San Pedro rivers, and Redfield Canyon (Young and Lopez 1995). Green sunfish is a predator of Gila chub in Sabino Creek (Dudley and Matter 2000). Substantial flooding apparently displaces many non-native

TABLE 1
AQUATIC SPECIES KNOWN FROM PIMA COUNTY AND ADJACENT WATERS

KEY: Native Species: AGCH = longfin dace (*Agosia chrysogaster*); CACL = desert sucker (*Catostomus clarki*); CAIN = Sonora sucker (*Catostomus insignis*); GIIN = Gila chub (*Gila intermedia*); POOC = Gila topminnow (*Poeciliopsis occidentalis*); RACH = Chiricahua leopard frog; RAYA = lowland leopard frog; RHOS = speckled dace (*Rhinichthys osculus*); THEQ = Mexican garter snake (*Thamnophis eques*). Non-native Species: AMME = black bullhead (*Ameiurus melas*); AMNA = yellow bullhead (*Ameiurus natalis*); CYCA = common carp (*Cyprinus carpio*); CYLA = red shiner (*Cyprinella lutrensis*); GAAF = mosquitofish (*Gambusia affinis*); LECY = green sunfish (*Lepomis cyanellus*); MISA = largemouth bass (*Micropterus salmoides*); ORVI = crayfish (*Orconectes virilis*); PIPR = fathead minnow (*Pimephales promelas*); RACA = bullfrog (*Rana catesbeiana*)

Location	Native Species									Non-native Species										
	AG CH	CA CL	CA IN	GI IN	PO OC	RA CH	RA YA	RH OS	TH EQ	AM ME	AM NA	CY CA	CY LA	GA AF	LE CY	MI SA	OR VI	PI PR	RA CA
CIENEGA CREEK																			
Mattie Canyon	X			X	X														
Headwaters				X	X	X													
Between Gardner and Springwater Canyons	X			X	X														
Between Oak Tree Canyon and Empire Gulch	X			X	X	?			X										
Downstream of Pump Canyon	X			X	X														
Upstream of Fresno Canyon	X			X	X		X												
Between Headwaters and Gardner Canyon	X			X	X		X												
Confluence with Davidson Canyon	X																		
Upstream of Marsh Station RR Bridge	X						X												
Immediately below USGS Gauging Station	X						X												X?
SANTA CATALINA MOUNTAINS																			
Sabino Creek				X			X							X	X	X	X		X
Bear Canyon (Rose Canyon Lake)							?							?	X		X		X
Cañada del Oro															X				
Romero Canyon															X				
Montrose Canyon							X												
Buehman Canyon	X						X												
Edgar Canyon	?						?												
Youtcy Canyon	?						?												
Espiritu Canyon							?								X				
Agua Caliente Canyon															X				
Agua Caliente Springs															X	X			X

TABLE 1
AQUATIC SPECIES KNOWN FROM PIMA COUNTY AND ADJACENT WATERS
(continued)

Location	AG CH	CA CL	CA IN	GI IN	PO OC	RA CH	RA YA	RH OS	TH EQ	AM ME	AM NA	CY CA	CY LA	GA AF	LE CY	MI SA	OR VI	PI PR	RA CA
RINCON MOUNTAINS																			
Chiminea Canyon							X												
Paige Canyon							X								X				
Agua Verde Creek							X		?										
WHETSTONE MOUNTAINS																			
Wakefield Canyon							X												
SANTA CRUZ RIVER	X	X	X		X									X	X	X		X	X
SAN PEDRO RIVER																			
San Manuel Crossing	X						X			X				X	X				
Near Cascabel	X	X					X			X				X	X			X	
11.3 km SE of Redington	X	X																	
Upstream locations	X	X					X			X	X	X		X	X			X	X
REDFIELD CANYON																			
11.3 km upstream of Redington	X	X	X	X				X		X					X			X	
91 m above Stone Ranch House	X	X	X	X											X				
Below Stone Ranch House	X	X	X	X				X							X				
Near Swamp Spring Canyon	X		X	X				X							X				
ARIVACA CREEK																			
Altar Valley: Arivaca Creek Drainage					X														X
Arivaca Cienega						?	?			?	?			X	X	X	X		X
Arivaca Lake						?	?			?	?			X	X	X	X		X
SANTA RITA MTS.																			
Box Canyon						X	X												
West Sawmill Canyon						X													
Fish Canyon						X													
CENTRAL ARIZONA PROJECT CANAL													X		X				

fish populations, but green sunfish may travel upstream during flooding. In a record flood of Sabino Creek in 1993, western mosquitofish were completely displaced whereas green sunfish were not, and may have migrated upstream (Dudley and Matter 1999). A three-mile reach of Sabino Creek was treated with antimycin and rotenone in 1999. Prior to releasing the toxin, as many native fishes as possible were removed to an upstream location. It is believed that green sunfish were successfully removed above Sabino dam (D. Duncan, USFWS, pers. comm. to K. Kingsley 26 July 2000). Green sunfish were present below the dam in April 2000 (K. Kingsley, personal observation). Green sunfish are also known from Rose Canyon Lake in the Bear Canyon drainage, and plans for their removal are currently being discussed (Halligan 2000). However, Rosen (2000 p. 16) states that "the current . . . concept of refurbishing this site seems insufficient . . . ." Green sunfish are also known from Romero Canyon, Agua Caliente Canyon, Espiritu Canyon, Paige Canyon, Arivaca Cienega, and Arivaca Lake (Rosen 2000). Green sunfish are also present in the Central Arizona Project canal and the aquifer recharge basins at the Central Avra Valley Storage and Recovery Project (K. Kingsley, personal observations). A species account for this species is included in another section of this document.

Western mosquitofish occurs in Sabino Creek, and the Santa Cruz and San Pedro rivers (Young and Lopez 1995). They have also been reported in Rose Canyon Lake (Rosen 2000). Mosquitofish negatively impact leopard frog and most native fishes (Rosen et al. 1995), including Sonoran topminnow (Meffe et al. 1983). Minckley (1999) noted that the establishment and spreading of mosquitofish coincides with the decline of Gila topminnow, and believes that mosquitofish must be actively and aggressively managed to prevent extinction of Gila topminnow. A species account for this species is included in another section of this document.

Several other species of fish are of concern, but do not rank as highly as the above species because they are not currently as well established or are not as clearly problematic at this time. In Pima County. Red shiner is currently not known from natural waters in Pima County, although it is present in water in the Central Arizona Project Canal and the aquifer recharge basins at the Central Avra Valley Storage and Recovery Project (K. Kingsley, personal observations). This species is also present in the Gila River drainage (Young and Lopez 1995). It is aggressive and reproduces rapidly, hybridizes with other congeners, and may serve as a host to Asian tapeworm (Fuller et al. 1999). Black bullhead occurs in the San Pedro River and Redfield Canyon (Young and Lopez 1995). Yellow Bullhead occurs in the San Pedro River (Young and Lopez 1995). Catfishes probably negatively impact most native fishes and leopard frogs (Rosen et al. 1995). The spiny softshell turtle is present in the Santa Cruz River (K. Kingsley, personal observation) and Cienega Creek (Rosen 2000). The impacts of this species on native species, especially Priority Vulnerable Species, have not been determined.

Ungulates may consume and/or contaminate water and alter riparian and aquatic vegetation. Domestic cattle and horses may be managed to minimize adverse impacts, however feral and/or poorly managed livestock may have adverse impacts on aquatic habitats. A recent survey of the literature on livestock influences on stream and riparian ecosystems in the western United States (Belsky et al. 1999) concludes that livestock grazing was found to negatively affect water quality and seasonal quantity, stream channel morphology, hydrology, riparian zone soils, in stream and streambank vegetation, and aquatic and riparian wildlife. No positive environmental impacts were found. Specific effects documented included:

> increase of nutrient concentrations due to runoff from disturbed streambanks, livestock urine and manure deposited into stream, nutrients concentrated in reduced quantity of water

increase in bacteria and protozoa due to direct fecal deposition into water and fecal material runoff as well as disturbance of buried sediments by hoof action

increase in sediment load and turbidity caused by in stream trampling, disturbance and erosion of banks, reduced sediment trapping by streambank and in stream vegetation, loss of bank stability, and increased peak flows from compaction of the watershed

increase in water temperature because of increased solar exposure due to reduced shade from streamside vegetation and loss of undercut streambanks, as well as widened stream channels and reduced summer flows

possible decline in dissolved oxygen levels due to higher water temperatures and high biological oxygen demand of fecal material and algal blooms

increase in channel depth due to downcutting caused by higher flood energy

decrease in channel stability during floods

decrease in water depth except during peak flows

alterations of stream beds, including loss of gravel in erosional segments and deposition of sediments in depositional segments

increase in algae because of exposure to more sunlight, higher temperatures, and higher concentrations of dissolved nutrients

decline in submerged and emergent plant species due to trampling and burying in deposited sediments or uprooting by floods

decrease in fish species diversity, abundance, and productivity due to water quality changes

alteration of invertebrate diversity, abundance, and species composition due to water quality changes

decline in diversity, abundance and species composition of amphibians and reptiles due to decline in structural richness of vegetative community, loss of prey base, increased aridity, loss of thermal cover and protection from predators, and water quality changes

alteration of diversity, abundance, and species composition of birds resulting from reduction in food, water quality, and water quantity; loss of perches, nesting sites, and protective plant cover; loss of complex vegetational structure

possible alteration of mammal diversity, abundance, and species composition, although the effects on mammals are not consistent

Newer grazing systems, involving more intensive management and some level of exclusion of cattle, were shown to improve streamside conditions relative to other grazing systems. Belsky et al. (1999) cited two studies that concluded that no grazing system was compatible with healthy aquatic ecosystems. However, they concluded that cattle grazing is not the only factor damaging stream and riparian habitats, but was only one of many factors resulting from human impacts. Livestock damage can be reduced by improving grazing methods, herding or fencing cattle away from streams, reducing livestock numbers, or increasing the period of rest from grazing. Improved livestock management may result in improvement of aquatic and riparian resources. However, the level of grazing management that would minimize adverse effects on aquatic and riparian resources may not be compatible with sustainable economics of ranching.

Several species of exotic invertebrates have become established in the waters of Pima County. No problematic mollusks are currently established in the waters of Pima County, although several species of exotic snails and clams are known (Bequaert and Miller 1973). It is possible that one or more of these, especially the Asiatic clam may become problematic in some situations. The Asiatic clam is known from the Central Arizona Project canal (U.S. Fish and Wildlife Service 1999). Nonnative mollusks may alter aquatic vegetation and vector fish diseases and parasites. Also, the effects of exotic mollusks on our native molluscan fauna are completely unknown, but are potentially problematic, as they have been elsewhere (Lodge et al. 1998; Strayer 1999). Crayfish are known to alter and deplete aquatic vegetation and consume water umbel. They are also predators on native species of invertebrates and may have direct and indirect effects on other native species of concern (Fernandez and Rosen 1996, Kubly 1997, Mieta 1999, Rosen 2000).

Aquatic, emergent, and riparian plants may cause water to dry up or become clogged with debris or may change salinity or other chemical composition of water. This may be lethal to aquatic wildlife in small bodies of water. Alternatively, use of plants such as cattails (*Typha* species) and tules (*Scirpus* species) may be a useful tool to eliminate habitat for bullfrogs and non-native fish (Rosen 2000).

Management Concerns and Considerations for Aquatic Species and Systems

Several aquatic facultative or obligate species in southeastern Arizona (*Thamnophis eques, T. rufipunctatus, Rana chiricahuaensis,* and *R. yavapaiensis*) have been impacted by introduced species (namely, fishes, bullfrogs, and crayfish) (Rosen 2000, Rosen and Schwalbe in prep.). However, it is difficult to determine the primary cause of ranid frog declines because several causative factors are confounded. Interactions between introduced species and other causes of native species declines are typically synergistic, as opposed to additive or neutral. Therefore, fast, proactive management action should be taken particularly for declining aquatic species (Rosen and Schwalbe in prep.). Despite unequivocal proof, it appears that introduced fishes and bullfrogs are at least partly responsible for losses of native frogs and fish (Rosen 2000; Rosen and Schwalbe in prep.; Knapp and Matthews 2000; Hayes and Jennings 1986). Of 69 fish species listed by the U.S. Fish and Wildlife Service, habitat alteration was listed as a factor in 63 cases and introduced species as a factor in 48 cases (Lassuy 1999).

In considering management for aquatic species, Rosen and Schwalbe (in prep.) and Rosen (2000) suggest that elimination of modified aquatic habitat may enhance reestablishment of native species. Such a program might restore watershed flow regimes that would continuously approach predisturbance conditions. Natural flood regimes would be more frequent and would likely negatively effect non-native fish populations. Indeed, Rosen and Schwalbe (in prep.) note that the "negative effects of introduced species may be facilitated by habitat modification." A definition of the most suitable habitat for various native species and the least suitable for various introduced species would be a useful tool for conservation planning, system restoration, and species reintroduction. Rosen (2000) has taken major steps toward this. Rosen and Schwalbe (in prep.) note that the transfer of such information by municipalities to management agencies is necessary to develop an accurate and workable definition. Rosen and Schwalbe (in prep.), Rosen (2000), and Minckley (1999) offered several other management suggestions:

1. Prohibit importation and transplantation of non-native aquatic species (except by permit).

2. Agencies should not import and release any new aquatic species and should not translocate non-native species to habitats with native species.

