

metamorphic offspring over the lifetime of a female. Preliminary data suggest that most California tiger salamander individuals require 2 years to become sexually mature. But some individuals may be slower to mature (Shaffer *et al.* 1993), and some animals do not breed until they are 4 to 6 years old. While individuals may survive for more than 10 years, many breed only once, and in some populations, less than 5 percent of marked juveniles survive to become breeding adults (Trenham 1998b). With such low recruitment, isolated populations can decline greatly resulting from unusual, randomly occurring natural events, as well as from human-caused factors that reduce breeding success and individual survival. Factors that repeatedly lower breeding success in isolated pools that are located too far from other pools to allow migrating individuals to replenish the population can quickly extirpate a population.

The life history and ecology of the California tiger salamander make it likely that this population has a metapopulation structure (Hanski and Gilpin 1991). A metapopulation is a set of local populations or breeding sites within an area, where typically migration from one local population or breeding site to other areas containing suitable habitat is possible, but not routine. Dispersal (movement between areas containing suitable habitat) is restricted by inhospitable conditions around and between areas of suitable habitat. Because many of the areas of suitable habitat may be small and support small numbers of salamanders, local extinction may commonly occur. A metapopulation's persistence depends on the combined dynamics of these local extinctions and the subsequent recolonization of these areas through dispersal (Hanski and Gilpin 1991; Hanski 1994; McCullough 1996).

The total number of individual California tiger salamanders is not known. The difficulty of estimating total California tiger salamander population size has been discussed by a number of biologists (Shaffer *et al.* 1993; Jennings and Hayes 1994). However, estimates have been made for a few populations in Monterey (Trenham *et al.* 2000; Barry and Shaffer 1994). Because data on numbers of individual California tiger salamanders are lacking, since they spend much of their lives underground, and because only a portion of the total number of animals migrate to pools to breed each year (Trenham *et al.* 2000), the availability of suitable habitat and documentation of its loss may be an appropriate method for assessing the status of the species.

Vernal pools and other seasonal ponds are the primary breeding areas used by California tiger salamanders (Storer 1925; Feaver 1971; Zeiner *et al.* 1988). The species occurs in 10 of the 17 Californian vernal pool regions defined by Keeler-Wolf *et al.* (1998), including northeastern Sacramento Valley, southeastern Sacramento Valley, Santa Rosa, Solano-Colusa, Livermore, Central Coast, Carrizo, southern Sierra Foothills, Santa Barbara, and San Joaquin Valley. Vernal pools typically form in topographic depressions underlain by an impervious layer (such as claypan, hardpan, or volcanic strata) that prevents downward percolation of water. Vernal pool hydrology is characterized by ponding of water during the late fall, winter, and spring, followed by complete desiccation during the summer dry season (Holland and Jain 1998). Vernal pools support diverse flora and fauna that are adapted to the dramatic seasonal changes in moisture and benefit from the lack of predation by nonnative fish. Thirty other federally or State listed species within the California tiger salamander's range are vernal pool specialists, including 24 plants, 4 crustaceans, and 1 insect (Keeler-Wolf *et al.* 1998). California tiger salamanders, like the listed vernal pool crustaceans, prefer seasonally ponded habitat. However, listed vernal pool crustaceans require only a few weeks of inundation to complete their life cycle (59 FR 48136; September 19, 1994); therefore, pools that support crustacean populations may not hold water long enough to allow successful metamorphosis of California tiger salamander larvae.

In addition to vernal pools and seasonal ponds, California tiger salamanders also use small artificial water bodies for breeding (Stebbins 1985; Zeiner *et al.* 1988; Shaffer *et al.* 1993). Stockponds for cattle (*Bos taurus*), sheep (*Ovis aries*), horses (*Equus caballus*) and other livestock have been, and continue to be, built to supply local water needs, especially in rural grazing lands in coastal and Sierra foothill areas where inexpensive public water or ground water is not available (Bennett 1970). Stockponds, constructed as water sources for livestock, are important habitats for the California tiger salamander throughout its range (H. Shaffer, pers. comm. 2003; P. Trenham, University of California, Davis, pers. comm. 2002). A large population of the California tiger salamander coexists with sheep and horses at the University of California Natural Reserve System's Jepson Prairie in Solano County (P. Trenham, pers.

comm. 2002; CNDDDB 2002). In some areas, stockponds have largely replaced vernal pools and provide important habitat for the species. For instance, of the 112 California tiger salamander locality records in the Livermore area where the wetland type was identified, 88 percent (98 sites) are located in stockponds (CNDDDB 2002).

However, stockponds often are poorer habitat for California tiger salamanders than natural vernal pools. Hydroperiods (amount of time the stockpond contains water) may be so short that larvae cannot metamorphose (e.g., when early drawdown of irrigation ponds occurs), or so long that predatory fish and bullfrogs *R. catesbeiana* can colonize the pond (Shaffer *et al.* 1993; Seymour and Westphal 1994). Permanent wetlands may occasionally support breeding California tiger salamanders if fish are not present, but extirpation of the salamander population is likely if fish are introduced (Shaffer *et al.* 1993; Seymour and Westphal 1994). Artificial ponds also require ongoing maintenance and are often temporary structures. Natural soil erosion, sometimes increased by pond breaching, stock animal impacts, and off-road vehicle (ORV) use, can cause ponds to silt in after a few decades (Hamilton and Jepson 1940), thereby reducing their quality as salamander habitat. Often ponds are not maintained because it may be more economical to construct a new pond when the old pond fills with silt and is no longer functional (Hamilton and Jepson 1940). Stockponds are often geographically isolated from other seasonal wetlands occupied by California tiger salamanders, and colonization of newly created ponds beyond the normal dispersal range may be slow or nonexistent (Pechmann *et al.* 1989).

Although stockponds can provide refugia for salamander populations and are important for the species, these habitats may be dynamic. Stockponds often dry out during drought, and flooding may destroy downstream impoundments or cause siltation, either of which may result in loss of aquatic habitat and extirpation of salamander populations. Periodic maintenance to remove silt from stockponds may also cause a temporary loss of habitat. Some eggs and larvae of the California tiger salamander are probably trampled by livestock on the perimeters of the stockponds. Populations of nonnative introduced predaceous fish and bullfrogs, although less prevalent than in natural habitats, sometimes become established in stockponds and have been implicated in the decline of the