Paiute Cutthroat Trout
(Oncorhynchus clarkii seleniris)

5-Year Review:
Summary and Evaluation

Photo by Michael Graybrook

U.S. Fish and Wildlife Service
Nevada Fish and Wildlife Office
Reno, Nevada
June 2013

5-YEAR REVIEW

Paiute cutthroat trout (*Oncorhynchus clarkii seleniris*)

TABLE OF CONTENTS

5-YEAR REVIEW

Paiute cutthroat trout (*Oncorhynchus clarkii seleniris*)

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 (ESA) 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 ESA, 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 ESA that includes public review and comment.

Species Overview:

Cutthroat trout (*Oncorhynchus clarkii*) have the most extensive range of any inland trout species of western North America, and occur in anadromous (migrating from salt to fresh water to spawn), non-anadromous, fluvial (river- or stream-dwelling), and lacustrine (lake-dwelling) populations (Behnke 1979, p. 27). Differentiation of the species into 14 recognized subspecies occurred during subsequent general desiccation and isolation of the Great Basin and Inter-mountain Regions since the end of the Pleistocene, and indicates presence of cutthroat trout in most of their historical range prior to the last major Pleistocene glacial advance (Loudenslager and Gall 1980, pp. 38–40; Behnke 1992, pp. 14–18). Paiute cutthroat trout (PCT) have the most restricted range of all cutthroat trout subspecies and historically occupied approximately 17.8 kilometers (km) (11.1 miles (mi)) of stream habitat within the Silver King Creek drainage, Alpine County, California. Paiute cutthroat trout now occupy approximately 37.8 km (23.5 mi) of stream habitat in five widely distributed drainages outside of their historical range. Like most salmonids, PCT require relatively clear, cold waters to maintain viable populations. Paiute cutthroat trout reproduce in the spring and are obligatory stream spawners. Paiute cutthroat trout evolved in the absence of other trout, and they are highly susceptible to hybridization and competition from introduced trout species.

Methodology Used to Complete This Review:

This review was prepared by the Nevada Fish and Wildlife Office (NFWO), following the Region 8 guidance issued in March 2008. We used information from the Paiute cutthroat trout Revised Recovery Plan (Service 2004, pp. 1–105) and the most recent 5-year review (Service 2008a, pp. 1–39), agency records, scientific literature, and survey information from experts who have been monitoring this species in various localities to update the species' status and threats.

Contact Information:

Lead Regional Office: Larry Rabin, Deputy Division Chief for Listing, Recovery, and Contaminants, Region 8, Pacific Southwest; (916) 414–6464.

Lead Field Office: Chad Mellison, Fish and Wildlife Biologist, Nevada Fish and Wildlife Office; (775) 861–6300.

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 April 27, 2012 (Service 2012, pp. 25112–25116). We received no information from the public in response to our Federal Register Notice initiating this 5-year review. We received valuable information from the California Department of Fish and Wildlife (CDFW).

Listing History:

Original Listing
FR Notice: Service (1967, p. 4001)
Date of Final Listing Rule: March 11, 1967
Entity Listed: *Salmo clarki* subsp. *Seleniris*, a fish subspecies
Classification: Endangered

Revised Listing
FR Notice: Service (1975, pp. 29863–29864)
Date Listed: July 16, 1975
Entity Listed: *Salmo clarki* subsp. *Seleniris*, a fish subspecies
Classification: Threatened

Associated Rulemakings:

Paiute cutthroat trout (*Salmo clarki seleniris*) was reclassified from endangered to threatened in 1975 (see Revised Listing above). A special rule under ESA section 4(d) was published in conjunction with the downlisting rule to facilitate management by the State of California and allow State-permitted sport harvest (Service 1975, p. 29864).

Review History:

The original recovery plan was published on January 25, 1985 (Service 1985, pp. 1–68). Two rangewide status assessments have been conducted (Behnke 1992, pp. 116–118; Moyle 2002, pp. 287–293); however, they did not conduct a five-factor analysis nor did they address the listing status. A revised recovery plan was published on August 10, 2004 (Service 2004, pp. 1–105). The initial 5-year review was completed on July 10, 2008 (Service 2008a, pp. 1–39).

Species' Recovery Priority Number at Start of 5-Year Review:

The recovery priority number for PCT is 9 according to the Service's 2012 Recovery Data Call for the NFWO, based on a 1–18 ranking system where 1 is the highest-ranked recovery priority and 18 is the lowest (Service 1983a, pp. 43098–43105; 1983b, p. 51985). This number indicates that the taxon is a subspecies that faces a moderate degree of threats and has a high potential for recovery.

Recovery Plan

> **Name of Plan:** Revised Recovery Plan for the Paiute Cutthroat Trout
> **Date Issued:** August 10, 2004
> **Dates of Previous Revisions:** January 25, 1985 (original recovery plan)

II. REVIEW ANALYSIS

Application of the 1996 Distinct Population Segment (DPS) Policy

The ESA defines "species" as including any subspecies of fish or wildlife or plant, and any distinct population segment (DPS) of any species of vertebrate wildlife. This definition of species under the ESA 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 ESA (Service 1996, pp. 4722–4725) clarifies the interpretation of the phrase "distinct population segment" for the purposes of listing, delisting, and reclassifying species under the ESA. Paiute cutthroat trout was originally listed in its entirety, and there is no new information regarding the application of the DPS policy.

Information on the Species and its Status

Species Biology and Life History

Paiute cutthroat trout are obligatory stream spawners. Spawning generally occurs from May through July, depending upon stream flow, elevation, and water temperature (Wong 1975, pp. 117–118; Behnke 1987, p. 541). Spawning habitat is typical of stream-spawning salmonids with site selection being based on a variety of factors including gravel size, velocity, water depth, and water temperature (Bjornn and Reiser 1991, pp. 89–97; Beechie *et al*. 2008, pp. 84–85).

Spawning areas must be well oxygenated and relatively silt-free for good egg survival (Bjornn and Reiser 1991, p. 99). Redds are generally located in riffles and pool tails (Wong 1975, pp. 117–118; Behnke 1987, p. 540). Paiute cutthroat trout generally become sexually mature around year two; consecutive year spawning is unknown, and few individuals survive to spawn again (Behnke 1987, p. 541).

Spawning behavior of PCT is also similar to other stream-spawning trout. Females excavate a redd (*i.e.*, nest) and then deposit eggs in the redd while the male simultaneously fertilizes the eggs (Wong 1975, pp. 117–125). The female then covers the fertilized eggs with gravel. Paiute cutthroat trout generally deposit between 250 and 400 eggs during spawning (Wong 1975, p. 128; Behnke 1987, p. 541). Eggs hatch in 6–8 weeks and fry (recently hatched) emerge from the gravel 2–3 weeks later and remain in shallow shoreline areas with small gravel/cobble for hiding cover (Wong 1975, pp. 102–108, 151–152; Moyle 2002, p. 291). By early fall the fry have developed into small (35–40 millimeters (mm) (1.4–1.6 inches (in))) fingerlings which set up feeding territories during the day and may school together at night in hiding cover (Wong 1975, pp. 105–108, 151–155).

Migratory behavior in PCT is not known to exist (Behnke 1987, p. 540). Diana and Lane (1978, pp. 444–448) found limited movement of adult PCT in North Fork Cottonwood Creek. Most individuals were recaptured in their original capture locations; however, both upstream and downstream movement was detected and a few individuals moved over 1 km (0.6 mi) (Diana and Lane 1978, p. 446).

Paiute cutthroat trout are opportunistic feeders, with diets consisting of drift organisms, typically terrestrial and aquatic insects (Wong 1975, pp. 133–138; Behnke 1987, p. 540; Moyle 2002, p. 290). Recent literature has documented the importance of terrestrial insects in the diet of stream salmonids (Baxter *et al*. 2005, pp. 201–214; Saunders and Fausch 2012, p. 1524). Wong (1975, pp. 133–138) found that PCT less than 100 mm (3.9 in) in length fed exclusively on small aquatic organisms while individuals over 100 mm (3.9 in) in length incorporated terrestrial organisms as well as larger aquatic invertebrates.

Paiute cutthroat trout may live up to 6 years of age (Wong 1975, pp. 88–99; Titus and Calder 2009, pp. 8–11). Growth rates of PCT are variable, with faster and greater growth occurring in larger habitats (Wong 1975, pp. 99–108; Titus and Calder 2009, pp. 8–12). Total length at age was higher in the Upper Fish Valley section of Silver King Creek opposed to the comparatively smaller headwater habitats of Silver King Creek and Coyote Creek (Titus and Calder 2009, p. 11).

Spatial Distribution

Paiute cutthroat trout are known from a single drainage in the Sierra Nevada range in east-central California. The presumed historical distribution was limited to 17.8 km (11.1 mi) of habitat in Silver King Creek (Alpine County), from Llewellyn Falls downstream to barriers in Silver King Canyon, as well as the accessible reaches of three small, named tributaries: Tamarack Creek,

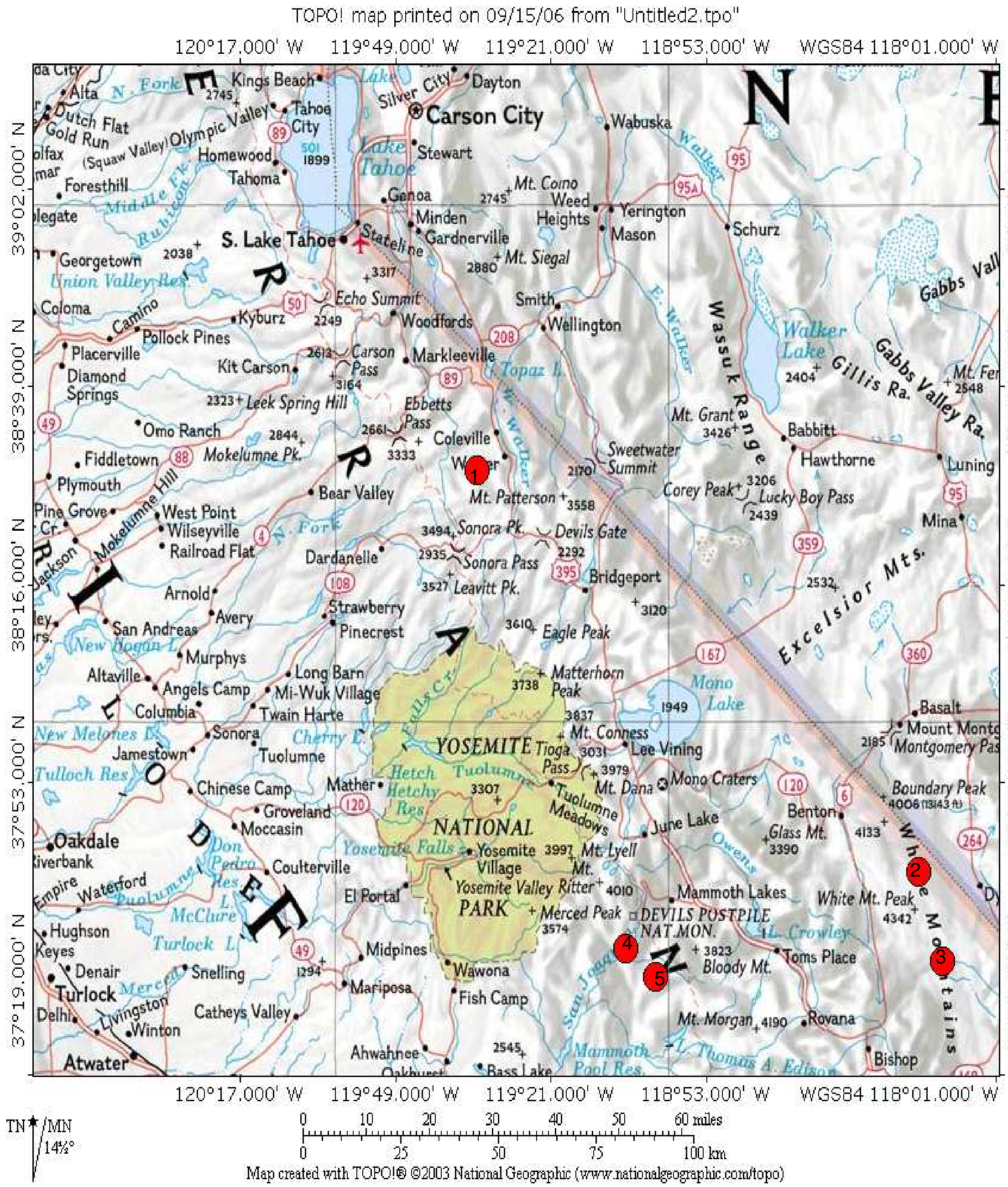

Figure 1. Location of existing Paiute cutthroat trout populations in the Sierra Nevada Mountain Range: 1) Silver King Creek, Humboldt-Toiyabe National Forest, Alpine County, California; 2) Cabin Creek, Inyo National Forest, Mono County, California; 3) North Fork Cottonwood Creek, Inyo National Forest, Mono County, California; 4) Stairway Creek, Sierra National Forest, Madera County, California; and 5) Sharktooth Creek, Sierra National Forest, Fresno County, California.

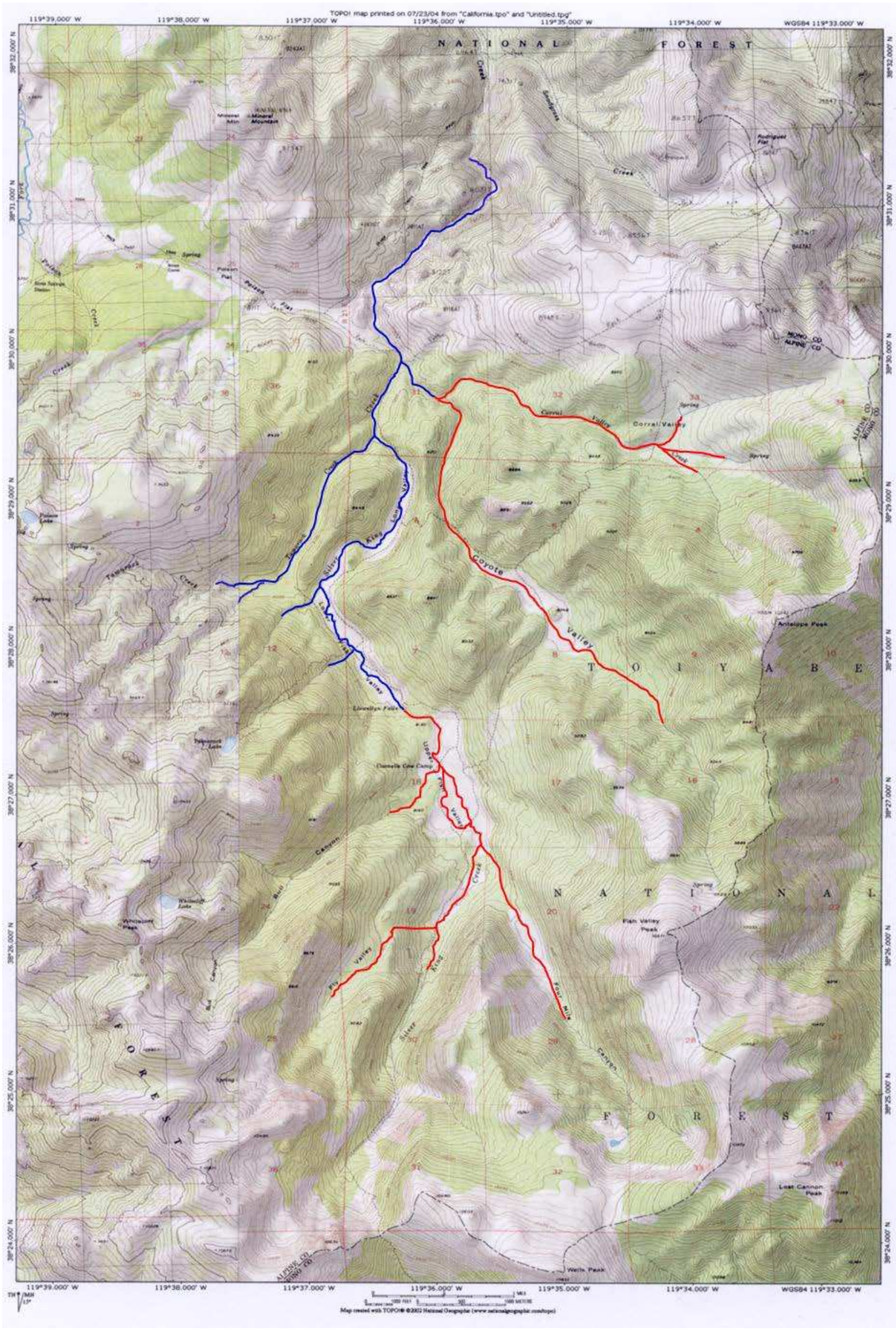

Figure 2. Historical (blue) and currently occupied (red) habitat for Paiute cutthroat trout in the Silver King Creek drainage (1), Humboldt-Toiyabe National Forest, Alpine County, California.

Tamarack Lake Creek, and the lower reaches of Coyote Valley Creek downstream of barrier falls (Figures 1 and 2; Service 2004, p. 12). Paiute cutthroat trout now occupy approximately 37.8 km (23.5 mi) of habitat in five widely distributed drainages (Figure 1). They were first established in the upper reaches of the Silver King Creek drainage (above natural barriers) in 1912, when local livestock operators transplanted fish above Llewellyn Falls (Figure 2; Service 2004, p. 13). The progeny of these early day transplants were then introduced into several other lakes and streams in California, many of which were not successful (Service 2004, p. 17). Four self-sustaining populations are now established outside their historical watershed (Figures 1, 3, and 4). Currently, no PCT occur within the historical range of the taxon. The current distribution of PCT has not changed since the 2008 5-year review (Service 2008a, pp. 4–5); however, estimates of both historically and currently-occupied habitat have increased due to more precise mapping resolution. Occupied habitat consists of the following locations:

Silver King Creek Drainage

This drainage is located in the Carson-Iceberg Wilderness, Humboldt-Toiyabe National Forest, Alpine County, California. Paiute cutthroat trout occupy approximately 11.9 km (7.4 mi) in the previously fishless upper reaches of Silver King Creek and its tributaries above Llewellyn Falls, including Four Mile Canyon Creek, Fly Valley Creek, and Bull Canyon Creek. The populations in Four Mile Canyon Creek (3.1 km, 1.9 mi) and Fly Valley Creek (1.8 km, 1.1 mi) are separated from Silver King Creek by impassable fish barriers. Two other occupied tributaries are located below Llewellyn Falls: Corral Valley (5.3 km, 3.3 mi) and Coyote Valley (6.1 km, 3.8 mi) Creeks. The middle portion of Silver King Creek proper (from below Llewellyn Falls to barriers in Silver King Canyon) and associated tributaries are the historical portion of PCT's range and currently occupied by nonnative rainbow trout (*O. mykiss*) (Figures 1 and 2; Service 2004, pp. 16, 20, 23; Finger *et al*. 2011, pp. 1378–1379).

North Fork Cottonwood Creek and Cabin Creek

Both of these drainages are located in the White Mountains Wilderness, Inyo National Forest, Mono County, California. Paiute cutthroat trout were first established in North Fork Cottonwood Creek in 1946 and currently occupy approximately 5.5 km (3.4 mi) of stream habitat. Cabin Creek was established in 1968 and 2.4 km (1.5 mi) of stream habitat are occupied (Figures 1 and 3; Service 2004, p. 23).

Stairway Creek and Sharktooth Creek

Both of these drainages are located on the Sierra National Forest. Stairway Creek is located in the Ansel Adams Wilderness, Madera County, California, and was established in 1972. Paiute cutthroat trout occupy approximately 3.5 km (2.2 mi) of stream habitat (Figures 1 and 4). Sharktooth Creek is located in the John Muir Wilderness, Fresno County, California, and was established in 1968. Paiute cutthroat trout occupy approximately 3.2 km (2 mi) of stream habitat (Figures 1 and 4; Service 2004, pp. 25–26).

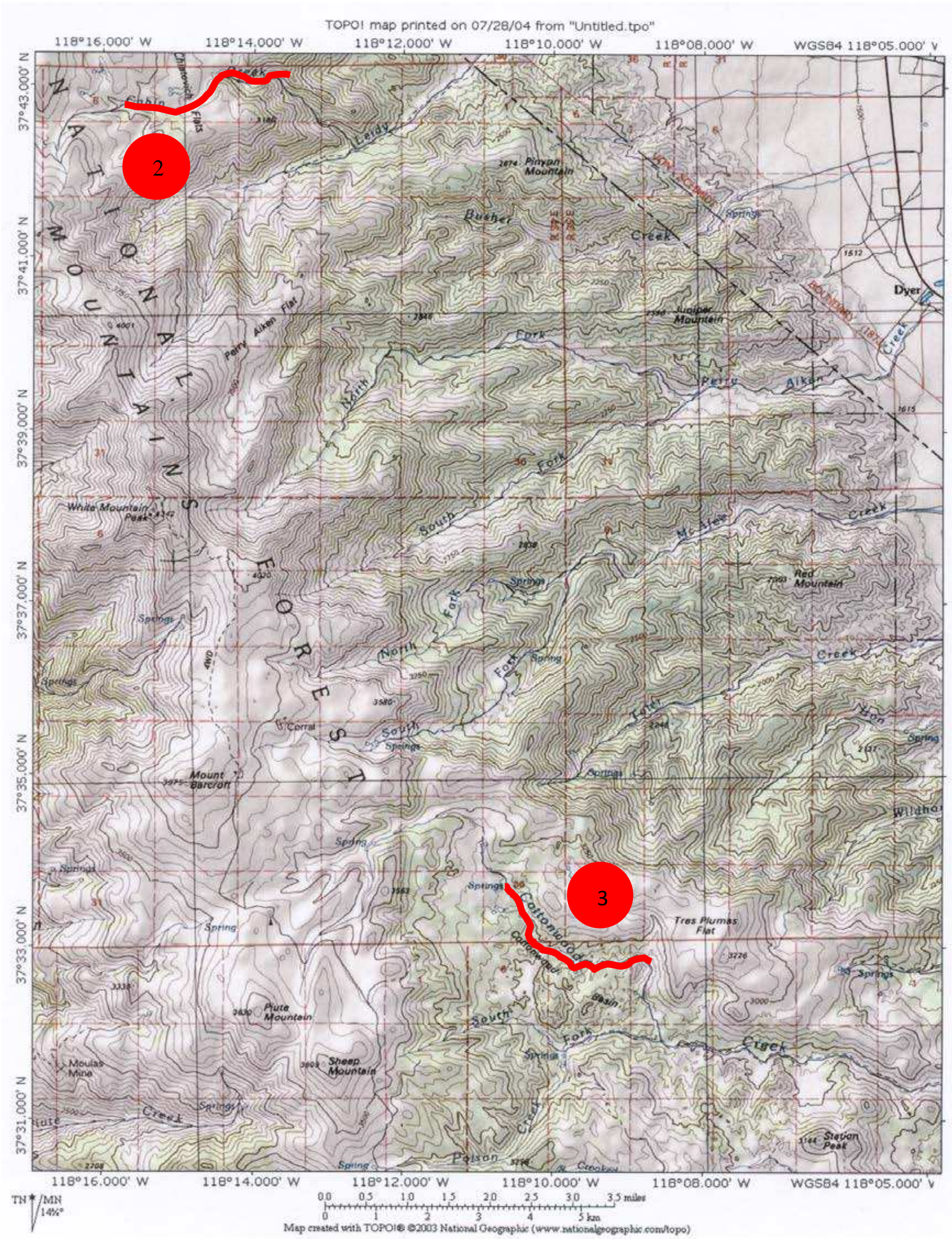

Figure 3. Refugial populations of Paiute cutthroat trout in Cabin Creek (2) and North Fork Cottonwood Creek (3), White Mountains, Inyo National Forest, Mono County, California.

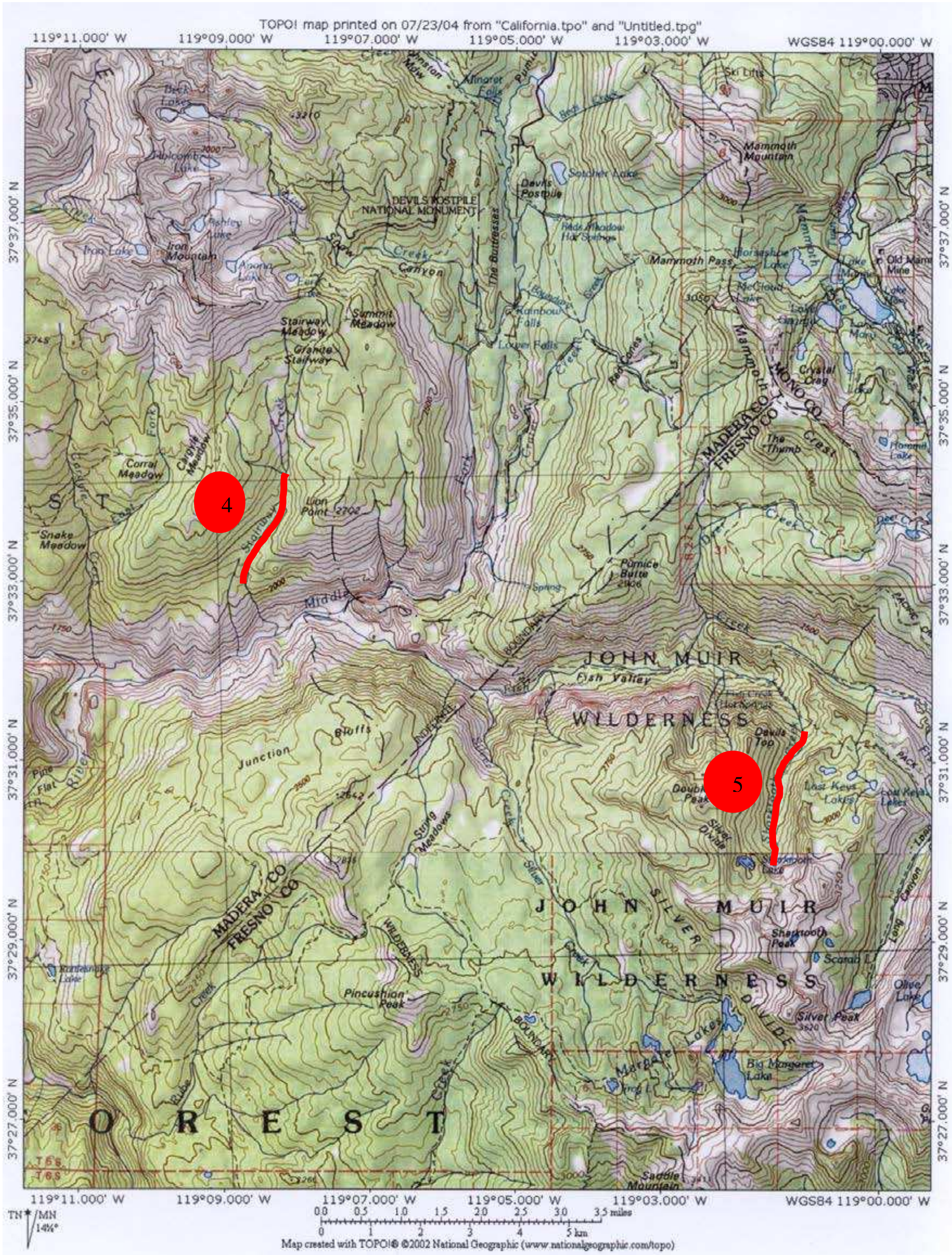

Figure 4. Refugial populations of Paiute cutthroat trout in Stairway Creek (4) and Sharktooth Creek (5), Sierra National Forest, Madera and Fresno Counties, California.