3. Revise pet trade regulations to avoid importation of potentially invasive species.

4. Novel solutions for control of non-native species should be identified and implemented if appropriate.

5. Agencies should continue to plan and implement translocation programs for all native fishes.

6. Protect all natural existing refugia and establish and maintain artificial refugia in perpetuity.

The Arizona Game and Fish Department has recommended to the Arizona Game and Fish Commission that regulations be promulgated that support these management suggestions. Further, Rosen (2000) recommends that wherever possible, lentic (lake and pond) systems should be replaced with lotic (flowing) systems. A natural flood regime would favor native species. Elimination or careful management of ponds and ponding sites would minimize the continual reestablishment of non-native aquatic species. Because of the demand for recreational fishing and the aesthetic popularity of lakes and ponds, full implementation of all of these suggestions may be politically difficult. Also, elimination of ponds may adversely impact bats by eliminating or reducing their water sources.

b. Riparian Species

Of course, riparian species are intricately interrelated with the aquatic component, but management as riparian may be more appropriate and expeditious—we have some areas of water with no riparian development, and vice versa, and the potentially problematic species may affect the aquatic and riparian components differently.

Priority Vulnerable Species known to be dependent on riparian areas include Merriam's mouse, western red bat (*Lasiurus blossevillii*), western yellow bat (*Lasiurus xanthinus*), Arizona shrew, Abert's towhee (*Pipilo aberti*), Bell's vireo (*Vireo belli*), western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), southwestern willow flycatcher (*Empidonax traillii extimus*), cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) (historically), Mexican garter snake (*Thamnophis eques megalops*), Chiricahua leopard frog, and lowland leopard frog.

Potentially problematic species that may occur in riparian areas and may have adverse impacts on native species of concern include tamarisk (may be beneficial or neutral), giant reed, Bermuda grass, cattails and tules, African sumac (*Rhus lancea*), cattle (horses and burros appear to be less of a problem than at springs), pig, bullfrog, brown-headed cowbird (*Molothrus ater*), bronzed cowbird (*Molothrus aenaeus*), fire ants, and honey bees. Also, a list of 25 species of exotic herbaceous species that occur in riparian ecosystems has been published (Stromberg and Chew 1997), but actual and potential problems caused by any of these have not been documented.

Problematic plants may often compete with desirable native riparian plant species for space, water, sunlight, and nutrients. They may also produce toxic byproducts, such as concentrated salts, that may poison other plants and some animals. These effects can result in an altered ecosystem. However, invasive exotic plants apparently thrive under disturbed hydrological regimes, and may not survive, thrive, or be problematic under more natural hydrological regimes (Stromberg and Chew in prep.). Also, plants may be useful for drying up ponded water in altered ecosystems, and thereby may be used as a management tool for restoration of habitats of native species (Rosen 2000). Furthermore, tamarisk may be an important resource for Bell's vireo and southwestern willow flycatcher. African sumac (*Rhus lancea*) has begun to appear as an escapee along urban and suburban washes and may become problematic (Segade 2000, M. Falk, pers. comm. to K. Kingsley).

Ungulates may consume and trample vegetation and have other direct and indirect adverse impacts on riparian resources. Recent reviews of the effects of ungulates on riparian resources include Belsky et al. (1999) and Ohmart (1996). Both of these conclude that the impacts of livestock grazing are generally adverse to healthy riparian ecosystems. Specific impacts cited by Belsky et al. (1999) include many of those listed above for aquatic resources and also:

increase of bare ground as a result of vegetation consumed and trampled by livestock

increase in erosion caused by soil compaction, removal of vegetational cover, and trampling disturbance

decrease of litter layer as a result of removal of aboveground plant biomass

increase of soil compaction and decrease of moisture infiltration

decline in soil fertility due to loss of soil components and alteration of structure

decline in streambank herbaceous and woody vegetation biomass, productivity, structural diversity, and native diversity due to grazing and trampling, including selective grazing of palatable species, lowered water table, and development of a drier, warmer, more exposed environment

other impacts on vegetation, including alteration of species composition, development of even-aged stands, alteration of plant phenology, and impedance of plant succession

Ohmart (1996) reviewed the historical and ecological literature on the effects of grazing on riparian resources. Historical impacts occurring in the 1890s resulted in major change of southwestern riparian ecosystems and many have not recovered. He cited studies that indicated increases in some species of birds resulted from exclusion of livestock. Among the species that apparently benefited from livestock exclusion were Bell's vireo and willow flycatcher. Changes in numbers of yellow-billed cuckoos were inconclusive.

Feral pigs are a problem in riparian habitat along the San Pedro River in Pima County (D. Harris, The Nature Conservancy [TNC], pers. comm. to K. Kingsley). Soil disturbance and direct consumption of plants by these animals impact riparian vegetation. These animals were originally released for hunting. An attempt to eradicate them has resulted in some reduction of the population, but the remaining animals are wary and difficult to capture or kill. Although feral pigs do not appear to be of widespread concern in the County at present, the potential for expansion into conservation areas and the damage they are capable of inflicting warrant vigilance on the part of land managers.

The bullfrog, discussed in more detail above, is a predator on riparian animals (e.g., garter snake, bats, native frogs). It is probably best managed as an aquatic species, during its extended, water-dependent tadpole stage (Rosen 2000).

Cowbirds, both brown-headed and bronzed, are nest parasites of many species of birds, including some that nest in riparian areas. Of specific concern are Bell's vireo and southwestern willow flycatcher. These species are known to be hosts of brown-headed cowbirds, and in some areas they may be severely impacted by cowbird parasitism. This has not been shown to be the case in Arizona yet, but the added stress of cowbird parasitism may have an adverse synergistic effect. Cowbird trapping has been a tool in management for least Bell's vireo and southwestern willow flycatcher in California and may be appropriate under certain circumstances in Pima County.

Introduced fire ants are known to consume caterpillars and other insects, in competition with birds. They are also known to attack and consume baby birds in the nest. This species has not yet become established in Arizona, but has frequently been discovered in small areas of this state. In areas of the U.S. where this species is established, it thrives in riparian areas. The species is especially well adapted for dispersion by floods. If fire ants become established in Arizona, the most likely natural habitat in which they will survive and become problematic is riparian, because of high moisture needs of the species. The effects of this species on riparian resources and wildlife cannot be predicted at this time, but every reasonable effort should be made to prevent its establishment. Managers of land and wildlife should become familiar with this species and vigilant for its presence. Immediate response may prevent establishment. Eradication of this species from areas in which it has become well established has proved difficult or impossible. Honey bees may alter pollination ecology of some native species. The potential effects are not yet known (Buchmann and Shipman 1996).

Management Concerns and Considerations for Riparian Species and Systems

So much of the historic riparian habitat in Pima County has been so altered by the variety of impacts that have occurred over the past century and by continued impacts to it by human uses that little remains in any condition resembling its proper functioning conditions. New riparian habitat has developed in the Santa Cruz River that depends upon effluent from wastewater treatment facilities. The single most crucial factor in the development and maintenance of riparian habitats is available water. Manipulation of available water may enable the establishment and development of desired riparian habitats and species, and may also be a valuable tool in controlling problematic species. Many of the same considerations that applied to aquatic ecosystems apply to the associated riparian ecosystems as well. Specific factors that may affect management of problematic species in riparian ecosystems are:

1. Much of the land is privately owned, and cooperation of landowners must be enlisted.

2. Management of invasive plants may require labor-intensive practices of cutting and treating with toxic chemicals (herbicides). Chemical use may be controversial, and may be potentially harmful to applicators and components of the environment if not handled properly.

3. Grazing management may be controversial and challenging, but it may have multiple benefits. A review of grazing systems and the effects of management schemes found that riparian habitats could be greatly improved and positive results may accrue to cooperative ranchers who better manage cattle in riparian areas (Ohmart 1996). These include savings in reduced feed costs, availability of permanent water supplies, better utilization of upland forage, and generally better health and productivity of livestock. Ohmart concluded that "abolition of livestock grazing on public rangelands and fencing are ruled out because of social acceptance and cost. The most viable method at present is herding with stubble height constraints. Strong incentives to both the land manager and permittee to restore proper functioning condition of western streams are key to restoring riparian habitat for optimum social, fish, and wildlife resource values" (Ohmart 1996 p. 274). Ohmart (1996) pointed out a very specific situation in which livestock grazing may benefit riparian resources. Cattle could be used economically to reduce the fuel load of tall grasses and annuals growing adjacent to and within cottonwood-willow habitats, effectively reducing or preventing fires that are highly detrimental to these trees. Managed grazing might also be useful in improving groundcover along rivers where the natural flood regime has been stopped by dams (Ohmart 1996).

4. Management of bullfrogs is probably best done by manipulation of water as suggested by Rosen (2000) and Rosen and Schwalbe (in prep.).

5. Management of cowbirds, if it is considered necessary, may best be done by trapping and/or shooting, both of which are unpopular with some people and neither of which has been clearly shown to be effective under conditions similar to those in Pima County.

6. Establishment of riparian vegetation will require application of water and maintenance of adequate water over a period of time. The most likely current source of water is effluent, but that has become an increasingly valuable commodity.

B. Terrestrial Ecosystems

1. Carbonate Terrains

Carbonate terrains are defined as those lands for which the geological parent material consists of calcium carbonate in its various forms and derivatives. Specifically, but not exclusively, included are limestone outcrops, which may include caves and subterranean aquatic ecosystems that are very poorly understood, and limestone-derived soils. Priority Vulnerable Species known from carbonate terrains include Mexican long-tongued bat (*Choeronycteris mexicana*), Allen's big-eared bat (*Idionycteris phyllotis*), lesser long-nosed bat (*Leptonycteris curasoae*), California leaf-nosed bat (*Macrotis californicus*), pale Townsend's big-eared bat (*Plecotus townsendii*), Arkenstone Cave pseudoscorpion (*Albiorix anopthalmus*), several species of talus snails (*Sonorella* spp.), Nichol's Turk's head cactus (*Echinocactus horizonthalonius* var. *nicholii*), and needle-spined pineapple cactus (*Echinomastus erectocentrus erectocentrus*). Additionally, many species of plants are known to be limestone endemics (but not specifically considered in this document), and some species may grow better on limestone-derived soils than elsewhere. For example, *Agave palmeri* apparently grows well on limestone soils (Gentry 1982). This plant is an important food source for the lesser long-nosed bat and Mexican long-tongued bat and is well represented by the population at Colossal Cave Park, where the bats are known to be present. Several previously unknown species of animals from caves in Pima County have been recently discovered and are in the process of being described (R. Pape and W. Peachey, pers. comms. to K. Kingsley). Not all of the Priority Vulnerable Species mentioned are exclusively dependent on carbonate terrains (with the exception of the Arkenstone Cave pseudoscorpion and Nichol's Turk's head cactus). However, the bats are dependent on caves and mines for roosts, the snails may need calcium carbonate for shell production, and the plants may benefit from the chemical composition of carbonate soils. Carbonate terrains are rare in Pima County. They are generally well mapped but not well explored or understood biologically and hydrologically.

The potentially problematic species that may affect carbonate terrain habitats and the species of conservation concern that may be present in them are people, introduced fire ants, and honey bees. People may affect these delicate ecosystems by limestone mining, groundwater depletion, water pollution, development, and recreational caving (Culver et al. 2000), and mine exploring, plant collecting (especially commercial collecting of rare plants), and collecting and observing snails. Fire ants are considered a potential problem for species of cave-dwelling animals in Texas, both as predators on and competitors with native cave-dwelling species (Elliott 1992a & 1992b; U.S. Fish and Wildlife Service 1998). Although they have not yet become established in Arizona, it is likely that they will eventually become established here, especially in riparian areas (K. Kingsley, personal opinion). They consume caterpillars and other insects that may be food for bats, and may have other ecosystem effects that are currently unknown. Honey bees that develop nests in caves and rock crevices may keep out or drive away bats and make it difficult to investigate and monitor caves. They may also affect pollination ecology of plants, and may compete with native bee species (Buchmann and Shipman 1996; Sugden et al. 1996).

Management Concerns and Considerations for Carbonate Terrains

The most important and necessary management concern is that carbonate terrains, as ecosystems, are very poorly understood, and the effects of potentially problematic species and activities on them are not known. Restrictions on human activities in delicate carbonate terrains are the most obvious option to limit damage by humans. These restrictions may include careful site selection for limestone mining, so as to mine in the least disruptive way those sites that do not include specific habitat features used by species of concern. It is possible that transplanting organisms and restoration of disrupted areas may also benefit (or protect) the species. Groundwater mining in carbonate terrains may require restrictions to protect delicate surface and subsurface aquatic ecosystems that are not well known. Land development on carbonate terrains may require protective planning or complete restriction. Access to caves and mines may require careful control, possibly in the form of gates and/or restricted seasonal access, so as to minimize disturbance of bats and other wildlife species. Continued and strengthened enforcement of Arizona's Native Plant Protection Law may be necessary to protect rare plants and their habitats. Access to talus snail habitat may require restriction. It is clear from examination of the range of the San Xavier talus snail that there has been some habitat damage by snail collectors (scientists) and observers. The Center for Biological Diversity testified that "members and staff also enjoy the biological, recreational and aesthetic values of the areas inhabited by this species . . . [and] have visited the habitat of the San Xavier talus snail for the purpose of supplementing other research efforts, including the gathering of and study of scientific information regarding that species, and plan to return to that habitat and continue similar research" (Kenna and Hickox 1998). If such activities are continued in talus snail habitats, it is possible that damage resulting in harm to the species may occur.

Continuing vigilance for fire ant establishment may protect against damage. Caretakers of potentially sensitive sites (e.g., Arkenstone Cave, Colossal Cave) should be trained in recognition of introduced fire ants and be prepared to apply control measures if the species is discovered. Increased effort of the State Department of Agriculture and the USDA Animal and Plant Health Inspection Service (APHIS), including border inspections and quarantine practices, may be warranted but is not planned. Indeed, funding for such programs has been declining at the Federal level, and APHIS is reconsidering their programs. The Arizona Department of Agriculture is committing resources to maintain the state free of fire ants, but without Federal help success may be much more difficult (Goar 2000).

