FISH MOVEMENT THROUGH INTERMITTENT STREAM CHANNELS

A CASE HISTORY STUDY

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Report to U.S. Bureau of Reclamation
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(Cover photo: Redrock Canyon, Santa Cruz Co., AZ. Top photo August 18, 2001, bottom photo June 26, 2006. Photos by J. Stefferud)

Introduction

Invasion of nonnative aquatic species, particularly fish, into habitats occupied by native southwestern fishes has been a major factor in the ongoing decline of the natives (Tyus and Saunders, III 2000; Clarkson et al. 2005; Marsh and Pacey 2005; Mueller 2005). A primary method for successfully controlling this threat is physical prevention of upstream movement of fish into habitats where native fish persist (Carpenter and Terrell 2006). The need for, and efficacy of, such measures has occasionally been questioned by land and water managers and the public due to misperceptions regarding the degree to which nonnative fish, once introduced, are able to migrate through the aquatic system. One particular aspect of that debate has been whether or not fish (native and nonnative) can move upstream through intermittent and ephemeral stream reaches, where surface flow is infrequent. That is the question addressed by this report, through examination of case studies in Arizona.

Few, if any, fish biologists with field experience in the southwest doubt the ability of most fish species to move through "dry" stream reaches, where surface flow occurs only irregularly. Although such movements are widely recognized as occurring, the phenomenon has been poorly documented. The concept of fish moving through "dry" stream channels seems counterintuitive and is often met with incredulity by nonbiologists (and terrestrial biologists), creating opposition to vital conservation measures and leading to assertions that fish biologists are failing to use "common sense."

The misperception is particularly strong in relation to upstream fish movement. It is relatively easy to understand that flooding may displace fish in a downstream direction through areas of stream that are normally dry. It seems intuitively true, although particularly for native fish such displacement actually is limited and has little effect on the population (Minckley and Meffe 1987; Stefferud and Rinne 1996). It is the ability of fish to move upstream through intermittent or ephemeral reaches that is less easily understood and has generated dispute.

Given the well-documented incompatibility between most nonnative fish and native fish, conservation of imperiled native fishes depends heavily on success in separating the two. The most technically effective means of segregation is prevention of upstream fish movement. If nonnative fish can, during periodic flows, move upstream through intermittent and ephemeral stream reaches, then emplacement of barriers in such reaches or at the downstream limit of perennial reaches is of critical importance to protection of native fish persisting upstream. If nonnative fish cannot move through such "dry" reaches, then the barriers are pointless. The future of native fish in the southwest may depend heavily on accurate assessment of the validity of this hypothesis.

When standing on the bank of a streambed of dry silt, sand, gravel, or boulders it does seem that "common sense" tells us that no fish can move through the area. But, a stream is by its very nature dynamic and the presence of a channel by definition tells us that water flows there some of the time. The channel we see is created by the flow of water and would not exist if the stream was always dry (see Rosgen 1995). So, "common sense" actually tells us that even though it looks dry today, there are times when flowing water is present.

Stream reaches that are sometimes dry are found in all climates, but they are particularly prominent in arid regions. The importance of their role in the hydrologic and biologic systems of arid-land streams has resulted in a system of categorization of these "dry" reaches. A variety of flow descriptors exist, with the most common being perennial, ephemeral, and intermittent.

Perennial -- A perennial stream is one that carries water year-long (Lopez 2006; http://capp.water.usgs.gov/GIP/h2o_gloss/#E). Because even perennial streams may cease to flow under severe drought conditions, some definitions of "perennial" include streams that flow greater than 90% of the time (www2.ncsu.edu/ncsu/CIL/WRRI/annual/01uwcintermittent.html).

Ephemeral -- An ephemeral stream is one that carries water only during and immediately after rain and is above the water table at all times (Gordon et al. 1992). It is sometimes called a storm channel (Lopez 2006), and may or may not have a well-defined channel (www2.ncsu.edu/ncsu/CIL/WRRI/annual/01uwcintermittent.html). The U.S. Geologic Survey defines it as a *stream or part of a stream that flows only in direct response to precipitation; it receives little or no water from springs, melting snow, or other sources; its channel is at all times above the water table* (http://capp.water.usgs.gov/GIP/h2o_gloss/#E).

Intermittent -- An intermittent stream is one that flows only at certain times of the year and may cease to flow during dry years or seasons or may be reduced to a series of separate pools or short areas of flow (Gordon et al. 1992). It has a well-defined channel. Flow results from precipitation or contact with the water table (Lopez 2006), and flow occurs about 30 to 90% of the time (www2.ncsu.edu/ncsu/CIL/WRRI/annual/01uwcintermittent.html). The USGS definition is a *stream that flows only when it receives water from rainfall runoff or springs, or from some surface source such as melting snow* (http://capp.water.usgs.gov/GIP/h2o_gloss/#E). Besides duration of flow, a major difference between ephemeral and intermittent streams is the absence (ephemeral) or presence (intermittent) of groundwater in contact with the stream channel. Several distinct categories of flow patterns occur in intermittent streams. These include perennial-interrupted, seasonally or temporally intermittent, spatially intermittent, and subterranean.

Perennial-interrupted or spatially intermittent-- Perennial-interrupted streams are those where perennial flow persists in some reaches, while other reaches cease to flow seasonally or during dry years. This is sometimes called spatially intermittent.

Seasonally or temporally intermittent -- A seasonally or temporally intermittent stream is one where all reaches of the stream become dry periodically. Because of the connection to groundwater, a temporally intermittent stream or seasonally intermittent reach of a perennial-interrupted stream can also be termed subterranean.

Arizona supports all of these types of stream flow patterns. Over the past 150 years, a variety of factors, such as climatic variation and water use and watershed alteration by human activities, have substantially decreased the total length of perennial stream in Arizona and increased the number of perennial-interrupted, seasonally intermittent, and ephemeral stream channels (McNamee 1994; Tellman et al. 1997). But, stream intermittency to varying degrees has been common here since the late Cenozoic, and loss of flow during seasons or in certain stream reaches has been a major determinant in distribution and physical and behavioral adaptations of native southwestern fishes (Naiman and Soltz 1981; Minckley et al. 1986).

Life-history strategies of a number of native southwestern fishes include colonization of habitats newly-available due to temporary surface flow. This is an evolutionarily desirable trait in a desert system where flow intermittency of various forms is common. Some native species, such as Gila topminnow (see Appendix A for scientific names), were historically highly dependent upon rapid colonization of seasonally or sporadically available streams, backwaters, and marshes to expand their populations prior to retreating into shrinking habitat during dry seasons or drought (Minckley 1999). Longfin dace often use intermittent and sometimes ephemeral reaches to reproduce. Longfin dace reproduction is tied to flooding, and fish may make substantial movements into newly-wetted reaches to rapidly recolonize all suitable habitats and reproduce before being forced out by drying (Minckley and Barber 1971). In addition to expanded habitat size and increased access to reproductive mates, rewatered intermittent reaches generally offer substantial benefits in decreased predation and competition, and increased food availability (Constantz 1981).

European settlement of the southwest resulted in the ongoing introduction and spread of a wide variety and increasing number of nonnative fishes (Rinne and Janisch 1995; Dill and Cordone 1997; Marsh and Pacey 2005). Invasive nonnative fishes tend to have life-histories and adaptations that allow them to rapidly colonize new areas and adapt to local conditions. This is one of the predominant characteristics of an invasive species – it readily and successfully invades new areas (see Laurenson and Hocutt 1985). Moyle and Light (1996) concluded that the most important determiner of success for an invading fish species is its adaptation to the local hydrologic regime. Generally, by the time a nonnative fish reaches the downstream end of an intermittent stream reach in the southwest, it has already established itself as a "successful" invader of the highly variable streams of the region. Most invading nonnatives that succeed in southwestern streams are well adapted to moving through intermittent and ephemeral reaches when the opportunity arises. Some, such as green sunfish, have proven highly successfully at colonizing intermittent streams and are often the first fish to enter rewatered areas (Moyle 2002). This can be seen in the case studies below.

When considering the potential for fish to move through a stream reach that is dry today, the questions that arise include: a) at what quantity, frequency, and duration does water flow through the channel, and b) what levels or combinations of those are needed for a fish to successfully transit the reach. The answers will differ substantially from stream to stream, between reaches of the same stream, and among fish species. The large array of variables and combinations of variables that will determine conditions governing upstream migration of an available nonnative invader make it extremely difficult to predict what will invade and where (Fuller and Drake 2000). However, evidence provided by changing distributions of fish species over time within the stream systems of the American southwest indicate that for most streams the likelihood of occurrence of the specific set of conditions necessary for movement of some fish species upstream through a "dry" stream reach is moderate over a multi-year period, rising to high on a multi-decadal basis.

The Background Information portion of the 2001 biological opinion on the Central Arizona Project and its potential to introduce and spread nonnative aquatic species contains a discussion regarding the phenomenon of fish moving through what are often considered "dry streambeds" (U.S.Fish and Wildlife Service 2001, pages 65-67). As this discussion points out there are often considerable periods of continuous flow in some of these streams, such as in the Santa Cruz River near its mouth, where flow is present 30% of the time, with documented periods of 30 to 150 days of consecutive flow at Continental. Or the Hassayampa River near Morristown where there is flow 50% of the time, and 30 days of consecutive flow to the mouth approximately once every 10 years. Even in Indian Bend Wash in Scottsdale, which is "normally" a park, flowing surface water occurs about 1% of the time.

Duration of flow in a temporally intermittent steam or intermittent reach of a perennial-interrupted stream varies greatly, as does the distance of flow. Velocities and sediment transport may differ substantially from one flow event to another and may influence the ability of fish to move through the stream. Water temperatures, food availability, and a variety of other factors may vary depending upon the timing of the flow event and may also help determine whether fish movement is likely. Only certain combinations of these variables may allow fish to move throughout the stream, and the combination may vary between species and between age-classes of a species. Some combinations may allow shorter movements, such as from one perennial reach of a perennial-interrupted stream to another, with complete colonization of the stream occurring as the result of several partial movements. Other combinations may result in movement of fish over a long distance, culminating in entry to a perennial area or into a connected stream or water.

The wide variety of factors that determine the conditions under which a given species is able to successfully move through a temporarily flowing channel are discussed in the Background Document for the CAP biological opinion (U.S.Fish and Wildlife Service 2001, pages 65-67). In summary, a fish is less likely to be able to successfully move through a "normally dry" reach if the reach is long (e.g., >10 miles), if surface flow occurs very infrequently and for only a short time (as in flash flooding), and if the velocity of flow is high (as in constricted canyon reaches or steep gradients). However, only an actual physical barrier, such as a waterfall, dam, or constructed fish barrier, will reduce that likelihood to or near zero.

Methods

Actual observation of fish movement during high flow events is not generally possible. Experimental efforts using tagged fish may yield useful data, if appropriate conditions and recaptures occur. However, such efforts are generally focused on movement within perennial streams (e.g., Bestgen et al. 1987, Williams 1991). In the dearth of such experimental data for upstream movement in intermittent and ephemeral streams, we have used case studies of changes in known distribution of fish in ephemeral and intermittent stream channels in Arizona to indicate where such movement has occurred. Because the evidence is anecdotal, there always remains some question as to the potential role of other factors. In any given case, it is possible that the fish that appeared to move from downstream to upstream may have actually come from some other source, such as an unknown population upstream or human stocking. The cases here were chosen because they have low probability of such confounding factors. The situations are generally remote and lack appropriate upstream waters.

Data on fish distributions in Arizona's smaller streams, particularly those that are intermittent or ephemeral, are limited. Historically, interest on fish in Arizona has been focused on trout and sport fish[1], which continue to receive the bulk of funding and effort. As a result, knowledge of fish distribution is primarily confined to larger and perennial streams. While some of the larger streams in Arizona have natural or anthropogenically-induced intermittent reaches, they also tend to have a wide range of connected reservoirs, ponds, adjacent streams, etc. and a high likelihood of stocking by agencies or individuals. This makes it difficult to determine the source of fish moving into a new area through an intermittent reach. To avoid many of these confounding factors, the case studies described here are limited to small streams with naturally intermittent or ephemeral flow characteristics, although the level of intermittency may be altered by human activities. In addition, these small streams have little, or in most cases no potential for sport fishery development, thus substantially reducing the likelihood that fish were stocked.

The following case studies are based primarily on the knowledge of the authors and do not represent an exhaustive search of the literature or agency records. The list is not inclusive and many more cases demonstrating fish movement up intermittent streams in Arizona likely exist.

The locations of the eighteen streams included in this study are shown on Figure 1. Table 1 displays the streams by basin and tributary. The streams are located in three basins tributary to the Gulf of Mexico, including six subbasins of the Gila River. To facilitate finding a particular stream, they are listed in the text in alphabetical order of the stream name.

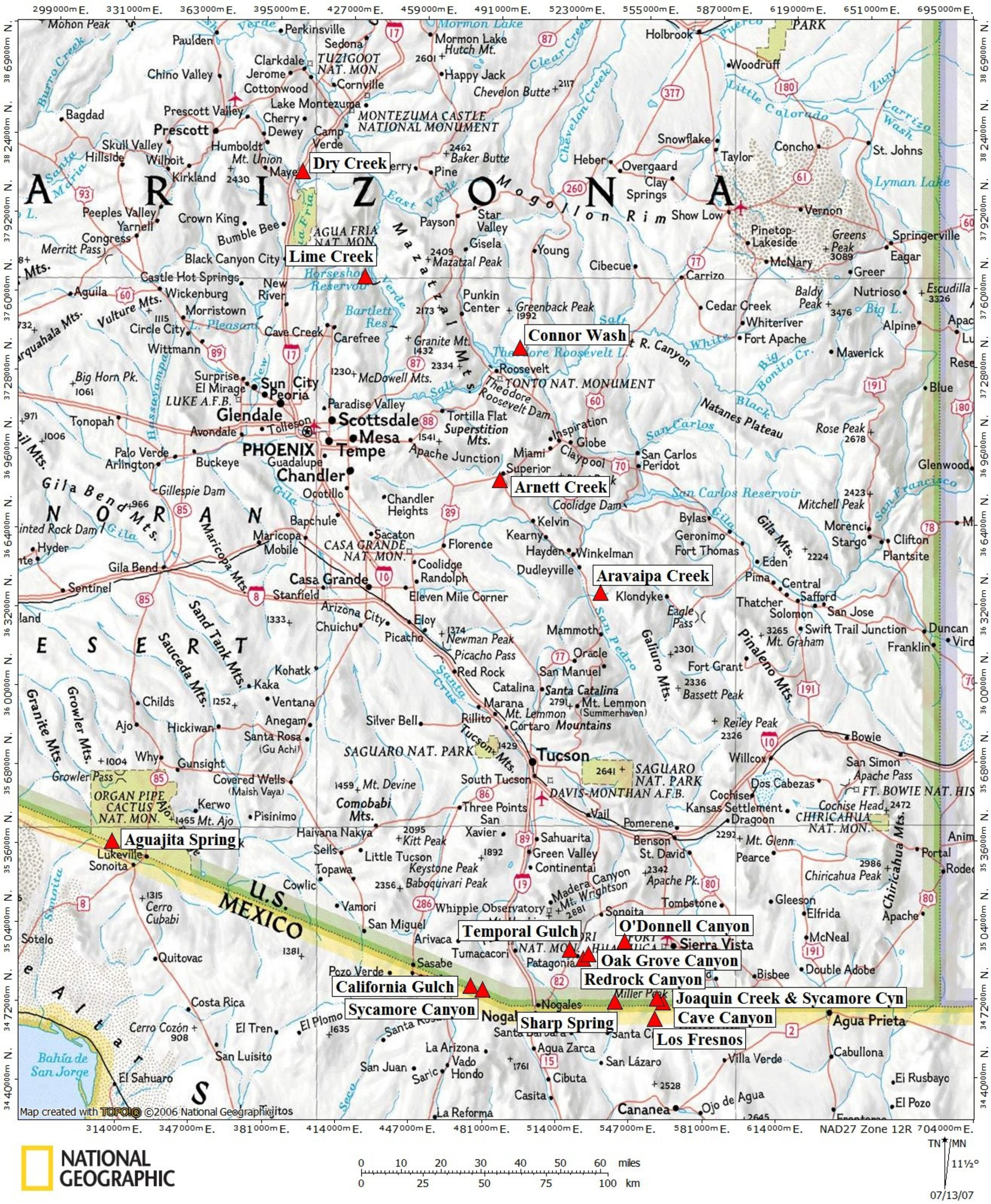
[1] All sport fish in Arizona, with two exceptions (Apache trout and roundtail chub), are nonnative species. Significant interest in sport fishing on these two species has been limited to Apache trout.

Table 1. Hydrologic Relationships of Case History Streams (shown in italics)

Basin	Subbasin	Primary Tributary	Secondary Tributary	Tertiary Tributary	Quaternary Tributary	Quinary Tributary
Gila River	Agua Fria River	Ash Creek	Little Ash Creek	***Dry Creek***		
	Queen Creek	***Arnett Creek***				
	Salt River	***Connor Wash***				
	San Pedro River	***Aravaipa Creek***				
		Las Nutrias	***Los Fresnos Arroyo***	***Cave Canyon (Los Alisos)***	***Joaquin Creek***	***Sycamore Canyon***
		Babocomari River	***O'Donnell Canyon***			
	Santa Cruz River	Sonoita Creek	***Redrock Canyon***	***Oak Grove Canyon***		
			Temporal Gulch			
		Sharp Spring				
	Verde River	***Lime Creek***				
		Sycamore Creek	***Unnamed Spring #0***			
Rio de la Concepcion (Magdalena)	Rio Altar	***Sycamore Canyon (Los Alisos)***	***California Gulch***			
Rio Sonoyta	***Aguajita Spring***					

- Case studies

Figure 1. Site Locations.



Aguajita Spring, Pima County, Arizona

Aguajita Spring is an area of semi-perennial flow just north of the U.S./Mexico border, in the intermittent Aguajita Wash, a tributary of the Rio Sonoyta in Sonora, Mexico (Figure 2). The wash drains the south side of the Cipriano Hills and east side of the Quitobaquito Hills on Organ Pipe Cactus National Monument. The only other perennial water is at Bonita Well, another 6 miles upstream. Aguajita Spring is 1.5 miles upstream from the confluence with the Rio Sonoyta, which is an intermittent stream with substantial areas of perennial-interrupted flow.

