BibKey
623168

Survey of Amphibians and Amphibian Habitat on the Upper Santa Cruz River, Arizona

Report to U.S. Bureau of Reclamation

Charles A. Drost
USGS Biological Resources Division
Colorado Plateau Research Station
Box 5614, Northern Arizona University
Flagstaff, AZ 86011

October 1998

Survey of Amphibians and Amphibian Habitat on the Upper Santa Cruz River, Arizona

Abstract. We conducted a baseline survey of amphibian species and numbers along the Santa Cruz River in the vicinity of the Nogales International Waste Water Treatment Plant (IWWTP) in southern Arizona during 1997 and 1998. The Santa Cruz River is an "effluent-dominated stream," with most of the water supplying the river coming from waste water released by the IWWTP. The river and associated riparian habitat support at least five species of amphibians, including Couch's and southern spadefoot toads, Woodhouse's toad, canyon treefrog, and the introduced bullfrog. Three species of semi-aquatic reptiles also occur along the river, including the Sonoran mud turtle, checkered garter snake, and black-necked garter snake. Amphibian diversity and numbers are highest in the floodplain of the river above the IWWTP, and at sites 10 - 25 km below the treatment plant. Toxic levels of ammonia are released by the IWWTP, and no amphibians are found along the river from the waste water outfall, downstream for several km. No sublethal effects (deformities, developmental abnormalities) were noted from other potential pollutants from the IWWTP, but our sample size was small.

INTRODUCTION

The Santa Cruz River rises in northern Mexico and flows north across the Mexico - United States border, joining the Gila River southeast of Phoenix, Arizona. The river enters the U.S. just east of the town of Nogales. Most of this upper section of the river in southern Arizona is dry for much of the year, except for a 25 km section north of Nogales. The source of this perennial section of the river is partly from Potrero Creek (also known as Nogales Wash); however, much of the water that maintains the flow in this reach is from the Nogales International Waste Water Treatment Plant (IWWTP).

Water from the IWWTP is largely responsible for maintaining a rich riparian system along the Santa Cruz River channel north of Nogales. Cottonwood - willow forest along this stretch of the river, and the variety of wildlife it supports, would not be present without this continued flow. However, water from the IWWTP carries levels of some pollutants (particularly ammonia) that are toxic to aquatic organisms, which limits the diversity and numbers of strictly aquatic species the river supports.

The Nogales IWWTP is under requirement to reduce the levels of ammonia and other pollutants it discharges into the Santa Cruz River. This study was undertaken as part of a larger baseline biological study that is evaluating existing conditions along the Santa Cruz River downstream of Nogales, including water quality and the diversity, abundance, and condition of animal and plant communities. Specific biological groups being studied include aquatic invertebrates, fish, and amphibians and reptiles. This report describes the results of surveys for amphibians and aquatic reptiles conducted in 1997 and 1998.

Objectives

Goals of the overall biological baseline study include assessment of current water quality with respect to proposed water quality standards in the Upper Santa Cruz River; evaluating the current status of aquatic biological communities, and their potential use as ecological criteria of natural and anthropogenic changes in the river; and determining potential release of complex refractory organic compounds and endocrine disrupting chemicals from the IWWTP. These

results should contribute to the ongoing NAWQA program of the U.S. Geological Survey, and the future contaminants study by the U.S. Fish and Wildlife Service.

Specific objectives of the amphibian portion of the study include:

1) determine species diversity of amphibians and aquatic-dependent reptiles along the Santa Cruz River in the vicinity of Nogales and the area affected by IWWTP water;

2) determine relative abundance of amphibians and reptiles at different study sites along this section of the river;

3) relate species occurrence and abundance to water quality (as affected by IWWTP effluent) and habitat variables;

4) investigate possible mortality or deformities in relation to endocrine disrupting chemicals, if these are found to be present.

STUDY AREA

The overall study area extends from the upper Santa Cruz River just north of the Mexican border, and Potrero Creek in the town of Nogales, north to the vicinity of Amado. Specific sample sites were chosen to coincide with water quality and aquatic macroinvertebrate sampling sites (Boyle 1998). These sites are listed in Table 1 (see also Figure 1). The sample sites may be divided into sites above the IWWTP outfall (Potrero Creek, IWWTP / upper), and hence not influenced by effluents from IWWTP, and sites below the IWWTP outfall (IWWTP / lower, and all sites downstream).

All sites were defined in terms of the river or creek bed and the adjacent flood plain, and generally took in a 200 - 300 m long stretch of the river. Channel morphology determined the width of the area surveyed at each site. For example, Potrero Creek is a steep-banked ditch along its lower section, so the area surveyed was confined to the stream itself and narrow banks on either side. The Santa Cruz River through the study area meanders across a broad flood plain along most of its course. This is very broad in some areas, extending into low-lying forest on either side of the river, and relatively narrow in others, confined between steep banks as at the Rio Rico bridge.