2. Grasslands

This includes the following classifications (Brown 1994): Semidesert Grassland 143.1, Plains Grassland 142.1, and Sonoran Savanna Grassland 144.3.

Priority Vulnerable Species in grasslands include lesser-long-nosed bat and Mexican long-tongued bat (distribution uncertain, probably limited to semidesert mixed grass-yucca-agave association because of agave dependence); rufous-winged sparrow (*Aimophila carpalis*), burrowing owl (*Athene cunicularia*), Swainson's hawk (*Buteo swainsoni*), Tucson shovel-nosed snake (*Chionactis occipitalis klauberi*), organ pipe shovel-nosed snake (*Chionactis palurostris organica*), ground snake (*Sonora semiannulata*), desert box turtle (*Terrapene ornata luteola*), talus snails (some may occur in specific microhabitats within areas mapped as "grasslands"), Pima pineapple cactus (*Coryphantha scheeri robustispina*), Acuña cactus (*Echinomastus erectocentrus acuñensis*), needle-spined pineapple cactus, and Tumamoc globeberry (*Tumamoca macdougalii*).

Potentially problematic species that may occur in grasslands and may affect the native species of concern include domestic and feral ungulates (cattle, horses, burros), buffelgrass (*Pennisetum ciliare*), Lehmann lovegrass (*Eragrostis lehmanniana*), red brome (*Bromus rubens*), cheat grass (*Bromus tectorum*), African daisy (*Dimorphotheca sinuata*), filaree (*Erodium cicutarium*), sweet resin bush (*Euryops multifidus*), and honey bees. Issues of exotic species in grasslands have been reviewed by Bock and Bock (in prep.).

Bock and Bock (in prep.) made the allegation that domestic livestock are the keystone species in grasslands. They suggest that cattle and their keepers have acted as selecting agents on the flora and fauna of grasslands, and that some native species likely have vanished without record, whereas others have flourished. The precise effects of grazing by ungulates are complex and dependent upon management, climate, weather, seasons of use, densities, and many other factors. Direct effects on wildlife species, especially Priority Vulnerable Species, are difficult to measure, and specific impacts are alleged, but not consistently supported by data. The majority of studies reviewed suggest that cattle can have a negative impact on North American xeric ecosystems, but that effects are variable (Jones 2000). Ungulates may alter vegetation composition and abundance and may trample soils, which may lead to erosion. The long-term effects of current management practices are not yet known and have not been specifically studied in relation to any of the Priority Vulnerable Species. The grasslands in Pima County are recovering from historical impacts of domestic ungulate grazing, as well as drought, and management science is improving. Ungulates may directly consume food plants of some native species, rendering them unavailable or reduced in value. Ungulates may also trample vegetation and animal burrows. Also, livestock grazing is implicated as one of several factors causing and enhancing the invasion of alien weeds into grassland, scrubland, and woodland communities (Belsky and Gelbard 2000). Livestock may consume agave stalks, thereby impacting food resources of the lesser long-nosed bat and Mexican long-tongued bat. Whether this is a problem or not has not been established by data. Livestock may cause changes in the abundance and availability of prey populations of birds of prey (Knopf 1996). These changes may be either increases or decreases of prey species, and the effects vary with prey species, locality, and grazing intensity. Livestock impacts on the reptile and cactus species are unknown. It may be reasonable to surmise that severe overgrazing of the range would be detrimental to some or all of the species, but the threshold at which damage is done is unknown. It is also possible that some level of grazing may benefit some of the species.

Exotic grasses and forbs may compete with desirable native species, alter vegetation composition and density, and result in high-temperature, fast-burning wildfires that may have devastating effects on plants and animals (Esque and Schwalbe in prep.). However, there may be beneficial effects of at least some of these non-native grasses, and management should be approached with caution, in a very specific manner (Winn 1995).

Nonindigenous grass species have permeated over 40 million hectares (100 million acres) of the grasslands, shrublands, and woodlands of the American West (Belsky and Gelbard 2000). The species of grasses that may be considered most problematic in Pima County are discussed in greater detail in another section of this document.

African Daisy and sweet resin bush may compete with desirable native species. Sweet resin bush prevents germination of native species and becomes a pure stand (Pierson and McAuliffe 1995, McAuliffe 2000).

Honey bees may alter pollination ecology of native plants and out compete native bees (Buchmann and Shipman 1996; Sugden et al. 1996; Bock and Bock, in prep.). The extent to which this is a problem is not known, and how it affects Priority Vulnerable Species is unknown.

Management Concerns and Considerations of Grassland Ecosystems

Modern trends in management of domestic ungulates and grasslands may be resulting in long-term improvement and restoration of grasslands, although the presence of non-native grasses has apparently become an established and uncontrollable factor, at least on the large scale. This has significantly altered the ecosystems in unmeasured ways. The impacts on Priority Vulnerable Species that live in grasslands are largely unknown and probably unknowable. Of particular concern is the change in fire regimes in grasslands and scrublands caused by the presence of non-native plants. Most native shrubs and trees in desert grasslands are resistant to fire, and fire may be considered beneficial to the grassland ecosystem under appropriate conditions. Fire may be used as a tool for the selective removal of some exotic species and restoration of native species that are resistant to fire (Bock and Bock in prep.). However, fires may be increased in intensity and frequency as a result of dense growth of non-native plants (Esque and Schwalbe in prep.), especially when combined with increased human use of the grasslands of Pima County, and some non-native plants may thrive following fire.

Bock and Bock (in prep.) reviewed some means to discourage exotic species in grasslands. These include:

1. reseeding with native seed
2. fire
3. herbicide application
4. biological control
5. using factors of the physical environment
6. doing nothing

Each approach has it values and liabilities, and none has been clearly shown to be effective for removing all non-native species or restoration of pristine conditions. Doing nothing, specifically meaning removal of livestock and no manipulation of the vegetation or land, appears to be the least expensive and possibly the most effective method of restoring conditions more closely resembling the pristine condition. Another technique, not discussed by Bock and Bock (in prep.) is hand grubbing of individual plants. This has been tried with some success for control of sweet resin bush, but is very labor intensive (Dan Robinette, pers. comm. to K. Kingsley). It is also used with some success for buffelgrass control at Organ Pipe Cactus National Monument, where removal over a period of at least two years was found to be necessary (Rutman and Dickson in prep.).

Several agencies are cooperating on weed management programs, including an interagency management plan for sweet resin bush and karoo bush. Included in their work is an important public information component, calling for public awareness and input. Significant areas of grassland in Pima County are under mixed management regimes and/or ownership, including State, Bureau of Land Management, private, and Forest Service. This may complicate management for control of potentially problematic species, because the different agencies and individuals have different priorities and capabilities. Interagency coordinated management is essential for success on the larger scale, but specific targeted management options may be applicable to preserves.

Honey bees may be impossible to control, on the large scale, but may be manageable within preserves.

3. Desertscrub

This includes Sonoran Desertscrub 154.11 and 154.12 and Chihuahuan Desertscrub 153.2.

Desertscrub ecosystems are the most extensive in Pima County and the least impacted by human uses and non-native species. However, there are several well-established non-native plants, such as filaree, brome grasses (*Bromus* spp.), and Mediterranean grasses (*Schismus* spp.), that have had major impacts (Esque and Schwalbe in prep.). Felger et al. (in prep.) estimate that up to 233 species of non-native plants, or nine percent of the Sonoran Desert flora, have been found in the Sonoran Desert region (most of which is desertscrub). Although no extinctions or local extirpations of native species are known to be due to non-native plants in the Sonoran Desert, Felger et al. (in prep.) state that "the patterns of population growth that we see and the information from other regions of earth indicate that extirpations are inevitable and imminent."

Priority vulnerable species in desertscrub areas include lesser-long-nosed bat, California leaf-nosed bat, rufous-winged sparrow, burrowing owl, Tucson shovel-nosed snake, organ pipe shovel-nosed snake, ground snake, giant spotted whiptail (*Cnemidophorus burti stictogrammus*), talus snails, Pima pineapple cactus, Acuña cactus, needle-spined pineapple cactus, and Tumamoc globeberry.

Potentially problematic species that may affect them are cattle, horses, burros, buffelgrass, Lehmann lovegrass, red brome, cheat grass, Mediterranean grasses, African daisy, filaree, sweet resin bush, Sahara mustard (*Brassica tournefortii*), and many other plants, and honey bees.

Ungulates may alter vegetation composition and abundance and may trample soils. The previously cited reviews on cattle grazing effects apply to desertscrub ecosystems also (Belsky and Gelbard 2000, Jones 2000). Other feral animals may also be problematic, especially in desertscrub ecosystems. Douglas and Leslie (1996) reviewed the effects of feral animals on western rangelands. They concentrated primarily on burros. Although feral burros are much less common than domestic cattle, they have been responsible for extensive damage to western rangelands by overgrazing, selective removal of preferred forage plants, trampling of plants, soil disturbance leading to erosion, impact on small vertebrates, and competitive interactions with desert bighorn sheep. Feral burros are not known to be problematic in Pima County, at present, except possibly in part of western Pima County and close to the county's eastern border in the San Pedro River valley (K. Kingsley, personal observations).

Many species of non-native plants have become established in desertscrub. A list of naturalized exotic species in the Sonoran Desert region will be published as an appendix to Tellman's forthcoming book (Tellman in prep.). Felger et al. (in prep.) review the history, general biology, and present details on several species that have become established. More than 200 species of non-native plants are recorded as growing wild in the Sonoran Desert. Even in protected, relatively pristine, desertscrub areas, non-native plants have become established. On Tumamoc Hill, in 1991, 53 non-native species were documented, representing 15.5 percent of the total known flora on the site. Most of the non-native plants were restricted to disturbed areas, but red brome, filaree, foxtail barley (*Hordeum murinum* ssp. *glaucum*), London rocket (*Sisymbrium irio*), and Mediterranean grasses had invaded undisturbed ground. More recently, buffelgrass has invaded and become established. Non-native species compete with desirable native species, alter vegetation composition and density, and result in fires that have devastating effect on plants and animals.

Fires are of particular concern in desertscrub, which is not well adapted to fire (Esque and Schwalbe, in prep.). The frequency, intensity, and damage done by fires are greatly enhanced by brome grasses and Mediterranean grasses. These species have expanded into relatively pristine areas such as Catalina State Park, Organ Pipe Cactus National Monument, and Saguaro National Park, and have become extremely abundant. Direct effects of fires include mortality to plants and animals. Indirect effects result from alterations of the biophysical environment, including changes in nutrient availability, loss of cover, and conversion of the plant community to less suitable conditions. Some animals use non-native plants as food, although they may not be preferred over native plants. The effects of these plants on any of the Priority Vulnerable Species has not been established or documented. However, the effects of fire, especially large area fire, might reasonably be expected to be detrimental to many, if not all, of the plants and animals resident on the burned area. Competition with non-native grasses, such as buffelgrass, Lehmann lovegrass, and red brome, may be a problem for Pima pineapple cactus. The introduction and spread of Lehmann lovegrass has affected up to 75% of Pima pineapple cactus habitat (USFWS 1993) and altered historical fire regimes (Roller 1996a, 1996b). Individual Pima pineapple cactus plants appear to exhibit less vigor in community types characterized by higher fire frequencies and continuous stands of Lehmann lovegrass (Roller 1996a and 1996b). Nurse plants may be destroyed, and stem succulents such as cactus species are highly susceptible to fire (Esque and Schwalbe in prep.). Saguaros are especially susceptible to destruction by fire, and this may lead to local food plant loss for lesser long-nosed bats. If fires occur during nesting season, birds may lose their nests. Esque and Schwalbe (in prep.) predict that losses of saguaros may cause reductions in cavity nesting birds, such as cactus ferruginous pygmy-owls. They also question the potential effects of dense non-native grasses on the giant spotted whiptail, a question that has as yet had no reported research effort (Esque and Schwalbe in prep.).

Other non-native plants of current concern in desertscrub include African daisy (*Dimorphotheca sinuata*) and sweet resin bush (*Euryops multifidus*). They may compete with desirable native species. Sweet resin bush prevents germination of native species and becomes a pure stand (McAuliffe 2000, Pierson and McAuliffe 1995) and may impact Pima pineapple cactus (M. Falk, USFWS, pers. comm. to K. Kingsley).

Honey bees may alter pollination ecology of native plants (Buchmann and Shipman 1996; Sugden et al. 1996). The Sonoran Desert is thought to be the richest biogeographic region for bees, with perhaps 1500 species, many of which may be adversely impacted by the more aggressive generalist introduced bees (Buchmann 1995).

Management Concerns and Considerations for Desertscrub

Many of the management concerns and considerations for desertscrub are essentially the same as for grasslands. There are no currently known reliable methods for controlling non-native grasses. Also despite intuitively obvious alleged effects, actual adverse effects have not been well documented, and many questions remain unanswered as to the effects of non-native species in desertscrub. Even if we were able to remove the invasive non-native plants, our current understanding is not sufficient to direct effective restoration of healthy desertscrub communities (Esque and Schwalbe in prep.).

Most of the desertscrub land in Pima County is on the Tohono O'odham Nation, in Saguaro National Park, Organ Pipe Cactus National Monument, the Barry M. Goldwater Range, or is State land. Conflicting management directives and policies of these various agencies may make effective cooperation difficult if an effort to manage land for the reduction of non-native species were to be mounted.

New species are becoming established in the Sonoran Desert and spreading at a rapid rate (Felger et al. in prep., Esque and Schwalbe in prep.). The potential effects of these are unknown and may be synergistic with the poorly understood effects of those non-native species that are already established.

