Santa Cruz Long-Toed Salamander
(*Ambystoma macrodactylum croceum*),

5-Year Review:
Summary and Evaluation

Photo by Dana Bland

U.S. Fish and Wildlife Service
Ventura Fish and Wildlife Office
Ventura, California

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5-YEAR REVIEW

Santa Cruz Long-Toed Salamander (*Ambystoma macrodactylum croceum*)

I. GENERAL INFORMATION

Purpose of 5-Year Reviews:

The U.S. Fish and Wildlife Service (Service) is required by section 4(c)(2) of the Endangered Species Act (Act) to conduct a status review of each listed species at least once every 5 years. The purpose of a 5-year review is to evaluate whether or not the species' status has changed since it was listed (or since the most recent 5-year review). Based on the 5-year review, we recommend whether the species should be removed from the list of endangered and threatened species, be changed in status from endangered to threatened, or be changed in status from threatened to endangered. Our original listing of a species as endangered or threatened is based on the existence of threats attributable to one or more of the five threat factors described in section 4(a)(1) of the Act, and we must consider these same five factors in any subsequent consideration of reclassification or delisting of a species. In the 5-year review, we consider the best available scientific and commercial data on the species, and focus on new information available since the species was listed or last reviewed. If we recommend a change in listing status based on the results of the 5-year review, we must propose to do so through a separate rule-making process defined in the Act that includes public review and comment.

Species Overview:

The Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*) inhabits temporary ponds for breeding and adjacent upland scrub and woodland areas during the nonbreeding season. These ponds and adjacent scrub and woodland habitats occur in relatively few areas along the central coast of California; this subspecies is restricted to southern Santa Cruz and northern Monterey Counties. The Santa Cruz long-toed salamander was initially discovered in 1954 at Valencia Lagoon, which was nearly eliminated in 1969 when Highway 1 was converted into a freeway. Subsequent surveys in 1956 revealed one other breeding site at Ellicott Slough. Since 1956, an additional 22 breeding sites have been discovered, all of which are threatened by several factors.

As summarized in the current draft recovery plan for this species, Draft Revised Recovery Plan for the Santa Cruz Long-Toed Salamander (Service 1999), the Santa Cruz long-toed salamander was known from three population clusters (metapopulations), between which the Pajaro River and Elkhorn Slough were believed to act as barriers. However, the term "metapopulation" suggests that some level of interaction is occurring within spatially separated populations. Based on recent genetic research by Savage (pers. comm. 2009), the term metapopulation may not be accurate in this case because it is likely that little or no interaction is taking place within the previously defined Santa Cruz metapopulation. Until the final results of this genetic research is made available to the Service, and for the purposes of this 5-year review, the Service will describe populations within Santa Cruz County as four metapopulations, and populations within Monterey County as two metapopulations (Figure 1).

Methodology Used to Complete This Review:

This review was prepared by the Ventura Fish and Wildlife Office, following the Region 8 guidance issued in March 2008. We used information from the Recovery Plan, survey information from experts who have been monitoring various localities of this species, and the California Natural Diversity Database (CNDDB) maintained by the California Department of Fish and Game (CDFG). The Recovery Plan and personal communications with experts were our primary sources of information used to update the species' status and threats. We received no information from the public in response to our Federal Register Notice initiating this 5-year review. This 5-year review contains updated information on the species' biology and threats, and an assessment of that information compared to that known at the time of the last update of the recovery plan (Service 1999). We focus on current threats to the species that are attributable to the Act's five listing factors. The review synthesizes all this information to evaluate the listing status of the species and provide an indication of its progress towards recovery. Finally, based on this synthesis and the threats identified in the five-factor analysis, we recommend a prioritized list of conservation actions to be completed or initiated within the next 5 years.

Contact Information:

Lead Field Office: Chad Mitcham, Fish and Wildlife Biologist (805) 644-1766, extension 335; and Michael McCrary, Listing and Recovery Coordinator; Ventura Fish and Wildlife Office; (805) 644-1766, extension 372.

Lead Regional Office: Diane Elam, Deputy Division Chief for Listing, Recovery, and Habitat Conservation Planning, and Jenness McBride, Fish and Wildlife Biologist, Region 8, California and Nevada; (916) 414-6464.

Federal Register (FR) Notice Citation Announcing Initiation of This Review: A notice announcing initiation of the 5-year review of this taxon and the opening of a 60-day period to receive information from the public was published in the Federal Register on March 5, 2008 (73 FR 11945). The Service did not receive any responses to the notice.

Listing History:

Original Listing
FR Notice: 32 FR 4001
Date of Final Listing Rule: March 11, 1967 under the Endangered Species Preservation Act of 1966
Entity Listed: *Ambystoma macrodactylum croceum* (Subspecies)
Classification: Endangered

State Listing
Santa Cruz long-toed salamander (*Ambystoma macrodactylum croceum*) was listed by the State of California as endangered in 1971.

Associated Rulemakings: June 22, 1978: Proposal to designate critical habitat (43 FR 26759). The proposal was withdrawn in 1979 (44 FR 12382).

Review History: N/A

Species' Recovery Priority Number at Start of 5-Year Review: The recovery priority number for *Ambystoma macrodactylum croceum* is 6C according to the Service's 2008 Recovery Data Call for the Ventura Fish and Wildlife Office, based on a 1-18 ranking system where 1 is the highest-ranked recovery priority and 18 is the lowest (Endangered and Threatened Species Listing and Recovery Priority Guidelines, 48 FR 43098, September 21, 1983). This number indicates that the taxon is a subspecies that faces a high degree of threat and has a low potential for recovery. The "C" indicates conflict with construction or other development projects or other forms of economic activity.

Recovery Plan or Outline

> **Name of Plan or Outline:** Draft Revised Recovery Plan for the Santa Cruz Long-Toed Salamander.
> **Date Issued:** April, 1999. Currently a revised recovery plan is in preparation.
> **Dates of Previous Revisions:** September, 1977, Original Approved Recovery Plan; December, 1985, Draft Revised Recovery Plan; April, 1999, Second Draft Revised Recovery Plan.

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) Policy

The Endangered Species Act defines "species" as including any subspecies of fish or wildlife or plants, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the Act limits listing as distinct population segments to species of vertebrate fish or wildlife. The 1996 Policy Regarding the Recognition of Distinct Vertebrate Population Segments under the Endangered Species Act (61 FR 4722, February 7, 1996) clarifies the interpretation of the phrase "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the Act. The Santa Cruz long-toed salamander is listed as a subspecies and the application of the DPS policy is not addressed further in this review.

Information on the Species and its Status

Species Biology and Life History

The Santa Cruz long-toed salamander utilizes terrestrial and aquatic habitats during the course of its life cycle. Terrestrial habitats include upland mesic coastal scrub and woodland areas of coast live oak (*Quercus agrifolia*) or Monterey pine (*Pinus radiata*) and riparian vegetation, such as arroyo willows (*Salix lasiolepis*). The Santa Cruz long-toed salamander spends most of its life underground in burrows of small mammals, under leaf litter, rotten logs, fallen branches, and among the root systems of trees. Santa Cruz long-toed salamanders breed in shallow, usually ephemeral, freshwater ponds. Some breeding sites are ephemeral, while others contain water

throughout the year. Ephemeral breeding ponds vary greatly in size and duration of persistence from year to year and may not fill with water during periods of below-average rainfall. However, breeding ponds are likely to fill with water at least once over a period of 5 to 10 years, enabling successful recruitment into Santa Cruz long-toed salamander populations, and the populations' survival over many generations. If water quality remains suitable, remaining in the pond for a longer period of time may be advantageous to the larvae. Time of hatching can influence size at metamorphosis, length of larval period, and survival to metamorphosis (Boone et al. 2002).