Table 1. Sampling sites for amphibians and semi-aquatic reptiles along the upper Santa Cruz River in the vicinity of Nogales, Arizona. Sites are listed from upstream (Mexican border) to downstream (Santa Cruz / Pima County border). Distance in km from the International Waste water Treatment Plant (IWWTP) is listed for each site. Kino Springs, Potrero Creek, and IWWTP / upper are above (upstream of) the outfall; all other sites are below (downstream).

Kino Springs: spring and artificial lake complex on the Santa Cruz River approximately 13.5 km upstream of the confluence with Potrero Creek, and the IWWTP [15 km upstream]

Potrero Creek: lower section of Potrero Creek (also called Nogales Wash); two areas of the creek were surveyed - at the Ruby Road interchange north of Nogales, and the lower creek just above its confluence with the Santa Cruz River (along the southeast side of the IWWTP) [1.5 km upstream]

IWWTP / upper: Santa Cruz River at the Nogales International Waste Water Treatment Plant, from Potrero Creek to the outfall of the treatment plant [0.1 km upstream]

IWWTP / lower: Santa Cruz River at the Nogales International Waste Water Treatment Plant, downstream from the treatment plant outfall [0 - 0.2 km downstream]

Rio Rico: Rio Rico Road bridge over the Santa Cruz River; separate 200 m stretches of the river were surveyed upstream of the bridge, and downstream of the bridge [3 km downstream]

Palo Parado: Santa Cruz River in the vicinity of the Palo Parado interchange on Interstate 19; site is accessed via a dirt road leading west from Pendleton Road, 8.3 km north of Rio Rico Road. The dirt road is opposite Camino Mar [10.5 km] - Exit 2 exits down from mission

Carmen: bridge across the Santa Cruz River on Bailey Road at Carmen, north of Tumacacori National Monument [18.5 km] Clark-crossing.

Tubac: bridge across the Santa Cruz River at Tubac [22 km]

Chaves Siding: bridge on Chaves Siding Road, south of the Chaves interchange [25 km]

Figure 1. Study area for the Santa Cruz River / Nogales International Waste water Treatment Plant (IWWTP) baseline biological survey. Sampling sites are listed along the study area reach, and range from Kino Springs on the upstream end to Chaves Siding on the downstream end. The outfall of the IWWTP is also indicated.

METHODS

Background data

There is a diverse amphibian fauna in southern Arizona in the vicinity of the upper Santa Cruz River. As an initial step in this survey, we prepared a hypothetical species list for the area (Table 2). The species listed are those which range into the upper Santa Cruz River area, and for which suitable habitat exists along the river corridor from the Mexican border north to the Santa Cruz - Pima County line. In addition to the amphibian species listed, there are also several reptile species that are closely associated with water, that we decided to include in the survey. These included: Sonoran mud turtle (*Kinosternon sonoriense*); black-necked garter snake (*Thamnophis cyrtopsis*); checkered garter snake (*T. marcianus*); and Mexican garter snake (*T. eques*).

We also conducted a museum and literature search to determine what has been previously documented of actual presence of amphibians and semi-aquatic reptiles along this stretch of the Santa Cruz River. We visited or obtained records from major Arizona museums (University of Arizona, Arizona State University, Museum of Northern Arizona) and national museums (University of Michigan). We reviewed records for Santa Cruz County (which includes all of the project study area), and noted those records in proximity to the Santa Cruz River. We noted species identification, number, date, precise location, and habitat, and compiled this information in a separate database

Table 2. Hypothetical List of Amphibians in the vicinity of the upper Santa Cruz River / Nogales area. Species are listed in taxonomic order.

Tiger Salamander (*Ambystoma tigrinum*)
Couch's Spadefoot (*Scaphiopus couchii*)
Southern Spadefoot (*Scaphiopus multiplicatus*)
Colorado River Toad (*Bufo alvarius*)
Great Plains Toad (*Bufo cognatus*)
Red-spotted Toad (*Bufo punctatus*)
Woodhouse's Toad (*Bufo woodhousii*)
Canyon Treefrog (*Hyla arenicolor*)
Western Narrow-mouthed Toad (*Gastrophryne olivacea*)
Bullfrog (*Rana catesbeiana*)
Chiricahua Leopard Frog (*Rana chiricahuensis*)
Lowland Leopard Frog (*Rana yavapaiensis*)

Field surveys

Amphibians and reptiles were surveyed during three sampling periods during the spring and summer (late spring and summer/monsoon), when local species are likely to be active in appropriate habitats. Surveys were designed to determine species composition, relative abundance, habitat use, and reproduction. Field sampling methods used included: 1) time-constrained searches; 2) night-time call surveys; and 3) night-time road surveys. We also raised up tadpoles and newly-transformed young toads, both to confirm identifications, and also to look for any abnormalities in mortality rate or morphological development. Survey methods are described in detail in the following paragraphs.