Wild burro management on Federal lands is complicated by a Federal law protecting them (Douglas and Leslie 1996).

4. Sky Islands

The "Sky Islands" is a term referring to insular mountains of the North American borderlands. Most of these are within lands administered by the U.S. Forest Service and National Park Service. Identification of lands that are available for inclusion in the SDCP and that are in the Sky Islands needs refinement. Biotic communities within Sky Islands are Madrean Evergreen Woodland 123.3, Petran Montane Conifer Forest 122.3, and Interior Chaparral 133.3.

An excellent compilation of papers on the Sky Islands exists (Debano et al. 1995). It includes several papers specifically dealing with non-native species concerns. Several Priority Vulnerable Species are known from the Sky Islands, including: lesser long-nosed bat, Mexican long-tongued bat, Allen's big-eared bat, pale Townsend's big-eared bat, Arizona shrew, several species of talus snails, and Gentry indigo bush.

Potentially problematic species within the Sky Islands are cattle, horses, burros, buffelgrass, fountain grass, Lehmann lovegrass, red brome, cheat grass, African daisy, filaree, sweet resin bush, and honey bees. None of these are unique to the Sky Islands, and their effects are essentially the same as in the other communities in which they were discussed. Gentry indigo bush is directly consumed and threatened by cattle. (Gentry indigo bush is a Priority Vulnerable Species in Pima County, although it is not currently known from the county.) Greater periwinkle (*Vinca major*) has recently become established along drainages in the Sky Islands. It is known to be present in the Huachuca Mountains at Ramsey Canyon, where The Nature Conservancy has apparently successfully eradicated it from the preserve (Tellman in prep.). However, populations of it are present in other canyons in the Huachucas and in the east fork of Sabino Canyon in the Santa Catalina Mountains (K. Kingsley, personal observations).

Many springs are present in the Sky Islands and have been diverted or "improved" for human uses. This directly affects the spring ecosystems and the downstream ecosystems.

Management Concerns and Considerations for Sky Islands

Because most of the land in Sky Islands land in Pima County is managed by two Federal agencies, management issues may be simplified. A survey of distribution of exotic plants was compiled for some areas of the Coronado National Forest (Baker 1999), and the Forest Service is in the process of developing a management program for exotic plant species (Coronado National Forest 2000). The National Park Service lands are managed with concern for non-native species (Connolly 2000).

IV. Species Accounts

Bullfrog (*Rana catesbeiana*)

Taxonomy

Family Ranidae, Genus *Rana,* species *catesbeiana*. No other scientific names are known.

Habitat

This species is amphibious. It requires water for its larval (tadpole) stage, and must have water that lasts for at least several months, but prefers permanent water. Bullfrogs have an April to August breeding season and a long tadpole stage that requires water through the spring drought season and into the fall (Rosen and Schwalbe in prep.). Survival of adult and larval bullfrogs was reduced in ponds where vegetation cover and debris were lacking (calbullfrog.txt). Adults are riparian and aquatic but are capable of long overland movements (Rosen 2000), especially on rainy nights (Stebbins 1985). Bullfrogs may be found in canals, springs, streams, rivers, cienegas, lakes, sewage, golf course and other ornamental ponds, and stock tanks (Howland 1992). Their known distribution In Pima County includes all of the sites indicated in Table 1 and also they are present at Sweetwater Wetlands and the County and City of Tucson sewage treatment facilities, and the Santa Cruz River downstream from the Roger Road treatment facility.

Effects on vulnerable species

Bullfrogs have been observed to prey on many native wildlife species, including Mexican garter snakes, Chiricahua leopard frogs, lowland leopard frogs, and even bats (Rosen and Schwalbe 1995; Rosen 2000; Rosen and Schwalbe in prep., Miera 1999). Bullfrogs have been implicated in the regional decline of native amphibians and the Mexican garter snake, although evidence for them as the sole causal mechanism is lacking or inconclusive (Hayes and Jennings 1986). It is likely that they are only one component of a synergy of factors that is affecting these species, including hydrologic changes, habitat changes, disease, and non-native species of fish (Rosen and Schwalbe in prep.). However, recovery of native frog species in the presence of bullfrogs is considered unlikely (Rosen 2000).

Rate of invasion, spread, or date of introduction

The bullfrog was introduced into western states in the late 1800s and early 1900s for food and sport hunting (Howland 1992). The current range includes nearly every state west of the Rockies (Stebbins 1985), including the western states of Texas, New Mexico, Colorado, Utah, and Arizona and Sonora and Chihuahua, Mexico (BISON-M 2000). The bullfrog has also been introduced into the Hawaiian Islands, Mexico, Cuba, Jamaica, Japan, and Italy (Stebbins 1985). Evidence suggests that this species was introduced into New Mexico west of the Continental Divide and was native east of it (BISON-M 2000). It is highly effective at colonizing new suitable habitat, as demonstrated by its current presence at Sweetwater Wetlands, which has been in operation less than four years (K. Kingsley, personal observation).

Population trend

Accurate information is not available, however the trend is clearly upward, as this species has been observed colonizing newly created habitat and invading areas of existing habitat, such as Cienega Creek, from which it was not previously known.

Factors affecting spread and distribution

This species requires long-standing or (preferably) permanent water. As human beings create new water sources such as ponds and artificial wetlands, bullfrogs move into them. In some instances, bullfrogs are deliberately planted as released pets. Improvement of wetland habitat, such as has occurred at Cienega Creek, apparently also benefits this species.

Legal status

A fishing license is required for the legal take of bullfrogs in Arizona. The bag and possession limit is unlimited dead. Live bullfrogs may not be kept (Arizona Game and Fish Commission Order 41).

Management methods, efficacy, and sensitivity

Rosen (2000) proposes what appears to be a potentially effective approach to bullfrog control. This approach combines several techniques. The basis of effective bullfrog control is most likely to be water regulation, preventing suitable bullfrog habitat from occurring by preventing water from standing during the pre-monsoon seasons and allowing periodic natural flooding. In some situations, this may be suitable for native leopard frogs, but would be detrimental to fish, whereas in other situations, it would be beneficial to native fish and detrimental to non-natives. Rosen and Schwalbe (in prep.) offer several suggestions for management:

(1) Importation and transplantation of non-native aquatic species should be outlawed except as specially permitted,

(2) Agencies should not import and release new aquatic species, and should not translocate non-native species to natural environments with native species.

(3) Regulations for the pet trade should be revised to avoid importation of species deemed likely to become naturalized.

(4) Habitats and habitat types most suitable for native species, and unsuitable for exotics, should be identified and defined, based on multiple, species-specific considerations, and in appropriate sites:

(a) monitoring of the biota should be formalized,
(b) non-native species should be removed promptly when they appear,
(c) presumably harmful habitat modifications should be avoided or removed, and
(d) artificial modifications to make such habitat less suitable for exotic species might

appropriately be contemplated.

(5) Decisive, proactive management action should be facilitated for aquatic species in steep decline, especially when more than one cause of decline is apparent.

(6) Novel solutions for the removal or control of non-native animals should be sought.

(7) The following aquatic reptiles and amphibians are currently most deserving of further field survey and research to investigate the impacts of exotic species in the Sonoran Desert region: narrow-headed garter snake and Sonoran mud turtle.

Collaboration with ranchers in management of stock ponds is encouraged and appears to offer promise (Rosen 2000). Direct hunting pressure, even with a concentrated effort over several years by dedicated bullfrog exterminators has not been demonstrated as a successful approach (Rosen and Schwalbe 1996).

Research ongoing and planned

Buenos Aires National Wildlife Refuge, Arizona Game and Fish Department, and area ranchers are involved in an experimental program of management of stock ponds (Rosen 2000 and C. Schwalbe, pers. comm. to K. Kingsley).

Potential future status in the planning area

In some respects, Pima County is now at a crossroads for actions that may determine the future status. If current trends continue unabated, it is likely that bullfrogs will persist and increase. However, if the suggestions proposed by Rosen (2000) and Rosen and Schwalbe (in prep.) are followed, then it is possible that bullfrogs may be controlled effectively in at least some of the aquatic habitats of Pima County.

Green Sunfish (*Lepomis cyanellus*)

Taxonomy

Family Centrarchidae, Genus *Lepomis,* species *cyanellus.* Other names that have been used are *Chaenobryttus cyanellus, Pomotis longulus, Bryttus longulus, Calliurus murinus, Calliurus longulus,* and *Apomotis cyanellus.*

Habitat

This species is, of course, aquatic, but is capable of surviving in a wide variety of aquatic habitats. It is most abundant in rocky waters (Minckley 1973). It has been recorded in the following locations that are within the Santa Cruz River basin (U.S. Fish and Wildlife Service 1999): Bog Hole, Fresno Canyon, Romero Canyon, Santa Cruz River at gage, Sharp Springs, Sonoita Creek below Patagonia Lake, Sonoita Creek @ TNC, Arivaca, Bear Grass, Fagan, Kennedy, Parker Canyon, Patagonia Lake, Peña Blanca, Silverbell, and Lakeside.

It is present in Sabino Creek, downstream from the dam, where is may be present in very small pools during seasons when most of the creek is dry. It is known from Rose Canyon Lake, a high-elevation lake created as a trout fishery. It is present in the warm waters of Agua Caliente Park. It is present in the water of the Central Arizona Project (CAP) Canal (U.S. Fish and Wildlife Service 1999) and in CAP water at the Central Avra Valley Storage and Recovery Project, and survives in the recharge basins and sumps (K. Kingsley, personal observations). Table 1 lists the known locations of this species in Pima County.

Effects on vulnerable species

Predation by green sunfish and other non-native fish is likely responsible, to some degree, for the decline of native ranid frogs, including the Chiricahua leopard frog (Rosen et al. 1995). It is a significant predator on the Gila chub in Sabino Creek (Dudley and Matter 2000), and may be responsible in large part for the loss of that and other native fish species from much of their former range. It may also compete with native fish species for food and prey on them (Minckley 1973). Non-native aquatic species are considered a primary obstacle to reestablishment of native species (Rosen 2000).

Rate of invasion, spread, or date of introduction

The green sunfish was introduced to Arizona as a sport fish. It was first collected by scientists in Arizona in 1926 (Minckley 1973). It has spread rapidly in waters that lack other fish in the family Centrarchidae. It was introduced to Sabino Canyon following completion of Sabino Dam in 1938 and was found upstream from the bridges since about 1982 (Dudley and Matter 2000). Stocking continued in Sabino Creek until about 1970 (O'Connell 1999a).

Population trend

No specific information is available on general population trend. This species has grown from not present in Arizona 75 years ago to present in almost every suitable body of water (except Cienega Creek) today. Populations may rise and fall with seasonal droughts, especially in canyon streams. Limited evidence suggests that this species may move upstream to colonize new areas during flood episodes (Dudley and Matter 1999). Efforts have recently been undertaken to exterminate this species in some of the waters to which it has been introduced (e.g., Sabino Canyon), and these have apparently been at least partially successful.

Factors affecting spread and distribution

This species was widely distributed in Arizona as a sport fish. It has been extremely successful in becoming established in waters that lack related fish species (Minckley 1973). Unlike many non-native fish species, the green sunfish is apparently not displaced downstream during floods, but is one of the few, if not the only, non-native species that is suspected of being capable of dispersing upstream during flood conditions (Dudley and Matter 1999).

Legal status

Green sunfish are considered game fish, and a valid State fishing license is required for taking them, except for residents or non-residents under the age of fourteen years and blind residents. There is no limit or closed season.

Management methods, efficacy, and sensitivity

Management methods that work for green sunfish are not specific, but will affect all other fish species and many other aquatic organisms as well. These include water manipulation, exclusion by means of fish barriers, electrofishing, and poisoning.

Water manipulation may be the most effective technique, if all suitable water is removed. Rosen (2000) recommends water manipulation and the elimination of artificially created habitat wherever appropriate. However, this may not be suitable for all situations. Green sunfish are capable of survival in remarkably small pools of water (K. Kingsley, personal observations) and may be capable of recolonizing areas that were thought to have been dried up, but in fact had a few small pools remaining. Draining is being considered as a method for renovating Rose Canyon Lake, in part to remove green sunfish. If the lake cannot be completely drained, use of rotenone is planned (Halligan 2000). This approach may be insufficient (Rosen 2000).

Green sunfish are known to be present in Central Arizona Project canal water. Fish barriers designed to exclude this and other non-native species from access to waters of Pima and Santa Cruz Counties are planned, as requirements of the biological opinions of the U.S. Fish and Wildlife Service. These barriers have not yet been built, and their efficacy has not yet been demonstrated.

Electrofishing was used to remove green sunfish in Sabino Creek in June, 1998, but many remained (O'Connell 1999a).

Poisoning of green sunfish was done in 1999 in Sabino Creek by a joint effort of Arizona Game and Fish Department and U.S. Forest Service. Native Gila chubs were removed by electrofishing and transplanted upstream of the poisoning site. The toxicants used were antimycin and rotenone, and they were applied repeatedly in two major efforts in June and October (O'Connell 1999a & 1999b). The effort was apparently successful (D. Duncan, USFWS pers. comm. to K. Kingsley). A three-mile reach of stream between bridge nine and the dam was treated, which was the entire area known to be inhabited by green sunfish above the dam. Green sunfish remained present in pools below the dam in April, 2000 (K. Kingsley, personal observation), but their survival through the spring drought is not known.