In May 1990, nonnative western mosquitofish and native Quitobaquito pupfish and longfin dace were discovered in Aguajita Spring (U.S. Fish and Wildlife Service 1990a). Fish had never previously been recorded from the spring or the drainage. The spring is located alongside the dirt road to Quitobaquito Spring and is frequently visited by Park Service staff, although no formal fish sampling is known to have occurred. All three fish species are common in the Rio Sonoyta.

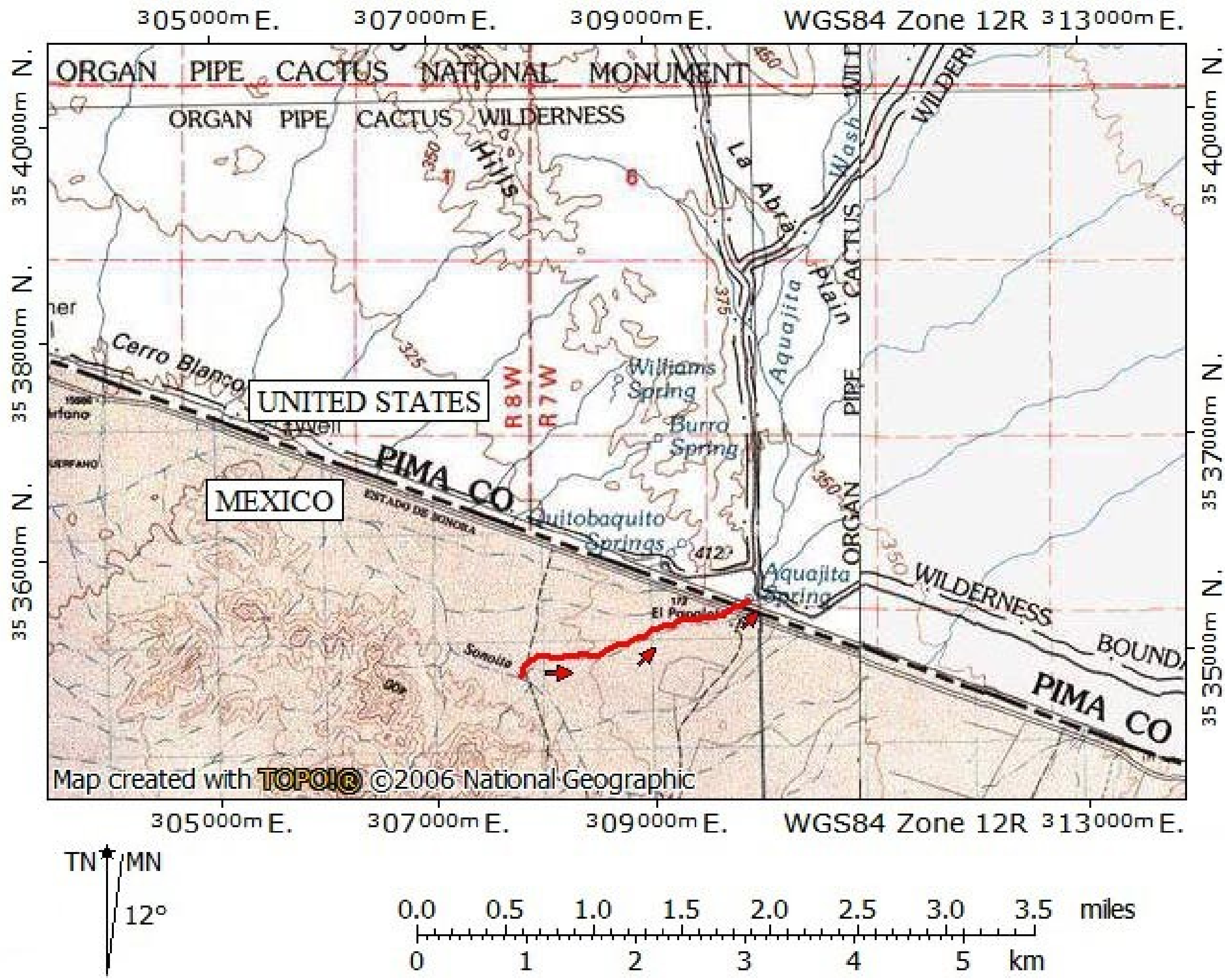
Because of the 1.5 miles of "normally dry" stream channel between the spring and river and the difficulty humans have envisioning fish moving through such "dry" channels, these fish were assumed to have been moved there. They were removed by Arizona Game and Fish Department because they were believed to pose a danger to the endangered pupfish at Quitobaquito Spring, about 0.75 miles away by dirt road and 3.75 miles away by stream channel. The belief was that if someone transported them from Rio Sonoyta to Aguajita Spring, then they might move them again into Quitobaquito. Fish have been stocked into Quitobaquito Spring in the past, included a single medium-sized black bullhead placed into the springhead in 1993 (Stefferud 2001). Quitobaquito is a large, obvious water which can be seen from the highway in Mexico. Due to natural factors and human alterations, there is no stream channel connecting Quitobaquito Spring and the Rio Sonoyta, eliminating natural fish migration from the river.

Aguajita Spring, by contrast, is small and water is not visible from the highway. The channel between the river and the spring is well-defined and flows during large precipitation events and long winter storms. The short distance of 1.5 miles from the river to the spring is a relatively simple migration for the fish and they were found in Aguajita Spring in winter, when conditions suitable to such migration are most likely to occur.

However, Aguajita Spring is not remote – it is only 0.2 miles from Mexican Highway 2. To drive from Rio Sonoyta to Aguajita Spring is 30 miles; crossing the border at Lukeville. But from Rio Sonoyta to Highway 2 is a drive of only 1.3 miles, and the border at that time was a barbed-wire fence. Still, it would require considerable time and effort to gather the three species from the river, drive them to the highway, and walk the 0.2 miles across the border to place the fish into an obscure site. These species have little utilitarian value to humans, making them less likely to be transported, and there is no apparent benefit to anyone from placing the fish in Aguajita Spring, which dries periodically and did so a short while after the fish were removed.

This case illustrates the difficulties in identifying the source of fish which appear in or above intermittent and ephemeral stream reaches. While we believe that the likelihood that these fish moved upstream to Aguajita Spring is substantially greater than the likelihood that they were moved there by humans, no definitive answer exists.

Figure 2. Aguajita Spring, Pima Co., AZ –
Longfin dace, western mosquitofish, and Quitobaquito pupfish migration route (red line and arrows)



Aravaipa Creek, Pinal County, AZ

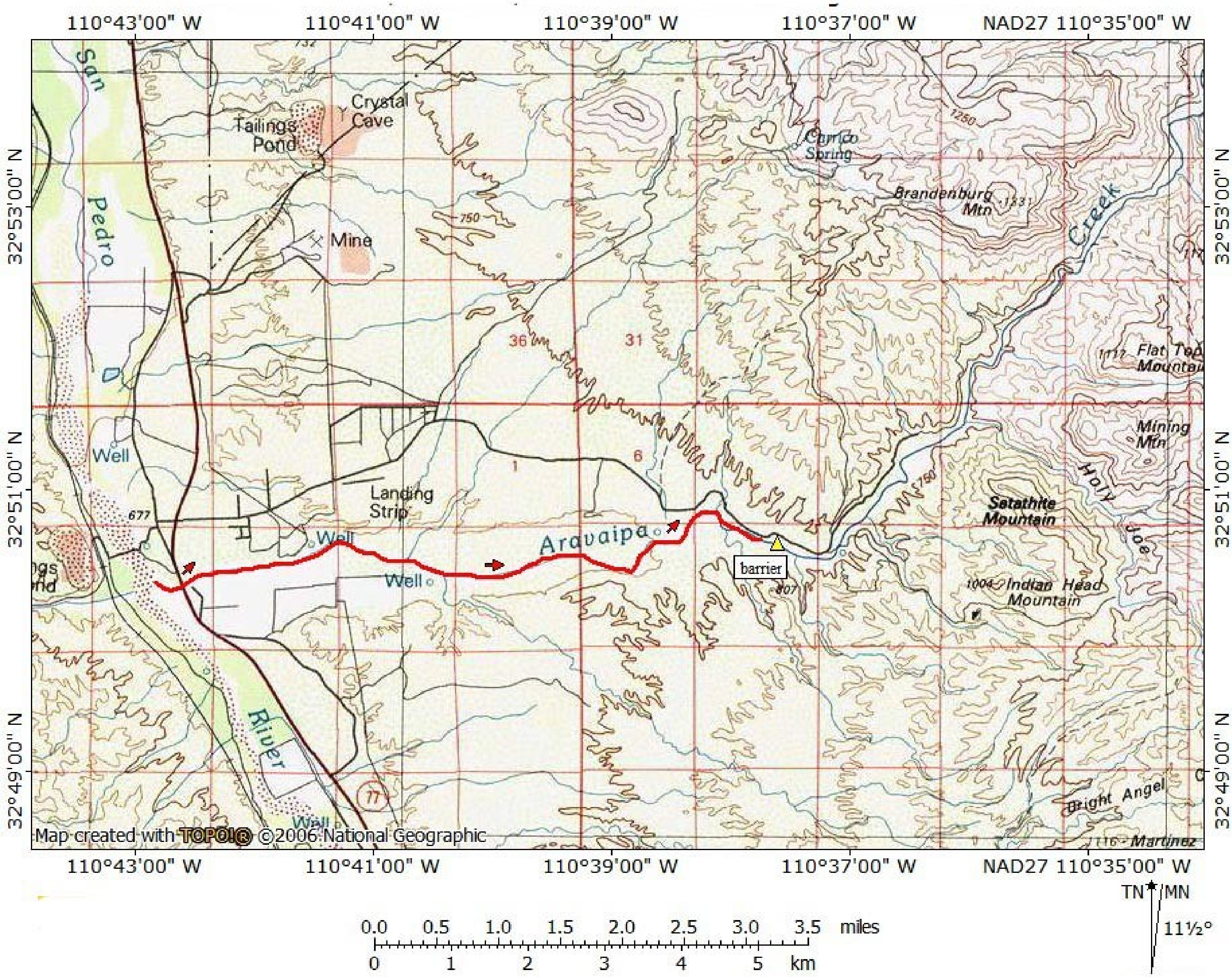
Aravaipa Creek (Figure 3) has been reported as seasonally intermittent and dry much of the year in its lower 5-6 miles, since the first European reports in the mid 1800's (Bell 1965; Campbell 1969). Although the length and duration of flow through this reach has increased in the past decade due to changes in agricultural water use within the canyon, it is still a seasonally intermittent reach. Upstream of this lies the renowned 21-mile perennial reach that supports seven native species of fish.

For many years the intermittent reach at the lower end was thought to provide a barrier to immigration of nonnative fishes from the San Pedro River, to which Aravaipa Creek is tributary. Several nonnatives that were not found in Aravaipa Creek were found in the river, including red shiner, a nonnative believed to be detrimental to several native fish species (Marsh et al. 1989; Douglas et al. 1994). Early discussions on the need for a constructed barrier on Aravaipa Creek to prevent nonnative fish invasion debated the effectiveness of this intermittent reach as a barrier (U.S. Fish and Wildlife Service 1990b; Matter 1991). However, by the late 1980's biologists had begun to understand the ability of many fish species to use seasonal flows to reach upstream perennial areas, as well as to understand the severe and irreversible consequences of these movements by nonnative species. As a result, in 2001 a pair of concrete barriers to upstream fish movement were completed on Aravaipa Creek near the end of perennial flow. The barriers were to have been completed by October 1997, but were delayed by various factors.

In 1990, red shiner overcame the "barrier" presented by the 5-6 miles of intermittent reach on lower Aravaipa Creek and moved upstream through that intermittent reach into the perennial portion of the creek. This occurred during several years in which the seasonal duration of flow in the lower reach was much longer than "normal." However, the red shiner were not successful in colonizing Aravaipa Creek and did not again manage to move through the intermittent reach until 1997. This colonizing attempt was successful and the species has persisted there to the present, moving throughout most of the perennial area (see summary in (Stefferud and Reinthal 2005). If the barriers had been completed as scheduled, it is likely that red shiner would have been prevented from successfully colonizing Aravaipa Creek.

A streamflow gauge exists on Aravaipa Creek, located about a half mile upstream from the constructed fish barrier. The location is shortly upstream from where the canyon widens and enters substantial alluvium, into which it often percolates. This percolation results in a significant loss of surface flow within the first mile below the gauge, with complete loss of flow being "normal" before reaching the San Pedro River. No periods of zero flow have been recorded at the gauge, the minimum is 0.3 cfs in August 1940. A flow of at least 0.93 cfs is expected 99.9% of the time (USGS records).

Figure 3. Aravaipa Creek, Pinal Co., AZ – Red shiner migration route (red line & arrows)



Arnett Creek, Pinal County, AZ

This case study is documented in the 2001 CAP biological opinion Background Document (U.S. Fish and Wildlife Service 2001, page 67). Arnett Creek is a small intermittent stream in the central Gila River Basin (Figure 4). It is tributary to Queen Creek, also an intermittent stream, which is tributary to the Gila River near Chandler. Several nonnative species had invaded Arnett Creek at some time in the past, presumably from downstream. These included western mosquitofish and green sunfish, both of which are documented as having detrimental effects to native fishes (Meffe et al. 1983; Dudley and Matter 2000).

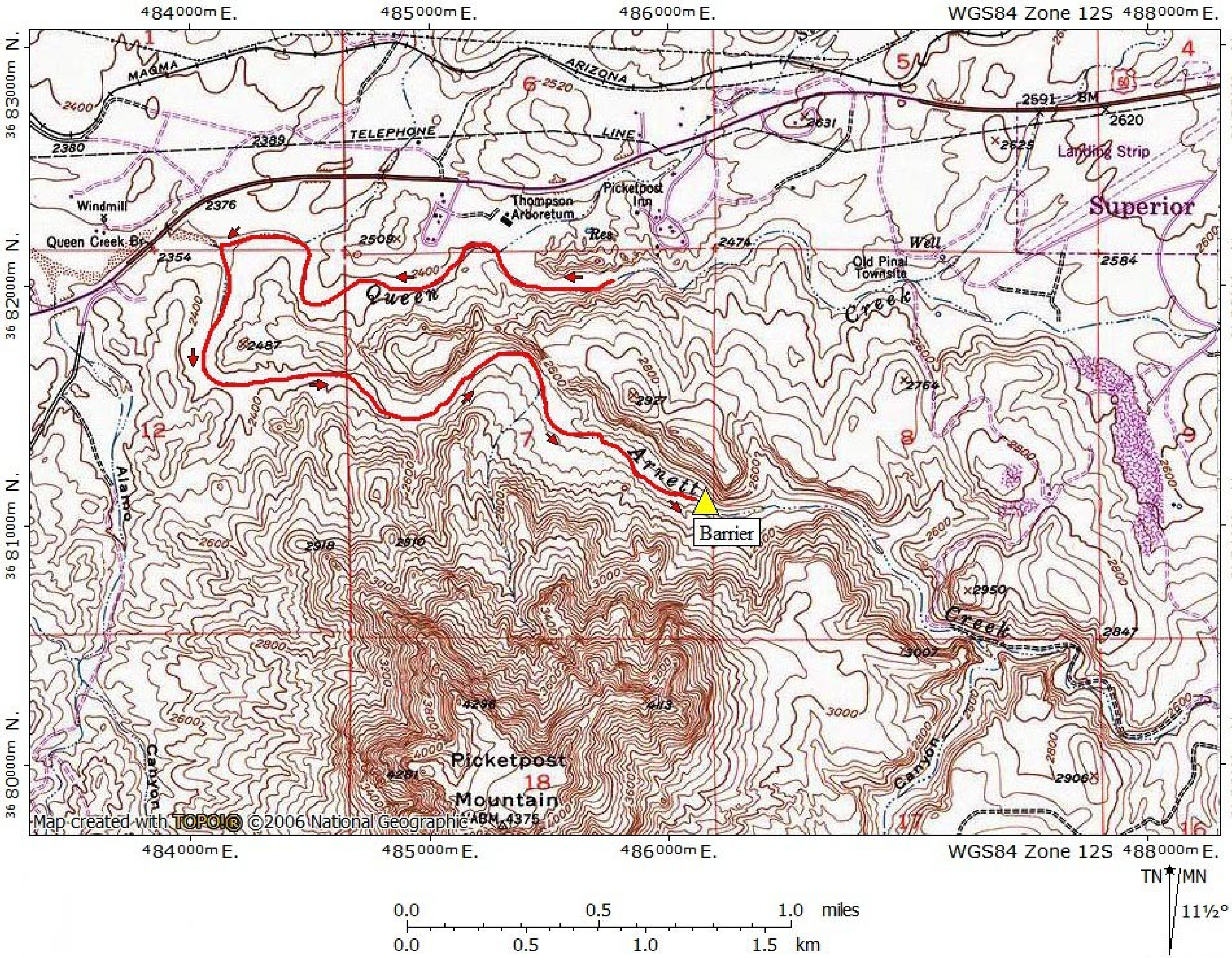
In 1996 the perennial-interrupted reach of stream was successfully treated with a piscicide to remove all fish, and a barrier to upstream fish movement was constructed preparatory to native fish restoration (Bizios 1997). Several native fish are planned for restoration, including at least two endangered species. The barrier is located about two miles upstream from the confluence with Queen Creek, and the reach below the barrier has no surface water most of the time. Queen Creek has perennial-interrupted reaches known to support nonnative green sunfish, the closest of which may be at Boyce-Thompson Arboretum about a mile upstream from the mouth of Arnett Creek, where perennial water is supported by outflow from the Superior sewage treatment plant.

On April 5, 2001, a green sunfish was found beside a pool on the spillway splash pad at the downstream base of the barrier (J. Stefferud, field notes, 5 April 2001). A storm event sometime during the 6 months prior to the green sunfish record left a debris line indicating a flow that filled the channel to approximately 18 inches deep. Because all fish had been removed from Arnett Creek upstream of the barrier, the only source for that green sunfish was from downstream through over 3 miles of “normally dry” streambed, first down one stream, then up another.

