

California Tiger Salamander (*Ambystoma californiense*)

Legal Status

Federal: Threatened Range-wide (USFWS 2004b);
Endangered Sonoma County (USFWS 2000);
Endangered Santa Barbara County (USFWS 2004a);
Critical habitat designated (USFWS 2005).

State: Species of Special Concern.



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Global and State Conservation Status: G2S2: Global rank, G2 = Imperiled: At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors. State Rank, S2 = Same general definition as global rank but only for the range of the taxa within California.

Recovery Plan: Under development.

Species Description and Life History

The California tiger salamander (*Ambystoma californiense*) is an amphibian in the family Ambystomatidae. These terrestrial salamanders are large and thickset, with a wide, rounded snout (USFWS 2004b). Adults range in size from 7.5 to 12.5 cm (2.95 to 4.92 in) snout to vent length (SVL) (Jennings and Hayes 1994). Average SVL for both adult males and females is approximately 9 cm (3.58 in), although the average total length for males and females is 20.3 and 17.3 cm (7.99 and 6.81 in), respectively (USFWS 2004b). Dorsal (back) coloration consists of a black background on the back and sides, interspersed with white or pale yellow spots or bars (USFWS 2004b). Ventral (belly) coloration ranges from almost uniform white or pale yellow to a variegated pattern of white, pale yellow, and black (Jennings and Hayes 1994). The salamander's small eyes have black irises and protrude from their heads (Jennings and Hayes 1994). During the breeding season, the cloacal region of males becomes enlarged (Petranka 1998) and is a useful means of distinguishing sexes. The cloaca is a body cavity that receives the collective discharges from the intestinal, urinary, and reproductive canals. Males also have larger tails with more developed fins.

The California tiger salamander is restricted to grasslands, oak savannah, and coastal scrub communities of lowlands and foothill regions where aquatic sites are available for breeding. California tiger salamanders are typically found at elevations below 460 m (1,509 feet) (USFWS 2004a), although the known elevational range extends up to 1,053 m (3,458 feet) (Jennings and Hayes 1994). Breeding sites generally consist of natural ephemeral pools (Barry and Shaffer 1994) or artificial ponds that mimic them (e.g., stock ponds that are allowed to dry). Bobzein and DiDonato (2007) report that in the East Bay Regional Park District (Contra Costa and Alameda Counties) California tiger salamanders breed almost exclusively in seasonal and perennial stock ponds. Breeding

sites may also include perennial features with open water refugia that do not support populations of bullfrog (*Rana catesbeiana*) or predatory fishes (Holomuzki 1986, Fitzpatrick and Shaffer 2004). Pools characterized by deep water may also support larvae through metamorphosis in relatively dry years (Trenham et al. 2000), whereas shallow pools may not (Semelitsch et al. 1996). Populations associated with shallow, natural vernal pools may be more dependent on suitable hydroperiod (Trenham et al. 2000). As illustrated by the 114-year old reservoir at Lagunita (Stanford University, Santa Clara County), constructed ponds may also serve as habitat for California tiger salamander as long as they are drained annually, thus preventing exotic fish and amphibian predators (i.e., bullfrogs) from establishing (Barry and Shaffer 1994). Barry and Shaffer (1994) attribute the persistence of the salamander population at Lagunita to (1) large size of both aquatic and terrestrial habitats, (2) the continuous filling and draining of the reservoir every year, which provides larvae a head start over fish predators each year.

