

Gila Topminnow Interactions With Western Mosquitofish: An Update

Douglas K. Duncan

Arizona Ecological Services Office, U.S. Fish and Wildlife Service, Tucson, Arizona

Abstract—Western mosquitofish *Gambusia affinis* has major impacts on Gila topminnow *Poeciliopsis occidentalis*. Thirteen years have passed since information on negative impacts has been published. I will list and discuss additional examples where mosquitofish have impacted topminnow. In addition, it appears that long-term drought has a synergistic and negative effect on this relationship. Since the last publications detailing the loss of Gila topminnow populations to mosquitofish, two natural topminnow populations have been lost in the Santa Cruz River basin: Redrock Canyon and Sharp Spring. Drought and climate change likely exacerbated the impacts of mosquitofish on these two populations, speeding the decline and disappearance of topminnow from both. Dynamic conservation actions are required to conserve and recover the Gila topminnow.

Introduction

It has long been known and thoroughly documented that *Gambusia affinis* western mosquitofish (mosquitofish) has major deleterious effects on individual *Poeciliopsis occidentalis* Gila topminnow (topminnow) and their populations. It has been 13 years since information on these negative impacts has been updated. In this paper I will list and discuss additional examples where mosquitofish have impacted topminnow. I will also summarize the apparent mechanisms of how mosquitofish extirpate topminnow, and what the future of topminnow conservation might require.

The last peer-reviewed paper on topminnow-mosquitofish interaction was by W. L. Minckley (1999), and the last publication of any sort discussing this was by Voeltz and Bettaso (2003). Further information can be found in Minckley and others (1977, 1991) and Meffe and others (1983). These publications and others (Meffe and others 1982; Miller 1961) have made it abundantly clear that mosquitofish negatively impact topminnow, and documented the likely mechanisms responsible (Meffe 1984, 1985; Schoenherr 1974). However, a brief review of the mechanisms by which mosquitofish impact multiple species, and topminnow populations in particular, are appropriate.

Mosquitofish was first collected in Arizona in the Phoenix area in 1926 (Miller and Lowe 1964), in habitats that also held topminnow and other native fishes. Subsequently, mosquitofish came to be distributed, most likely through purposeful release, not all legally, throughout Arizona (Meffe 1985; Minckley 1973). They have also been released worldwide (Courtenay and Meffe 1989; ISSG 2010), and have been called the most introduced species in the world (Welcome 1988).

In addition to impacts on Gila topminnow, mosquitofish have impacted other native fish in the western United States (Deacon and others 1964; Meffe 1985; Whitmore 1997) and the rest of the world (Arthington and Lloyd 1989; Glover 1989; Milton and Arthington 1983; Unmack and Brumley 1991). Mosquitofish have also been shown or suspected to prey on tadpoles (Goodsell and Kats 1999; Morgan and Buttemer 1997; Webb and Joss 1997), newts (Gamradt and Kats 1996), frogs (Rosen and others 1995), and aquatic insects (Carchini and others 2003; Englund 1999). Several studies have demonstrated that mosquitofish (Crandall and Bowser 1982; Dykova and others 1994; Lom and Dykova 1995; Moravec 1998) and related species (Perlmutter and Potter 1987) carry parasites and disease that can be transferred into aquatic systems where they are released. Lastly, once introduced, mosquitofish are also known to cause cascading changes in the function of aquatic systems (Bence 1988; Hoy and others 1972; Hurlbert and others 1972; McDowall 1990; Ortega-Mayagoita and others 2002). Mosquitofish have been widely distributed by state vector control agencies to control mosquitoes.

The predominant mechanisms of mosquitofish effect on topminnow are aggression and predation (Meffe and others 1983; Minckley and Deacon 1968; Schoenherr 1977). Mosquitofish often replace topminnow in a matter of months (Meffe and others 1983; Schoenherr 1974), but with exceptions where the two species coexisted for years (Minckley 1999). Possible means of coexistence have been shown to be the species' differential response to flooding (Galat and Robertson 1988; Meffe 1984), or theorized greater habitat size and complexity (Meffe 1985). Another potential mechanism for prolonged coexistence is that mosquitofish do not invade springheads with extreme water quality (Hubbs 1995), but are occupied by congeners (Hubbs 1957, 1971). Topminnow is tolerant of extreme springhead conditions (Marsh and Minckley 1990; Minckley 1973). The sites where mosquitofish have extirpated topminnow in a few months to a few years have all been small and simple habitats, generally reestablishment sites; in natural habitats replacement takes longer.

