CALIFORNIA GOLDEN TROUT
***Oncorhynchus mykiss aguabonita* (Jordan)**

Critical Concern. Status Score = 1.9 out of 5.0. California Golden trout are likely to become extinct in the wild in the next 50-100 years. While the Golden Trout Creek (GTC) population is relatively secure, the South Fork Kern River (SFKR) population is threatened by introgression with rainbow trout and predation and competition from introduced brown trout.

Description: The California golden trout is named for its bright colors. Behnke (2002) describes their coloration as follows: "The color of the back is brassy or copper, becoming bright golden yellow just above the lateral line. A deep red stripe runs along the lateral line and the golden yellow body color intensifies below. A deep crimson color suffuses the ventral region from the anal fin to beneath the lower jaw… (p. 105)." Fish from GTC are particularly brightly colored. Young and most adults have about 10 parr marks centered along the lateral line. The parr marks on adults are considered to be a distinctive characteristic (Needham and Gard 1959), but they are not always present, especially in larger fish from introduced lake populations. Large spots are present, mostly on the dorsal and caudal fins and on the caudal peduncle. The pectoral, pelvic, and anal fins are orange to yellow. The anal, dorsal, and pelvic fins have white to yellow tips, preceded by a black band. Basibranchial teeth are absent and there are 17-21 gill rakers. Other characteristics include 175-210 scales along the lateral line, 34-45 scales above the lateral line, 8-10 pelvic rays, 25-40 pyloric caeca, and 58-61 vertebrae (Schreck and Behnke 1971).

Taxonomic Relationships: The complex history of golden trout taxonomy and nomenclature is reported in Behnke (2002) and is presented here in a simplified version. Originally, three species of golden trout were described from the upper Kern River basin: *Salmo aguabonita* from the SFKR, *S. whitei* from the Little Kern River, and *S. roosevelti* from GTC. However, the first two forms were eventually recognized as subspecies of *S. aguabonita*: *S. a. aguabonita* and *S. a. whitei*. *S. roosevelti* was shown to be a color variant of *S. a. aguabonita* (Moyle 2002). Berg (1987) concluded that the two recognized subspecies of golden trout are more closely related to the Kern River rainbow trout (*O. m. gilberti*) than either are to each other. However, Bagley and Gall (1998) and M. Stephens (2007), using improved genetic techniques, found that California golden trout and Little Kern golden trout represent two independent lineages derived from coastal rainbow trout. *O. m. aguabonita* is referred to in some lists as South Fork Kern golden trout or as Volcano Creek golden trout but California golden trout seems more appropriate, given its status as the official state freshwater fish of California.

The American Fisheries Society (Page et al. 2013) gives the official common name as just Golden Trout, which is considered a full species, *O. aguabonita.* The reasoning behind the species designation is that the golden trout is "recognized as a species by L. M. Page and B. M. Burr (2011) and herein because of lack of evidence of intergradation with *O. mykiss* (p. 206)." Presumably, Page et al. (2013) were thinking in terms of *natural* intergradation because interbreeding with introduced rainbow trout is a major problem for all golden trout (see below). However, natural interbreeding may have resulted in the Kern River rainbow trout, which has genetic characteristics of both species (Moyle 2002). An additional problem is that Little Kern golden trout should, under this classification scheme, be considered a separate species as well because they are a separate lineage from California golden trout. We therefore continue to favor treating the three forms as separate subspecies (lineages) of rainbow trout.

Life History: California golden trout live in cold, clear alpine streams. They have comparatively slow growth rates due to the truncated growing season and low productivity of high elevation streams in their native range (Knapp and Dudley 1990, Knapp and Matthews 1996). In streams, they are usually 3-4 cm SL at the end of their first summer of life, 7-8 cm SL at the end of their second summer, 10-11 cm SL at the end of their third summer, and grow 1-2 cm per year thereafter; they reach a maximum size of 19-20 cm SL and a maximum age of 9 years (Knapp and Dudley 1990). In alpine lakes, individuals from introduced populations grow to 4-5 cm FL, 10-15 cm FL, 13-23 cm FL, and 21-28 cm FL at the end of their first through fourth years, respectively (Curtis 1934); they can reach 35-43 cm FL by the seventh year. The largest on record from California weighed 4.5 kg, from Virginia Lake, Madera County, in 1952. However, most records of golden trout growth in lakes are suspect because populations were established from introductions that may have been hybridized with rainbow trout.