Larvae require a minimum of approximately 10 weeks to complete metamorphic transformation (P. Anderson 1968, Feaver 1971), significantly longer than other amphibians such as the Pacific tree frog (*Pseudacris regilla*) and western spadefoot (*Spea hammondi*). Hydroperiod, or the timing and duration of waters in potential breeding sites, can be critical for reproductive success. Shaffer et al. (2008) indicate that California tiger salamanders can breed successfully in stock ponds, and in natural or constructed vernal pools remaining wet until mid-May. Larvae in coastal regions may not metamorphose until late July, and pools holding water into June, July, or later generally have higher success (Barry and Shaffer 1994). Larvae have been documented overwintering in perennial ponds in the higher-elevations of the Ohlone Regional Wilderness in Alameda County (Bobzien and DiDonato 2007). Compared to the western toad (*Bufo boreas*) or western spadefoot, California tiger salamanders are poor burrowers and require subterranean refuges constructed by ground squirrels and other burrowing mammals (Jennings and Hayes 1994). Salamanders spend the dry season, which comprises most of a year, within these burrows (USFWS 2004b). Although California tiger salamanders are often considered to be in a state of dormancy, called aestivation, during the period in which they occupy these burrows, evidence suggests that salamanders may remain active while within their burrows (S. Sweet in litt. in USFWS 2004b).

Males usually migrate to the breeding ponds before females (Twitty 1941, Shaffer et al. 1993, Loredó and Van Vuren 1996, Trenham 1998b) and remain in the ponds for an average of 6 to 8 weeks, while females stay for approximately 1 to 2 weeks (USFWS 2004b). Salamanders typically return to the same pond to breed in subsequent breeding seasons (Trenham 1998b). However, interpond dispersal does occur and is dependent on the distance between ponds and the quality of intervening upland habitat (Trenham 1998a). It appears that breeding takes place in pulses, with time between breeding events and the proportion of breeding adults per event associated with rainfall patterns and wetland inundation (J. Alvarez pers. comm., S. Bobzien pers. comm., D. Cook pers. comm., M. Ryan pers. comm.) In Sonoma County there is a main breeding event in mid-December, which corresponds to the first large winter rain event that is sufficient to fill vernal pools, followed by 1-2 smaller breeding events after the next rainfalls (D. Cook

pers. comm.) In drought years, insufficient water in the breeding pools may prevent breeding (Barry and Shaffer 1994). Trenham et al. (2000) found that within a population in Monterey County, female California tiger salamanders skipped breeding opportunities at a higher rate than males in years with later rainfall, a bias attributed to the date of pond filling, but not to total annual rainfall. Barry and Shaffer (1994) suggest that while local California tiger salamander populations may not breed during drought years when ephemeral pools do not fill, the longevity of adults is probably sufficient to ensure population persistence through all but the longest of droughts.

After mating, females lay their eggs in the water of the breeding habitat (Twitty 1941, Shaffer *et al.* 1993, Petranka 1998). Females usually attach their eggs to twigs, grass stems, vegetation, or debris (Storer 1925, Twitty 1941, Jennings and Hayes 1994). After breeding, adults leave the pool and return to the upland habitat, taking shelter during the day in small mammal burrows and emerging at night to feed during the breeding season (Shaffer et al. 1993, Loredó *et al.* 1996, Trenham 1998a). In 2 to 4 weeks, eggs hatch into aquatic larvae (Petranka 1998). Larvae feed on zooplankton, small crustaceans, and aquatic insects for about 6 weeks and then begin consuming larger prey such as small tadpoles (J. Anderson 1968). The larval stage usually lasts 3 to 6 months (Petranka 1998), but individuals may remain in their breeding sites over the summer if breeding pools remain inundated (Shaffer and Trenham 2005). The longer the inundation period, the larger the larvae and metamorphosed juveniles are able to grow, and the more likely they are to survive and reproduce (Semlitsch *et al.* 1988, Pechmann *et al.* 1989, Morey 1998, Trenham 1998b).