Abundance

It is difficult to fully characterize the abundance of PCT. Like most wildlife populations, numbers of PCT fluctuate annually due to biotic and abiotic factors. Further, population estimation methods have varied by location, which means only general comparisons among the populations can be made. Overall, population estimates suggest that PCT are stable. Abundance information for each drainage is discussed below.

Silver King Creek Drainage

Silver King Creek (Upper Fish Valley): Population estimates for Silver King Creek in Upper Fish Valley have been periodically conducted since 1964 using triple-pass depletion electrofishing and snorkeling. Four separate 150-m (500-ft) sections spaced throughout Upper Fish Valley are used to estimate the PCT population. The stream section in Upper Fish Valley is approximately 1.9 km (1.2 mi) long (W. Somer, CDFW, unpubl. data). Upper Silver King Creek and its tributaries were chemically treated from 1991 to 1993. Paiute cutthroat trout were reintroduced into Upper Fish Valley from 1994 to 1998 using populations in Fly Valley and Coyote Valley Creeks (Table 1). The population increased from 0 in 1993 to an estimated 608 adult fish in 2000. The population then declined to an estimated 63 adult fish in 2003. However, the population then increased to an estimated 500 adult fish in 2005. The adult population was lower again in 2012 with an estimated 111 adult fish (Figure 5). The mean for the entire population (adults and juveniles) over a 48-year period (1964–2012) is 798 individuals while the mean for the adult population is 392 individuals (Figure 5; W. Somer, CDFW, unpubl. data). As mentioned above, biotic and abiotic factors influence population sizes of PCT. For example, high run-off events occurred in 1969, 1982, 1986, 1995, 1997, 2005, 2006, and 2011; severe anchor ice was observed in 1989 and 2012; mechanical removal of hybrid fish occurred from 1973 to 1975; and chemical treatments occurred in 1964, 1976, and 1991–1993. Population estimates were not made in 1965, 1967, 1977, 1978, 1983, 2009, 2010, and 2011.

Table 1. Paiute cutthroat trout reintroductions to Upper Fish Valley, Silver King Creek, following the 1991–1993 chemical treatment.

Year	**Number Stocked**	**Donor Stream**
1994	139	Coyote Valley
1995	49	Fly Valley
1995	109	Coyote Valley
1996	134	Coyote Valley
1997	145	Coyote Valley
1998	30	Fly Valley
Total	**606**	
Source: W. Somer, CDFW, unpubl. data		

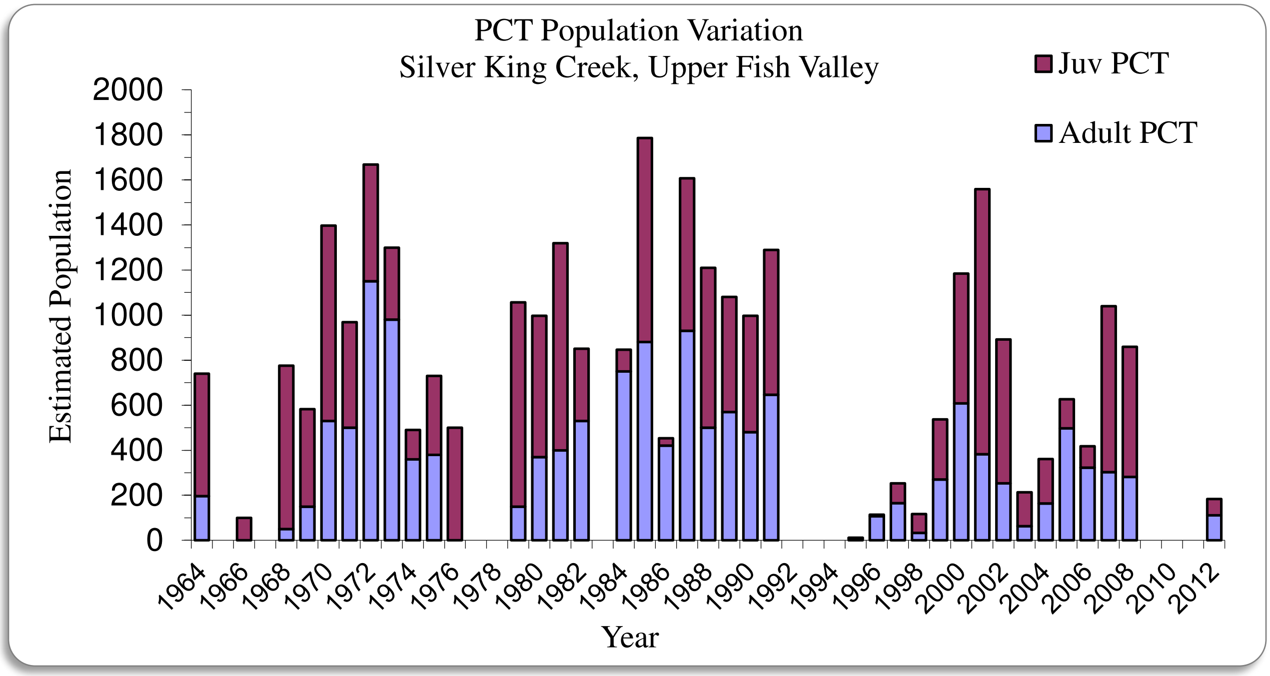

Figure 5. Population estimates for Upper Fish Valley, Silver King Creek from 1964 to 2012. Blue bars represent adults (over 150 millimeters (mm), 6 inches (in)); red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

<u>Fly Valley Creek:</u> Ten population density surveys have been conducted on Fly Valley Creek. The first survey was in 1984 and the last was in 2012. In 2012, CDFW surveyed 150 m (500 ft) of stream and estimated 98 adult fish/km (158 fish/mi) which is slightly higher than the mean of 92 adult fish/km (147 fish/mi). While juvenile numbers have historically fluctuated, adult numbers have stayed relatively constant (Figure 6; W. Somer, CDFW, unpubl. data).

<u>Four Mile Canyon Creek:</u> Twenty-three population density surveys have been conducted on Four Mile Canyon Creek. The first was in 1968 and the last was in 2012. In 2012, CDFW surveyed 255 m (835 ft) of stream and captured only 1 fish. This prompted crews to continue surveying all available habitat for 1,300 m (4,265 ft) upstream of the test section. An additional 12 individuals were captured, 4 of which were adults (Figure 7; 2012b). The mean estimated adult population in Four Mile Canyon Creek is 49 fish/km (79 fish/mi) (Figure 7; W. Somer, CDFW, unpubl. data).

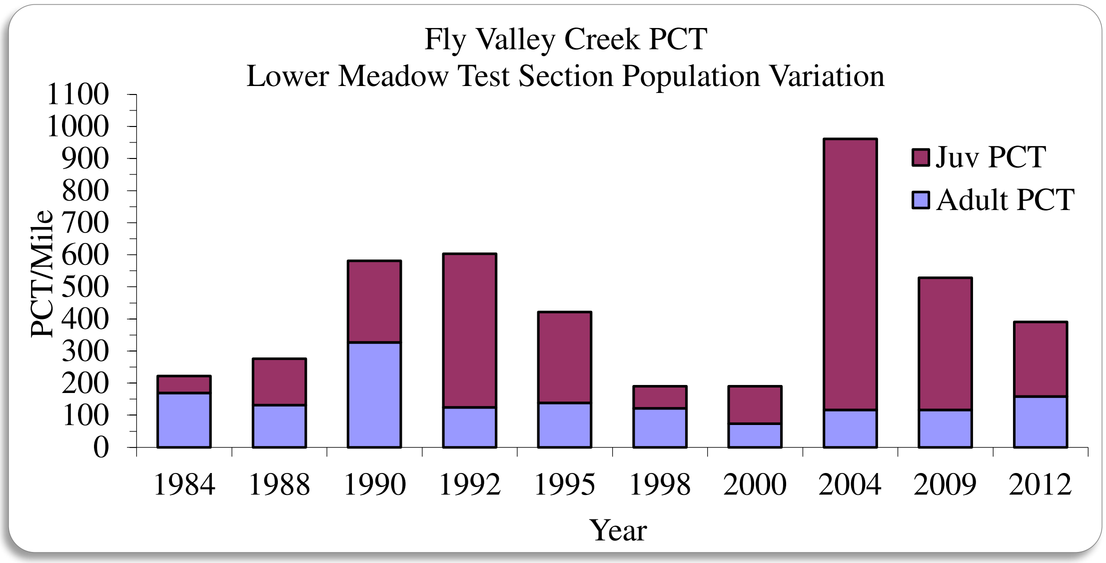

Figure 6. Population density estimates for Paiute cutthroat trout in Fly Valley Creek from 1984 to 2012. Blue bars represent adults (over 150 mm (6 in)); red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

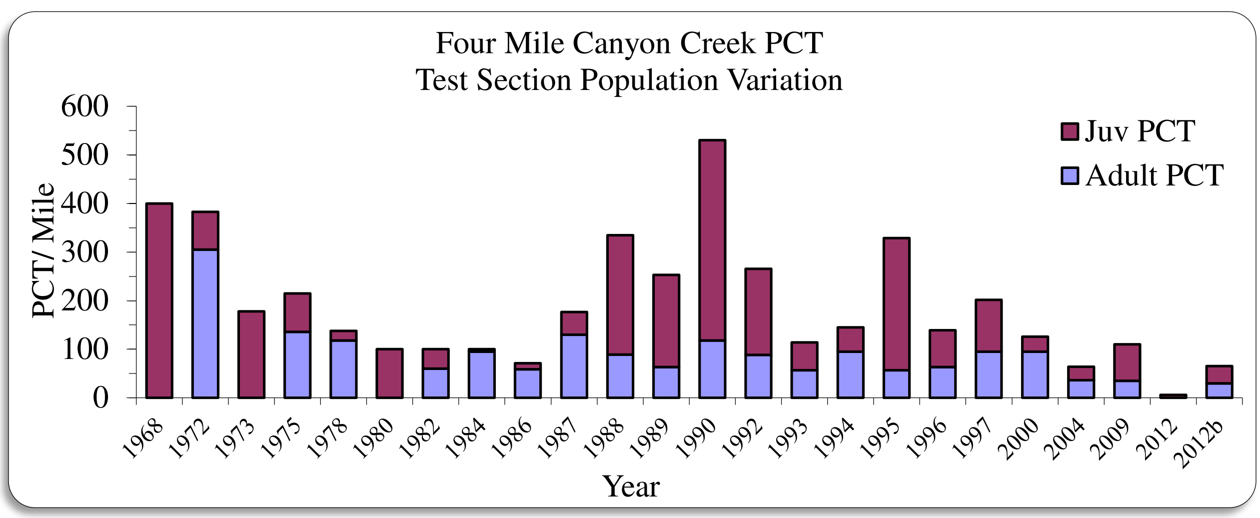

Figure 7. Population density estimates for Paiute cutthroat trout in Four Mile Canyon Creek from 1968 to 2012. Blue bars represent adults (over 150 mm (6 in)); red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

Corral Valley Creek: Population density surveys on Corral Valley Creek were conducted from 1974 to 2012. In 2012, CDFW surveyed a 150 m (500 ft) section and estimated 33 adult fish/km (53 fish/mi), which is lower than the average of 59 adult fish/km (95 fish/mi) (Figure 10; W. Somer, CDFW, unpubl. data). Like Coyote Valley Creek, Corral Valley Creek is very productive with the large majority of individuals being juveniles (Figure 10).

Coyote Valley Creek: Population density surveys on Coyote Valley Creek were sporadically conducted from 1964 to 2012. Two separate 150 m (500 ft) sections, Upper Meadow and Lower Meadow, were surveyed. In 2012, CDFW estimated 69 adult fish/km (110 fish/mile) for the Lower Meadow section which is lower than the average of 88 adult fish/km (141 fish/mi). The Upper Meadow section had an estimated 39 adult fish/km (63 fish/mi), which is well below the average of 112 adult fish/km (180 fish/mi) (Figures 8 and 9; W. Somer, CDFW, unpubl. data). Coyote Valley Creek is very productive with high levels of juvenile fish nearly every year; particularly in the Lower Meadow section (Figures 8 and 9; W. Somer, CDFW, unpubl. data).

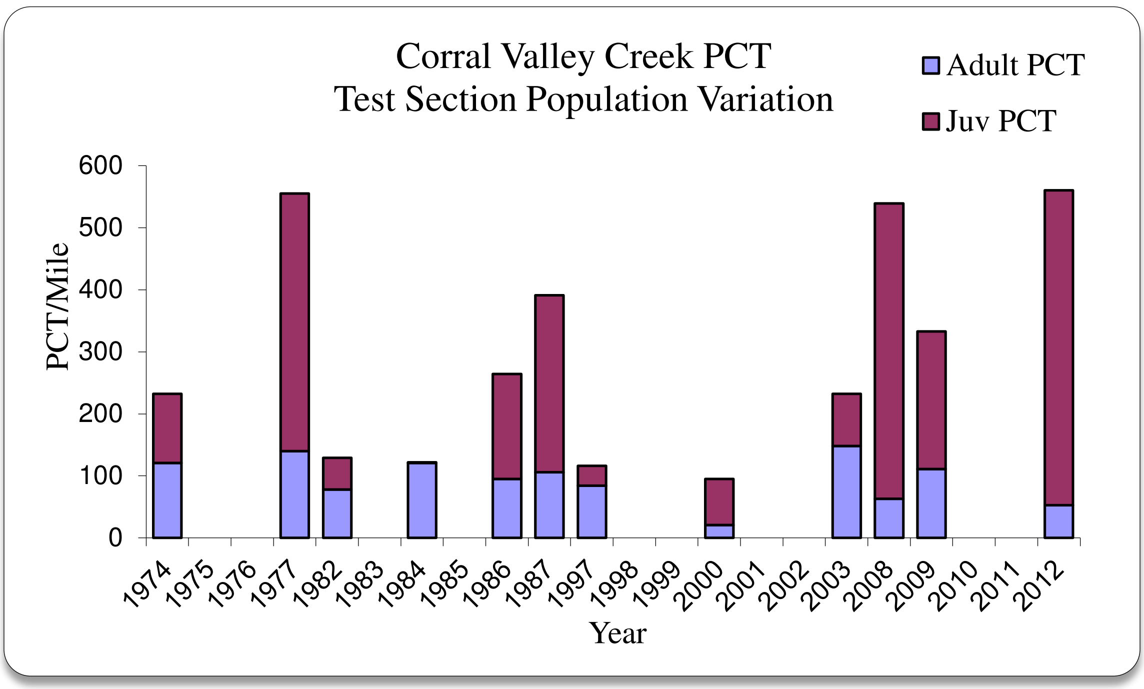

Figure 10. Population density estimates for Paiute cutthroat trout in Corral Valley Creek from 1974 to 2012. Blue bars represent adults (over 150 mm (6 in)); red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

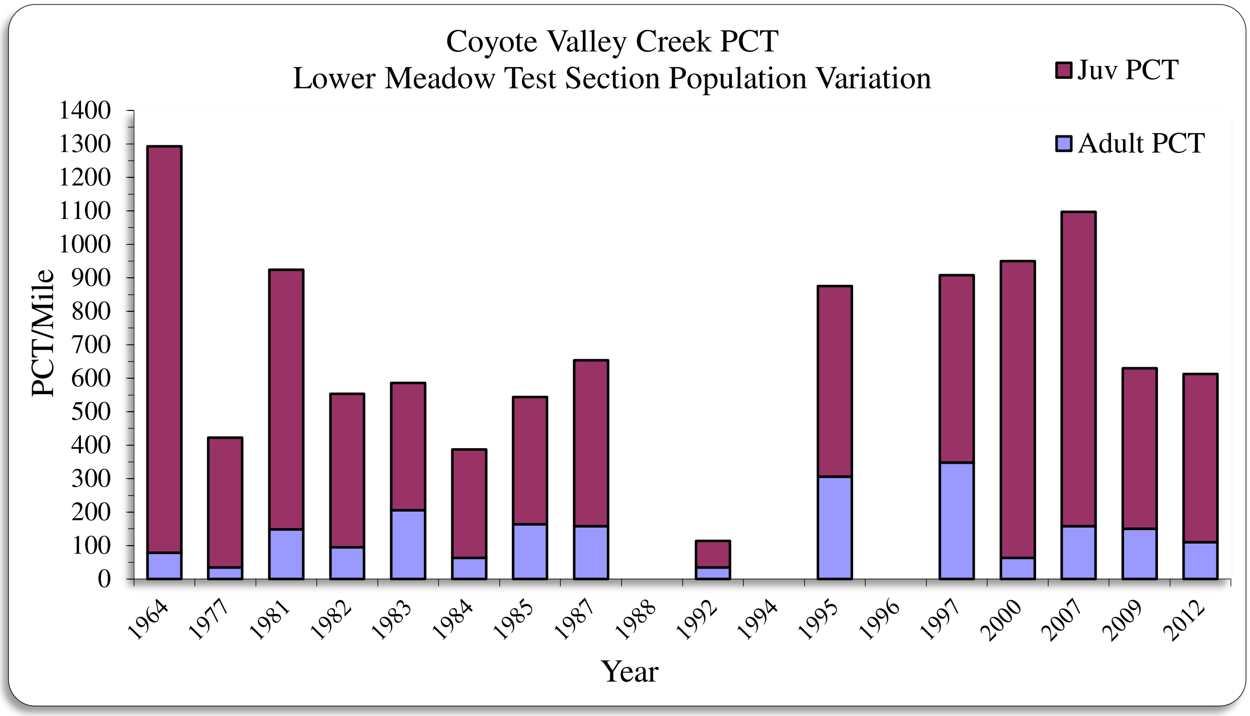

Figure 8. Population density estimates for Paiute cutthroat trout in the Lower Meadow section of Coyote Valley Creek from 1964 to 2012. Blue bars represent adults (over 150 mm (6 in)); red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

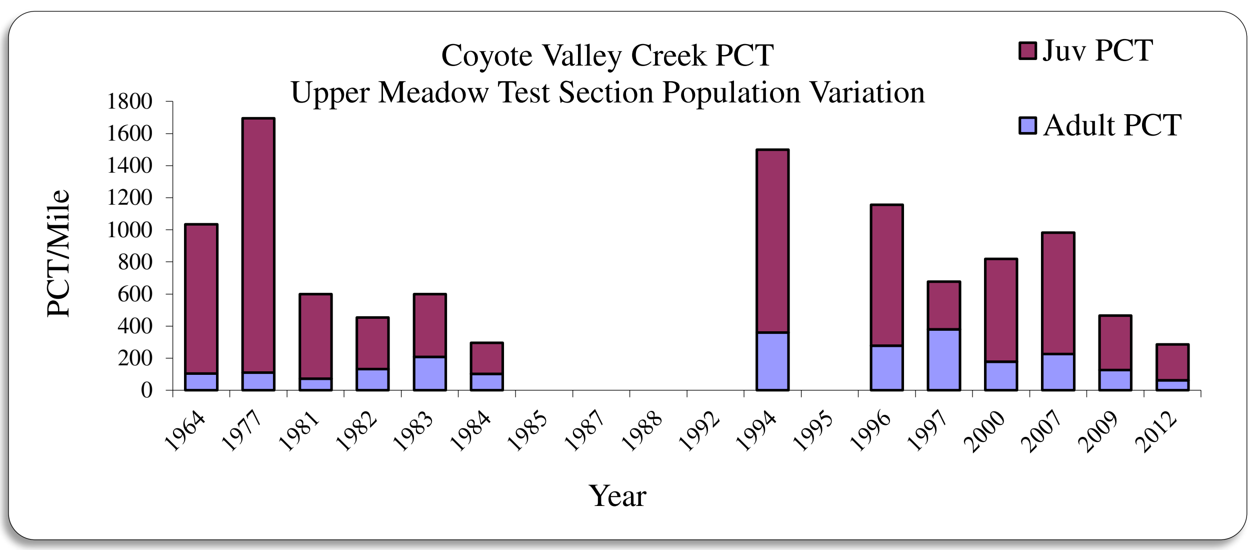

Figure 9. Population density estimates for Paiute cutthroat trout in the Upper Meadow section of Coyote Valley Creek from 1964 to 2012. Blue bars represent adults (over 150 mm (6 in)), while red bars represent juveniles (less than 150 mm (6 in)) (W. Somer, CDFW, unpubl. data).

Sharktooth and Stairway Creeks

The Sierra National Forest has used a fly rod depletion method (Stephens and Christenson 1980, p. 1) on an approximate 5-year rotation for sampling PCT on Sharktooth and Stairway Creeks. Sharktooth Creek was sampled in 1999, 2004, 2009, and 2012 (Figure 11) while Stairway Creek was sampled in 2000, 2005, and 2012 (Figure 12). This method of sampling is not intended to be a good estimator of population size and is biased towards larger fish; however, other information can be collected such as size distribution. The size distribution indicates that there are multiple age classes present, and while numbers fluctuate between years, the populations in Sharktooth and Stairway Creeks seem stable (Figures 11 and 12; P. Strand, Sierra National Forest and K. Johnson, CDFW, unpubl. data).

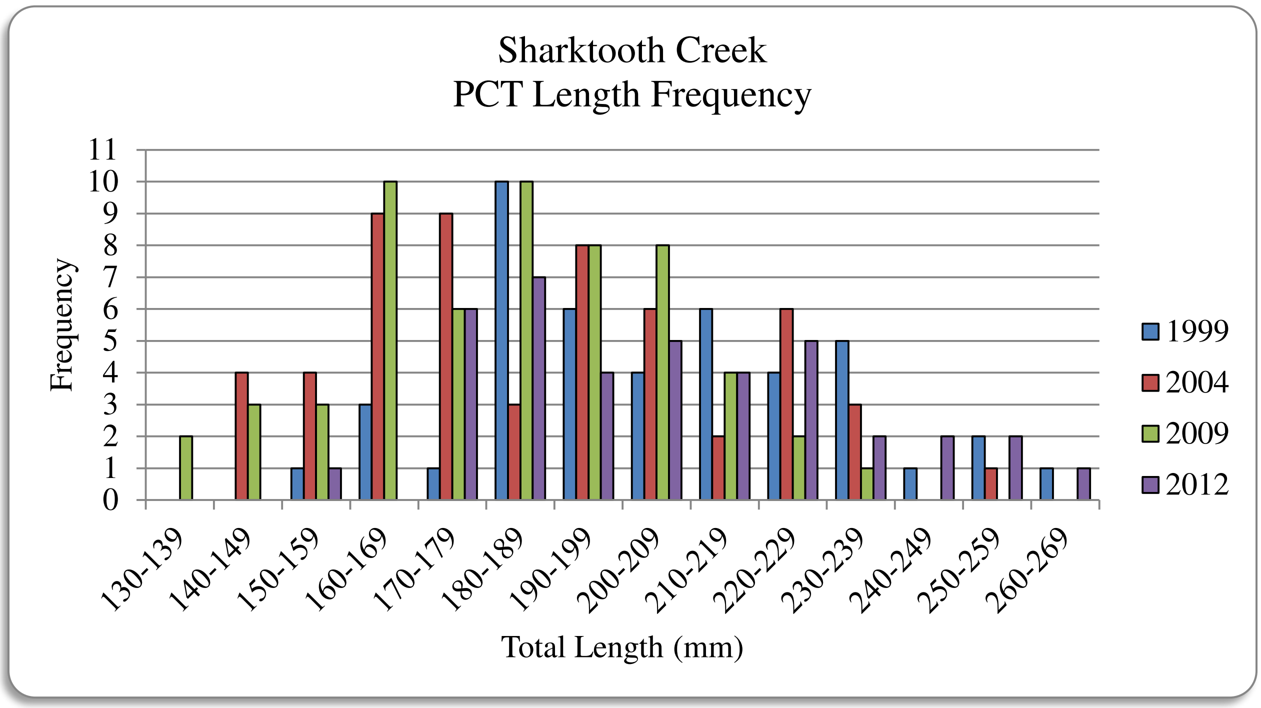

Figure 11. Length frequency data for Paiute cutthroat trout in Sharktooth Creek, Sierra National Forest (P. Strand, Sierra National Forest and K. Johnson, CDFW, unpubl. data).

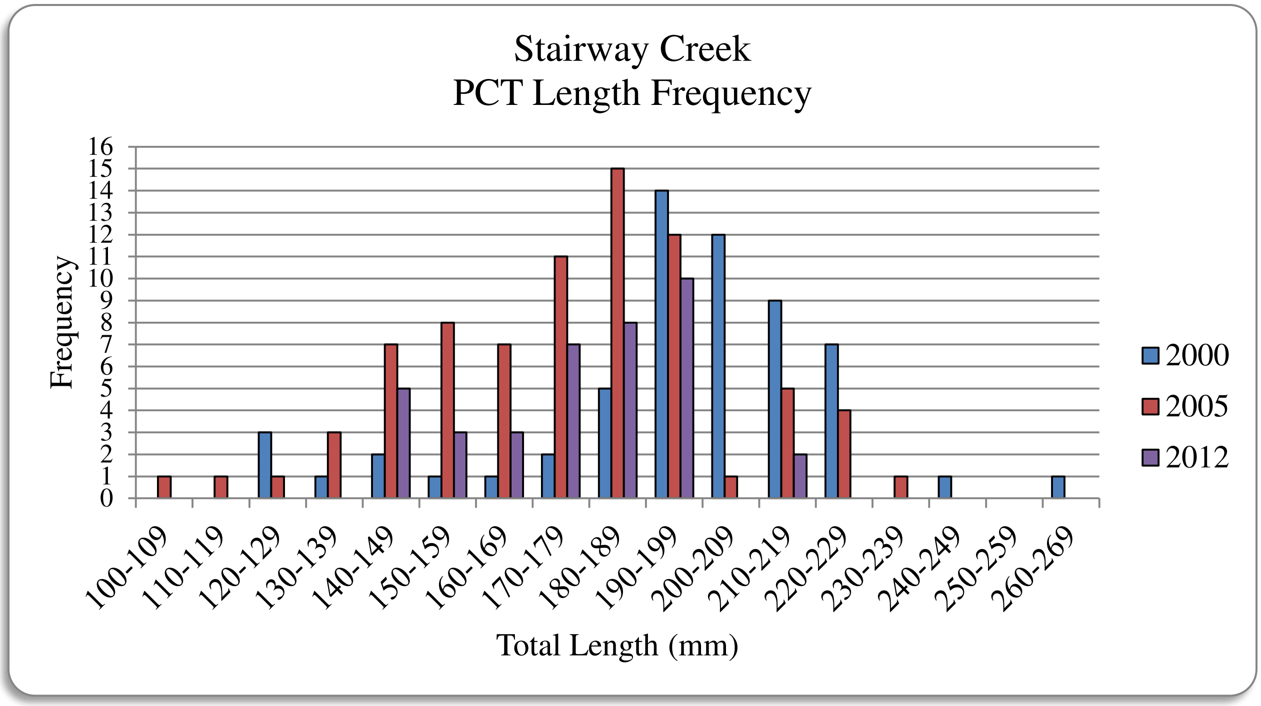

Figure 12. Length frequency data for Paiute cutthroat trout in Stairway Creek, Sierra National Forest (P. Strand, Sierra National Forest and K. Johnson, CDFW, unpubl. data).