The presence of a “normally dry” intermittent reach of Arnett Creek downstream from the area targeted for native fish conservation was not sufficient to prevent reinvasion by green sunfish. If the barrier had not been in place in 2001, the green sunfish found on the splash pad would likely have continued upstream into the native species conservation area. It is unlikely that this fish was the only one making this migration and recolonization of the nonnnative-free area would have occurred, negating a substantial input of time and funds and preventing native fish restoration.

Arnett Creek has no stream gauge.

Figure 4. Arnett Creek, Pinal Co., AZ – Green sunfish migration route (red line & arrows)



California Gulch, Santa Cruz County, Arizona

California Gulch is a small intermittent stream in south-central Arizona (Figure 5). It is tributary to Sycamore Canyon (called Los Alisos in Mexico), joining that stream about 5 miles south of the U.S. border in Sonora, Mexico. It is a part of the drainage of the Rios Altar and Magdalena/de la Concepcion. In the United States, California Gulch has perennial water only at a rock drop called the tinaja (labeled "dam" on Figure 5), in artificial ponds at Ruby, and in a livestock exclosure at the border. (Ruby is a mining townsite located about 3.5 miles north of the upper border of Figure 5.) The remainder of the stream is intermittent to ephemeral. Information on water in California Gulch in Sonora is limited, but in a 1988 helicopter survey Hendrickson and Romero (1990) reported seeing no permanent water in any tributaries in the northern portions of the Altar basin other than upper Sycamore Canyon.

Despite the very limited surface water, several fish species are known to exist in California Gulch. Native threatened Sonora chub are present, as are nonnative green sunfish, bluegill, largemouth bass, black bullhead and western mosquitofish. The nonnatives are fed into the system from the impoundments at Ruby and persist in the channel in perennial pools immediately upstream from the tinaja. Sonora chub are native to the Rio Magdalena system but were not recorded in California Gulch until 1995 (Young 1995).

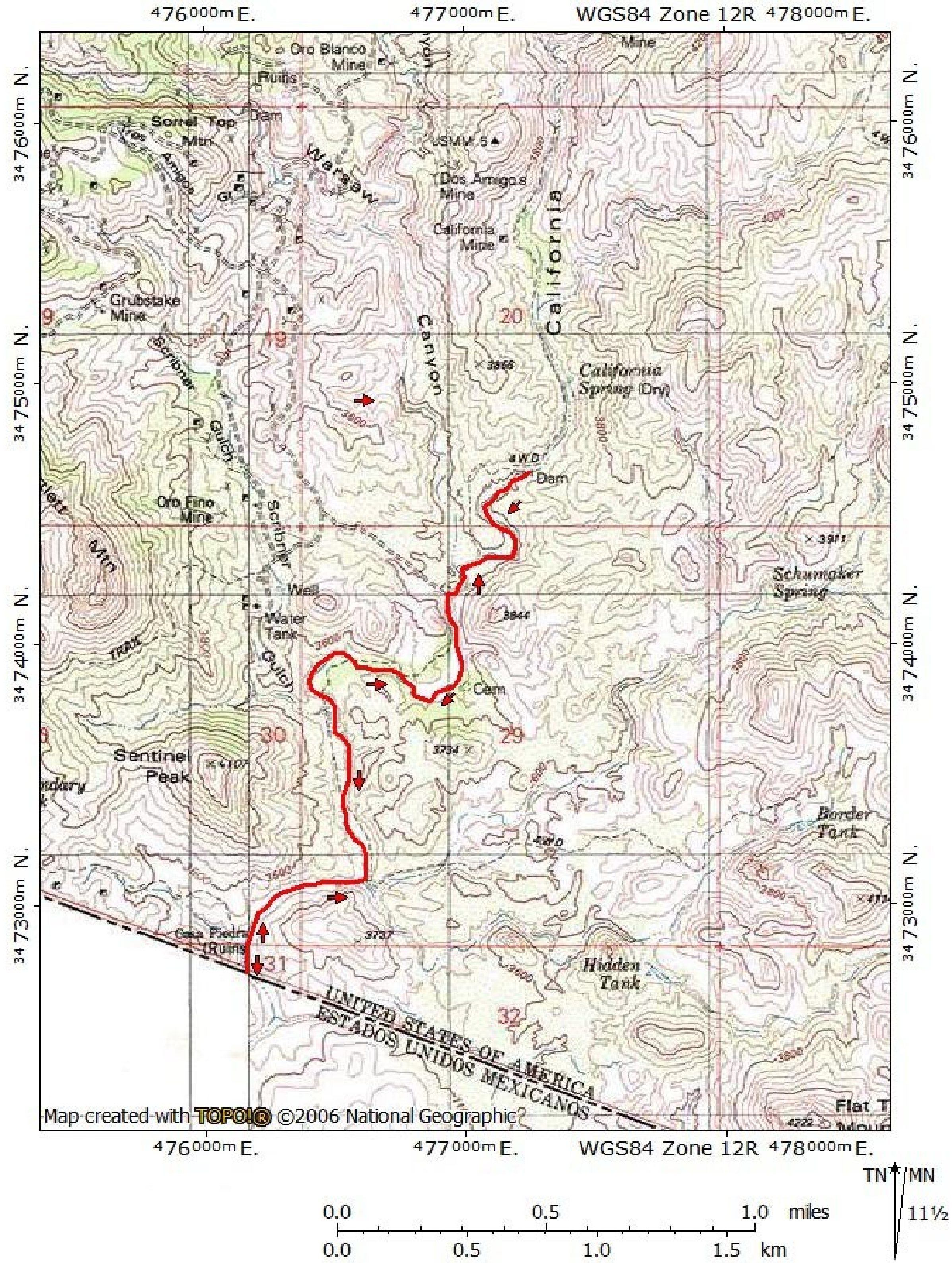
Two theories as to the source of the Sonora chub in California Gulch have been put forward, primarily in connection with controversy regarding effects to the chub from U.S. Forest Service management of livestock on the Montana allotment under permit to Jim and Sue Chilton. The Chiltons believe that Sonora chub do not exist on a permanent basis in California Gulch in the United States, but migrate into the area from Mexico during periods of precipitation-induced flows, with all of them dying as flows recede (Chilton and Chilton 2000). The extent of the population in Mexico is unknown, as is the distance the fish would have to cover to enter the U.S.

Data gathered on fish in California Gulch, including weekly fish surveys during July-August 2000, have documented significant expansion and contraction of Sonora chub distribution within the U.S. portion of California Gulch (Stefferud 2000). This study found what are apparently long-term populations to exist in the tinaja and border exclosure. According to this information, the species exists on a permanent basis in the U.S. and during periods of flow moves out from the two core areas to occupy all of the intervening 2.2 miles.

Although both upstream and downstream migration is likely involved in this population, Sonora chub regularly recolonize at least 2.2 miles of intermittent stream channel to occupy any surface flow available.

No stream gauge exists on California Gulch.

Figure 5. California Gulch, Santa Cruz Co., AZ – Sonora chub migration route (red line & arrows)



CAVE CANYON, COCHISE COUNTY, AZ

Cave Canyon is an intermittent stream of perennial-interrupted flow draining south off the Huachuca Mountains in southeastern Arizona (Figures 6 and 7). It flows southeast into Mexico where it is called Los Alisos. It is tributary to Los Fresnos Arroyo, a San Pedro River headwater tributary.

Native longfin dace are scattered throughout the perennial-interrupted water of Cave Canyon and its tributary streams (Bear and Joaquin Creek) and have been reported in various locations since 1968 (SONFISHES; Stefferud and Stefferud 2004) (see Figure 6). The distribution over time indicates core populations in perennial reaches with frequent movement through, and colonization of, intermittent stretches when flow is present. These recolonization patterns require movement upstream through significant reaches of "normally dry" streambed.

In 1996 nonnative green sunfish were reported for the first time from Cave Canyon near the confluence with Joaquin and Bear Creeks (Stefferud and Stefferud 2004). In 2003, green sunfish were found scattered throughout the 1 mile of stream between the U.S./Mexico border and the junction with Bear Creek (Stefferud and Stefferud 2004). Most of that reach had discontinuous flow at the time of sampling. Except for pools in a narrow bedrock stretch near the confluence with Joaquin Creek, the lower portion of Cave Canyon in the U.S. appears to be dry most of the year. Source of green sunfish is most likely from downstream, where they are known from Presa La Casa Grande at the junction of Los Alisos and Los Fresnos arroyos (Rorabaugh et al. 2006; Rorabaugh 2006). At present, their upstream movement in Cave Canyon is restricted by bedrock drops that form partial barriers to fish movement through a 1.5 mile reach above the confluence with Bear Creek. This provides some protection to longfin dace occupying the upper portion of the canyon, including a perennial reach just downstream of Forest Road 61.

Upstream movement of green sunfish from Presa La Casa Grande requires transiting substantial streambed that is dry most of the year. In the U.S., that includes from the border to near Joaquin Creek. Information from Los Alisos in Mexico is incomplete, but a survey in 2006 found 300 m of wetted channel about 1.5 miles south of the border, in an otherwise dry reach (Rorabaugh et al. 2006). It is approximately 5.5 miles from the Presa La Casa Grande to the confluence of Cave Canyon and Joaquin Creek, where perennial water supporting green sunfish is known to exist. Nonnative black bullhead, which have recently moved upstream in Los Fresnos (see that entry) from the vicinity of Presa La Casa Grande, are likely to make a similar invasion of the Los Alisos/Cave Creek/Joaquin Creek system. Black bullhead are a predatory species that has shown an ability to invade new areas, including those that are intermittent (Moyle 2002).

Bear Creek and its tributary Lone Mountain Creek are perennial-interrupted tributaries of Cave Canyon. However, no green sunfish have been recorded from those streams. This is surprising, since green sunfish have successfully invaded far upstream in the other Cave Canyon tributary, Joaquin Creek (see that entry). About a mile of stream channel on private land in the lower part of Bear Creek has not been surveyed and may contain a natural or man-made fish barrier.

No stream gauges exist on Cave Canyon or Los Alisos.

Figure 6. Cave Canyon, Bear and Joaquin Creeks, Cochise Co., AZ
– Longfin dace distribution in the U.S.

(Longfin dace core areas are indicted by a red line. A black dashed-line indicates probable distribution during periods when intermittent and ephemeral reaches flow.)

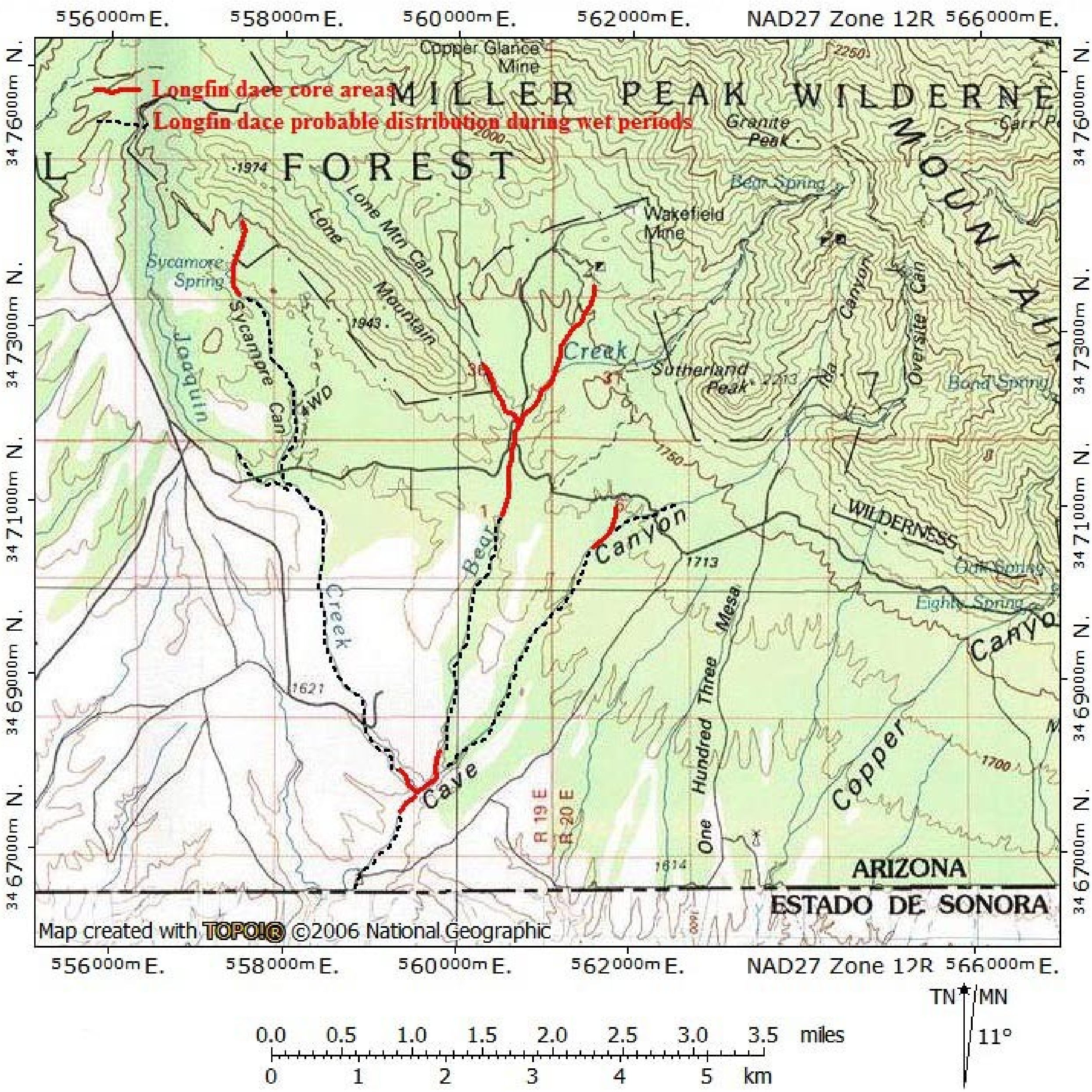
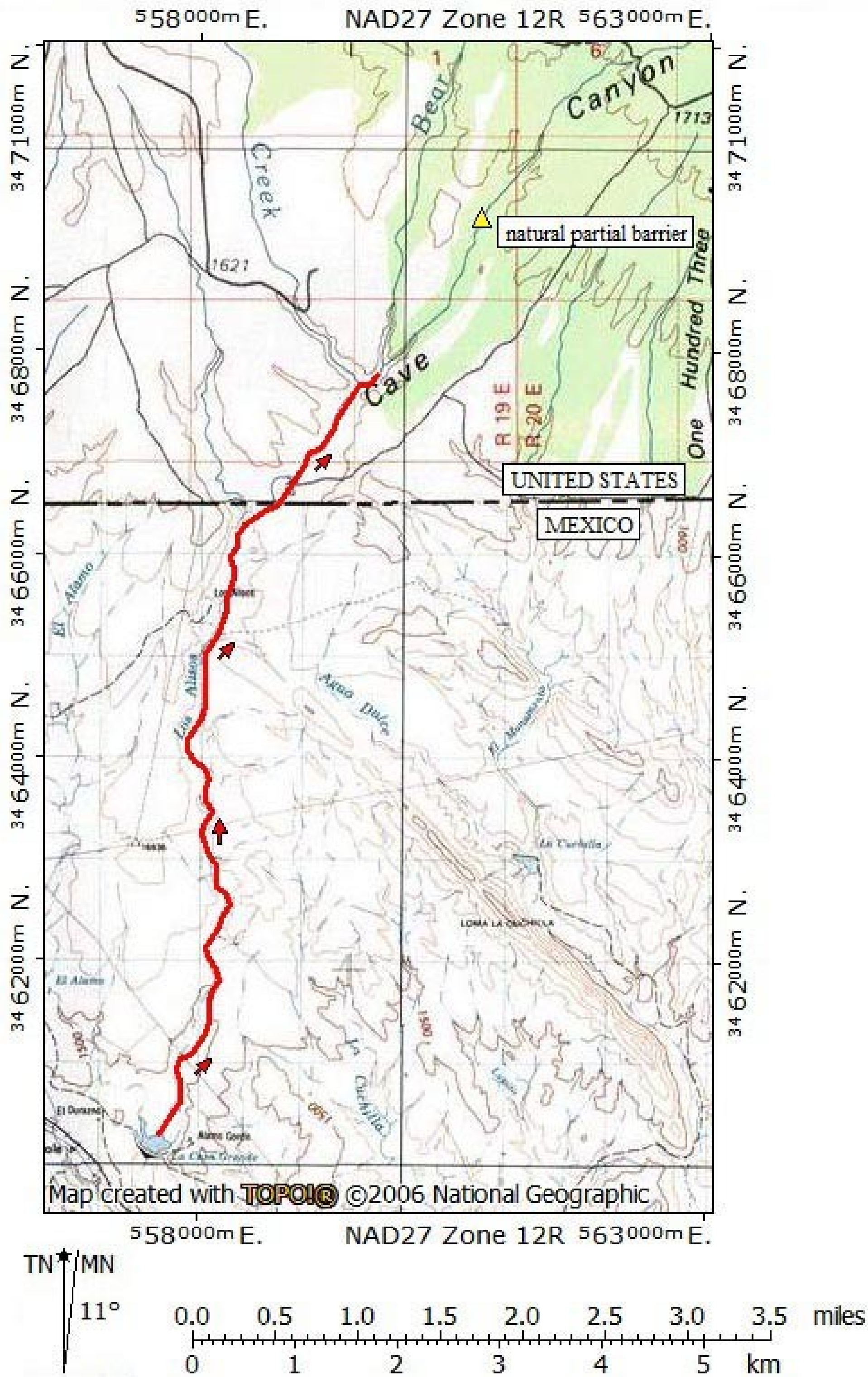


Figure 7. Cave Canyon, Cochise Co., AZ – Green sunfish migration route (red line & arrows)



Connor Wash, Gila County, Arizona

Connor Wash is an intermittent tributary of Cottonwood Wash, which drains into the Salt River on the north side of Roosevelt Lake (Figure 8). Cottonwood Wash and its tributaries (Parker Creek and Connor Wash and its tributaries Connor Canyon and Celler or Cellar Creek) form a network of drainages on the southwestern slope of the Sierra Ancha in central Arizona. The lower portion of Connor Wash and all of Cottonwood Wash may be ephemeral, without contact with the groundwater table.