Lifetime reproductive success for California tiger salamanders is generally low, with many individuals breeding only once in their lifetime (Trenham 1998b, Trenham *et al.* 2000). Over the lifetime of a female, only a small number of metamorphic offspring are produced; and only a small percentage of a cohort survive to become breeding adults (Trenham 1998b, Trenham et al. 2000). Trenham *et al.* (2000) found that reproduction at Hastings Reserve in Monterey County was lower than replacement in all of six years studied. According to this study, the average female California tiger salamander breeds 1.4 times over a lifetime, producing 8.5 young surviving to metamorphosis per event and 12 lifetime metamorphic offspring per female (Trenham et al. 2000). To achieve 1:1 replacement by this reasoning would require 18.2% survival from metamorphosis to breeding; survival at Hastings during this time was only 5%, leading the authors to suggest that isolated breeding ponds may be insufficient for maintaining viable populations over the long-term.

Juvenile California tiger salamanders have been observed to disperse up to 2.59 kilometers (1.6 mile) from breeding pools to upland areas (Austin and Shaffer 1992). Adults have been observed up to 2 km (1.3 miles) from breeding ponds. Trenham *et al.* (2001) observed California tiger salamanders moving up to 670 m (2,198 feet) between breeding ponds in Monterey County. Similarly, Shaffer and Trenham (2005) found that 95 percent of California tiger salamanders resided within 640 m (2,100 feet) of their breeding pond at Jepson Prairie in Solano County.

Adults emerge from upland sites on rainy nights during fall and winter rains to feed and migrate to breeding ponds (Stebbins 1989, 2003, Shaffer *et al.* 1993). Adults use the same migratory routes between breeding pools and upland burrows year after year (Petranka 1998, Loredó *et al.* 1996). Metamorphosed juveniles leave the breeding sites in late spring or early summer and migrate to small mammal burrows (Zeiner *et al.* 1988, Shaffer *et al.* 1993, Loredó *et al.* 1996). Like adults, juveniles may emerge from burrows to feed during nights of high relative humidity (Storer 1925, Shaffer *et al.* 1993) before settling in their selected upland sites for the summer months. While most California tiger salamanders rely on rodent burrows for shelter, some individuals may utilize soil crevices as temporary shelter during upland migrations (Loredó *et al.* 1996).

The distance between occupied upland habitat and breeding sites depends on local topography and vegetation, and the distribution of California ground squirrel (*Spermophilus beecheyi*) or other rodent burrows (Stebbins 1989). California tiger salamanders seem to follow the pattern of a broadly defined metapopulation structure, in which a population is divided into a set of subpopulations—some of which become extinct and are later recolonized by migrants from other subpopulations (USFWS 2004b). Semlitsch (1997) points out that because many vernal pools and ponds used by salamanders are temporary over geological and ecological time, local extinction must be counterbalanced by colonization of new sites; thus, conservation plans must incorporate terrestrial habitats providing corridors for movement to new sites. In the case of California tiger salamanders, Trenham (1998b) indicates that the spatial arrangement of ponds and the migratory behavior of salamanders substantially affect pond utilization and sustainability of local populations. Interpond distances directly affect the probability of recolonization and subsequent opportunities for population rescue, which is important because physiology limits the distance that amphibians are able to disperse (Semlitsch 2000). While Marsh and Trenham (2001) reviewed the fit between theoretical metapopulations and pond breeding amphibians and found that random extinctions of local populations were uncommon as long as terrestrial habitats were intact, Trenham and Shaffer (2005) found that local extinctions were likely where the probability of reproductive failure exceeded 0.5, and that reproductive failure common in both permanent and highly ephemeral pools, underscoring the importance interconnected breeding sites.

Habitat Requirements and Ecology

A diverse array of flora and fauna have adapted to the seasonal hydric cycle of vernal pools (USFWS 2004b). Vernal pools and other seasonal rain pools are the primary breeding habitat of California tiger salamanders (USFWS 2004a). Within the species range, there are numerous other sensitive vernal pools species, comprising 24 plants, four crustaceans, and one insect (Keeler-Wolf *et al.* 1998). Listed vernal pool crustaceans are able to complete their life cycle within a relatively short period of inundation (USFWS 1994). Therefore, many pools that support vernal pool crustaceans may not retain water for the 10 weeks or more required to complete metamorphosis of California tiger salamander larvae (P. Anderson 1968, Feaver 1971). Laabs *et al.* (2001) reported that, in eastern Merced County, California tiger salamander larvae were observed only in the

largest vernal pools. California tiger salamanders, unlike vernal pool crustaceans, are known to successfully reproduce in perennial ponds (USFWS 2004b).

