

amphibian community composition at a vernal pool complex, with salamanders becoming proportionally less abundant as bullfrogs increased in number.

Although bullfrogs are unable to establish permanent breeding populations in unaltered vernal pools and seasonal ponds because they require more than 1 year to complete their larval stage, 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). A strong negative correlation exists between bullfrog presence and California tiger salamander presence (Shaffer *et al.* 1993; 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 where Central California tiger salamanders occur. In one study of the eastern San Joaquin Valley, it was found that 22 of 23 ponds (96 percent) 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 as food, and may be taken without limit under a fishing license, the threat of transport for intentional establishment in new habitat suitable for the Central California tiger salamanders is significant.

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 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 (K. Boyce, Sacramento County/Yolo County Mosquito and Vector Control District, *in litt.* 1994; Moyle 2002) by about 50 local mosquito abatement districts. Western mosquitofish are ubiquitous because of their tolerance of poor water quality and wide temperature ranges (K. Boyce, *in litt.* 1994).

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. Leyse and Lawler (2000) found that the survival of California tiger salamander in experimental ponds stocked with western mosquitofish, at densities similar to those found in many stock ponds, was significantly reduced. Larvae that survived in ponds with western mosquitofish were smaller, took longer to reach metamorphosis, and had injuries such as shortened tails.

Western mosquitofish prey on other amphibian species, such as California newt (*Taricha torosa*) (Gamradt and Kats 1996) and Pacific treefrog (Goodsell and Kats 1999) tadpoles in both field and laboratory experiments, even when given the optional prey of mosquito larvae (Goodsell and Kats 1999; L. Kats, Pepperdine University, pers. comm. 1999). Western 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 Central California tiger salamanders. If they have the same effects, the use of western mosquito fish in Central California tiger salamander habitat threatens its persistence.

Other nonnative fish have either been directly implicated in predation of California tiger salamanders or appear to have the potential to prey upon them. 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 Central California tiger salamanders from several breeding sites in Santa Barbara County (65 FR 3096). Nonnative 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 American 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.

Nonnative 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 ranids 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 the introductions (Hayes and Jennings 1986). We believe the same threat may apply to the Central California tiger salamander. Thus, we consider introductions of such nonnative fish species into Central California tiger salamander breeding habitat a potential threat to the persistence of the species.

The range and breeding habitats of the Central California tiger salamander also overlap with the ranges and habitats of several nonnative and native crayfish (*Pacifastacus*, *Orconectes*, and *Procambarus* spp.). Crayfish prey on California tiger salamanders (Shaffer *et al.* 1993) and are thought to have eliminated some populations (Jennings and Hayes 1994). In Sonoma County, a nonnative crayfish has been found throughout ditches within California tiger salamander range, but not in any nearby pools known to support California tiger salamander breeding (D. Cook, The Wildlife Society, pers. comm. 2002). Crayfish are also known to prey on California newt eggs and larvae, despite toxins produced by these amphibians, and crayfish may be a significant factor in the loss of newts from several streams in southern California (Gamradt and Kats 1996). Thus, based on direct and indirect evidence, we believe that crayfish, especially several nonnative species, represent a considerable threat to the persistence of the Central California tiger salamander.

Another nonnative species which may represent a threat to the species, is the wild pig (*Sus scrofa*). The wild pig population in California, which was recently estimated at about 106,000 to 160,000 individuals (Waithman *et al.* 1999), resulted from numerous introductions, both from domesticated pigs escaping captivity, and more recently from deliberate introductions for sport-hunting, over the last two centuries. Although range expansion of introduced wild pigs has ceased in many regions of the United States, it increased significantly since the 1950s in California (Waithman *et al.* 1999). Wild pigs are now distributed within parts of 49 of California's 58 Counties (Waithman *et al.* 1999), with densities as high as 3.8 (Sweitzer *et al.* 2000) to 4.7 pigs per square kilometer (9.8 to 12.2 pigs per square mile) (Schauss *et al.* 1990).

Wild pigs have been widely implicated in declines and extinctions of numerous species worldwide, and have had pronounced negative ecological effects on Central California tiger salamanders when their populations are high (Waithman *et al.*