DRAFT

Water Quality Requirements of Native Aquatic Species in Pima County

Sonoran Desert Conservation Plan
2001

Pima County, Arizona
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County Administrator
Chuck Huckelberry

MEMORANDUM

Date: October 1, 2001

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

From: C.H. Huckelberry
County Administrator

Re: **Water Quality Requirements of Native Aquatic Species in Pima County**

Background

The Pima Association of Governments is working with Pima County to address water quality issues related to both the Sonoran Desert Conservation Plan and the Comprehensive Land Use Plan Update. The workplan includes the following tasks:

- Overview of the quality of various water sources in Pima County
- Review and summarize existing state and federal regulations
- Review and compile existing data on water quality requirements of aquatic species
- Identify the highest priority watersheds for water quality monitoring and restoration
- Compile water quality data for the highest priority watersheds
- Assess land uses and potential pollution sources that might impact the water quality of the highest priority aquatic habitats
- Review planning alternatives and identify potential impacts on water quality
- Propose mitigation measures to ensure that water quality of priority aquatic habitats is maintained or improved, and propose a water quality monitoring program for the highest priority aquatic habitats
- Draft a water quality report for the Environmental Planning Element of the Comprehensive Plan Update

The attached report represents task three: it is a review and compilation of existing data on water quality requirements of eight aquatic species. By identifying the water quality requirements of priority vulnerable species of concern, and assessing the quality of water that serves or might serve as potential habitat, we begin to understand which sources will support priority aquatic species identified by the Sonoran Desert Conservation Plan.

Findings

The priority vulnerable aquatic species reviewed in this introductory analysis included: (1) Chiricahua leopard frog; (2) Lowland leopard frog; (3) Longfin dace; (4) Desert sucker; (5) Sonora sucker; (6) Desert pupfish; (7) Gila chub; and (8) Gila topminnow. The general location of such species includes the San Pedro, Cienega-Rincon, Altar Valley and Middle Santa Cruz watershed subareas of the Sonoran Desert Conservation Plan. Following a description of study methods and constraints, and a general discussion of water quality, the species specific water quality studies and other data led the authors to conclude in part that:

- Native aquatic species have a relatively high tolerance for wide ranges in temperature, pH levels of water, and salinity.
- Available data for some of Pima County's major streams indicates that general water quality parameters are within the range capable of supporting native aquatic species.
- "Based on the information we have for natural waterbodies in Pima County, current general water quality conditions appear to be acceptable for meeting the needs of native aquatic species. Habitat destruction and the introduction of non-native species appear to be the major threats to these vulnerable species. However, additional water quality data is needed on the specific requirements and threats to the native species, and in particular to the leopard frogs and desert suckers." (P. 18)

The Arid West Water Quality Research Project being conducted by Pima County and the United States Environmental Protection Agency will provide a comprehensive characterization of unique aquatic habitats in the arid west. The University of Arizona is also working on two projects that will provide more detail about the water quality requirements of desert fishes.

Next Steps

In preparation for the next task of the workprogram, Pima Association of Governments created a preliminary list of the twenty highest priority streams for water quality and quantity monitoring, management and restoration. Stream selection was based primarily on the presence of perennial or intermittent stream flow, the area of riparian habitat, the presence of historic or existing populations of native fish and frog species, and location with respect to other surface water sources and possible wildlife corridors. The authors did not take into account the potential threat to any individual stream. Some streams did not have as high habitat value as others but were included because they were considered to be priority by federal, state or county personnel.

The Sonoran Desert Conservation Plan Riparian Element report and the County's study on the historic occurrence of native fish were used to determine the resources present in and around each stream. The following descriptions of each stream essentially summarize the information presented in the Riparian Element report. Additionally, the list reflects ongoing discussions with Arizona Game and Fish regarding establishment and maintenance of native fish.

Preliminary List of Highest Priority Streams for Monitoring, Management and Restoration

1. Agua Caliente Canyon -- More than 1000 acres hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; historic leopard frog location. Rare perennial spring in Tucson Basin. Agua Caliente Spring has perennial flow and potential for restoration projects for both aquatic flora and fauna.

2. Agua Verde Creek -- Intermittent stream flow (15 miles); approximately 300 acres Class A Riparian Habitat; mesquite bosque; shallow groundwater; leopard frogs; fish exist but species unknown; no information available for hydro-mesoriparian habitat. Corridor between Rincon and Santa Rita Mountains.

3. Arivaca Creek -- Perennial and intermittent stream flow (more than 3 miles); more than 1000 acres hydro-mesoriparian habitat; deciduous riparian forest; shallow groundwater; historic leopard frog location; native fish establishment potential. One of few perennial water sources in the area.

4. Bingham Cienega -- Perennial stream flow; pygmy-owl habitat; leopard frogs; native fish establishment potential. Unique marsh environment.

5. Buehman Canyon -- Perennial and intermittent stream flow (more than 7.5 miles); more than 200 acres Class A riparian habitat; 1 native fish species extant; leopard frogs; native fish establishment potential. Unique Waters designation.

6. Canada del Oro -- Perennial and intermittent stream flow (more than 5 miles); 300 acres hydro-mesoriparian habitat; mesquite bosque; two native fish species; historic leopard frog location.

7. Cienega Creek (lower) -- Perennial and intermittent stream flow (7.5 miles); more than 550 acres hydro-mesoriparian habitat; more than 55 acres Class A Riparian Habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; one native fish species extant; leopard frogs; native fish establishment potential. Unique Water designation.

