

by trapping, shooting, fumigation of burrows, use of toxic (including anticoagulant) baits, and habitat modification, including deep-ripping of burrow areas (UCIPM internet website 2003).

California ground squirrel control programs are widely conducted (frequently via bait stations placed at specific problem sites) on and around various commercial agricultural operations, including grazing/range lands and various croplands including vineyards (R. Thompson, Science Applications International Corporation, *in litt.* 1998). Also, numerous agencies, particularly flood control agencies and levee districts, conduct extensive California ground squirrel control programs around levees, canals and other facilities they manage.

The pocket gopher, which also provides the required upland retreats for some California tiger salamanders (Loredo *et al.* 1996; Trenham 1998a; D. Cook, pers. comm. 2001), is targeted by certain control operations that may also pose threats to the amphibian. This species is also classified as a non-game mammal by CDFG. Pocket gopher control measures (UCIPM internet website 2003) are similar to measures used for California ground squirrel control, except that shooting is not an effective approach because of the pocket gophers' nearly continuous seclusion underground. Pocket gopher control typically is most common around golf courses and other large, landscaped areas, and around residential homes and gardens. Widespread control in agricultural situations is much less common than for California ground squirrels.

Two of the most commonly used rodenticides, chlorophacinone and diphacinone, are anticoagulants that cause animals to bleed to death. These chemicals can be absorbed through the skin and are considered toxic to fish and wildlife (EPA 1985; EXOTONET 1996). These two chemicals, along with strychnine, are used to control rodents (R. Thompson, *in litt.* 1998). Although the effects of these poisons on California tiger salamander have not been assessed, any uses in close proximity to occupied Central California tiger salamander habitat could have various direct and indirect toxic effects. Gases, including aluminum phosphide, carbon monoxide, and methyl bromide, are used in rodent fumigation operations and are introduced into burrows by either using cartridges or by pumping. When such fumigants are used, animals inhabiting the fumigated burrow are killed (Salmon and Schmidt 1984).

In addition to possible direct adverse effects of rodent control chemicals and gasses, California ground squirrel and pocket gopher control operations may have the indirect effect of reducing the number of upland burrows available to specific California tiger salamander populations (Loredo-Prendeville *et al.* 1994). Because the burrow density required by California tiger salamanders is unknown, the impacts of burrow loss are also unknown.

Shaffer *et al.* (1993) believe that rodent control programs could be the cause for lack of California tiger salamanders in certain areas. Active California ground squirrel colonies probably are needed to sustain California tiger salamanders, because inactive burrow systems likely become progressively unsuitable over time. Loredo *et al.* (1996) found that burrow systems usually collapsed within 18 months following cessation of California ground squirrel use, and did not report California tiger salamanders utilizing any collapsed burrows. Also, deep ripping of rodent burrow areas as a rodent control measure would be likely to completely destroy burrows and harm or kill any California tiger salamanders using them.

Many Central California tiger salamander sites are currently occupied by livestock. Livestock owners' concern over livestock breaking their legs in rodent burrows is a reason for many California ground squirrel control efforts, especially around livestock watering tanks and ponds. These and other California ground squirrel and pocket gopher control efforts clearly have potential to adversely affect Central California tiger salamanders if they are implemented without knowledge of, and concern for, the species.

Mosquito Control

In addition to the use of western mosquitofish, a common chemical method of mosquito control in California involves the use of methoprene. Methoprene is an insect hormone mimic which increases the level of juvenile hormone in insect larvae and disrupts the molting process. Lawrenz (1984, 1985) found that methoprene (Altosoid SR-10) retarded the development of selected crustacea that had the same molting hormones (*i.e.*, juvenile hormone) as insects, and anticipated that the same hormone may control metamorphosis in other arthropods. Because the success of many aquatic vertebrates relies on an abundance of invertebrates in temporary wetlands, any delay in insect growth could reduce the numbers and density

of prey available (Lawrenz 1984, 1985). The use of methoprene could have an indirect adverse effect on California tiger salamanders by reducing the availability of prey.

In more recent studies, methoprene did not cause increased mortality of gray treefrog (*Hyla versicolor*) tadpoles (Sparling and Lowe 1998). However, it caused reduced survival rates and increased malformations in northern leopard frogs (Ankley *et al.* 1998), and increased malformations in southern leopard frogs (*R. utricularia*) (Sparling 1998). Blumberg *et al.* (1998) correlated exposure to methoprene with delayed metamorphosis and high mortality rates in northern leopard and mink (*R. septentrionalis*) frogs. Methoprene appears to have both direct and indirect effects on the growth and survival of larval amphibians.

Road-Crossing Mortality

Although no systematic studies of the California tiger salamander have been conducted, it is known that significant numbers of the species in other portions of its range are killed by vehicular traffic while crossing roads (Hansen and Tremper 1993; S. Sweet, *in litt.* 1993; Joe Medeiros, Sierra College, pers. comm. 1993). For example, during one 15-day period in 2001 at a Sonoma County location, 26 road-killed California tiger salamanders were found (D. Cook, pers. comm. 2002). Overall breeding population losses of California tiger salamanders due to road kills have been estimated to be between 25 and 72 percent (Twitty 1941; S. Sweet, *in litt.* 1993; Launer and Fee 1996). Mortality may be increased by associated roadway curbs and berms as low as 9 to 12 centimeters (3 to 5 in), which allow California tiger salamanders access to roadways but prevent their exit from them (Launer and Fee 1996; S. Sweet, *in litt.* 1998).

Vehicular usage on California roads is increasing rapidly and directly with human population and urban expansion. During November 2002, California's estimated total vehicular travel on State highway system roads alone was 23 billion km (14.27 billion mi) (this figure and subsequent vehicular-use data from California Department of Transportation's internet website 2003). From 1972 to 2001, State highway system total vehicular usage rose steadily from 108.6 km to 270 billion km (67.1 to 167.8 billion mi) annually. For the 23 California Counties in which the California tiger salamander may occur, State highway system total annual vehicular usage in 1999, 2000, and 2001 was 86.0, 90.0, and 92.1 billion km (53.3, 55.9, and 57.2 billion