Research ongoing and planned

Follow-up surveys for green sunfish in Sabino Creek are necessary. Monitoring and evaluation of efficacy of fish barriers associated with the Central Arizona Project is also necessary. Monitoring is required as a part of the Reasonable and Prudent Alternative for the CAP (U.S. Fish and Wildlife Service 1999). Also, funding at the amount of $50,000 per year for 25 years, for research on and control of nonnative aquatic species within the Santa Cruz subbasin is required. This research may include, but is not limited to, the status, biology, ecology, habitats, and life history of native and non-native species, toxicology of various fish toxicants, and community ecology. It is not certain that these will be carried out in the long term.

Potential future status in the planning area

Unknown. The future status depends entirely on management efforts. It is possible that this species might be eliminated from the planning area, if sufficient effort is expended. More likely, it may be locally extirpated (or nearly so) from some waters but will continue to survive in others and may become reestablished in waters from which it was thought to be removed (K. Kingsley, personal opinion).

Western Mosquitofish (*Gambusia affinis*)

Taxonomy

Family Poeciliidae, Genus *Gambusia,* species *affinis.* Synonyms are *Heterandria affinis* and *Gambusia patruelis.*

Habitat

Aquatic, found in a wide range of aquatic habitats. Minckley (1973 p. 197) stated: "The fish is remarkable adaptable and succeeds in almost any conceivable habitat, ranging from clear, cool springs through turbid, hot, stock tanks." This species is native to the Mississippi River and Gulf Slope drainages west of the Mississippi. It has been introduced to every western state except North Dakota and South Dakota (Fuller et al. 1999). It is known to occur in the following waters within the Santa Cruz River basin (U.S. Fish and Wildlife Service 1999): Alambre Tank, Bog Hole, Santa Cruz River at gage and at Rio Rico, Fresno Canyon, Redrock Canyon, Sheehy Spring, Sharp Spring, Sonoita Creek below Fresno Canyon, Sonoita Creek below Patagonia Lake, Kennedy, Silverbell, and Lakeside. It is known from the CAP Canal, but apparently not from the Tucson reach. It is also present in several golf course ponds in Green Valley and the Tucson area (K. Kingsley, personal observations). Table 1 summarizes the known distribution in Pima County, but does not include many small bodies of water in which this fish was stocked for mosquito control. It is not currently known to occur in Cienega Creek, which is the last bastion of native fish. It was known from Sabino Canyon but may have been displaced by the 1993 flood (Dudley and Matter 1999) and killed by fish poisoning in 1999.

Effects on vulnerable species

Mosquitofish negatively impact leopard frog and most native fishes (Rosen et al. 1995), including Sonoran topminnow (Meffe et al. 1983). Minckley (1999) noted that the establishment and spreading of mosquitofish coincides with the decline of Gila topminnow and believes that mosquitofish must be actively and aggressively managed to prevent extinction of Gila topminnow.

Rate of invasion, spread, or date of introduction

This species was first recorded in Arizona in 1926 (Minckley 1973), but the date of introduction is not recorded. The first reported introductions of mosquitofish in the U.S. were done in the early 1900s (Fuller et al. 1999). They were widely used to combat mosquitoes and were stocked in many bodies of water in Pima County by the County Health Department in the 1980s (K. Kingsley, personal observations) but are no longer used (R. Baird, County Vector Control Officer, pers. comm. to K. Kingsley). Because of their widespread distribution by human intention, no information is available on their unassisted rate of invasion.

Population trend

Reliable information is extremely limited. This species is no longer routinely used for mosquito control, which suggests that the population trend may be downward, compared to the time when it was constantly replenished in areas where populations had crashed. It may have been eradicated from Sabino Canyon in 1993 and/or 1999.

Factors affecting spread and distribution

The most important factor affecting spread and distribution is the intentional distribution of this species for mosquito control. In some instances, it is possible that stocked fish have escaped into natural waters from sites where they were introduce (Fuller et al. 1999). It is apparently negatively impacted, even eliminated, by flooding (Dudley and Matter 1999; Rosen 2000).

Legal status

A valid State fishing license is required for taking mosquitofish (and all aquatic wildlife), except for residents or non-residents under the age of fourteen years and blind residents. There is no limit or closed season. Mosquitofish are considered live bait fish and are legal and unlimited on all waters of the counties of La Paz, Maricopa, Mohave, Pinal, and Yuma. No waters of Pima County are open for their use as bait fish (Arizona Game and Fish Commission Order 40).

Management methods, efficacy, and sensitivity

Management methods for mosquitofish are essentially the same as for green sunfish, discussed above. This species may be more effectively controlled by flooding than green sunfish.

Research ongoing and planned

Monitoring is required as a part of the Reasonable and Prudent Alternative for the CAP (U.S. Fish and Wildlife Service 1999). Also, funding at the amount of $50,000 per year for 25 years, for research on and control of nonnative aquatic species within the Santa Cruz subbasin, is required. This research may include, but is not limited to, the status, biology, ecology, habitats, and life history of native and non-native species, toxicology of various fish toxicants, and community ecology.

Potential future status in the planning area

Unknown. The future status depends entirely on management efforts. It is possible that this species might be eliminated from the planning area, if sufficient effort is expended. More likely, it may be locally extirpated (or nearly so) from some waters, but will continue to survive in others, and may become reestablished in waters from which it was thought to be removed (K. Kingsley, personal opinion).

The value of this fish for mosquito control should be carefully considered, especially in the context of emerging mosquito-borne diseases (such as West Nile virus and dengue fever). Public and agency pressure is mounting for increasing mosquito control efforts, in part because of the seriousness of these diseases. Also, as public sentiment in favor of restoring or creating wetlands increases, mosquito control issues are likely to rise to the forefront. Although some evidence suggests that native fish species may be more beneficial than mosquitofish for mosquito control, the complications of legal status (including listing as Endangered Species) are such that native fish may not be available. Recent efforts on the part of the U.S. Fish and Wildlife Service to utilize native species in appropriate mosquito control situations are to be applauded and, hopefully, expanded. If native species can be used for mosquito control, then all arguments for the use of mosquitofish are moot.

Red Shiner (*Cyprinella lutrensis*)

Taxonomy

Family Cyprinidae, Genus *Cyprinella,* species *lutrensis.* Synonyms include *Leuciscus lutrensis, Moniana laetabilis, Hysilepis iris, Cliola iris, Notropis (Moniana) lutrensis, Notropis lutrensis,* and *Cyprinella lutrensis.*

Habitat

Aquatic. Native range is the Mississippi River basin from southern Wisconsin and eastern Indiana to South Dakota and Wyoming, south to Louisiana. Also Gulf of Mexico drainages west of the Mississippi River to the Rio Grande in Texas, New Mexico, and Colorado. In Arizona, it has been introduced to the Colorado River and its major tributaries, including the Gila River (Fuller et al. 1999, Minckley 1973). Minckley (1973) does not show this species as present in Pima County. AGFD records (cited in U.S. Fish and Wildlife Service 1999) indicate that this species is known from the following locations in the Santa Cruz River basin: Fresno Canyon, Sonoita Creek below Fresno Canyon, Sonoita Creek below Patagonia Lake, and Sonoita Creek @ TNC. None of these are in Pima County. In Pima County at present, the only known locations of this species are the CAP canal, including the Tucson reach, and from the Central Avra Valley Storage and Recovery Project (U.S. Fish and Wildlife Service 1999, K. Kingsley, personal observation). The red shiner thrives "under conditions of intermittency, high turbidities, high temperatures, and so on. . . . [they] increase dramatically in abundance when drought or other factors decrease stream flow and alter the species composition of competing fishes. . . . The introduction of this species into the relatively depauperate waters of Arizona, where extremes in physical and chemical features are the rule, resulted in exactly what might be expected. It has spread to most waters at lower elevations (below about 1,500 meters), excepting where excluded by physical barriers such as dams or waterfalls" (Minckley 1973 p. 137).

Effects on vulnerable species

Effects on vulnerable species have not been clearly demonstrated. However, red shiners are omnivorous, and known to consume and compete with other native fishes. Circumstantial evidence implicates this species in the reduction of the spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) (Minckley 1973). These are threatened species not currently considered as Priority Vulnerable Species in Pima County, but for which critical habitat in the San Pedro River in Pima County has been proposed. The red shiner is implicated in the introduction of the Asian tapeworm to the Virgin River and the subsequent infestation of the woundfin (an endangered species) (Fuller et al. 1999). This species is considered the second greatest threat to the welfare of indigenous southwestern fishes, after the mosquitofish (Dill and Cordone 1997 cited in Fuller 1999).

Rate of invasion, spread, or date of introduction

The date of introduction of this species is not available. It was first reported from Arizona in 1954 as a probable escapee into the Colorado River from the Arizona Fish Farms in Ehrenberg (Fuller et al. 1999). It was probably introduced as a bait fish in other Arizona waters. It is also available in the aquarium trade under the name "rainbow dace." Where it has been studied, this species has had explosive growth following initial introduction, followed by dispersal and aggressive colonization (Fuller et al. 1999). It has not yet become established in waters of Pima County, other than the CAP canal and recharge basins.

Population trend

This species has become one of the most widespread and abundant fishes in waters in which it has become established. It is newly arrived in Pima County and is currently kept in close confinement, but in a situation in which it could possibly become established.

Factors affecting spread and distribution

Use of this species as bait and its dispersal by bait buckets, combined with the interconnection of waters by canals and ditches and the absence of competing, related fishes all contribute to the explosive growth of this prolific fish.

Legal status

A valid State fishing license is required for taking this fish (and all aquatic wildlife), except for residents or non-residents under the age of fourteen years and blind residents. There is no limit or closed season. Red shiners are considered live bait fish and are legal and unlimited on all waters of the counties of La Paz, Maricopa, Mohave, Pinal, and Yuma. No waters of Pima County are open for their use as bait fish (Arizona Game and Fish Commission Order 40).

Management methods, efficacy, and sensitivity

The management methods discussed above also will apply to this species. This species has not yet become established in Pima County and is confined to CAP waters, where management may be appropriately directed. Fish barriers, as mandated by the U.S. Fish and Wildlife Service, may be successful in keeping this species out of Pima County waters but have not been demonstrated to be effective (and have not yet been built).

Research ongoing and planned

This species would appropriately be one of the species studied under the mandated programs for the CAP; however, no ongoing or planned research targeted at this species is currently known.

Potential future status in the planning area

If this species can be confined to the CAP water, then it has very limited potential future status. If CAP water is used for discharge into the Santa Cruz River, such as for created wetlands or aquifer recharge projects, then it is likely that this species will become established. That would effectively preclude use of the river and its tributaries from being suitable for the recovery of native fish (K. Kingsley, personal opinion).

Northern Crayfish (*Orconectes virilis*) and Red Swamp Crayfish (*Procambarus clarkii*)

Taxonomy

Two species of crayfish have been introduced in Arizona; both are in the family Cambaridae. The northern Genus *Orconectes,* species *virilis,* is the only species known from Pima County at this time. The red swamp crayfish Genus *Procambarus,* species *clarkii,* is known from the Salt River Project and Florence-Casa Grande Canals and may eventually turn up in Pima County, either in the San Pedro River (via the Gila River) or via the CAP (U.S. Fish and Wildlife Service 1999). This species account will deal with the northern crayfish, except to point out that land managers should be aware of the possible arrival of the red swamp crayfish and that, because it is a burrowing animal, problems resulting from its burrowing habits may exacerbate those caused by its omnivorous diet.

Habitat

Crayfish are aquatic animals, but they are capable of surviving in mud after all water has evidently dried up (Miera 1999). The northern crayfish is widespread in rivers and streams and along lake margins with rocky substrates. It is present in Sabino Creek, Rose Canyon Lake, Arivaca Cienega, Arivaca Lake, and the San Pedro River. The red swamp crayfish is much less widespread, and burrows in fine sediments of ponds and lakes (Kubly 1997).

Effects on vulnerable species

Northern crayfish have been implicated in the decline of many native aquatic species. Crayfish are known to alter and deplete aquatic vegetation and consume Huachuca water umbel. They are also predators on native species of invertebrates and may have direct and indirect effects on other native species of concern They have been documented preying upon baby Sonoran mud turtles (Fernandez and Rosen 1996), and are associated with (and blamed for) declines in native and non-native fish, as well as native frogs (Chiricahua leopard frog) and garter snakes (Fernandez and Rosen 1996, Kubly 1997, Mieta 1999, Rosen 2000). Effects may include direct predation, competition for food, and changes in water turbidity. On the other hand, crayfish are an important food for the endangered Yuma clapper rail (Todd 1986) (not a species in Pima County) and the river otter in those parts of Arizona in which these animals are present (K. Kingsley, personal observations).

Rate of invasion, spread, or date of introduction

Arizona has no native crayfish (Kubly 1997). The exact dates of introduction are not known, but some evidence suggests that crayfish were introduced repeatedly in Arizona, beginning in the 1950s and continuing to 1993 (Kubly 1997, Erickson 2000).

Population trend

Population trend is unknown, other than that crayfish are a relatively recent introduction that are now widespread and thriving. They become established and reproduce rapidly following introduction (Fernandez and Rosen 1996). Observations of crayfish in the San Pedro River during the early summer drought of 2000 showed that many crayfish of all ages died as the river dried, but that the remaining pools had large numbers of small crayfish (K. Kingsley, personal observation). The same conditions were present in lower Sabino Creek in April 2000. The ability of crayfish populations to survive drought and respond to changed conditions following rainfall has not been documented in Arizona but is probably very great. Crayfish are known to survive drought by burying themselves deep in mud (Miera 1999). The duration of drought is undoubtedly important in determining crayfish survival but has not been documented.

Factors affecting spread and distribution

Crayfish were introduced to many waters of Arizona by the Arizona Game and Fish Department and the U.S. Fish and Wildlife Service for aquatic weed control and forage for sport fish.