Time-constrained searches involve searching through a defined area for a set amount of time (one hour in the case of our surveys) and noting and identifying all amphibians and reptiles seen. Our search areas were 200 - 300 m sections of stream and adjacent flood plain, and we searched these areas by walking back and forth across the entire area, working along the edges of the stream, and wading through the stream, looking for animals active on the surface or in the water. We also turned over available cover (driftwood, rocks, boards) and searched through debris piles, as amphibians and reptiles frequently take shelter in these locations. We scanned for both adult amphibians and larvae (tadpoles) in the water, both in the main stream channel and also in overflow pools in the flood plain. We swept pools and stream with aquatic nets, especially around aquatic plants, or where the water was turbid, to capture aquatic animals.

We visited the survey sites at night and conducted *call surveys*. Breeding anurans (frogs and toads) gather around pond and stream sites at night during their breeding period. Listening for their distinctive calls at these areas is the best way to locate and identify some species. We conducted call surveys at the survey sites between dusk and midnight, with time at individual sites varying from 15 minutes to an hour. For all amphibians heard, we recorded date, time, survey site, specific location within the site, species identification, estimated number, and environmental conditions at the time.

We also conducted *night-time road surveys* on secondary roads paralleling or crossing the Santa Cruz River in the vicinity of designated survey sites. Amphibians and reptiles frequently come out onto, or are seen crossing such roads during the evening hours. We drove along roads slowly (20 - 25 mph) looking carefully in the light of the vehicle headlights, for toads, frogs, and snakes on the road. For any animals seen, we stopped the vehicle and captured the animal if possible, or got close enough to confirm species identification. We noted time, location, species identification, and individual animal data, for all animals seen.

For all animals captured, we recorded species identification, along with standard measurements (age, sex, body length, tail length, weight, and any special identifying characteristics). For some tadpoles and newly-transformed young toads and frogs, we also collected samples of live individuals and transported them back to the lab to aquaria or terraria, where we raised them up. This was done both to confirm species identifications in some instances, and also to assess the health of young individuals.

At each site, we recorded habitat information, including size of stream (width, depth, rate of flow, presence of pools or slack water areas), substrate, presence of aquatic plants, and water temperature and turbidity. We also noted size and character of flood plain, presence of overflow areas, and the composition, extent, and condition of terrestrial vegetation within the flood plain. Environmental conditions (air temperature, water temperature, cloud cover, wind, and rain) were recorded during individual surveys.

RESULTS

We spent a total of 35 field-hours on time-constrained searches and night call surveys for amphibians along the upper Santa Cruz River, during three sampling sessions in May and September 1997, and May 1998 (Table 3). This was broken down as 7.3 hrs in May 1997, 19.7 hrs in August 1997, and 8 hrs in May 1998. In addition, we spent approximately 5 hours in road-driving at night.

Table 3. Timing and location of amphibian surveys along the upper Santa Cruz River for Nogales International Waste water Treatment Plant baseline study. Within each month's sampling period, sites are listed in order from upstream to downstream. Methods are general overview and search of an area, time-constrained search (TCS), dip-netting (Dip), and road surveys at night (Night).

Site	Date	Method(s)	Time (min.)
May 1997			
Potrero Creek/Ruby	05/21/97	General	30
Potrero Creek	05/21/97	TCS, Dip	40
IWWTP/lower	05/21/97	TCS	35
Rio Rico/upstream	05/20/97	TCS	70
Rio Rico/downstream	05/20/97	TCS	68
Carmen	05/21/97	TCS, Dip	75
Tubac	05/20/97	TCS	60
Chaves Siding	05/21/97	General	60
August 1997			
Kino Springs	08/23/97	TCS	270
Potrero Creek/Ruby	08/21/97	General	30
IWWTP/upper	08/21-22/97	TCS, Night	180
IWWTP/lower	08/21/97	General	45
Rio Rico	08/21/97	TCS, Night	180
Palo Parado	08/22/97	TCS, Night	165
Carmen	08/23/97	TCS	180
Tubac	08/21/97	Night	30
Chaves Siding	08/22-23/97	TCS, Night	100
May 1998			
IWWTP/upper	05/15-17/98	TCS, Night	82
Rio Rico	05/17/98	TCS, Night	83
Palo Parado	05/16/98	TCS	94
Carmen	05/16/98	TCS, Dip	61
Tubac	05/16/98	TCS, Night	80
Chaves Siding	05/16-17/98	TCS, Night	80

Amphibian and reptile species

We recorded at least five amphibian species in surveys throughout the study area (Table 4, Figure 2). These included two spadefoot toad species, one true toad, one treefrog, and one ranid frog - the introduced bullfrog from eastern North America. On a preliminary survey along the river near the Carmen site, we briefly heard the calls of what sounded like western narrow-mouthed toads. However, we did not hear or see this species again during the course of the survey work, so we have listed this species on a provisional basis, pending confirmation of its occurrence.

