GOOSE LAKE REDBAND TROUT
Oncorhynchus mykiss newberrii

Moderate Concern. Status Score = 3.1 out of 5.0. Goose Lake Redband trout do not face immediate extinction risk. However, California populations are not secure because they are largely isolated from one other, most are small, and, during drought periods, the lake population disappears and stream populations contract.

Description: Goose Lake Redband trout are similar in appearance to other rainbow/redband trout. Their bodies are a yellowish to orange color with a brick-red lateral stripe, with generous spotting along the body. The dorsal, anal, and pelvic fins are white-tipped. Stream-dwelling adults retain parr marks, while lake-dwelling adults become silvery-grey in color. The Goose Lake Redband trout has two ecological types: a lake-dwelling form that attains lengths of 45-50 cm TL and a stream-dwelling form that rarely grows larger than 25 cm TL. Behnke (1992) examined six specimens collected by J. O. Snyder in 1904 from Cottonwood Creek, in the Oregon portion of the basin. These fish had 21-24 (mean, 23) gill rakers, 61-64 (mean, 63) vertebrae, and averaged 30 scale rows above the lateral line and 139 scales in the lateral series. See Behnke (2002) for color plates of both lake and stream forms.

Taxonomic Relationships: Redband trout are inland forms of Rainbow trout (Behnke 1992, 2002) and the Goose Lake redband belongs in the group that Behnke (2002) calls "redband trout of the northern Great Basin, *O. m. newberrii*." The Goose Lake Redband trout is most similar to redband trout of two adjacent basins: the Warner Basin, California, Oregon and Nevada, and the Chewaucan Basin, Oregon (Behnke 2002). This conclusion is based on the lower vertebral counts and higher gill-raker counts of redband trout in these basins and distinct genetic markers.

The USFWS lumped Goose Lake Redband trout with five other Great Basin redband trout as one Distinct Population Segment when considering a petition for listing them as threatened under the Federal Endangered Species Act (*Federal Register* 65(54), March 20, 2000, 14932-14936). Although the Goose Lake watershed may have had connections to other Great Basin watersheds during wetter climatic periods, it is clearly isolated from other basins today and, presumably, has been for thousands of years. While *O. m. newberrii* is a reasonable taxonomic designation, the Goose Lake Redband trout is clearly also a distinct evolutionary unit/population segment, confined to the Goose Lake basin and nearby headwater streams in the upper Pit River.

Warner Lakes Redband trout are similar genetically to Goose Lake Redbands, and inhabit only a very small portion of water in an adjacent basin to Goose Lake in California (Dismal and Twelvemile creeks). Recent studies using DNA (amplified fragment length polymorphism AFLP techniques) indicate a close relationship between Goose Lake redbands with Warner Lakes Redband trout (M. Stephens 2007, Currens et al. 2009). Currens et al (2009), using both mitochondrial and nuclear DNA, posited that redband trout from the upper Pit watershed, Goose Lake, and the Warner Lakes basin form a distinctive lineage that is perhaps deserving of its own ESU under the criteria developed by the U.S. Fish and Wildlife Service. This has since been confirmed by more recent work from Simmons et al. (2011), Muhlfeld et al. (2015), and DeHaan et al. (2015). In addition the Goose Lake Redbands and Warner Lakes fish show very low levels of introgression with coastal rainbow trout, which is fortunate given past stocking in the Oregon portion of the watershed (DeHaan et al. 2015). While the California Department of Fish and

Wildlife consider the Warner Lakes Redband population a separate qualifying trout from the Goose Lake Redbands for the California Heritage Trout Challenge (CDFW 2016), we group them with the related Goose Lake Redbands in this account.

Life History: Goose Lake Redband trout have two life history strategies: a lake strategy and a headwater strategy. Lake strategy fish live in Goose Lake, where they grow to large size and spawn in tributary streams. Headwater strategy fish remain small and may spend their entire life cycle in streams. It is almost certain that the two forms represent one population because the aperiodic desiccation of Goose Lake presumably has eliminated the lake form repeatedly in the past. This was demonstrated in 1992 when the lake dried up entirely during a prolonged drought. In the next two years, the lake refilled and, about three years later, small runs of large trout again appeared in the streams. It is assumed that the lake dwelling form was reestablished from tributary stream-resident populations. In the small, cold streams of the Warner Mountains to the east of Goose Lake, scattered populations of resident trout persist, completing their entire life cycle in these streams. They look quite different from lake fish because of small size and more vibrant color patterns, reflecting responses to a stream environment. Many of these populations are above potential barriers to upstream movement of fish from the lake (Muhlfeld et al. 2015, M. Dege, CDFW, pers. comm. 2016). Presumably, small numbers of headwater redbands always move downstream, a natural mechanism for dispersing to new habitats or for recolonizing streams wiped out by drought or other natural disasters. Some of these fish reach the lake and, a few years later, they mature and spawn, renewing the cycle. It is also possible that progeny of lake-strategy fish can persist in some lower-elevation tributaries (e.g., Cold Creek).