8. Cienega Creek (upper) -- Perennial and intermittent stream flow (more than 12 miles); 900 acres hydro-mesoriparian habitat; mesquite bosque; shallow groundwater; three native fish species extant; leopard frogs.

9. Davidson Canyon -- Perennial and intermittent stream flow (2 miles); Class A riparian vegetation; shallow groundwater; one native fish species; leopard frogs; native fish establishment potential. Corridor between Santa Rita Mountains / Sonoita Valley and Rincon Mountains.

10. Empire Gulch -- Perennial and intermittent stream flow (1.5 miles); leopard frogs; information on riparian vegetation and shallow groundwater not available; native fish establishment potential; priority for the Bureau of Land Management.

11. Espiritu Canyon -- Perennial and intermittent stream flow (4.5 miles); leopard frogs; information on shallow groundwater not available; native fish establishment potential.

12. Florida Canyon -- Intermittent stream flow (more than 3 miles); leopard frogs; riparian vegetation and native fish species information not available.

13. Mattie Canyon -- Perennial and intermittent stream flow (more than 1.5 miles); three native fish species; historic leopard frog location; riparian vegetation information not available; priority for the Bureau of Land Management.

14. Quitobaquito Spring -- Perennial pools and short stream; one native fish species (endemic); small riparian habitat; unique aquatic habitat in Western Pima County, where there are few perennial water sources.

15. Rincon Creek -- Intermittent stream flow (more than 11 miles); more than 500 acres hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; one native fish species extant; leopard frogs.

16. Sabino Canyon -- Perennial and intermittent stream flow (more than 18 miles); more than 800 acres hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; historically, three native fish species; historic leopard frog location; native fish establishment potential.

17. San Pedro River -- Perennial and intermittent stream flow (12 miles); more than 2300 acres hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; historically, ten native fish species; one native fish species extant; leopard frogs; and potential pygmy- owl habitat.

18. Santa Cruz River (mid/lower) -- Perennial and intermittent stream flow (more than 22 miles); 3500 acres hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; historic leopard frog location; shallow groundwater and native fish species information not available; pygmy owl habitat; native fish establishment potential.

19. Tanque Verde Creek (upper) -- Perennial and intermittent stream flow (more than 17 miles); more than 1000 acres of hydro-mesoriparian habitat; deciduous riparian forest; mesquite bosque; shallow groundwater; one native fish species; leopard frogs.

20. Wakefield Canyon/ Nogales Spring -- Perennial and intermittent stream flow (approximately 2 miles); more than 35 acres Class A Riparian Habitat; leopard frogs; native fish establishment potential; series of springs; no information on shallow groundwater. Corridor between Whetstone and Rincon Mountains.

Conclusion

During the next weeks, Pima Association of Governments work with the preliminary list above and carry out the following analysis for each of the streams on the list:

- Compile existing water quality data, identify any impairments, identify any data gaps;
- Assess land uses and potential pollution sources that might affect the water quality;
- Propose mitigation measures to ensure water quality of the streams; and
- Propose a water quality monitoring program.

The attached study on the *Water Quality Requirements of Native Aquatic Species in Pima County* establishes a basis for these detailed follow up studies that will contribute to the establishment of aquatic species protection under the Sonoran Desert Conservation Plan.

Attachment

Water Quality Requirements of Native Aquatic Species in Pima County

Prepared for the Pima County Comprehensive Plan and Sonoran Desert Conservation Plan

Draft

September, 2001

Prepared By

Pima Association of Governments

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Draft
September 20, 2001

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Introduction

Background

This report attempts to identify the water quality requirements of aquatic species identified as priority species by the Sonoran Desert Conservation Plan. Used in conjunction with the previous water quality reports, this report could provide a tool for the County in its efforts to develop plans to protect these species.

PAG recently submitted two draft reports to the County. One report summarized water quality data available for the principal types of water sources in Pima County: groundwater, CAP water, treated wastewater, stormwater runoff, and surface waterbodies such as streams. The second report summarized rules and regulations that protect the water quality of these sources.

By knowing the quality of the various water sources in the County and the degree to which their quality is protected by law, and by comparing these to the water quality requirements of aquatic species, it should be possible to determine which water sources would be appropriate for supporting the priority aquatic species identified in the Plan.

Purpose

The purpose of this report is to summarize what is known about the water quality requirements of priority vulnerable aquatic species identified in the Pima County Sonoran Desert Conservation Plan.

Limitations

The information provided in this report is limited entirely to data that were available from published literature and other agencies' monitoring programs. PAG did not conduct any original research for this project. Also, PAG's literature search was significantly constrained by time and resources. The literature used for this study was primarily that which was readily accessible from the University of Arizona library, local agency contacts (particularly Pima County Flood

Control District, Pima County Wastewater Management Department, Arizona Department of Environmental Quality, and Arizona Game and Fish Department), and the Internet. Additional information was probably available, but not included in this report.

An additional, important consideration is that this report does not address hydrologic factors affecting aquatic habitat. Preliminary indications from the County's on-going Water Quality Research Project suggest that physical characteristics of streams, such as flood frequency and streambed geology, could be as important as water quality in determining which aquatic species are found in a stream.

Species Addressed in this Report

We reviewed and compiled existing data on the water quality requirements of the priority vulnerable aquatic species described in the County Plan (Table 1). In cases where data were very limited, available studies involving closely related species were used as well.