Generally, success at the population level is determined primarily by the number and quality of metamorphosing larvae leaving an aquatic environment, and thus the number recruited into the terrestrial population (Semlitsch 2002). During the onset of winter rains, metamorphs disperse farther away from the pond, and do not return until they reach sexual maturity at 2 to 3 years (Ruth 1988; Laabs 2000, 2001, 2002, 2003).

Based on data from pitfall trap studies at a known breeding pond (Seascape Pond 1) and adjacent uplands (Willow Canyon), Biosearch (2002) estimated that between 26 to 36 percent of the adult population of Santa Cruz long-toed salamanders at the pond traveled at least 335 meters (1,100 feet) to reach suitable upland habitat. Biosearch (2002) recaptured (in a drift fence installed in the Willow Canyon uplands) 49 percent of the adult Santa Cruz long-toed salamanders that were originally captured along the same drift fence and marked (toe-clipping method) while migrating towards Seascape Pond 1. This high recapture rate suggests that adult Santa Cruz long-toed salamanders return to the uplands areas from which they migrated previously in the breeding season.

During 6 consecutive years of research, Laabs (2000, 2001, 2002, 2003, 2004) reported average snout-to-vent lengths (svl) and weights of adult Santa Cruz long-toed salamander females and males. In general, adult female Santa Cruz long-toed salamanders have longer svl, and weigh more than adult males. Post-metamorphic juvenile (metamorph) Santa Cruz long-toed salamanders are slightly greater than half the svl of adults, and generally weigh less than half the weight reported for adults.

Spatial Distribution

To date, 24 breeding sites for Santa Cruz long-toed salamanders have been identified; 17 of the breeding sites occur in southern Santa Cruz County, and 7 are in northern Monterey County. At the time of listing, the subspecies was known from three sites in Santa Cruz County. The subspecies likely has been extirpated from two locations; Bennett Slough/Struve Pond in Monterey County and Rancho Road Pond in Santa Cruz County. It is not known whether two other previously known breeding locations (Green's Pond and Anderson's Pond) in Santa Cruz County still exist. Additionally, breeding has not been documented at Lower Moro Cojo Slough (in Monterey County) since 1990. Breeding has been documented at 19 of the 24 known locations since the last draft revised recovery plan for the subspecies (Service 1999) was published.

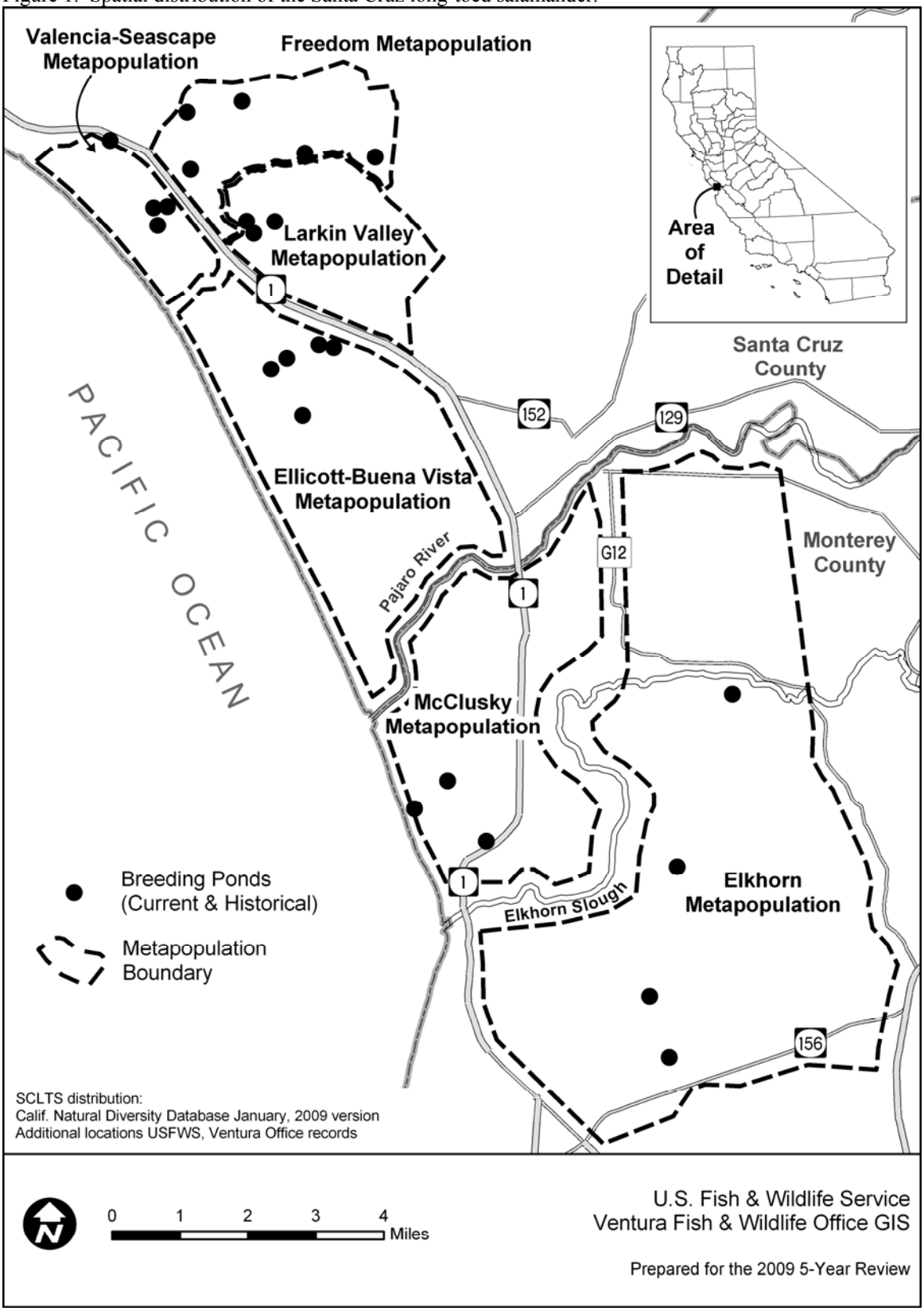
The draft recovery plan (Service 1999) described the distribution of breeding sites of the Santa Cruz long-toed salamander as occurring within three metapopulations, based upon available

survey data and the speculation that large rivers, sloughs, or extensive areas of coastal scrub and grasslands separated subpopulations from each other. These metapopulations were named "Northern or Santa Cruz metapopulation" (in Santa Cruz County), "Central or McClusky metapopulation" and "Southern or Moro Cojo metapopulation" (in Monterey County). Based on recent genetic research and knowledge of the current distribution of Santa Cruz long-toed salamanders, we believe the Santa Cruz County population clusters are comprised of four metapopulations rather than one. We also recognize the Pajaro River and Elkhorn Slough as substantial barriers to dispersal of Santa Cruz long-toed salamanders, and therefore recognize two metapopulations for the Santa Cruz long-toed salamander in Monterey County (Figure 1, Appendix A).

The draft recovery plan (Service 1999) describes four complexes that contained two-thirds of the known occurrences at that time. These complexes were considered essential for recovery of the subspecies, and required protection and management in order for the Santa Cruz long-toed salamander to be considered for downlisting. Due to the discovery of additional breeding sites since the draft recovery plan was published, this document will refer to six "metapopulations" that we recognize as requiring protection and management. These metapopulations are shown in Figure 1 and Appendix B and include: Valencia-Seascape, Ellicott-Buena Vista, Freedom, Larkin Valley, McClusky, and Elkhorn, which account for all known occurrences of the subspecies.

