Conservation and conflict between endangered desert fishes

Jennifer M. Gumm*, Jennifer L. Sneker and Murray Itzkowitz

Department of Biological Sciences, Lehigh University, 111 Research Drive, Bethlehem, PA 18015, USA

*Author for correspondence (jmg404@lehigh.edu).

Conservation of naturally sympatric endangered species requires unique considerations. While impacts of invasive species garner much attention, interactions between endangered species must also be managed. The endangered Leon Springs pupfish, Cyprinodon bovinus, has suffered a population decline due to decreasing natural habitat. As breeding habitat is lost, C. bovinus is also adversely affected by the sympatric, endangered Pecos gambusia, Gambusia nobilis. Here, we document interactions between these species, finding significantly more G. nobilis accumulated at pupfish spawning events than randomly distributed on breeding grounds in the absence of spawning. As a known egg predator, our results suggest that G. nobilis presence at spawnings may further decrease pupfish numbers while also altering the evolutionary dynamics of C. bovinus breeding tactics. Habitat restoration may decrease Gambusia concentrations or influence C. bovinus breeding behaviour and increase the number of territorial males resulting in viable population sizes for both critically endangered fishes.

Keywords: Cyprinodon; Gambusia; predation; species interactions

1. INTRODUCTION

Direct conflicts between naturally sympatric endangered species present unique challenges to conservation. Antagonism between species may increase as resources, such as food or breeding habitat, become more limited (Barrows et al. 2005) and may ultimately result in species loss (Scott & Helfman 2001). Solutions to conflicts between endangered species are difficult to mediate as management typically focuses on individual species and recovery plans can directly oppose one another (Throgood et al. 2000; Barrows et al. 2005; Soule et al. 2005). Managing the impacts of invasive species, however, receives much attention. Multiple invasive species flock in Laguna Chichancanab, Yucatan, an African cichlid (genus Oreochromis) invasion resulted indirectly in pupfish (Cyprinodon simus, Cyprinodon maya) population declines due to food competition, while Astyanax spp. invasion resulted directly in pupfish declines (Cyprinodon esconditus, Cyprinodon labiosus, C. maya, C. simus, Cyprinodon verecundus) through predation on fry and juveniles (Strecker 2006).

Livebearers (Poeciliidae) are commonly invasive due to high reproductive rates and widespread use for mosquito control (Krumholz 1948). Indirectly, invasive livebearers (Gambusia affinis, Gambusia holbrooki) have caused declines in endemic species because, as generalists, they out compete native species for resources (Courtenay & Meffe 1989; Mills et al. 2004; Relage et al. 2005). Invasive Poecilia reticulata also sexually harass endangered heterospecifics (Valero et al. 2008). Directly, invasive livebearers often prey upon native species (Meffe 1985). The combined effects of exposure to G. affinis result in significantly smaller populations of White Sands pupfish, Cyprinodon tularosa (Rogowski & Stockwell 2006). Invasiveness, however, is not required for poeciliids to threaten other species and native Gambusia species are often sympatric with endangered pupfishes.

Given the widespread negative effects of Gambusia, we aimed to understand how Gambusia may influence pupfish reproduction by documenting interactions between two endangered species: the Pecos gambusia, Gambusia nobilis, and the Leon Springs pupfish, Cyprinodon bovinus. These fishes are naturally sympatric; however, the population of C. bovinus has been declining. Changing dynamics within either population may lead to alterations in interactions between the species. First, we estimated breeding male C. bovinus numbers over seven years. Second, we examined G. nobilis behaviour in relation to C. bovinus reproduction. C. bovinus males defend territories on a breeding shelf and share costs of defence against G. nobilis that potentially eat pupfish eggs and interrupt spawnings by intruding into territories and garnering aggression (Leiser & Itzkowitz 2003). As the number of territorial males’ declines, however, they may no longer be effective at defending against intruders and consequently suffer increased egg predation or complete spawning failure.