Table 1. Priority Vulnerable Aquatic Species in Pima County (Pima County, 2000a)

Species	Location
Chiricahua Leopard Frog *(Rana chiricahuensis)* Lowland Leopard Frog *(Rana yavapaiensis)*	Middle San Pedro, Cienega-Rincon, Altar Valley, and the Middle Santa Cruz watershed subareas.
Longfin Dace *(Agosia chrysogaster)* Desert Sucker *(Catostomus clarki)* Sonora Sucker *(Catostomus insignis)* Desert Pupfish *(Cyprinodon macularius macularius)* Gila Chub *(Gila intermedia)* Gila Topminnow *(Poeciliopsis occidentalis)*	Middle San Pedro, Cienega-Rincon, Altar Valley, and the Middle Santa Cruz watershed subareas

General Discussion of Water Quality

Little information was readily available on the specific water quality requirements of the aquatic species targeted by this study. Most studies we found were limited in scope. This is significant, because toxicity testing in aquatic environments is highly complex, due to the varying effects of hydrologic conditions, and the interrelationships between, and combined effects of, multiple water quality constituents.

Water quality factors generally associated with the health of streams and rivers, as well as fish survival rates, include the chemical characteristics of pH, buffering capacity, dissolved oxygen and nutrient levels. They also include physical characteristics such as stream width, temperature, substrate, water velocity, and volume. Several detailed studies have been done, but in general we need more data to establish meaningful water quality standards for fish in the Southwest.

Along these lines, Pima County Wastewater Management Department is conducting a major study on water quality: *The Arid West Water Quality Research Project* (WQRP). The objective of the WQRP is to determine whether existing federal and state standards for wastewater discharges to ephemeral streams need modification or if a new set of standards needs to be developed specifically to protect effluent-dependent aquatic and riparian habitat in the arid west. The scope of the project covers seven states and looks at 10 study sites. (Pima County Wastewater Management Department, 2001).

In contrast to the lack of data for the species listed in Table 1, there are large amounts of data on aquatic invertebrates and the impairment factors that affect their communities. Aquatic invertebrates are worms and insects like mayflies, stoneflies, and caddisflies that live in water. These animals are sensitive to water quality degradation and are more abundant in good quality streams. Therefore, they are useful in determining the relative quality of the water (USGS, 2000). Macroinvertebrates are good indicators of localized conditions because they are sensitive to their environment and relatively immobile (Lawson, 1995).

Water quality is affected by many factors. Riparian environments influence the physical and chemical characteristics of streams and are essential in the health of the waterbody. In higher reaches streamside trees provide shade that helps the water maintain a cool temperature, thereby increasing the stream's oxygen-carrying capacity. Also, the roots of these trees stabilize stream banks, reducing erosion and slowing down runoff, allowing sediments to settle out. The middle reaches of streams tend to be wider, warmer, sunnier, and sandier than headwater streams. These stream reaches tend to support a greater variety of aquatic life as they have conditions and qualities of both the headwater regions and the lower reaches. The lower stream reaches are typically broad and sunny and may be deep. They support life that filters food and oxygen from the water, prefers quiet, still waters, and tolerates a lower dissolved oxygen content (Boquet River Association, 2001).

Arizona Game and Fish Department stated that they typically monitor water that native fish inhabit for four basic water quality parameters throughout the year: pH, conductivity, dissolved oxygen and temperature (Blasius, 2001). The pH of a water indicates its degree of alkalinity or acidity. A pH of 7.0 indicates a water that is neither acidic nor alkaline. Natural, unpolluted waterbodies in southeastern Arizona are naturally alkaline and generally have a pH in the range of 6.9-8.6. Extreme pH values (high or low) can lead to the development of conditions that can be toxic to aquatic life. Changes of pH in a waterbody can be due to chemical, physical or biological processes. Most aquatic organisms have an optimum pH range of 6.5-8.5 (Lawson, 1995).

Conductivity, or specific electrical conductance (EC), is a measurement of the ability of water to carry an electric current. This ability depends on the presence of ions, their concentration, and the temperature. The conductivity of distilled water is in the range of 0.5-3.0 µmhos/cm, potable water is generally 50-1500 µmhos/cm, and some industrial wastewaters can have conductivities over 10,000 µmohs/cm. Since EC is an indirect measurement of the concentration of total dissolved solids in a solution, it can be used as an indicator of pollution problems in some cases (Lawson, 1995; Standard Methods, 1998). However, many waterbodies are naturally high in TDS.

Dissolved oxygen (D.O.) is necessary to all aquatic organisms that need oxygen for life processes. The solubility of oxygen in water depends on water temperature and air pressure. Because of this, warm water or water at high elevations cannot carry as much D.O. as cold water or water at lower elevations. Dissolved oxygen in water comes from the atmosphere, surface turbulence, and photosynthesis by aquatic plants. Waters that have consistently high D.O. are considered healthy. D.O. concentrations in unpolluted, southeast Arizona waters typically range from 7.5-8.3 mg/l. The State of Arizona has set water quality standards for D.O. as minimum numerical concentration limits or 90% dissolved oxygen saturation. In the Santa Cruz River, south of Pima County, at one springflow sampling site the water was found to be routinely 15-30% below saturation. Springflow is typically low in D.O. and the fish and aquatic insects living at this site did not show signs of stress from the D. O. levels (Lawson, 1995). Biochemical oxygen demand (BOD) is an empirical test in which standardized laboratory procedures are used to determine the relative oxygen requirements of wastewaters and effluents. The test measures the molecular oxygen utilized during a specific incubation period for the biological degradation of organic material (Standard Methods, 1998).