North Fork Cottonwood and Cabin Creeks

A standard section of North Fork Cottonwood Creek from Granite Meadows downstream to just above the Tres Plumas barrier has been surveyed visually since 1989 by CDFW (D. Emery, CDFW, unpubl. data). Visual surveys conducted since 1999 indicates a stable population with multiple age classes present (Figure 13; D. Emery, CDFW, unpubl. data). Visual encounter surveys underestimate population sizes and may be biased towards larger size classes because smaller fish are more difficult to see (Bozek and Rahel 1991, p. 40). Visual surveys were conducted on Cabin Creek in 1995, 2000, and 2009 (D. Emery, CDFW, unpublished data). In 1995, 139 fish were observed and were broken down into size classes. Thirty-eight fish were between 100 and 200 mm (4 and 8 in). The remaining 101 fish were between 200 and 254 mm (8 and 10 in). In 2000, 186 fish were observed. The 2000 survey did not break down individual sizes, although multiple size classes were present. The 2009 survey was incomplete due to time constraints and heavy willow (*Salix* sp.) growth which made observations difficult; however, all age classes were observed (D. Emery, CDFW, unpubl. Data).

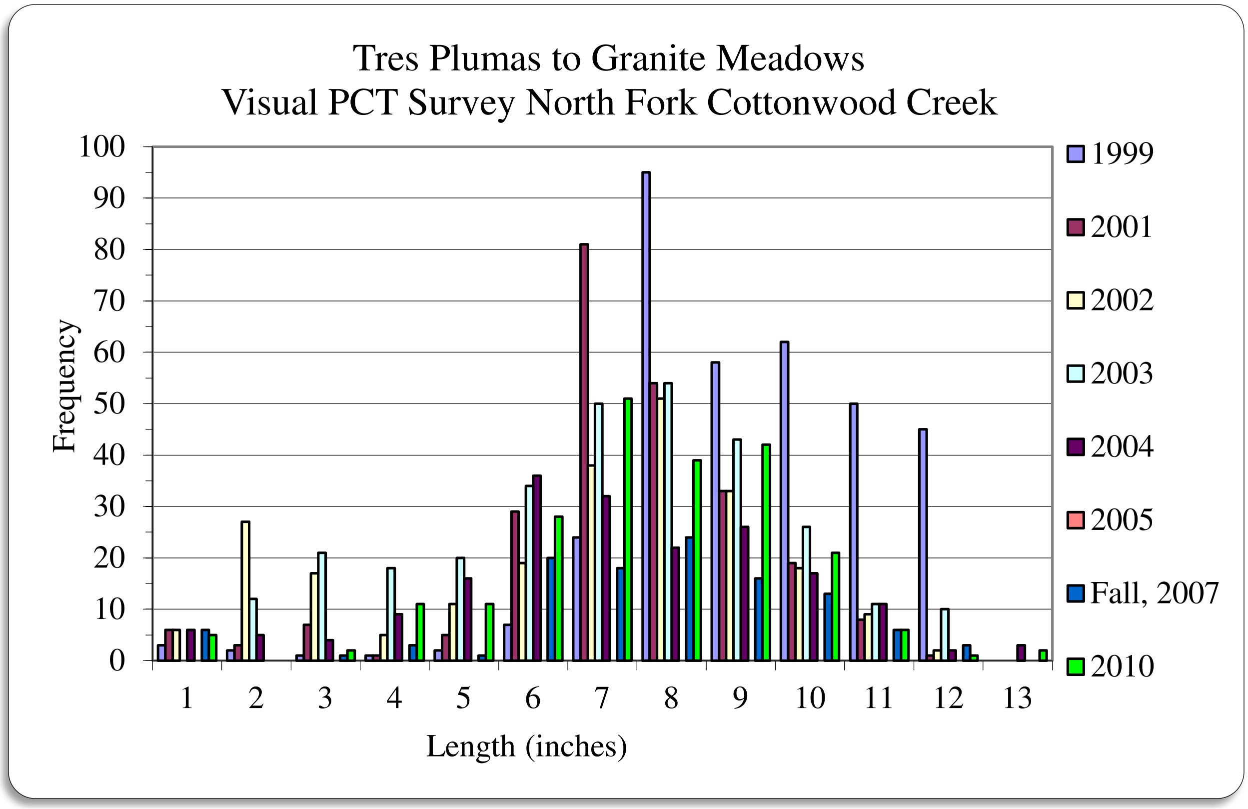

Figure 13. Length frequency distribution of Paiute cutthroat trout in North Fork Cottonwood Creek, Inyo National Forest. This section of stream is from Granite Meadows downstream to just above the Tres Plumas barrier (D. Emery, CDFW, unpubl. data).

Habitat or Ecosystem

Paiute cutthroat trout habitat requirements appear to be similar to those reported for other western stream-dwelling salmonids (Hickman and Raleigh 1982, pp. 3–7). All life stages require cool, well oxygenated waters. Adult fish prefer stream pool habitat in low gradient meadows with undercut or overhanging banks and abundant riparian vegetation (Ashley 1970, pp. 5, 22). Pools are important rearing habitat for juveniles and act as refuge areas for all life stages during winter (Brown *et al*. 2011, pp. 19–21). During the winter months, trout move into pools to avoid physical damage from ice scouring and to conserve energy (Cunjak 1996, p. 268; Brown *et al*. 2011, pp. 12–13). As with other salmonids, suitable winter habitat may be more restrictive than summer habitat (Jakober *et al*. 1998, pp. 229, 233; Brown *et al*. 2011, p. 14). Paiute cutthroat trout survive in lakes, but there is no evidence that they ever occurred naturally in any lakes within the Silver King basin (Behnke and Zarn 1976, p. 34).

Silver King Creek Drainage

This description of habitat is based on the account presented by Ryan and Nicola (1976, pp. 12–18; Figure 2). Silver King Creek is a tributary of the East Fork Carson River, which drains into the Lahontan Basin. Silver King Creek originates at 2,926 m (9,600 ft) elevation in the southernmost portion of the drainage, and flows north through three distinct valleys (Upper Fish Valley, Lower Fish Valley, and Long Valley) for approximately 22.5 km (14 mi) where it meets the East Fork Carson River. Between the headwaters and the confluence of Silver King Creek with the East Fork Carson River, eight tributaries, three above and five below Llewellyn Falls, join Silver King Creek. Llewellyn Falls, at an elevation of 2,438 m (8,000 ft), is located at the head of Lower Fish Valley, some 16.2 km (10 mi) above the confluence with the East Fork Carson River.

From its source, Silver King Creek flows precipitously down gradient for 3.2 km (2.0 mi) before beginning a gradual descent to Upper Fish Valley in an area of washed-out beaver ponds just above the mouth of Fly Valley Creek. For 2.4 km (1.5 mi) through Upper Fish Valley, it is a typical meandering meadow creek, averaging 3.7 m (12 ft) wide and 0.3 m (1 ft) deep in the summer. Several soda springs occur in the valley, with some seeping directly into the stream. From the southeast, Four Mile Canyon Creek enters 2.0 km (1.2 mi) above Llewellyn Falls, while Bull Canyon Creek joins the mainstem from the west 0.8 km (0.5 mi) above Llewellyn Falls. In 1984, an abandoned stream channel (side channel) was reconnected with the mainstem, providing approximately 0.5 km (0.3 mi) of spawning and juvenile rearing habitat. The upstream portion of the side channel begins approximately 0.2 km (0.1 mi) below the confluence of Silver King Creek and Four Mile Canyon Creek. The lower portion of the side channel rejoins the mainstem immediately above the confluence of Silver King Creek and Bull Canyon Creek.

At the lower end of Upper Fish Valley, the stream gradient increases through a sparsely forested section before reaching Llewellyn Falls. The vertical drop of Llewellyn Falls is approximately 6.1 m (20 ft). Within the 2.8 km (1.7 mi) length of Lower Fish Valley, two small tributaries enter the mainstem from the west: Tamarack Lake Creek, located 1.2 km (0.7 mi) below Llewellyn Falls, and a short, unnamed tributary downstream another 1.2 km (0.7 mi). Long Valley, only 1.5 km (0.9 mi) in length, is the shortest of the three valleys. No tributaries enter this section of Silver King Creek. Between Lower Fish Valley and Long Valley the gradient increases, but no barriers similar to Llewellyn Falls are known to exist in this section. Approximately 0.6 km (0.4 mi) downstream of Long Valley, Tamarack Creek enters Silver King Creek from the west, and Coyote Valley Creek enters from the east 1 km (0.6 mi) farther downstream.

Approximately 2.8 km (1.7 mi) below the mouth of Coyote Valley Creek, Silver King Creek descends through Silver King Canyon and emerges from the canyon in the vicinity of Snodgrass Creek. Upstream from Snodgrass Creek, in the canyon, a series of falls present a fish barrier to nonnative trout and other native fish species that occur downstream. No tributary of significance enters Silver King Creek from Snodgrass Creek downstream for 5.4 km (3.4 mi) until its confluence with the East Fork Carson River. Three small lakes occur in the drainage: Tamarack Lake, Whitecliff Lake, and an unnamed lake in the headwaters of Four Mile Canyon Creek. The average gradient of Silver King Creek is 4.1 percent, which is less than any of its tributaries. However, the portion of Silver King Creek between Fly Valley and Coyote Valley Creeks has an average gradient of 1.6 percent.

North Fork Cottonwood Creek

The occupied reach in North Fork Cottonwood Creek ranges from 2,784 to 3,096 m (9,141 to 10,155 ft) in elevation. Wong (1975, pp. 32–35) described the stream in three sections. The upper section flows through relatively flat stringer meadows with sections of heavy willow growth. The second section flows through a narrow canyon with increasing gradient, creating a series of cascades that form barrier falls 3–4 m (10–13 ft) high. This section of stream is characterized by large boulders that create plunge pools, and it is heavily overgrown with a tree canopy of aspen (*Populus tremuloides*) and understory of willow. The third section again flows through more meadows with low gradient, and willow dominates as stream cover. A 2.3 m (7 ft) natural barrier is located 100 m (330 ft) above the confluence with Tres Plumas Creek. The occupied reach has an average gradient of 5.6 percent.

Cabin Creek

The occupied reach of Cabin Creek ranges from 3,048 to 3,353 m (10,000 to11,000 ft) in elevation. The Inyo National Forest (U.S. Forest Service (USFS) 2009, pp. 7–8) describes Cabin Creek as relatively steep compared to the other occupied streams with an average gradient of 8 percent through the 2.4 km (1.5 mi) occupied reach. Shallow riffles and scattered small pools dominate the habitat. The occupied reach can be split into two distinct segments based on gradient and riparian vegetation. The upper segment is approximately 1.6 km (1 mi) in length and has a gradient of 9 percent, has heavy willow cover, and is well armored with rocky substrate. The middle section is approximately 0.8 km (0.5 mi), has an average gradient of 6 percent, and has scattered willows and sedges (*Carex* sp.) that dominate the riparian plant community. A 0.4 km (0.25 mi) segment below the middle reach increases in gradient to 14 percent with willow dominating the riparian area and may be occupied by PCT but probably in low numbers due to poor habitat. Beyond this segment the stream gradient increases to 20 percent until its confluence with Leidy Creek.

Stairway Creek

Stairway Creek originates in two forks at 2,743 m (9,000 ft) elevation and flows south into the Middle Fork San Joaquin River. Strand and Eddinger (1999, pp. 9–12, 15) described Stairway Creek based on a survey conducted in 1996. The survey focused on a 2.5 km (1.6 mi) low gradient section of stream, just upstream of a 500 m (1,640 ft) long section of stream with a greater than 40 percent gradient, above the confluence with the Middle Fork San Joaquin River. This section serves as a natural barrier to fish from downstream. A combination of A2 (greater than 4 percent gradient, confined channel, boulder substrate) and B3 (1–4 percent gradient, moderately confined channel, boulder/cobble substrate) Rosgen types (Rosgen 1996, pp. 5-40–5-43, 5-68–5-71) describe this 2.5 km (1.6 mi) reach. Using USFS Region 5 habitat typing methods (USFS 1996, pp. 1–15), 6 percent of the stream length was characterized as fast water while 94 percent was slow water. Channel stability was rated "good" for all reaches sampled. Canopy cover was approximately 40 percent in the riparian zone, accounting for the low quantity of large woody debris, 3.3 pieces per 100 m (328 ft), found in the stream (Strand and Eddinger 1999, pp. 9–12).

Sharktooth Creek

Sharktooth Creek exits Sharktooth Lake at 2,999 m (9,836 ft). It is a headwater tributary to Fish Creek that flows northwest into the Middle Fork San Joaquin River. Sharktooth Creek is described by Strand and Eddinger (1999, pp. 6–8, 15) as having high gradient sections that provide natural migration barriers. A 250-m (820-ft) section of stream near the confluence with the Lost Keys Lake outflow is described as a cascade/falls that has a gradient of 35 percent with large cobble and boulders as substrate. Upstream of this point a step-pool sequence develops as the gradient reduces to less than 15 percent. Then comes a low gradient (less than 2 percent) section, approximately 1,565 m (5,133 ft) in length, that is described in greater detail below. Above this section, the stream again increases in gradient to the outflow of Sharktooth Lake.

A Stream Condition Inventory reach was established in 1999 by Sierra National Forest personnel on the lower gradient middle section (approximately 1.6 km (1 mi)) of Sharktooth Creek, in order to monitor long-term habitat trends within Sharktooth Creek (Strand and Eddinger 1999, pp. 6–8, 15). This section of stream is a Rosgen type C3 (less than 2 percent gradient, well developed floodplain, mostly cobble with lesser amounts of gravel and sand) (Rosgen 1996, pp. 5-92–5-95), and included 205 pieces of large woody debris with 7 aggregations, and stream shading was 71 percent, which indicates that the riparian area is dominated by large woody species of trees. Sixty percent of the stream length was characterized as fast water (riffles, cascades, and step-pools) while 40 percent was slow water (pools, glides and runs). Bank stability was 75 percent or greater for all 50 transect points, which are considered good ratings (Strand and Eddinger 1999, pp. 6–8, 15).

More recent habitat data have been collected on Stairway (2005) and Sharktooth (2004) Creeks (P. Strand, 2005, USFS, pers. comm.). Analysis indicates that both streams continue to recover from a 1997 rain-on-snow event, which caused severe flooding. This event simplified the habitat by reducing riparian vegetation, reducing large woody debris, and changing pool habitat to runs and riffles (P. Strand, 2005, USFS, pers. comm.). Now, riparian vegetation is recolonizing eroded areas, and large woody debris is being deposited into the stream channels which is forming more pools and creating more complex and diverse habitat (P. Strand, 2005, USFS, pers. comm.).

Changes in Taxonomic Classification or Nomenclature

Paiute cutthroat trout was first listed as *Salmo clarki seleniris*; however, all western North American trout have been reclassified from the genus *Salmo* to the genus *Oncorhynchus*, as summarized by Smith and Stearly (1989, pp. 4–10) and adopted by the American Fisheries Society's Committee on Names of Fishes, the accepted authority on North American fish taxonomy (Robins *et al*. 1991, pp. 28, 79). More recently, the species name for all cutthroat trout changed from *clarki* to *clarkii* to reflect the original spelling (Nelson *et al*. 2004, pp. 98, 209).

Genetics

Paiute cutthroat trout are genetically and meristically (physically) similar to Lahontan cutthroat trout (*O. c. henshawi*) from which they recently diverged (Behnke and Zarn 1976, p. 32). Behnke and Zarn (1976, p. 32) concluded that the separation of PCT from Lahontan cutthroat trout occurred relatively recently (no more than 10,000 years ago), following the desiccation of Lake Lahontan. Investigations of population genetic structure of the Lahontan group of cutthroat trout detected no unique alleles in PCT; however, microsatellite allelic frequency data indicated considerable genetic differentiation from Lahontan cutthroat trout which had not been previously documented (Nielsen and Sage 2002, pp. 381, 383). Paiute cutthroat trout have limited genetic variability, due in part to bottleneck and founder effects when PCT were originally isolated from a common ancestor with Lahontan cutthroat trout and/or more recent bottlenecks resulting from the past history of stocking and management of PCT (Nielsen and Sage 2002, pp. 381, 383; Cordes *et al*. 2004, pp. 112–116). Additionally, there is no population that currently possesses all of the alleles known to PCT, so further transfers to maintain what is left of genetic diversity may be required (Cordes *et al*. 2004, p. 110). Cordes *et al*. (2004, p. 116) concluded that all extant populations of PCT should be considered part of a single management unit with regard to restoration, and recommended that restocking should ideally consist of large numbers of fish from multiple donor populations with as much genetic variation as possible in order to minimize loss of diversity and the effects of inbreeding.

Busack and Gall (1981, p. 948) conducted an allozyme analysis of PCT populations within the Silver King and North Fork Cottonwood drainages and determined that these populations had been introgressed with nonnative rainbow trout. A more recent genetic study using nuclear microsatellite and singular copy nuclear DNA markers evaluated the efficacy of past nonnative trout eradication efforts for the conservation of PCT by determining levels of rainbow trout hybridization and relationships among nine populations of PCT (Cordes *et al*. 2004, pp. 105–106). This study indicates that past efforts to remove trout hybrids in several creeks in the Silver King Creek drainage and the North Fork Cottonwood Creek have been successful as no evidence of rainbow trout introgression was observed in any of the nine populations sampled (Cordes *et al*. 2004, pp. 109, 111–112). These include PCT populations in the Silver King Creek drainage (Fly Valley Creek, Upper Silver King Creek, Four Mile Canyon Creek, Bull Canyon Creek, Coyote Valley Creek, and Corral Valley Creek) and the four out-of-basin populations (North Fork Cottonwood Creek, Cabin Creek, Stairway Creek, and Sharktooth Creek). In contrast, the fish residing in Silver King Creek downstream of Llewellyn Falls (including Tamarack Creek) are nonnative hybrids of rainbow trout and California golden trout (*O. aguabonita*), comprised mostly of rainbow trout with very little cutthroat trout genetic influence in the trout population within the historical range of PCT (Finger *et al*. 2011, pp. 1378–1379).

<u>Species-specific Research and/or Grant-supported Activities</u>

Listed below are examples of research and restoration projects which the Service has recently funded for PCT recovery efforts.

Six Diagnostic Single Nucleotide Polymorphism Markers for Detecting Introgression Between Cutthroat and Rainbow Trouts-University of California, Davis (Finger et al. 2009, pp. 759–763): Six diagnostic single nucleotide polymorphisms (SNP) were found which distinguish California golden trout and rainbow trout from PCT and Lahontan cutthroat trout. These SNPs will be useful in monitoring hybridization between these two groups of trout. Project Status: Complete.

Determining Age and Growth Rates of Paiute Cutthroat Trout in Silver King Creek-California Department of Fish and Game (Titus and Calder 2009, pp. 1–15): This study provided valuable demographic information on PCT within the Silver King Creek drainage, specifically age and growth of the various populations. Paiute cutthroat trout were found to live up to 6 years and growth of individuals varied depending on the size of habitat. Project Status: Complete.

Rotenone Toxicity to Rainbow Trout and Several Mountain Stream Insects-California Department of Fish and Game (Finlayson et al. 2010, pp. 102-111): Due to concerns about the impacts of rotenone to non-target macroinvertebrates during native trout restoration projects, this study evaluated the toxicity of two formulations of rotenone to rainbow trout and six species of aquatic insects. Results indicate rotenone is more toxic to rainbow trout than macroinvertebrates used in the study. Additionally, formulations of rotenone which use the synergist piperonyl butoxide increase the toxicity of rotenone only to macroinvertebrates but not to rainbow trout; therefore, the authors recommend using rotenone formulations without the synergist. Project Status: Complete.

National Environmental Policy Act and California Environmental Quality Act Analysis of Implementing the Paiute Cutthroat Trout Restoration Project-ENTRIX, (U.S. Fish and Wildlife Service and California Department of Fish and Game 2010, pp. 1-284): The Service and California Department of Fish and Game analyzed the environmental impacts of implementing the Paiute Cutthroat Trout Restoration Project under the National Environmental Policy Act and California Environmental Quality Act. Our joint analysis was upheld in court; however, the project has been enjoined since 2010 due to Wilderness Act compliance (U.S. District Court 2011, pp. 1–63). Project Status: Complete.

Application of a Method for Estimating Effective Population Size and Admixture Using Diagnostic Single Nucleotide Polymorphisms (SNPs)-University of California, Davis (Finger et al. 2011, pp. 1369–1386): Using the six diagnostic single nucleotide polymorphisms (SNP) found in Finger *et al*. (2009, pp. 759–763), the authors were able to estimate the amount of hybridization between California golden trout and rainbow trout with PCT in the historical range of Silver King Creek. In addition the effective population size of the hybridized population was estimated. Project Status: Complete.

Paiute Cutthroat Trout Habitat Restoration Project-California Department of Fish and Wildlife: On September 24, 2009, California Department of Fish and Game received a Section 6 grant from the Service to implement the Paiute Cutthroat Trout Restoration Project. Implementation has been stalled due to legal issues. An extension was granted until 2015. Project Status: Ongoing.

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 ESA. The final listing rule did not include a five-factor analysis (Service 1967, p. 4001). The final downlisting rule described the destruction, drastic modification, or severe curtailment of their habitat and hybridization with other trout species as threats to PCT (Service 1975, p. 29863). The Revised Recovery Plan identified threats from: (1) displacement and/or hybridization with nonnative trout; (2) degraded and/or limited habitat; and (3) overutilization for recreational purposes (Service 2004, pp. 41–45).

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

Nonnative Fish

Nonnative salmonid species are currently the greatest threat to PCT, resulting in loss of available habitat and range constrictions primarily through hybridization. The introduction of nonnative fish has been documented as a global threat to native fish species (Townsend 1996, pp. 15–16; Cambray 2003, pp. 61–64; Morita *et al*. 2004, pp. 969–970; Jug *et al*. 2005, pp. 386–387; Spens *et al*. 2007, p. 659; Crawford and Muir 2008, pp. 313–337; Cucherousset and Olden 2011, pp. 215–223). In the western United States, Lomnicky *et al*. (2007, p. 1086) found that over half of stream lengths surveyed contained nonnative vertebrates and that increased stream order (larger streams) had higher occupancy of nonnative vertebrates. They also found that the most common nonnative vertebrates were brook trout (*Salvelinus fontinalis*) (17 percent of all nonnative vertebrates present), brown trout (*Salmo trutta*) (16 percent), and rainbow trout (14 percent) (Lomnicky *et al*. 2007, p. 1086). Of the 30,400 km (18,890 mi) of streams sampled in California, 34 percent of stream miles contained nonnative vertebrates (Lomnicky *et al*. 2007, p. 1086). Using the same dataset, Whittier and Peck (2008, p. 1889) analyzed the surface area occupied by nonnative vertebrates and found that 64.8 percent of the waters sampled in California were occupied by nonnatives. The authors also found a greater likelihood of finding nonnative vertebrates in larger streams (Whittier and Peck 2008, p. 1890).

Silver King Creek has a long and complicated history of trout management (Table 2; Cordes *et al*. 2004, pp. 103–105). Five different trout species have been moved into and around the Silver King drainage, including PCT, Lahontan cutthroat trout, California golden trout, rainbow trout, and brook trout (Finger *et al*. 2011, p. 1372). Paiute cutthroat trout are now extirpated from their historical habitat due to introduced trout, but exist in formerly fishless areas of the Silver King Creek drainage and four out-of-basin watersheds above fish passage barriers.

Sometime in the 1860s or 1870s, PCT were transplanted from Silver King Creek into Corral Valley and Coyote Valley Creeks by loggers. In 1890, Virgil Connell (sheepherder) observed that there were no fish present above Llewellyn Falls. In 1912, a Basque sheepherder, Joe Jaunsaras, transported fish by bucket from Lower Fish Valley to Upper Fish Valley upstream of Llewellyn Falls. In 1914, California golden trout were reportedly planted downstream of Llewellyn Falls in Silver King Creek; however, there are no records of this stocking. By 1924, PCT that had been planted upstream of Llewellyn Falls had established a robust population and the fishery downstream had become "mixed with other kinds, probably due to stocking" (Letter from Virgil Connell in Ryan and Nicola (1976)). A summary of fish stocking records from the CDFW are in Table 2.