Geologic processes have repeatedly modified the course of the Pajaro River (Curry et al. 2003). Probably within the past 20,000 years, the Pajaro River has been repeatedly offset northward through faulting, sometimes emptying to the coast through Elkhorn Slough at Moss Landing, and other times commingling with Corralitos Creek as it does today (Curry et al. 2003). The Army Corps of Engineers (Corps) completed a flood-control project in 1949, which constrained the Pajaro River to its current course using an extensive system of levees and embankments (Philip Williams & Associates, Ltd. 2003). Currently, the Corps is considering various alternatives for modifications to the current flood-control system of dikes and levees. Based upon the current location of the Pajaro River and associated levees, metapopulations of Santa Cruz long-toed salamanders in Monterey County and Santa Cruz County are likely to remain physically isolated from each other, regardless of which flood-control alternative the Corps proposes to implement.

Figure 1. Spatial distribution of the Santa Cruz long-toed salamander.



Abundance

Valencia-Seascape Metapopulation

This metapopulation consists of four ponds, three of which (Seascape Ponds 1, 2, and 3) are managed through the Seascape Habitat Conservation Plan (HCP). Population monitoring and pond management continues as part of the Seascape HCP; however, current budget constraints preclude population monitoring at Pond 2. Populations appear stable at ponds 1 and 3 as of 2007. As required in the HCP, drift fencing and tunnels were installed across roads to promote safe dispersal. It was determined that the tunnels were not effective in promoting safe passage as less than 10 percent of Santa Cruz long-toed salamanders that encountered the drift fencing used the tunnels (Allaback and Laabs 2002). Currently, several organizations and agencies have secured funds to purchase the Willow Canyon property, which consists of 63.81 acres of upland habitat that is located adjacent to and north of the Seascape HCP area. This land will support the Seascape populations by providing upland habitat for dispersing Santa Cruz long-toed salamanders.

The remaining site (Valencia Lagoon), which is adjacent to Highway 1, is owned by CDFG. Limited upland habitat is available at this site which is bordered by Highway 1 to the north, and residential development to the west, south, and east. Mark-recapture pitfall trapping at Valencia Lagoon and its associated drainage channel in 2007-2008 estimated the population at this site at 734 adults (Biosearch 2008). This is markedly lower than the last estimate of population size at Valencia Lagoon, based upon mark and recapture efforts in 1977-1978, which was approximately 2,583 adults (Reed 1979). The 2007-2008 study was designed to use similar trap arrangements and methodology as the 1977-1978 effort. The decline in population size can be attributed to its isolation from other breeding ponds, mortality of migrating individuals on nearby roadways, and the loss of adjacent uplands to residential development (Biosearch 2008). Breeding was last confirmed at Valencia Lagoon during the 2007-2008 study.

Ellicott-Buena Vista Metapopulation

Two of the five known breeding locations within this metapopulation have been acquired and are afforded protection from development. These two ponds, Ellicott Pond and Buena Vista Pond, are currently managed by the Ellicott Slough National Wildlife Refuge (ESNWR) and CDFG respectively, which are both conducting management actions for the salamander. Buena Vista Pond is located within the 289-acre Buena Vista property, which was acquired in 2004. The property will be managed under a cooperative agreement with the Service as part of the nearby ESNWR. Monitoring by Service personnel and others at Ellicott Pond and Buena Vista Pond observed breeding in both of these ponds as of 2008; however, due to low levels of rainfall, no recruitment was expected at either of the ponds in 2008 (Kodama, pers. comm. 2009).

The three remaining ponds in this metapopulation are under private ownership. Breeding was last confirmed at these ponds in 1989 (Green's Pond), 1996 (Rancho Road Pond), and the 1960s (Anderson's Pond) (Service 1999). Rancho Road Pond functioned as a breeding site in 1996; however, culvert repairs along Rancho Road altered the hydrology for this pond and as a result it no longer supports Santa Cruz long-toed salamander breeding (Allaback pers. comm. 2009). It is unknown whether Green's Pond and Anderson's Pond currently exist and/or support Santa Cruz long-toed salamanders.

Freedom Metapopulation

Two of the five ponds (Tucker and Millsap) located within this metapopulation have been secured and are afforded protection from development. Tucker Pond is currently being managed for Santa Cruz long-toed salamanders under the Tucker HCP. In 2007 and 2008, aquatic sampling was completed at this site, in which no Santa Cruz long-toed salamander larvae were detected. A baseline population of 984 adult Santa Cruz long-toed salamanders was detected in 2002 (Biosearch 2008). According to the Tucker HCP, the adult population study must be repeated during the first winter season following grading of the residential development, which is expected to take place in 2009. In July 2007, non-native goldfish (*Carassius* spp.) and bullfrogs (*Rana catesbeiana*) were present in the pond. The pond dried in 2007, thus eliminating the goldfish and hundreds of bullfrog tadpoles; however, bullfrogs were again present in 2008. The pond was subsequently drained in October 2008 (Biosearch 2008). Continued management is needed at this site to assist in the continued establishment of Santa Cruz long-toed salamanders.

Millsap pond was acquired by the Trust for Public Land (TPL) in 2007, and subsequently transferred to CDFG. Management options are currently being explored at this location. Population studies were completed at Millsap Pond in 2000-2001, and an estimate of 137 ± 21 adults was derived (Biosearch 2001). Pitfall trap studies were completed at this pond in 2004-2005 in which 30 juveniles and 59 adults were captured (Dana Bland and Associates 2005).

The remaining three ponds are not being managed for Santa Cruz long-toed salamanders. Santa Cruz long-toed salamanders were discovered in Palmer Pond in 2004, which is within property owned by Aptos High School. No population studies have been completed at this location to date. Santa Cruz long-toed salamanders were discovered in Merk Pond in 2003, and breeding was last confirmed there in 2005. During a survey of the pond in 2005, catfish (*Ictalaurus* spp.) along with other fish species were found in this pond (D'Amore pers. comm. 2009). Management of this pond, possibly consisting of draining the pond to eliminate fish species may be needed to aid in the continued existence of the salamander at this location. Population studies have not been completed at Merk Pond. Salamanders were discovered at Racehorse Lane Pond in 2005, and an upland presence/absence study was completed here in 2008, in which Santa Cruz long-toed salamanders were again confirmed (Bland pers. comm. 2009).

Larkin Valley Metapopulation

Of the three ponds in this metapopulation, one (Calabassas) is owned by the ESNWR and is currently being managed for Santa Cruz long-toed salamanders. Successful breeding and recruitment was confirmed at this pond in 2008; however, several desiccated larvae were found suggesting that this site did not hold water long enough in 2008 for maximum recruitment (Mitcham pers. obs.). Population studies have not been completed at this location. Chytrid fungal infections of Santa Cruz long-toed salamanders breeding here have been observed. The remaining two breeding ponds in this metapopulation (Olives, Suess) are privately owned and the current status of Santa Cruz long-toed salamanders at these ponds is unknown. Breeding was last confirmed at both ponds in 2004.