Outside of the breeding season, post-metamorphic California tiger salamanders spend most time in burrows of small mammals, such as California ground squirrels and Botta's pocket gopher (*Thomomys bottae*) (Storer 1925, Loredó and Van Vuren 1996, Petranka 1998, Trenham 1998a). Active rodent burrow systems are considered an important component of California tiger salamander upland habitat (Seymour and Westphal 1994, Loredó *et al.* 1996). Utilization of burrow habitat created by burrowing mammals such as ground squirrels suggests a commensal relationship (a relationship between two species in which one obtains food or other benefits without detriment or benefit to the other) between the two species (Loredó *et al.* 1996). Loredó *et al.* (1996) indicate that active ground-burrowing rodent populations are probably necessary to sustain California tiger salamander populations because inactive burrow systems begin to deteriorate and collapse over time. In a two year radiotelemetry project in Monterey County (Hastings), Trenham (2001) found that salamanders preferentially used open grassland and isolated oaks; salamanders present in continuous woody vegetation were never more than 3m from open grassland, potentially because ground squirrels prefer to construct burrows in open habitats (Jameson and Peeters 1988 *in* Trenham 2001).

Species Distribution and Population Trends

Distribution

The California tiger salamander is endemic to California. Within the coastal range, the species occurs from southern San Mateo County south to San Luis Obispo County, with isolated populations in Sonoma and northwestern Santa Barbara Counties (CNDDDB 2005). In the Central Valley and surrounding Sierra Nevada foothills, the species occurs from northern Yolo County southward to northwestern Kern County and northern Tulare and Kings Counties (CNDDDB 2004).

Recorded occurrences of California tiger salamanders in Yolo County include an occurrence of several larvae in a stock pond on the west slope of the Capay Hills east of Rumsey Rancheria (Downs 2005), and five occurrences in the northern end of the Solano-Colusa vernal pool region, west and northwest of Dunnigan (CNDDDB 2007). Four recorded occurrences were located within an area bounded by Interstate 5 to the east, Bird Creek to the south, and Buckeye Creek to the north and west. A fifth recorded occurrence, from 1993, represents an individual found in the Willows apartment complex in Davis, adjacent to a wildlife habitat area managed by the Yolo Audubon Society (CNDDDB 2007). Queries of the online databases of the California Academy of Sciences (2008) and Museum of Vertebrate Zoology (2008) yielded no additional occurrence records.

Population Trends

California tiger salamanders still occur throughout much of their historical range Trenham *et al.* (2000) and can be common at localities where it still occurs. Total adult population size is unknown, but certainly exceeds 10,000. Populations are thought to be declining due to habitat loss. Approximately 75 percent of the species' historical natural habitat has been lost. The species has been eliminated from 55 to 58 percent of historical breeding sites. Holland (1998) indicated that about 75 percent of the historical vernal pool breeding habitat has been lost, although some question the reliability of this estimate. Barry and Shaffer (1994) stated that this salamander soon will be in danger of extinction throughout its range and noted that it already is gravely threatened in the San Francisco Bay Area and in the San Joaquin Valley. In Santa Barbara County, half of the 14 documented breeding sites have been destroyed or have suffered severe degradation since mid-1999 (USFWS 2000).

Little is known of the population trends of California tiger salamanders in Yolo County. Four of the five recorded occurrences of the species in the county are from within an area that now comprises the Dunnigan Creek Unit (Central Valley Region Unit 1) of designated critical habitat. Land ownership within this unit is entirely private (USFWS 2005) and therefore restricted. The fifth recorded occurrence, in the City of Davis, consists of a solitary individual; lack of supporting habitat suggests this observation is the result of a translocated individual or a released pet (M. Ryan, pers. comm.).