In addition to the amphibians, we also included in the survey reptile species that are more or less dependent on surface water. Reptiles encountered along the Santa Cruz River in the survey area that match this description include the Sonoran mud turtle and two garter snake species. Other reptiles encountered during the surveys that are not dependent on water included tree lizard (*Urosaurus ornatus*), Sonoran spotted whiptail (*Cnemidophorus sonorae*), long-nosed snake (*Rhinocheilus lecontei*), and western diamondback rattlesnake (*Crotalus atrox*).

Among the amphibians, indication of breeding was found for the two spadefoot toad species (tadpoles for southern spadefoot, newly transformed young for Couch's spadefoot), Woodhouse's toad (tadpoles), and bullfrog (tadpoles). Only adult individuals were seen or heard for the other species.

Table 4. Amphibian and semi-aquatic reptile species recorded along the upper Santa Cruz River in a baseline biological study for the Nogales International Waste Water Treatment Plant, between May 1997 and May 1998. Species are listed in taxonomic order.

Amphibians
Couch's Spadefoot (*Scaphiopus couchii*)
Southern Spadefoot (*Scaphiopus multiplicatus*)
Woodhouse's Toad (*Bufo woodhousii*)
Canyon Treefrog (*Hyla arenicolor*)
Western Narrow-mouthed Toad (*Gastrophryne olivacea*) [1]
Bullfrog (*Rana catesbeiana*)
Reptiles
Sonoran Mud Turtle (*Kinosternon sonoriense*)
Black-necked Garter Snake (*Thamnophis cyrtopsis*)
Checkered Garter Snake (*Thamnophis marcianus*)

Insert Fig. 2

Distribution and numbers

Couch's spadefoot and Woodhouse's toad were the most common amphibians in the study area. We recorded a total of 21 juvenile and adult Couch's spadefoot toads at four of the sampling sites (day and night surveys combined), and 20 juvenile and adult Woodhouse's toads at five sampling sites. Figure 3 (a. and b.) shows distribution of these species in the study area. A total of 11 adult bullfrogs were found at four sites (Fig. 3c). Southern spadefoot toad was only found at one site (Palo Parado, where several tadpoles were found in an overflow pool), and is included in the map for Couch's spadefoot. The lone canyon treefrog recorded was a single individual heard calling upstream of the Rio Rico bridge on 16 May 1998.

Semi-aquatic reptiles were scarce along the river. Only two mud turtles were found, at two sites - one adult in lower Potrero Creek, and one juvenile in an overflow pool along the river downstream of the Rio Rico bridge (Fig. 3d). Likewise, only two garter snakes were found in the study area, one black-necked garter snake at the IWWTP above the outfall, and one checkered garter snake downstream from the Rio Rico bridge (Fig. 3e).

No amphibians were found in the river below the IWWTP outfall, and a single juvenile Couch's spadefoot was the only amphibian found at the Rio Rico bridge, the sampling site downstream of the outfall. Woodhouse's toad was generally distributed along the river, except for the IWWTP reach below the outfall, and the Rio Rico site (Figure 4, upper). The spadefoot toads (Couch's and southern spadefoot combined) were found in numbers at the IWWTP site above the outfall and at the Palo Parado site, but were essentially absent elsewhere along the river (Figure 4, lower).

Mortality / developmental abnormalities

No evidence of unusual mortality was seen among adult or larval amphibians, nor among semi-aquatic reptiles. Likewise, no developmental abnormalities were noted in the field. We captured small numbers of all species encountered, and kept a sample of four newly-transformed Couch's spadefoot toads to raise up in a terrarium in the lab (Figure 2, top). No abnormalities were noted in any of the animals examined in the hand, nor among the spadefoot toads that were raised to maturity.

Figure 3. (*following pages*) Distribution of amphibians and semi-aquatic reptiles along the Santa Cruz River in the vicinity of the Nogales International Waste Water Treatment Plant. Distribution data are from surveys conducted for a baseline biological survey of the area between May 1997 and May 1998.

Figure 4. Distribution of Woodhouse's toad and spadefoot toads (*Scaphiopus* sp.) in sampling areas along the Santa Cruz River in the vicinity of the Nogales International Waste Water Treatment Plant (IWWTP). Abbreviations for sampling sites are: TP/u - IWWTP, upper (above the treatment plant outfall); TP/l - IWWTP, lower (below the treatment plant outfall); RRi - Rio Rico bridge; PPa - Palo Parado; Car - Carmen; Tub - Tubac; Cha - Chaves Siding Road.

Relation to effluent compounds and water quality

Water quality data were collected separately throughout the time span of this study by Dr. Terry Boyle of the USGS Midcontinent Ecological Science Center (Boyle 1998). Table 5 summarizes data collected between May 1997 and March 1998 (see Appendix 2 for detailed, site by site data). We concentrated on the spring and summer water quality data, because all amphibian breeding, and most amphibian activity, occurred during this time period. Water temperature varied over a moderate range at the different study sites, and was comparatively warm in the August samples (Fig. 5). In the May data, input from the IWWTP is relatively warm, and temperatures decrease downstream [note in Fig. 5 that PCr, Potrero Creek, is a tributary of the Santa Cruz River above the IWWTP, and TP/I (=Treatment Plant / lower) is just downstream of the IWWTP outfall].