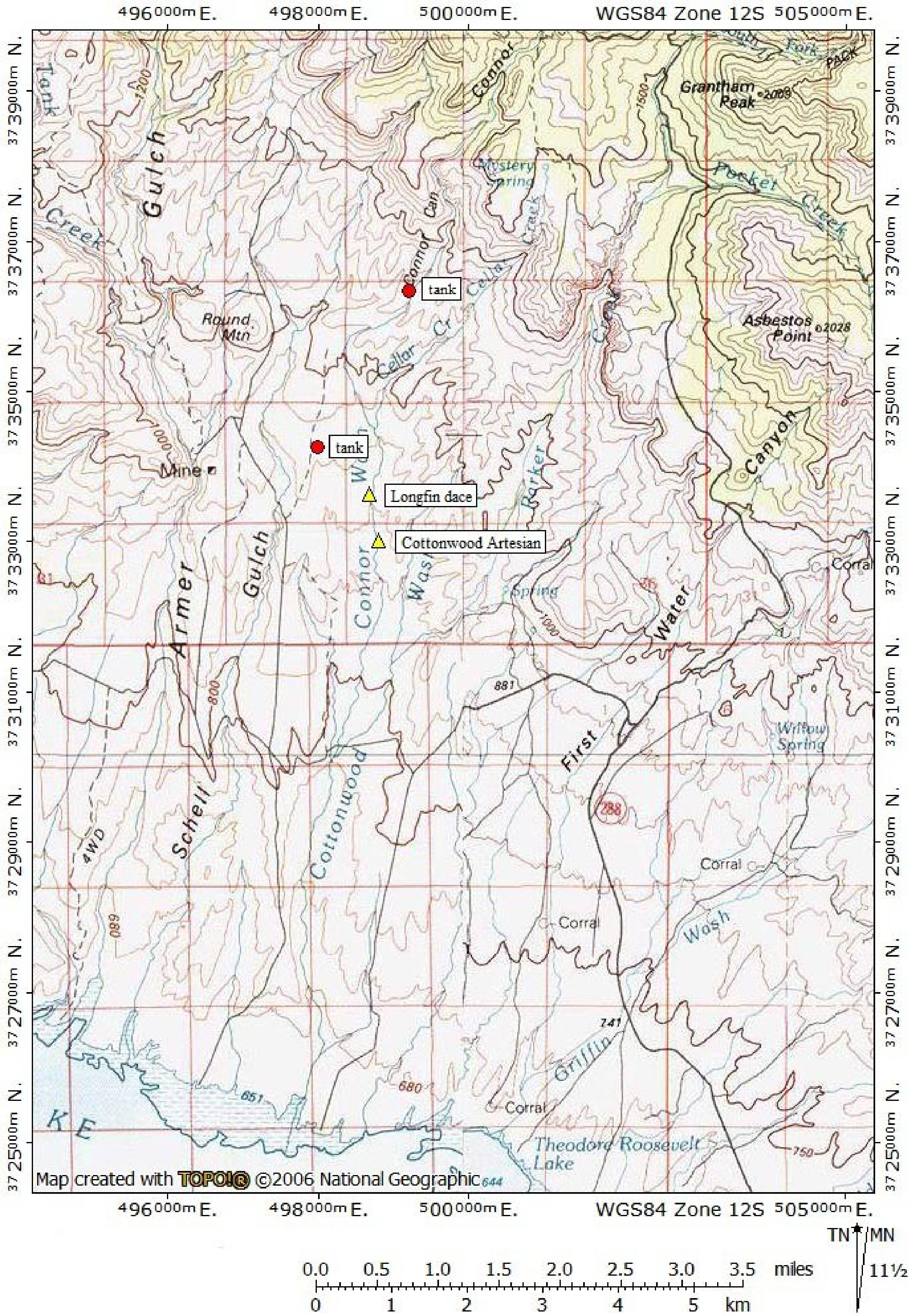
Known water in the watershed is limited. An artesian well exists at Cottonwood Artesian, feeding a livestock water tank and constructed habitat for endangered Gila topminnow. Cottonwood Artesian is located just to the east of Connor Wash about 5 miles upstream from Roosevelt Lake and about 2 miles upstream of the junction of Connor Wash with Cottonwood Wash. No surface water from Cottonwood Artesian reaches Connor Wash. Two other livestock tanks are shown on the Forest Service map, one in the upper reaches of an unnamed tributary to Cottonwood Wash, to the west of Connor Wash, and a second in Connor Wash about 2.6 miles upstream of Cottonwood Artesian. USGS topographic maps also show water at Mystery Spring in upper Celler Creek about 4 miles upstream of Cottonwood Artesian and a spring in Parker Creek, about 2.25 miles up from its confluence with Cottonwood Wash. There are no known fish surveys of these springs or stock tanks. Sampling at Cottonwood Artesian has occurred periodically since introduction of Gila topminnow in 1982. No other fish species occur there (Voeltz and Bettaso 2003).

In January 1994, longfin dace were found in about 200 feet of flowing water in Connor Wash about 0.5 miles upstream from Cottonwood Artesian (J. Stefferud, field notes, 30 Jan. 1994; SONFISHES). There are cottonwoods at the site, indicating the presence of consistent subsurface water, but sampling in July 2001 found no surface water and no fish at the site (S. Stefferud, field notes 12 July 2001). The source from which longfin dace migrated into this site in 1994 is unknown. Cottonwood Wash empties directly into Lake Roosevelt, which is not known to support longfin dace (SONFISHES). There is no known perennial water in the drainage below the site where the fish were found. Perhaps the stock tank about 2.2 miles upstream may hold water perennially and was stocked with longfin dace by unknown persons, or perhaps there is a resident population of longfin dace upstream in the steep canyon reach another 2 miles above the stock tank or in the upstream portions of Celler or Parker Creeks.

The appearance of fish at isolated sites of short-term surface flow, like this one, illustrates the ability of fish to move substantial distances through ephemeral and intermittent channels. The longfin dace in Connor Wash may have come from up to 5.5 miles downstream or up to 4 miles upstream and may do so periodically to occupy this site when water is present.

There is no stream gauge on Cottonwood Wash.

Figure 8. Connor Wash, Gila Co., AZ – Longfin dace of unknown source



Dry Creek, Yavapai County, AZ

Dry Creek, as its name implies, does not flow perennially. It is an intermittent tributary to Little Ash Creek, which is a perennial-interrupted tributary of the Agua Fria River in north-central Arizona (Figure 9).

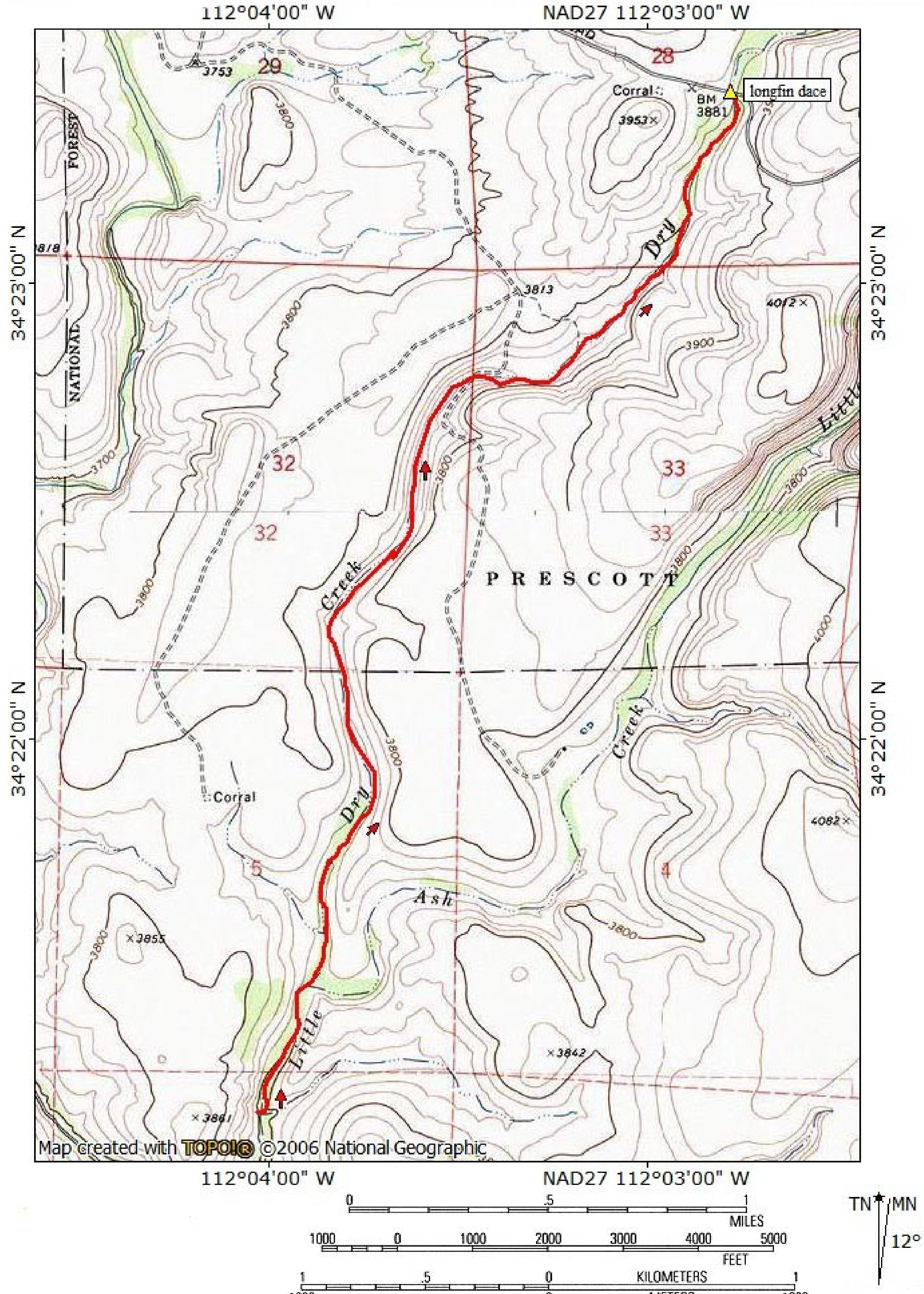
On August 8, 1980, and again on April 8, 1991, native longfin dace were found in a short stretch of water (several hundred feet) above and below the Dugas Road (Prescott National Forest Road 68) (S. Stefferud field notes, 8 April 1991; SONFISHES). Unidentified fish of the family Poeciliidae, likely western mosquitofish, were also seen at this locality in May 1988 (S. Stefferud, field notes, 8 April 1991). This location on Dry Creek is marked on the Forest Service maps as an in-channel spring or area of perennial water in an otherwise dry channel. The stream is "normally dry" between here and the confluence with Little Ash Creek, about 3.3 miles downstream.

Five species of fish have been documented in Dry Creek at its confluence with Little Ash Creek, including longfin dace and western mosquitofish (SONFISHES), providing a source population for periodic colonization movements upstream during flow events. At the time of the 1991 sample of longfin dace, it was noted that there had been recent extensive spring rains.

The ability of the native longfin dace to make long colonizing runs up and downstream into intermittent and ephemeral reaches when flow is available, is well known, although not particularly well documented. In this case, the approximately 3.3 miles of "dry" stream in Dry Creek posed no substantial barrier to at least two upstream movements by the species.

There is no streamflow gauge on Dry Creek.

Figure 9. Dry Creek, Yavapai Co., AZ – Longfin dace migration route (red line & arrows)



JOAQUIN CREEK AND SYCAMORE CANYON, COCHISE COUNTY, AZ

Joaquin Creek and its tributary Sycamore Canyon are intermittent streams in the Cave Canyon drainage of southeastern Arizona (Figures 6 and 10, see also Cave Canyon entry above). They drain off the south-west slope of the Huachuca Mountains and enter Cave Canyon about a mile above the US/Mexico border.

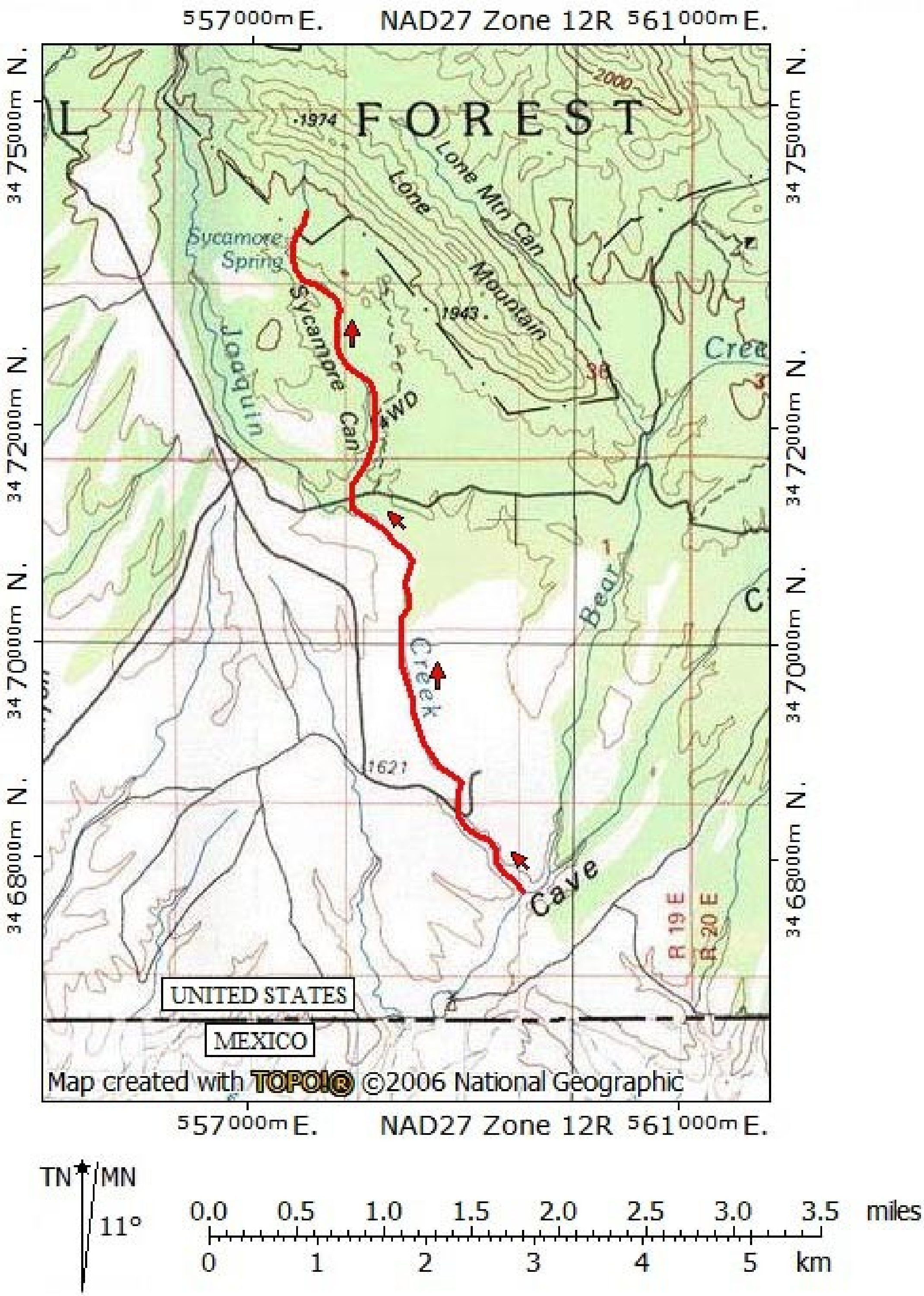
Since 1950 it has been known that these two streams support native longfin dace (Silvey et al. 1984; Stefferud and Stefferud 2004). The longfin dace are scattered throughout the system, concentrating in the perennial reaches of the perennial-interrupted flow during dry times and spreading out to occupy much of the stream channel during periods of flow (see Figure 6). A 1968 record of longfin dace is from a reach of Joaquin Creek near the mouth of Sycamore Canyon, an area that in March 2003 was part of a long dry area reaching up both of the channels, with sparse riparian vegetation and an unstable channel braided through coarse sediment.

Nonnative green sunfish were not recorded from the Joaquin Creek drainage until 1996, when they were noted at the mouth (J. Stefferud, field notes, 9 April 1996). That survey did not include upstream reaches of Joaquin Creek. In 2003, green sunfish were found at the mouth, approximately 1.3 miles upstream of the mouth, and in a 0.5 mile reach at Sycamore Spring in Sycamore Canyon about 4.5 upstream of the mouth of Joaquin Creek (Stefferud and Stefferud 2004). These reaches contained the only in-channel water in drainage in March 2003, with the exception of a small area of flow in upper Joaquin Creek, over 4 miles upstream from the confluence with Sycamore Canyon. No fish were present in that uppermost flow.

Green sunfish in Joaquin Creek and Sycamore Canyon are part of the upstream invasion from Presa La Casa Grande into the Cave Canyon/Los Alisos and Los Fresnos Arroyo drainage network (see also the entries for those streams). There is no barrier preventing green sunfish in lower Cave Canyon from entering Joaquin Creek and moving upstream through that system. By 2003, they had made it as far upstream as Sycamore Spring, approximately 4.5 miles upstream of the confluence of Joaquin Creek and Cave Canyon. Most of this distance consists of intermittent flow and is "normally dry." The reach where both green sunfish and longfin dace were found 1.3 miles upstream of the Joaquin Creek mouth, was small with the length of surface flow only a few hundred feet. While small perennial and semi-perennial areas like these probably facilitate upstream migration, they comprise only a tiny portion of the stream channel that is traversed.

No stream gauges exist in Joaquin Creek or Sycamore Canyon.

Figure 10. Joaquin Creek and Sycamore Canyon, Cochise Co., AZ – Green sunfish migration route (red line & arrows)



LIME CREEK, YAVAPAI COUNTY, AZ

Lime Creek is a small intermittent stream with perennial-interrupted flow in central Arizona (Figure 11). It is tributary to the Verde River in what is now Horseshoe Reservoir. There are several reaches of perennial flow within the drainage, separated by areas in which flow is infrequent. The reach immediately upstream of the reservoir is generally dry. In August 2001, there was approximately a mile of stream with no flow between the reservoir and streamflow (Bagley 2002).