Legal status

Crayfish are considered aquatic wildlife, requiring a valid State fishing license for take. The Arizona Game and Fish Commission recently approved the Arizona Game and Fish Department to begin rule-making proceedings that will change the rules on crayfish. The proposed rules will modify the use of live crayfish as bait and prohibit importation, purchase, possession, and sale of live crayfish. They will liberalize methods of take for use as bait at the site of capture and for human consumption (Demlong, M., Arizona Game and Fish Department, e-mail alert June 20, 2000).

Management methods, efficacy, and sensitivity

Effective management methods have not been demonstrated. Where crayfish are an agricultural or horticultural pest, management is by trapping (which is partially effective if trapping is maintained), by poisoning in turf (but not in water), and by draining rice fields (UC Pest Management Guidelines at www.ipm.ucdavis.edu). Water manipulation, including draining and leaving the area dry for a year or more, is probably the only effective method. There are no EPA registered pesticides for crayfish control.

Research ongoing and planned

Jeannette Carpenter, U.S. Geological Survey and University of Arizona, is currently studying impacts of crayfish on native fish. Crayfish may be included in the research and monitoring mandated by the CAP biological opinion. Crayfish control is a hoped-for objective of the planned renovation of Rose Canyon Lake. This will probably involve some level of monitoring and applied research.

Potential future status in the planning area

Unknown. It is unlikely that effective control will be completely achieved in the areas in which crayfish have become established.

<u>Saltcedar (*Tamarix* sp.)</u>

Taxonomy

Taxonomy of *Tamarix* is a source of confusion for many people. The species name has been changed several times in the past two decades. The latest available treatment (DiTomaso 1997) states that *Tamarix* is one of four general of Tamaracaceae, which has about 90 species worldwide. Eight species of *Tamarix* have been introduced into the United States, and five are present in the Southwest. *T. ramosissima* and *T. parviflora* are common, weedy species; *T. aphylla, T. chinensis,* and *T. gallica* are uncommon. *T. parviflora* has overlapping, linear leaves and 4-parted flowers. *T. ramosissima* has overlapping, ovate leaves and 5-parted flowers. *T. parviflora* was previously known as *T. tetrandra,* and *T. ramosissima* was formerly known as *T. pentandra.*

Some botanists do not accept this nomenclature. For example, Baker (2000) refers to the species that is most abundant in Pima County as "*T. chinensis,*" whereas Felger et al. (in prep.) call it "*Tamarix ramosissima*" including a host of synonyms or scarcely distinguishable taxa. In one publication (Kunzman et al. 1989) the species is called both *T. ramosissima* and *T. chinensis.* Finally, Stromberg and Chew (in prep.) say "*Tamarix chinensis, pentandra* and/or *ramosissima,* depending on the authority."

Habitat

Saltcedar grows to about 1,650 m (5,400 ft) in elevation, often in saline soils, and usually in close association with water, either surface water or ground water close to the surface. It is most abundant along streams, particularly streams that have been altered from their natural hydrologic regime (Stromberg and Chew in prep.), especially those that have been dammed. In undammed streams with more-or-less natural flow regimes, saltcedar may become just one more component of the riparian woodland community (Stromberg and Chew in prep.).

In Pima County, saltcedar is most abundant and dense along the effluent-dominated reach of the Santa Cruz River (Baker 2000, K. Kingsley, personal observations). The saltcedar association is distributed over a wider area of the Santa Cruz River floodplain than the Goodding willow association, and extends from the water's edge to areas removed from the flow. It is also present in many of the small side drainages of the Santa Cruz, and occurs in scattered locations upstream from the effluent-dominated reach. Baker (2000) found that a saltcedar-dominated vegetation community comprised 333.5 acres, or 9.5 percent of the total cover of hydromesic vegetation (vegetation dependent on above regionally normal soil moisture) and 15.7 percent of the total tree cover of riparian woodland in the 28 miles of the Santa Cruz River he studied. Saltcedar was also present as a component of other vegetation associations, including a Goodding willow/saltcedar association. Baker (2000) found that saltcedar woodlands tended to occur more where there was available runoff from agricultural fields, where substrates were more stable in comparison to the channel edges, where Goodding willow was dominant.

Saltcedar is also present, and in places abundant, along the San Pedro River in Pima County and along many (perhaps all) drainages in the county where groundwater is within reach of roots. It is known to be present in the Cabeza Prieta National Wildlife Refuge (NWR), Organ Pipe Cactus National Monument, Buenos Aires NWR, Saguaro National Park, Colossal Cave Mountain Park, Cienega Creek Natural Preserve, Bingham-Cienega Natural Preserve, and Coronado National Forest (although it is not on the lists included in Connolly 2000). It is not listed from Catalina State Park (Connolly 2000), but this is probably an oversight. It is hoped that the riparian mapping being done as part of the SDCP will provide additional information on the distribution and relative density of saltcedar.

Effects on vulnerable species

Although saltcedar is often cursed as a weed that is threatening to take over riparian areas and springs (see papers in Kunzman et al. 1989), actual data indicating its effects on Priority Vulnerable Species are lacking or do not support the conclusion that saltcedar is necessarily bad. Saltcedar has been blamed for drying up springs and small streams, for exuding salt that causes damage to soil and water quality, and for out competing native plant species (DiTomaso 1997). Extensive, dense saltcedar stand commonly occur along rivers and streams with modified flow regimes and that have been subjected to intensive grazing pressure. These have been accused of keeping out more desired, native species.

Saltcedar may also be beneficial to vulnerable species. Southwestern willow flycatchers at low elevations in Arizona appear to be closely tied to tamarisk: 95 percent of nests studied in 1999 were in tamarisk (Paradzick et al. 2000). Saltcedar may also be used as a nest substrate by Bell's vireo, which may be common in some saltcedar-dominated areas (Brown 1993). It is an important nesting substrate for many other birds, not considered as Priority Vulnerable Species, and may also benefit a range of human interests (Kunzman and Johnson 1989).

In riparian areas with modified hydrology or intense grazing pressure, conditions may be such that native riparian plant species cannot survive and saltcedar can. It may be inappropriate to fear or curse saltcedar, when it is land and water use practices that have altered the ecosystem, and saltcedar has merely taken advantage of the opportunity provided by human actions (Stromberg and Chew in prep.)

Rate of invasion, spread, or date of introduction

The introduction of saltcedar to the U.S. is lost knowledge. Tellman (1997) recounts several possibilities and certainties. It is known to have been released for cultivation in the U.S. by the U.S. Department of Agriculture in 1870 and to have escaped cultivation in 1880 in Utah and 1897 in Texas. In 1901 it was established along the Salt River in Arizona. It is reported to have first appeared along the Gila River in 1916. It spread most rapidly in the 1930s through to the 1960s (and later, such as in the Grand Canyon) as a result of human alteration of hydrology by building dams (Tellman 1997, Stromberg and Chew in prep.). In the mid-1960s, it was estimated that tamarisk occupied over one million acres in the Southwest (Stromberg and Chew in prep.)

Along the effluent-dominated reach of the Santa Cruz River, some of the saltcedar woodlands are much older than the Goodding willow woodlands, but ages were not determined. Some of the saltcedar woodlands and some of the more widely scatter saltcedars there are definitely less than seven years old and grew up since the 1993 flood (Baker 2000).

Population trend

After many years of explosive growth, the population trend of saltcedar in the Southwest is probably slowing or stabilizing because most of the suitable habitats have probably been colonized (K. Kingsley, personal opinion). Still, areas of local population growth do occur, such as along the Santa Cruz River, where saltcedar has grown since the 1993 flood (Baker 2000).

Currently, many land management agencies practice some form of program of saltcedar removal (summarized in Connolly 2000), which may have slowed growth of this species in some areas.

Factors affecting spread and distribution

This species is an extremely prolific producer of seeds, which are carried by wind and water. A single large individual can produce a half million seeds per year (DiTomaso 1997). Altered flood regimes and the loss of native riparian species contribute to the establishment and growth of saltcedar stands (Stromberg and Chew in prep.)

Legal status

Saltcedar has no legal status. It is not listed as a noxious weed by the State of Arizona.

Management methods, efficacy, and sensitivity

Hoddenbach (1989) reviewed management methods. Many have been tried, but the most consistently efficacious appears to be a combination of manual removal followed immediately by application of a chemical herbicide directly to the cut stump. Flooding for 24 months or longer gives good control. Burning every other year reduced competitive ability. Repeated treatments of any type are apparently necessary (Hoddenbach 1989). Recently several species of insects have been tested as biological controls and at least two show promise as potential control agents. However, concern for the endangered southwestern willow flycatcher has apparently stopped release of the insects. The most appropriate approach is probably restoration of native riparian communities, which will require restoration of natural hydrological conditions and grazing management (Stromberg and Chew in prep.).

Research ongoing and planned

Some research is apparently continuing under the auspices of the U.S. Department of Agriculture on biological control, and this is likely to grow. Most of the recent and apparently current research on tamarisk has been on control methods or in the context of larger ecological studies.

Potential future status in the planning area

Uncertain at this time. The potential future status depends upon continued management on the small scale (such as at springs or small, intensively managed riparian preserves) and, probably more importantly, on decisions that remain to be made regarding water management and land management issues, as well as the release and success of the proposed biological control agents.

Non-native Grasses

The best available current list of naturalized exotic species of plants in the Sonoran region lists 60 species of grasses that are considered naturalized (Tellman in prep.). Some of these are definitely or potentially problematic in Pima County, and an arbitrarily chosen few of these are discussed below. These were chosen because they are (arguably) the most significant from the potential harm they can cause to the Priority Vulnerable Species.

Buffelgrass (*Pennisetum ciliare*)

Taxonomy

Family Poaceae, Tribe Paniceae, Genus *Pennisetum,* species *setaceum.* It is also known as *Cenchrus ciliare.* Felger et al. (in prep.) call it *Pennisetum ciliare.* The common name is variously buffel grass (Tellman 1997, and Appendix C in Tellman in prep.) or buffelgrass (Búrquez et al. in prep., Felger et al. in prep., and the USDA Plants Database (http://plants.usda.gov/plants).

Habitat

This species may occur in a variety of habitats, from large areas of land in which it has been planted in Mexico (Búrquez et al. in prep.), to roadsides and canyons in Pima County where it has recently become established (Felger et al. in prep.). It occurs in grasslands, desert scrub, and along rocky canyons. It is abundant in disturbed areas along roads, up to about 4,000 ft elevation.

In Pima County it is present in the City of Tucson, in the Cabeza Prieta NWR, at Organ Pipe Cactus National Monument, Saguaro National Park (both units), Colossal Cave Mountain Park, and Sabino Canyon. It is not listed as present at Buenos Aires NWR, Cienega Creek Natural Preserve, Bingham-Cienega Natural Preserve, Coronado National Forest (although it is present along the Catalina Highway and several canyons below about 4,000 ft elevation in the Santa Catalina Mountains [K. Kingsley, personal observations]), and Catalina State Park (lists in Connolly 2000).

Effects on vulnerable species

In areas where this grass is the dominant species (in Sonora, Mexico), there appears to be a reduction of all native species, either brought about intentionally in the process of converting native plant communities to grassland by ranchers in Mexico or by crowding and competition as buffelgrass (Búrquez et al. in prep.). Crowding and competition for water and growing space may affect native plants. Increased frequency and intensity of fires has occurred where this species is abundant (Búrquez et al. in press, Felger et al. in prep.), and this may result in loss of many native plant species, with a cascade effect on animal species. However, there are no available conclusive data demonstrating consistent effects on any of the Priority Vulnerable Species being considered in the SDCP.

Rate of invasion, spread, or date of introduction

Buffelgrass was introduced from South Africa by the Soil Conservation Service in the 1940s (Tellman 1997). Mexican ranchers have intentionally replaced thousands of hectares of Sonoran Desert vegetation with buffelgrass, and it has escaped to invade natural areas (Tellman 1997, Búrquez et al. in prep., Felger et al. in prep.). Since the late 1960s and early 1970s buffelgrass has spread into many natural areas of Arizona, and has become an abundant roadside and urban weed (Felger et al. in prep.). In the past five years it has greatly increased around Tucson and along roads in Pima County and canyons of the Santa Catalina Mountains (K. Kingsley, personal observation).

Population trend

The population trend is clearly and rapidly upward, but has not been quantified.

Factors affecting spread and distribution

Intentional planting of buffelgrass was done over a large area in Mexico. The plant is a prolific seed producer, and its seeds are dispersed by wind and carried by animals, clothing, and vehicles. Grazing and disturbance appear to hasten dispersal and establishment. Colonization of new areas usually begins near roads or areas where buffelgrass was deliberately introduced. It progresses along watercourses and becomes established easily under tree crowns. Disturbance appears to be a major factor in the rapid establishment of buffelgrass. Water and nutrient availability also have a role (Búrquez et al. in prep.).

Legal status

This species is not currently on the State Noxious Weed List.

Management methods, efficacy, and sensitivity

The only currently known effective method for buffelgrass control is repeated hand grubbing (Rutman and Dickson in prep.). This is effective but very labor intensive. Herbicides may be effective, but are not very selective and will affect native species. Burning is clearly not effective and may encourage buffelgrass (Búrquez et al. in prep.).

Research ongoing and planned

Saguaro National Park is testing herbicides for buffelgrass control. Park staff have been surveying and mapping all non-native species since 1997 and enlisting the aid of volunteer groups for controlling this and other non-native plants (Connolly 2000). Organ Pipe Cactus National Monument will continue its program of eradication and has apparently been fairly successful. Records are kept as part of this program, and a report of the work is to be published (Rutman and Dickson in prep.).

Potential future status in the planning area

This species appears to be rapidly increasing and is unlikely to be effectively controlled on the large scale. Small-scale control in restricted areas appears to be possible, given sufficient labor and management commitment.