Dissolved oxygen levels are moderate to somewhat low, and show a dip below the IWWTP outfall (particularly evident in the May data; Fig. 6). However, dissolved oxygen levels are not so low as to have an effect on amphibian populations. Other water quality parameters measured (pH, alkalinity, conductivity) are within a normal range, and are not expected to affect amphibian occurrence or numbers. However, ammonia (NH3) and ammonium (NH4+) spike up to high levels at the IWWTP outfall, then gradually decrease to baseline levels well downstream (Fig. 7).

Table 5. Mean and range (in parentheses) of monthly values for water quality measurements from the Santa Cruz River in the vicinity of the Nogales International Waste Water Treatment Plant. DO is dissolve oxygen in ml/l, temperature is in ^{o}C, COND is conductivity in µS, ALK is alkalinity in mg/l, NH3 and NH4 are ammonia and ammonium ion, respectively, in mg/l.

DATE	DO	TEMP	COND	PH	ALK	NH3	NH4
May 97	5.7 (4.1-8.6)	19.1 (17.0-23.0)	17.1 (14.0-17.9)	8.0 (7.8-8.3)	225.5 (200.0-251.0)	0.299 (0.002-0.633)	8.376 (0.047-16.884)
Aug. 97	4.6 (3.6-6.7)	27.0 (24.0-30.0)	14.7 (11.3-17.1)	7.7 (7.5-7.9)	181.2 (135.0-229.0)	0.336 (0.015-0.764)	8.865 (0.281-18.093)
Dec. 97	9.5 (8.6-10.2)	9.2 (6.0-11.0)	507.0 (240.0-752.0)	8.0 (7.8-8.2)	166.1 (79.0-236.0)	0.191 (0.006-0.438)	10.406 (0.617-24.211)
Mar. 98	7.5 (6.2-10.2)	13.2 (12.0-14.0)	459.2 (235.0-566.0)	7.6 (7.3-8.1)	176.0 (89.0-210.0)	0.095 (0.001-0.204)	11.891 (0.088-27.113)

Insert Fig. 5, 6, 7:

No amphibians were found between the IWWTP outfall and the Rio Rico bridge, and significant numbers of amphibians were not encountered until the Palo Parado site, 10.5 km downstream from the outfall. Along the Santa Cruz River just above the IWWTP outfall, we found adults and large numbers of tadpoles of Woodhouse's toads and Couch's spadefoot toads. At Palo Parado, 10.5 km below the IWWTP outfall, we found numbers of adult and larval Woodhouse's toads and Couch's and southern spadefoot toads. Except for one small Couch's spadefoot toad found at the lower Rio Rico Site (RR4 in Fig. 7) in August 1997, and a canyon treefrog heard calling along the stream just above the Rio Rico bridge in the May 1998 sampling period, no amphibians were encountered in the intervening area of high ammonia levels (0.37 - 0.76 mg/l).

DISCUSSION

Amphibian and reptile species

Overall amphibian diversity and numbers along the river were low during all survey periods. Five species of amphibians (and a possible sixth), two species of aquatic snakes, and one turtle were recorded during this survey. The most abundant amphibian species along the river were Couch's spadefoot toad and Woodhouse's toad. The bullfrog, a non-native species introduced from eastern North America, was present at a few sites along Potrero Creek and the Santa Cruz River. Small numbers of semi-aquatic reptiles were found, including black-necked garter snake and checkered garter snake and Sonoran mud turtle. The amphibian species found amounted to about half of the species that should be expected for this area (see Table 2). The most noteworthy absence is the lowland leopard frog. Although there are no historical collection records for this species along this stretch of the Santa Cruz River (J. Howland, Arizona Game and Fish Dept., pers. comm.), the river and its associated habitats may provide good potential for supporting the species.

Distribution and numbers

During the winter rainy season, the entire length of the Santa Cruz River from the Mexican border to well north of the study area has flowing water. Outside of the wet season, however, the river dries up except for the area from Potrero Creek downstream to the Chaves Siding area. Above Potrero Creek and below Chaves siding, the stream channel is generally dry. The intervening perennial portion of the river receives its water from Potrero Creek and the IWWTP. There are some amphibians outside of the perennial area of the stream, but numbers are probably quite low, and activity strongly limited to wet periods from summer monsoon storms. For example, we noted toad tracks in damp mud at the Kino Springs site (well upstream of Potrero Creek), but the river channel was dry and no other evidence of amphibians was seen.

Amphibians were generally distributed in low to moderate numbers along the perennial portion of the Santa Cruz River and Potrero Creek, except for the 10 km stretch below the IWWTP outfall (Fig. 3 and 4). Highest numbers were found 1) in the broad floodplain of the river between the mouth of Potrero Creek, and the IWWTP outfall; 2) around overflow pools at Palo Parado; and 3) along the river at Chaves Siding. Spadefoot toads were the most numerous species at the first two sites. At the uppermost site, adult Couch's spadefoots were present on the mudflats during night surveys, and recently transformed young were common during the day between the confluence with Potrero Creek, and the IWWTP outfall. At the lowermost site (Chaves Siding), adult and young Woodhouse's toads were most common.