McClusky Metapopulation

This metapopulation contains three known breeding locations including: Zmudowski Pond, McClusky Slough, and Bennett Slough/Struve Pond. Forty-one acres adjacent to Zmudowski State Beach, including the southern portion of the westernmost part of McClusky Slough, Zmudowski Pond and some surrounding uplands, are owned by CDFG. Biosearch (2003) estimated a population of 19 adult Santa Cruz long-toed salamanders at Zmudowski Pond in 2002-2003. Upland habitat suitable for Santa Cruz long-toed salamanders at this location is sparse, and increasing salinity of the aquatic habitat threatens the pond. California Department of Parks and Recreation (CDPR) and CDFG are coordinating regarding the management of the uplands adjacent to Zmudowski Pond. Biosearch (2003) estimated an adult population of 97 Santa Cruz long-toed salamanders at McClusky Slough, based on mark and recapture efforts conducted in 2001-2002. Biosearch (2003) reported that the length and weight of both adult females and males at McClusky Slough and Zmudowski Pond (data combined) were skewed markedly towards smaller individuals, in comparison to adult Santa Cruz long-toed salamanders caught in the same season at Seascape Pond (Laabs 2003) and Tucker Pond (Dana Bland and Associates 2002). These results could suggest that the population here is not increasing, does not have a stable age distribution, and may not be self-sustaining. Santa Cruz long-toed salamanders were discovered breeding in Bennett Slough/Struve Pond in 1973-1974 (Talent and Talent 1980). In March 1985, Rainey (1985) observed a single female adult Santa Cruz long-toed salamander, swollen with eggs. Rainey (1985) speculated that Santa Cruz long-toed salamanders likely experienced reproductive failure at Bennett Slough/Struve Pond in 1985, and possibly during the two preceding winters, due to increased salinity. Population studies have not been conducted at this breeding location since 1974, and larval sampling has not been conducted here since 1978. It is not known how tolerant eggs and larvae of Santa Cruz long-toed salamanders are to salinity. Rainey (1985) reported that salinity levels in Bennett Slough/Struve Pond exceeded 10 parts per thousand (ppt). Researchers from the Elkhorn Slough National Estuarine Research Reserve (ESNERR) sampled Bennett Slough in 2004, reported salinity levels of about 40 ppt, and did not find larvae of Santa Cruz long-toed salamanders. It is likely that Santa Cruz long-toed salamanders are extirpated from this site due to increased salinity. Breeding was last confirmed at McClusky Slough and Zmudowski Pond in 2004, and at Bennett Slough/Struve Pond in 1985.

Elkhorn Metapopulation

The Elkhorn metapopulation contains four known breeding sites including: Lower Cattail Swale, Oxbow Pond, Upper Moro Cojo Slough, and Lower Moro Cojo Slough. Santa Cruz long-toed salamanders were discovered breeding at Lower Cattail Swale in 2003 (Savage, pers. comm. 2003a). Savage (pers. comm. 2003b) stated that 8 of the 10 larvae that were captured via dipnet sampling in 2003 contained abnormalities that were visually apparent. Abnormalities included edema, abnormal fusion of joints, and extra limbs and toes. Population studies for the subspecies have not been conducted at this breeding location. ESNERR currently manages Lower Cattail Swale for the Santa Cruz long-toed salamander. Breeding was last confirmed at this location in 2008. In 2007, the Santa Cruz long-toed salamander was discovered at Oxbow Pond, which the Agriculture and Land-Based Training Association (ALBA) currently owns. During surveys in 2008, larvae were confirmed, as were the presence of bullfrogs and crayfish (*Procambarus* spp.) (D'Amore pers. comm. 2009). ALBA is currently working to develop a long range plan that will aid in the continued existence of the Santa Cruz long-toed salamander at

this location. Santa Cruz long-toed salamanders were discovered at Upper Moro Cojo Slough in 1978 (Reed 1979), and larval Santa Cruz long-toed salamanders were discovered there in May 1978. The ESF currently holds an easement over portions of the site. Breeding was last confirmed here in 2007 (John Gilchrist and Associates 2007). The North Monterey County Unified School District has identified vacant land the District owns adjacent to Upper Moro Cojo Slough, in an environmentally sensitive habitat area, as a site for expansion of athletic fields for the North Monterey County High School. Due to a misunderstanding of allowed activities, the study site has been graded several times over the past few years, most recently in the winter of 2005-2006. The project site may have supported seasonal breeding sites for Santa Cruz long-toed salamander, prior to grading; but it remains uncertain to what extent aquatic habitat was present on the site (John Gilchrist and Associates 2007). Upland surveys conducted in 2006-2007 and 2007-2008 discovered Santa Cruz long-toed salamanders dispersing across this property (John Gilchrist and Associates 2008). The ESF currently owns much of the property surrounding Oxbow Pond, Upper Moro Cojo Slough, and Lower Cattail swale, which contains several ponds that could support the subspecies. The ESF intends on surveying this area to determine further presence/absence of the Santa Cruz long-toed salamander (D'Amore pers. comm. 2009). Lower Moro Cojo Slough represents the southern extent of the known breeding range for the subspecies. This location is called "Upper Moro Cojo Slough" in CDFG's natural Diversity Database, although this location is the southernmost known breeding site within Moro Coro Slough. This breeding location is privately owned, and breeding was last confirmed here in 1990.

Habitat or Ecosystem

Prior to large-scale urbanization and conversion of lands for agricultural uses, it is probable that suitable upland sheltering and dispersal habitats were more widespread and contiguous in Santa Cruz and Monterey Counties. Similarly, freshwater marshes and vernal pools likely occurred in greater abundance, in comparison to the present. Terrestrial and aquatic habitats suitable for Santa Cruz long-toed salamanders have been removed and altered due to urbanization and agricultural activities, and barriers to dispersal have been created, resulting in subpopulations which are isolated from each other. New breeding sites for the Santa Cruz long-toed salamander are likely to be discovered, due to the amount of non-surveyed, privately-owned habitat in the region. Based upon a review of recent aerial photographs, additional breeding sites in Santa Cruz County may occur near ESNWR, south of Freedom Boulevard and north of White Road, south of White Road and north of Larkin Valley Road, and in Pleasant Valley north of Merk Pond. Additional breeding sites in Monterey County may occur near Elkhorn and Moro Cojo Sloughs, and in isolated locations adjacent to and south of Trafton Road.

Changes in Taxonomic Classification or Nomenclature

Recent genetic research, (Savage pers. comm., 2008), has revealed that the genetics, biochemistry, physiology, and life history traits of the Santa Cruz long-toed salamander may support the separation of the Santa Cruz long-toed salamander as a distinct species. However, additional analysis is needed.

Genetics

Little is known about the population biology and genetics of the subspecies; however, recent and ongoing research indicates that the majority of Santa Cruz long-toed salamander

metapopulations (as defined in this document) have recently (probably well within the last 100 generations) undergone significant population bottlenecks (Savage pers. comm. 2009). These clusters of genetically-defined populations are distinct operating units of breeding sites for which gene flow is highly restricted. That is, breeding ponds within a genetically defined cluster have shared migrants more recently than with breeding sites outside of that cluster. This is important to consider in the case of the Valencia-Seascape complex, which operates as a single genetic population to the exclusion of all other nearby breeding sites. This complex likely was populated by a small number of individuals, which would explain the high probability that individuals in any of the Valencia-Seascape sites will have highly similar genotypes (i.e., they are related as half-siblings or cousins, etc.) (Savage pers. comm. 2009). Once the final results of this research is available to the Service and the public, analyses regarding the causes and effects of population bottlenecks, as well as actions needed to assist the subspecies in avoiding future/ongoing bottlenecks will need to be investigated. Results of migration rate estimates that distinguish between historical and current gene flow among breeding sites will also assist in identifying core habitats. While the information presented is thus far preliminary, it provides strong evidence that each metapopulation is isolated, and therefore unable to exchange migrants, resulting in population genetic isolation and reductions in gene flow. It is well documented from both theoretical and empirical studies that animal populations can be severely affected by reduced genetic variability, particularly when gene flow is reduced and census population sizes are low. These conditions place any one breeding deme (inter-breeding population) at an increased risk of local extirpation resulting from the inability to adapt to new threats such as climate change, disease, or various stochastic events. The likelihood of recolonization from other sites if a local extinction occurs is low because of habitat fragmentation. Results from the current population genetic work by Dr. Savage and from further genetic studies, as well as a focused analysis of this work in conjunction with understanding local demography and population sizes, are needed to better understand threats facing the subspecies on a pond-by-pond basis.

Species-specific Research and/or Grant-supported Activities

In 2006, the Service awarded Section 6 funding for the purchase of 8.5 acres of Santa Cruz long-toed salamander upland habitat in the Larkin Valley area. The Wildlife Conservation Board is currently working to complete this land transaction. Additionally, the Service has provided Section 6 funding for a range-wide Santa Cruz long-toed salamander larval presence/absence study, which is to be conducted in 2009 (if appropriate water levels exist).