Golden trout spawn when they are three or four years old, when water temperatures exceed 10°C, with daily maximums of 16-18°C, in late June and July (Stefferud 1993; Knapp and Vredenburg 1996). Average daily temperatures for spawning are around 7-10°C and spawning occurs in gravel riffles in streams. Spawning behavior is typical of other members of the rainbow trout group, although golden trout spawn successfully in finer substrates (decomposed granite) more than most other trout (Knapp and Vredenburg 1996). Females produce 300-2,300 eggs, depending on body size (Curtis 1934). Embryos hatch within 20 days at an incubation temperature of 14°C. Fry emerge from the gravel two to three weeks after hatching, at which time they are about 25 mm TL. In introduced lake populations, fry move into lakes from spawning streams when they are about 45 mm TL.

In streams, golden trout are active at all times of day and night but tend to stay in the same areas for long periods of time (Matthews 1996a). They feed on both terrestrial and aquatic invertebrates, mostly adult and larval insects, taking whatever is most abundant. In lakes, they feed mainly on benthic invertebrates, especially midge pupae (*Chironomidae*) (T. Armstrong, UC Davis, unpubl. data). Although bright coloration makes them highly visible, there are very few natural predators in their range (Moyle 2002). Their tendency to be more active during the day than most trout also suggests low predation. Thus, their bright coloration may have evolved for reproductive advantage. However, bright coloration has also been implicated as providing camouflage against the bright colors of the volcanic substrates in the clear, shallow streams within their range (Needham and Gard 1959). When these trout are removed from mountainous streams and brought down to low elevation streams, they may lose their brightness and take on dull gray and red colors (Needham and Gard 1959). In lakes, they become paler in color, often appearing silvery.

Habitat Requirements: Golden trout evolved in streams of the southern Sierra Nevada, at elevations above 2,300 m. The valleys of the Kern Plateau are broad, flat, and filled with glacial alluvium, which results in wide meadows through which streams meander. These streams are small, shallow, and have only limited riparian vegetation along the edges. The exposed nature of the streams California golden trout inhabit is largely the result of heavy grazing of livestock on a fragile landscape, which began in the 1860s. Grazing causes compaction of soils, collapse of stream banks, and elimination of riparian plant cover (Odion et al. 1988, Knapp and Matthews 1996, Matthews 1996b). Stream bottoms are mostly volcanic sand and gravel, with some cobble. The water is clear and mostly cold, although summer temperatures can fluctuate from 3 to 20°C (Knapp and Dudley 1990). California golden trout generally prefer pool habitat and congregate near emergent sedges and undercut banks (Matthews 1996a). Environmental tolerances are presumably similar to those of coastal rainbow trout.

Distribution: California golden trout are native to the SFKR, which flows into Isabella Reservoir, and to GTC (including its tributary, Volcano Creek), which flows into the Kern River (Berg 1987). Initially (1909 and earlier), California golden trout were collected from GTC and transported north by pack train, extending their range by some 160 km by 1914 (Fisk 1969). They were also translocated into many other waters within and outside California, including Cottonwood Lakes, not far from the headwaters of GTC, and headwaters of the SFKR, such as Mulkey Creek (Stephens et al. 2004). Cottonwood Lakes served as a source of golden trout eggs for stocking other waters beginning in 1917. (Stephens et al. 2004). As a result of stocking in California, fish considered to be golden trout are now found in more than 300 high mountain lakes and 1,100 km of streams outside their native range (Fisk 1969), including Ash Meadows, Diaz Creek, and the Owens River drainage (Stephens et al. 2013). Many of these transplanted populations have hybridized with rainbow trout, including the golden trout from Cottonwood Lakes that have been used as brood stock for transplants (Moyle 2002, Stephens et al. 2004). California golden trout have also been introduced in lakes and streams in the Rocky Mountains, and in various ranges in Utah and Wyoming. However, most populations are also likely hybridized with either rainbow or cutthroat trout, although some populations in Wyoming generally show low levels of introgression (Stephens et al. 2013). Most out-of-basin transplants, however, show limited amounts of genetic diversity (Stephens et al. 2013). Some unhybridized populations apparently still exist from early transplants in the Sierra Nevada, but these too appear to have limited genetic diversity due to small numbers used to establish these populations (Stephens and May 2011).