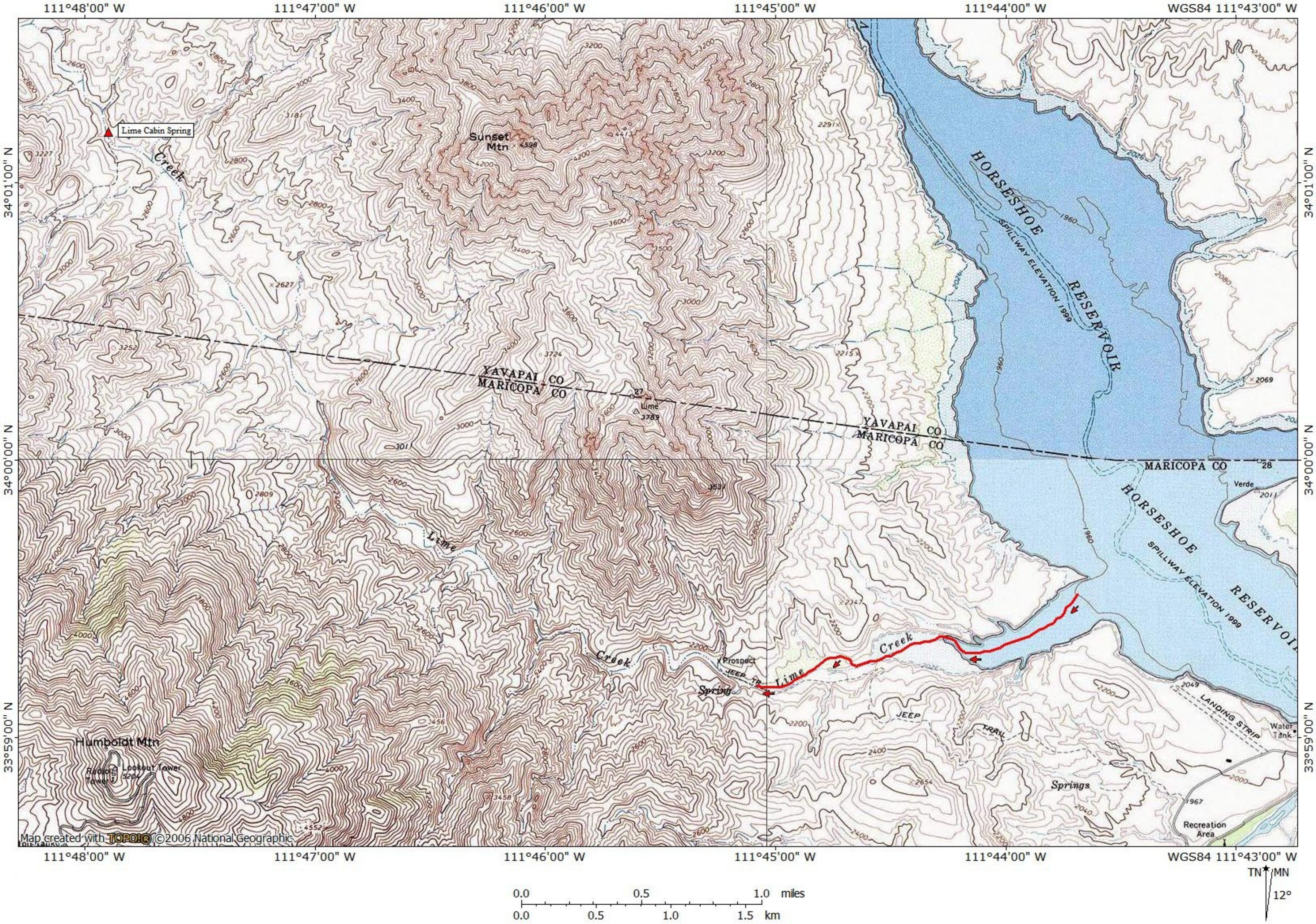
Native longfin dace are found throughout Lime Creek, wherever flow is found. Gila topminnow were stocked into the canyon in 1982 in the vicinity of Lime Cabin Spring in mid-drainage (Brooks 1985). They have been periodically sampled since then and are scattered throughout the mid to lower canyon (Weedman and Young 1997; Voeltz 2004).

Nonnative green sunfish have been periodically found in the lower reaches of the perennial-interrupted flow but not further upstream (Bagley 2002; Voeltz and Bettaso 2003). They apparently move upstream from the reservoir and may not persist, but reinvade when conditions are suitable. A barrier to prevent their incursion further upstream into the reaches occupied by Gila topminnow has been recommended (Voeltz and Bettaso 2003).

Although green sunfish have not yet successfully colonized the middle reaches of Lime Creek, the likelihood that they will do so persists. The lesson learned from red shiner in Aravaipa Creek should be applied to Lime Creek and a barrier constructed before the green sunfish become well established in the drainage.

Lime Creek has no stream gauge.

Figure 11. Lime Creek, Yavapai Co., AZ – Green sunfish migration route (red line & arrows)
(lake shoreline was at elevation 1960' at the time of the 1996 and 2002 fish surveys)



Los Fresnos, Sonora, Mexico

Although Los Fresnos Arroyo is in Mexico, it is the continuation of School Canyon, which drains south off the Huachuca Mountains in Cochise County, in southeastern Arizona (Figure 12). It is a headwater tributary of the San Pedro River, which reenters the United States approximately 30 stream miles downstream (about 17 straight-line miles) from Los Fresnos Cienega. Los Fresnos Cienega is a reach of perennial-interrupted flow in the intermittent School Canyon/Los Fresnos Arroyo.

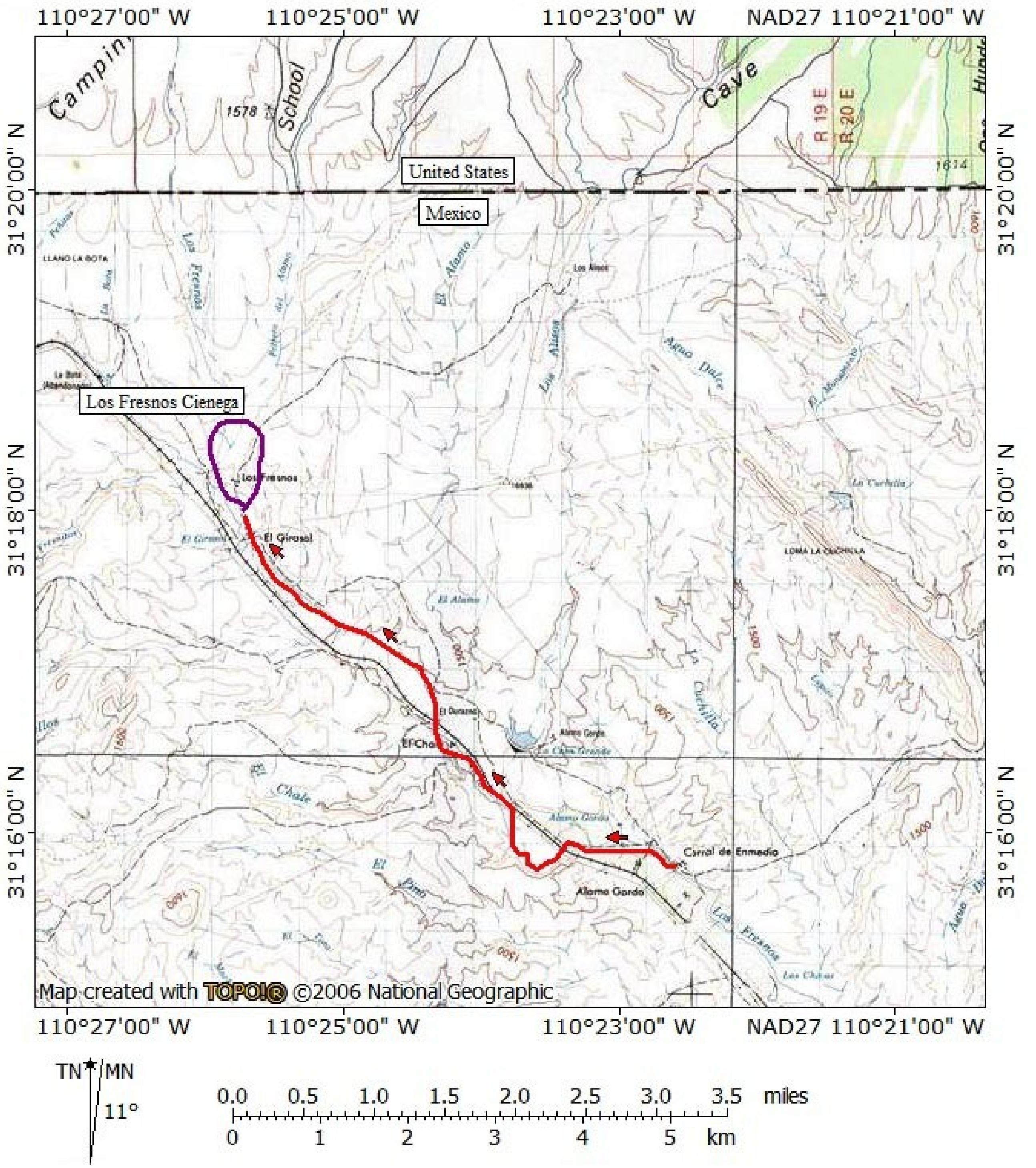
In August 1990, the cienega was occupied by native Gila chub, longfin dace, and Sonora tiger salamander (Varela-Romero et al. 1990). Downstream, the arroyo was dry for 2 miles below the cienega. From 2 to 3 miles below the cienega there were small areas of interrupted flow occupied by longfin dace, with 2 additional miles of dry stream downstream to standing water at a concrete road crossing, where longfin dace and nonnative green sunfish and western mosquitofish were present (S. Stefferud, field notes, 25-26 Aug. 1990). In January 2003, School Canyon was surveyed and no water found in the U.S. portion of the stream, although limited water was present in small off-channel stock tanks (Stefferud and Stefferud 2004).

In May and August 2006, surveys found no Gila chub, longfin dace, or Sonora tiger salamander at Los Fresnos Cienega. The only fish present were green sunfish, which had apparently moved upstream through the five miles of perennial-interrupted arroyo (Rorabaugh et al. 2006; Rorabaugh 2006; Duncan et al. 2006). The arroyo was dry downstream of the cienega, but black bullhead were found 3.5 miles downstream from the cienega at the Presa La Casa Grande. By October 2006, nonnative green sunfish, black bullhead, and native longfin dace were all present in the perennial reach of Los Fresnos Arroyo just below the cienega, where only longfin dace were found in 1990 (Duncan et al. 2006).

The 5 miles of perennial-interrupted stream and over two miles of “dry” channel immediately below the cienega were insufficient to prevent upstream movement by harmful nonnative fishes into the cienega. This invasion is the presumed cause of the apparent extirpation of both native fishes from the cienega and possible the loss of two endangered native species (Gila chub and Sonora tiger salamander).

There is no streamflow gauge on School Canyon or Los Fresnos Arroyo.

Figure 12. Los Fresnos Cienega and Arroyo, Sonora, MX –
Green sunfish and black bullhead migration route (red line and arrows)



OAK GROVE CANYON, SANTA CRUZ COUNTY, ARIZONA

Oak Grove Canyon is an intermittent tributary of Redrock Canyon in southeastern Arizona (Figure 13. Redrock Canyon is a tributary of Harshaw Creek which drains into Sonoita Creek at the town of Patagonia. See the Redrock Canyon entry below for further information.

Oak Grove Canyon sustains perennial water only at Oak Grove Spring and an unnamed spring (called Richard Hale Spring by the U.S. Forest Service) in a side drainage. In the late 1980's and early 1990's there were significant reaches of flow at these two sites as well as others, but only the two have surface water at present, and neither have had significant surface flow during dry months for several years.

Fish sampling in Oak Grove Canyon has been infrequent, but three fish species have been recorded; native longfin dace and Gila topminnow and nonnative western mosquitofish. No permanent habitat for any of these species exists at this time in Oak Grove Canyon, although habitat enhancement efforts are ongoing in an attempt to provide such. Longfin dace were found in the canyon in 1987, 2001, and 2002, with the most upstream location being about 1.25 miles upstream from the confluence with Redrock Canyon (Simons 1987a; Simons 1987b; Stefferud and Stefferud 2004). This reach is entirely intermittent, with no perennial water, but is colonized during periodic high flows by migrating longfin dace.

Gila topminnow have also been found as far upstream as 1.25 miles in Oak Grove Canyon (Simons 1987a; Simons 1987b). This has only been recorded once, in April 1987, when topminnow were also found in Oak Grove Canyon near the mouth. The nearest Gila topminnow found in Redrock Canyon proper during this sampling was at Pig Camp Spring, a perennial water located just off-channel about 0.25 miles upstream from the mouth of Oak Grove Canyon. The intervening 1.5 miles of "normally dry" stream channel did not preclude the Gila topminnow from migrating a substantial distance upstream into Oak Grove Canyon.

In 1990, western mosquitofish were found in Oak Grove Canyon about 1.6 miles upstream in the canyon (Stefferud and Stefferud 1994). At the time, the stream channel downstream was intermittently flowing, although it is usually dry. These mosquitofish most likely were an upstream extension of those found in the semi-perennial reach near the USFS boundary during the same sampling event (see Redrock Canyon entry). Their total migration from Sonoita Creek to the Oak Grove Canyon location was about 6.5 miles, traversing substantial areas that flow only occasionally.

There is no stream gauge on Oak Grove or Redrock Canyons or Sonoita Creek.

Figure 13. Oak Grove Canyon, Santa Cruz Co., AZ – Longfin dace (blue line & arrows) and Gila topminnow (red line & arrows) migration routes

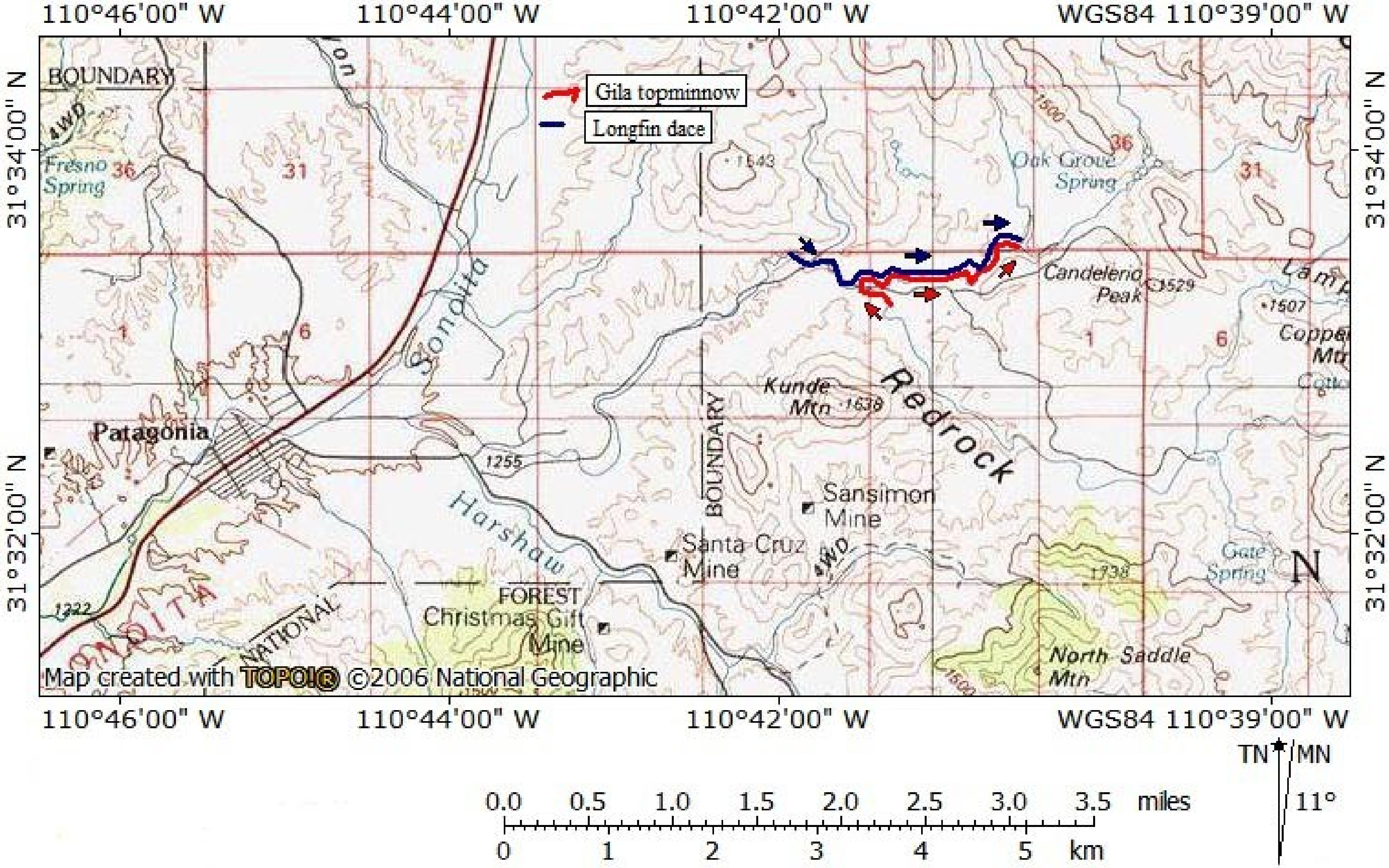
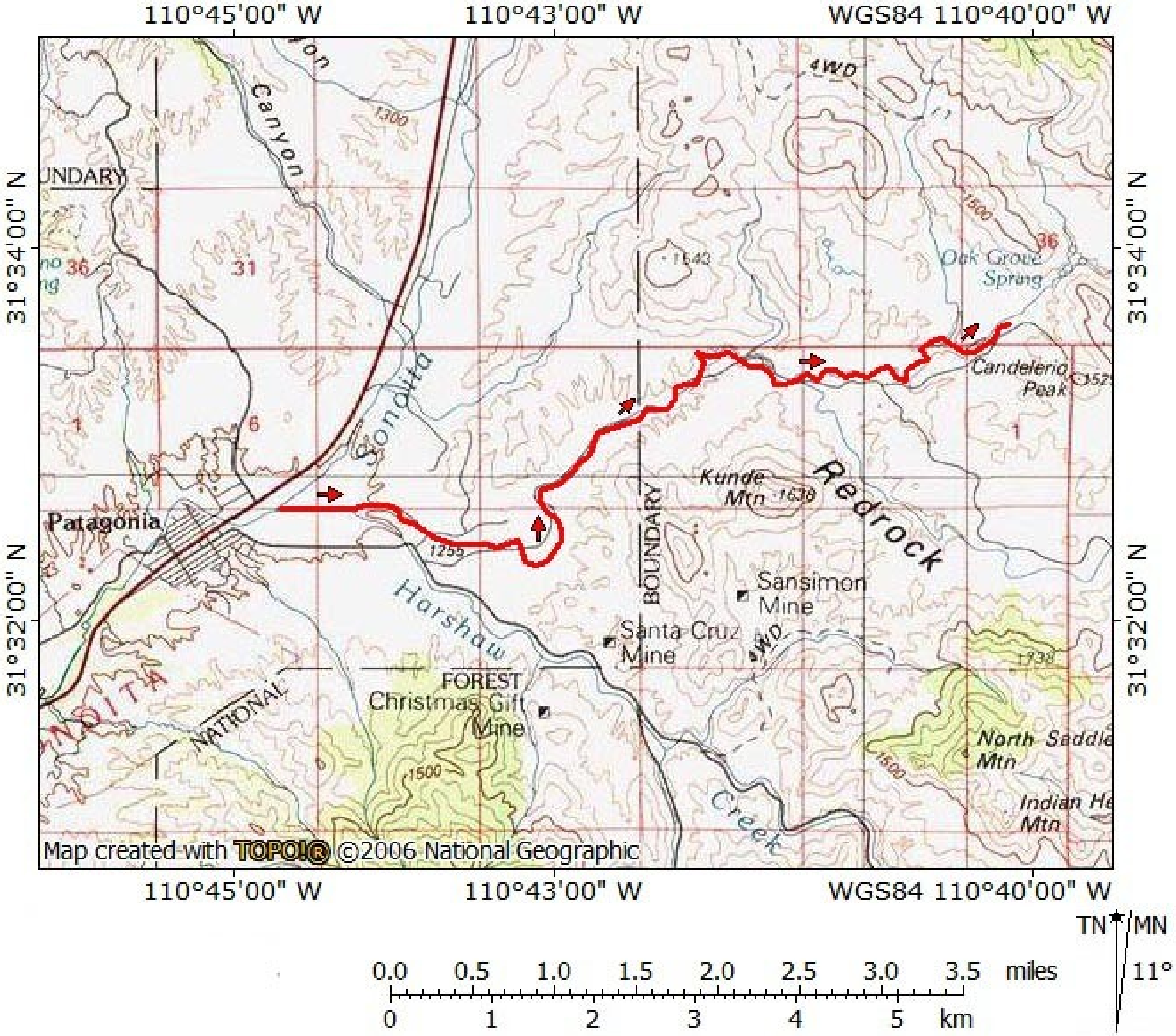