Five-Factor Analysis

The following five-factor analysis describes and evaluates the threats attributable to one or more of the five listing factors outlined in section 4(a)(1) of the Act.

The Santa Cruz long-toed salamander was listed as endangered (under the Endangered Species Preservation Act) in 1967 (32 FR 4001) and received additional Federal protections with the passage of the Act in 1973. The Santa Cruz long-toed salamander was designated as an endangered species prior to enactment of the Act; therefore, there was no formal listing package identifying threats to the subspecies, as required by Section 4(a)(1) of the Act.

FACTOR A: Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

The prime factors that continue to endanger populations of the Santa Cruz long-toed salamander throughout its range include degradation, fragmentation, and loss of aquatic and upland habitats through agriculture, road construction, and urbanization. Roads, highways, buildings, walls, and fences may form complete barriers to dispersing Santa Cruz long-toed salamanders. Additionally, vehicular traffic frequently kills Santa Cruz long-toed salamanders attempting to cross roads and highways. Together, these factors result in genetically isolated subpopulations and mortality of Santa Cruz long-toed salamanders. The loss of upland habitat through urbanization reduces or eliminates terrestrial retreats such as viable root systems and small mammal burrows that are necessary for the subspecies during the non-breeding season.

Efforts to protect the subspecies habitat have resulted in the protection of important aquatic and upland habitat areas, scattered throughout its range; however, urbanization and intensive agriculture have resulted in the fragmentation of protected habitats, likely preventing dispersal and migration of the Santa Cruz long-toed salamander within and between populations. The trend of wetland habitat loss continues throughout its range, resulting in relatively small parcels that are extremely susceptible to the changing hydrological conditions, more easily influenced by rainfall fluctuations, at risk of invasion by nonnative plants and animal species, increased sedimentation, and other conditions that serve to make habitat less suitable for the Santa Cruz long-toed salamander.

Invasive non-native plants such as eucalyptus trees (*Eucalyptus* sp.), jubata grass (*Cortaderia jubata*) and pampas grass (*C. selloana*) reduce the area available for native vegetation, and thus reduce the availability of root systems that are preferred by the species. Additionally, the presence of non-native invasive plants may reduce the numbers of invertebrates available as prey for Santa Cruz long-toed salamanders.

The type and degree of threats vary by geographic location, and Santa Cruz long-toed salamanders are subject to more than one threat at all known locations (see Table 1. in Appendix A.). In Santa Cruz County, the primary threats have been road construction and urbanization; in Monterey County, the primary threats are extensive and intensive agricultural practices and urbanization. Pesticides and herbicides that have been used in treating agricultural fields have been shown to negatively impact amphibians, and are discussed in greater detail in Factor E below.

From 1900 to 1992, California experienced eight dry periods, or droughts (California Department of Water Resources 2004). During this time period, droughts averaged approximately 3.5 years in duration, the longest drought lasted 6 years, the length of time between droughts averaged approximately 9 years, and the longest time period between droughts was 15 years (California Department of Water Resources 2004). Droughts could affect aquatic habitat of Santa Cruz long-toed salamanders by reducing the availability of water in ephemeral ponds; in drought years, rainfall is sometimes insufficient to allow normal breeding and larval development to occur. Droughts could also benefit Santa Cruz long-toed salamanders in some situations by reducing the numbers of non-native fish and bullfrogs in aquatic habitats. Drought

could affect upland habitat for the species by causing mortality of some coast live oaks (Regents of the University of California 2000). Additionally, climate change is likely to have further effects on hydrologic regimes throughout the subspecies' range. The effects of climate change on the Santa Cruz long-toed salamander are discussed in Factor E below.

FACTOR B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

Overutilization for commercial purposes was not known to be a factor at the time of listing and does not appear to be a threat at this time.

FACTOR C: Disease or Predation

Santa Cruz long-toed salamanders are vulnerable to several predators. Eggs and larvae may be preyed upon by mosquitofish (*Gambusia* spp.) and crayfish. These introduced species have also been implicated in the declines of other amphibian species (Blyth 1994; Axelsson et al. 1997; Gillespie and Hero 1999). Larvae are also eaten by adult Santa Cruz long-toed salamanders, California tiger salamanders (*Ambystoma californiense*) (Blau 1972), predacious aquatic insects, and bird species. Larvae and metamorphs probably are preyed upon by herons (*Ardea herodias, Butorides striatus, Egretta* spp.), grebes (*Podilymbus podiceps*, *Podiceps* spp.), and kingfishers (*Ceryle alcyon*). Mammalian predators of Santa Cruz long-toed salamanders include introduced opossums (*Didelphis virginiana*), striped skunks (*Mephitis mephitis*), and raccoons (*Procyon lotor*). Metamorphs and adults are also prey to California tiger salamanders and garter snakes (*Thamnophis sp.*) (Ruth 1988).

Trematode infestations naturally occur in the subspecies, but their rate of incidence may be increased due to human-related factors such as reduced water quality. In addition, eutrophication may increase parasitic infections (Johnson and Chase 2004). Studies by Sessions and Ruth (1990) suggested that mechanical disruption of developing limb tissues by trematode cysts stimulate the outgrowth of supernumerary limb structures (extra legs). Trematode parasites can result in direct mortality of amphibians through infection, and indirect mortality of individuals through impaired fitness associated with malformations (Johnson and Lunde 2005).

Chytrid fungus has been found to infect a number of amphibian populations that are declining, and has been confirmed in Santa Cruz long-toed salamanders in both Santa Cruz and Monterey Counties. This disease is caused by the zoosporic fungal pathogen *Batrachochtrium dendrobatidis* (BD). All amphibians seem to be susceptible to infection; however, effects of BD infection differ greatly among host species. Some species succumb to overt disease leading to mortality. Other species can test positive for the pathogen, but remain relatively asymptomatic (Padgett-Flohr 2008). Research on the effects of chytrid on the Santa Cruz long-toed salamander is needed to gain further insights on its potential impacts.

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

The inadequacy of existing regulatory mechanisms was not identified as a threat to the Santa Cruz long-toed salamander at the time of listing. The 1999 Recovery Plan did not identify inadequacy of existing regulatory mechanisms as a threat to the species, nor did it identify recovery tasks that would mitigate this factor. We found no information in the scientific literature that indicates this factor is a threat to the Santa Cruz long-toed salamander.

The Act is the primary Federal law providing protection for this species. Since its listing, the Service has analyzed the potential effects of Federal projects under section 7(a)(2), which requires Federal agencies to consult with the Service prior to authorizing, funding, or carrying out activities that may affect listed species. A jeopardy determination is made for a project that is reasonably expected, either directly or indirectly, to appreciably reduce the likelihood of both the survival and recovery of a listed species in the wild by reducing its reproduction, numbers, or distribution (50 C.F.R. § 402.02). A non-jeopardy opinion may include reasonable and prudent measures that minimize the amount or extent of incidental take of listed species associated with a project. Incidental take refers to taking of listed species that results from, but is not the purpose of, carrying out an otherwise lawful activity by a Federal agency or applicant (50 C.F.R. § 402.02). In cases where some incidental take is unavoidable, the Service works with the agency to include additional conservation measures to minimize negative impacts. For projects without a Federal nexus that may negatively impact listed species, the Service may issue incidental take permits pursuant to section 10(a)(1)(B). To qualify for an incidental take permit, applicants must develop, fund, and implement a Service-approved HCP that details measures to minimize and mitigate the project's adverse impacts to listed species. Regional HCPs in some areas now provide an additional layer of regulatory protection for covered species, and these HCPs are coordinated with the related Natural Community Conservation Planning (NCCP)-State program.