Threats to the Species and Other Conservation Issues

Conversion of land to residential, commercial, and agricultural activities is considered the most significant threat to California tiger salamanders. These activities result in destruction and fragmentation of upland and/or aquatic breeding habitat, and killing of individual California tiger salamanders (Twitty 1941, Hansen and Tremper 1993, Shaffer *et al.* 1993, Jennings and Hayes 1994, Fisher and Shaffer 1996, Launer and Fee 1996, Loredo *et al.* 1996, Davidson *et al.* 2002).

Fisher and Shaffer (1996) found an inverse relationship between introduced exotics and native amphibians. Exotic species, such as bullfrogs (*Rana catesbeiana*), mosquitofish (*Gambusia affinis*), sunfish species (e.g., largemouth bass [*Micropterus salmoides*] and bluegill [*Lepomis macrochirus*]), catfish (*Ictalurus* spp.), and fathead minnows (*Pimephales promelas*), that live in perennial ponds—such as stock ponds—are considered to have negatively affected California tiger salamander populations by preying on larval salamanders (Anderson 1968, Morey and Guinn 1992, Graf and Allen-Diaz 1993, Shaffer *et al.* 1993, Seymour and Westphal 1994, Fisher and Shaffer 1996, Lawler *et al.* 1999, Laabs *et al.* 2001, Leyse 2005). Shaffer *et al.* (2008) found that for other ambystomatids, introduction of larger fish can result in the loss of salamander life stages within one year while introduction of mosquitofish (*Gambusia affinis*) can eliminate salamanders in 3-4 years. Native fish, including salmonids, are known to prey on amphibian larvae that are palatable (Hencar and M'Closkey 1996). In a thorough review of available data, Fisher and Shaffer (1996) found that historic California tiger

salamander localities are lower in elevation than current ones implying extirpation in many areas occurring below 200 meters. In general, introduced exotics now occupy lower elevations, and suggest that habitat modification and low levels of topographic relief may facilitate invasion by increasing opportunities for dispersal through interconnected watersheds or suitable terrestrial habitats, or through deposition by floodwaters (Fisher and Shaffer 1996). Bobzien and DiDonato (2007) found pond co-occurrence to be negatively correlated for California tiger salamander and California newt, with sympatry only occurring in xeric regions of oak savannas and open woodland habitats. California newts are generally associated with mesic habitats such as redwood forests, deciduous hardwood forests, and oak bay woodlands, suggesting that California tiger salamanders and California newts segregate out along elevation lines (Bobzien and DiDonato 2007).

Pond size may bear on the ability of California tiger salamander to avoid invertebrate predators. In large fishless ponds, *A. Tigrinum nebulosum* larvae avoided predation by aquatic invertebrates by moving from the shallow- vegetated margins to deeper waters while predators were active (Holomuzki 1986), underscoring the importance of pond size and open water refuge for larval success.

Riley et al. (2003) examined hybridization between California tiger salamanders and an introduced congener, the tiger salamander (*Ambystoma tigrinum*). The tiger salamander has been deliberately introduced as fish bait in California and is contaminating the genome of California tiger salamanders through interbreeding (Riley et al. 2003). In the Salinas Valley, Riley et al. (2003) sampled salamanders from four artificial ponds and two natural vernal pools. Based on mitochondrial DNA and two nuclear loci, Riley et al. (2003) found that hybrids were present in all six ponds, and that these hybrids were viable and fertile. Hybridization with the barred tiger salamander (*Ambystoma tigrinum mavortium*) has been occurring since fishermen and bait shop owners began introducing the species 50-60 years ago, resulting 15-30 generations of genetic mixing (Fitzpatrick and Shaffer 2004). Fitzpatrick and Shaffer (2004) report more nonnative alleles in large perennial ponds despite the proximity of ephemeral ponds, perhaps attributable to the presence of open water refugia providing an extended breeding season or facilitating a paedomorphic life history strategy in which adult salamander retain larval characteristics. Fitzpatrick and Shaffer (2007) report evidence of hybrid vigor or increased fitness of hybrids based on early-larval survival. This finding raises questions regarding the relative values of genetic purity versus fitness and viability that are central to developing conservation strategies for California tiger salamander.