Temperature readings are used in the calculation of various forms of alkalinity, calculation of salinity and in general laboratory operations. Water temperatures generally closely follow air temperatures, and data imply that temperature dependent processes (chemical, physical, and biological) may be very dynamic (Lawson, 1995; Standard Methods, 1998).

Additional water quality constituents of potential concern include nutrients (nitrogen and phosphorus), pesticides, trace metals, and polycyclic aromatic hydrocarbons (PAHs) (Liston and Maher, 1997). High levels of nutrients can lead to eutrophication of aquatic environments, while pesticides, trace metals, and PAHs can be toxic to aquatic life. One form of nitrogen, NH_3, is also toxic.

Species-Specific Water Quality Studies

Longfin Dace

Lewis (1978) looked at the effects of mining wastes in streams and the acute toxicity of heavy metals in water on native fish species. A series of toxicity tests were conducted on juvenile longfin dace *(A. chrysogaster)* in hard water using copper, zinc and manganese, and copper-zinc and copper-manganese mixtures. The results indicate that the longfin dace is more sensitive to zinc and slightly less sensitive to copper than the commonly studied fathead minnow. The longfin dace appears to be more resistant to manganese than juvenile trout. It was shown that metals in combination generally exhibit additive toxicity, with the copper-zinc solutions being more toxic than any single-metal solution. The results are shown on Tables 2 and 3.

Table 2. Mean Concentration of Metal (mg/l) added as inorganic salt and percent survival (%) at 96 hours of juvenile *Agosi chrysogaster* exposed to toxicant levels. Values represent the mean of each test and replicate (Lewis, 1978).

Cu (mg/l)	Zn (mg/l)	Mn (mg/l)	Cu-Zn (mg/l)	Cu-Mn (mg/l)
20.4 (0%)	25.5(0%)	436 (0%)	20.0-23.0 (0%)	20.5-430 (0%)
4.0 (0%)	4.4 (0%)	269 (0%)	3.5-4.0 (0%)	3.4-219 (0%)
1.8 (0%)	2.4 (0%)	150 (0%)	2.0-2.3 (0%)	2.0-171 (0%)
1.3 (30%)	0.5 (60%)	84 (60%)	0.3-0.6 (0%)	0.8-100 (0%)
0.3 (80%)	0.3 (90%)	56 (90%)	0.2-0.4 (40%)	0.2-28 (80%)
			0.1-0.2 (100%)	0.1-14 (100%)

Table 3. 96 Hour Lethal Concentrations of Heavy Metals in mg/l, to Juvenile *Agosia chrysogaster* and Slope Functions of Response Curves to the Same Metals (Lewis, 1978).

Metal	° C	pH	DO* mg/l	Total hardness mg/l **	Test organisms exposed	Lethal Concentration ‡	Slope function †
Copper	19.3	7.7	9.5	221	100	0.86 (0.7-1.1)	1.53
Zinc	18.9	7.8	9.3	217	100	0.79 (0.4-1.5)	2.86
Manganese	19.0	7.6	8.7	224	100	130 (100-169)	1.50
Copper-Zinc	18.7	7.8	8.9	219	100	0.21 (0.15-0.29)	1.78
						0.28 (0.18-0.45)	2.14
Copper-Manganese	19.5	8.0	9.0	231	100	0.45 (0.31-0.64)	1.79
						64.0 (47-88)	1.75

* Experimental Conditions
** as CaCo3
‡ Number shown is 96-L.C. 50, which indicates the lethal concentration at which 50% of the test organisms died after a 96 hour test. Values include background concentrations in dilution water (mg/l): Cu-0.02, Zn-0.001, and Mn- 0.004. Numbers in () indicate 95% confidence limits.
†Values indicate variation of response of the test population to the poison.

Extensive monitoring of the Upper Santa Cruz River was conducted in the early 1990's. The most common fish in the river is the longfin dace, which is also the most abundant native minnow in Arizona's low elevation streams. The study, completed by ADEQ and volunteers, was conducted to document fish species occurrence and to determine if there were any environmental factors adversely affecting fish in the effluent dependant reach of the river.

Water quality in the study area was generally considered good. Metals concentrations did not appear to have a negative effect on aquatic life. Nutrients added to the river through the treatment plant diminished downstream. This species, *Agosia chrysogaster*, is tolerant of high water temperatures, low D.O. (as low as 1.0 mg/l for short periods) and is able to gulp air when low D.O. conditions are present (Lawson, 1995). This fish was found in the greatest density at the control site (above the treatment plant) and at the sample location farthest downstream. Selected water quality data are shown on Table 4.