Figure 14. Oak Grove Canyon, Santa Cruz Co., AZ – western mosquitofish migration routes (red line & arrows)



O'DONNELL CANYON, SANTA CRUZ COUNTY, ARIZONA

O'Donnell Canyon is a north-flowing tributary to the Babocomari River, which drains into the San Pedro River (Figure 15). O'Donnell Canyon is an intermittent, perennial-interrupted stream with Canelo Cienega located about half-way up the watershed. Cienegas or springs are also present on several tributaries within the O'Donnell Canyon system (Freeman Springs, Welch Spring, Turkey Creek). Lower O'Donnell Canyon, from the confluence with Turkey Creek to the Babocomari River, is a wide, low-gradient floodplain with multiple channels. The Babocomari River is also an intermittent stream with perennial-interrupted flow.

O'Donnell Canyon at Canelo Cienega supports populations of endangered Gila chub and Gila topminnow as well as native longfin dace and Sonora sucker (SONFISHES; Stefferud and Stefferud 2004). Nonnative green sunfish invaded the cienega about 1990 and populations of native fishes declined (Weedman et al. 1996; Gori 1998). To protect the native fish, green sunfish were removed using piscicide in 2002 (Blasius 2002). Gila chub and Sonora sucker were restocked and Gila topminnow and longfin dace reappeared within the treated area. Prevention of reinvasion from downstream depends upon two old concrete structures, apparently built as grade-control devices. These structures are eroding and in poor condition and plans are underway to repair them for retention as fish barriers (Clarkson et al. 2007).

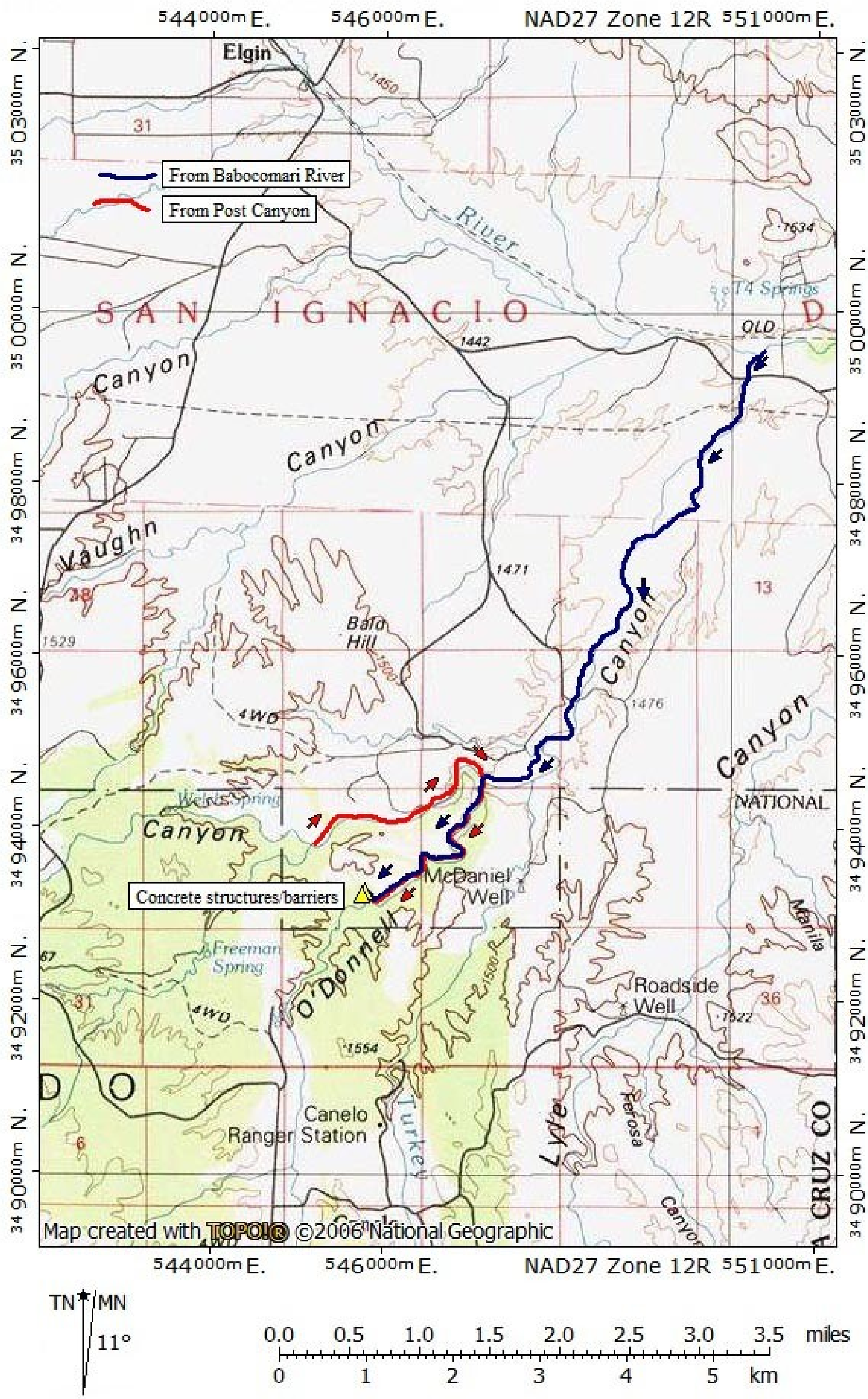
Green sunfish remain in the O'Donnell Creek system downstream of the concrete structures/fish barriers. They are present, along with largemouth bass, in Post Canyon and possibly elsewhere (Stefferud and Stefferud 2004). In addition, green sunfish, black bullhead, largemouth bass, mosquitofish and other nonnative fish species are present in the Babocomari River (SONFISHES) and have the potential to move upstream into O'Donnell Creek. There are about 6 miles of intermittent stream channel between the existing structures and the Babocomari River. There are about 3.25 miles of intermittent channel between the lowest record of green sunfish in Post Canyon and the O'Donnell mainstem structures.

In April 2007, sampling immediately below the structures in O'Donnell Canyon found two green sunfish (Clarkson et al. 2007). No nonnative fishes were found in extensive sampling upstream of the structures. It is most likely that the recently found green sunfish were from Post Canyon but they may have come from the Babocomari River. There were substantial monsoonal rains in 2006 (http://www.wrh.noaa.gov/images/twc/climate/seazDM/canelo.png), which likely resulted in periods of extensive flow through the stream channels of the O'Donnell Creek watershed, perhaps with flow all the way to the river.

The April 2007 findings demonstrate that green sunfish within the O'Donnell Canyon or Babocomari River system have the potential to reinvade the Canelo Cienega. Only with a physical barrier to upstream fish movement will the native fish community of Canelo Cienega remain viable.

There is no stream gauge on O'Donnell Canyon.

Figure 15. O'Donnell Canyon, Santa Cruz Co., AZ – Green sunfish migration routes (red line & arrows are route from Post Canyon, blue line & arrows show route from Babocomari River)



REDROCK CANYON, SANTA CRUZ COUNTY, ARIZONA

Redrock Canyon is a small intermittent stream in southeastern Arizona. It drains the southwest side of the Canelo Hills and is a tributary of Harshaw Creek shortly before it joins Sonoita Creek in the Santa Cruz River basin (Figures 16 and 17). Harshaw Creek is an intermittent stream. Sonoita Creek is also intermittent, with a perennial reach in the area of confluence with Redrock Canyon, supported in part by treated sewage return flows from the town of Patagonia. Flow in Redrock Canyon is perennial-interrupted, with four main areas of perennial or semi-perennial flow in the approximately 15 miles of the mainstem and a headwater tributary known as Cott Tank Drainage (Stefferud and Stefferud 1994). A natural barrier exists in Redrock Canyon about 5.5 miles upstream of the confluence with Sonoita Creek. A perennially-watered reach exists just downstream of the barrier and a semi-perennial reach exists about 1.5 miles downstream of the barrier.

Redrock Canyon supports one of the few remaining natural populations of the endangered Gila topminnow and has been the subject of study for over 20 years. Sampling of fish throughout the mainstem and a portion of the tributaries occurs at least annually. Four native fish species have been recorded in Redrock Canyon; longfin dace, Gila topminnow, desert sucker and speckled dace. Longfin dace appear to maintain a long-term population in the reach below the barrier (Stefferud and Stefferud 1994; Stefferud and Stefferud 2004). Gila topminnow have maintained a population in that area for over 15 years, but have not been found in the reach since 2002, presumably due to the extended drought. Desert sucker and speckled dace have been recorded in Redrock Canyon only in this lower reach. Desert sucker have been found just below the barrier falls in 1987 and again in 2002 and in the lower semi-perennial reach in 2001. Speckled dace have only been recorded once, from the semi-perennial reach in 2001.

Precipitation for four years before the 1987 record of desert sucker was substantially above average. There was near-record precipitation in 2000 when they were again recorded, and in 2001, when both desert sucker and speckled dace were present, precipitation was average (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?az1231). There is no stream gage on either Redrock Canyon or, since 1972, on Sonoita Creek. However, in February 2001, during dry weather, the authors recorded flow (and longfin dace) about 1.25 miles below the US Forest Service lower boundary, in a "normally dry" reach about a third of the way between the semi-perennial flow and Sonoita Creek. We were also present in August 2001 when Redrock Canyon flowed to Sonoita Creek during a monsoon event. That event was not unusually large and it is likely that the canyon flowed to its mouth multiple times during the late summer and early fall of 2001, giving fish the opportunity to migrate upstream through the 4.5 mile lower reach of Harshaw Creek and Redrock Canyon. Both desert sucker and speckled dace are relatively common in Sonoita Creek in the perennial section at Patagonia (Foster and Mitchell 2005).

Although the junction of Harshaw Creek, Redrock Canyon, and Sonoita Creek was historically a large cienega (Hendrickson and Minckley 1984), it is now a wide, unstable, sandy wash with little channel structure. Despite that obstacle, desert sucker have successfully migrated at least twice into Redrock Canyon, surmounting the 4 mile dry reach to the semi-perennial area near the USFS boundary, then the additional 1.5 miles of "normally dry" reach to the foot of the falls barrier. Speckled dace are only known to have made this migration once, but it is likely they have accomplished it other times without being recorded.

Nonnative western mosquitofish are periodically recorded in the reach of Redrock Canyon below the natural barrier falls. They were present in the semi-perennial reach in 1990 and 2000 and were present just downstream of the falls in 2001 and 2002. They are also found in Sonoita Creek in the reach between the town of Patagonia and Patagonia Lake (SONFISHES; Sullivan 1995; Rodgeveller 2000). It appears that with mosquitofish there are two different sources of fish into lower Redrock Canyon, some coming from upstream and some entering Redrock Canyon from Sonoita Creek. The mosquitofish found in 1990 and 2000 were near the USFS boundary about 4 miles upstream of Sonoita Creek (and up into Oak Grove Canyon – see entry for that stream). The nearest upstream mosquitofish recorded in both those years were near Silver Tank Well, about 7.6 miles upstream, most of that channel "normally dry." The mosquitofish in lower Redrock and Oak Grove Canyons in 1990 and 2000, both years of strong precipitation, probably migrated the 4 to 5.6 miles upstream from Sonoita Creek. However, in 2001 and 2002 mosquitofish in this lower reach were located at the base of the falls about 5.5 miles upstream of Sonoita Creek and none were found downstream. The nearest upstream mosquitofish that year were recorded only about 1 mile upstream of the barrier falls, leading to a conclusion that the mosquitofish in the lower reach probably migrated the 6 miles downstream from the Silver Tank Well area.

The fish community of the lower end of Redrock Canyon is an excellent example of how fish use permanent and temporary habitats and migration corridors in intermittent streams. In well-watered years, longfin dace are abundant throughout the entire wetted area, extending downstream to the lower end of flow. The perennial area at the base of the falls, and the semi-perennial reach near the USFS boundary provide long-term populations of some species (longfin dace, Gila topminnow), while others periodically migrate in from upstream (mosquitofish) and downstream (desert sucker, speckled dace, and mosquitofish). This adaptive habitat-use strategy is well-suited to survival in arid-land streams.

Figure 16. Redrock Canyon, Santa Cruz Co., AZ – Desert sucker (red line & arrows) and speckled dace (blue line & arrows) migration routes