Trends in Abundance: California golden trout populations suffered major declines during the 19^{th} and first half of the 20^{th} century from overfishing and heavy grazing. Invading brown trout displaced California golden trout, including hybrids, from all reaches below artificial barriers, so golden trout are now confined to a few kilometers of stream in the GTC watershed and in the South Fork Kern watershed. Within their native range, California golden trout occur at both low densities (0.02 - 0.17 fish per m^2 in streams) (Knapp and Dudley 1990) and at high densities (1.3-2.7 fish per m^2). Low densities are most likely to be in found in grazed reaches of stream with little cover and food, with some exceptions (see next paragraph). Presumably, densities were much higher, on average, before livestock began grazing the drainage. Although California golden trout were widely introduced outside their native range during the 19^{th} and 20^{th} centuries, the introduced populations should not be regarded as contributing to conservation because most (if not all) have hybridized with introduced coastal rainbow trout.

Knapp and Dudley (1990) estimated that golden trout streams typically support 8-52 fish/ 100 m of stream, although a recent estimate for Mulkey Creek, a tributary to the SFKR which supports an introduced population, was 472 fish/100m (Carmona-Catot and Weaver 2006). If the Knapp and Dudley figures are accurate, in 1965, when the first major CDFW habitat management plan was issued (CDFG 1965), there would have been 2,400-15,600 individuals in GTC (30 km) and 4,000-26,000 in the South Fork Kern (50 km). Curiously, the high numbers in the SFKR are found in reaches that have been degraded by grazing, presumably because the reaches contain decomposed granite substrates that are used for spawning (Knapp et al. 1998, S.

Stephens, CDFW, pers. comm. 2008). Lack of cover in these reaches selects for smaller fish, which are more numerous, but may have lower fecundity due to small body.

At present, if unhybridized fish exist only in 5 km of Volcano Creek, then there are only 400-2600 'pure' golden trout left in their native range, a decrease of at least 95% from historical numbers. The percentage of these fish that reproduce every year is unknown but likely to be small. A caveat on this very rough calculation is that it is based on genetic studies (Stephens et al. 2004) that show many fish that are counted as hybrids have a very low incidence of 'foreign' genes; thus it may not be necessary to eliminate all rainbow trout genes from introgressed populations through eradication, if there is no impact on phenotypes. If golden trout populations with phenotypes that show low introgression of rainbow trout genes are considered to have conservation value, then the numbers of golden trout would be considerably higher and might include fish both within and outside their native range as well. For example, the introduced population in Mulkey Creek may be as large as 40,000 fish (>75 mm FL) in roughly 10 km of habitat, with very low levels of introgression (2%; Stephens 2007). Nevertheless, because golden trout had been eliminated through hybridization and predation from most of the lower SFKR by 1965, where populations would have been most dense, the 95 percent decline figure for the native range may still be valid, even if populations with low introgression are counted.

California golden trout in the upper SFKR and GTC are introgressed with non-native rainbow trout, but introgression levels are markedly different in these two streams. Nearly all SFKR trout are introgressed with rainbow trout to some degree. There is also a cline of introgression from the lower Kennedy Meadows area (94%) upstream to the headwaters (2%). Such a pattern is reflective of stocking in the lower river with upstream movement of introgressed or rainbow trout through time (Stephens et al. 2013). Kennedy Meadows also contains dense populations of brown trout. In many reaches of GTC, however, levels of introgression are low. Recent work by Stephens et al. (2013) suggests that several populations within GTC show less than 5% introgression. Nevertheless, genetically 'pure' populations exist in only a few km of streams and will continue to do so for the short term (<5 yrs.).

Overall, unhybridized California golden trout are much less abundant than they have been in the past in their native range. In areas where they still persist, numbers may be higher than they were in the days of heavy harvest and grazing, but these numbers are still presumably less than historical highs (pre-1800s) because of the continued presence of hybridized fish, grazing, and other human impacts. More recently, drought in California has decreased habitat availability to the point that the CDFW determined a drought rescue was necessary. Forty-two California golden trout were taken from Volcano Creek by CDFW staff on September 19th, 2016 due to concerns about low population levels, the ongoing drought, and potential decrease in habitat quality. Fish were placed into separate raceways based on natal streams at the American River Hatchery to be reared through the winter and spring until their habitat is suitable for reintroduction, perhaps in the late summer or early fall, depending on habitat evaluation. Genetic samples will be taken from all fish to determine diversity in the population. Once CDFW completes a broad habitat assessment to determine adequate conditions exist for the species, the fish will be released back into the wild. Fortunately, these fish were kept in raceways that were unaffected by warm, turbid waters in the hatchery that forced hatchery staff to relocate and release tens of thousands of juvenile Chinook salmon and rainbow trout (J. Weaver, CDFW, pers. comm. 2016).