The Santa Cruz long-toed salamander was listed as endangered under the California Endangered Species Act (CESA) in 1971. Under CESA, the Santa Cruz long-toed salamander cannot be "taken" under CESA without first obtaining a permit. "Take" is defined in section 86 of the California Fish and Game Code as to "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill." If the take is incidental, CDFG requires that the permit applicant fully mitigate for it. If the take is intentional or purposeful (e.g., for research purposes), the researcher must first obtain a Memorandum of Understanding (MOU) with the CDFG.

The CDFG classified the Santa Cruz long-toed salamander as a fully protected species. A fully protected species may not be taken or possessed at any time and no licenses or permits may be issued for their take except for collecting for necessary scientific research. Hence, incidental take and purposeful take are not authorized for a fully protected species except for collecting for necessary scientific research and relocation of bird species for the protection of livestock.

FACTOR E: Other Natural or Manmade Factors Affecting Its Continued Existence

Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Field et al. 1999, Cayan et al. 2005, IPCC 2007). However, predictions of climatic

conditions for smaller sub-regions such as California remain uncertain. It is unknown at this time if climate change in California will result in a warmer trend with localized drying, higher precipitation events, or other effects. While we recognize that climate change is an important issue with potential effects to listed species and their habitats, we lack adequate information to make accurate predictions regarding its effects to particular species at this time. Therefore, the unpredictable impacts of climate change on Santa Cruz long-toed salamander habitat makes it impractical for the Service to determine the effect on known breeding locations for the Santa Cruz long-toed salamander.

Degraded water quality through chemical contamination (e.g., pesticides, herbicides, petroleum products) and sedimentation via runoff reduces the growth or survival of salamander larvae (Semlitsch 2002). Methoprene, an insect growth regulator and larvicide, has been used at Valencia Lagoon and other ponds to control mosquito populations. Data on its effects on Santa Cruz long-toed salamanders are not available, but effects on other amphibians have been observed. Although methoprene did not cause increased mortality of gray treefrog (*Hyla versicolor*) tadpoles (Sparling and Lowe 1998), it has been implicated in reduced survival rates and the development of malformations in northern leopard frogs (*Rana pipiens*) (Ankley et al. 1998), and with malformations in southern leopard frogs (*Rana utricularia*) (Sparling 1998). Blumberg et al. (1998) also correlated exposure to methoprene with delayed metamorphosis and high mortality rates in both northern leopard frogs and mink frogs (*R. septentrionalis*). Other insecticides (e.g., temephos) have caused reductions in growth rates of gray treefrog tadpoles and increased mortality rates in green frog (*Rana clamitans*) tadpoles (Sparling and Lowe 1998), and increased mortality rates in southern leopard frogs (Sparling 1998). The survival of many amphibians relies on an abundance of invertebrates, and any delay in insect growth could reduce the numbers and density of prey available to Santa Cruz long-toed salamanders.

III. RECOVERY CRITERIA

Recovery plans provide guidance to the Service, states, and other partners and interested parties on ways to minimize threats to listed species, and on criteria that may be used to determine when recovery goals are achieved. There are many paths to accomplishing the recovery of a species and recovery may be achieved without fully meeting all recovery plan criteria. For example, one or more criteria may have been exceeded while other criteria may not have been accomplished. In that instance, we may determine that, over all, the threats have been minimized sufficiently, and the species is robust enough, to downlist or delist the species. In other cases, new recovery approaches and/or opportunities unknown at the time the recovery plan was finalized may be more appropriate ways to achieve recovery. Likewise, new information may change the extent that criteria need to be met for recognizing recovery of the species. Overall, recovery is a dynamic process requiring adaptive management, and assessing a species' degree of recovery is likewise an adaptive process that may, or may not, fully follow the guidance provided in a recovery plan. We focus our evaluation of species status in this 5-year review on progress that has been made toward recovery since the species was listed (or since the most recent 5-year review) by eliminating or reducing the threats discussed in the five-factor analysis. In that context, progress towards fulfilling recovery criteria serves to indicate the extent to which threat factors have been reduced or eliminated.

The draft revised recovery plan (Service 1999) contains "recovery objectives" which are similar to the recovery criteria in more recent recovery plans. New information that has been collected since the latest recovery plan was published has resulted in changes to the distribution and description of Santa Cruz long-toed salamander metapopulations. Currently, a revised recovery plan is being prepared that will take into account this new information, which the Service feels is necessary to adequately determine appropriate downlisting and delisting criteria.

The draft revised recovery plan (Service 1999) describes four complexes (Valencia-Seascape, Larkin Valley, Ellicott-Buena Vista, and McClusky Slough) that should be protected and managed such that habitat is conserved, maintained, and/or restored. Each complex must contain at least two functional breeding ponds or sites, as well as sufficient upland habitat to support self sustaining populations. A self-sustaining population is defined as one exhibiting an average adult sex ratio of 1:1 and either a stable age distribution (that is, not skewed toward larger, presumably older, individuals, nor strongly skewed toward smaller, presumably newly-matured animals), or evidence of a population increasing in size (that is, more small adults than expected in a stable age distribution, without loss of older, larger individuals). Evidence of continued breeding success, metamorphosis, and recruitment of adults must be documented over a 20-year period. Twenty years should be long enough to monitor the Santa Cruz long-toed salamander and its habitat through at least one drought cycle, and will allow sufficient time for evaluation of management actions, determination of population trends, and alteration of management actions if necessary. Each secured population must be self-maintaining, that is, not requiring any direct human assistance to reproduce successfully and maintain a stable or growing population during years of average or above average precipitation. All protected areas must provide sufficient acreage and habitat diversity to ensure that each subpopulation is capable of self-maintenance, even after adverse environmental conditions such as drought, heavy rains, or fire. Upland scrub or woodland habitats must be adjacent to the breeding ponds or within migration distance, protected corridors for migration to nonbreeding habitat must be established and maintained where necessary, and protected corridors for dispersal to other ponds in the complex must be established and maintained. The most effective way to achieve this goal is to protect the whole drainage surrounding the breeding pond, as well as protecting and enhancing existing ponds or creating one or more new breeding ponds within 1.0 kilometer of currently protected or managed breeding sites.

Although 21 additional breeding sites have been identified since the time of listing; resulting in the expansion of the known range, threats to the subspecies remain the same. Degradation and fragmentation of habitat continues to be the main threat, resulting in the lack of sufficient upland habitat and disruption of movement corridors between subpopulations. Also, due to the lack of consistent range-wide monitoring and studies, the Service is unable to determine if the majority of the known breeding sites contain stable populations. Since the Santa Cruz long-toed salamander is relatively long-lived, the potential exists that individuals identified in known locations may be individuals that have not consistently reproduced. The acquisition of movement corridors and discovery or creation of additional ponds may be needed to ensure that each subpopulation can be self-sustaining. The subspecies requires sufficient upland habitat and connectivity between ponds to ensure that subpopulations remain stable, and that genetic flow is being maintained.

IV. SYNTHESIS

At the time of listing in 1967, the Santa Cruz long-toed salamander was only known from three sites. It has now been known to occur at 24 locations. Fifteen of the known 24 locations have been protected from development through various methods such as HCPs, conservation easements, or ownership under various conservation agencies or organizations. Nine of the known breeding locations are not ensured protection from development and are not being managed for Santa Cruz long-toed salamanders. Although 15 sites are protected from development, 1 of these is presumed extirpated due to increasing salinity, and threats still exist at all remaining sites which preclude the species from meeting many of the downlisting criteria.

While recent genetic research presented in this document is thus far preliminary, it provides strong evidence that each metapopulation is isolated, and therefore unable to exchange migrants, resulting in population genetic isolation and reductions in gene flow. Animal populations can be severely affected by reduced genetic variability, particularly when gene flow is reduced and census population sizes are low. These conditions place any one breeding deme at an increased risk of local extirpation resulting from the inability to adapt to new threats such as climate change, disease, or various stochastic events. The likelihood of recolonization from other sites if a local extinction occurs is low because of habitat fragmentation. Additionally, population studies have been completed only sporadically since the time of listing, and only at 10 of the known breeding locations. The lack of population and genetic studies at the majority of these locations leaves the Service with little knowledge on breeding and recruitment success at each site, as well as whether genetic exchange between subpopulations is occurring. We remain concerned that without knowledge and assurance regarding the success of genetic exchange and recruitment, extirpation could result in the long-term throughout portions of the subspecies range.