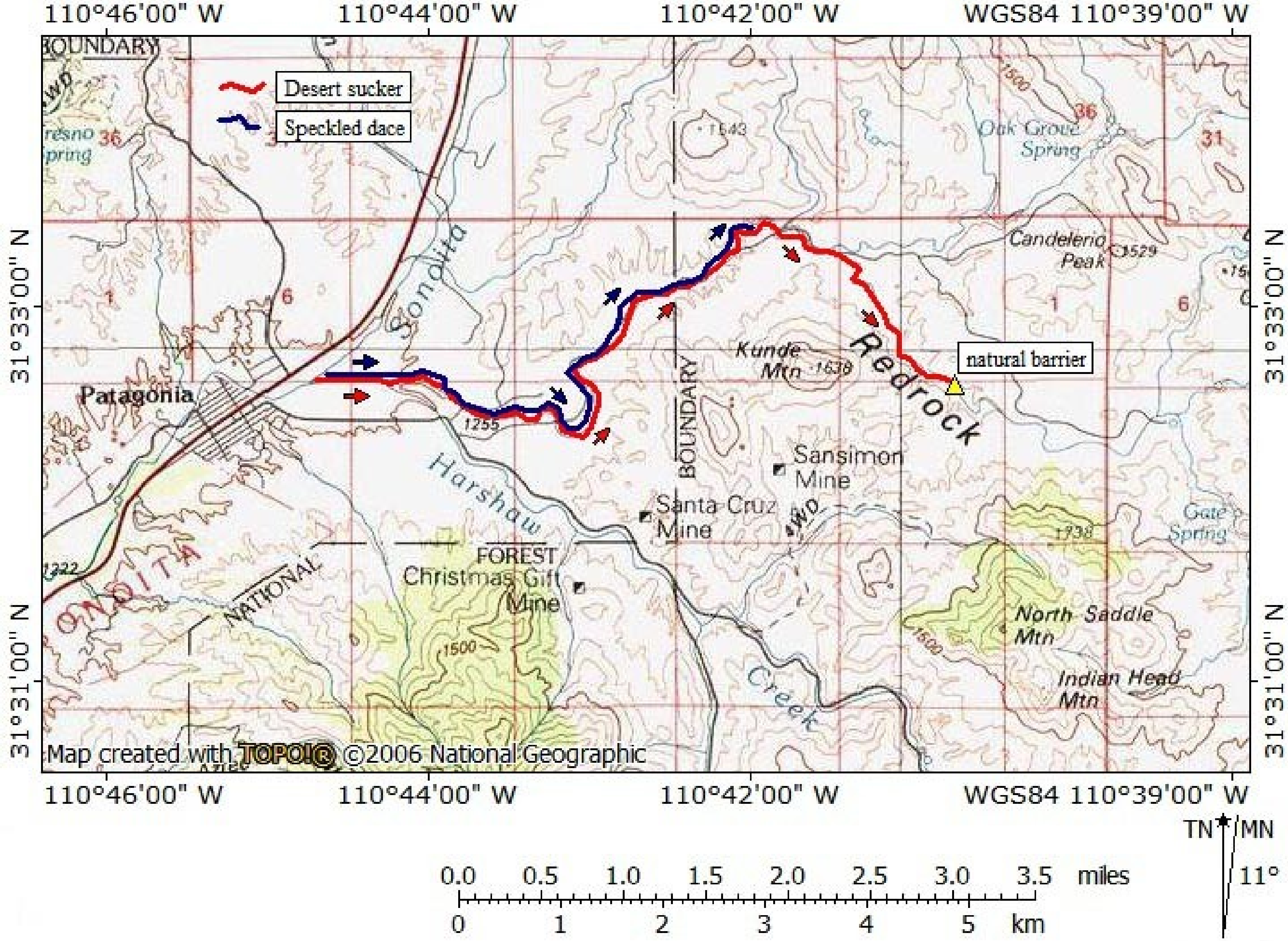
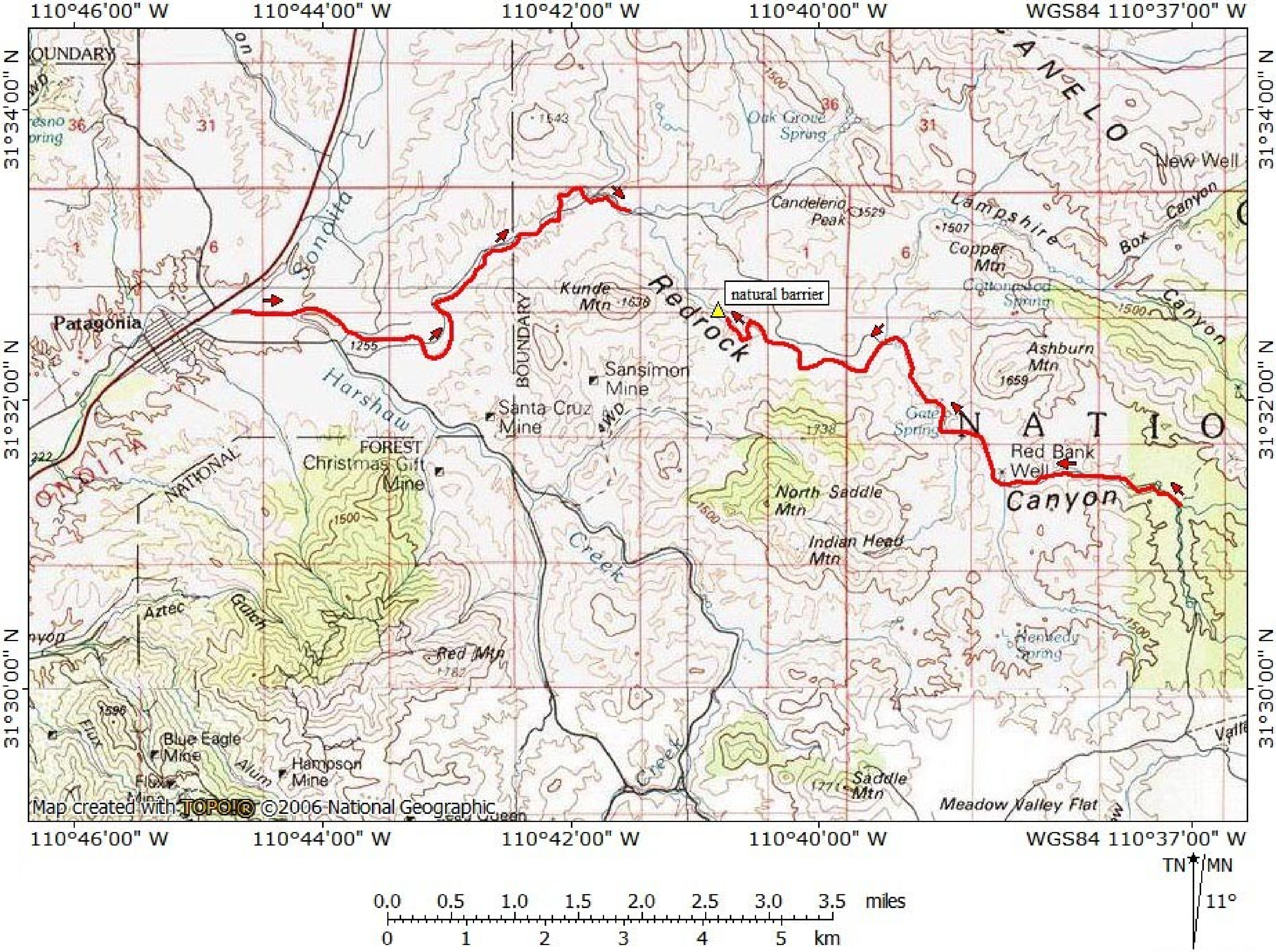


Figure 17. Redrock Canyon, Santa Cruz Co., AZ – Western mosquitofish migration routes (red lines and arrows)



SHARP SPRING, SANTA CRUZ COUNTY, ARIZONA

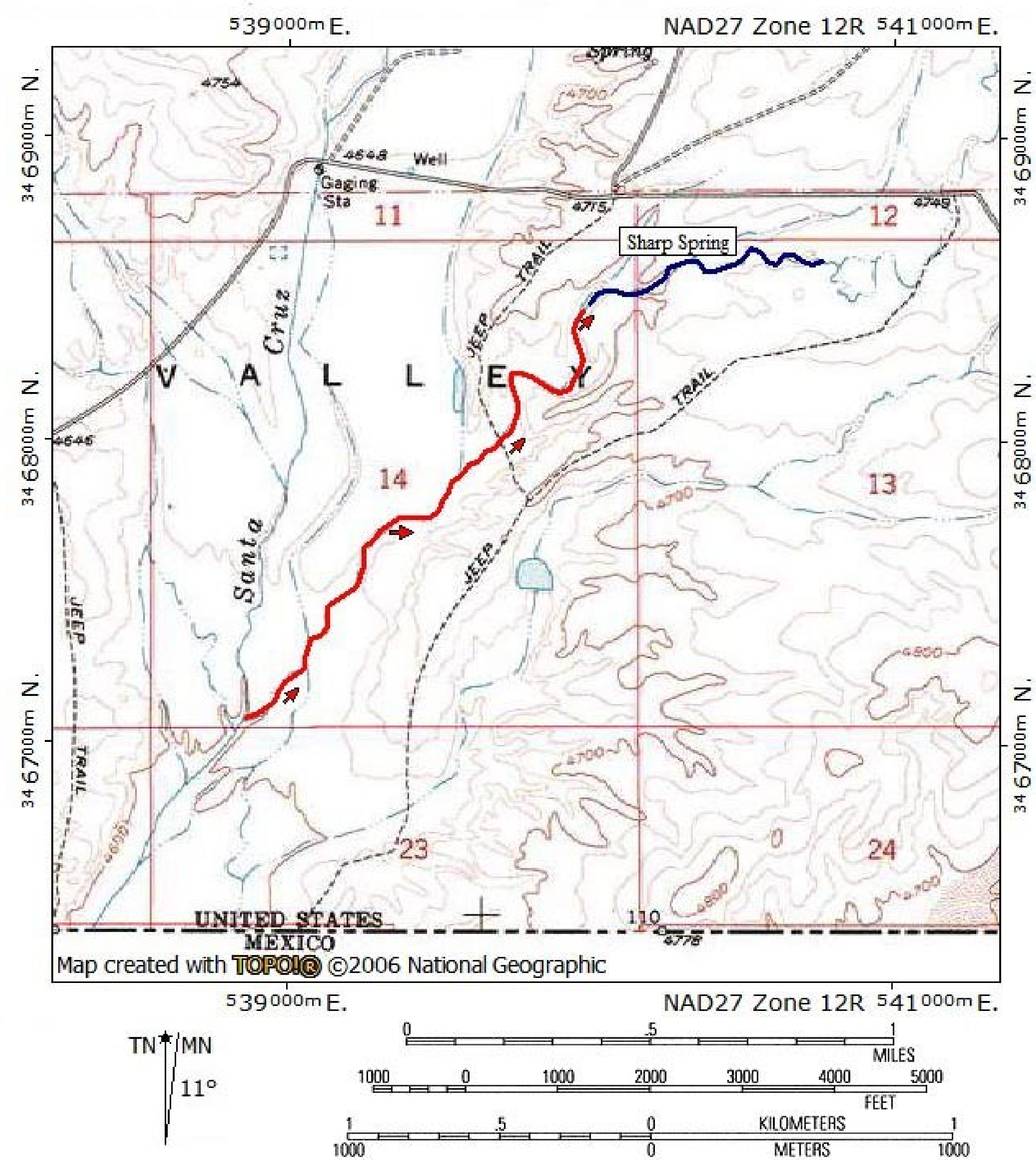
Sharp Spring is a medium-sized cienega in a short drainage tributary to the upper Santa Cruz River in the San Rafael Valley in southeastern Arizona (Figure 18). It enters the Santa Cruz River near the U.S./Mexico border. The Santa Cruz River is a perennial-interrupted stream with a reach of perennial flow in that vicinity. The drainage connecting Sharp Spring and the river is "normally" dry for about 1.3 miles below the cienega. The cienega is composed of a series of pools. Depending upon climatic and weather fluctuations, some pools may be connected by small channels, others by marshy areas with no channel, and others only by subsurface flow (Stefferud and Stefferud 2004).

Sharp Spring supports a naturally-occurring population of endangered Gila topminnow. Nonnative western mosquitofish have been known to exist in the adjacent Santa Cruz River since the mid 1960's (SONFISHES). When Sharp Spring was first sampled in August 1979 mosquitofish had already invaded the system from the Santa Cruz River, but had colonized only the lower third of the cienega system (Meffe et al. 1982). This situation held through 1981, but by 1985 mosquitofish were found throughout the entire system (Meffe et al. 1983; Brooks 1986).

Western mosquitofish, a small species that lives in waters with little or no current, is not known for exceptional speed or endurance in swimming (Casterlin and Reynolds 1977), but it has shown remarkable ability to surmount obstacles, sometimes by migrating through sheet flow (Bagley and Marsh 1995). Clearly the 1.3 mile reach of seldom-flowing channel between Sharp Spring and the Santa Cruz River was insufficient to block the successful colonization of the cienega by mosquitofish. This has been highly detrimental to the Gila topminnow, which has declined precipitously (Stefferud and Stefferud 2004).

There is no stream gauge on Sharp Spring. There is a gauge on the Santa Cruz River a short way upstream from the confluence of the two drainages, but data from that gauge would not accurately reflect flow in the Sharp Spring drainage. The Santa Cruz River at that point has gathered flow from the Canelo Hills, Huachuca and Patagonia Mountains, and flow is highly influenced by localized precipitation events far removed from the Sharp Spring area. Flow in the Sharp Spring drainage is primarily from localized events on Jones Mesa or the southwest side of the Huachuca Mountains or by widespread storms.

Figure 18. Sharp Spring, Santa Cruz Co., AZ – Western mosquitofish migration route (red line & arrows; blue line indicates the extent of Sharp Spring cienega)



Sycamore Canyon, Santa Cruz County, Arizona

Sycamore Canyon is an intermittent stream with a perennial-interrupted flow consisting of isolated pools or sometimes continuous flow in the approximately 6 miles upstream of the U.S./Mexico border (Figure 19). Flow seldom reaches the border, sinking into the alluvium as the canyon widens in that area (Hendrickson and Juarez-Romero 1990). Upstream in the U.S., the canyon is narrow and rock-bound. Sycamore Canyon is a headwater tributary of the Rio Altar. Its continuation in Mexico is known as Los Alisos.

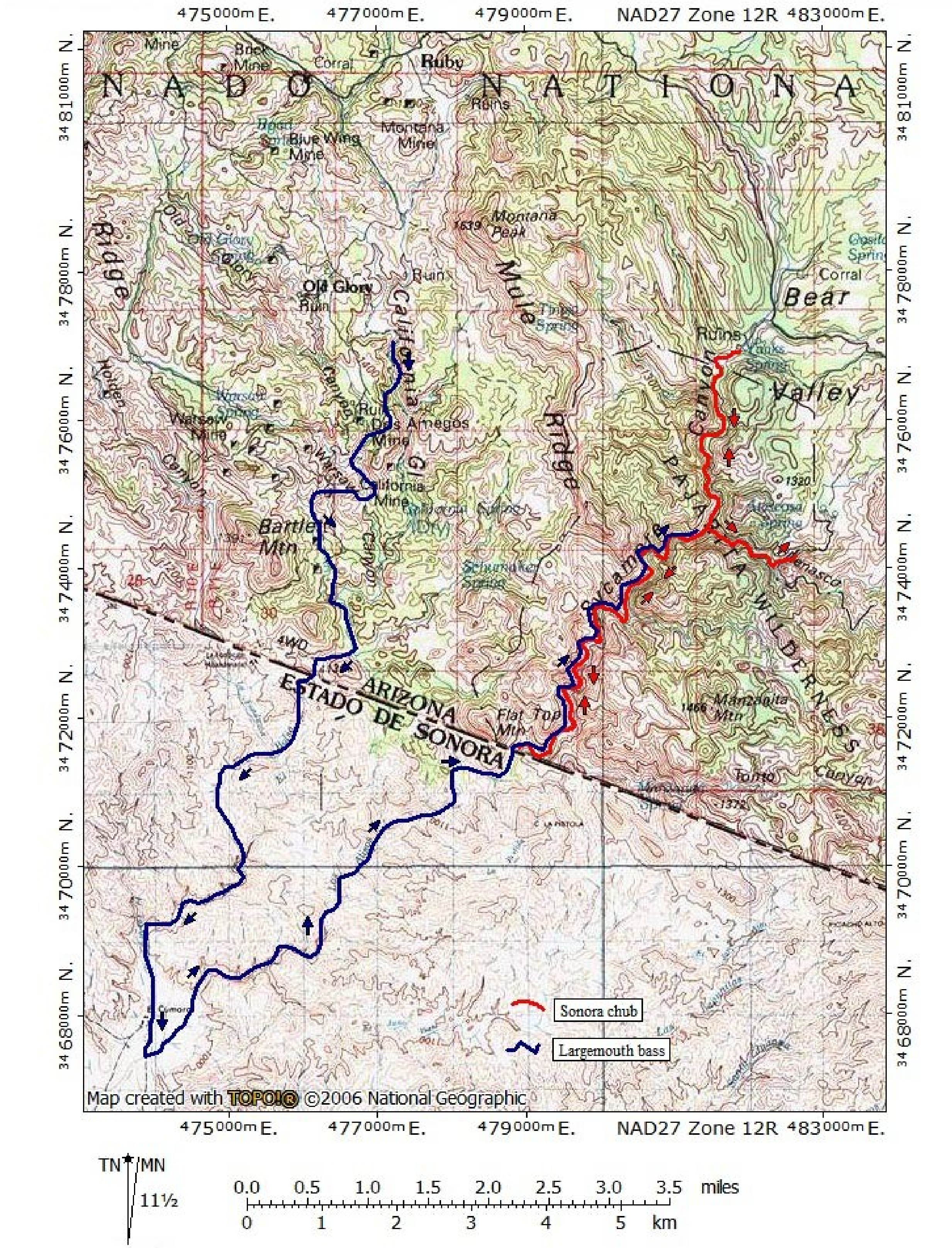
Native Sonora chub are found throughout Sycamore Canyon, wherever water is present. The species has a remarkable ability to pass upstream over rock drops and seemingly impassable barriers (Carpenter and Maughan 1993). It is also found in three side tributaries to Sycamore Canyon (Penasco Canyon, Tinaja Spring Canyon and Little Tinaja Spring Canyon), with the areas of perennial-interrupted flow in those tributaries often separated from water in the main canyon by areas of dry channel up to a mile in length. The ability of Sonora chub to move through the intermittent stream reaches that are "normally dry" is well documented. Carpenter and Maughan (1993) frequently observed Sonora chub moving between pools that were connected only temporarily by flow following precipitation, including fish movement as the channel was about to become dry.

Nonnative green sunfish and mosquitofish have been reported from Sycamore Canyon in the past (Carpenter and Maughan 1992). In July 2007, University of Arizona and Arizona Game and Fish Department biologists captured a largemouth bass deep within the perennial-interrupted area of Sycamore Canyon (P. Rosen, Univ. of AZ, pers. com., 1 July 2007). Tom Newman, former U.S. Forest Service biologist in the area, reports that he did not find any exotic fish during his stock tank surveys in the Sycamore Canyon drainage and is not aware of any source of largemouth bass within the U.S portion of the watershed (D. Mitchell, AZ Game and Fish Dept., pers. com., 3 July 2007). Largemouth bass are known from California Gulch, which joins Sycamore Canyon, about 5 miles downstream from the U.S. border (Stefferud 2000). They are also present downstream in the Rio Altar near the town of Saric (Hendrickson and Juarez-Romero 1990). The distance to be traversed from California Gulch would be about 17 miles, of primarily "normally dry" stream (see entry for California Gulch). If the bass came from downstream in the Rio Altar, the distance to the nearest largemouth bass record (in 1988) is approximately 25 miles.

The invasion of largemouth bass into Sycamore Canyon is bad news for Sonora chub. Largemouth bass are highly predatory and in the confined pools of Sycamore Canyon could have serious detrimental effects on Sonora chub. They are known to exert substantial negative effect on native species elsewhere in the southwest (Bonar et al. 2004). It remains to be seen if they can successfully colonize and establish a reproducing population in Sycamore Canyon. Given the volatility of the habitat, this step may be more difficult than the migration through intermittent stream reaches. Indeed, as the experience with red shiner in Aravaipa Canyon demonstrates, the invasion by movement through "normally dry" stream reaches may occur several times before successful colonization is achieved.

Sycamore Canyon has no stream gauge.

Figure 19. Sycamore Canyon, Santa Cruz Co., AZ – Sonora chub (red line & arrows) and largemouth bass migration routes (blue line & arrows)



TEMPORAL GULCH, SANTA CRUZ COUNTY, ARIZONA

Temporal Gulch is an intermittent stream that is tributary to Sonoita Creek in the Santa Cruz River basin in southeastern Arizona (Figure 19). Temporal Gulch drains off the east side of the Santa Rita Mountains. Sonoita Creek, also intermittent, has a reach of perennial-interrupted flow in the area of confluence with Temporal Gulch, supported in part by treated sewage return flows from the town of Patagonia.