Minckley (1999) also mentioned an additional alternative based on work by Hubbs (1991, 1992, 1996) showing that some western mosquitofish do not cannibalize their young. Minckley theorized that certain stocks of mosquitofish could be less predatory, and that could

In: Gottfried, Gerald J.; Ffolliott, Peter F.; Gebow, Brooke S.; Eskew, Lane G.; Collins, Loa C., comps. 2013. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

be an explanation for coexistence of topminnow and mosquitofish. Minckley (1999) also offered an alternative hypothesis involving groundwater inflow. Groundwater inflow tends to be warmer than surrounding waters, and may provide thermal refuge during periods of prolonged freezing temperatures. However, topminnows have been observed swimming below surface ice. Most perennial waters that harbor or have harbored topminnow also are groundwater dependent. However, I believe reliable water is the reason topminnows persist at those sites, and not the thermal refuge provided there.

Results/Update

There are several additional topminnow sites with mosquitofish where topminnow in Arizona have been lost since Minckley's review (1999). Table 1 shows these sites, as well as updates the status of the natural populations. The draft revised Gila topminnow recovery plan (Weedman 1999:58) defines a natural population as "a population which existed prior to fish transplants by humans, which exists today in its historic location free of known mixing with other populations by humans (Simons 1987)." While only a few sites have been recently lost to mosquitofish, any loss of populations of an endangered species is disconcerting, especially natural populations, which are crucial for species survival (Weedman 1999).

There have been two natural populations lost since 1999. Sharp Spring, a tributary headwater spring to the upper Santa Cruz River, was where Meffe (1984) conducted field studies demonstrating that Gila topminnow withstood floods better than mosquitofish. The last year topminnow were found in Sharp Spring, in the San Rafael Valley, was 2001 (Voeltz and Bettaso 2003). Since 2001, no topminnow have been found despite one to two surveys annually there, while mosquitofish are usually numerous. Mosquitofish were first recorded

here in the late 1970s. Sharp Spring contained a large and vigorous population of topminnow until mosquitofish accessed the system. Since 1995, I have observed the continual decline in the amount of aquatic habitat at Sharp Spring.

Redrock Canyon is the other natural topminnow population lost to mosquitofish since 1999. Redrock Canyon is significant for Gila topminnow conservation for two reasons: it is one of only two populations on public land (U.S. Forest Service) (Rinne and others 1980; Stefferud and Stefferud 1995), and it was the one remaining site that may have mimicked the historical expansion and contraction within basins and subbasins (Minckley 1999). A single topminnow was captured here in 2008 (Stefferdud and Stefferud 2008). Mosquitofish are still found in a small drainage from Cott Tank to Redrock Canyon where the last Gila topminnow was found; longfin dace *Agosia chrysogaster* are uncommon in lower Redrock Canyon although were common throughout the drainage before the 2000's. Reviews of management, condition, and fish surveys in the Redrock Canyon watershed can be found in Stefferud and Stefferud (1995), U.S. Bureau of Reclamation and U. S. Forest Service (2008), and U.S. Fish and Wildlife Service (1999:262-276). Redrock Canyon likely had more surface water historically, but has been dryer over the last decade (USBR and USFS 2008). The flow or extent of water in Redrock has not been regularly measured.

I believe that mosquitofish impacts on topminnow, in combination with long-term drought, was a factor in the extirpation of topminnow at Redrock Canyon and Sharp Spring. Long-term drought and climate change also appear to be a factor in the extirpation or reduction of other Gila topminnow populations (Bodner and others 2007; Duncan and Garfin 2006; Voeltz and Bettaso 2003).