Evidence of amphibian breeding was seen at most sites where we recorded amphibians. Larval (tadpole) or recently transformed young spadefoot toads were recorded at the floodplain above the IWWTP, below the Rio Rico bridge (one individual), and at Palo Parado. Woodhouse's

toads were more widespread: we found tadpoles or young toads at the floodplain area, Palo Parado, Carmen, and Chaves Siding. A single bullfrog tadpole was caught in an overflow pond along the river at the Palo Parado site, and a juvenile Sonoran mud turtle was found in a floodplain pool downstream of the Rio Rico bridge.

Numbers of amphibians and semi-aquatic reptiles were lower than expected along much of the perennial stretch of the Santa Cruz River, and were absent entirely in the stretch of river below the IWWTP outfall. There are a number of probable reasons for this: 1) As discussed below, there were toxic levels of ammonia in the stretch of river below the IWWTP; 2) Overflow pools were limited or non-existent along parts of the river. These pools are favored breeding areas for some of the species that occur in the area, and channelization and other alterations to the river appear to have severely reduced these habitats; 3) For the semi-aquatic reptiles, scarcity of food is probably limiting. Fish, frogs and toads, and tadpoles are important prey for both the garter snakes and the mud turtles. These prey species are entirely absent for several km below the IWWTP outfall, and are low in number further downstream. The levels of ammonia in the river probably do not cause direct mortality of the reptile species, but indirect effects (scarcity of their prey) probably accounts for the low numbers observed (cf. Jennings et al. 1992).

Mortality / developmental abnormalities

Acute toxicity from high levels of ammonia appears to be the most important factor influencing the species composition and numbers of amphibians along this stretch of the Santa Cruz River (discussed below). The amphibians along Potrero Creek and the Santa Cruz River above the IWWTP outfall are upstream of chemical compounds contained in the IWWTP effluent. Adult and young amphibians examined in this area appeared healthy and had no apparent abnormalities. Similarly, young and adult toads from farther downstream (where levels of ammonia had decreased to non-toxic levels) did not show evident abnormalities. Sample sizes were quite small, however, and we do not consider these limited results to be conclusive for sublethal effects.

Relation to effluent compounds and water quality

Amphibians were absent from the stretch of the Santa Cruz River with high levels of ammonia and ammonium ion (Figure 7; Appendix 2). Unionized ammonia is much more toxic than ammonium ion (Abel 1989), so we concentrated our analysis on ammonia. Above the IWWTP outfall, levels of ammonia were very low during the spring and summer (0.01 mg/l or less), and both Couch's spadefoot and Woodhouse's toad were found in moderate numbers. Below the outfall and downriver for over 10 km, ammonia levels sharply increase, reaching levels of at least 0.75 mg/l. Ammonia does not decrease to moderate levels (less than 0.2 mg/l) until downstream of Rio Rico. Except for one juvenile Couch's spadefoot found downstream of the Rio Rico bridge, no amphibians were found below the IWWTP outfall, until the Palo Parado site (between Rio Rico / RR4 and Santa Gertrudis in Fig. 7).

Levels of ammonia of 0.3 - 0.5 mg/l are highly toxic to a variety of fish species (Jφrgensen et al., 1991), and apparently to the toads and spadefoots along this stretch of the Santa Cruz River. In fact, we observed virtually no living aquatic organisms between the IWWTP outfall and the Rio Rico sites. Aquatic invertebrates were conspicuously absent. Likewise, fish were not found in over 10 km of river below the IWWTP. In general, fish distribution and abundance paralleled that of amphibians. Dace and topminnows were noted in greatest abundance in Potrero Creek and the river above the IWWTP outfall. No fish were seen in the river below the IWWTP or at the Rio Rico bridge site, in spite of careful searching and clear waters in which fish would be easily seen. We did not see numbers of fish in the river again until well downstream, at the Carmen site (fish species and numbers along the Santa Cruz River were studied in detail by a separate investigator, as part of the overall baseline survey for the IWWTP).

→ Find paralled b/t fish & amphibs @ baseline data

Sonoran Institute & other agencies annually monitor the upper ~~Sonoran~~ Santa Cruz → fish are an indicator that is monitored.
↳ if Park can correlate amphib pop to fish pop make trends.

Overview and Recommendations

Based on the results of this work, we draw the following conclusions:

1. Five amphibian species and three semi-aquatic reptiles live along the Santa Cruz River in the vicinity of, and downstream from, the Nogales International Waste Water Treatment Plant (IWWTP), with Couch's spadefoot toad and Woodhouse's toad most numerous. Amphibian numbers are highest in the broad river floodplain above the IWWTP, and at the Chaves Siding site, farthest downstream from the IWWTP.