Native longfin dace, desert sucker, and speckled dace have been recorded from Temporal Gulch. Longfin dace are found upstream beyond Mansfield Canyon, about 8 miles upstream of the confluence with Sonoita Creek (Stefferud and Stefferud 2004). Longfin dace may persist at all times in small remnant areas of flow in protected areas throughout the canyon. Water and habitat conditions in the stream make it unlikely that the other two species, particularly desert sucker, sustain long-term populations in the stream. Both desert sucker and speckled dace are relatively common in Sonoita Creek in the perennial section at Patagonia (Foster and Mitchell 2005).

Desert sucker are periodically found in Temporal Gulch, and they are believed to reinvade the stream from Sonoita Creek when connecting flow occurs. In 1991, desert sucker were found about 1.8 miles upstream in Temporal Gulch (SONFISHES). Then in 2001, numerous desert sucker were found in several locations 5 to 6 miles up Temporal Gulch from the mouth (Newman 2001). The record of these sightings notes that many of the pools in which these fish were found were likely to dry up within a few weeks. In August 2002, desert sucker were found about 3.5 miles up from the mouth in what appeared to be a seasonally flowing reach that would be dry after the monsoon season (Stefferud and Stefferud 2004).

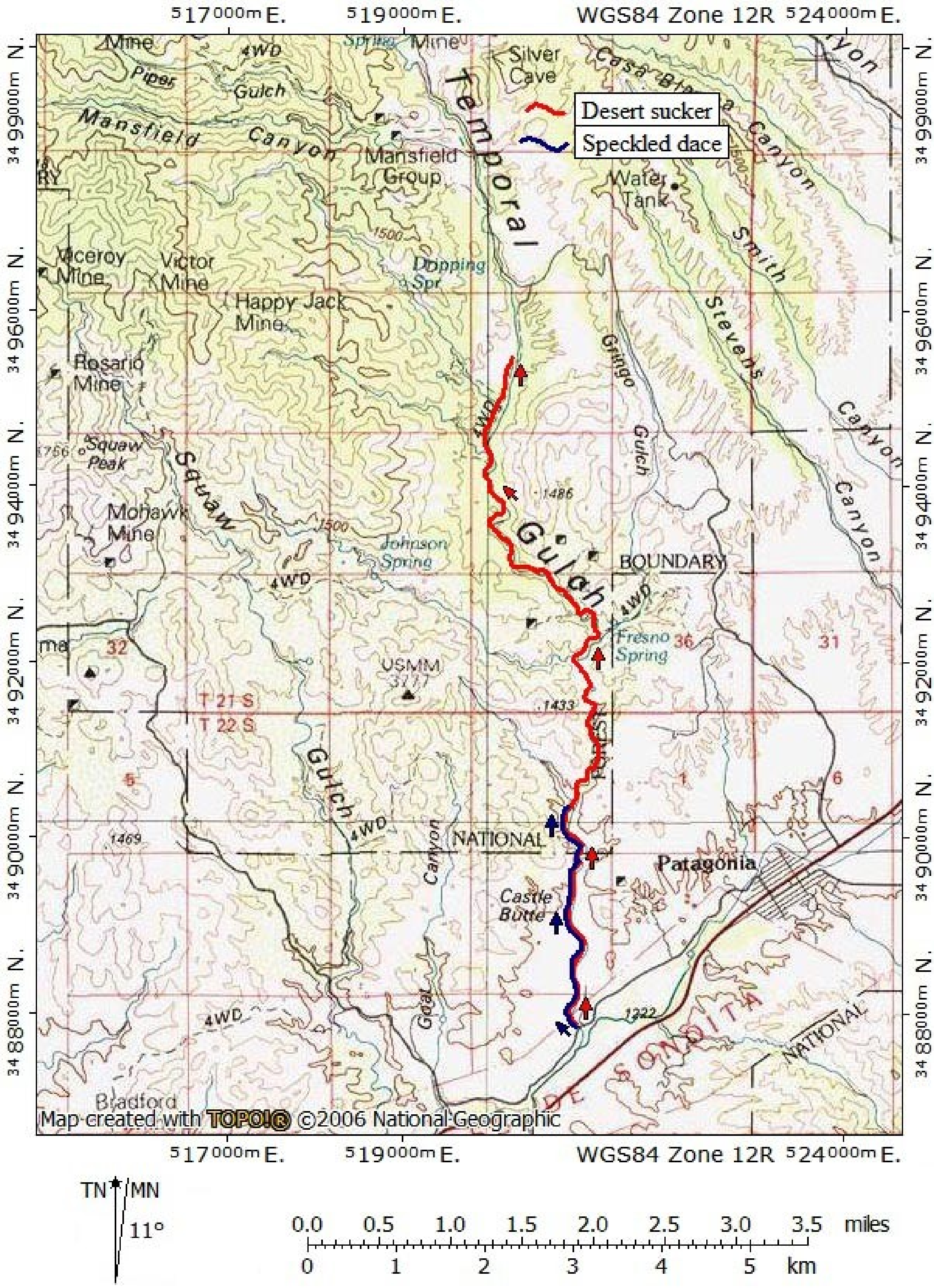
Speckled dace have only been recorded once in Temporal Gulch, in 1991 in a location about 1.8 miles upstream from the mouth. This is the point at which perennial-interrupted flow ends and the channel downstream of there runs only during precipitation.

The lower 2 miles of Temporal Gulch appear very inhospitable to fish movement. The channel is about 100-200 feet wide with multiple sandy braids and very little riparian vegetation. The active channel had no lateral control and moves back and forth through multiple channels (Stefferud and Stefferud 2004). Streambank erosion is active. Transiting this area during flow events would pose a significant challenge, with high sediment, little cover, and multiple channels. However, it appears that desert sucker, and perhaps speckled dace, can successfully overcome that obstacle as well as several additional miles of intermittent stream channel, to periodically occupy the lower 6 miles of Temporal Gulch.

Nonnative green sunfish are present in Sonoita Creek in the Patagonia area (Killeen 2005). Although they are not known to have immigrated into Temporal Gulch, the potential for them to do so exists and is a threat to the native fish in Temporal Gulch. Given the demonstrated ability of green sunfish to transit substantial intermittent reaches in other streams, and given that desert sucker are able to do so in Temporal Gulch, then it is only a matter of time until green sunfish colonize the perennial-interrupted reaches of Temporal Gulch.

There is no stream gauge on Temporal Gulch.

Figure 20. Temporal Gulch, Santa Cruz Co., AZ – Desert sucker (red line & arrows) and speckled dace (blue line & arrows) migration routes



Unnamed Spring #0, Maricopa County, Arizona

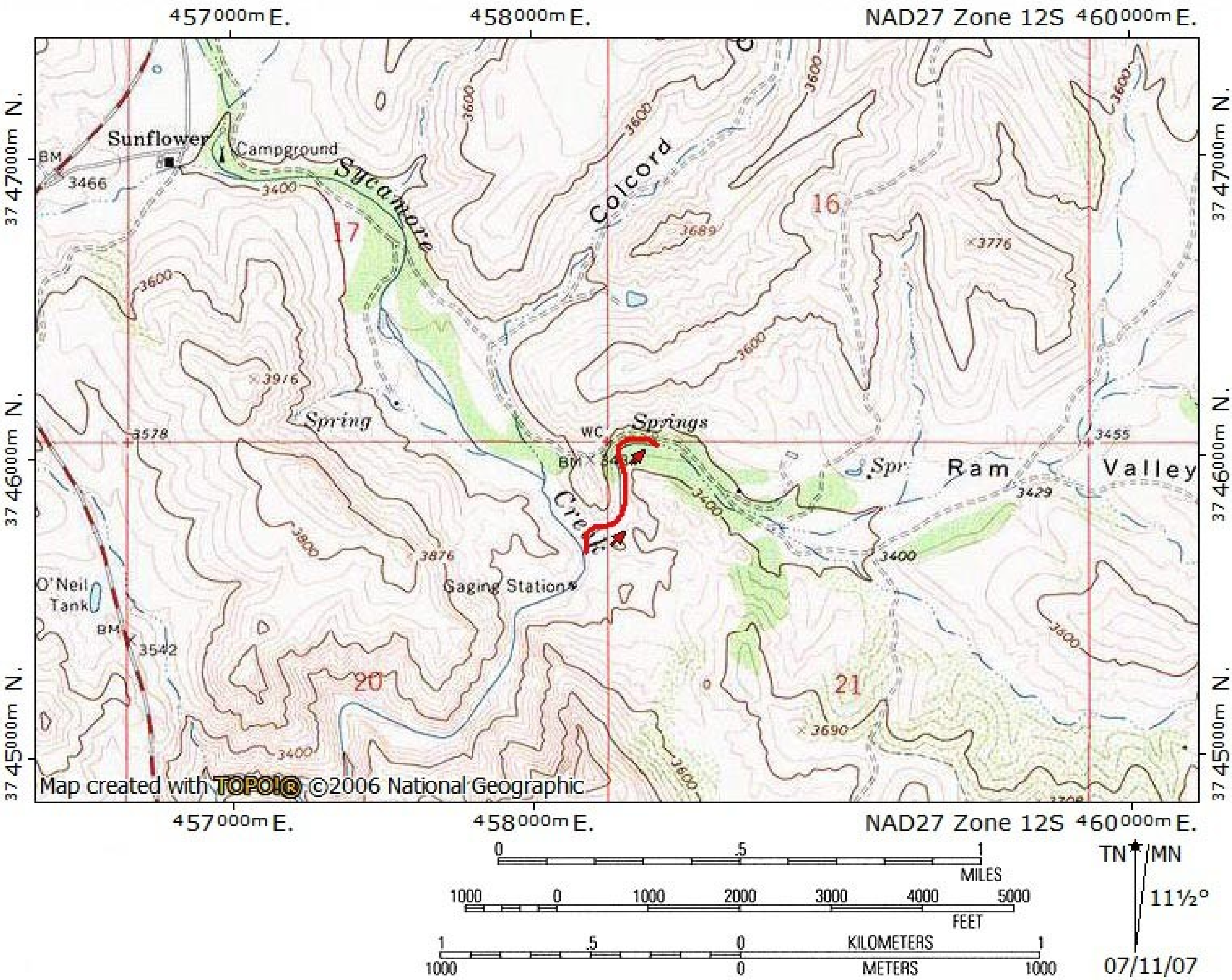
Unnamed Spring #0 is an in-channel upwelling in an intermittent tributary to Sycamore Creek in central Arizona (Figure 20). This is the Sycamore Creek that is tributary to the lower Verde River on the Fort McDowell Indian Reservation. Unnamed Spring #0 is located about 0.4 miles upstream from the confluence with Sycamore Creek, a perennial-interrupted stream with semi-perennial flow in this reach.

Unnamed Spring #0 was stocked in 1982 with endangered Gila topminnow. At the time it was fishless, as were two upstream tanks that were also stocked (Brooks 1985). By 1985, all of these sites were again fishless and one of the tanks was reported dry. In 1986, sampling located native longfin dace at the site (Voeltz and Bettaso 2003) and in 1989, both longfin dace and nonnative fathead minnow were present (Bagley et al. 1991). The two tanks upstream were dry (S. Stefferud, field notes, 8 Aug. 1989). The site was again sampled in 1993, with only longfin dace found, but crayfish were now present (Voeltz and Bettaso 2003).

Longfin dace are common in adjacent Sycamore Creek and fathead minnow have been found in Sycamore Creek since 1969 (SONFISHES). Crayfish are present in Sycamore Creek and are believed to have been introduced about 1985 or 1986 (Fernandez and Rosen 1996). It appears that the 0.4 mile reach of the unnamed tributary to the perennial water at Unnamed Spring #0 presents little, if any, barrier to upstream movement of longfin dace, fathead minnow, and crayfish.

A stream gauge existed on Sycamore Creek just downstream of the confluence with the tributary from Unnamed Spring #0 from 1962 to 1976. During that period, Sycamore Creek supported flow 95% of the time. The median flow was 0.52 cfs.

Figure 21. Unnamed Spring #0, Maricopa Co., AZ – Fathead minnow and longfin dace migration route (red line & arrows)



Conclusions and Summary

Table 2. Intermittent streams and upstream fish movement -- summary

STREAM	SPECIES (N=native; I=invading nonnative)	MILES OF INTERMITTENT "BARRIER"	DATE OF SAMPLE OR OBSERVATION	DATA SOURCE
Aguajita Spring	Mosquitofish – I Longfin dace – N Quitobaquito pupfish-N	1.5 miles	1990	U.S. Fish and Wildlife Service 1990a
Aravaipa Creek	Red shiner – I	5-6 miles	1997	Stefferud and Reinthal 2005
Arnett Creek	Green sunfish – I	3 miles	2001	J. Stefferud field notes 2001
California Gulch	Sonora chub – N	2.2 miles	2000	Stefferud 2000
Cave Creek	Green sunfish – I Longfin dace – N	5.5 miles	1996, 2003	Stefferud and Stefferud 2004
Connor Wash	Longfin dace – N	??	1994	J. Stefferud field notes 1994 SONFISHES
Dry Creek	Longfin dace -N	3.3 miles	1980, 1991	S. Stefferud field notes 1991 SONFISHES
Joaquin Creek and Sycamore Canyon	Green sunfish – I Longfin dace – N	4.5 miles	1996, 2003	J. Stefferud field notes 1996 Stefferud and Stefferud 2004
Lime Creek	Green sunfish -I	1 mile	1996-2002	Bagley 2002 Voeltz & Bettaso 2003 Weedman 1996
Los Fresnos Arroyo	Green sunfish – I Black bullhead - I	5 miles	1990-2006	Varela-Romero et al. 1990 Rorabaugh et al. 2006 Duncan et al. 2006
Oak Grove Canyon	Mosquitofish – I Longfin dace – N Gila topminnow - N	1.5 – 6.5 miles	1987-2002	Simons 1987a Simons 1987b Stefferud and Stefferud 1994
O'Donnell Canyon	Green sunfish - I	3.25-6 miles	2007	Clarkson et al. 2007
Redrock Canyon	Desert sucker – N Speckled dace – I Mosquitofish – I	5.5 miles	1987, 1990, 2000, 2001, 2002	AGFD data Stefferud and Stefferud 2004
Sharp Spring	Mosquitofish – I	1.3 miles	1979-1985	Meffe et al. 1982, 1983 Brooks 1986
Sycamore Canyon	Largemouth bass –I Sonora chub – N	17 miles	2007	P. Rosen and D. Mitchell pers. com 2007 Carpenter and Maughan 1993 Stefferud 2000
Temporal Gulch	Desert sucker – N	6 miles	1991-2002	SONFISHES Newman 2001 Stefferud and Stefferud 2004
Unnamed Spring #0	Fathead minnow – I Longfin dace – N Crayfish – I	0.4 miles	1986-1993	Brooks 1985 Bagley et al. 1991 Voeltz and Bettaso 2003

The case studies examined are summarized in Table 2. They support the concept that native and nonnative fish can and do move upstream through "normally dry" reaches that flow only intermittently or ephemerally. The seventeen cases (eighteen streams) examined here provide a substantive, inferential basis for concluding that such movement has a high likelihood of occurrence in most Arizona intermittent streams and can occur through long reaches of "dry" channel or perennial-interrupted flow. Whether these migrations are accomplished in one movement or whether they occur as a series of successive movements between perennial or semi-perennial reaches cannot be determined from the limited data. Given the pattern illustrated by these case studies, it is reasonable to expect the continuing use of intermittent and ephemeral habitats by native fishes and the ongoing spread of nonnative fishes into the smaller streams of Arizona and the desert southwest.

The twelve species involved in these cases are a mix of native (six) and nonnative (six) and represent a wide range of habitat requirements and swimming abilities. Despite this disparity, all have shown the ability to move through "normally dry" stream channels in defiance of "common sense." The evidence from these studies does not support an assumption that a reach of "normally dry" intermittent or ephemeral channel will prevent invasion of upstream habitats by nonnative fish species.

The dominance of western mosquitofish and green sunfish in these case studies is notable. These two nonnative species have often been implicated in declines of native fish (Minckley 1999; Dudley and Matter 2000). Their ability to move through temporary flows to colonize new habitats is consistent with their known distribution throughout large and small, natural and man-made waters in Arizona. From these and other data, it appears that green sunfish in particular may be gradually expanding in range in the Gila River basin to include many smaller, perennial-interrupted streams, and that this expansion has accelerated in the past 10-15 years. Further examination of recent changes in the distribution of green sunfish may be warranted.

As David Simberloff pointed out (Brown et al. 2007), our ability to predict nonnative species invasions is poor, our ability to reverse invasions almost nonexistent, and the consequences are often very serious. We cannot afford to avoid actions to prevent such invasions because it "would be cheaper and easier in the short-term to say that we lack proof and should delay regulation." He believes we should treat invasive species as if they are "guilty until proven innocent." In the case of invasive fish in intermittent and ephemeral streams in Arizona, this translates to accepting our current understanding of nonnative fish invasions upstream through intermittent and ephemeral reaches as sufficient to act upon, identifying streams where such potential invasions could affect native fishes, and moving rapidly to emplace structures or other mechanisms to prevent such invasions.

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APPENDIX A
Scientific Names of Species

<u>Native species</u>

Apache trout	*Oncorhynchus apache*
Desert sucker	*Pantosteus clarki*
Gila chub	*Gila intermedia*
Gila topminnow	*Poeciliopsis occidentalis*
Longfin dace	*Agosia chrysogaster*
Quitobaquito pupfish	*Cyprinodon eremus* (formerly in desert pupfish *C. macularius*)
Roundtail chub	*Gila robusta*
Sonora chub	*Gila ditaenia*
Sonora tiger salamander	*Ambystoma tigrinum stebbinsi*
Speckled dace	*Rhinichthys osculus*

<u>Nonnative species</u>

Black bullhead	*Ameiurus melas*
Fathead minnow	*Pimephales promelas*
Green sunfish	*Lepomis cyanellus*
Largemouth bass	*Micropterus salmoides*
Red shiner	*Cyprinella lutrensis*
Western mosquitofish	*Gambusia affinis*