Hybridization

Hybridization from nonnative salmonids is a common threat to all native western salmonid species, including the Little Kern golden trout (*O. mykiss whitei*) (Service 1978, p. 15428), Lahontan cutthroat trout (Service 1995, pp. 25–26), greenback cutthroat trout (*O. c. stomias*) (Service 1998, pp. 7–8), Great Basin redband trout (*O. mykiss*) (Service 2000, p. 14933), Bonneville cutthroat trout (*O. c. utah*) (Service 2001, p. 51365), California golden trout (Service 2002, p. 59242), westslope cutthroat trout (*O. c. lewisi*) (Service 2003a, p. 47004), Gila trout (*O. gilae*) (Service 2003b, pp. 30–31), PCT (Service 2004, pp. 43–44), Yellowstone cutthroat trout (*O. c. bouvieri*) (Service 2006, pp. 8828–8829), Colorado River cutthroat trout (*O. c. pleuriticus*) (Service 2007, pp. 32597–32599), Rio Grande cutthroat trout (*O. c. virginalis*) (Service 2008b, pp. 27908–27909), and Apache trout (*O. apache*) (Service 2009, p. 21). Nonnative rainbow trout and golden trout readily hybridize with native cutthroat trout and produce fertile offspring; however, fitness and survival rates decreases as the proportion of rainbow trout admixture increases (Muhlfeld *et al*. 2009, pp. 329–331; Rasmussen *et al*. 2010, pp. 362–364). Even with reduced fitness, hybridization spreads rapidly because the initial F_1 (first generation) hybrids have high fitness, hybrids tend to stray more frequently, and all offspring of hybrids are hybrids (Boyer *et al*. 2008, p. 666; Muhlfeld *et al*. 2009, pp. 329–331). Extensive genetic mixing of natives, nonnatives, and hybrids contribute to the loss of locally-adapted genotypes and can lead to the extinction of a population or an entire species (Leary *et al*. 1995, p. 97; Rhymer and Simberloff 1996, pp. 96–100; Finger *et al*. 2011, pp. 1378–1379). As indicated by a recent genetic analysis, hybridization by nonnative species has eliminated PCT from their entire historical habitat (Finger *et al*. 2011, pp. 1378–1379). All populations of PCT have rainbow trout in stream reaches downstream of occupied habitat. Natural fish barriers separate the two species on all occupied streams.

Table 2. California Department of Fish and Wildlife fish stocking records for the Silver King Creek drainage (1930–1991).

Date	Trout Species	Number	Hatchery Source	Stocking Location
Silver King Creek				
8/15/1930	Rainbow	5,000	Mt. Whitney	
8/18/1930	Steelhead[1]	5,000	Mt. Whitney	
8/27/1931	Rainbow	10,000	Alpine	
9/15/1932	Rainbow	10,000	Alpine	
8/13/1933	Rainbow	10,000	Alpine	
7/20/1935	Brook	5,000	Alpine	
9/12/1935	Lahontan cutthroat	10,000	Alpine	
8/21/1946	Lahontan cutthroat	8,700	Hot Creek	near Poison Valley
9/5/1947	Lahontan cutthroat	19,600	Hot Creek	Long Valley-Forks
9/6/1947	Lahontan cutthroat	19,600	Hot Creek	Forks-mouth
9/7/1947	Lahontan cutthroat	9,800	Hot Creek	Long Valley-Forks
9/29/1949	Rainbow	8,400	Hot Creek	below Llewellyn Falls
9/30/1949	Rainbow	5,040	Hot Creek	above Llewellyn Falls
8/8/1951	Rainbow	6,010	Markleeville	Snodgrass Canyon above Corral Valley Creek
8/13/1952	Rainbow	5,017	Markleeville	Upper Bagley Valley to Llewellyn Falls
8/7/1953	Rainbow	4,960	Markleeville	2 mi above Vaquero Camp
9/23/1976	Rainbow	960	American	Lower Fish Valley
9/23/1976	Rainbow	2,900	American	Lower Fish Valley
1991*	Rainbow-Paiute cutthroat hybrids	unknown	wild	Lower Fish Valley
Whitecliff Lake				
1955	Lahontan cutthroat	unknown	unknown	Whitecliff Lake
1956	Lahontan cutthroat	unknown	unknown	Whitecliff Lake
Coyote Creek				
8/21/1946	Lahontan cutthroat	1,740	Hot Creek	Lower stream
9/7/1947	Lahontan cutthroat	4,200	Hot Creek	Mouth to barrier

[1] Steelhead (*Oncorhynchus mykiss*) is the anadromous form of rainbow trout.

Table 2 continued. California Department of Fish and Wildlife fish stocking records for the Silver King Creek drainage (1930–1991).

Date	Trout Species	Number	Hatchery Source	Stocking Location
Tamarack Lake				
1955	Lahontan cutthroat	1,005	unknown	Tamarack Lake
1957	Lahontan cutthroat	1,000	unknown	Tamarack Lake
1959	Lahontan cutthroat	1,035	unknown	Tamarack Lake
1962	Lahontan cutthroat	1,020	unknown	Tamarack Lake
1967	Lahontan cutthroat	4,000	unknown	Tamarack Lake
1968	Brook	500	unknown	Tamarack Lake
1968	Lahontan cutthroat	5,000	unknown	Tamarack Lake
1969	California Golden	1,018	unknown	Tamarack Lake
1971	Lahontan cutthroat	4,000	unknown	Tamarack Lake
1972	California Golden	1,000	unknown	Tamarack Lake
1973	California Golden	1,141	unknown	Tamarack Lake
1973	Lahontan cutthroat	3,600	unknown	Tamarack Lake
1974	California Golden	2,250	unknown	Tamarack Lake
1975	Lahontan cutthroat	3,600	unknown	Tamarack Lake
1976	California Golden	2,272	unknown	Tamarack Lake
1976	Lahontan cutthroat	4,000	unknown	Tamarack Lake
1980	Lahontan cutthroat	4,000	unknown	Tamarack Lake
1982	Lahontan cutthroat	4,000	unknown	Tamarack Lake
1985	Paiute cutthroat	173	wild	Tamarack Lake
1987	Lahontan cutthroat	3,000	unknown	Tamarack Lake
1987	Paiute cutthroat	100	wild	Tamarack Lake
1991*	Rainbow-Paiute cutthroat hybrids	unknown	wild	Tamarack Lake

Source: W. Somer, CDFW, unpubl. data
*In 1991, prior to chemical treatment of Upper Silver King Creek, multiple age classes of hybrid rainbow-Paiute cutthroat were transported to Lower Fish Valley and Tamarack Lake.

Summary of Nonnative Fish Impacts

In summary, nonnative species, particularly hybridizing salmonids, pose the greatest threat to the continued existence of PCT. Nonnative salmonids were historically stocked in Silver King Creek which caused the eradication of PCT in its historical habitat. Nonnative rainbow trout currently occupy the entire historical range of PCT and are present downstream of all currently-occupied habitat.

Population Isolation and Habitat Fragmentation

Habitat fragmentation is one of the leading causes of cutthroat trout population declines in the western United States (Dunham *et al*. 1997, pp. 1130–1131; Peterson *et al*. 2008, p. 558). Habitat fragmentation reduces the total habitat available, reduces habitat complexity, and prevents gene flow (Rieman and McIntyre 1995, pp. 293–294; Dunham *et al*. 1997, pp. 1130–1131; Wenburg and Bentzen 2001, pp. 1063–1065; Frankham 2005, pp. 133–134; Wofford *et al*. 2005, pp. 631–633; Pritchard *et al*. 2007, pp. 614–617; Guy *et al*. 2008, pp. 1754–1755; Cook *et al*. 2010, pp. 1505–1508). Fragmentation accelerates extinction, especially when movement of fish among stream segments is not possible, which is the case with all PCT populations (Fagan 2002, pp. 3244–3248; Fahrig 2002, p. 349; Hilderbrand 2003, p. 263; Frankham 2005, pp. 133–134). Isolated populations are vulnerable to extinction through demographic stochasticity (random fluctuations in birth and death rates); environmental stochasticity (random variation in environmental attributes) and catastrophes; loss of genetic heterozygosity (genetic diversity) and rare alleles (inherited forms of a genetic trait); and human disturbance (Hedrick and Kalinowski 2000, pp. 140–142; Lande 2002, pp. 18–35; Reed and Frankham 2003, pp. 233–234; Noss *et al*. 2006, pp. 213–240; Pringle 2006, pp. 243–246; Whiteley *et al*. 2010, pp. 1937–1939). Completely isolated populations are the most severe form of fragmentation because gene flow among populations does not occur, thereby inflicting inbreeding depression dynamics on the population and reducing fitness (Hedrick and Kalinowski 2000, pp. 140–142; Reed and Frankham 2003, pp. 232–233; Frankham 2005, pp. 135–136; Scribner *et al*. 2006, pp. 390–392; Pritchard *et al*. 2007, pp. 614–617; Guy *et al*. 2008, p. 1758). Moyle *et al*. (2011, pp. 2414–2422) consider PCT as one of the most imperiled native fish in California due to loss of genetic diversity and habitat fragmentation. Evidence of loss of genetic diversity has been found in all PCT populations (Cordes *et al*. 2004, pp. 112–113). All current PCT populations are completely isolated from each other which does not allow for genetic exchange or recolonization after a disturbance.

Apart from the isolation that habitat fragmentation causes, the short length of stream segments and small population sizes that they support are of concern for PCT. Several studies found that population viability of cutthroat trout is correlated with stream length or habitat size (Hilderbrand and Kershner 2000, pp. 515–518; Harig and Fausch 2002, pp. 542–548; Young *et al*. 2005, pp. 2403–2405). Stream length is important because trout move throughout stream networks searching for a variety of habitats necessary to complete their life cycle (*i.e.,* spawning, rearing, migration corridors, refugium) (Baltz *et al*. 1991, pp. 173–175; Fausch and Young 1995, pp. 364–365; Young 1996, pp. 1405–1407; Muhlfeld *et al*. 2001, pp. 174–175; Schmetterling 2001, pp. 511–519; Hilderbrand and Kershner 2004, pp. 1043–1045; Schrank and Rahel 2004, pp. 1531–1536; Colyer *et al*. 2005, pp. 957–961; Neville *et al*. 2006, pp. 908–914; Umek 2007, pp. 13–28; Sanderson and Hubert 2009, pp. 332–335; Young 2011, pp. 945–949). The shorter the stream reach the more likely it is that one or more of PCT's required habitats is either missing or inadequate for completion of the species' life cycle. In contrast, longer stream reaches have more complexity and have a higher probability that no particular habitat type limits the population (Horan *et al*. 2000, pp. 1254–1261; Harig and Fausch 2002, p. 546; Dunham *et al*. 2003, pp. 185–187; Huusko *et al*. 2007, pp. 478–479).

To ensure long-term persistence, Hilderbrand and Kershner (2000, p. 515) estimated that a population should consist of at least 2,500 cutthroat trout, and that at least 8.2 km (5.1 mi) of habitat is required to maintain a population of that size when fish density was high (300 fish/km; 484 fish/mi). Adding a 10 percent loss rate of individuals, to account for emigration and mortality, increased the required length up to 9.3 km (5.8 mi) in order to maintain 2,500 fish. For streams with smaller population densities of 200 fish/km (320 fish/mi) and 100 fish/km (160 fish/mi), the corresponding stream length increased to 12.5 km (7.8 mi) and 25 km (15.5 mi), respectively, to maintain a population of 2,500 (Hilderbrand and Kershner 2000, p. 515). In a similar study, Young *et al*. (2005, p. 2405) found that to maintain a population of 2,500 cutthroat trout, 8.8 km (5.5 mi) of stream habitat were needed.

The PCT population in Silver King Creek was a naturally isolated population consisting of 17.8 km (11.1 mi) of habitat. The size of the drainage, the size of the population, and the quality and distribution of habitat allowed a viable population of PCT to persist and evolve for thousands of years.

While there is approximately 23.5 km (14.5 mi) of occupied habitat within the Silver King Creek drainage, populations of PCT are fragmented and isolated into five separate areas: (1) Four Mile Canyon Creek, (2) Fly Valley Creek, (3) Upper Silver King Creek and associated tributaries, (4) Coyote Valley Creek, and (5) Corral Valley Creek. Standard three-pass electrofishing surveys have been conducted in the Silver King drainage since the 1960s. Fish densities are typically in the high range (300 fish/km; 484 fish/mi) in all locations except for Four Mile Canyon Creek which has low densities (100 fish/km, 160 fish/mi). It should be noted that monitoring locations for population estimates are conducted in the best habitat available (low gradient meadow stream segments) in that particular stream and fish densities decline sharply outside of the sampled areas (typically higher gradient stream segments). The PCT population in Four Mile Canyon Creek is isolated from Silver King Creek by a fish barrier. Occupied habitat is approximately 3.1 km (1.9 mi). Fly Valley Creek is also isolated from Silver King Creek by a fish barrier and has 1.8 km (1.1 mi) of occupied habitat. Paiute cutthroat trout populations in Corral Valley Creek and Coyote Valley Creek are separated by a fish barrier which is located on Coyote Valley Creek just upstream from the confluence of the two streams. Corral Valley Creek has 5.3 km (3.3 mi) of occupied habitat, and Coyote Valley Creek has 6.1 km (3.8 mi) of occupied habitat. Upper Silver King Creek, an associated side channel in Upper Fish Valley, and lower Bull Canyon Creek are connected and represent approximately 7.2 km (4.5 mi) of combined habitat which is below the minimum amount of habitat predicted (9.3 km; 5.8 mi) for long-term persistence.

Standardized population estimates are not used for the four out-of-basin populations; therefore, the population density component of the persistence requirements cannot be used. Regardless of population density, the PCT populations in these streams currently do not meet long-term persistence criteria based on the minimum amount of stream habitat (9.3 km; 5.8 mi) described above (Hilderbrand and Kershner 2000, p. 515). On the Inyo National Forest, occupied habitat in North Fork Cottonwood Creek is approximately 5.5 km (3.4 mi) and Cabin Creek is 2.4 km (1.5 mi). The same situation exists for streams on the Sierra National Forest where occupied habitat on Stairway Creek (3.5 km; 2.2 mi) and Sharktooth Creek (3.3 km; 2.0 mi) are less than half of what is needed for long-term persistence.

In summary, all populations of PCT do not meet minimum habitat requirements for long-term persistence. These data indicate that habitat fragmentation and isolation pose a substantial threat to all PCT populations.

<u>Land Use Activities</u>

Grazing

Impacts of livestock grazing to stream habitat and fish populations can be separated into acute and chronic effects. Acute effects are those which contribute to the immediate loss of individuals, loss of specific habitat features (*e.g.*, undercut banks, spawning beds) or localized reductions in habitat quality (*e.g.*, sedimentation, loss of riparian vegetation). Chronic effects are those which, over a period of time, result in loss or reduction of entire populations of fish, or widespread reduction in habitat quantity and/or quality.

Behnke and Zarn (1976, p. 5) identified livestock grazing as the greatest threat to the integrity of stream habitat in the western United States. Native and domestic grazers, especially cattle, are attracted to these narrow green strips of vegetation due to the presence of water, shade, succulent vegetation, and gentle topography (Platts 1979, p. 42; 1991; p. 393; Marlow and Pogacnik 1986, pp. 213–215; Smith *et al*. 1992, pp. 387–389; Kie and Boroski 1996, pp. 485–487; Parsons *et al*. 2003, pp. 337–340). Riparian areas are most vulnerable to the effects of overgrazing because cattle tend to concentrate in them (Platts 1979, p. 42; 1991; p. 393). Hot season grazing (July 1 through September 15) focuses livestock use on riparian areas because of the availability of water, green vegetation, trees and shrubs for cover and food, and the cooler microclimate associated with areas near water and shade (Platts 1979, p. 42; 1991, pp. 407–408).

Livestock grazing can affect riparian areas by changing, reducing, or eliminating vegetation, and by the actual loss of riparian areas through channel widening, channel degradation, or lowering of the water table (Government Accounting Office 1988, pp. 20–25; Schulz and Leininger 1990, pp. 297–299; Overton *et al.* 1994, pp. 5–7; Dobkin *et al.* 1998, pp. 213–218). Effects on fish habitat include reduction of shade and cover and resultant increases in water temperature, changes in stream morphology, and the addition of sediment due to bank degradation and off-site soil erosion (Knapp and Matthews 1996, pp. 811–818; Belsky *et al*. 1999, pp. 425–428; Isaak and Hubert 2001, pp. 359–363). Direct adverse effects of livestock grazing on salmonids include wallowing and wading in streams. Wading in streams by livestock can be assumed to induce mortality on trout eggs and pre-emergent fry (Gregory and Gamett 2009, pp. 364–366; Peterson *et al*. 2010, pp. 958–964).

Silver King Cattle and Horse Allotment (Silver King Allotment) is composed of 4,812 hectares (11,891 acres) which encompasses Silver King Creek and its tributaries. Sheep grazing was authorized from the early 1900's until about the 1930's when cattle predominantly grazed the area. From 1977 to 1987 the Term Grazing Permit was for 525 cow/calf pairs from July 14 to September 30. The permit was transferred to a new permittee in 1987 and included the same occupancy rates and season of use dates. However, the actual authorized use for most years was 225 cow/calf pairs from July 16 to September 7 (USFS 2012b, pp. 5–6).

In 1984, 1987, and 1990, physical habitat and biological field surveys were conducted within the Silver King Creek drainage. The objectives of this effort were to provide the USFS with a general assessment of habitat and to provide recommendations for future management. Habitat surveys were performed using the General Aquatic Wildlife System (GAWS) procedures (Duff 1989, pp. 1–26). A Habitat Condition Index (HCI) is obtained using the GAWS methodology which can then be used to provide habitat trend data. Nine stations were monitored on Silver King Creek above Llewellyn Falls, two stations on Bull Canyon Creek, one station on Fly Valley Creek, two stations on Four Mile Canyon Creek, four stations on Coyote Valley Creek, and two stations on Corral Valley Creek. The HCI over this 6-year period improved in nearly all of the stations monitored, which was primarily due to a change in grazing management including riparian exclosure fencing (Duff 1991, pp. 2–5, 7–8). However, even though most stations increased their HCI rating, 12 of the 21 stations still rated as fair to poor (Duff 1991, pp. 2–5, 7–8).

In 1991, another habitat assessment was conducted to describe and compare stream reaches in Upper Fish Valley and Coyote Creek in grazed and ungrazed sections (Overton *et al*. 1994, pp. 3–27). This study used the USFS's Region 1/Region 4 (Northern Region/Intermountain Region) Fish Habitat Procedures Protocol (Overton 1994, pp. 16–27). Significant differences between grazed and ungrazed stream sections were found in several stream habitat measurements (Overton *et al*. 1994, pp. 5–11). The ungrazed stream segments had greater bank stability, deeper bank undercuts, deeper and narrower stream channels with lower width to depth ratios (Overton *et al*. 1994, pp. 5–11).

California Department of Fish and Wildlife conducted stream channel morphology measurements at a number of locations in both Upper Fish and Lower Fish Valleys in 1999–2002 (Flint 2004, pp. 3–4). Flint (2004, pp. 5–7) concluded that both valleys are recovering from grazing impacts, stream banks are stable, and willows and sedges are rapidly recolonizing the riparian area.

Due to the status of PCT, between 1987 and 1994 the Silver King Allotment was rested several times for resource protection, and in 1995, the term grazing permit was cancelled due to permittee noncompliance, and the Allotment has remained vacant since that time. The Paiute cutthroat trout Revised Recovery Plan recommended the closure of the Silver King Allotment (Service 2004, p. 54) and, in 2012, the Humboldt-Toiyabe National Forest officially closed the Allotment to all livestock grazing for the protection of PCT (USFS 2012c, p. 5).

The Cottonwood Creek and Tres Plumas Allotments on North Fork Cottonwood Creek also have the potential to affect PCT habitat (Wong 1991, p. 184; Kondolf 1994, pp. 506–507). Grazing was suspended for both these Allotments in 2000, and they have been in non-use status since that time (USFS 2000, pp. 1–10). Cabin Creek is within an active grazing allotment (Indian Creek Allotment), and historical grazing management resulted in some degradation of habitat due to bank failure and increased sediment input (USFS 2009, p. 10). A new 10-year grazing permit was issued for the Indian Creek Allotment which set conservative utilization and streambank disturbance levels aimed to minimize impacts from livestock grazing (Service 2010, pp. 20–23). To date the Indian Creek Allotment has been vacant. Stairway Creek is within the 77 Corral Allotment which is currently closed to grazing (Strand and Eddinger 1999, p. 17). Sharktooth Creek is within the Cassidy Allotment; however, the Sharktooth Unit of the Allotment, which encompasses Sharktooth Creek, is closed to grazing for the protection of PCT (USFS 2010, p. 17). Therefore, grazing does not currently affect occupied habitat in Stairway and Sharktooth Creeks.

Recovery Actions

Recovery actions since the 2008 5-year review have focused on habitat improvement projects and implementing the Paiute Cutthroat Trout Restoration Project. The purpose of the Paiute Cutthroat Trout Restoration Project is to remove nonnative salmonids from the historical range of PCT and repatriate PCT from existing populations (Service and California Department of Fish and Game 2010, pp. 1-284). However, due to legal challenges regarding the use of rotenone, the project has not been implemented. In 2009, the Inyo National Forest completed a gravel augmentation project to improve spawning habitat in North Fork Cottonwood Creek. As mentioned above, the Humboldt-Toiyabe National Forest officially closed the Silver King Allotment to all livestock grazing for the conservation of PCT

Summary for Factor A

Paiute cutthroat trout populations continue to be threatened by interactions with nonnative species, and habitat fragmentation and isolation. Paiute cutthroat trout have been extirpated from their entire historical habitat by nonnative salmonids. Additionally, hybridizing salmonids are present downstream of all currently occupied habitat. Paiute cutthroat trout occupy stream habitat in five widely separated drainages and are primarily confined to isolated, short headwater stream reaches. These factors work to reduce gene flow between populations and reduce the ability of populations to recover from catastrophic events, thus threatening their long-term viability. The literature suggests that to ensure long-term viability, populations should consist of more than 2,500 individuals, occupy at least 9.3 km (5.8 mi) of stream habitat, and have no nonnative species present. Currently, no population meets the minimum requirements. The purpose of the Paiute Cutthroat Trout Restoration Project is to eliminating threats from nonnative fish and repatriate PCT into its historical habitat which will meet the minimum habitat requirements for long-term persistence. Livestock grazing has been a past threat (Service 1985, pp. 20–21; 2004, pp. 41–42; Service 2008a, pp. 9–10); however, grazing has either been eliminated from occupied habitat or conservative grazing management objectives are in place for active grazing allotments. Nonnative salmonids were identified as threats in the reclassification rule (Service 1975, pp. 29863–29864), both recovery plans (Service 1985, pp. 17–22; 2004, p. 43), and the 2008 5-year review (Service 2008a, p. 13). Based on the best scientific and commercial information available, we conclude that the present or threatened destruction, modification, or curtailment of its habitat or range is still a significant threat to the continued existence of PCT.

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

Recreational

No threats from overutilization were identified under this factor at the time of reclassification (Service 1975, p. 29863). The final reclassification rule states the PCT would benefit from regulated taking by sportfishing and finalized regulations that permitted sportfishing of PCT in accordance with applicable State law, and that violation of State law will also be a violation of the ESA (50 CFR 17.44(a)).

Contrary to the 1975 reclassification rule (Service 1975, p. 29863), PCT are susceptible to unregulated angling. Both the 1985 recovery plan (Service 1985, p. 19) and the revised recovery plan (Service 2004, pp. 42–43) address the issue of unregulated angling. Connell (letter in Ryan and Nicola 1976, pp. 54–55) reported that in 1890 he and a companion took 1,500 fish from Silver King Creek in only 3 days of fishing. He noted that "...they fished only a very small part of the time" and that their angling success was enhanced when his fishing companion "...conceived the idea of putting two hooks on his line and succeeded in bringing out two fish in the majority of his casts." From 1952 to 1965, Silver King Creek was open to angling to reduce the number of hybrid fish and the PCT population above Llewellyn Falls was severely depleted. Angling has been closed in Silver King Creek above Llewellyn Falls since 1965. In the early 1970s, the population above the Llewellyn Falls was again significantly reduced following a brief period of unauthorized angling by military personnel (Ryan and Nicola 1976, p. 31).

Fishing in Silver King Creek from Llewellyn Falls downstream to the confluence of Tamarack Lake Creek has recently (2006) been closed to reduce the threat of intentional movement of nonnative salmonids above Llewellyn Falls into occupied habitat (Section 7.50(b)(178), Title 14, California Code of Regulations). Additionally, North Fork Cottonwood Creek, an out-of-basin population, is closed to fishing. The other occupied streams are open to fishing; however, due to their remote locations, fishing has not been documented to be a threat. Currently, there are no data to indicate that overutilization from recreation is occurring.

Scientific and Educational

Annual sampling of PCT populations is an important aspect of fisheries management and scientific research. Federal and State biologists sample various PCT populations in the Silver King Creek drainage on an annual basis. Most other populations are variably sampled using visual or fly rod depletion methods (Strand and Eddinger 1999, p. 6). Sampling stream populations of PCT in the Silver King Creek drainage is usually performed with electrofishing equipment. Electrofishing is a process by which an electrical current is passed through water containing fish in order to stun them—thus making them easy to capture. It can cause a suite of effects ranging from simple harassment to actual mortality (all life stages) (Snyder 2003, pp. 42–55).

The amount of unintentional harassment and harm attributable to electrofishing may vary widely depending on the equipment used, the settings on the equipment, and the expertise of the technician. Reported effects of electrofishing on salmonids range from mortality (Hudy 1985, p. 476; Dwyer *et al*. 1993, pp. 841–843; McMichael 1993, pp. 230–231; Dwyer and Erdahl 1995, pp. 648–650; Habera *et al*. 1996, pp. 195–197; Ainslie *et al*. 1998, p. 908; Roach 1999, pp. 925–926; Cho *et al*. 2002, pp. 226–227; Walsh *et al*. 2004, pp. 318–319), spinal injuries (Sharber and Carothers 1988, pp. 118–119; McMichael 1993, pp. 230–231; Hollender and Carline 1994, pp. 645–646; Dalby *et al*. 1996, pp. 563–564; Habera *et al*. 1996, pp. 195–197; Kocovsky *et al*. 1997, pp. 310–311; Thompson *et al*. 1997a, pp. 146–147; Ainslie *et al*. 1998, pp. 908–910; Habera *et al*. 1999, pp. 122–123; Carline 2001, pp. 574–575; Walsh *et al*. 2004, pp. 318–319), hemorrhaging (McMichael 1993, pp. 230–231; Hollender and Carline 1994, pp. 645–646; Habera *et al*. 1996, pp. 195–197; Thompson *et al*. 1997a, p. 147; Habera *et al*. 1999, pp. 122–123; Walsh *et al*. 2004, pp. 318–319), behavioral changes (Mesa and Schreck 1989, pp. 648–652; Sorensen 1994, pp. 863–864), and changes in growth (Gatz *et al*. 1986, pp. 177–178; Dwyer and White 1995, pp. 149–150; Dalby *et al*. 1996, pp. 565–566; Thompson *et al*. 1997b, pp.156–157; Ainslie *et al*. 1998, pp. 910–911; Carline 2001, p. 578).