Table 4. Selected Parameters from the Santa Cruz River—Guevavi Ranch Control Site, Upstream from the Nogales International Wastewater Treatment Plant (Lawson, 1995)

Date Sampled	Temp Water (°C)	DO (mg/l)	EC (field) (µmhos /cm)	pH (field)	TDS (mg/l)	TSS (mg/l)	Turbidity (NTU)	Total Alkalinity (mg/l)	Total Phosphate (mg/l)	Nitrate (mg/l)
11/20/92	14.5	N/A	404	7.78	277	4	0.03	160	0.091	0.44
12/16/92	18.5	N/A	N/A	7.59	281	2	0.20	151	0.067	0.63
02/03/93	10	8.2	309	8.16	228	295	23	106	0.388	0.54
02/23/93	8.5	9.60	251	7.68	166	180	39	83.0	0.32	0.33
03/31/93	17.0	N/A	354	8.05	251	39	20	148	0.19	0.4
04/28/93	21.5	9.7	388	7.86	220	4	0.66	132	0.19	0.41
05/11/93	15.5	7.55	354	7.79	225	4	0.54	134	0.15	0.26
06/23/93	12.0	6.89	380	7.71	201	4	0.32	144	0.05	0.28
07/21/93	16.0	6.95	354	7.76	233	4	0.39	138	0.18	0.31
08/19/93	18.5	6.55	347	7.76	230	4	0.50	142	0.11	0.24
09/08/93	16.0	6.1	373	7.39	230	4	0.52	143	0.092	0.30
10/13/93	13.5	6.4	380	7.61	230	10	0.48	157	0.13	0.42

Gila Topminnow

The Gila topminnow favors a habitat of shallow, warm, quiet waters in perennial and intermittent streams, marshes and riverbanks where there are dense mats of algae and debris and sandy substrate (Matthews, 1990). Though more information is needed on the specific water quality components of the fish's preferred environment, their temperature range is known to extend from near freezing under ice to 37 °C, with a maximum tolerance of 43 °C for brief periods. Topminnows can live in a fairly wide range of water chemistries, with recorded values of pH from 6.6-8.9, dissolved oxygen readings from 2.2 to 11 mg/l and salinities from very dilute to seawater. It has been reported that they can tolerate almost total loss of water by burrowing into the mud for 1-2 days (Weedman, 1998).

The biggest threats to this species are habitat destruction and the introduction of non-native species (Weedman, 1998). Minckley (1999) conducted a study for a recovery program for the Gila topminnow. This study noted that the reasons for the disappearance of the Gila topminnow from 96 locations was apparent: 57 were desiccated, 27 were lost to flooding, 6 to winter cold and 1 or 2 to mosquitofish, water quality, dredging or livestock overuse.

A study on another topminnow species, the Sonoran topminnow, showed that the steady decline of this species is correlated with and primarily attributed to habitat destruction and the introduction and establishment of mosquitofish and other exotic fishes. Between August 1979 and July 1981 all known populations of the Sonoran topminnow were visited from one to 10 times. Several environmental parameters were measured at all sites. The minimum and maximum values of the environmental parameters encountered by *P. occidentalis* are presented on Table 5. The author considered these ranges to be a minimum of those tolerable to this species as these are considered "remnant habitats of a formerly wide-ranging fish…"(Meffe, et al., 1983).

Table 5. Environmental Ranges under Which Extant Populations of Sonoran Topminnows are Found. From: Factors Resulting in Decline of the Endangered Sonoran Topminnow *Poeciliopsis occidentalis* (Atheriniformes: Poeciliidae) in the United States. By Meffe, Hendrickson, and Minckley (1983).

Site	Temp (°C)	O2 (mg/l)	Conductivity (umhos)	Alkalinity Total (meq/l)	pH	Cl (mg/l)	S04-S (mg/l)	Si (mg/l)	No3-N (mg/l)	Soluble reactive Phosphate (mg/l)	Total Dissolved Phosphate (mg/l)
Monkey Spring	26.5-27.5	2.4	990-1200	1.1-5.0	6.9*-7.6	4.0*-8.8	81.1-*563.0	1.3-3.7	0.09-0.32	0.00-0.04	0.002-0.096
Cottonwood Spring	26.0-31.0	-	1200-1350	3.3*	6.9*	6.8	73.5	2.9	0.02-0.28	0.00-0.10	0.001-0.16
Sheehy Spring	6.0-20.0	4.5-7.3	290-520	3.3	6.9-8.9	6.4-7.6	0.0-0.1	3.2-5.2	0.00-0.09	0.00-0.04	0.005-0.098
Unnamed Spring	7.0-26.8	2.7-6.1	290-540	3.0-5.9	7.4-8.8	2.2-15.2	0.3-25.0	3.4-5.7	0.01-0.03	0.00-0.06	0.014-0.12
Santa Cruz River	23.5	-	300	-	8.2	7.3	13.1	2.7	0.00-0.01	0.016-0.019	0.02-0.04
Redrock Canyon	14-24	-	1200-2300	2.8-3.3	7.4-8.5	-	-	-	-	-	-
Cienega Creek	10.5-22	-	470-535	4.0	-	8.8	18.3	4.0	0.00-0.01	0.002	0.001-0.003
Cocio Wash	22-29	8-11	1099-2210	3.8-5.6	7.5-7.6	-	-	-	-	-	-
Bylas Springs	17.0-36.7	3.0-9.0	1350-5050	2.0-3.4	6.6-8.5	8.5	26.1-52.3	4.4-11.1	0.00-1.1	0.00-0.02	0.001-0.025
San Bernadino Creek	11.7-32.0	6.8	540-680	3.4	7.6-8.5	14.2	16.7	4.6	0.02	0.12	0.17
Artesian Wells	22.0-29.1	2.2-8.1	390-500	3.7-4.0	7.2-8.6	8.2-9.5	5.6-9.2	4.0-4.9	0.64-1.3	0.003-0.076	0.003-0.083

Mesa Spring	18.2-23.0	2.2	-	-	-	-	-	-	-	-	-
Leslie Creek	12.7-21.0	-	620-660	-	7.3-7.6	6.8	36.0	5.7	6.2-8.3	0.00-0.02	0.001-0.016
Sonoita Creek	-	-	515-1000	4.2	7.0-7.8	10.1	36.0	5.5	0.00-0.01	0.009-0.024	0.006-0.034

If more than one reading for any parameter was available, then minimum and maximum values are presented. Otherwise the single available figure is given.
*= from Schoenherr, 1974.