Factors Affecting Status: The principal threats to California golden trout are interactions with alien trout species, followed by grazing.

Alien species. The major threats from alien species are hybridization with rainbow trout and competition and predation from brown and rainbow trout. There is a long history of planting rainbow trout in the upper Kern River basin to improve recreational angling. The peak of stocking was probably 1931-1941, when 85,000-100,000 rainbows were planted every year (Gold and Gold 1976). Stocking of hatchery rainbows in the SFKR at Kennedy Meadow occurred until 2008 (B. Beal, CDFW, pers. comm. 2012). This portion of the SFKR also supports a fishery for wild brown trout. In addition, golden trout were introduced in Cottonwood Lakes in 1891, with a subsequent egg-taking station established by 1918; this population, the source of most golden trout transplants to other watersheds, was apparently contaminated with rainbow trout fairly early in its history. While Pister (2010) refers to the Cottonwood Lakes population as remaining "physically very attractive," a comment on their phenotypic similarly to California golden trout, the Cottonwood Lakes population is highly introgressed and likely offers little conservation value (Cordes et al. 2006).

In the SFKR, brown trout were eliminated, using piscicides, from headwaters in the early 1980s and Ramshaw, Templeton and Schaeffer barriers were constructed to prevent their reinvasion. Rainbow trout, however, were able to move upstream over the deteriorated Schaeffer Fish Barrier to the Templeton Fish Barrier. Brown trout still dominate about 780 km of stream in the SFKR basin (Stephens et al. 2004). Recent electrofishing data conducted by the Department of Fish and Wildlife at multiple reaches on the SFKR estimated an average of 775 brown trout/km, compared to 181 California golden trout/km within the same reaches (DFW 2009).

Recent efforts have focused on the removal of brown trout, but not introgressed California golden trout. Hybridized trout have been found upstream of the Templeton Barrier all the way to the headwaters of the SFKR. When these events occurred is not known because the original barriers have been replaced with improved structures. Improved structures, however, do not minimize the threat of introgression without the simultaneous removal of hybridized populations upstream of barriers. This combination of events has resulted in rainbow trout or rainbow trout-golden trout hybrids invading most streams in the native range of California golden trout in the SFKR and hybridizing with non-introgressed individuals (Cordes et al. 2006). By the early 1990s, both Templeton and Schaeffer fish barriers had deteriorated and the Schaeffer Barrier allowed upstream fish passage. Both barriers were replaced with substantial concrete structures in 1996 and 2003, respectively. In these reaches, golden-type trout (goldens of varying degrees of hybridization) coexist with both brown trout and native Sacramento sucker (Carmona-Catot and Weaver 2006), although the long-term viability of this assemblage is not known. In GTC, hybridization affects only a small percentage (about 5%) of the trout and many of these populations represent the highest conservation priority (Stephens et al. 2013). In the SFKR basin, only a few headwater populations may have escaped hybridization (Cordes et al. 2006), while in Volcano Creek and some smaller tributaries most populations show extremely low levels or no signature of introgression. Both GTC and SFKR populations show some reduction in genetic diversity, but Stephens et al. (2013) suggested that levels of genetic diversity in most native range populations is not of primary concern.

Most places where golden trout have been planted outside their native range have also likely been planted with rainbow trout, or the golden trout actually originated from hybridized stocks (i.e., Cottonwood Lakes). Hybridization with rainbow trout results in fish that are likely to be less brightly-colored than native golden trout. The rainbow trout phenotype eventually becomes dominant, so the fish look more like rainbow trout. This has been well demonstrated in the lower SFKR, where hatchery rainbow trout had been planted annually from the 1930s until the late 2000s. The few wild golden trout left are heavily hybridized, having a rainbow-like appearance. After 2004, only sterile triploid rainbow trout were stocked in the lower SFKR, with stocking entirely discontinued in 2008. Hybridization can ultimately result not only in the loss of the uniquely colored variety of trout, but also loss of genetic material that reflects adaptations to the distinctive environment of the upper Kern River basin. However, it is possible that populations with a low frequency of rainbow trout alleles (genes) may be able to retain golden trout coloration, a high degree of genetic fitness, and adaptability to their habitats.