Pesticides, hydrocarbons, and other pollutants are all thought to negatively affect breeding habitat, while rodenticides and gases used in burrowing mammal control (e.g., chlorophacinone, diphacinone, strychnine, aluminum phosphide, carbon monoxide, and methyl bromide) are considered toxic to adult salamanders (Salmon and Schmidt 1984). California ground squirrel and pocket gopher control operations may have the indirect effect of reducing the availability of upland burrows for use by California tiger salamanders (Loredo-Prendeville et al. 1994).

Roads can fragment breeding and dispersal migratory routes in areas where they traverse occupied habitat. Features of road construction, such as solid road dividers, can further impede migration, as can other potential barriers such as berms, pipelines, and fences.

Critical habitat has been designated in Santa Barbara County (USFWS 2004c) and within 20 counties in central California, including Yolo County (USFWS 2005). The Dunnigan Creek Unit (Central Valley Region Unit 1) of designated critical habitat, comprising 1,105 ha (2,730 acres), located just west of Interstate 5 and the town of Dunnigan in north-central Yolo County, is the only unit within the Plan Area.

In the USFWS's (2005) critical habitat designation for the California tiger salamander, the concept of critical habitat was described as follows: "Critical habitat identifies specific areas, both occupied and unoccupied by a listed species, which are essential to the conservation of the species and that may require special management considerations or protection." The USFWS (2005) further stated that "primary constituent elements for the California tiger salamander are aquatic and upland areas, including vernal pool complexes, where suitable breeding and non-breeding habitats are interspersed throughout the landscape, and are interconnected by continuous dispersal habitat," and that one or more of the primary constituent elements are present in all areas proposed for designation as critical habitat for the central population.

A recovery plan has not yet been prepared for the California tiger salamander, although the USFWS (2004b) has stated its intention to do so. In the interim, efforts toward conservation and recovery of the species should emphasize habitat preservation. Specifically, efforts should be directed toward protecting sites with vernal pool and other suitable rain pool habitat—in the largest blocks possible—from loss, fragmentation, degradation, and incompatible uses. Surrounding upland habitats will require similar protections that conserve burrowing mammals. Managed grazing programs may be a necessary component at many or all preserve sites in order to maintain the open, low-height grasslands required to sustain populations of California ground squirrels.

Physical disturbances to the underlying soils of seasonal rain pools should be avoided, as such disturbances could reduce their water-retaining capacity (Jennings and Hayes 1994). Such disturbances to vernal pool substrates also could destroy eggs of listed crustacean species.

In locations where roads traverse potential migratory routes, tunnels should be incorporated into the road design (Barry and Shaffer 1994). Barriers to migration, in the form of solid road dividers, should also be avoided on roads traversing potential migratory routes (Shaffer *et al.* in Jennings and Hayes 1994). Other potential barriers, such as berms and certain types of pipelines or fences, that can inhibit or prevent migration, should be avoided (Jennings and Hayes 1994).

Pesticides, hydrocarbons, and other pollutants should not be used or applied in a manner that run-off of these substances is transported into potential California tiger salamander breeding habitat. Rodenticides and gases used in burrowing mammal control may be

toxic to resident adult and juvenile salamanders. Operations to control California ground squirrel and pocket gopher populations should be avoided in areas where California tiger salamanders may be present due to direct effects on the species and the potential indirect effects of reducing the availability of upland burrows.

