

California red-legged frogs and foothill yellow-legged frogs (*Rana mucosa*) within the San Joaquin Valley of California to habitat alteration coupled with predation and competition from bullfrogs. Although bullfrogs are unable to establish permanent breeding populations in unaltered vernal pools and seasonal ponds, dispersing immature bullfrogs take up residence in such water bodies during winter and spring where they prey on native amphibians, including larval salamanders (Morey and Guinn 1992; Seymour and Westphal 1994).

Because bullfrogs are known to travel at least 2.6 km (1.6 mi) from one pond to another (Bury and Whelan 1984), they have the potential to naturally colonize new areas where they do not currently exist, including ponds where Sonoma County California tiger salamanders occur. In one study of the eastern San Joaquin Valley, 22 of 23 (96 percent) ponds with California tiger salamanders were within the bullfrogs' potential dispersal range (Seymour and Westphal 1994). In addition, because bullfrogs are still sought within California for sport and food, and may be taken without limit under a fishing license, the threat of transport for intentional establishment in new locations where California tiger salamanders exist or could exist is significant.

One of the pools at the Hall Road breeding site, and two of the pools contained at the FEMA/Broadmore North preserves, are located within 46 m (150 ft) of ditches or creek channels known to contain bullfrogs or crayfish. Bullfrogs likely occur in Roseland Creek, which is near the FEMA/Broadmore North preserve and breeding sites associated with the Air Center (D. Cook, pers. comm., 2002). Bullfrogs are likely present in ditches that cross the Hall Road Preserve (D. Cook, pers. comm., 2002). The direct and indirect evidence thus indicates that non-native bullfrogs represent a continuing significant threat to the persistence of the Sonoma County California tiger salamander.

Western mosquitofish (*Gambusia affinis*) are native to central North America (watersheds tributary to the Gulf of Mexico) and have been introduced throughout the world for mosquito control, including in California beginning in 1922. Western mosquitofish now occur throughout California wherever the water does not get too cold for extended periods, and they are still widely planted throughout the State (Boyce, UCD, *in litt.*, 1994) by about 50 local mosquito abatement districts.

Salamanders may be especially vulnerable to western mosquitofish predation due to their fluttering external gills, which may attract these visual predators (Graf and Allen-Diaz 1993). Loredó-Prendeville *et al.* (1994) found no California tiger salamanders inhabiting ponds containing western mosquitofish. Western mosquitofish prey on other amphibian species, such as the California newt (*Taricha torosa*) (Gamradt and Kats 1996) and Pacific treefrog (Goodsell and Kats 1999) tadpoles in both field and laboratory experiments, even given the optional prey of mosquito larvae (Goodsell and Kats 1999; L. Kats, Pepperdine University, pers. comm., 1999). Mosquitofish have also been observed ingesting and then spitting out California newt larvae, causing severe damage to the newts in the process (Graf and Allen-Diaz 1993). Given the effects of western mosquito fish on other amphibian species, they are likely to have similar effects on California tiger salamanders. If they have the same effects, the use of mosquito fish in California tiger salamander habitat threatens the persistence of the species, especially in the isolated Sonoma County California tiger salamander population.

Other non-native fish have either been directly implicated in predation of California tiger salamanders or appear to have the potential for such. For example, introductions of sunfish species (*e.g.*, largemouth bass (*Micropterus salmoides*) and bluegill (*Lepomis macrochirus*)), catfish (*Ictalurus* spp.), and fathead minnows (*Pimephales promelas*) are believed to have eliminated California tiger salamanders from several breeding sites in Santa Barbara County (Service 2000). Non-native sunfish species, catfish, and bullheads (*Ameiurus* spp.) have been, and still are, widely planted in ponds in California to provide for sportfishing. By 1984, the California fish fauna included about 50 such transplanted and exotic species, mostly from eastern North America origin (Hayes and Jennings 1986). More recently, Moyle (2002) estimated that, on average, California is losing about one native species or subspecies of fish every 5 to 6 years, and gaining an average of one alien species about every 2 years.

Non-native fish introductions may be responsible for the declines of frog species in western North America (Hayes and Jennings 1986). Such introduced fish may be a problem for California raids because of their specialization for preying on aquatic life (including eggs and larvae), and because the affected amphibians may have

evolved under conditions of limited fish predation, which now increases the impacts of such introductions (Hayes and Jennings 1986). We believe the same threat applies to the California tiger salamander. Thus, potential introduction of such non-native fish species in Sonoma County California tiger salamander breeding habitat should be considered a threat to the persistence of this DPS.

The degree to which predation from native fish have affected the Sonoma County California tiger salamanders is unknown. For example, sticklebacks (*Gasterosteus* spp.), which have been present in California for at least 16 million years, were believed to be the factor preventing the Sonoma County California tiger salamander from establishing at a site in Sonoma County (Cook and Northen 2001). One pool at the Hall Road Preserve appears to have all of the biological components for successful California tiger salamander breeding, but has a small connector to a drainage ditch containing stickleback. Sonoma County California tiger salamanders have never been found at this site, and it is suspected that predation of their eggs and larvae by this fish is the limiting factor (D. Cook, pers. comm., 2002).

Non-native and native crayfish (*Pacifastacus*, *Orconectes*, and *Procambarus* spp.) apparently prey on California tiger salamanders (Shaffer *et al.* 1993) and may have eliminated some populations (Jennings and Hayes 1994). Crayfish prey on California newt eggs and larvae, despite toxins produced by these amphibians, and they may be a significant factor in the loss of newts from several streams in southern California (Gamradt and Kats 1996). These crayfish have been found at both the FEMA/Broadmore North and Hall Road Preserves. At the FEMA property, crayfish were found in the pool (D. Cook, pers. comm., 2002). The crayfish likely came from the adjacent Roseland Creek Channel. Louisiana crayfish have been found in the ditches that cross the Hall Road Preserve, but not at any of the pools known to support Sonoma County California tiger salamander populations (D. Cook, pers. comm., 2002). The presence of both stickleback and crayfish, along with the suspected presence of bullfrogs, could negatively affect Sonoma County California tiger salamanders within the Hall Road Preserve.

California tiger salamanders are also likely preyed on by many native species of fish and wildlife. In healthy salamander populations, such predation is probably not a significant threat. But when combined with other impacts,