In addition to threats from rainbow trout, predation and competition from introduced brown trout are a continuous threat. In 1993, CDFW biologists found a reproducing population of brown trout above the lowermost barrier (Schaeffer) and a population was also found in Strawberry Creek in 2003 (S. Stephens et al. 2004). How they arrived there is not known, but it would have been relatively easy for anglers to move fish over the barrier. While barriers that prevent fish from migrating upstream can eliminate or reduce gene flow among golden trout, they may be the only solution to preventing additional upstream movement of alien trout. Construction of an additional barrier is possible near Dutch John Flat, upstream of Kennedy Meadows, to create an additional isolated area (B. Beal, CDFW, pers. comm. 2012).

Grazing. Livestock grazing is permitted in designated Wilderness Areas, such as the Golden Trout Wilderness Area; grazing occurs around GTC and the SFKR where California golden trout reside. According to the USFWS (October 11, 2011, 76 FR 63094), about 95 percent of areas around golden trout streams have been grazed by livestock for 130 years. Not surprisingly, some sections of stream and entire meadows have been severely damaged. The negative effects of grazing at all levels in the fragile meadow systems of this region have been well documented (Knapp and Matthews 1996, Matthews 1996b). Grazing impacts to instream and riparian habitats include: reducing the amount of streamside vegetation, collapsing banks, making streams wider and shallower, reducing bank undercutting, polluting waters with feces and urine, increasing temperatures, increased siltation in spawning beds (smothering embryos), and generally making habitats less complex and suitable for trout. These impacts may result in declines in trout populations.

Levels of cattle grazing have been reduced in recent years and the USFS has adopted guidelines to allow heavily grazed areas to recover (USFWS October 11, 2011, 76 FR 63094). Two of the four grazing allotments on the Kern Plateau have been rested since 2001 (S. Stephens et al. 2004). Future management of grazing for the four allotments is being considered by the USFS with a decision concerning grazing yet to be determined (as of 2016). Herbst et al. (2012) showed that eliminating grazing in the Golden Trout Wilderness meadows resulted in improved streambank structure and macroinvertebrate diversity, while fencing short sections of stream did not have the same effect. The authors suggest that removal of grazing at broader spatial scales (i.e., meadow) was more effective in achieving ecosystem and biotic recovery than small, reach-scale improvements. Such broad spatial habitat improvements are likely to be reflected in larger, more robust golden trout populations. The grazing allotment decision and the future enforcement of improved grazing practices will have major impacts on the health of golden trout populations in their native range.

Recreation. Although California golden trout waters are entirely within Sequoia and Inyo National Forests and largely within the Golden Trout Wilderness, they are still impacted by human activities, including off-road vehicles (in the lower portions of the SFKR) and recreational damage by hikers, horse riders and pack stock. A particular threat is off-road vehicle use in the vicinity of Monache Meadows and the severe degradation of the lower SFKR due to multiple causes throughout that area.

Harvest. Recreational fishing within the Golden Trout Wilderness is allowed from the last Saturday in April through November 15, is restricted to artificial lures with barbless hooks, and a five fish daily bag and possession limit is allowed. Harvest rates are unknown, but are presumably low due to the remote nature of most golden trout-bearing streams, along with shifts in angler preference toward catch-and-release fishing, particularly for native or unique forms of trout with limited distributions.

Hatcheries. Golden trout, usually partially hybridized, are still raised in hatcheries for the purpose of supporting recreational fisheries, but these fish are not planted in the native range.

Factor	**Rating**	**Explanation**
Major dams	n/a	All major dams outside native range of California golden trout.
Agriculture	n/a	
Grazing	Medium	Ongoing threat but greatly reduced from the past.
Rural /residential development	n/a	
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	Historical mines are present but have no known impacts.
Transportation	Low	Trails and off-road vehicle routes can be a source of sediment and pollution input into streams; direct habitat impacts from wet route crossings.
Logging	Low	This is an important land use in the broader region but probably has no direct effect on golden trout streams.
Fire	Low	Because of fire suppression, headwater areas could be impacted by hot fires, although this is unlikely given sparse plant communities in region.
Estuary alteration	n/a	
Recreation	Low	Pure populations within the GTC watershed are entirely within designated wilderness; South Fork populations with conservation value are also within designated wilderness.
Harvest	Low	Potential impact; light pressure, mostly catch and release.
Hatcheries	Low	Residual effects of hybridization with hatchery fish.
Alien species	High	Major cause of limited distribution in South Fork Kern River; however, very limited introgression with rainbow trout and no brown trout in waters within GTC watershed.