Lehmann Lovegrass (*Eragrostis lehmanniana*)

Taxonomy

Family Poaceae, Tribe Andropogoneae, Genus *Eragrostis,* species *lehmanniana.*

Habitat

This species thrives on sandy-loam soil in elevations spanning 2,400 to 4,500 feet, with average precipitation ranging from 11 to 20 inches per year; additionally, this species can endure and even expand its range in regions where average rainfall reaches a mere 3.5 inches for 40 days in the summer (Anable et al. 1992). In Pima County it is found throughout the elevation range and is reported from Organ Pipe Cactus National Monument, Buenos Aires NWR, Saguaro National Park, Colossal Cave Mountain Park, Cienega Creek Natural Preserve, and Sabino Canyon (lists in Connolly 2000), and the northern Santa Rita Mountains (Santa Rita Experimental Range, Cable 1971). In much of its range, as in the Buenos Aires NWR and the Santa Rita Experimental Range, it may form dense monotypic stands that exclude (or replace) native species.

Effects on vulnerable species

Specific effects of this species on Priority Vulnerable Species have not been documented. However, this species is associated with general reduction of species of native plants and animals in grasslands in Arizona (Cable 1971. Bock et al. 1986, Winn 1995, Bock and Bock in prep.). Lehmann lovegrass easily displaces native grasses due to its high seed count and propensity for increasing fire frequency (Anable et al. 1992). The fire tolerance of many invasive, non-native grasses offers these species an advantage over native grasses, including many that cannot withstand fire. Additionally, nonindigenous species are able to expand into niches generated by the loss to fire of native species. The absence of native grass as well as the loss of cryptogamic crust associated with stabilized desert soils produces a perfect habitat for the proliferation of these invasive species. A cycle of disturbance is thus created, including a further increase in non-native grass biomass and optimized conditions for increased fire occurrences.

Rate of invasion, spread, or date of introduction

This species, originally from South Africa, was introduced into Arizona in 1932 by the Soil Conservation Service (SCS). Intended for livestock grazing, Lehmann lovegrass has expanded its range to over 187,000 hectares (approximately 460,000 acres). While *E. lehmanniana* is no longer endorsed by the Natural Resource Conservation Service (formerly SCS), it is still used commercially for cattle grazing and cover for disturbed areas along right-of-ways, construction areas, and golf courses (Anable et al. 1992).

Population trend

A well-established species in southern Arizona, Lehmann lovegrass can displace indigenous grasses with its high seed count and tendency to increase fire frequency (Anable et al. 1992, Winn 1995). Similar population densities of *E. lehmanniana* in grazing exclosures and adjacent grazed regions suggest that disturbance is not necessary for the expansion of this species. This pattern, noted by Anable et al. (1992), bolsters the suggestion by Crawley (1986, 1987) that it is low average plant cover, not disturbance, that affords the conditions and, therefore, the opportunity for expansion of this nonindigenous species. In some areas, if Lehmann lovegrass were not present, there might be no, or few, native species because of past damage done to the land (Winn 1995).

Factors affecting spread and distribution (hosts, etc.)

E. lehmanniana has expanded aggressively from the intentional seedings accomplished by the SCS approximately 70 years ago. Known factors contributing to the spread of this species include low plant cover (Crawley 1986, 1987; Winn 1995) and increased fire frequency. *E. lehmanniana* expansion is also limited by environmental factors, including minimum winter temperatures, summer rainfall, and soil depth; seed arrival, not disturbance, is essential to successful proliferation of this species. Seed dispersal from nearby intentional seedings of

Lehmann lovegrass is accomplished via wind and water. This species will continue to spread in the absence of further intentional seedings although artificially augmenting local populations will expedite expansion of this species (Anable et al. 1992). All Lehmann lovegrass consists of genetically identical individuals, and this makes it extremely well adapted for the specific conditions under which it thrives (Winn 1995).

As this species dominates perennial grass composition, Anable et al. (1992) has predicted that fire occurrences will be more common in stands of Lehmann lovegrass, relative to the frequency of fire occurrence in native grass stands. Increased fire activity destroys native vegetation, fostering a positive environment for *E. lehmanniana* expansion.

Legal status

This species is not restricted by any law. It is not listed as a noxious weed in Arizona.

Management methods, efficacy, and sensitivity

Management options appear to be few and of limited effectiveness. Because of its value as livestock forage and for erosion control, Lehman lovegrass has major economic importance. Control within natural areas and preserves may be warranted. Experiments at the University of Arizona and Buenos Aires NWR have examined ways to replace Lehmann lovegrass stands with native grasses. These involved use of herbicide, followed by seeding with native species, and also used mulch (mowed lovegrass). Burning is not effective but apparently encourages Lehmann lovegrass (Winn 1995). It has been suggested that a combination of herbicide application, seeding with natives, and supplemental irrigation would be the most effective approach (Winn 1995). Cultivation has also been suggested as effective for small-scale infestations.

Research ongoing and planned

Michael H. Winn (pers. comm. to L. Woods) is continuing research on control of Lehmann lovegrass and restoration of native species. He is actively involved in the SDCP Steering Committee. Also, active studies and control efforts are under way at the Buenos Aires NWR.

Potential future status in the planning area

Lehmann lovegrass is probably effectively naturalized and will not go away. It is well established in most of its potential range, but can and will move into newly disturbed areas and may expand into areas in which it is present but not yet the dominant species (Winn 1995).

Red Brome (*Bromus rubens*)

Taxonomy

This species is known by several common names, including foxtail brome, foxtail chess (Parker 1958), and bromo rojo (Felger et al. 1997). Red brome has been the subject of recent taxonomic debate; the commonly known name, *Bromus rubens,* was split into the subspecies *Bromus madritensis rubens* and *B. m. madritensis* (Wilken and Painter 1993). In this document, this species will be referred to as *Bromus rubens.*

Habitat

This grass is a spring ephemeral that is seasonally abundant in natural and disturbed habitats in the Sonoran Desert (Felger et al. in prep.). It is to be found essentially everywhere in Pima County below about 5,000 ft elevation (K. Kingsley, personal observations). It is especially abundant along roadsides and in mesquite-dominated riparian areas. It is listed as present on the Cabeza Prieta NWR, Organ Pipe Cactus National Monument, Buenos Aires NWR, Saguaro National Park, Colossal Cave Mountain Park, Cienega Creek Natural Preserve, Bingham-Cienega Natural Preserve, Sabino Canyon, Catalina State Park, and it is abundant (although not listed) in the Coronado National Forest (lists in Connolly 2000).

Effects on vulnerable species

Specific, direct effects on Priority Vulnerable Species have not been documented. However, indirect effects caused by the increase in intensity and frequency of fires is highly likely and is discussed above and in the forthcoming book chapter by Esque and Schwalbe (in prep.). The effects of fires caused by this species are likely to be very significant on the local level in desertscrub and mesquite bosques.

Rate of invasion, spread, or date of introduction

This species has had rapid, explosive growth since its introduction. Esque and Schwalbe (in prep.) discuss the rapid expansion of this species in the Southwest. *B. rubens,* originally from the Mediterranean, was established in California by 1848. It was noted in Tucson by 1909 (Felger 1990). It is now extremely abundant (possibly one of the most abundant plants) throughout its current range, although its abundance is closely tied to the exact amount and timing of rainfall. Originally, this species may have been introduced to this region from the Santa Rita Experimental Range, where it was introduced as a forage plant (Felger 1990). Due to a high seed count and dense growth, this species spreads rapidly. Yet, with an abbreviated growing period and low palatability, *B. rubens* has significant limitations as a forage grass (James 1995).

Population trend

Red brome appears to be spreading in Sonora and Arizona (Esque and Schwalbe in prep.).

Factors affecting spread and distribution

Biological characteristics of the species that foster its explosive growth include its production of large numbers of seeds, its ability to germinate with less available moisture than many native plants, rapid germination, and high growth rates (Esque and Schwalbe in prep.). Other factors that foster its growth are preference for (not exclusive) disturbed soil, variation in rainfall, and resistance to fire.

Legal status

Red brome has no legal status; it is not on the Arizona Noxious Weed List.

Management methods, efficacy, and sensitivity

Methods that have been considered include physical removal, chemical herbicides, livestock grazing, and biological controls. Currently there are no known methods that are effective on the large-scale. Herbicides in combination with seasonally heavy livestock grazing may show promise (Esque and Schwalbe in prep.).

Research ongoing and planned

Esque and Schwalbe raise many questions that warrant further research, and may be pursuing some of them. Specific research targeted at this species (as opposed to broader ecosystem studies) is not known.

Potential future status in the planning area

Probably all of the planning area that is suitable for this species has already had it well established. It may vary in density and dominance from year to year and between locations. However, it is apparently a permanent, abundant, and important component of the ecosystem and will probably not go away.

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APPENDIX A

Potentially Problematic Species Initially Identified by the Science Technical Advisory Team

Table 7 - Pest Species in Pima County, Arizona

Scientific Name	Common Name	Distribution	Habitat Needs	Comments
Ambystoma tigrinum	Tiger Salamander	Widespread (introduced species)	Aquatic	May cause damage to pupfish, topminnow and other salamander populations
Ameiurus melas	Black Bullhead	?	Aquatic	Check with Will Hayes at AGFD for more information
Ameiurus natalis	Yellow Bullhead		Aquatic; found in isolated water bodies	
Arctotis stoechadifolia	African Daisy	Widespread	?	Displaces native annuals; this is a plant to watch out for
Arundo donax	Giant Reed			
Biomphalaria havanensis	Ghost Rams-horn (snail)	?	Aquatic	?
Bos taurus	Cattle	Global		
Brassica tournefortii	Asian Mustard	Widely distributed	?	
Bromus rubens	Red Brome	Widespread	?	
Canis familiaris	Dogs	Global		
Chelydra serpentina	Snapping Turtle	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Chrysemys picta	Painted Turtle	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Columba livia	Rock Dove (Pigeon)	Widespread		

Table 7 - Pest Species in Pima County, Arizona

Scientific Name	Common Name	Distribution	Habitat Needs	Comments
Corbicula manilensis	Asian Clam	Widespread	?	
Ctenosaura hemilopha	Spiny-tailed Iguana	Sonora	Aquatic	Not likely to spread according to some sources
Ctenosaura pectinata	Black Iguana (Mexican Spiny-tailed Iguana)			
Eragrostis lehmanniana	Lehman's Lovegrass	Widespread	Grasslands	Abundance of this grass depresses natives and affects fires
Erodium cicutarium	Filaree	Widespread	?	
Euryops multifidus	Sweet Resin Bush	?	?	
Felis spp.	Cats	Global		
Gambusia affinis	Western Mosquitofish	Widespread	?	
Graptemys spp.	Map Turtles	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Helix aspersa	Escargot Snail	Widely distributed in residential areas	?	
Hemidactylus turcicus	Mediterranean Gecko			
Lamellaxis gracilis	Graceful Awlsnail	Widespread	Gardens	
Lepomis cyanellus	Green Sunfish	?	Aquatic	
Lepomis macrochirus	Bluegill	Widespread	Aquatic	

Table 7 - Pest Species in Pima County, Arizona

Scientific Name	Common Name	Distribution	Habitat Needs	Comments
Limax valentianus	Three-band Garden Snail	Widespread	Aquatic	
Macroclemys temmincki	Alligator Snapping Turtle	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Micropterus salmoides	Largemouth Bass	Widespread	Aquatic	
Molothrus aeneus	Bronzed Cowbird	Widespread		Will sometime parasitize the nests of other bird species
Molothrus ater	Brown-headed Cowbird	Widespread		Will sometimes parasitize the nests of other bird species.
Mus musculus	House Mouse	Widely distributed in urban settings	Urban - will expand into natural settings during population explosions; agricultural areas	Not too much concern - does not compete with natives in the natural setting
Oncorhynchus mykiss	Rainbow Trout	Widespread	Aquatic	Introduced game fish
Orconectes virilis and others	Crayfish	Widespread	Aquatic	Jeanette Carpenter (USGS) is studying this species
Otala lactea	Milk Snail	Widespread	Gardens	
Ovis aries	Goat	Global		
Oxychilus draparnaudi	Dark-bodied Glass-snail	Widespread	Gardens; plant nurseries	
Passer domesticus	House Sparrow	Widespread		
Pennisetum ciliare	Buffelgrass	African origin; increasing in Mexico; invades from disturbed areas along roadways	Grasslands	Very bad for bird species in grassland communities

Table 7 - Pest Species in Pima County, Arizona

Scientific Name	Common Name	Distribution	Habitat Needs	Comments
Pennisetum setaceum	Fountain Grass	Widespread	?	
Pscudemys rubriventris	Red-bellied Turtle	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Pseudemys concinna	River Cooter	Widespread	Aquatic	Known from Maricopa County; not verified in Pima County; expansion from urban ponds; released by humans
Pseudemys scripta	Slider (Turtle)	Widespread	Aquatic	Expansion from urban ponds; released by humans
Pseudosuccinea columella	Mimic Columella	Widespread	Aquatic	
Quiscalus mexicanus	Great-tailed Grackle	Widespread		
Radix auricularia	Big-eared Radix	Widespread	Aquatic	
Rana berlandieri	Rio Grande Leopard Frog	Narrow distribution	Aquatic	May arrive in Pima County via the Central Arizona Project canal; may outcompete native leopard frogs
Rana catesbeiana	Bullfrog	Widespread	Aquatic	Competes with native frogs; efforts are currently underway to combat the problem
Rumina decollata	Decollate Snail	Widespread	Gardens	
Salvinia	Salvinia	Widespread	Aquatic	Exotic species which displaces native aquatic ecosystems
Sturnus vulgaris	Starling	Widespread	Saguaro cavities (mostly in developed areas)	
Succinea campestris	Crinkled Ambersnail	Very isolated	?	