Gila Chub

The Gila chub is often associated with cienegas and deep pools in smaller headwater streams provided with dense vegetative cover. During the day it spends its time under the cover of cutbanks, vegetative overhang or aquatic vegetation (Adams). Habitat-specific water quality data are not readily available. The BLM has identified reaches of Cienega Creek occupied by the Gila chub. Gila chub inhabit portions of seven stream miles of approximately 24 miles of stream above Interstate 10. The status of the Gila chub in this area is considered stable and secure. The population is believed to be healthy, and pool habitat is stable with minimal threat of non-native species introduction (Weedman, 1996).

Arizona Game and Fish recommends that all existing Gila chub populations be identified, protected, and monitored. They believe that reduction of land erosion, preservation of habitat, and stream improvement structures on some sites could benefit Gila chub populations. Habitats critical to their survival include cienegas, headwaters, spring-fed streams, and spring-fed ponds that are free of non-native species (Weedman, 1996).

Desert Pupfish

According to U.S. Fish and Wildlife Service in the *Desert Pupfish Recovery Plan*, "the desert pupfish (*Cyprinodon macularius*) occupied a diversity of habitats ranging from cienegas and springs to small streams and margins of larger bodies of water. Most habitats were shallow and had soft substrates and clear water." It is also noted that the pupfish can survive under conditions of very high water temperatures (to 45°C), low dissolved oxygen (concentrations of 0.1-0.4 mg/l) and high salinity (concentrations twice that of seawater). They can also survive abrupt changes in temperature and salinity that would be lethal to other fish species. In environments with other species the pupfish typically occupies shallower water than adults of the other species (Marsh and Sada, 1993).

In Pima County a large population of pupfish, *C. macularius eremus*, is endemic to Quitobaquito Springs (Miller and Fuiman, 1987). Some water quality data are available for the pond and the spring; the data are shown on Table 6.

Table 6. Chemical Constituents in Water at Quitobaquito, Arizona. From Description and Conservation Status of *Cyprinodan macularius eremus.* A New Subspecies of Pupfish from Organ pipe Cactus National Monument, Arizona. Miller and Fuiman, 1987.

*Parameter	Quitobaquito Pond, 1982,	Quitobaquito Pond, 1963,1964	Quitobaquito Spring, 1982	Quitobaquito Spring, 1963-64
TDS	820		670	
TSS	<10		<10	
pH	9.22		8.07	
HCO3	220	411	300	316-402
F	4.9	5.3	4.1	4.3
Cl	190	383	150	148-318
PO4	<0.50		<0.50	
NO3	<0.50		9.9	
SO4	110	100	95	71-91
Na	230	350	188	191-284
K	3.1	7.0	2.7	4.5-6.0

* No units were included in the journal article for this data, convention is mg/l for these parameters except pH, which is in standard units

Transplanted stocks of desert pupfish have been found in Buehman Canyon in 1989 but as of 1993 their status was uncertain (Marsh and Sada, 1993).

According to information posted by a state fishery biologist on the California Department of Fish and Game's web site (Keeney, 2001), the presence of nonnative fishes may be the most significant threat to desert pupfish populations. However, Keeney also stated "pollution by toxic by-products of agricultural activities threaten the desert pupfish." Keeney cited a recent study concluding that high selenium levels in agricultural runoff posed a danger of reproductive failure.

Desert Sucker and Sonora Sucker

No studies specific to these fish were found. Limited information is included in the following section of this report ("Studies of Multiple Species").

Leopard Frogs

The vulnerable lowland leopard frog and the Chiricahua leopard frog are also of interest in Pima County. The lowland leopard frog is generally found in small-to-medium sized streams. It can also be found in stock ponds, springs, or large rivers. Large pools enhance its chances of survival as an adult and reproduction, whereas small pools and extensive marshy vegetation aid the survival of juveniles. Threats to this species are disease, flooding, alteration of riparian habitat by livestock grazing, and the introduction of non-native, predatory fish, crayfish and bullfrogs (Pima County, 2001).

The Chiricahua leopard frogs' habitat includes rocky streams with deep rocky pools, overflow pools and oxbows of rivers, permanent springs, ponds, and wetlands. It also utilizes stock tanks, wells, and mainstream river reaches. Ideal habitat includes permanent water during breeding season, deep pools with nearby shallow areas, undercut banks, overhanging terrestrial vegetation, and aquatic vegetation. While the species can use a variety of aquatic habitats, generally perennial streams and springs are the most important. Potential threats to this species are introduced pest species, loss of habitat resulting from water diversion, groundwater pumping, pollution, and anoxia (Pima County, 2001).