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of California golden trout. Factors were rated on a five-level ordinal scale where a factor rated "critical" could push a species to extinction in 3 generations or 10 years, whichever is less; a factor rated "high" could push the species to extinction in 10 generations or 50 years whichever is less; a factor rated "medium" is unlikely to drive a species to extinction by itself but

contributes to increased extinction risk; a factor rated "low" may reduce populations but extinction is unlikely as a result. A factor rated "n/a" has no known negative impact. Certainty of these judgments is high. See methods for explanation.

Effects of Climate Change: The major predicted impacts of climate change in the Sierra Nevada are reduction in snow pack, increased likelihood of rain-on-snow events, and shifts in peak runoff from late spring/early summer months to late winter/early spring months due to warmer temperatures. This will have the least effect in the southern Sierra Nevada because the mountain elevations are highest there and may continue to retain a great deal of snow. Thus, snow melt is likely to maintain flows in golden trout streams. Nevertheless, snow pack may not persist as long in the extensive meadows of the Kern Plateau and meadows are likely to become drier by the end of summer, with reduced base flows in streams. Elimination of grazing and other activities that compact meadows (reducing their ability to store water) and reduce riparian cover and shade can mitigate, in part, for the effects of climate change. Temperatures are likely to increase earlier in the season in golden trout streams and it is possible that spawning times may become earlier, with unknown consequences. Moyle et al. (2013) rated California golden trout as "critically vulnerable" to climate change, indicating that extirpation from its native range is likely by 2100 if present trends continue.

In addition, climate change is likely to increase the variability of precipitation patterns in California, and may increase the frequency and intensity of drought in California. For example, as a direct result of California's ongoing historic drought, golden trout in Volcano Creek and adjacent wetland meadows (Tulare Co.) were rescued from drying, isolated pool habitat. As predictions of more frequent drought become reality, such continues are likely to be necessary in the future to continue persistence of the species.

Status Score = 1.9 out of 5.0. Critical Concern. The California golden trout is listed as a Species of Special Concern by California Department of Fish and Wildlife and as a Sensitive Species by the USDA Forest Service. The American Fisheries Society lists it as threatened, while NatureServe lists it as "Critically Imperiled" (Jelks et al. 2008).

A petition to the USFWS to list California golden trout as federally endangered was submitted by Trout Unlimited in 2000 (Behnke 2002). The U.S. Fish and Wildlife Service determined in a 90-day finding that the proposal deserved additional consideration. After a 10 year review, the USFWS concluded (October 11, 2011, 76 FR 63094) that listing was not warranted because of the collaborative efforts taking place to protect the trout, particularly the ongoing and active implementation of the Conservation Assessment and Strategy for the California Golden Trout (1994). This cooperative conservation agreement, signed by state and federal agencies and concerned NGOs, indicated that listing the fish would provide few, if any, additional benefits to it. According the *Federal Register* (76 FR 63094): "The purposes of the Conservation Strategy are to: (1) Protect and restore California golden trout genetic integrity and distribution within its native range; (2) Improve riparian and instream habitat for the restoration of California golden trout populations; and (3) Expand educational efforts regarding California golden trout restoration and protection." Until recently, the California golden trout was perceived as secure because it had been widely introduced throughout the Sierra Nevada and the Rocky Mountains. However, these introduced populations are likely on a different evolutionary trajectory from the native populations (most are in lakes) and they have also largely hybridized with rainbow trout. Nonetheless, Stephens and May (2011) show a number of populations do exist outside the native range that are unhybridized or only slightly introgressed. As Stephens and May (2011) point out:

> "…it is possible that these populations could be preserved *in situ* as an insurance policy against the loss of CAGT [California golden trout] within their native range or possibly utilized in other conservation or restoration efforts. Any introduction of these fish into the native CAGT range should be considered with caution: 1) future genetic analysis may reveal introgression previously undetected, 2) they do not appear to contribute any unique allelic diversity not already represented in the extant native range populations, and 3) they may have experienced substantially different selection regimes in their watersheds, possibly rendering them less (or more) fit than extant CAGT (p. 12)."

Meanwhile, even slightly hybridized populations in the native range can only be maintained through constant intervention such as building and repairing barriers and eradication of non-native trout and golden-rainbow hybrids (Behnke 2002).