The severity of the effects to fish reported in these studies depended on many factors including type of electrical current (alternate current or direct current), waveform (pulsed or continuous), the frequency (Hz) and voltage used, type of electrofishing unit used (backpack versus boat mounted), frequency of sampling through time (number of times an individual or population is sampled), species of fish, life stage of species (egg, juvenile, adult), size of the individual fish, and the conductivity of the water. Only a few studies have examined the long-term effects of electrofishing on salmonid survival and growth (Dalby *et al*. 1996, pp. 564–566; Thompson *et al*. 1997b, p. 158; Ainslie *et al*. 1998, pp. 911–912; Schill and Elle 2000, pp. 732–733). These studies indicate that although some fish suffer hemorrhage and spinal injury, few die as a result. However, severely injured fish grow at slower rates and sometimes show no growth at all (Dalby *et al*. 1996, pp. 565–566; Ainslie *et al*. 1998, pp. 910–911). Most biologists have many years of experience with electrofishing and a large number of State and Federal biologists who work with PCT have taken the Principles and Techniques of Electrofishing course offered by the Service through the National Conservation Training Center in Shepherdstown, West Virginia (Alan Temple, Service, pers. comm. 2009). Snyder (2003, p. 98) concluded that population effects were unlikely except for intensively sampled populations.

The special rule for PCT under ESA section 4(d) facilitates management by the State and allows regulated angling (Service 1975, p. 29864; 50 CFR 17.44(a)). Collection of PCT for scientific and educational purposes is controlled through State permitting processes that prevent excessive sampling. In addition, advancements in molecular technology have resulted in non-lethal techniques to perform genetic analyses. Scientific and educational overutilization are not believed to be significant threats to PCT at this time.

Summary of Factor B

In summary, recreational fishing was a historical threat to PCT within the Silver King Creek drainage. Because small streams are vulnerable to overharvest, recreational fishing has been closed for populations of PCT in the Silver King Creek drainage and North Fork Cottonwood Creek. The other populations are open to fishing; however, due to their remote locations recreational fishing is not a significant effect at this time. Scientific sampling of PCT populations within the Silver King Creek drainage with electrofishing equipment occurs on an annual basis, but most populations are not sampled every year and biologists are trained in the proper use of electrofishing equipment. Scientific and educational sampling is also regulated by State permitting processes and new, non-lethal techniques have been developed for genetic analyses. Overutilization was not identified as a threat in the 2008 5-year review (Service 2008a, p. 12). Consistent with our previous determination, we conclude that the best scientific and commercial information available indicate that PCT are not threatened by overutilization for commercial, recreational, scientific, or educational purposes.

FACTOR C: Disease or Predation

Predation

There are several natural predators to PCT eggs and fry including water shrews (*Sorex palustris*), dippers (*Cinclus mexicanus)*, and trichopteron larvae, but few prey on adult fish (Wong 1975, pp. 110–115). Predation does not seem to be a significant threat at this time.

Disease

Disease is apparently a significant cause of adult PCT mortality in North Fork Cottonwood Creek, particularly in the post-spawning period. Wong (1975, pp. 115–116) observed extensive fungal infections on the dorsal and caudal fins of several spawned-out fish in North Fork Cottonwood Creek. Many of these fish were so weakened by spawning they were unable to recover. It is unknown how this infection affects PCT at the population level; however, it should be noted the population has persisted in North Fork Cottonwood Creek since the fungus was first observed in the early 1970's. Due to this fungus, CDFW altered their sampling techniques from electrofishing to visual encounter surveys. This disease has not been observed outside of North Fork Cottonwood Creek (Service 2004, p. 43); therefore, disease does not seem to be a significant threat to the species throughout its current range.

Summary of Factor C

Disease and predation were not identified as threats in the reclassification rule (Service 1975, pp. 29863–29864), either recovery plan (Service 1985, pp. 17–22; 2004, p. 43), nor the 2008 5-year review (Service 2008a, p. 13). Disease and predation are not believed to be significant threats to PCT at this time.

FACTOR D: Inadequacy of Existing Regulatory Mechanisms

State Protections in California

There are several State and Federal laws and regulations that are pertinent to federally-listed species, each of which may contribute in varying degrees to the conservation of listed and non-listed species. These laws, most of which have been enacted in the past 30–40 years, have reduced or eliminated the threat of habitat destruction. These laws are discussed below.

State Protections in California

California Endangered Species Act (CESA): The CESA (California Fish and Game Code (CFGC) section 2080 *et seq.*) prohibits the unauthorized take of State-listed threatened or endangered species. Paiute cutthroat trout are not State-listed in California.

California Environmental Quality Act (CEQA): The CEQA requires review of any project that is undertaken, funded, or permitted by the State or a local governmental agency. If significant effects are identified, the lead agency has the option of requiring mitigation through changes in the project or to decide that overriding considerations make mitigation infeasible (CEQA section 21002). Protection of listed species through CEQA is, therefore, dependent upon the discretion of the lead agency involved.

California Lake and Streambed Alteration Program: The Lake and Streambed Alteration Program (CFGC sections 1600–1616) may promote the recovery of listed species in some cases. This program provides a permitting process to reduce impacts to fish and wildlife from projects affecting important water resources of the State, including lakes, streams, and rivers. This program also recognizes the importance of riparian habitats to sustaining California's fish and wildlife resources, including listed species, and helps prevent the loss and degradation of riparian habitats.

State Bill SB 1573: This bill was signed into law in 2002 and established an Interagency Aquatic Invasive Species Council to provide for the development of a State Aquatic Invasive Species Plan. The plan, prepared by CDFW's Habitat Conservation Planning Branch, will follow Federal guidance and fall under the direction of the State invasive species coordinator.

Federal Protections

National Environmental Policy Act (NEPA): NEPA (42 U.S.C. 4371 *et seq.*) provides some protection for listed species that may be affected by activities undertaken, authorized, or funded by Federal agencies. Prior to implementation of such projects with a Federal nexus, NEPA requires the agency to analyze the project for potential impacts to the human environment, including natural resources. In cases where that analysis reveals significant environmental effects, the Federal agency must propose mitigation alternatives that would offset those effects (40 C.F.R. 1502.16). These mitigations usually provide some protection for listed species.

However, NEPA does not require that adverse impacts be fully mitigated, only that impacts be assessed and the analysis disclosed to the public.

Clean Water Act: Under section 404, the U.S. Army Corps of Engineers (USACE) regulates the discharge of fill material into waters of the United States, which include navigable and isolated waters, headwaters, and adjacent wetlands (33 U.S.C. 1344). In general, the term "wetland" refers to areas meeting the USACE's criteria of hydric soils, hydrology (either sufficient annual flooding or water on the soil surface), and hydrophytic vegetation (plants specifically adapted for growing in wetlands). Any action with the potential to impact waters of the United States must be reviewed under the Clean Water Act, NEPA, and ESA. These reviews require consideration of impacts to listed species and their habitats, and recommendations for mitigation of significant impacts.

Wilderness Act: The Wilderness Act of 1964 established a National Wilderness Preservation System made up of federally-owned areas designated by Congress as "wilderness" for the purpose of preserving and protecting designated areas in their natural condition. Commercial enterprise, road construction, use of motorized vehicles or other equipment, and structural developments are generally prohibited within designated wilderness. Livestock grazing is permitted within designated wilderness, subject to other applicable laws, if it was established prior to the passage of the Wilderness Act. All historical and currently occupied PCT habitat occurs in designated wilderness areas including the Carson-Iceberg Wilderness, John Muir Wilderness, Ansel Adams Wilderness, and the White Mountains Wilderness. The Wilderness Act has likely helped to protect PCT habitat from development or other types of habitat conversions and disturbances.

National Forest Management Act: Under the National Forest Management Act of 1976, as amended (NFMA) (16 U.S.C. 1600 *et seq*.), the USFS is tasked to manage National Forest lands based on multiple-use, sustained-yield principles, and implement land and resource management plans (LRMP) on each National Forest to provide for a diversity of plant and animal communities. The purpose of an LRMP is to guide and set standards for all natural resource management activities for the life of the plan (10–15 years). NFMA requires the USFS to incorporate standards and guidelines into LRMPs. The 1982 planning regulations for implementing NFMA (USFS 1982, pp. 43026–43058), under which all existing forest plans in the Sierra Nevada were prepared until recently, guided management of National Forests and required that fish and wildlife habitat on National Forest system lands be managed to maintain viable populations of existing native and desired nonnative vertebrate species in the planning area. A viable population is defined as a population of a species that continues to persist over the long term with sufficient distribution to be resilient and adaptable to stressors and likely future environments. In order to insure that viable populations will be maintained, habitat must be provided to support, at least, a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area.

On April 9, 2012, the USFS published a final rule (USFS 2012, pp. 21162–21276) amending 36 CFR 219 to adopt new National Forest System land management regulations to guide the development, amendment, and revision of LRMPs for all Forest System lands. These revised regulations, which became effective on May 9, 2012, replace the 1982 planning rule. The 2012 planning rule requires that the USFS maintain viable populations of species of conservation concern at the discretion of regional foresters. This rule could thereby result in removal of the limited protections that are currently in place for PCT under the Sierra Nevada Forest Plan Amendment (SNFPA), as described below. Thus, the impact of the 2012 rule to listed species is unknown at this time.

Sierra Nevada Forest Plan Amendment: In 2001, a record of decision was signed by the USFS for the Sierra Nevada Forest Plan Amendment (SNFPA), based on the final environmental impact statement for the SNFPA effort and prepared under the 1982 NFMA planning regulations. The Record of Decision amends the USFS Pacific Southwest Regional Guide, the Intermountain Regional Guide, and the LRMPs for National Forests in the Sierra Nevada and Modoc Plateau. This document affects land management on all National Forests throughout the range of PCT. The SNFPA addresses and gives management direction on issues pertaining to old forest ecosystems; aquatic, riparian, and meadow ecosystems; fire and fuels; noxious weeds; and lower west-side hardwood ecosystems of the Sierra Nevada. In January 2004, the USFS amended the SNFPA, based on the final supplemental environmental impact statement, following a review of fire and fuels treatments, compatibility with the National Fire Plan, compatibility with the Herger-Feinstein Quincy Library Group Forest Recovery Pilot Project, and effects of the SNFPA on grazing, recreation, and local communities (USFS 2004, pp. 26–30).

Relevant to PCT, the Record of Decision for SNFPA aims to protect and restore aquatic, riparian, and meadow ecosystems, and to provide for the viability of associated native species through implementation of an aquatic management strategy. The aquatic management strategy is a general framework with broad policy direction. Implementation of this strategy is intended to take place at the landscape and project levels. There are nine goals associated with the aquatic management strategy: (1) the maintenance and restoration of water quality to comply with the Clean Water Act; (2) the maintenance and restoration of habitat to support viable populations of native and desired nonnative riparian-dependent species, and to reduce negative impacts of nonnative species on native populations; (3) the maintenance and restoration of species diversity in riparian areas, wetlands, and meadows to provide desired habitats and ecological functions; (4) the maintenance and restoration of the distribution and function of biotic communities and biological diversity in special aquatic habitats (such as springs, seeps, vernal pools, fens, bogs, and marshes); (5) the maintenance and restoration of spatial and temporal connectivity for aquatic and riparian species within and between watersheds to provide physically, chemically, and biologically unobstructed movement for their survival, migration, and reproduction; (6) the maintenance and restoration of hydrologic connectivity between floodplains, channels, and water tables to distribute flood flows and to sustain diverse habitats; (7) the maintenance and restoration of watershed conditions as measured by favorable infiltration characteristics of soils and diverse vegetation cover to absorb and filter precipitation, and to sustain favorable conditions of streamflows; (8) the maintenance and restoration of instream flows sufficient to sustain desired conditions of riparian, aquatic, wetland, and meadow habitats, and to keep sediment regimes within the natural range of variability; and (9) the maintenance and restoration of the physical structure and condition of streambanks and shorelines to minimize erosion and sustain desired habitat diversity.

If these goals of the aquatic management strategy are pursued and met, threats to PCT resulting from habitat alterations could be reduced. However, the aquatic management strategy is a generalized approach that does not contain specific implementation timeframes or objectives, and it does not provide direct protections for PCT. Additionally, as described above, the April 9, 2012, final rule (USFS 2012, pp. 21162–21276) that amended 36 CFR 219 to adopt new National Forest System land management planning regulations could result in removal of the limited protections that are currently in place for PCT under the SNFPA.

Endangered Species Act of 1973, as amended (ESA): The ESA is the primary Federal law providing protection for PCT. The Service's responsibilities include administering the ESA, including sections 7, 9, and 10 that address take. Since 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 CFR 402.02). A non-jeopardy biological opinion may include reasonable and prudent measures that minimize the amount or extent of incidental take of listed species associated with a project. Since 2003, four non-jeopardy biological opinions have been completed for PCT.

Section 9 prohibits the taking of any federally-listed endangered or threatened species. Section 3(18) defines "take" to mean "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Service regulations (50 CFR 17.3) define "harm" to include significant habitat modification or degradation which actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering. Harassment is defined by the Service as an intentional or negligent action that creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. The ESA provides for civil and criminal penalties for the unlawful taking of listed species. Incidental take refers to taking of listed species that result from, but is not the purpose of, carrying out an otherwise lawful activity by a Federal agency or applicant (50 CFR 402.02).

Section 4(d) of the ESA provides for special rules for species listed as threatened, through regulations deemed necessary and advisable to provide for the conservation of the species. Under specified circumstances, 4(d) rules may include exemptions from section 9 take prohibitions. A 4(d) rule was published on July 16, 1975, in conjunction with reclassifying PCT from endangered to threatened, to facilitate management by the State and allow State-permitted sport harvest (Service 1975, p. 29864; 50 CFR 17.44(a)).

Summary of Factor D

In summary, the ESA is the primary Federal law that provides protection for PCT since its reclassification from endangered to threatened in 1975 (Service 1975, pp. 29863–29864). Other Federal and State regulatory mechanisms provide discretionary protections for the species based on current management direction, but do not guarantee protection for the species absent its status under the ESA. Inadequacy of existing regulatory mechanisms was not identified as a threat in the reclassification rule (Service 1975, pp. 29863–29864), either recovery plan (Service 1985, pp. 17–22; 2004, p. 43), nor the 2008 5-year review (Service 2008a, pp. 13–15). Consistent with our previous determination, we continue to believe the inadequacy of other laws and regulations are not a threat to PCT at this time.

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

Climate Change

In this section, we discuss the aspects of climate change that will most likely affect PCT and their habitat. We present information that indicates climate change is occurring on a global scale and information regarding local effects from the Sierra Nevada, and discuss how climate change will likely exacerbate the threats to PCT discussed previously in this review.

Our analyses under the ESA include consideration of ongoing and projected changes in climate. The terms "climate" and "climate change" are defined by the Intergovernmental Panel on Climate Change (IPCC). The term "climate" refers to the mean and variability of different types of weather conditions over time, with 30 years being a typical period for such measurements, although shorter or longer periods also may be used (IPCC 2007, p. 78). The term "climate change" thus refers to a change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2007, p. 78).

Scientific measurements spanning several decades demonstrate that changes in climate are occurring, and that the rate of change has been faster since the 1950s. Warming trends documented over the past 50 years in the United States are predicted to continue to increase (Field *et al*. 2007, pp. 626–627); however, the magnitude varies spatially across the continent, is most pronounced during spring and winter months, and has affected daily minimum temperatures more than daily maximum temperatures (Field *et al*. 2007, p. 620). Results of scientific analyses presented by the IPCC show that most of the observed increase in global average temperature since the mid-20th century cannot be explained by natural variability in climate, and is "very likely" (defined by the IPCC as 90 percent or higher probability) due to the observed increase in greenhouse gas (GHG) concentrations in the atmosphere as a result of human activities, particularly carbon dioxide emissions from use of fossil fuels (IPCC 2007, pp. 5–6; Solomon *et al*. 2007, pp. 21–35; Serreze 2010, pp. 11–13). Further confirmation of the role of GHGs comes from analyses by Huber and Knutti (2011, p. 4), who concluded it is extremely likely that approximately 75 percent of global warming since 1950 has been caused by human activities.

Scientists use a variety of climate models, which include consideration of natural processes and variability, as well as various scenarios of potential levels and timing of GHG emissions, to evaluate the causes of changes already observed and to project future changes in temperature and other climate conditions (Meehl *et al*. 2007, pp. 747–845; Ganguly *et al*. 2009, pp. 11555, 15558; Prinn *et al*. 2011, pp. 527, 529). All combinations of models and emissions scenarios yield very similar projections of increases in the most common measure of climate change, average global surface temperature (commonly known as global warming), until about 2030. Although projections of the magnitude and rate of warming differ after about 2030, the overall trajectory of all the projections is one of increased global warming through the end of this century, even for the projections based on scenarios that assume that GHG emissions will stabilize or decline. Thus, there is strong scientific support for projections that warming will continue through the 21st century, and that the magnitude and rate of change will be influenced substantially by the extent of GHG emissions (IPCC 2007, pp. 44–45; Meehl *et al*. 2007, pp. 760–764, 797–811; Ganguly *et al*. 2009, pp. 15555–15558; Prinn *et al*. 2011, pp. 527, 529).

Climate change is predicted to have several effects on cold water habitat including: (1) Increased water temperature; (2) decreased stream flow; (3) change in the hydrograph; and (4) increased frequency and severity of extreme events such as drought and fire (Stewart *et al*. 2005, pp. 1140–1154; Ficke *et al*. 2007, pp. 583–593; Bates *et al*. 2008, pp. 102–106; Webb *et al*. 2008, pp. 909–911; Williams *et al*. 2009, pp. 538–546; Kaushal *et al*. 2010, pp. 462–464; Wenger *et al*. 2011, pp. 14176–14178; Isaak *et al*. 2012, pp. 513–515). These effects are discussed below.

Increased Water Temperature

Recent literature has documented increases in stream temperatures across the globe (Bates *et al*. 2008, p. 36; Webb *et al*. 2008, pp. 909–911); however, the magnitude varies considerably due to the very complex and site-specific processes influencing water temperature (Poole and Berman 2001, pp. 789–792; Brown and Hannah 2008, pp. 960–965; Chu *et al*. 2008, pp. 301–307). It should be noted that all waterbodies will not be influenced by increasing air temperatures in the same way and a 1°C (1.8°F) increase in air temperature does not equate to a 1°C (1.8°F) increase in water temperature (Stefan and Preud'homme 1993, pp. 27–29; Poole and Berman 2001, pp. 789–792; van Vliet *et al*. 2011, pp. 12–14).

Several studies have modeled the effects of increased water temperatures due to climate change on North American salmonids (Keleher and Rahel 1996, pp. 4–5; Jager *et al*. 1999, pp. 232–236; Rahel 2002, pp. 100–103; Mohseni *et al*. 2003, pp. 398–405; Flebbe *et al*. 2006, pp. 1376–1378; Preston 2006, pp. 101–110; Rieman *et al*. 2007, pp. 1556–1558; Kennedy *et al*. 2009, pp. 508–511; Isaak *et al*. 2012, pp. 513–515). The extent of habitat predicted to become unsuitable for salmonids ranges from 17 to 97 percent, depending on various factors such as the magnitude of the temperature increase, which climate model is used, and the region of North America in which the species exists (Rahel 2002, pp. 100–103; Flebbe *et al*. 2006, pp. 1376–1378; Preston 2006, pp. 101–110; Rieman *et al*. 2007, pp. 1556–1558; Wenger *et al*. 2011, p. 14176). Additionally, these studies predict the loss of suitable habitat for salmonids, mainly at the southern extent of their range and at lower elevations.

Water temperature influences the survival and distribution of salmonids and all aquatic life (Allan 1995, p. 74). Alterations in the temperature regime from natural background levels can negatively affect population viability, when considered at the scale of the watershed or individual stream (McCullough 1999, p. 160). High temperatures can suppress appetite and growth (Meeuwig *et al.* 2004, pp. 211–212), influence behavioral interactions with other fish (De Staso and Rahel 1994, pp. 292–293), increase susceptibility to disease (McCullough 1999, pp. 104–116; Schisler *et al*. 2000, pp. 861–862), or be lethal (Dickerson and Vinyard 1999, p. 518). Salmonids inhabiting warm stream segments have higher probabilities of mortality due to stress (McCullough 1999, p. 156; Meeuwig *et al.* 2004, p. 214). All current PCT populations occur between 2,438 and 3,353 m (8,000 and 11,000 ft) in elevation, and thus, stream temperatures are not likely to exceed PCT's thermal tolerance levels.

Winter conditions can strongly influence survival of salmonids (Huusko *et al*. 2007, pp. 469–470; Brown *et al*. 2011, pp. 12–21). Impacts from stream freezing, anchor ice (submerged ice attached to the stream bottom), and frazil ice (ice crystals in the water column) have been shown to cause overwinter mortality in salmonids at all life stages; however, the egg and juvenile stages are most susceptible (Huusko *et al*. 2007, pp. 470–476; Brown *et al*. 2011, pp. 12–21). An important function in small streams is the insulating properties of snow when it completely covers the stream. Gard (1963, p. 196) found that diurnal air temperatures above the snow varied by nearly 35.4°C (64°F); however, below 483 mm (19 in) of snow, air temperatures varied only 1.2°C (2.25°F) and water temperatures varied 0.3°C (0.55°F). Berg (1994, p. 381) found extensive ice formation on streams in the Sierra Nevada during a particularly cold fall prior to any snowfall. Extensive ice formations were observed in Silver King Creek during January 2012 as there was no snow in the Sierra Nevada until mid-January (Natural Resources Conservation Service 2012, p. 1).

While disease is not currently a major threat to PCT (see Factor C above), increasing temperatures may cause higher stress levels which may increase their susceptibility to disease (McCullough 1999, pp. 104–105; Rahel *et al*. 2008, p. 555). Schisler *et al*. (2000, p. 861) performed laboratory experiments and found that mortality of rainbow trout due to whirling disease increased at higher temperatures. The authors also looked at the effects of adding multiple stressors in the presence of *Myxobolus cerebralis*, the parasite that causes whirling disease. As the number of stressors increased, mortality also increased (Schisler *et al*. 2000, p. 862). Other studies have found increased prevalence of *M. cerebralis* in wild salmonids as stream temperatures increased (Thompson *et al*. 1999, p. 318; de la Hoz Franco and Budy 2004, p. 1183).

Decreased Streamflow

Climate models are predicting an overall increase in precipitation over most of North America except for the southwestern United States (Christensen *et al.* 2007, p. 890). In western North America, the predicted increase in precipitation has a strong north-south orientation with higher predicted precipitation in northern latitudes and lower predicted precipitation at southern latitudes (Christensen *et al.* 2007, p. 890). For the Sierra Nevada there is much uncertainty on the effects of climate change on total precipitation (PRBO 2011, p. 18). Despite this uncertainty, there is greater predictability in terms of winter and spring warming which will cause an increased fraction of winter precipitation to come as rain, resulting in a reduced snowpack, an earlier snowmelt, decreased spring runoff, and reduced summer streamflows (Hayhoe *et al*. 2004, pp. 12425–12426; Stewart *et al.* 2005, pp. 1140–1144; Knowles *et al*. 2006, pp. 4548–4550, Bates *et al*. 2008, p. 102; PRBO 2011, pp. 19–24). Dettinger *et al*. (2004, p. 307) predict that by the last quarter of the century, the amount of average snowwater content in the Carson River drainage may be reduced by 67 percent. A reduction in streamflow will reduce the amount of PCT occupied habitat, particularly in high elevation headwater streams.

For salmonids and other aquatic organisms, flow regimes in streams and rivers determine the amount and availability of water, the types of micro- and macrohabitats, and the seasonal patterns of disturbance to aquatic communities (Swanston 1991, pp. 148–152; Spence *et al*. 1996, p. 92; Marchetti and Moyle 2001, pp. 537–538; Kiernan and Moyle 2012, p. 1158). Low flow conditions can reduce the amount of habitat available for juvenile refugia from predators, limit refugia suitable for avoidance of elevated water temperatures, reduce the availability of food which may affect growth (Harvey *et al*. 2006, p. 1002), and increase competition for space and food sources (Spence *et al*. 1996, p. 210). Reduced flows can strand fish in isolated pools, which increases their susceptibility to predation, disease, and extreme environmental conditions such as high temperatures and low dissolved oxygen (Spence *et al.* 1996, pp. 143–145). In addition, desiccation of recently spawned eggs or newly-hatched fry will occur if redds are no longer covered with water. During the summer of 2012, flows were so low in Upper Fish Valley, a fish rescue was performed in the side channel as it had been reduced to a few isolated pools (C. Mellison, Service, unpub. data).

Lower streamflows can alter the biotic composition, structure, and function of aquatic and riparian ecosystems (Richter *et al.* 1996, p. 1164; Poff *et al*. 1997, p. 769). Decreased flows can negatively affect intra- and inter-annual flows which are necessary for maintenance of many riparian plant species (Poff *et al*. 1997, p. 775), stream channel maintenance and development (Chavez 1996, p. 148; Ryan 1997, pp. 847–851), and the sustainability of the native biodiversity (Bain *et al.* 1988, pp. 389–390; Kiernan and Moyle 2012, p. 1158). Reduced flows during the summer months can increase water temperature (Gu and Li 2002, p. 54; van Vliet *et al*. 2011, pp. 6–18), reduce available habitat for aquatic species (Bjornn and Reiser 1991, p. 123), and stress riparian vegetation (Smith *et al.* 1991, pp. 95–96).

Change in Hydrograph

Changes in air temperature and precipitation will likely lead to changes in the magnitude, timing, and duration of runoff (Bates *et al*. 2008, p. 102). Stewart *et al.* (2005, pp. 1140–1144) report that spring streamflow during the last five decades has shifted so that the major peak now arrives 1–4 weeks earlier, resulting in declining fractions of flow in the spring and summer (see Decreased Streamflow above). Additionally, flooding events, particularly during the winter, are expected to increase (Hamlet and Lettenmaier 2007, pp. 14–17; Coats *et al*. 2013, pp. 64–65). The life history of salmonids is closely associated with flow regimes (Bjornn and Reiser 1991, pp. 87–90). Changes in the flow regime can have differential effects on species due to differences in their life history (Wenger *et al*. 2011, pp. 14176–14178 ; Kiernan and Moyle 2012, pp. 1150–1159). A change in timing or magnitude of floods can scour the streambed, destroy eggs, or displace recently emerged fry downstream (Erman *et al*. 1988, pp. 2197–2199; Kondolf *et al*. 1991, pp. 181–182; Wenger *et al*. 2011, p. 14176). Seegrist and Gard (1972, pp. 478–480) found decreased abundance of fall spawning brook trout during winter flood events and decreased abundance of spring spawning rainbow trout during spring flood events which were attributed to a reduction in recruitment success. Wenger *et al*. (2011, p. 14176) predict that fall spawning salmonids (*e.g.*, brook trout and brown trout) will be significantly more impacted by an increased frequency and magnitude of winter flood events as compared to spring spawning salmonids (e.g., rainbow and cutthroat). Since PCT spawn in the spring, any change in the timing, or magnitude of spring runoff could disrupt recruitment and survival.