In California, the lake-dwelling form ascends small tributaries to spawn. Landowners in the area have seen large adults ascending Cottonwood (Oregon) and Pine creeks in the spring, presumably migrating for this purpose, while CDFW have documented large spawning adults in Lassen, Cold, and Willow Creeks (CDFW unpubl. obs.). If sufficient flows are available, they also spawn in Buck Creek, a small tributary of Willow Creek. Upstream of its confluence with Cold Creek, a steep, rocky gorge apparently prevents spawners from ascending further up Lassen Creek. In Oregon, they formerly spawned in Thomas Creek and its tributaries and, possibly, in Cottonwood and Drews creeks. Spawning migrations occur following snow melt and rain in the spring, usually during late March or in April. Spawning fish are rather pale looking, perhaps as a result of time spent in Goose Lake's highly turbid waters. Adults return to the lake following spawning. Young trout apparently spend one or more years in streams before dispersing downstream (if they leave at all) into Goose Lake. In the lake, the trout likely feed on Goose Lake Tui chub, Tadpole shrimp, and other super-abundant food. Growth appears rapid; scales from 6 spawning fish (27-48 cm TL) taken in 1967 indicated that they were all 3 years old (CDFW unpubl. data).

The life history of the stream-dwelling form has not been studied but it is thought to be similar to other redband and rainbow trout that live in small, high-elevation streams. Surveys by CDFW (CDFG unpublished data; Hendricks 1995) indicate that headwater streams have 4-5 length classes of trout, with a maximum size around 240 mm TL, though about 80% of the population measured less than 150 mm (Weaver and Mehalick 2010). It appears that fish in their third summer are 9-12 cm TL. Lake fish were observed spawning May 14-15, 2007 (CDFW unpubl. data), though spawning time is highly dependent on variable water years and amount of runoff.

Habitat Requirements: Goose Lake is a large, alkaline lake that straddles the California border; it is shallow (mostly < 3 m when full), extremely turbid, and highly variable in area (about 500 km^2). Because of its high elevation (1430 m), the lake generally remains cool (< 22°C) although summer temperatures in the lake may reach 24°C or higher during the day. During calm days, water temperatures stratify with warm water within the first 25-50 cm of the surface; on most days the wind causes temperatures to be uniformly cool (R. White and P. Moyle, unpublished data, 1989). Goose Lake Redbands nevertheless survive warm temperatures, high alkalinities, and high turbidity that exist in Goose Lake during summer months. Presumably, a major factor contributing to their survival is the extraordinarily high abundance of fish, tadpole shrimp (*Lepidurus lemmoni*) and other food in the lake (P. Moyle and R. White, unpubl. obs.).

Spawning takes places in March-May, whenever flows in Willow and Lassen creeks are high enough to attract trout for an upstream migration (M. Yamagiwa, USFS, and S. Reid, pers. comm. 2007). Most spawning areas are located in reaches and tributaries with permanent flows, such as Cold Creek, a tributary to Lassen Creek about 15 km upstream from the lake. Spawning sites are reaches with clean gravels and riparian cover that maintain cool water temperatures. Goose Lake Redbands have been observed to spawn in the lower reaches of Willow and Lassen creeks when access to upstream areas is blocked (P. Chappell, USFS, pers. comm. 1995), but most spawning areas are upstream of the Highway 395 crossing. However, spawning migrations and behavior of Goose Lake Redband Trout has been poorly recorded in California.

Tate et al. (2005) evaluated temperatures in the two largest California tributaries to Goose Lake, Lassen and Willow creeks. Lassen Creek, the larger of the two (1-2 cfs flows in late summer), became progressively warmer from headwaters to mouth, so that headwater reaches were typically < 16°C in summer, while lower reaches typically averaged 18-21°C, all reasonable temperatures for trout. However, in the summer of 2007, temperatures in some reaches supporting trout regularly reached 24-26°C (S. Purdy, unpublished data). Likewise, Tate et al. (2005) found temperatures in Willow Creek of 24°C on occasion, although intermediate reaches in a shaded canyon were considerably cooler.