Metric	Score	Justification
Area occupied	1	Unhybridized California golden trout are confined to a few small tributaries in one watershed.
Estimated adult abundance	3	Volcano Creek populations may be <1,000 but, if other populations with conservation value within native range are counted, the numbers would be much higher, perhaps 50,000.
Intervention dependence	2	Annual monitoring of barrier performance required; continued implementation of Conservation Strategy is critical. Rescued individuals from Volcano Creek will need to be re-introduced based on genetic management strategy.
Tolerance	3	Generally tolerant of a wide range of conditions and habitats within their native range.
Genetic risk	1	Hybridization with rainbow trout is a constant high risk.
Climate change	1	Rated critically vulnerable in Moyle et al. (2013).
Anthropogenic threats	2	1 High, 1 Medium threat.
Average	1.9	13/7.
Certainty (1-4)	4	Well documented.

Table 2. Metrics for determining the status of California golden trout in California, where 1 is a poor value and 5 is excellent. Each metric was scored on a 1-5 scale, where 1 is a major negative factor contributing to status; 5 is a factor with no or positive effects on status; and 2-4 are intermediate values. Certainty of these judgments is high. See methods for explanation.

Management Recommendations: The overarching goal of California golden trout management should focus on the maintenance of self-sustaining populations in refuges that can persist through long periods of less intensive management and/or extended drought. Populations in their native range have persisted because of continuous, cooperative actions by the California Department of Fish and Wildlife, USFWS, and U.S. Forest Service, along with volunteers from multiple groups. Ever since it was realized in 1968 that California golden trout in the SFKR were threatened by alien trout, mainly brown trout, major efforts have been undertaken to create refuges for golden trout in the upper reaches of the SFKR by constructing three barriers (Ramshaw, Templeton, Schaeffer) and then applying rotenone and antimycin to eradicate unwanted fish above or between barriers. From 1969 through 2000, 10 treatments were carried out, with varying degrees of success (Stephens et al. 2004). In addition, gill netting of selected headwater lakes (e.g. Chicken Spring Lake, Rocky Basin lakes) to remove hybridized fish has been successful and these lakes are now fishless. The future focus of conservation should be protection of the original gene pools of golden trout in GTC and SFKR as: (1) a source for future fish transplants into restored streams, (2) stocks that can be genetically compared with introduced populations, and (3) an aesthetic measure. However, special protection should also be provided to demonstrably unhybridized populations outside the native range, as an insurance policy against complete loss of unhybridized fish from within the native range.

Implementation of the Conservation Strategy for California golden trout should reduce the threat of extinction through management of hybrids, maintenance of multiple barriers (redundancy in case one fails), improved management of watersheds, and elimination of non-native trout populations (S. Stephens et al. 2004). This strategy continues to be implemented and several key goals of this document have been met. These include the replacement of two failing fish barriers and increased genetic research to better understand the overall status of California golden trout. Construction of an additional barrier in the lower portions of the South Fork Kern drainage is being explored. Two of the four existing grazing allotments in the area have been rested since 2001. Additional management actions needed include: (1) repair or replacement of barriers, (2) eradication of all rainbow trout and brown trout populations that threaten California golden trout, (3) utilization of recent genetics techniques to refine management, (4) improved management of livestock grazing, (5) modified recreation management strategies, and (6) expanded efforts to further implement the Conservation Strategy.

Barrier improvement. Barriers to prevent alien trout from invading golden trout waters are important, if ultimately short-term, management measures. Templeton and Schaeffer barriers were replaced with major concrete structures in 1996 and 2003 respectively, and have reduced the probability of unwanted invasions. However, because accessible barriers that have golden trout on one side and brown trout on the other are inherently flawed (by the ease of moving fish over the barrier), other solutions are needed. D. Christensen and S. Stephens suggested (USFS, CDFW, pers. comm. 1995) that "It would seem appropriate to construct a bedrock barrier downstream of Monache Meadows in the gorge area or even further downstream in the drainage, and extend the [California golden trout] population. This would provide a permanent barrier with a great deal less public access." Such a structure at Dutch John Flat is in the early planning stages about 10 km upstream of Kennedy Meadows. Whether such a structure will ever be built in designated wilderness remains uncertain (S. Stephens, CDFW, pers. comm. 2016).

Eradication of alien species. Eradication of non-native trout continues to be a necessary and important measure. Unfortunately, such eradication generally requires the use of the controversial piscicide, rotenone. Alternate toxins (e.g., antimycin) have yet to be approved in California so are unavailable for use. A thorough risk analysis should be conducted for streams in which their use is proposed. The analysis should include risks entailed to the continued existence of the species if they are *not* used.