Extreme Events

Natural disturbances have been and will continue to be important processes shaping aquatic habitat (Benson *et al*. 2002, p. 680; Benda *et al*. 2003, pp. 107–112; Germanoski and Miller 2004, pp. 110–117; Miller *et al*. 2004, pp. 49–83). Recovery of aquatic systems from disturbance varies with the severity, magnitude, frequency and type (*i.e.,* pulse or chronic), and availability of refugia (Niemi *et al*. 1990, pp. 573–585; Sedell *et al*. 1990, pp. 714–719; Magoulick and Kobza 2003, pp. 1186–1195). The frequency, severity, and magnitude of disturbances such as drought and fire are expected to increase with climate change (Westerling *et al*. 2006, pp. 941–942; Field *et al*. 2007, p. 627; Wehner *et al*. 2011, p. 1374).

<u>Drought</u>

Drought has been an important natural disturbance in the western United States since the early Holocene (Cook *et al*. 2004, p. 1017; Mensing *et al*. 2004, pp. 31–37; Yuan *et al*. 2004, pp. 7–9). Cook *et al*. (2004, p. 1016) report the percentage of the western United States in drought conditions has gradually increased over the last century and that the current drought rivals the drought conditions in the 1930's; however, these more recent droughts (*i.e.*, in the last century) pale in comparison to conditions found 700–1,100 years before present in terms of duration and severity. Century-long drought conditions have been determined with pollen records throughout the western portion of the Great Basin with drought termination dates at approximately 1,800, 1,200, 800, and 550 years before present (Mensing *et al*. 2008, p. 85). These historical drought conditions likely negatively impacted PCT. However, despite these severe recurring drought conditions, the PCT population in Silver King Creek was able to persist due to the size of the Silver King Creek drainage, the size of the population, and the quality and distribution of habitat (Lake 2003, pp. 1166–1167; Wilcox *et al*. 2006, p. 859).

Drought-related effects can impact many different scales of organizational complexity, including effects to individuals, local populations, local fish assemblages, metapopulations, watershed or regional faunas, ecosystems, and evolutionary impacts (Labbe and Fausch 2000, pp. 1784–1788; Lake 2003, pp. 1164–1166; Matthews and Marsh-Matthews 2003, p. 1234). In a review of 50 different studies on drought-related impacts to fish, Matthews and Marsh-Matthews (2003, p. 1237) reported the most common impacts were decreases in numbers at the population and community level, loss of habitat, poor water quality (*i.e.,* hypoxia and temperature), decreased ability for movement, crowding, and desiccation. The authors also noted that studies of the effects of drought have occurred on a local scale but that large spatial studies incorporating metapopulations dynamics were lacking (Matthews and Marsh-Matthews 2003, p. 1236).

Small streams are more susceptible than larger streams to drying, increased stream temperatures during the summer, and freezing during the winter (Lake 2003, pp. 1163–1164). Although not all small streams have equal risk from drought (*i.e.*, spring-dominated flow has less risk than snowmelt-dominated flow), small headwater streams, especially those with an inadequate number of deep pools, are most likely to lose suitable habitat (Lake 2003, pp. 1163–1164). However, functioning small streams with good quality habitat (*e.g.*, deep pools) and limited anthropogenic influences can sustain salmonids during drought conditions (Magoulick and Kobza 2003, pp. 1186–1195; White and Rahel 2008, p. 891). Since PCT populations are small and isolated, any reduction in population size due to drought can also reduce genetic diversity and fitness (Rutledge *et al.* 1990, pp. 215–216; Faber *et al*. 2000, pp. 1470–1471).

<u>Fire</u>

Fire has been one of the dominant factors shaping ecosystems for millennia (Skinner and Chang 1996, p. 1041; Van Wagtendonk and Fites-Kaufman 2006, p. 270). Median fire return intervals in eastside Sierra Nevada forests where PCT reside are believed to be 8–16 years with a range of 5–47 years (Skinner and Chang 1996, p. 1056; Van Wagtendonk and Fites-Kaufman 2006, pp. 288–289; North *et al*. 2009, pp. 25–30; Van de Water and North 2010, pp. 388–391). In this fire regime type the following effects occur: (1) Fire controls plant species composition by favoring species that require sunlight (*e.g*., Jeffrey pine (*Pinus jeffreyi*) over shade-tolerant forms such as white fir (*Abies concolor*)), and by favoring fire-resistant and fire-dependent species over non-fire dependent species; (2) fire consumes understory vegetation without damaging the overstory; (3) crown fires are rare and patchy; and (4) small patches of intense surface burning often result in openings (Chang 1996, pp. 1071–1072).

Changes in historical fire regimes are well documented in the western United States (McKelvey *et al*. 1996, pp. 1033–1039; Arno 2000, pp. 100–105; Stephens and Sugihara 2006, pp. 431–441; Richardson *et al*. 2007, pp. 277–278; Brooks 2008, pp. 33–45; Van de Water and North 2011, pp. 222–226). Around the late 1800's, high-frequency, low-intensity fire regimes associated with dry forest types, as found in the eastern Sierra Nevada, began having longer fire return intervals due to: (1) Relocation of Native Americans which disrupted their historical burning practices; (2) loss of fine fuels, which carried low-intensity ground fires, due to extensive overgrazing; (3) disruption of fuel continuity on the landscape due to irrigation, agriculture, and development; and (4) fire exclusion management policies (Arno 2000, pp. 100–101; Keane *et al.* 2002, pp. 1–2). Effects from the post-Euroamerican settlement influence on fire regimes include longer fire return intervals which allow fuel loads to increase. In return, relatively small, low-intensity ground fires have become uncharacteristically large, stand-replacing fires (Arno 2000, p. 101; Miller *et al*. 2009, pp. 22–30; Miller and Safford 2012, pp. 45–54).

Changing climate has affected summer temperatures and the timing of spring snowmelt, which have contributed to increasing the length of the wildfire season, wildfire frequency, and the size of wildfires (McKenzie *et al*. 2004, pp. 893–897; Westerling *et al*. 2006, p. 941; Miller *et al*. 2009, pp. 22–30). Westerling *et al.* (2006, p. 942) conclude that there are robust statistical associations between wildfire and climate in the western United States and that increased fire activity over recent decades reflects responses to climate change. Miller *et al*. (2009, pp. 22–30) studied the frequency, severity, and size of fires in the Sierra Nevada forests and found that all three parameters are increasing. Although PCT evolved in a fire-prone environment, increases in wildfire frequency, size, and severity due to increased fuel loads and effects from climate change (Westerling *et al*. 2006, p. 942; Miller *et al*. 2009; p. 26) have increased the threats due to wildfire. Wildfires are a larger threat to PCT because of the current fragmented and isolated state of occupied habitat (Haak *et al*. 2010, p. 47)

Fish mortalities can occur from increases in water temperatures which exceed lethal levels, fire induced changes in pH, increased ammonia levels from smoke gases absorbed into surface waters, and increased phosphate levels leached from ash (Brown 1989, pp. 107–108; Spencer and Hauer 1991, pp. 26–29; Rinne 1996, pp. 654–657; Rieman and Clayton 1997, pp. 51–53; Gresswell 1999, pp. 194–199; Earl and Blinn 2003, pp. 1020–1028; Ranalli 2004, pp. 1–21; Neary *et al*. 2005, pp. 119–134). Studies have shown that post-fire hydrologic events can severely reduce or extirpate local fish populations (Novak and White 1990, pp. 122–123; Propst *et al*. 1992, p. 120; Bozek and Young 1994, p. 92; Rinne 1996, p. 654; Rieman *et al*. 1997, pp. 50–53; Burton 2005, pp.142–148; Sestrich *et al*. 2011, pp. 139–140). Recolonization rates depend on the proximity and relative location of refugia, access from refugia to disturbed areas (*i.e*., no fish barriers), presence of nonnative fish, and interactions with complex life history traits and overlapping generations (Gresswell 1999, p. 210; Dunham *et al*. 2003, pp. 185–186; Howell 2006, pp. 990–993; Dunham *et al*. 2007, pp. 340–344; Neville *et al*. 2009, pp. 1321–1324; Sestrich *et al*. 2011, pp. 143–144). Isolated fish populations are at a much higher risk of extinction because they cannot recolonize after a large disturbance (Rinne 1996, p. 656; Dunham *et al*. 1997, p. 1131; Dunham *et al.* 2003, pp. 187–189; Burton 2005, pp.142–148; Dunham *et al*. 2007, pp. 340–344; Williams *et al.* 2009, pp. 543–546). Additionally, effects on small headwater streams are more severe because larger proportions of the drainage are burned at these smaller spatial scales, in contrast to larger stream orders, where relatively small proportions of the drainage burn (Romme *et al*. 2011, pp. 1204–1205; Sestrich *et al*. 2011, p. 143). All occupied PCT habitat is located in the headwaters of each watershed.

Haak *et al*. (2010, pp. 1–67) analyzed the potential cumulative impacts of increased stream temperatures, winter flooding, wildfire, and drought on the persistence of 10 native salmonids in the western United States, including Lahontan cutthroat trout, a closely-related subspecies to PCT. While PCT were not included in the study, we have used the results for Lahontan cutthroat trout from the Sierra Nevada portion of its range as a surrogate for PCT since similar Lahontan cutthroat trout occupied habitat surrounds the Silver King Creek drainage. The primary climate risk factors for Lahontan cutthroat trout populations in the Sierra Nevada are from winter flooding and wildfires while drought and increased stream temperatures were low to moderate risk (Haak *et al*. 2010, pp. 44–48).

Climate Change Summary

The impacts to PCT from climate change are not known with certainty. Predicted outcomes of climate change imply that negative impacts will occur through increased stream temperatures, decreased stream flow, changes in the hydrograph, and increased frequency of extreme events. Water temperatures are expected to increase in the future; however, all occupied PCT habitat is located above 2,438 m (8,000 ft) and thus, stream temperatures are not likely to rise above critical thresholds. Rising stream temperatures may increase their susceptibility to various diseases which are not current threats. Reductions in streamflow through changes in the hydrograph and drought are predicted to have a negative impact on PCT populations because of the fragmented nature of PCT populations, the small size of occupied stream habitats, and the close association of recruitment and survival to stream flow. Although PCT evolved in a fire-prone environment, increases in wildfire frequency and severity due to increased fuel loads and effects from climate change (Westerling *et al*. 2006, p. 941) have increased the threats due to wildfire. Current wildfires are a larger threat to PCT because of the current fragmented and isolated state of occupied habitat (Haak *et al*. 2010, p. 47). These impacts associated with climate change will likely intensify the threats to PCT previously described under Factor A. Climate change impacts were not evaluated in our 2008 5-year review; however in light of the above considerations, we now conclude climate change is likely a threat to PCT.

III. RECOVERY CRITERIA

Recovery plans provide guidance to the Service, States, 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 2004 PCT Revised Recovery Plan identifies criteria that must be met before the subspecies can be delisted (Service 2004, pp. 49–52). The Service is currently using these criteria to guide recovery activities. The recovery criteria, as presented in the 2004 PCT Revised Recovery Plan, are summarized below.

> The objective of this recovery plan is to recover PCT by improving its status and habitat and eliminating nonnative salmonids so it can be delisted. Criteria for accomplishing the goal of delisting are:
>
> 1. All nonnative salmonids are removed from Silver King Creek and its tributaries downstream of Llewellyn Falls to fish barriers in Silver King Canyon;
>
> 2. A viable population occupies all historical habitat in Silver King Creek and its tributaries downstream of Llewellyn Falls to fish barriers in Silver King Canyon;
>
> 3. PCT is maintained in all occupied streams;
>
> 4. The refuge populations in Corral and Coyote Creeks, Silver King Creek, and tributaries above Llewellyn Falls as well as out-of-basin populations are maintained as refugia and are secured from the introduction of other salmonid species; and
>
> 5. A long-term conservation plan and conservation agreement are developed, which will be the guiding management documents once PCT are delisted.
>
> The primary threat to PCT is hybridization with nonnative trout, compounded by its extremely limited distribution (making it vulnerable to catastrophic events). Consequently, it is critical to remove nonnative trout from the historical range downstream of Llewellyn Falls and reestablish PCT populations there, monitoring population abundance and genetics to evaluate success. Reinvasion of PCT habitat by nonnative trout should be prevented by monitoring or establishing instream barriers and discouraging deliberate introductions. Because PCT are vulnerable to angling pressure, appropriate fishing regulations and closures should be maintained and enforced by a stream guard and signage. Potential habitat degradation should be addressed by appropriate fish habitat improvement actions, including management of recreational

access and grazing, and control of beaver populations as necessary. The recovery criteria above should be met by addressing these threats, as detailed below.

Meeting the first and second recovery criteria will secure long-term protection and population viability of PCT by their expansion within their native range. This range expansion will be accomplished by removing nonnative trout from the Silver King Creek drainage from Llewellyn Falls downstream to the Silver King Canyon, including tributaries, followed by reintroduction with PCT from donor tributaries best suited as determined by genetic testing (Israel *et al*. 2002, p. 13). A viable population will be achieved when the population is secure and comprises three or more age classes for 5 years, and consists of a minimum of 2,500 fish greater than 75 millimeters (3 inches) (Hilderbrand and Kershner 2000, p. 515). This figure is a preliminary estimate and may need to be revised as additional information becomes available. Population estimates will be made during the nonnative fish eradication. This estimate will be used as a surrogate to help us understand the population size of PCT that will be expected within the historical range and aid in validating the minimum number needed for recovery. Once this estimate is made, population data from above Llewellyn Falls will be used to estimate a range in the population size that can be expected due to inherent natural fluctuations.

Since the last 5-year review in 2008, nonnative salmonids still occupy all historical PCT habitat. Management agencies have been trying to implement the Paiute Cutthroat Trout Restoration Project, which would implement Recovery Criteria 1 and 2; however, legal challenges have stalled the project. A joint Environmental Impact Statement/Environmental Impact Report (Service and California Department of Fish and Game 2010, pp. 1–284) has been published and upheld in court; however, the project has been enjoined since 2010 due to Wilderness Act compliance (U.S. District Court 2011, pp. 1–63). The USFS submitted a revised Minimum Requirements Decision Guide to comply with the Court and on May 13, 2013, U.S. District Court for the Eastern District of California dissolved the injunction allowing the agencies to move forward with project implementation (U.S. District Court 2013, pp. 1–2).

The third recovery criterion is to maintain suitable habitat for PCT. Historical and occupied PCT stream and riparian habitat should have no degradation from existing conditions due to anthropogenic effects. The condition of existing habitat will be identified using established stream habitat monitoring protocols which use measurable and repeatable methods. Beaver control will need to be conducted in the event that they repopulate the drainage. To secure the protection of the North Fork Cottonwood population, a second barrier will be needed to protect the population from the introduction of nonnative trout species from downstream. Cabin Creek is within an active grazing allotment where continued management will be necessary to ensure degradation of PCT habitat does not occur. Stairway and Sharktooth Creeks are subject to limited human disturbance since they are in designated wilderness areas, are inaccessible to livestock, and get limited recreational use. Therefore, habitat monitoring should be done periodically to document stochastic events such as a rain on snow event which occurred in 1997.

Since 2008 several projects have been implemented for Recovery Criteria 3. To protect PCT habitat, the Humboldt-Toiyabe National Forest closed the Silver King Allotment to all livestock grazing and the Inyo National Forest implemented strict grazing levels for the Indian Creek Allotment which encompasses Cabin Creek. The Inyo National Forest also conducted a gravel augmentation project to improve spawning habitat in North Fork Cottonwood Creek. All populations have been visited at least once since 2008 and no habitat related concerns have been documented.

The fourth recovery criterion is to protect and enhance PCT that do not occupy historic habitat. To protect against a catastrophic event that could affect the entire Silver King Creek gene pool, populations in Corral Valley and Coyote Valley Creeks, Silver King Creek and tributaries (Four Mile Canyon, Fly Valley, and Bull Canyon Creeks) above Llewellyn Falls, and the four out-of-basin populations must be maintained as Paiute cutthroat trout refugia. Monitoring these populations will aid in management decisions aimed to maintain and improve the abundance of PCT and collection of long-term trend data. Continued genetic monitoring of all populations of PCT will be used to: (1) monitor population genetic diversity, (2) evaluate effective population size and reproductive isolation, (3) examine populations for evidence of hybridization, and (4) identify appropriate donor sources.

Since 2008, all populations have been monitored at least once (Figures 5–13). Genetic material has also been collected from all populations for hybridization analysis and conservation genetic analyses. See Species-specific Research and/or Grant-supported Activities above.

The fifth and final criterion is to develop a long-term conservation plan and conservation agreement that will guide the agencies responsible for the management of PCT after it is delisted. The purpose of the conservation plan is to ensure that adequate regulatory mechanisms and management programs remain in existence after delisting to ensure that all populations of PCT and their habitat are maintained. The conservation plan will be consistent with other existing cutthroat trout subspecies conservation plans. The purpose of the conservation agreement is to define the role of the management agencies and to document their commitment to implementing the conservation plan. The conservation plan and conservation agreement will need to be approved and signed by all responsible agencies before delisting occurs.

No work has occurred on Recovery Criteria 5 since 2008.

Recovery efforts as outlined in the Revised Recovery Plan continue to be implemented. Legal challenges continue to slow our progress in conducting Recovery Criteria 1 and 2; however, management agencies continue to seek approval from the courts. Anthropogenic impacts to PCT habitat are negligible at this time; conditions seem to be stable or improving. Populations are monitored at adequate frequencies and intensities for management decisions. We continue to support and implement the recovery criteria outlined in the Revised Recovery Plan.

IV. SYNTHESIS

All PCT populations are isolated and confined to small habitat patches. These factors reduce gene flow between populations, and reduce the ability of populations to recover from extreme events thus threatening their long-term persistence and viability. The literature suggests that to ensure long-term persistence, populations should consist of more than 2,500 individuals, occupy at least 9.3 km (5.8 mi) of habitat, and have no nonnative species present. Currently no population meets the minimum population size or minimum habitat size, and all populations have hybridizing species immediately downstream of occupied habitat.

Overutilization, disease, and predation are not believed to be significant threats at this time.

The ESA is the primary Federal law that provides protection for PCT since its listing as threatened in 1975. Other Federal and State regulatory mechanisms provide discretionary protections for the species based on current management direction, but do not guarantee protection for the species absent its status under the ESA. The ESA provides adequate protection for PCT at this time.

The impacts to PCT from climate change are not known with certainty. Predicted outcomes of climate change imply that negative impacts will occur through increased stream temperatures, decreased streamflow, changes in the hydrograph, and increased frequency of extreme events such as drought and fire. These impacts will likely increase the magnitude and severity of other existing threats to PCT. Adding stressors predicted by climate change may exacerbate the current threats to PCT populations throughout its range, many of which already have multiple stressors affecting their persistence.

We conclude that PCT still meets the definition of threatened throughout its range. Paiute cutthroat trout populations are small and isolated which increases their risk of extinction. All currently occupied habitats have hybridizing species found downstream from fish migration barriers, and no population meets long-term persistence criteria. The only habitat patch which meets minimum stream length criteria for long-term persistence is the historical range in Silver King Creek which is currently occupied by nonnative rainbow trout.

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

VI. RECOMMENDATIONS FOR ACTIONS OVER THE NEXT 5 YEARS

1. **Implement the Paiute Cutthroat Trout Restoration Project.**
   Recent legal challenges to project implementation have been dismissed; therefore, project implementation is moving forward in 2013. Implementation will fulfill Recovery Criteria 1 and 2 in the Revised Recovery Plan (Service 2004, pp. 49–50).

2. **Develop a genetics management plan.**
   A genetics management plan will help the agencies make decisions regarding the management of PCT. Conservation genetics plays a vital role in the management of PCT, in particular, testing for hybridization, evaluating donor populations, and maintaining genetic diversity of extant populations. A genetics management plan will help fulfill Recovery Criteria 1, 2, 3, 4, and 5.

3. **Reevaluate habitat conditions in Silver King Creek.**
   Habitat monitoring was conducted in the late 1980's, 1990's, and early 2000's by agency researchers (Duff 1991, pp. 1–11; Overton *et al*. 1994, pp. 1–27; Flint 2004, pp. 1–14). Valuable baseline habitat information was collected at this time. Changes in habitat have been occurring since cessation of livestock grazing in 1995. Documenting changes in habitat will help fulfill Recovery Criteria 3 in the Revised Recovery Plan (Service 2004, pp. 49, 51).

4. **Improve population estimates in Silver King Creek drainage.**
   Population estimates for PCT are routinely conducted in low stream gradient meadow habitat. Fish densities are known to decrease in higher gradient portions of occupied streams but the extent of this decrease is unknown. To better understand population dynamics in all habitat types of Silver King Creek and its tributaries, population monitoring should also include higher gradient sections. A better understanding of population dynamics will help fulfill Recovery Criteria 2.

VII. REFERENCES CITED

Ainslie, B.J., J.R. Post, and A.J. Paul. 1998. Effects of pulsed and continuous DC electrofishing on juvenile rainbow trout. North American Journal of Fisheries Management 18:905–918.

Alexiades, A.V. 2010. Movement patterns, habitat use, and survivorship of Lahontan cutthroat trout (*Oncorhynchus clarkii henshawi*) in the Truckee River. M.S. Thesis. University of Nevada, Reno. 48 pp.

Allan, J.D. 1995. Stream Ecology: Structure and Function of Running Waters. Chapman and Hall, New York. 388 pp.

Ambruzs, S.L. 2008. Winter movement of Lahontan cutthroat trout in Marys River, Nevada. M.S. Thesis. University of Nevada, Reno. 43 pp.

Arno, S.F. 2000. Fire in western forest ecosystems. Pages 97–120 in K.J. Brown and J.K. Smith (editors), Wildland fire and ecosystems: effects of fire on flora. General Technical Report RMRS-GTR-42-volume 2. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 257 pp.

Ashley, R.R. 1970. Habitat management plan - Paiute trout. Toiyabe National Forest, Reno, Nevada. 19 pp.

Bain, M.B., J.T. Finn, and H.E. Brooke. 1988. Streamflow regulation and fish community structure. Ecology 69:382–392.

Baltz, D.M., B. Vondracek, L.R. Brown, and P.B. Moyle. 1991. Seasonal changes in microhabitat selection by rainbow trout in a small stream. Transactions of the American Fisheries Society 120:166–176.

Bates, B.C., Z.W. Kundzewicz, S. Wu, and J.P. Palutikof (editors). 2008. Climate change and water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva. 210 pp.

Baxter, C.V., K.D. Fausch, and W.C. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. Freshwater Biology 50:201–220.

Beechie, T., H. Moir, and G. Pess. 2008. Hierarchical physical controls on salmonid spawning location and timing. Pages 83–101 in D.A. Sear and P. DeVries (editors), Salmonid spawning habitat in rivers: physical controls, biological responses, and approaches to remediation. American Fisheries Society Symposium 65, Bethesda, Maryland.

Behnke, R.J. 1979. Monograph of the native trouts of the genus *Salmo* of western North America. U.S. Department of Agriculture, Forest Service, Lakewood, Colorado. 215 pp.

Behnke, R.J. 1987. The Paiute cutthroat trout. Pages 539–545 in R.L. Di Silvestro, W.J. Chandler, K. Barton, and L. Labate (editors), Audubon Wildlife Report 1987. National Audubon Society, Academic Press, New York, New York.

Behnke, R.J. 1992. Native trout of Western North America. American Fisheries Society Monograph 6. 275 pp.

Behnke, R.J., and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. General Technical Report GTR-RM-28. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experimental Station. 45 pp.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54:419–431.

Benda, L., D. Miller, P. Bigelow, and K. Andras. 2003. Effects of post-wildfire erosion on channel environments, Boise River, Idaho. Forest Ecology and Management 178:105–119.

Benson, L., M. Kashgarian, R. Rye, S. Lund, F. Paillet, J. Smoot, C. Kester, S. Mensing, D. Meko, and S. Lindström. 2002. Holocene multidecadal and multicentenial droughts affecting Northern California and Nevada. Quaternary Science Reviews 21:659–682.

Berg, N.H. 1994. Ice in stream pools in California's central Sierra Nevada: spatial and temporal variability and reduction in trout habitat availability. North American Journal of Fisheries Management 14:372–384.

Bjornn, T.C., and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. Pages 83–138 in W.R. Meehan (editor), Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Symposium 19, Bethesda, Maryland.

Boyer, M.C., C.C. Muhlfeld, and F.W. Allendorf. 2008. Rainbow trout (*Oncorhynchus mykiss*) invasion and the spread of hybridization with native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). Canadian Journal of Fisheries and Aquatic Sciences 65:658–669.

Bozek, M.A., and F.J. Rahel. 1991. Comparison of streamside visual counts to electrofishing estimates of Colorado River cutthroat trout fry and adults. North American Journal of Fisheries Management 11:38–42.

Bozek, M.A., and M.K. Young. 1994. Fish mortality resulting from delayed effects of fire in the Greater Yellowstone Ecosystem. Great Basin Naturalist 54:91–95.

Brooks, M.L. 2008. Plant invasions and fire regimes. Pages 33–45 in K. Zouhar, J.K. Smith, S. Sutherland, and M.L. Brooks (editors), Wildland fire in ecosystems: fire and nonnative invasive plants. General Technical Report RMRS-GTR-42-volume 6. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 355 pp.

Brown, J.K. 1989. Effects of fire on streams. Pages 106–110 in F. Richardson, and R.H. Hamre (editors), Wild Trout IV: proceedings of the symposium. U.S. Government Printing Office, Washington, D.C.

Brown, L.E., and D.M. Hannah. 2008. Spatial heterogeneity of water temperature across an alpine river basin. Hydrological Processes 22:954–967.

Brown, R.S., W.A. Hubert, and S.F. Daly. 2011. A primer on winter, ice, and fish: what fisheries biologists should know about winter ice processes and stream-dwelling fish. Fisheries 36:8–26.

Burton, T.A. 2005. Fish and stream habitat risks from uncharacteristic wildfire: observations from 17 years of fire-related disturbances on the Boise National Forest, Idaho. Forest Ecology and Management 211:140–149.

Busack, C.A., and G.A.E. Gall. 1981. Introgressive hybridization in populations of Paiute cutthroat trout (*Salmo clarki seleniris*). Canadian Journal of Fisheries and Aquatic Sciences 38:939–951.

Cambray, J.A. 2003. The global impact of alien trout species- a review; with reference to their impact in South Africa. African Journal of Aquatic Science 28:61–67.

Carline, R.F. 2001. Effects of high-frequency pulsed-DC electrofishing on a wild brown trout population. North American Journal of Fisheries Management 21:571–579.