Table 7 - Pest Species in Pima County, Arizona

Scientific Name	Common Name	Distribution	Habitat Needs	Comments
Sus scrofa	Pig	Global	Riparian	Found along the San Pedro River
Tamarix chinensis	Fivestamen Tamarisk	Widespread	Riparian	
Trionyx spiniferus	Spiny Softshell Turtle	Widespread	Aquatic	Bad for native fish populations
Vallonia pulchella	Lovely Vallonia	Widespread		
Viviparus chinensis	Mystery Snail	Widespread	Aquatic (cold water); does not like warm water	Introduced in the aquarium trade.
Xenopus laevis	African Clawed Frog	Narrow distribution in U. S.; populations introduced	Aquatic	Bad for native fish populations

APPENDIX B

Non-native or Introduced Species of Management Concern in Pima County

Non-native or introduced species of management concern in Pima County

Scientific Name	Common Name	Taxon	Pima Co Location	Pima Co Distribution		Primary Habitat		Affected resource		Level of Threat		Status/ Occurrence		Management Feasibility	
Canis familiaris	Dogs	1	E	Widespread	very local	?	urban, suburban	?	not known to be problematic here	low	low in Pima Co.	domesticated	some feral, but don't last long in wild	moderate	
Mus musculus	House mouse	1	E	Widespread		Urban		?	not known to be problematic here	low			synanthropic	low	
Pseudemys concinna	River cooter	3	E	Widespread	not known to be established	Aquatic		Aq spp	not known to be problematic here	low		no		?	
Ctenosaura hemilopha	Spiny-tailed iguana	3	E	?	not known to be established	Aquatic		Herps	not known to be problematic here	low		?		?	
Columba livia	Rock dove	2	E	Widespread	very local	Urban	some in rural areas	birds	not known to be problematic here		low		synanthropic	low	
Passer domesticus	House sparrow	2	E	Widespread	very local	Urban		birds	not known to be problematic here		low		synanthropic	low	
Sturnus vulgaris	Starling	2	E	Widespread	very local	?		birds	not known to be problematic here		low		synathropic	low	
Quiscalus mexicanus	Great-tailed grackle	2	E	Widespread	very local	?	urban, riparian	birds			not certain	naturalized	self-naturalized	low	
Pseudemys scripta	Slider Turtle	3	E	Widespread	very local	Aquatic		Aq spp				?		?	
Pseudemys rubiventris	Red-bellied turtle	3	E	Widespread	not known to be established	Aquatic		Aq spp				no		?	
Macroclemys temmincki	Alligator snapping turtle	3	E	Widespread	not known to be established	Aquatic		Aq spp				no		?	
Chyrsemys picta	Painted turtle	3	E	Widespread	not known to be established	Aquatic		Aq spp				no		?	
Graptemys spp.	Map turtles	3	E	Widespread	not known to be established	Aquatic		Aq spp				no		?	
Chelydra serpentina	Snapping turtle	3	E	Widespread	not known to be established	Aquatic		Aq spp				no		?	
Hemidactylus turcicus	Mediterranean gecko	3	?	Tucson	synanthropic	Urban		Herps	not known to be problematic here		none		synathropic	low	

Taxon: 1 = mammals; 2 = birds; 3 = reptiles; 4 = amphibians; 5 = fish; 6 = invertebrates; 7 = plants

Non-native or introduced species of management concern in Pima County

Scientific Name	Common Name	Taxon	Pima Co Location	Pima Co Distribution		Primary Habitat		Affected resource		Level of Threat		Status/ Occurrence		Management Feasibility	
Ctenosaura pectinata	Black iguana	3	?	?	not known to be established	?		Herps	not known to be problematic here		none	?		?	
Rana berlandieri	Rio Grande leopard frog	4	E	Narrow	not known to be established	Aquatic		Aq spp				no	not here yet?	low	
Micropterus salmoides	Largemouth bass	5	E/W	Widespread	ponds and lakes	Aquatic	few locations in Pima Co.	Aq spp	locations are artificial		minimal under existing conditions	naturalized		high	
Lepomis cyanellus	Green sunfish	5	Sabino Canyon	Widespread	also CAP water	?	Aquatic	fish	and aquatic insects		serious	?	naturalized	moderate	moderate, beware of reintroductions by CAP
Gambusia affinis	Western mosquitofish	5	E	Widespread	also CAP water	Aquatic			fish and aquatic insects		high-moderate	?	naturalized	?	moderate, beware of reintroductions by CAP
Ameiurus natalis	Yellow bullhead	5	E	?		Aquatic		fish				?		?	
Ameiurus melas	Black bullhead	5	E	?		Aquatic		fish				?		?	
Lepomis macrochirus	Bluegill	5	E/W	Widespread	very local	Aquatic		fish	fish and aquatic insects			?		low	
Oncorhynchus mykiss	Rainbow trout	5	E	Widespread	very local	Aquatic		fish	fish and aquatic insects			?	some may still be present in Sabino Ck.	moderate	
Lamellaxis gracilis	Graceful Awlsnail	6	E	?	synanthropic	Urban			not known to be problematic here		?	?	synanthropic	?	
Oxychilus draparnaudi	Dark-bodied glass-snail	6	E	Widespread	synanthropic	Urban			not known to be problematic here		?	?	synanthropic	?	
Limax valentianus	Three-band garden snail	6	E	Widespread	synanthropic	Aquatic	terrestrial		not known to be problematic here		?	?	synanthropic	?	
Vallonia pulchella	Lovely vallonia	6	E	Widespread	synanthropic	?	terrestrial		not known to be problematic here		?	?	synanthropic	?	
Radix auricularia	Big-eared radix	6	E	Widespread	synanthropic	Aquatic	ponds		not known to be problematic here		?	?	synanthropic/feral?	?	
Pseudosuccinea columella	Mimic columella	6	E	Widespread		Aquatic	ponds		not known to be problematic here		?	?	?	?	

Taxon: 1 = mammals; 2 = birds; 3 = reptiles; 4 = amphibians; 5 = fish; 6 = invertebrates; 7 = plants

Non-native or introduced species of management concern in Pima County

Scientific Name	Common Name	Taxon	Pima Co Location	Pima Co Distribution		Primary Habitat		Affected resource		Level of Threat		Status/ Occurrence		Management Feasibility	
Rumina decollata	Decollate snail	6	E	Widespread	synanthropic	Urban	gardens		not known to be problematic here		?	?	synanthropic	?	
Biomphalairia havanensis	Ghost rams-horn	6	E	?		Aquatic	ponds		may be a problem for fish and invertebrates in ponds		?	?	pond-dependent	?	moderate
Corbicula manilensis	Asian clam	6	E	Widespread	? Not sure for Pima Co.	?	lakes, rivers and streams		may be a problem for some native bivalves		?	?	not certain for Pima Co.	?	moderate
Succinea campestris	Crinkled ambersnail	6	W	Narrow	synanthropic	?	gardens		not known to be problematic here		?	?	synathropic	?	
Otala lactea	Milk snail	6	E	Widespread	narrow, synanthropic	Urban	gardens		not known to be problematic here		?	?	synathropic	?	?
Helix aspersa	Escargot snail	6	E	Widespread	narrow, synanthropic	?	gardens		not known to be problematic here		?	?	synanthropic	?	
Viviparus chinensis	Mystery snail	6	SE	Widespread	narrow, synanthropic	Aquatic	ponds		not known to be problematic here		?	?	may be extinct	?	moderate
Orconectes virilis and others	Crayfish	6	E	Widespread		Aquatic	rivers, streams, lakes, ponds		all aquatic life		serious	?	naturalized	?	difficult
Dimorphotheca sinuata	African daisy	7	E	Widespread	scattered	?	terrestrial, desert, roadsides	Annuals	not known to be problematic here		not known to be invasive	naturalized	naturalized	?	?
Erodium cicutarium	Filaree	7	E/W	Widespread	everywhere below 2000 meters	?	terrestrial	Annuals	not known to be problematic here		?	naturalized	a major component of our flora	low	impossible
Euryops multifidus	Sweet resin bush	7	Santa Rita ER	?	narrow	?		?	Pima ineapple cactus?		minor	?	locally naturalized	?	moderate-easy

Taxon: 1 = mammals; 2 = birds; 3 = reptiles; 4 = amphibians; 5 = fish; 6 = invertebrates; 7 = plants

Top Ten List
by Ken Kingsley

Criteria:

1. Non-native species that presents a high level of threat to the survival and recovery of species of concern or biotic communities of concern
2. Established in Pima County or likely to become established
3. At least moderate management feasibility, at least in certain circumstances (e.g., at springs or other limited riparian areas).

Ranked in order of my personal preference and concerns, that is, I think that management of these species should be included as part of the SDCP.

1. Bullfrog: important predator of aquatic and riparian small animal species, known to be established at several locations in Pima County, some of which may afford an opportunity for effective control.

2. Green Sunfish: important predator of aquatic species, known to be established at several locations in Pima County, potentially controllable with intensive program of repeated poisoning and other methods. Last year's control effort at Sabino Creek was insufficient.

3. Western Mosquitofish: potentially important predator/competitor with Gila Topminnow at some locations, depending on conditions, which are not fully understood. May also disrupt aquatic ecosystems and harm other fish species, but not clearly documented in this area. Potentially controllable, but also important in public health for mosquito control.

4. Red Shiner: important predator of aquatic species, known to be established at several locations in Pima County, potentially controllable with intensive program of repeated poisoning and other methods.

5. Crayfish: important predator in aquatic ecosystems, probably harms native fish, frogs, garter snakes, snakes, Huachuca Water Umbel, known to be established in many bodies of water, potentially controllable, but effective control methods not known to me.

6. Fivestamen Tamarisk at springs: potentially capable of crowding out other riparian plants and sucking up water, but not yet demonstrated to do so in Pima County, except maybe at a few springs. No evidence that it is problematic in healthy river and stream corridors, but it takes over in situations that have been damaged by human activities (such as dams). Important nest substrate for Southwestern Willow Flycatcher (which is not known to nest in Pima County)--95% of nests located last year by AGFD were in Tamarix. Potentially controllable at springs and other very limited water locations, not likely to be controllable along rivers and streams with hydrologic alteration

7. Imported Fire Ant: not yet known from Pima County, or established in Arizona, but likely to become established in riparian and urban areas. Potentially disruptive in riparian areas, may outcompete native ants, prey on native insects and disrupt food chain, and may prey on birds

(babies) and small mammals. Also may impact cave animals. Hazardous to people. Potentially controllable. Was not included in original list of species to consider.

8. Africanized Bee: well-established in Pima County, effects unknown but may have very significant competition effect on native pollinators and consequential effect on native plants as well as health and life hazard for some wildlife, domestic animals, and people. Potentially controllable, but with difficulty in some situations. Was not included in original list of species to consider.

9. Non-native grasses (Red Brome, Lehman's Lovegrass, Buffle Grass, Bermuda Grass, Cheat Grass): well-established in Pima County, serious fire hazard for many species of native plants and animals, also may compete with native plants, and result in change of food and cover availability for native animals. Potentially controllable in some situations, but control is likely to be very difficult. (I realize I cheated and combined several species, including some not on the original list.)

10. Asian mustard: important competitor of sand dune plants and other plants that require sandy, open soil, known to be established in natural habitats in western Pima County as well as roadsides, potentially controllable with intensive hand labor at limited sites.

Other species of Some Concern and Management Potential that were on the list

Giant Reed: potentially capable of crowding out other riparian plants, but not yet well enough established or conditions not right for this at locations I know. May be especially problematic at springs, where it may suck up a lot of water, but also may be especially controllable at springs.

Cattle: potentially damaging by excessive herbivory and soil impacts when not properly managed. Historically have caused or contributed to great damage, but better management appears to be reducing ecosystem stresses, and it is possible that some carefully managed grazing may be neutral or beneficial with some native species management goals. Highly controversial. Cattle industry is clearly declining, and would probably not exist without government subsidies. Recent Supreme Court decision may change economics. Much politicized issue. Easily manageable if political will exists.

Rio Grande Leopard Frog: potentially serious predator/competitor with native leopard frogs, not yet documented from Pima County. May be controllable.

Pig: a locally important animal in the San Pedro Valley in Pima County, digs and consumes plants, also possibly ground-nesting birds' eggs, potentially controllable by trapping and shooting.

Some Additional Thoughts

I think a better approach than dealing with individual species would be to consider ecosystems and their management, with reduction or elimination of potentially problematic species within each. For example:

Aquatic Ecosystems: many of the species above are aquatic or riparian, and the only approach to control them that makes sense is to work on the stream or spring ecosystem, carefully examining it for potentially problematic species and developing a system-wide management approach.

Rangeland Ecosystems: collaboration with ranchers may be possible for management of potentially problematic range grasses and cattle.

Non-native Hymenoptera (bees and ants): a constant surveillance program should be developed for preserve areas, and appropriate tools made available for instant application by preserve managers in the event that these species are discovered on site. Swarm traps show promise for bee management.

I am also very concerned about the possibility of the arrival of non-native wildlife diseases, such as West Nile Virus and dog heartworm, which can be lethal to native wildlife species, and about which little can be done except mosquito control. West Nile Virus is known to be lethal to some birds, and we don't know yet which species. Think about what would happen if it were lethal to Cactus Ferruginous Pygmy-owls. The virus arrived in the U.S. last year, in New York City. It is also lethal to people. The Center for Disease Control and the state health departments in Arizona and California are very concerned about its potential arrival here. It is vectored by common mosquitoes, as is dog heartworm.