Use of genetic techniques. Increased use of new genetic techniques is occurring and necessary in order to allow for genetics-based management. A genetics management plan

(GMP) for California golden trout was completed in 2013 (Stephens et al. 2013). The best management approach in the GTC watershed is to monitor populations at intervals of five years or more to assess estimates of introgression from SNPs (single nucleotide polymorphism) and microsatellite analyses. After fully defining the genetic landscape, Stephens et al. (2013) recommend segregating SFKR and GTC populations into distinct management units and then ranking subpopulations within SFKR and GTC based on their conservation value. Conservation value should reflect some composite of genetic status, abundance, and likelihood of responding positively to recovery actions, for example (Stephens et al. 2013). Once the genetic landscape is defined and populations are ranked, recovery actions may proceed. Genetic recovery actions primarily focus on establishing refuge populations outside the native range, considering the use of a conservation hatchery where strict genetic protocols are in place to maximize genetic diversity, and translocating individuals of similar ancestry from one population to another (Stephens et al. 2013). Such actions should help to conserve important genetic diversity. There are risks associated with these actions, such as the potential for outbreeding depression or artificial selection associated with a hatchery environment, but there are also potential benefits regarding the conservation of important genetic diversity. As such, recovery actions should be conducted experimentally and within an adaptive management framework.

As mentioned, there is a cline of hybridization in the SFKR with levels of introgression with non-native rainbow trout increasing downstream (Stephens 2007). Plans to install a new fish barrier at Dutch John Flat should be pursued. Using the guidance of the GMP and the Conservation Strategy, managers should develop appropriate plans and take steps to fully eradicate brown trout and hybrid golden trout utilizing the system of SFKR barriers. These activities may take years to accomplish, but offer large rewards for golden trout in terms of greatly expanded range and protection from hybridization, competition and predation.

Grazing. Improvements have been made in livestock grazing management in the Golden Trout Wilderness Area in recent decades, but further refinement and restrictions may be necessary to protect golden trout populations and their habitat. Continued resting of grazing allotments (or elimination of allotments altogether) should result in recovery of riparian vegetation and associated shading, improved stream channel morphology, and increased abundance of invertebrate food supplies for fish (Herbst et al. 2012). According to the USFWS (2011, *Federal Register* 76 FR 63094), changes in grazing management practices for the past 10 years or so, including resting allotments, have removed grazing as a primary threat to golden trout but the practice may still cause degradation of streams. If complete elimination of grazing is infeasible, then intense management of grazing to reduce impacts on streams should be continued and expanded, including the use of allotment rotation, seasonal closures during periods when meadows are wet, herd size reduction, expanded fencing, and active herd management to keep cattle away from streams. Monitoring of grazing practices needs to continue in order to document compliance with appropriate U.S. Forest Service guidelines.

Recreation management. Improvement of recreation management is needed, which should include better enforcement of existing laws and increased public education programs. Forest Road (Route) closures should be implemented where needed (e.g., eliminate off-road vehicles from areas where they are currently directly impacting streams).

Integrated management. The CDFW performs regular monitoring of populations in the native range (Carmona-Catot and Weaver 2006, Weaver and Mehalick 2008, Weaver and Mehalick 2009), and these surveys should continue in order to determine population status and to document the presence and distribution of non-native trout. The CDFW plans greatly expanded genetics, population structure and abundance, and habitat monitoring in the near future which will include random stratified sampling of sites throughout the SFKR and GTC drainages (J. Weaver, CDFW, pers. comm. 2013). This level of sampling will provide scientifically rigorous and objective data to inform future management on a much broader spatial scale than ever performed. Beyond expanded monitoring, two kinds of refuges in the native range should also be established for managing California golden trout: (1) streams containing unhybridized populations and (2) streams containing populations with low levels of hybridization (S. Stephens et al. 2004). Defensible streams (by barriers) that do not meet these criteria should be converted to one or the other type of refuge as soon as possible. This type of intensive management requires periodic genetic assessments of refuge populations. In addition, populations of unhybridized California golden trout found outside the native range should also receive special protection and management, as described for populations in the native range. These would serve as additional refuge populations and could be used for experiments in management (e.g., modified grazing practices, introductions from other populations to increase genetic diversity) without compromising genetically 'pure' populations within the native range. For information on additional management measures, see Stephens et al. (2004) and Sims and McGuire (2006).

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