Arizona State Parks collected water level data at Sharp Spring from 2000 to 2006 demonstrating reduced water quantity over time (unpublished). Though water levels were highly variable (fig. 1), there was an overall downward trend in water levels (fig. 1: trend lines). Of the 10 pools measured, 8 had downward trending water levels, one was static, and one had a slight upward trend. Seven pools went dry at some time, and all of those were also dry in the last two measurements (fig. 1:2005-2006). The flow or extent of water in Redrock has not been regularly measured. The best discussion of water in the Redrock system is the Bureau of Reclamations' and U.S. Forest Service's Redrock Barrier environmental assessment (USBR and USFS 2008).

In addition to many of the sites that were reestablished in the 1980s that were lost to desiccation (Minckley 1999; Simons 1987; Voeltz and Bettaso 2003), I believe Gila topminnow at Heron Spring, Johnson Wash Spring, and Willow Spring were extirpated (table 2) (Robinson 2010; Voeltz and Bettaso 2003), and populations at Cienega Creek reduced, due to drying caused or exacerbated by the current drought (Bodner and others 2007).

Heron Spring was stocked in 1981 with topminnow from nearby Sharp Spring (Voeltz and Bettaso 2003). Heron Spring is a small plunge pool that intercepts the locally high water table, with cienega conditions extending as outflow for about 100 m. Topminnow, though rare, were generally found in the plunge pool (Voeltz and Bettaso 2003) until 2007 when we captured no topminnow and measured dissolved oxygen at 1ppm (Ehret 2009). Gila topminnow can sometimes tolerate that little dissolved oxygen, but the oxygen may have been less than that before we measured it. The staff gauges maintained by Arizona State Parks there showed no decline in water levels (unpublished data). Discussions with others lead us to believe reduced subflow into the spring, floating vegetation covering the pond surface, and aquatic vegetation reducing outflow, combined to reduce dissolved oxygen until topminnow could no longer survive in Heron Spring.

Table 1—Status of all natural Gila topminnow populations in the United States and Mexico. Sites in bold CAPS are ones where topminnow no longer occur (from Minckley 1999, Voeltz and Bettaso 2003, and USFWS files).

Site	Extant? ^a	Mosquitofish?
Bylas Spring S1	YES ^b	NO ^c
Cienega Creek	YES	NO
Coal Mine Spring	YES	NO
Cocio Wash	NO 1982	DRY
Cottonwood Spring	YES	NO ^d
Fresno Canyon	YES	NO ^e
Middle Spring S2	YES	NO ^{b,c}
Monkey Spring	YES	NO
REDROCK CANYON	NO 2005	YES^f
Salt Creek S3	YES	NO ^{b,c}
San Pedro River	NO 1976	YES
Santa Cruz River		
San Rafael	NO ^g	YES
Tumacacori	YES 2003	YES
SHARP SPRING	NO 2001	YES
Sheehy Spring	NO 1987	YES
Sonoita Creek	YES	YES

^a If no, last year recorded.

^b Renovated.

^c None recently, they have been recorded.

^d Recorded in spring run, never in head spring.

^e Recorded downstream, below barrier. Renovated to remove green sunfish in 2007 and is free of nonnatives; Sonoita Creek has many nonnatives.

^f Slated for renovation.

^g In Mexico 2006, United States in 1993.