PAG found no information on water quality requirements for *Rana chiricahuensis* or *Rana yavapaiensis*. However, we found one study of the effects of nitrate and nitrite solutions on newly hatched larvae of five species of pond-breeding amphibians from the Pacific Northwest: *Rana pretiosa, Rana aurora, Bufo boreas, Hyla regilla*, and *Ambystoma gracile*. The ranid species had acute effects in water with nitrite. All species showed high mortality at 5 mg/l nitrite-N and significant larval mortality at 1 mg/l nitrite-N. Nitrate at 90 mg/l as N was highly toxic for R. pretiosa and A. gracile larvae (Marco et al.,1999).

Studies of Multiple Species

Friends of the Santa Cruz River monitored water quality in the Santa Cruz River downstream from the Nogales International Wastewater Treatment Plant (NIWTP) for seven years. Since 1995 they have seen an increase in total ammonia, nitrates and nitrites. They documented the negative effect the ammonia had on local fish populations including the endangered Gila topminnow. Also noted was a decline in longfin dace populations. The ammonia is a product of sewage and it has a toxic effect on fish. ADEQ documented the effects of ammonia on longfin dace populations at the Rio Rico Bridge site. It was determined that there was a strong correlation between fish mortality and frequency of diseased fish with the increased concentration of ammonia at that site (Floyd, 2000).

U.S. Fish and Wildlife Service took a closer look at the upper Santa Cruz and in October 1999 published a study by Kirke King and others entitled: *Contaminants as a Limiting Factor of Fish and Wildlife Populations in the Santa Cruz River, Arizona.* This study was prompted by the declining Gila topminnow populations in the Santa Cruz. Four native fish species (longfin dace, desert sucker, Sonoran sucker, and the Gila topminnow) were found in the Santa Cruz River at the various sampling stations. In 1997 the contaminant levels in water, sediment, invertebrates, fish, and birds were assessed. The normal pH of the water in the area ranged from 7.4-7.9. Un-ionized ammonia concentrations as high as 0.49 mg/l were measured. This value is in the range known to be toxic to invertebrates and fish. The water quality data from this study are shown on Table 4 (King et al., 1999).

Table 7. Santa Cruz River Water Quality Parameters, May 30, 1997 (King et al., 1999).

Site Name	Un-ionized Ammonia (mg/l)	pH	Residual Chlorine (mg/l)	Water Temperature °C
Nogales Wash	<0.01	7.9	<0.05	20.5
Rio Rico Bridge	0.49	7.8	<0.05	23.3
Rio Rico North	0.23	7.5	<0.05	23.8
Santa Gertrudis	0.03	7.6	<0.05	23.8
Tubac	<0.01	7.4	<0.05	23.8

The Nogales Wash sampling location is above the wastewater treatment plant. All other locations are downstream from the treatment plant from 1.7 to 11.3 miles from the treatment plant outfall.

There are several captive native fish populations in Pima County. Represented in the captive populations are Gila chub, desert pupfish, Gila topminnow and desert suckers.
The following water quality problems have been noted in the captive populations:

- Winter die-off of aquatic vegetation causing nitrate poisoning of the desert pupfish at one location;
- High chlorine content of potable water supply;
- Desert pupfish adult predation of young due to lack of algae food supply (Pima County, 2000).

In the captive fish populations it has also been noted that the Gila topminnow populations are expanding, but one location noted that system cleaning seems to stress the fish and cause some die-off. The desert pupfish seems to be more sensitive to water quality, i.e. chlorine (Pima County, 2000).

Additional Water Quality Data

Because the literature available on the water quality requirements of the aquatic species of interest were so limited, PAG compiled readily accessible water quality data for the streams in which these species have been found. Although these data do not indicate a water quality requirement for any of the species, they might be useful in a general sense for estimating an acceptable level of water quality.

ADEQ has a significant amount of data for several of the major streams in Pima County. Some of these streams currently support or historically supported several of the vulnerable aquatic species. Longfin dace, Gila topminnow, and Gila chub have been found in Cienega Creek, Davidson Canyon, Mattie Canyon, Santa Cruz River and Sabino Canyon Creek in the Santa Catalina Mountains (Pima County, 2000). Buehman Canyon has longfin dace populations. It was also known to have populations of desert pupfish, but their status is currently uncertain. Although no historic records exist for the portion of the San Pedro River in Pima County, it is assumed that the same species of fish that exist or existed upstream of the Pima County line also existed here. Five species (longfin dace, speckled dace, desert sucker, Sonoran sucker and Gila chub) are known to occur in isolated canyon tributaries of the San Pedro in Pima County (Pima County, 2000). In addition, the Bingham Cienega supports populations of longfin dace and lowland leopard frogs. Canada del Oro and Agua Caliente Canyon were historic leopard frog locations and currently support native fish species. Table 8 includes sample results for four parameters from some of the significant streams in the county. There are currently no data in ADEQ's database for the following priority streams in Pima County: Mattie Canyon, Empire Gulch, Davidson Canyon, Rincon Canyon, Wakefield Canyon, and Romero Canyon.

Table 8. Selected Water Quality Data from ADEQ Database.