Efforts should be undertaken to control the spread and introduction of exotic predatory species such as bullfrogs, mosquitofish, sunfish, catfish, and fathead minnows that live in perennial ponds—especially in areas where California tiger salamanders are known to occur. Although the sale of non-native tiger salamanders for use as fish bait has been banned in California, efforts should continue to prevent the introduction and spread of this species, which has been shown to interbreed with native California tiger salamanders.

Based on a Monterey County study and a limited understanding of essential terrestrial habitats and buffer requirements of the species, Trenham *et al.* (2001) recommended that plans to maintain local populations of California tiger salamanders should include pond(s) surrounded by buffers of terrestrial habitat occupied by burrowing mammals, but noted that single isolated ponds might not support populations indefinitely even if surrounded by optimal uplands (Pechman and Wilbur 1994, Semlitsch and Brodie 1998 *in* Trenham *et al.* 2001). Based on individual dispersal of juveniles up to 1000 meters from their pool of origin, Searcey and Shaffer (2008) estimated that 95% of the reproductive value from a single large pond falls within approximately 2.4 km. Based on these findings, Shaffer *et al.* (2008) recommend a minimum buffer of one mile around breeding pools, relating to a preserve size of approximately 800 ha (1,977 acres), greatly exceeding the 290-m upper bound described by Semlitsch and Brodie (2003). This recommendation provides a useful and reasonable guideline for establishing salamander preserves of minimal functional size. Due to the potential for extirpation at single ponds due to random, stochastic events, sites with multiple complexes of vernal pools surrounded by much larger areas of suitable upland habitat should be considered for preserve sites, if feasible. Furthermore, sites with potential linkage corridors to other sub-populations should be considered. Sites chosen for preserves should also be occupied by burrowing mammals, especially California ground squirrels, in order to provide terrestrial habitat. Because contiguous blocks of land this size are not always available (e.g. Sonoma County), an experimental metapopulation approach may be required.

In their final report to USFWS titled “Guidelines for the relocation of California tiger salamanders (*Ambystoma californiense*),” Shaffer *et al.* (2008) make the following principal management recommendations: (1) eliminate fish and bullfrogs, (2) provide a means for draining all permanent ponds or eliminate them in favor of ephemeral ponds, (3) pools ponds should have sufficient watershed to provide an adequate hydroperiod for metamorphosis (3-6 months), (4) graze or burn to manage upland and wetland vegetation. Maret *et al.* (2006) found that disturbance of disruption of natural disturbance regimes can increase invasability by exotic predators, but that disturbance-intolerant fish and bullfrogs can be eliminated by pond drying. Bullfrogs, which prefer permanent or semi-permanent water (Stebbins 1951), may be less likely to establish in ephemeral waters (Barry and Shaffer 1994). Increased drying regimes can limit predators, but can also

reduce viability of salamander populations by limiting salamander breeding. However, Maret et al. (2006) found that the negative effects of drying on Sonoran tiger salamanders were generally minor relative to the negative effects of less frequent drying, and recommend ponds of varying depth to maintain a suitable hydroperiod for successful salamander reproduction while keeping exotic predators in check. At appropriate densities, cattle grazing can extend hydroperiod in ephemeral wetlands (Marty 2005) and may be an important factor in counteracting the hydrologic changes associated with climate change (Pyke and Marty 2005). Livestock grazing may also assist in maintaining open grassland and oak savanna communities that support rodents such as California ground squirrel and valley pocket gophers that provide retreats for California tiger salamanders (Bobzien and DiDonato 2007).

The most significant data gaps regarding California tiger salamanders are a lack of knowledge of its distribution and population trends within the Plan Area. California tiger salamanders may be more abundant in the Plan Area than available occurrence records indicate; however, surveys have not been conducted within the Dunnigan Unit of proposed critical habitat area and other areas where the species potentially occurs, and no information indicates recent or ongoing surveys at any Yolo County sites from which occurrences have been recorded.

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