Chang, C. 1996. Ecosystem responses to fire and variations in fire regimes. Pages 1071–1099 in Sierra Nevada Ecosystem Project: Final Report to Congress, volume II, Assessments and scientific basis for management options. University of California, Centers for Water and Wildland Resources, Davis.

Chavez, L. 1996. Above-below diversion study. Pages 145–150 in D. Neary, K. Ross, and S. Coleman (editors), National Hydrology Workshop Proceedings; 1992 April 27–May 1; Phoenix, Arizona. General Technical Report RM–GTR–279. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Cho, G.K., J.W. Heath, and D.D. Heath. 2002. Electroshocking influences Chinook salmon egg survival and juvenile physiology and immunology. Transactions of the American Fisheries Society 131:224–233.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Lapriee, V. Magaňa Rueda, L. Mearne, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr, and P. Whetton. 2007. Regional climate projections in Climate Change 2007: The Physical Science Basis. Pages 847–940 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (editors), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Chu, C., N.E. Jones, N.E. Mandrak, A.R. Piggott, and C.K. Minns. 2008. The influence of air temperature, groundwater discharge, and climate change on the thermal diversity of stream fishes in southern Ontario watersheds. Canadian Journal of Fisheries and Aquatic Sciences 65:297–308.

Coats, R., M. Costa-Cabral, J. Riverson, J. Reuter, G. Sahoo, G. Schladow, and B. Wolfe. 2013. Projected 21st century trends in hydroclimatology of the Tahoe Basin. Climatic Change 116:51–69.

Cook, E.R., C.A. Woodhouse, C.M. Eakin, D.M. Meko, and D.W. Stahle. 2004. Long-term aridity changes in the western United States. Science 306:1015–1018.

Cook, N., F.J. Rahel, and W.A. Hubert. 2010. Persistence of Colorado River cutthroat trout populations in isolated headwater streams of Wyoming. Transactions of the American Fisheries Society 139:1500–1510.

Colyer, W.T., J.L. Kershner, and R.H. Hilderbrand. 2005. Movements of fluvial Bonneville cutthroat trout in the Thomas Fork of the Bear River, Idaho-Wyoming. North American Journal of Fisheries Management 25:954–963.

Cordes, J.F., J.A. Israel, and B. May. 2004. Conservation of Paiute cutthroat trout: the genetic legacy of population transplants in an endemic California salmonid. California Fish and Game 90:101–118.

Crawford, S.S., and A.M. Muir. 2008. Global introductions of salmon and trout in the genus *Oncorhynchus*: 1870–2007. Reviews in Fish Biology and Fisheries 18:313–344.

Cucherousset, J., and J.D. Olden. 2011. Ecological impacts of nonnative freshwater fishes. Fisheries 36:215–230.

Cunjak, R.A. 1996. Winter habitat of selected stream fishes and potential impacts from land-use activity. Canadian Journal of Fisheries and Aquatic Sciences 53 (Supplement 1):267–282.

Dalbey, S.R., T.E. McMahon, and W. Fredenberg. 1996. Effect of electrofishing pulse shape and electrofishing-induced spinal injury on long-term growth and survival of wild rainbow trout. North American Journal of Fisheries Management 16:560–569.

de la Hoz Franco, E.A., and P. Budy. 2004. Linking environmental heterogeneity to the distribution and prevalence of *Myxobolus cerebralis*: a comparison across sites in a northern Utah watershed. Transactions of the American Fisheries Society 133:1176–1189.

Dettinger, M.D., D.R. Cayan, M.K. Meyer, and A.E. Jeton. 2004. Simulated hydrologic responses to climate variations and change in the Merced, Carson, and American River Basins, Sierra Nevada, California, 1900–2099. Climatic Change 62:283–317.

De Staso, J., and F.J. Rahel. 1994. Influence of water temperature on interactions between juvenile Colorado River cutthroat trout and brook trout in a laboratory stream. Transactions of the American Fisheries Society 123:289–297.

Diana, J.S., and E.D. Lane. 1978. The movement and distribution of Paiute cutthroat trout, *Salmo clarki seleniris*, in Cottonwood Creek, California. Transactions of the American Fisheries Society 107:444–448.

Dickerson, B.R., and G.L. Vinyard. 1999. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. Transactions of the American Fisheries Society 128:516–521.

Dobkin, D.S., A.C. Rich, and W.H. Pyle. 1998. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern Great Basin. Conservation Biology 12:209–221.

Duff, D.A. 1989. General Aquatic Wildlife System (GAWS). Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Region. 26 pp.

Duff, D.A. 1991. Functional Assistance Trip Report-1991 Monitoring of Paiute Cutthroat in Silver King Creek Drainage, Carson Ranger District, Toiyabe National Forest. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Region. 11 pp.

Dunham, J.B., G.L. Vinyard, and B.E. Rieman. 1997. Habitat fragmentation and extinction risk of Lahontan cutthroat trout. North American Journal of Fisheries Management 17:1126–1133.

Dunham, J.B., M. Young, and R.E. Gresswell. 2003. Effects of fire on fish populations: landscape perspectives on persistence of native fishes and non-native fish invasions. Forest Ecology and Management 178:183–196.

Dunham, J.B., A.E. Rosenberger, C.H. Luce, and B.E. Rieman. 2007. Influences of wildfire and channel reorganization on spatial and temporal variation in stream temperature and the distribution of fish and amphibians. Ecosystems 10:335–346.

Dwyer, W.P., W. Fredenberg, and D.A. Erdahl. 1993. Influence of electroshock and mechanical shock on survival of trout eggs. North American Journal of Fisheries Management 13:839–843.

Dwyer, W.P., and D.A. Erdahl. 1995. Effects of electroshock voltage, wave form, and pulse rate on survival of cutthroat trout eggs. North American Journal of Fisheries Management 15:647–650.

Dwyer, W.P., and R.G. White. 1995. Influence of electroshock on short-term growth of adult rainbow trout and juvenile arctic grayling and cutthroat trout. North American Journal of Fisheries Management 15:148–151.

Earl, S.R., and D.W. Blinn. 2003. Effects of wildfire ash on water chemistry and biota in south-western U.S.A. streams. Freshwater Biology 48:1015–1030.

Erman, D.C., E.D. Andrews, and M. Yoder-Williams. 1988. Effects of winter floods on fishes in the Sierra Nevada. Canadian Journal of Fisheries and Aquatic Sciences 45:2195–2200.

Faber, J.E., and M.M. White. 2000. Comparison of gene flow estimates between species of darters in different streams. Journal of Fish Biology 57:1465–1473.

Fagan, W.F. 2002. Connectivity, fragmentation, and extinction risk in dendritic metapopulations. Ecology 83:3243–3249.

Fahrig, L. 2002. Effect of habitat fragmentation on the extinction threshold: a synthesis. Ecological Applications 12:346–353.

Fausch, K.D., and M.K. Young. 1995. Evolutionary significant units and movement of resident stream fishes: a cautionary tale. American Fisheries Society Symposium 17:360–370.

Ficke, A.D., C.A. Myrick, and L.J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries 17:581–613.

Field, C.B., L.D. Mortsch, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. Pages 617–652 in M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (editors), Climate change 2007: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom.

Finger, A., M. Stephens, N.W. Clipperton, and B. May. 2009. Six diagnostic single nucleotide polymorphism markers for detecting introgression between cutthroat and rainbow trouts. Molecular Ecology Resources 9:759–763.

Finger, A.J., E.C. Anderson, M.R. Stephens, and B.P. May. 2011. Application of a method for estimating effective population size and admixture using diagnostic single nucleotide polymorphisms (SNPs): implications for conservation of threatened Paiute cutthroat trout (*Oncorhynchus clarkii seleniris*) in Silver King Creek, California. Canadian Journal of Fisheries and Aquatic Sciences 68:1369–1386.

Finlayson, B.J., W.L. Somer, and M.R. Vinson. 2010. Rotenone toxicity to rainbow trout and several mountain stream insects. North American Journal of Fisheries Management 30:102–111.

Flebbe, P.A., L.D. Roghair, and J.L. Bruggink. 2006. Spatial modeling to project southern Appalachian trout distribution in a warmer climate. Transactions of the American Fisheries Society 135:1371–1382.

Flint, R.A. 2004. Cross-section surveys in Silver King Creek, Alpine County, California. California Department of Fish and Game File Report. 14 pp. + appendices.

Frankham, R. 2005. Genetics and extinction. Biological Conservation 126:131–140.

Ganguly, A., K. Steinhaeuser, D. Erickson, M. Branstetter, E. Parish, N. Singh, J. Drake, and L. Buja. 2009. Higher trends but larger uncertainty and geographic variability in 21st century temperature and heat waves. Proceedings of the National Academy of Sciences 106:15555–15559.

Gard. R. 1963. Insulation of a Sierra stream by snow cover. Ecology 44:194–197.

Gatz, A.J., Jr., J.M. Loar, and G.F. Cada. 1986. Effects of repeated electroshocking on instantaneous growth of trout. North American Journal of Fisheries Management 6:176–182.

General Accounting Office (GAO). 1988. Public rangelands: some riparian areas restored but widespread improvements will be slow. Report to Congress GA/RCED–88–105. Resources, Community, and Economic Development Division, Washington, DC. 85 pp.

Germanoski, D., and J.R. Miller. 2004. Basin sensitivity to channel incision in response to natural and anthropogenic disturbance. Pages 88–123 in J.C. Chambers, and J.R. Miller (editors), Great Basin Riparian Ecosystems: Ecology, Management, and Restoration. Island Press, Washington DC.

Gregory, J.S., and B.L. Gamett. 2009. Cattle trampling of simulated bull trout redds. North American Journal of Fisheries Management 29:361–366.

Gresswell, R.E. 1999. Fire and aquatic ecosystems in forested biomes of North America. Transactions of the American Fisheries Society 128:193–221.

Gu, R.R., and Y. Li. 2002. River temperature sensitivity to hydrolic and meteorological parameters. Journal of Environmental Management 66:43–56.

Guy, T.J., R.E. Gresswell, and M.A. Banks. 2008. Landscape-scale evaluation of genetic structure among barrier-isolated populations of coastal cutthroat trout, *Oncorhynchus clarkii clarkii*. Canadian Journal of Fisheries and Aquatic Sciences 65:1749–1762.

Haak, A.L., J.E. Williams, D. Isaak, A. Todd, C. Muhlfeld, J.L. Kershner, R. Gresswell, S. Hostetler, and H.M. Neville. 2010. The potential influence of changing climate on the persistence of salmonids of the inland west. U.S. Geological Survey Open File Report 2010–1236. 74 pp.

Habera, J.W., R.J. Strange, B.D. Carter, and S.E. Moore. 1996. Short-term mortality and injury of rainbow trout caused by three-pass AC electrofishing in a southern Appalachian stream. North American Journal of Fisheries Management 16:192–200.

Habera J.W., R.J. Strange, and A.M. Saxton. 1999. AC electrofishing injury of large brown trout in low-conductivity streams. North American Journal of Fisheries Management 19:120–126.

Hamlet, A.F., and D.P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S. Water Resources Research 43:W06427.

Harig, A.L., and K.D. Fausch. 2002. Minimum habitat requirements for establishing translocated cutthroat trout populations. Ecological Applications 12:535–551.

Harvey, B.C., R.J. Nakamoto, and J.L. White. 2006. Reduced streamflow lowers dry-season growth of rainbow trout in a small stream. Transactions of the American Fisheries Society 135:998–1005.

Hayhoe, K., D. Cayan, C.B. Field, P.C. Frumhoff, E.P. Maurer, N.L. Miller, S.C. Moser, S.H. Schneider, K.N. Cahill, E.E. Cleland, L. Dale, R. Drapek, R.M. Hanemann, L.S. Kalkstein, J. Lenihan, C.K. Lunch, R.P. Neilson, S.C. Sheridan, and J.H. Verville. 2004. Emisions pathways, climate change, and impacts on California. Proceedings of the National Academy of Science 101:12422–12427.

Hedrick, P.W., and S.T. Kalinowski. 2000. Inbreeding depression in conservation biology. Annual Reviews in Ecology and Systematics 31:139–162.

Hickman, T., and R.F. Raleigh. 1982. Habitat suitability index models: cutthroat trout. U.S. Fish and Wildlife Service. FWS/OBS-82/10.5. 38 pp.

Hilderbrand, R.H. 2003. The roles of carrying capacity, immigration, and population synchrony on persistence of stream-resident cutthroat trout. Biological Conservation 110:257–266.

Hilderbrand, R.H., and J.L. Kershner. 2000. Conserving inland cutthroat trout in small streams: how much is enough? North American Journal of Fisheries Management 20:513–520.

Hilderbrand, R.H., and J.L. Kershner. 2004. Are there differences in growth and condition between mobile and resident cutthroat trout? Transactions of the American Fisheries Society 133:1042–1046.

Hollender, B.A., and R.F. Carline. 1994. Injury to wild brook trout by backpack electrofishing. North American Journal of Fisheries Management 14:643–649.

Horan, D.L., J.L. Kershner, C.P. Hawkins, and T.A. Crowl. 2000. Effects of habitat area and complexity on Colorado River cutthroat trout density in Unita Mountain streams. Transactions of the American Fisheries Society 129:1250–1263.

Howell, P.J. 2006. Effects of wildfire and subsequent hydrologic events on fish distribution and abundance in tributaries of North Fork John Day River. North American Journal of Fisheries Management 26:983–994.

Huber, M., and R. Knutti. 2011. Anthropogenic and natural warming inferred from changes in Earth's energy balance. Nature Geoscience. Published online December 4, 2011; DOI: 10.1038/NGEO1327. 6 pp. + supplemental material.

Hudy, M. 1985. Rainbow trout and brook trout mortality from high voltage AC electrofishing in a controlled environment. North American Journal of Fisheries Management 5:475–479.

Hurd, B., N. Leary, R. Jones, and J. Smith. 1999. Relative regional vulnerability of water resources to climate change. Journal of the American Water Resources Association 35:1399–1409.

Huusko, A., L. Greenberg, M. Stickler, T. Linnansaari, M. Nykänen, T. Vehanen, S. Koljonen, P. Louhi, and K. Alfredsen. 2007. Life in the ice lane: the winter ecology of stream salmonids. River Research and Applications 23:469–491.

Intergovernmental Panel on Climate Change (IPCC). 2007. Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K., and A. Reisinger (editors)]. Geneva, Switzerland. 104 pp.

Isaak, D.J., and W.A. Hubert. 2001. A hypothesis about factors that affect maximum summer stream temperatures across montane landscapes. Journal of the American Water Resources Association 37:351–366.

Isaak, D.J., S. Wollrab, D. Horan, and G. Chandler. 2012. Climate change effects on stream and river temperatures across the northwest U.S. from 1980–2009 and implications for salmonid fishes. Climatic Change 113:499–524.

Israel, J.A., J.F. Cordes, and B. May. 2002. Genetic divergence among Paiute cutthroat trout populations in the Silver King Creek drainage and out-of-basin transplants. Genomic Variation Laboratory, University of California, Davis. Final Report submitted to the California Department of Fish and Game, Rancho Cordova, California. 20 pp.

Jager, H.I., W. Van Winkle, and B.D. Holcomb. 1999. Would hydrologic climate change in Sierra Nevada stream influence trout persistence? Transactions of the American Fisheries Society 128:222–240.

Jakober, M.J., T.E. McMahon, R.F. Thurow, and C.G. Clancy. 1998. Role of stream ice on fall and winter movements and habitat use by bull trout and cutthroat trout in Montana headwater streams. Transactions of the American Fisheries Society 127:223–235.

Jug, T., P. Berrebi, and A. Snoj. 2005. Distribution of non-native trout in Slovenia and their introgression with native trout populations as observed through microsatellite DNA analysis. Biological Conservation 123:381–388.

Kaushal, S.S., G.E. Likens, N.A. Jaworski, M.L. Pace, A.M. Sides, D. Seekell, K.T. Belt, D.H. Secor, and R.L. Wingate. 2010. Rising stream and river temperatures in the United States. Frontiers in Ecology and the Environment 8:461–466.

Keane, R.E., K.C. Ryan, T.T. Veblen, C.D. Allen, J. Logan, and B. Hawkes. 2002. Cascading effects of fire exclusion in Rocky Mountain ecosystems: a literature review. General Technical Report RMRS–GTR–91. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 pp.

Keleher, C.J., and F.J. Rahel. 1996. Thermal limits to salmonid distributions in the Rocky Mountain region and potential habitat loss due to global warming: a geographic information system (GIS) approach. Transactions of the American Fisheries Society 125:1–13.

Kennedy, T.L., D.S. Gutzler, and R.L. Leung. 2009. Predicting future threats to the long-term survival of Gila trout using a high resolution simulation of climate change. Climatic Change 94:503–515.

Kie, J.G., and B.B. Boroski. 1996. Cattle distribution, habitats, and diets in the Sierra Nevada of California. Journal of Range Management 49:482–488.

Kiernan, J.D., and P.B. Moyle. 2012. Flows, droughts, and aliens: factors affecting the fish assemblage in a Sierra Nevada, California, stream. Ecological Applications 22:1146–1161.

Knapp, R.A., and K.R. Matthews. 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: Impacts and management implications. North American Journal of Fisheries Management 16:805–820.

Knowles, N., M.D. Dettinger, and D.R. Cayan. 2006. Trends in snowfall versus rainfall for the western United States, 1949-2004. Journal of Climate 19:4545–4559.

Kocovsky, P.M., C. Gowan, K.D. Fausch, and S.C. Riley. 1997. Spinal injury rates in three wild trout populations in Colorado after eight years of backpack electrofishing. North American Journal of Fisheries Management 17:308–313.

Kondolf, G.M. 1994. Livestock grazing and habitat for a threatened species: Land use decisions under scientific uncertainty in the White Mountains, California, USA. Environmental Management 18:501–509.

Kondolf, G.M., G.F. Cada, M.J. Sale, and T. Felando. 1991. Distribution and stability of potential salmonid spawning gravels in steep boulder-bed streams of the eastern Sierra Nevada. Transactions of the American Fisheries Society 120:177–186.

Labbe, T.R., and K.D. Fausch. 2000. Dynamics of intermittent stream habitat regulate persistence of a threatened fish at multiple scales. Ecological Applications 10:1774–1791.

Lake, P.S. 2003. Ecological effects of perturbation by drought in flowing waters. Freshwater Biology 48:1161–1172.

Lande, R. 2002. Incorporating stochasticity in population viability analysis. Pages 18–40 in S.R. Beissinger and D.R. McCullough (editors), Population Viability Analysis. University of Chicago Press, Chicago, Illinois.

Leary, R.F., F.W. Allendorf, and G.K. Sage. 1995. Hybridization and introgression between introduced and native fish. American Fisheries Society Symposium 15:91–101.

Lomnicky, G.A., T.R. Whittier, R.M. Hughes, and D.V. Peck. 2007. Distribution of nonnative aquatic vertebrates in western U.S. streams and rivers. North American Journal of Fisheries Management 27:1082–1093.

Loudenslager, E.J., and G.A.E. Gall. 1980. Geographic patterns of protein variation and subspeciation in cutthroat trout, *Salmo clarki*. Systematic Zoology 29:27–42.

Magoulick, D.D., and R.M. Kobza. 2003. The role of refugia for fishes during drought: a review and synthesis. Freshwater Biology 48:1186–1198.

Marlow, C.B., and T.M. Pogacnik. 1986. Cattle feeding and resting patterns in a foothills riparian zone. Journal of Range Management 39:212–217.

Matthews, W.J., and E. Marsh-Matthews. 2003. Effects of drought on fish across axes of space, time, and ecological complexity. Freshwater Biology 28:1232–1253.

Marchetti, M.P., and P.B. Moyle. 2001. Effects of flow regime on fish assemblages in a regulated California stream. Ecological Applications 11:530–539.

McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. U.S. Environmental Protection Agency, Seattle, Washington. Report Number EPA 910–R–99–010. 279 pp.

McKelvey, K.S., C.N. Skinner, C. Chang, D.C. Erman, S.J. Husari, D.J. Parsons, J.W. Van Wagtendonk, and C.P. Weatherspoon. 1996. An overview of fire in the Sierra Nevada. Pages 1033–1040 in Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and scientific basis for management options. University of California, Centers for Water and Wildland Resources, Davis.

McKenzie, D., Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climate change, wildfire, and conservation. Conservation Biology 18:890–902.

McMichael, G.A. 1993. Examination of electrofishing injury and short-term mortality in hatchery rainbow trout. North American Journal of Fisheries Management 13:229–233.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy, A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.C. Zhao. 2007. Global Climate Projections. Pages 747–845 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (editors), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. 996 pp.

Meeuwig, M.H., J.B. Dunham, J.P. Hayes, and G.L. Vinyard. 2004. Effects of constant and cyclical thermal regimes on growth and feeding of juvenile cutthroat trout of variable sizes. Ecology of Freshwater Fish 13:208–216.

Mensing, S.A., L.V. Benson, M. Kashgarian, and S. Lund. 2004. A Holocene pollen record of persistent droughts from Pyramid Lake, Nevada, USA. Quaternary Research 62:29–38.

Mensing, S.A., J. Smith, K.B. Norman, and M. Allan. 2008. Extended drought in the Great Basin of western North America in the last two millennia reconstructed from pollen records. Quaternary International 188:79–89.

Mesa, M.G., and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Transactions of the American Fisheries Society 118:644–658.

Miller, J.D., and H.D. Safford. 2012. Trends in wildfire severity: 1984 to 2010 in the Sierra Nevada, Modoc plateau, and southern Cascades, California, USA. Fire Ecology 8:41–57.

Miller, J.D., H.D. Safford, M. Crimmins, and A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade Mountains, California and Nevada, USA. Ecosystems 12:16–32.

Miller, J.R., K. House, D. Germanoski, R.J. Tausch, and J.C. Chambers. 2004. Fluvial geomorphic responses to Holocene climate change. Pages 49–87 in J.C. Chambers, and J.R. Miller (editors), Great Basin Riparian Ecosystems: Ecology, Management, and Restoration. Island Press, Washington DC.

Mohseni, O., H.G. Stefan, and J.G. Eaton. 2003. Global warming and potential changes in fish habitat in U.S. streams. Climatic Change 59:389–409.

Morita, K., J-I. Tsuboi, and H. Matsuda. 2004. The impact of exotic trout on native charr in a Japanese stream. Journal of Applied Ecology 41:962–972.

Moyle, P.B. 2002. Inland Fishes of California. University of California Press, Berkeley, California. 502 pp.

Moyle, P.B., J.V.E. Katz, and R.M. Quiñones. 2011. Rapid decline of California's native inland fishes: a status assessment. Biological Conservation 144:2414–2423.

Muhlfeld, C.C., D.H. Bennett, and B. Marotz. 2001. Fall and winter habitat use and movement by Columbia River redband trout in small streams in Montana. North American Journal of Fisheries Management 21:170–177.

Muhlfeld, C.C., S.T. Kalinowski, T.E. McMahon, M.L. Taper, S. Painter, R.F. Leary, and F.W. Allendorf. 2009. Hybridization rapidly reduces fitness of a native trout in the wild. Biology Letters 5:328–331.

Natural Resources Conservation Service (NRCS). 2012. Nevada water supply outlook report for January 1, 2012. U.S. Department of Agriculture, NRCS, Reno, Nevada. http://www.wcc.nrcs.usda.gov/cgibin/bor2.pl?state=nv&year=2012&month=1&format=text (Accessed January 7, 2013).

Neary, D.G., J.D. Landsberg, A.R. Tiedemann, and P.F. Ffolliott. 2005. Water quality. Pages 119–134 in D.G. Neary, K.C. Ryan, and L.F. DeBano editors, Wildland fire in ecosystems: effects of fire on soils and water. General Technical Report RMRS-GTR-42-volume 4. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 250 pp.

Nelson, J.S., E.J. Crossman, H. Espinosa-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, 6th edition. American Fisheries Society, Special Publication 29, Bethesda, Maryland. 386 pp.

Neville, H.M., J.B. Dunham, and M.M. Peacock. 2006. Landscape attributes and life history variability shape genetic structure of trout populations in a stream network. Landscape Ecology 21:901–916.

Neville, H., J. Dunham, A. Rosenberger, J. Umak, and B. Nelson. 2009. Influences of wildfire, habitat size, and connectivity on trout in headwater streams revealed by patterns of genetic diversity. Transactions of the American Fisheries Society 138:1314–1327.

Nielsen, J.L., and G.K. Sage. 2002. Population genetic structure in Lahontan cutthroat trout. Transactions of the American Fisheries Society 131:376–388.

Niemi, G.J., P. DeVore, N. Detenbeck, D. Taylor, A. Lima, J. Pastor, J.D. Yount, and R.J. Naiman. 1990. Overview of case studies on recovery of aquatic systems from disturbance. Environmental Management 14:571–587.

North, M.P., K.M. Van de Water, S.L. Stephens, and B.M. Collins. 2009. Climate, rain shadow, and human-use influences on fire regimes in the eastern Sierra Nevada, California, USA. Fire Ecology 5:20–34.

Noss, R., B. Csuti, and M.J. Groom. 2006. Habitat fragmentation. Pages 213–251 in M.J. Groom, G.K. Meffe, and C.R. Carroll (editors), Principles of Conservation Biology (Third Edition). Sinauer Associates, Incorporated, Sunderland, Massachusetts.

Novak, M.A., and R.G. White. 1990. Impact of fire and flood on the trout population of Beaver Creek, upper Missouri basin, Montana. Pages 120–127 in F. Richardson and R.H.

Hamre, (editors), Wild Trout IV: proceedings of the symposium. Trout Unlimited, Arlington, Virginia.

Overton, C.K., G.L. Chandler, and J.A. Pisano. 1994. Northern/Intermountain regions' fish habitat inventory: grazed, rested, and ungrazed reference stream reaches, Silver King Creek, California. General Technical Report GTR–INT–311. Ogden, Utah: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 27 pp.

Parsons, C.T., P.A. Momont, T. Delcurto, M. McInnis, and M.L. Porath. 2003. Cattle distribution patterns and vegetation use in mountain riparian areas. Journal of Range Management 56:334–341.

Peterson, D.P., B.E. Rieman, J.D. Dunham, K.D. Fausch, and M.K. Young. 2008. Analysis of trade-offs between threats of invasion by nonnative brook trout (*Salvelinus fontinalis*) and intentional isolation for native westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). Canadian Journal of Fisheries and Aquatic Science 65:557–573.

Peterson, D.P., B.E. Rieman, M.K. Young, and J.A. Brammer. 2010. Modeling predicts that redd trampling by cattle may contribute to population declines of native trout. Ecological Applications 20:954–966.