The prime threats, which include habitat degradation and fragmentation due to urbanization and agriculture, continue to constrain the subspecies with limited upland habitat for dispersal and little connectivity between breeding locations. Federal, State, and local laws have succeeded in protecting several of the known breeding sites; however, efforts have not been sufficient to ensure recovery of the subspecies. Depending on how land is zoned, land conversions could take place that do not require County permits and, therefore, may not consider Santa Cruz long-toed salamanders or their habitat.

Amphibian populations, such as those of the Santa Cruz long-toed salamander, naturally undergo large fluctuations in population size as a result of random natural events such as drought and fire. Their ability to recover from these events is dependent upon year-to-year survival of larvae and adults, the presence of refugia to endure natural events and escape predators, and successful reproduction during years of adequate rainfall. The loss of upland habitats and the loss of individuals through agricultural and development activities can leave small populations that are unable to withstand decreases in size as a result of such events.

Other factors affecting the Santa Cruz long-toed salamander include the effects of drought, mortality on roads, and contaminants. As urban areas continue to expand, roads continue to fragment remaining habitat and increase the threat of pollution from run-off into known or

potential breeding sites. Mortality on roads is a threat faced by nearly all Santa Cruz long-toed salamander subpopulations, and has been widely documented as contributing to the increasing decline of amphibians worldwide, particularly in populated areas. Efforts to reduce road mortality of dispersing Santa Cruz long-toed salamanders at the Seascape Ponds has met with disappointing results, indicating that more research is necessary to identify appropriate tunnel design and efficiency.

Disease and predators continue to threaten the Santa Cruz long-toed salamander. Although the direct effect of disease on Santa Cruz long-toed salamanders is unknown, several pathogenic agents, including at least one bacterium, fungus, and viruses have been associated with die-offs of closely related salamander species. Native and non-native predators are present at several of the known breeding ponds. In healthy salamander populations, predation by native species is not known to be a significant threat; however, when combined with other impacts, such as predation by non-native species, contaminants, or habitat alteration, the cumulative result may be a substantive decrease in population abundance and viability.

Since the draft recovery plan was published in 1999, 10 new breeding sites have been discovered or created, which has created information gaps regarding the adequacy of the recovery plan to fully address recovery of the subspecies. Currently, a draft revised recovery plan in is preparation. In 2009, a range-wide larval study is planned, which will provide updated information on the current status of the subspecies at each location.

Based on our analysis of the status and threats to the Santa Cruz long-toed salamander, we are recommending that although known breeding locations have increased since the time of listing it remain listed as endangered for the following reasons: 1) threats to the species identified at the time of listing remain, particularly loss and fragmentation of habitat; 2) a lack of population studies at known breeding sites leaves no assurance that each subpopulation is stable; and 3) recent genetic studies suggest that gene flow within each metapopulation is highly restricted, resulting in geographically and genetically isolated metapopulations.

V. RESULTS

Recommended Listing Action:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (indicate reason for delisting according to 50 CFR 424.11):
    ____ *Extinction*
    ____ *Recovery*
    ____ *Original data for classification in error*
__**X**__ No Change

New Recovery Priority Number and Brief Rationale: No change is recommended at this time.

VI. RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS

Research and Management

- Conduct consistent population monitoring at all known breeding locations.
- Study the aquatic ecology of larvae to understand physical and biological determinants of recruitment; research water quality parameters to determine acceptable Santa Cruz long-toed salamander breeding conditions.
- Research the genetic composition of the Santa Cruz long-toed salamander within each metapopulation to determine the success of genetic exchange between subpopulations.
- Remove non-native predators from known and potential breeding ponds.
- Contact landowners of known breeding locations to encourage positive management of those sites.
- Survey potential breeding habitat where status of the subspecies is unknown.
- Continue working with partners to protect breeding and upland habitat.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW

Santa Cruz Long-Toed Salamander (*Ambystoma macrodactylum croceum*)

Current Classification: Endangered

Recommendation Resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
✓ No change needed

Review Conducted By: Chad Mitcham

FIELD OFFICE APPROVAL:

Lead Field Supervisor, U.S. Fish and Wildlife Service

Approve Diane K. Noda Date 5/28/09

Appendix A

Table 1. Status of and threats to Santa Cruz long-toed salamanders at the 24 known breeding locations, Santa Cruz and Monterey Counties, California.

Breeding Location	Status	Threats								
		Agriculture	Grazing	Urbanization	Exotic Animals	Exotic Plants	Disease/ Infection	Sedimentation	Contaminants	Salinization
Santa Cruz County										
Valencia-Seascape	P	○	○	● 1,2,3		●	T	●	● ro	
Valencia Lagoon	P	○	○	● 1,2,3	○	●	T	●	● lv, ro	
Seascape Pond 1	P	○	○	● 1,2	○	●	T	●		
Seascape Pond 2	P	○	○	● 1,2		●	T	●		
Seascape Pond 3	P	○	○	● 1,2		●	T	●		
Ellicott-Buena Vista										
Buena Vista Pond	P	○	○	○		●	U	●		
Rancho Road Pond	X?	○	○	●				●	●	
Green's Pond	P	●	○	● 1,2		●	U	●		
Ellicott Pond	P	●	○	● 2		●	T	●		
Anderson's Pond	P	●	○	● 1,2	?	●	U	●		
Freedom										
Palmer Pond	P	○	○	● 1,2		●	U	●		
Tucker Pond	P	○	○	● 2		●	U	●		
Millsap Pond	P	○	○	● 1,2		●	U	●		
Merk Pond	P	●	○	● 2		●		●	● h, p	
Racehorse Lane Pond	P	○	○	● 1,2,3	?	●	U	U	● ro	
Larkin Valley										
Calabasas Pond	P	○	○	● 2		●	C	●		
Suess Pond	P	○	○	● 1,2		●	U	●		
Olives Pond	P	○	●	● 1,2	?	●	U	●		

Appendix A

Breeding Location	Status	Threats								
		Agriculture	Grazing	Urbanization	Exotic Animals	Exotic Plants	Disease/ Infection	Sedimentation	Contaminants	Salinization
Monterey County										
McClusky										
McClusky Slough	P	● 1,2,3	○			●	T	●	● h, p	●
Zmudowski Pond	P	● 1,2,3	○			●	U	●	● h, p	●
Bennett Slough/Struve Pond	X	○ 1,2,3	○	○		○	○	○	○ h, p	○ ●
Elkhorn										
Oxbow Pond	P	● 1,2,3	○	● 1,2			T,C	●	● h, p	
Lower Cattail Swale	P	● 1,2,3	○	● 1,2,3		●	T,C	●	● h, p	●
Northern Moro Cojo Slough	P	● 1,2,3	●	● 1,2,3		●	U	●	● h, p	?
Southern Moro Cojo Slough	P	● 1,2,3	●	● 1,2,3		●	U	●	● h, p	?