2. Toxic levels of ammonia apparently exclude amphibians from over 10 km of the river below the IWWTP outfall. We did not find evidence of lethal or sublethal effects (e.g. malformities, developmental abnormalities) from other compounds, but our sample size was small.

3. In spite of the high levels of ammonia that exclude amphibians below the IWWTP, the river and associated riparian habitat, which are supported in large measure by discharges from the IWWTP, are valuable habitats for local amphibians. If lower levels of toxic ammonia were released from the IWWTP, the area would support higher numbers, and possibly more species, of amphibians and semi-aquatic reptiles.

4. With improved water quality from the IWWTP, this stretch of river may provide potential habitat for some state-rare native species, such as the lowland leopard frog (*Rana yavapaiensis*).

LITERATURE CITED

Abel, P. D. 1989. Water pollution biology. Ellis Horwood Ltd., Chichester, England.

Boyle, Terence P. 1998. [Report on water quality and aquatic macroinvertebrates, Santa Cruz River / IWWTP]. USGS Midcontinent Ecological Science Center, Colorado State University

Crump, M. L., and N. J. Scott, Jr. 1994. Visual encounter surveys. pp. 84-91 in: W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, eds. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, USA.

Jennings, W. B., D. F. Bradford, and D. F. Johnson. 1992. Dependence of the garter snake *Thamnophis elegans* on amphibians in the Sierra Nevada of California. Journal of Herpetology 26:503-505.

Jones, K.B. 1986. Amphibians and reptiles. Chapter 14 In A.Y. Cooperrider, R.J. Boyd, and H.R. Stuart. (eds). Inventory and monitoring of wildlife habitat. United States Department of Interior, Bureau of Land Management Service Center, Denver, CO.

Jφrgensen, S. E., S. N. Nielsen, and L. A. Jφrgensen. 1991. Handbook of ecological parameters and ecotoxicology. Elsevier, Amsterdam.

Shafer, H.B., and J.E. Juterbock. 1994. Night driving. pp 163-166 in Chapter 7, Supplemental Approaches, In W.R. Heyer, M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster, eds. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, USA.

Appendix 1. Species and numbers of amphibians and semi-aquatic reptiles recorded in surveys along the upper Santa Cruz River for Nogales International Waste water Treatment Plant baseline study. For each month, sites are listed in order from upstream to downstream.

Date	Site	Species	Age	Number
May 1997				
05/21/97	Potrero Creek/Ruby	Bullfrog	adult	2
05/21/97	Potrero Creek	Sonoran Mud Turtle	adult	1
05/21/97	IWWTP/lower			0
05/20/97	Rio Rico/upstream			0
05/20/97	Rio Rico/downstream	Checkered Garter Snake	adult	1
05/21/97	Carmen			0
05/20/97	Tubac / Bridge Road			0
05/21/97	Chaves Siding			0
August 1997				
08/23/97	Kino Springs			0
08/23/97	Kino Springs Lake	Bullfrog	adult	6
08/21/97	Potrero Creek/Ruby	Bullfrog	adult	2
08/21/97	IWWTP/upper	Couch's Spadefoot	juvenile	8
08/21/97	IWWTP/upper	Black-necked Garter Snake	adult	1
08/22/97	IWWTP/upper	Couch's Spadefoot	adult	2
08/21/97	IWWTP/lower			0
08/21/97	Rio Rico			0
08/22/97	Rio Rico/downstream	Sonoran Mud Turtle	juvenile	1
08/22/97	Rio Rico/downstream	Couch's Spadefoot	juvenile	1
08/22/97	Palo Parado	Southern Spadefoot	larvae	2
08/22/97	Palo Parado	Couch's Spadefoot	juvenile	7
08/22/97	Palo Parado	Couch's Spadefoot	adult	1
08/22/97	Palo Parado	Bullfrog	adult	1
08/23/97	Carmen	Toad sp. (unid.)	juvenile	1
08/21/97	Tubac / Bridge Road			0
08/23/97	Chaves Siding	Woodhouse's Toad	adult	1
08/23/97	Chaves Siding	Woodhouse's Toad	juvenile	3
08/22/97	Chaves Siding			0
May 1998				
05/17/98	IWWTP/upper	Woodhouse's Toad	larvae	50000
05/15/98	IWWTP/upper	Woodhouse's Toad	adult	8
05/15/98	IWWTP/upper	Woodhouse's Toad	larvae	200
05/17/98	Rio Rico			0
05/16/98	Rio Rico	Canyon Treefrog	adult	1
05/16/98	Palo Parado	Woodhouse's Toad	adult	2
05/16/98	Palo Parado	Woodhouse's Toad	larvae	2
05/17/98	Palo Parado	Woodhouse's Toad	adult	1
05/16/98	Carmen	Woodhouse's Toad	larvae	4
05/16/98	Carmen	Bullfrog	larvae	1
05/16/98	Tubac			0
05/17/98	Tubac	Woodhouse's Toad	adult	1
05/16/98	Chaves Siding			0
05/17/98	Chaves Siding	Woodhouse's Toad	adult	4

Appendix 2. Physical/Chemical Data for the Santa Cruz River during a baseline survey of amphibians in conjunction with planned upgrade of the Nogales International Waste Water Treatment Plant. Data provided by Dr. Terry Boyle, USGS Midcontinent Ecological Science Center. DO is dissolved oxygen in ml / l; NH3 and NH4 are unionized ammonia and ammonium ion, respectively, in mg / l.