Platts, W.S. 1979. Livestock grazing and riparian/stream ecosystems - an overview. Pages 39–45 in O.B. Cope (editor), Proceedings of the Forum – Grazing and riparian/stream ecosystems; November 3–4, 1976. Denver, Colorado. Trout Unlimited, Vienna, Virginia. 94 pp.

Platts, W.S. 1991. Livestock grazing. American Fisheries Society Special Publication 19:389–423.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The natural flow regime. BioScience 47:769–784.

Poole, G.C., and C.H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human caused thermal degradation. Environmental Management 27:787–802.

PRBO Conservation Science. 2011. Projected effects of climate change in California: ecoregional summaries emphasizing consequences for wildlife. Version 1.0. http://data.prbo.org/apps/bssc/climatechange (Accessed February 10, 2011).

Preston, B.L. 2006. Risk-based reanalysis of the effects of climate change on U.S. cold-water habitat. Climatic Change 76:91–119.

Pringle, C. 2006. The fragmentation of aquatic ecosystems and the alteration of hydrologic connectivity. Pages 243–246 in M.J. Groom, G.K. Meffe, and C.R. Carroll (editors), Principles of Conservation Biology (Third Edition). Sinauer Associates, Incorporated, Sunderland, Massachusetts.

Prinn, R., S. Paltsev, A. Sokolov, M. Sarofim, J. Reilly, and H. Jacoby. 2011. Scenarios with MIT integrated global systems model: significant global warming regardless of different approaches. Climatic Change 104:515–537.

Pritchard, V.L., K. Jones, and D.E. Cowley. 2007. Genetic diversity within fragmented cutthroat trout populations. Transactions of the American Fisheries Society 136:606–623.

Propst, D.L., J.A. Stefferud, and P.R. Turner. 1992. Conservation and status of Gila trout, *Oncorhynchus gilae*. Southwestern Naturalist 37:117–125.

Rahel, F.J. 2002. Using current biogeographic limits to predict fish distributions following climate change. American Fisheries Society Symposium 32:99–110.

Rahel, F.J., B. Bierwagen, and Y. Taniguchi. 2008. Managing aquatic species of conservation concern in the face of climate change and invasive species. Conservation Biology 22:551–561.

Ranalli, A.J. 2004. A summary of the scientific literature on the effects of fire on the concentration of nutrients in surface waters. U.S. Department of the Interior, U.S. Geological Survey, Open-File Report 2004–1296. 23 pp.

Rasmussen, J.B., M.D. Robinson, and D.D. Heath. 2010. Ecological consequences of hybridization between native westslope cutthroat (*Oncorhynchus clarkii lewisi*) and introduced rainbow (*Oncorhynchus mykiss*) trout: effects on life history and habitat use. Canadian Journal of Fisheries and Aquatic Sciences 67:357–370.

Reed, D.H., and R. Frankham. 2003. Correlation between fitness and genetic diversity. Conservation Biology 17:230–237.

Rhymer, J.M., and D. Simberloff. 1996. Extinction by hybridization and introgression. Annual Review of Ecology and Systematics 27:83–109.

Richardson, D.M., P.W. Rundel, S.T. Jackson, R.O. Teskey, J. Aronson, A. Bytnerowicz, M.J. Wingfield, and S. Proches. 2007. Human impacts in pine forests: past, present, and future. Annual Reviews in Ecology, Evolution, and Systematics 38:275–297.

Richter, B.D., J.V. Baumgartner, J. Powell, and D.P. Braun. 1996. A method for assessing hydrologic alteration within ecosystems. Conservation Biology 10:1163–1174.

Rieman, B.E., and J. Clayton. 1997. Wildfire and native fish: issues of forest health and conservation of sensitive species. Fisheries 22:6–15.

Rieman, B.E., and J.D. McIntyre. 1995. Occurrence of bull trout in naturally fragmented habitat patches of varied size. Transactions of the American Fisheries Society 124:285–296.

Rieman, B.E., D. Lee, G. Chandler, and D. Meyers. 1997. Does wildfire threaten extinction for salmonids: responses of redband trout and bull trout following recent large fires on the Boise National Forest. Pages 47–57 in J. Greenlee (editor), Proceedings of the symposium on fire effects on threatened and endangered species and their habitats. International Association of Wildland Fire, Fairfield, Virginia.

Rieman, B.E., D. Isaak, S. Adams, D. Horan, D. Nagel, C. Luce, and D. Myers. 2007. Anticipated climate warming effects on bull trout habitats and populations across the interior Columbia River basin. Transactions of the American Fisheries Society 136:1552–1565.

Rinne, J.N. 1996. Short-term effects of wildfire on fishes and aquatic macroinvertebrates in the southwestern United States. North American Journal of Fisheries Management 16:653–658.

Robins, C.R., R.B. Bailey, C.E. Bond, J.R. Booker, E.L. Lechner, R.N. Lea, and W.B. Scott. 1991. Common and scientific names of fishes from the United States and Canada, 5th edition. American Fisheries Society, Special Publication 20, Bethesda, Maryland. 183 pp.

Roach, S.M. 1999. Influence of electrofishing on the mortality of arctic grayling eggs. North American Journal of Fisheries Management 19:923–929.

Romme, W.H., M.S. Boyce, R. Gresswell, E.H. Merrill, G.W. Minshall, C. Whitlock, and M.G. Turner. 2011. Twenty years after the 1988 Yellowstone fires: lessons about disturbance and ecosystems. Ecosystems:14:1196–1215.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, Colorado. 364 pp.

Rutledge, C.J., E.G. Zimmerman, and T.L. Beitinger. 1990. Population genetic responses of two minnow species (Cyprinidae) to seasonal intermittency. Genetica 80:209–219.

Ryan, J.H., and S.J. Nicola. 1976. Status of the Paiute cutthroat trout, *Salmo clarki seleniris* Snyder, in California. California Department of Fish and Game, Inland Fisheries Branch, Sacramento, California. Administrative Report Number 76–3. viii + 56 pp.

Ryan, S. 1997. Morphologic response of subalpine streams to transbasin flow diversions. Journal of the American Water Resources Association 33:839–854.

Sanderson, T.B., and W.A. Hubert. 2009. Movements by adult cutthroat trout in a lotic system: implications for watershed scale management. Fisheries Management and Ecology 16:329–336.

Saunders, W.C., and K.D. Fausch. 2012. Grazing management influences the subsidy of terrestrial prey to trout in central Rocky Mountain streams (USA). Freshwater Biology 57:1512–1529.

Schill, D.J., and F.S. Elle. 2000. Healing of electroshock-induced hemorrhages in hatchery rainbow trout. North American Journal of Fisheries Management 20:730–736.

Schisler, G.J., E.P. Bergersen, and P.G. Walker. 2000. Effects of multiple stressors on morbidity and mortality of fingerling rainbow trout infected with *Myxobolus cerebralis*. Transactions of the American Fisheries Society 129:859–865.

Schmetterling, D.A. 2001. Seasonal movement of fluvial westslope cutthroat trout in the Blackfoot River drainage, Montana. North American Journal of Fisheries Management 21:507–520.

Schrank, A.J., and F.J. Rahel. 2004. Movement patterns in inland cutthroat trout (*Oncorhynchus clarki utah*): management and conservation implications. Canadian Journal of Fisheries and Aquatic Sciences 61:1528–1537.

Scribner, K.T., G.K. Meffe, and M.J. Groon. 2006. Conservation genetics: the use and importance of genetic information. Pages 375–415 in M.J. Groom, G.K. Meffe, and C.R. Carroll (editors), Principles of Conservation Biology (Third Edition). Sinauer Associates, Incorporated, Sunderland, Massachusetts.

Schulz, T.T., and W.C. Leininger. 1990. Differences in riparian vegetation structure between grazed and ungrazed areas and exclosures. Journal of Range Management 43:295–299.

Sedell, J.R., G.H. Reeves, F.R. Hauer, J.A. Stanford, and C.P. Hawkins. 1990. Role of refugia in recovery from disturbances: modern fragmented and disconnected river systems. Environmental Management 14:711–724.

Seegrist, D.W., and R. Gard. 1972. Effects of floods on trout in Sagehen Creek, California. Transactions of the American Fisheries Society 101:478–482.

Serreze, M.C. 2010. Understanding recent climate change. Conservation Biology 24:10–17.

Sestrich, C.M., T.E. McMahon, and M.K. Young. 2011. Influence of fire on native and nonnative salmonid populations and habitat in a western Montana basin. Transactions of the American Fisheries Society 140:136–146.

Sharber, N.G., and S.W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. North American Journal of Fisheries Management 8:117–122.

Skinner, C.N., and C. Chang. 1996. Fire regimes, past and present. Pages 1041–1069 in Sierra Nevada Ecosystem Project: Final Report to Congress, vol. II, Assessments and scientific basis for management options. University of California, Centers for Water and Wildland Resources, Davis.

Smith, G.R., and R.F. Stearly. 1989. The classification and scientific names of rainbow and cutthroat trouts. Fisheries 14:4–10.

Smith, M.A., J.D. Rodgers, J.L. Dodd, and Q.D. Skinner. 1992. Habitat selection by cattle along an ephemeral channel. Journal of Range Management 45:385–390.

Smith, S.D., A.B. Wellington, J.L. Natchlinger, and C.A. Fox. 1991. Functional responses of riparian vegetation to streamflow diversion in the eastern Sierra Nevada. Ecological Applications 1:89–97.

Snyder, D.E. 2003. Electrofishing and its harmful effects on fish. Information and Technology Report USGS/BRD/ITR–2003–0002: U.S. Government Printing Office, Denver, Colorado. 149 pp.

Solomon, S., D. Qin, M. Manning, R.B. Alley, T. Berntsen, N.L. Bindoff, Z. Chen, A. Chidthaisong, J.M. Gregory, G.C. Hegerl, M. Heimann, B. Hewitson, B.J. Hoskins, F. Joos, J. Jouzel, V. Kattsov, U. Lohmann, T. Matsuno, M. Molina, N. Nicholls, J. Overpeck, G. Raga, V. Ramaswamy, J. Ren, M. Rusticucci, R. Somerville, T.F. Stocker, P. Whetton, R.A. Wood, and D. Wratt. 2007. Technical Summary. Pages 19–91 in S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (editors), Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom. 996 pp.

Sorensen, P.W. 1994. Effects of electroshocking on the sexual behavior of goldfish and brook trout. North American Journal of Fisheries Management 14:862–865.

Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR–4501–96–6057. ManTech Environmental Research Services Corporation, Corvallis, Oregon. 372 pp.

Spencer, C.N., and F.R. Hauer. 1991. Phosphorus and nitrogen dynamics in streams during a wildfire. Journal of the North American Benthological Society 10:24–30.

Spens, J., A. Alanärä, and L-O. Eriksson. 2007. Nonnative brook trout (*Salvelinus fontinalis*) and the demise of native brown trout (*Salmo trutta*) in northern boreal lakes: stealthy, long-term patterns? Canadian Journal of Fisheries and Aquatic Science 64:654–664.

Stefan, H.G., and E.B. Preud'homme. 1993. Stream temperature estimation from air temperature. Water Resources Bulletin 29:27–45.

Stephens, S., and D. Christenson. 1980. Little Kern Golden Trout standard population inventory method. Unpublished methodology. California Department of Fish and Game. 1 p.

Stephens, S.L., and N.G. Sugihara. 2006. Fire management and policy since European settlement. Pages 431–443 in N.G. Sugihara, J.W. Van Wagtendonk, J. Fites-Kaufman, K.E. Shaffer, and A.E. Thode (editors), Fire in California Ecosystems. University of California Press, Berkeley, California.

Stewart, I.T., D.R. Cayan, and D.M. Dettinger. 2005. Changes toward earlier streamflow timing across the western North America. Journal of Climate 18:1136–1155.

Strand, P., and H. Eddinger. 1999. Status of Paiute cutthroat trout (*Oncorhynchus clarki seleniris*) on the Sierra National Forest. Sierra National Forest, Clovis, California. 22 pp.

Swanston, D.N. 1991. Natural Processes. American Fisheries Society Special Publication 19:139–180.

Thompson, K.G., E.P. Bergersen, and R.B. Nehring. 1997a. Injuries to brown trout and rainbow trout induced by capture with pulsed direct current. North American Journal of Fisheries Management 17:141–153.

Thompson, K.G., E.P. Bergersen, R.B. Nehring, and D.C. Bowden. 1997b. Long-term effects of electrofishing on growth and body condition of brown trout and rainbow trout. North American Journal of Fisheries Management 17:154–159.

Thompson, K.G., R.B. Nehring, D.C. Bowden, and T. Wygant. 1999. Field exposure of seven species or subspecies of salmonids to *Myxobolus cerebralis* in the Colorado River, Middle Park, Colorado. Journal of Aquatic Animal Health 11:312–329.

Titus, R.G., and L. Calder. 2009. Age and growth of Paiute cutthroat trout, *Oncorhynchus clarkii seleniris*, in the Silver King Creek drainage, California. Technical Completion Report, California Department of Fish and Game, Sacramento, California. 15 pp.

Townsend, C.R. 1996. Invasion biology and ecological impacts of brown trout (*Salmo trutta)* in New Zealand. Biological Conservation 78:13–22.

Umek, J.W. 2007. Lahontan cutthroat trout movement in a high desert watershed; inferences from a microsatellite study. M.S. Thesis, University of Nevada, Reno. i-v + 34 pp.

U.S. District Court (Eastern District of California). 2011. *Memorandum and Order in Californians for Alternatives to Toxics, Wilderness Watch, Friends of Silver King Creek, Laurel Ames, and Ann McCampbell v. U.S. Fish and Wildlife Service and the U.S. Forest Service (No. CIV. S–10–1477 FCD/CMK)*. September 6, 2011. 63 pp.

U.S. District Court (Eastern District of California). 2013. *Order Dissolving Injunction in Californians for Alternatives to Toxics, Wilderness Watch, Friends of Silver King Creek, Laurel Ames, and Ann McCampbell v. U.S. Fish and Wildlife Service and the U.S. Forest Service (No. 2:10-cv-01477-GEB-CMK)*. May 13, 2013. 2 pp.

U.S. Fish and Wildlife Service (Service). 1967. Native fish and wildlife: Endangered species. Federal Register 32:4001. March 11, 1967.

U.S. Fish and Wildlife Service (Service). 1975. Threatened status for three species of trout. Federal Register 40:29863–29864. July 16, 1975.

U.S. Fish and Wildlife Service (Service). 1978. Endangered and threatened wildlife and plants: Listing of the Little Kern golden trout as a threatened species with critical habitat. Federal Register 43:15427–15429. April 13, 1978.

U.S. Fish and Wildlife Service (Service). 1983a. Endangered and threatened species listing and recovery priority guidelines. Federal Register 48:43098–43105. September 21, 1983.

U.S. Fish and Wildlife Service (Service). 1983b. Endangered and threatened species listing and recovery priority guidelines correction. Federal Register 48:51985. November 15, 1983.

U.S. Fish and Wildlife Service (Service). 1985. Recovery plan for the Paiute cutthroat trout (*Salmo clarki seleniris*). Portland, Oregon. ix + 68 pp.

U.S. Fish and Wildlife Service (Service). 1995. Lahontan cutthroat trout, *Oncorhynchus clarki henshawi*, Recovery Plan. Portland, Oregon. 147 pp.

U.S. Fish and Wildlife Service (Service). 1996. Policy regarding the recognition of Distinct Vertebrate Population Segments under the Endangered Species Act. Federal Register 61:4722–4725. February 7, 1996.

U.S. Fish and Wildlife Service (Service). 1998. Greenback cutthroat trout recovery plan. Denver, Colorado. i–iv + 62 pp.

U.S. Fish and Wildlife Service (Service). 2000. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Great Basin redband trout as threatened or endangered. Federal Register 65:14932–14936. March 20, 2000.

U.S. Fish and Wildlife Service (Service). 2001. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Bonneville cutthroat trout as threatened throughout its range. Federal Register 66:51362–51366. October 9, 2001.

U.S. Fish and Wildlife Service (Service). 2002. Endangered and threatened wildlife and plants: 90-day finding on a petition to list the California golden trout as endangered. Federal Register 67:59241–59243. September 20, 2002.

U.S. Fish and Wildlife Service (Service). 2003a. Endangered and threatened wildlife and plants: Reconsidered finding for an amended petition to list the Westslope cutthroat trout as threatened throughout its range. Federal Register 68:46989–47009. August 7, 2003.

U.S. Fish and Wildlife Service (Service). 2003b. Gila trout (*Oncorhynchus gilae*) recovery plan (third revision). Albuquerque, New Mexico. i–vii + 78 pp.

U.S. Fish and Wildlife Service (Service). 2004. Revised recovery plan for the Paiute cutthroat trout (*Oncorhynchus clarki seleniris*). Portland, Oregon. i-ix + 105 pp.

U.S. Fish and Wildlife Service (Service). 2006. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Yellowstone cutthroat trout as threatened. Federal Register 71:8818–8831. February 21, 2006.

U.S. Fish and Wildlife Service (Service). 2007. Endangered and threatened wildlife and plants: 12-month finding for a petition to list the Colorado River cutthroat trout as threatened or endangered. Federal Register 72:32589–32605. June 13, 2007.

U.S. Fish and Wildlife Service (Service). 2008a. 5-Year Review: Summary and Evaluation. Paiute cutthroat trout (*Oncorhynchus clarkii seleniris*). Region 8, Sacramento, California. 39 pp.

U.S. Fish and Wildlife Service (Service). 2008b. Endangered and threatened wildlife and plants: Status review for Rio Grande cutthroat trout; Proposed Rule. Federal Register 73:27900–27926. May 14, 2008.

U.S. Fish and Wildlife Service (Service). 2009. Apache Trout (*Oncorhynchus apache*) Recovery Plan, Second Revision. Albuquerque, New Mexico. i–vii + 76 pp.

U.S. Fish and Wildlife Service (Service). 2010. Biological Opinion for the Cabin Creek Unit of the Indian Creek Allotment (File No. 2010–F–0088). June 1, 2010. Nevada Fish and Wildlife Office, Reno, Nevada. 41 pp.

U.S. Fish and Wildlife Service (Service). 2012. Endangered and threatened wildlife and plants; 5-year reviews of species in California and Nevada. Federal Register 77:25112–25116. April 27, 2012.

U.S. Fish and Wildlife Service (Service) and California Department of Fish and Game. 2010. Paiute cutthroat trout Restoration Project Final Environmental Impact Statement/Environmental Impact Report. Nevada Fish and Wildlife Office, Reno, Nevada, California Department of Fish and Game, Rancho Cordova, California. 284 pp. + appendices.

U.S. Forest Service (USFS). 1982. National forest system land and resource management planning. Federal Register 47:43037–43058. September 30, 1982.

U.S. Forest Service (USFS). 1996. Stream habitat classification and inventory procedures for northern California. Fish Habitat Relationships Program Technical Bulletin, Number 1. Region 5, Pacific Southwest Region, Vallejo, California. 15 pp.

U.S. Forest Service (USFS). 2000. Decision Notice and Finding of No Significant Impact for the Cottonwood and Tres Plumas Grazing Allotments, October 18, 2000. Inyo National Forest, Bishop, California. 10 pp.

U.S. Forest Service (USFS). 2004. Sierra Nevada Forest Plan Amendment (SNFPA) Final Supplemental Environmental Impact Statement, volume 1. Pacific Southwest Region, Vallejo, California. January 2004. 492 pp.

U.S. Forest Service (USFS). 2009. Biological assessment for the Indian Creek Grazing Allotment, October 21, 2009. Inyo National Forest, Bishop, California. 19 pp.

U.S. Forest Service (USFS). 2010. 10-year term grazing permit for the Cassidy and Mono Allotments, July 13, 2010. Sierra National Forest, Clovis, California. 19 pp.

U.S. Forest Service (USFS). 2012a. National forest system land management planning; final rule. Federal Register 77:21162–21276. April 9, 2012.

U.S. Forest Service (USFS). 2012b. Environmental Assessment for the East Alpine Rangeland Project. Humboldt-Toiyabe National Forest, Carson Ranger District, Carson City, Nevada. September 2012. 201 pp.

U.S. Forest Service (USFS). 2012c. Decision Notice and Finding of No Significant Impact for the East Alpine Rangeland Project. Humboldt-Toiyabe National Forest, Carson Ranger District, Carson City, Nevada. September 2012. 20 pp.

Van de Water, K., and M. North. 2010. Fire history of coniferous riparian forests in the Sierra Nevada. Forest Ecology and Management 260:384–395.

Van de Water, K., and M. North. 2011. Stand structure, fuel loads, and fire behavior in riparian and upland forests, Sierra Nevada Mountains, USA: a comparison of current and reconstructed conditions. Forest Ecology and Management 262:215–228.

van Vliet, M.T.H., F. Ludwig, J.J.G. Zwolsman, G.P. Weedon, and P. Kabat. 2011. Global river temperatures and sensitivity to atmospheric warming and changes in river flow. Water Resources Research, 47, W02544, doi:10.1029/2010WR009198.

Van Wagtendonk, J.W., and J. Fites-Kaufman. 2006. Sierra Nevada bioregion. Pages 264–294 in N.G. Sugihara, J.W. Van Wagtendonk, J. Fites-Kaufman, K.E. Shaffer, and A.E. Thode (editors), Fire in California Ecosystems. University of California Press, Berkeley, California.

Walsh, M.G., D.L. Winkelman, and R.J. Bahr. 2004. Electrofishing injury and short-term mortality in hatchery reared rainbow trout stocked into an Ozark stream. North American Journal of Fisheries Management 24:316–321.

Webb, B.W., D.M. Hannah, R.D. Moore, L.E. Brown, and F. Nobilis. 2008. Recent advances in stream and river temperature research. Hydrological Processes 22:902–918.

Wehner, M., D.R. Easterling; J.H. Lawrimore, R.R. Heim Jr., R.S. Vose, and B.D. Santer. 2011. Projections of future drought in the continental United States and Mexico. Journal of Hydrometeorology 12:1359-1377.

Wenburg, J.K., and P. Bentzen. 2001. Genetic and behavioral evidence for restricted gene flow among coastal cutthroat trout populations. Transactions of the American Fisheries Society 130:1049–1069.

Wenger, S.J., D.J. Isaak, C.H. Luce, H.M. Neville; K.D. Fausch, J.B. Dunham, D.C. Dauwalter, M.K. Young, M.M. Elsner, B.E. Rieman, A.F. Hamlet, and J.E. Williams. 2011. Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change. Proceedings of the National Academy of Sciences 108:14175–14180.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and earlier spring increase western U.S. forest wildfire activity. Science 313:940–943.

White, S.M., and F.J. Rahel. 2008. Complementation of habitats for Bonneville cutthroat trout in watersheds influenced by beavers, livestock, and drought. Transactions of the American Fisheries Society 137:881–894.

Whiteley, A.R., K. Hastings, J.K. Wenburg, C.A. Frissell, J.C. Martin, and F.W. Allendorf. 2010. Genetic variation and effective population size in isolated populations of coastal cutthroat trout. Conservation Genetics 11:1929–1943.

Whittier, T.R., and D.V. Peck. 2008. Surface area estimates of streams and rivers occupied by nonnative fish and amphibians in the western USA. North American Journal of Fisheries Management 28:1887–1893.

Wilcox, C., B.J. Cairns, and H.P. Possingham. 2006. The role of habitat disturbance and recovery in metapopulation persistence. Ecology 87:855–863.

Williams, J.E., A.L. Haak, H.M. Neville, and W.T. Colyer. 2009. Potential consequences of climate change to persistence of cutthroat trout populations. North American Journal of Fisheries Management 29:533–548.

Wofford, J.E.B., R.E. Gresswell, and M.A. Banks. 2005. Influence of barriers to movement on within-watershed genetic variation of coastal cutthroat trout. Ecological Applications 15:628–637.

Wong, D.M. 1975. Aspects of the life history of the Paiute cutthroat trout, *Salmo clarki seleniris* Snyder, in North Fork Cottonwood Creek, Mono County, California, with notes on behavior in a stream aquarium. M.A. Thesis, California State University, Long Beach. 178 pp.

Wong, D.M. 1991. Life history and management of Paiute cutthroat trout in the White Mountains, Mono County, California. Pages 182–190 in C.A. Hall, Jr., V. Doyle-Jones, and B. Widawski (editors), Natural history of eastern California and high altitude research. University of California, White Mountain Research Station, Bishop, California.

Young, M.K. 1996. Summer movements and habitat use by Colorado River cutthroat trout (*Oncorhynchus clarki pleuriticus*) in small, montane streams. Canadian Journal of Fisheries and Aquatic Sciences 53:1403–1408.

Young, M.K. 2011. Generation-scale movement patterns of cutthroat trout (*Oncorhynchus clarkii pleuriticus*) in a stream network. Canadian Journal of Fisheries and Aquatic Sciences 68:941–951.

Young, M.K., P.M. Guenther-Gloss, and A.D. Ficke. 2005. Predicting cutthroat trout (*Oncorhynchus clarkii*) abundance in high-elevation streams: revisiting a model of translocation success. Canadian Journal of Fisheries and Aquatic Sciences 62:2399–

2408.

Yuan, F., B.K. Linsley, S.P. Lund, and J.P. McGeehin. 2004. A 1,200 year record of hydrologic variability in the Sierra Nevada from sediments in Walker Lake, Nevada. Geochemistry Geophysics Geosystems, 5, Q03007, doi:10.1029/2003GC000652.

Personal Communications

Emery, D. 2013. Fisheries Biologist, California Department of Fish and Wildlife, Bishop, California. Unpublished data.

Johnson, K. 2012. Fisheries Biologist, California Department of Fish and Wildlife, Sacramento, California. Unpublished data.

Mellison, C. 2012. Fisheries Biologist, Nevada Fish and Wildlife Office, Reno, Nevada. Unpublished data.

Somer, W. 2013. Senior Fisheries Biologist, California Department of Fish and Wildlife, Rancho Cordova, California. Unpublished data.

Strand, Philip. 2005. Fisheries Program Manager, Sierra National Forest, Clovis, California and Sequoia National Forest, Porterville, California. Electronic mail to Chad Mellison, received on September 27, 2005. Subject: PCT summaries.

Temple, Alan. 2009. Biologist, U.S. Fish and Wildlife Service, Shepherdstown, West Virginia. Telephone conversation between Alan Temple and Chad Mellison, on January 8, 2009. Subject: we discussed the number of State and federal biologists who work with Paiute cutthroat trout who have taken the Principles and Techniques of Electrofishing course.

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

Paiute cutthroat trout (*Oncorhynchus clarkii seleniris*)

Current Classification: Threatened

Recommendation Resulting from the 5-Year Review:

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

Review Conducted By: Nevada Fish and Wildlife Office, Reno, Nevada

Date Submitted to Region 8: June 6, 2013

FIELD OFFICE APPROVAL:

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

Approve [signature] Date 6/6/13