Key to threats identified in table:
P = present, X = likely extirpated, ? = unknown
○ = past threat, ● = current threat
1 = loss of upland habitat; 2 = mortality on roads or in fields; 3 = isolation from other subpopulations
= bullfrogs, = non-native fish (*e.g.,* mosquitofish, bass, goldfish), = crayfish
C = chytrid fungus (chytridiomycosis), T = trematode infections, U = unknown
h = herbicides, lv = larvicides (*e.g.,* methoprene), p = pesticides, ror = run-off contaminants (petroleum products) from roads

Appendix B

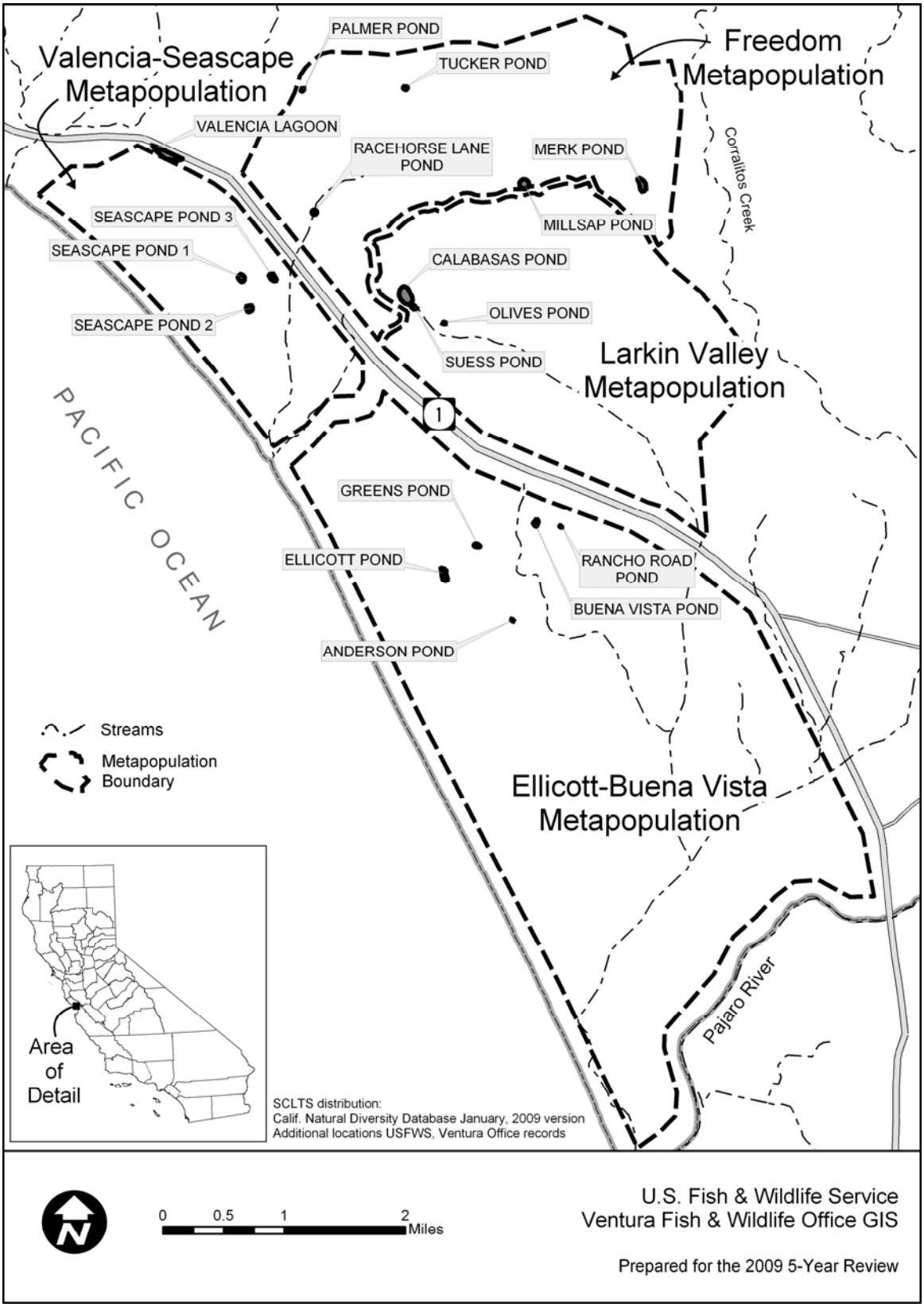

Figure 2. Santa Cruz long-toed salamander breeding locations in Santa Cruz County.

Appendix B

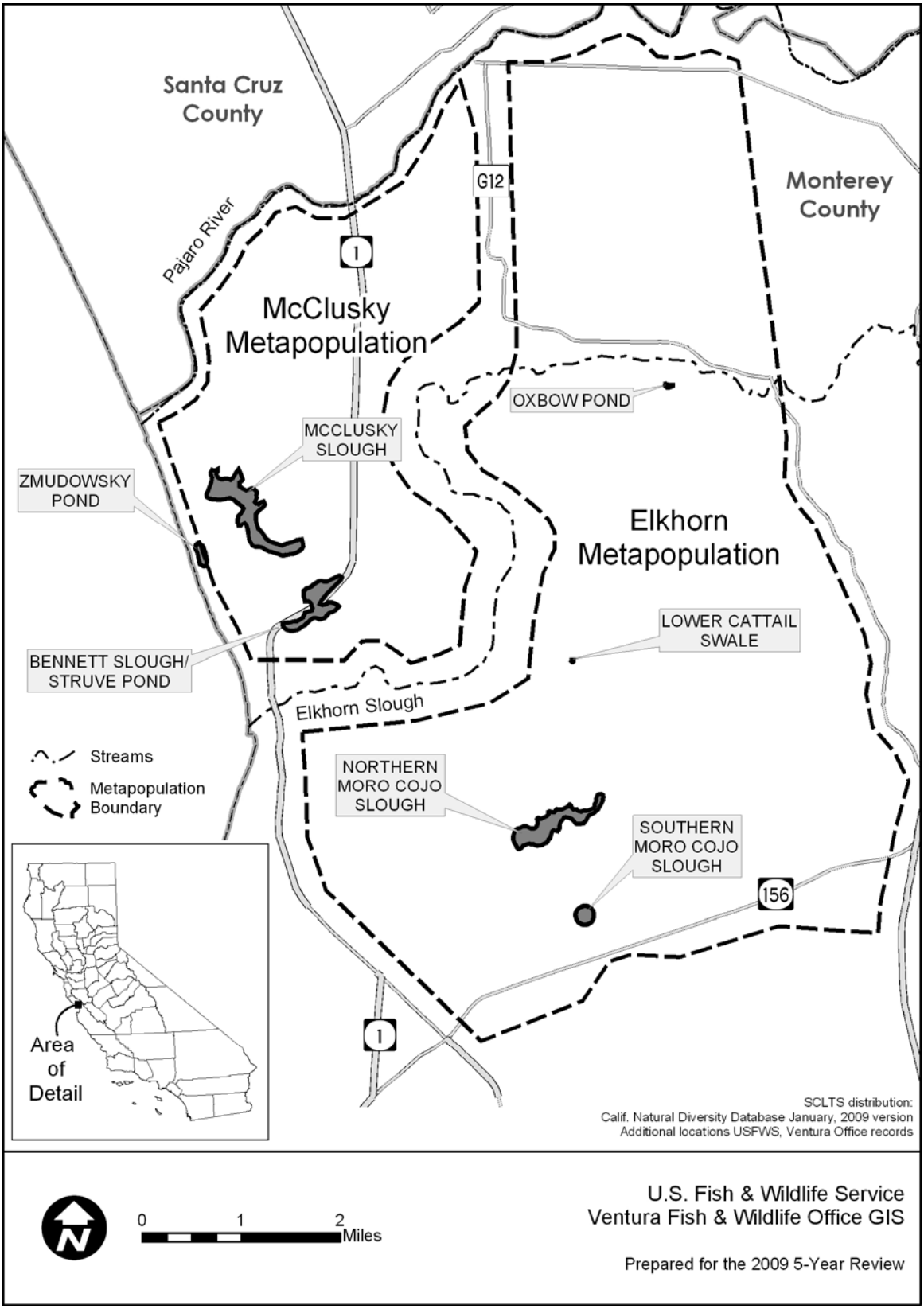

Figure 3. Santa Cruz long-toed salamander breeding locations in Monterey County.