2. MATERIAL AND METHODS

(a) Study system

Cyprinodon boensis and G. nobilis are endemic to Diamond Y Spring and associated watercourses near Fort Stockton, Texas. The headwater pool (14×25×3.5 m²) is the largest and historically most stable population of pupfish, although they may also occur in a smaller, intermittent pool (0.3×0.02 m²) and downstream watercourse (Echelle et al. 2004). Immigration between pools is possible, however, they are separated by a 1600 m channel choked with bulrush and immigration between watercourses is unlikely due to 3 km of dry land separating them (Echelle et al. 2004). This is the only habitat for C. boensis while G. nobilis is found in three other Chihuahuan desert spring systems (Hubbs et al. 2002). C. boensis has a promiscuous breeding system and males exhibit alternative reproductive tactics with large males defending territories while smaller males acquire spawnings as non-territorial satellites or sneakers (Leiser & Itzkowitz 2003). In the Diamond Y head pool, males defend territories on a rocky shelf (1×3 m²) which is the only known breeding grounds in the pool and associated outflow stream. Females enter spawning grounds and descend to the substrate, pausing until joined by a male. The male sidles next to a
Photographs and the number of standard length of the large pupfish or tag was measured on identifiable landmarks. Data were analysed using unpaired t-tests. Satellite males are smaller in size (Leiser & Itzkowitz 2003) and the satellite based on male size and location on the breeding shelf. All photographs, but when possible was identified as territorial or satellite. The breeding tactic of the spawning male could not be identified in the spawning pair or tag was quantified. There was one territorial male was observed, resulting in a population size much lower than expected from previous years (95% CI for 2000–2005: 8.84–19.49). This male’s territory was similar in size to those held by males in other years (M. Itzkowitz 2000–2006, personal observation).

In 2006, G. nobilis were closely associated with pupfish. Gambusia descended to the substrate oriented close to the posterior of spawning pupfish pairs and appeared to engage in searching and foraging. Further, G. nobilis distribution was based on distribution of spawning pupfish. There were significantly more G. nobilis present within one body length of spawnings (n=104) than when no spawning was occurring (n=60; t(163) = −11.88, p<0.01; figure 1c). When breeding tactic was identifiable, there were no differences in the number of G. nobilis present at spawnings of the territorial male (n=35) compared with satellite males (n=24; t(58) = −1.83, p=0.07).

4. DISCUSSION
Territorial male C. bovinus have declined since 2000. In other species, absence of territorial individuals results in males abandoning alternative tactics to control available territories (Beletsky & Orians 1987). Smaller male C. bovinus can hold territories and, in previous years, have defended low-quality territories, peripheral to the main breeding shelf (Leiser & Itzkowitz 2003). Nonetheless, we observed smaller males expressing satellite behaviour despite the availability of high-quality breeding territories. This may be due to altered costs and benefits of territoriality.

One typical advantage of territoriality in C. bovinus is fewer intrusions by Gambusia (Leiser & Itzkowitz 2003). In contrast to their observations, we found few intrusions by Gambusia. This may be due to altered costs and benefits of territoriality.

3. RESULTS
The number of territorial males in the natural population of C. bovinus has declined since 2000 (r=−0.83, p=0.02; figure 1a). In 2006, a single territorial male was observed, resulting in a population size much lower than expected from previous years (95% CI for 2000–2005: 8.84–19.49).
high concentrations of Gambusia around the one territorial male in our study. This suggests that individual territoriality is not adequate and that a cluster of territorial males is necessary to keep Gambusia densities low on spawning grounds. This effect would protect both territorial and satellite males from costs of Gambusia including spawning intrusions and egg predation. While we did not test the mechanism by which G. nobilis are costly to pupfish, presence of equivalent numbers of G. nobilis at the territorial and satellite males’ spawnings suggests that the combined costs were similar across mating tactics. The high numbers of G. nobilis at spawnings may have resulted in changes in the breeding system such that smaller males remained satellites instead of defending available territories.

Solutions to conflicts in conservation remain inadequate, despite recent emphasis on multispecies and ecosystem-based recovery plans (Barrows et al. 2005; Soulé et al. 2005). For example, recovery of endangered island foxes (Urocyon littoralis) may require the lethal removal of protected golden eagles (Aquila chrysaetos; Courchamp et al. 2003). In our system, successful removal of G. nobilis is impractical; however, if left undisturbed it is likely that Gambusia will continue to be favoured at the expense of C. bovinus. Long-term management of these species may require multiple approaches, one of which is to manipulate the environment to indirectly solve the conflict between species. For example, artificially increasing the breeding ground area may aid in pupfish recovery via multiple mechanisms. First, by modifying the spatial distribution of resources, males may disperse and escape interrupted spawnings and egg predation associated with high concentrations of Gambusia. Habitat restoration may also increase population size by altering the expression of phenotypes via further decreasing competition among males (Watters et al. 2003), resulting in more territorial males and increased spawning rates typically associated with high-quality territories.

While the specific environmental changes leading to the decreased numbers of territorial male pupfish are unknown, the altered dynamics between pupfish and G. nobilis may indicate an ecosystem at risk. When naturally sympatric species are both endangered, negative interactions must be understood and considered to develop successful recovery plans for all species involved (Barrows et al. 2005; Soulé et al. 2005). This situation is exemplified by interactions between C. bovinus and G. nobilis, where the success of one endangered species is ultimately dependent upon management of another endangered species.

We thank the Texas Nature Conservancy and J. Karges for allowing us access to the study site and C. Gabor, S. McRobert, S. Mullen and B. Wisenden for their helpful comments on this manuscript. All methods abided by the laws of the US and ASAB guidelines (IACUC No. A3877-01).