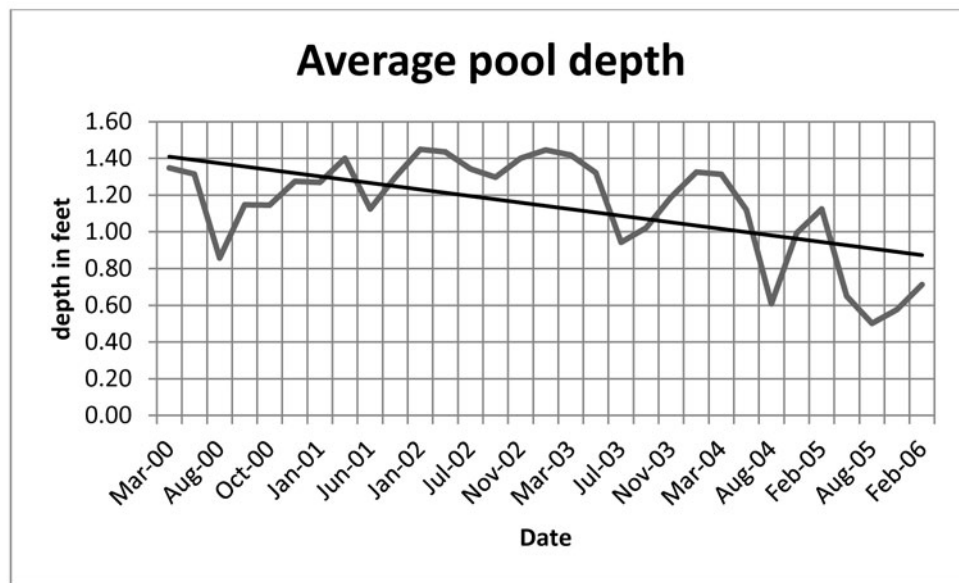


Figure 1—Averaged staff gauge measurements and trend line at Sharp Spring, Arizona (Arizona State Parks, unpublished).

Table 2—Status of some reestablished Gila topminnow populations in the United States. Site in bold CAPS is where topminnow no longer occur (from Minckley 1999, Voeltz and Bettaso 2003, and USFWS files).

Site	Extant? ^a	Mosquitofish?
HERON SPRING	NO 2006	NO
JOHNSON WASH SPRING	NO 2001	NO
Kayler Spring	YES 2004	YES
WATSON WASH	NO 1998	DRY^b
WILLOW SPRING	NO 2009 ^c	DRY

^a If no, last year recorded.

^b Well capped – mosquitofish present at capping.

^c Topminnow released in 2009.

Cienega Creek has the largest occupied topminnow habitat in the United States (Weedman 1999), though numbers in the upper perennial reach of Cienega Creek declined from 1989 to 2005 (Bodner and others 2007). The actual location of the first pool has moved downstream (Bodner and others 2007; personal observation) since about 2001, indicating reduced groundwater levels and subflow in that area. This has likely led to reduced dissolved oxygen in combination with more vegetation (trees shading the water surface, biological oxygen demand from decaying vegetation).

It appears that reduced volume and complexity of topminnow habitat, when combined with presence of mosquitofish, is more problematic for the persistence of topminnow, as opposed to the presence of mosquitofish alone. Therefore, since climatologists expect the southwestern United States to be warmer and drier (Seager and 2007), the impact of mosquitofish on topminnow populations is expected to be greater in the coming decades as topminnow habitat quality and quantity continues to decline.

Future Management

Actions to conserve and recover the Gila topminnow in Arizona and New Mexico are ongoing and additional actions are planned. Many new sites have been stocked with topminnow in the last 5 years (NMDGF and others 2010; Robinson 2010; USFWS and others 2007), and only time will tell if they persist. The involved management agencies and landowners will continue with stockings, under the Arizona Game and Fish Department Safe Harbor Agreement (AGFD 2007) and other mechanisms. They will also continue stream maintenance, habitat restoration, augmentation stocking, population and habitat monitoring, and outreach and education. Only vigorous conservation efforts can lead to the conservation and recovery of topminnow in the face of the threats they face. We are also exploring the use of topminnow in vector control programs in place of mosquitofish. Lastly, all attention must be given to reducing the use, populations, and movement of mosquitofish.

Acknowledgments

I would like to acknowledge all those individuals whose conversations regarding topminnow conservation, and specifically mosquitofish issues, have assisted my understanding of the issue; AGFD: Rob Bettaso, Rebecca Davidson, Ross Timmons, Jeremy Voeltz, Dave Weedman, Kirk Young; USFWS: Sally Stefferud; BLM: Heidi Blasius, Jeff Simms; ASU: Paul Marsh, W. L. Minckley; BR: Rob Clarkson; USFS: Jerry Stefferud. I would also like to thank my peer reviewers, Ross Timmons and Jerry Stefferud.

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