LOCATION *	Date Sampled	Temperature (water)	Specific Conductivity	Dissolved Oxygen	pH
Agua Caliente Canyon	4/13/95	14.9	136	9.3	7.28
Buehman Canyon (1)	5/18/00	21	461/460	56.5 % 4.44 mg/l	6.93 7.2
Buehman Canyon (2)	7/15/97	19.6	380/399	69.5 % 5.7 mg/l	7.32 7.48
Canada del Oro	4/7/94	13	102	9.6	8.01
San Pedro	8/13/91	33.0	550/590	109.9 % 7.20 mg/l	8.4 8.2
Sabino Creek (1)	7/23/91	12.5	127	N/A	6.63
Sabino Creek (2)	4/18/01	15.4	53	96.7 % 9.5 mg/l	6.9
Cienega Creek (1)	9/28/98	19.7	993	97.5 % 8.13 mg/l	7.92
Cienega Creek (2)	9/29/98	20.2	703	57.4 % 4.59 mg/l	7.6

*Location Descriptions:
Agua Caliente Canyon at the national forest boundary; Buehman Canyon (1) two miles below confluence with Bullock Creek; Buehman Canyon (2) above the USFS roads 801 and 654; Canada del Oro at the Pima/Pianl County line; Tanque Verde Creek at Sabino Canyon; San Pedro River at Redington; Sabino Creek (1) below Summerhaven; Sabino Creek (2) above the visitor center near first rest stop; Cienega Creek (1) at Marsh Station Road; Cienega Creek (2) above the Diversion Dam.

Cienega Creek was monitored by ADEQ at several locations. Stream Ecosystem Monitoring was conducted below Stevenson Canyon and below the Narrows in 1998. No results are listed in the 305(b) report but ADEQ designated these sections as being Full Support. ADEQ monitored Cienega Creek above the Narrows for the Biocriteria Program from 1992-1996. This segment was also classified as being in Full Support and no results were provided in the report. Also, sampling in 1992 and 1993 below the Empire Cienega Resource Conservation Area indicated full support. The portion of Cienega Creek from Interstate 10 to the Del Lago Dam was monitored at several locations. In 1998 a sample was collected from above the diversion dam and was analyzed for Dissolved Oxygen. The result of 4.59 mg/l did not meet the standard, and ADEQ commented that the low DO was naturally occurring. Stream Ecosystem Monitoring was also conducted above and below Davidson Canyon in 1998. The DO result for above Davidson Canyon was 5.4 mg/l and did not meet the standard. The use support was designated full and ADEQ commented that there was "naturally low DO". Twenty samples were collected from Cienega Creek at Marsh Station Road 1991-1995 for analyses of Dissolved Oxygen. The results ranged from 4.75-11.2 mg/l with 1 of 25 not meeting the standard (ADEQ, 2000).

Summary and Conclusions

Little detailed information is readily available on the specific water quality requirements of Pima County's native aquatic species. Other threats aside, aquatic species generally thrive when the waterbodies in which they reside have water quality characteristics that are typical of "healthy" waterbodies. For Pima County this includes physical characteristics as well as chemical characteristic of pH ranging from 6.5-8.5, EC from 50-1500 µmohs/cm, and DO between 7.5-8.3mg/l.

Some studies were found that focused on specific water quality concerns and particular species. The following conclusions can be drawn from those studies:

- Longfin dace are generally more sensitive to zinc toxicity and less sensitive to copper toxicity than fathead minnows.
- Metals in solution in combination generally exhibit additive toxicity with a copper-zinc solution being more toxic to the longfin dace than any single metal solution studied.
- Natural populations of longfin dace and Gila topminnow declined when un-ionized ammonia at concentrations of up to 0.49 mg/l were found in the upper Santa Cruz River.
- Desert pupfish can survive under conditions of very high water temperatures (45 °C), low DO (0.1-0.4 mg/l), and high salinity.
- Gila topminnows can live in waters with pH ranges from 6.6-8.9, DO levels from 2.2-11.0 mg/l and salinities as high as seawater.
- Available data for some of Pima County's major streams indicate general water quality parameters are within the range capable of supporting native aquatic life. EC ranges from 53-993 µmohs/cm, pH from 6.63-8.4, and DO from 4.44-9.5 mg/l.
- A study of several different species of frogs in the Pacific Northwest found that newly hatched larvae showed acute effects to nitrite. All the species studied showed high mortality at nitrite concentrations of 5 mg/l and significant larval mortality at 1 mg/l.

At this time a comprehensive project that is characterizing the unique aquatic and terrestrial habitats in the arid west in nearing completion. The Arid West Water Quality Research Project (WQRP) is being conducted by Pima County Wastewater Management Department with cooperation from the U.S. Environmental Protection Agency. The objective of this project is to determine if existing standards for dischargers to ephemeral streams need to be modified or if a new set of standards for dischargers should be developed to protect effluent-dependent aquatic and riparian habitat in the arid west. Other objectives are to define biological resources and their needs for protection, and to develop a habitat classification system for the arid west (Pima County Wastewater Management Department, 2001).

In addition, the University of Arizona is just beginning work on two projects aimed at studying water quality requirements of desert fishes. One project will look at temperature requirements of selected desert species and the other will involve mapping stream conditions in Arizona and their relationship with fish distribution (Bonar, 2001).

Based on the information we have for natural waterbodies in Pima County, current general water quality conditions appear to be acceptable for meeting the needs of native aquatic species. Habitat destruction and the introduction of non-native species appear to be the major threats to these vulnerable species. However, additional water quality data is needed on the specific requirements and threats to the native species, and in particular the leopard frogs and the desert suckers. More regional information may be available with the completion of the above mentioned studies.

Native aquatic species seem to be able to tolerate low dissolved oxygen levels, a wide range of temperatures and pH, and high salinities. High concentrations of nutrients and metals appear to be toxic.

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