Date	DO	Temp. (C)	Conductivity	pH	Alkalinity	NH3	NH4
Site 1: Border							
3/5/98	9.2	14	235	7.3	89	0.0005	0.0915
Site 2: Nogales Wash							
5/21/97	8.6	17	14.03	8.34	200	0.0032	0.0473
8/21/97	6.7	27	12.52	7.93	163	0.0154	0.2810
12/4/97	9.8	8	240	7.8	79	0.0061	0.6166
3/5/98	10.2	12	403	8.1	170	0.0024	0.0884
Site 4: Railroad Bridge							
5/21/97	4.6	23	17.68	7.83	251	0.5554	16.8838
8/21/97	5.5	27	17.12	7.61	229	0.4760	18.0933
12/4/97	8.6	11	752	7.96	236	0.4380	24.2108
3/5/98	6.8	14	560	7.4	210	0.1702	27.1131
Site 5: Rio Rico Above Bridge							
5/21/97	4.1	21	17.9	7.96	241	0.6325	16.4697
8/21/97	4.1	30	16.8	7.76	225	0.7636	16.6991
12/4/97	9.4	11	350	7.93	116	0.1164	6.8959
Site 5a: Rio Rico a							
5/21/97	4.1	21	17.9	7.96	241	0.6325	16.4697
8/21/97	4.1	30	16.8	7.76	225	0.7636	16.6991
12/4/97	9.4	11	350	7.93	116	0.1164	6.8959
3/5/98	6.2	14	465	7.5	203	0.2043	25.8423
Site 5b: Rio Rico b							
5/21/97	4.1	21	17.9	7.96	241	0.6325	16.4697
8/21/97	4.1	30	16.8	7.76	225	0.7636	16.6991
12/4/97	9.4	11	350	7.93	116	0.1164	6.8959
3/5/98	6.2	14	465	7.5	203	0.2043	25.8423
Site 6: North Rio Rico							
5/21/97	4.8	18	17.64	7.97	230	0.3881	12.3122
8/21/97	3.6	30	15.07	7.71	165	0.3745	9.1886
12/4/97	10.2	6	546	8.04	169	0.2088	14.2776
3/5/98	6.7	12	444	7.7	175	0.1521	14.1591

Appendix 2. Physical/Chemical Data for Santa Cruz River (continued).

Date	DO	Temp. (C)	Conductivity	pH	Alkalinity	NH3	NH4
Site 7: Santa Gertrudis							
5/21/97	5	17	16.85	7.89	214	0.0950	3.9017
8/21/97	4.1	24	14.62	7.53	157	0.0746	4.2101
12/4/97	9.3	9	605	7.87	233	0.1681	13.3729
3/5/98	6.3	13	446	7.5	181	0.0682	9.3188
Site 8: Carmen							
5/21/97	6.7	17	16.69	8.08	205	0.0391	1.0368
8/21/97	4.9	24	13.58	7.59	141	0.0518	2.5476
12/4/97	10.2	8	598	8.17	194	0.3171	13.6887
3/5/98	7	13	468	7.6	177	0.0700	7.5968
Site 9: Tubac							
5/21/97	6.9	18	16.87	7.96	214	0.0015	0.0500
8/21/97	4.3	24	12.08	7.52	147	0.0375	2.1690
12/4/97	9.4	9	649	8.2	206	0.2955	10.9992
3/5/98	7.9	13	540	7.6	177	0.0473	5.1322
Site 10: Chavez Siding							
5/21/97	8.1	18	17.06	8.32	218	0.0086	0.1216
8/21/97	4.8	24	11.28	7.54	135	0.0374	2.0633
12/4/97	8.8	8	630	8.13	196	0.1311	6.2060
3/5/98	8.3	13	566	7.6	175	0.0343	3.7248

Figure 2. Two of the amphibian and reptile species from the upper Santa Cruz River in the vicinity of the Nogales International Waste water Treatment Plant. Couch's Spadefoot Toad (top, young individual) is the most common toad along this part of the river. Checkered Garter Snake (bottom) is one of two semi-aquatic snake species in the area.

Fig. 3a: Woodhouse's Toad

Fig. 3b: Spadefoot Toads (Couch's and Southern Spadefoot, combined)

Fig. 3c: Bullfrog

Fig. 3d: Sonoran Mud Turtle

Fig. 3e: Garter Snakes (Black-necked and Checkered Garter Snake, combined)