The habitat requirements of the stream-dwelling form are similar to other populations of redband trout that occupy small, cool, high-elevation streams. Forested, headwater streams with complex substrates provide habitat for most Goose Lake Redbands (Scheerer et al. 2010). Streams in the Warner Mountains are generally dominated by riffles with undercut banks. Pools in meadow areas provide habitat for larger fish. Dense overhanging vegetation, especially willows, provide essential cover.

The environmental tolerances of Goose Lake Redband Trout have not been measured, but it can be inferred that they can survive temperatures of 24°C for short periods on a regular basis, highly turbid, alkaline water (pH 8-9), and dissolved oxygen levels at < 50% saturation, although growth may be inhibited under more extreme conditions.

Distribution: Goose Lake Redband Trout are endemic to Goose Lake and its major tributaries and a few tributaries to the upper Pit River. In California, Lassen and Willow creeks are their principal streams although they are also present in smaller streams (Pine, Cottonwood, Davis, Turner, and Corral creeks). In Oregon, they inhabit the extensive Thomas-Bauers Creek system as well as 12 smaller streams (Fall, Dry, Upper Drews, Lower Drews, Antelope, Muddy, Cottonwood, Deadman, Crane, Cogswell, Tandy, and Kelley creeks) (Oregon Department of Fish and Wildlife 2005). Berg (1987) reported that Joseph and Parker and creeks, tributaries of

the North Fork Pit River in California, and East Creek, tributary to Mill Creek and the South Fork Pit River, contained trout genetically similar to Goose Lake Redbands. Similar results for upper Pit River Redbands were found by M. Stephens (2007). Simmons (2011) identified genetically similar fish in North Fork Fitzhugh Creek, tributary to South Fork Pit River and in Parker Creek, tributary to North Fork Pit River, south of Goose Lake. In addition, two populations, from Crump Lakes (Deep and Twentymile creeks) and Honey Creek (Hart Lake) in the eastern Warner Mountains above Surprise Valley, OR, seem to be Goose Lake Redbands, perhaps as the result of historical introductions (Stephens 2007, DeHaan et al. 2015). Goose Lake Redbands have been reported from Pine Creek (1993) and Turner Creek (1986) during electrofishing surveys, although they could have been misidentified (CDFW 2015 electrofishing data).

Trends in Abundance: According to local history, in the 19th century these trout were once abundant enough in the lake that they were harvested commercially and sold to logging camps. Conversations with local residents (P.B. Moyle 1989) indicated that both sport and commercial fisheries existed for Goose Lake Redband trout and that large runs occurred in local creeks, especially Thomas Creek in Oregon. The Goose Lake Redband trout population historically has undergone major fluctuations, being depleted during series of dry years and recovering in wet periods. The lacustrine population was severely depleted during the 1976-1977 drought, recovered during the wet early 1980s, and dropped precipitously during the 1986-1992 drought. Most recently, the lake was dry in 2009, nearly dry in 2010, extremely low and most likely dry in 2013, and completely dry in both 2014 and 2015 (M. Dege, CDFW, pers. comm. 2016). As a result, there is likely no lacustrine population at the moment, but the potential for that life history expression still exists in trout in tributaries to the lake.

In California, Lassen Creek and its tributary, Cold Creek, have been the principal spawning streams. Numbers of spawning fish have fluctuated from ten or so individuals to several hundred, but the creek appears to have the potential to support perhaps 1,000 spawning fish under optimal flow conditions (E. Gerstung, CDFW, pers. comm. 1995). The only large run documented in recent years in Lassen Creek (1988) was comprised of several hundred spawners (J. Williams, unpubl. data), which suggests that there were fewer than 1,000 adults from California streams in Goose Lake, assuming many of the lake fish were immature one and two year old fish. In 1989, in the middle of a drought, only about a dozen fish appeared in the creek and there was no evidence of successful spawning.

Goose Lake dried up in 1992 but, by March, 1997, a run was reported in Lassen Creek and spawning was reported in April in Cold Creek (M. Yamagiwa, USFS, pers. comm. 2007). In May, 1999, (S. Reid, CDFW, pers. comm. 2007) observed "…big fish (40-70 cm) stacked four deep (literally) in the pools (estimated 75 at Hwy. 395)." This suggests that runs of several hundred fish had redeveloped in these tributaries and others in a relatively short period of time.

The stream form of Goose Lake Redband trout apparently exists in about 20 small headwater streams. ODFW (2005) estimated that about 102,000 trout (+/-32%) age 1+ and older ($0.14/m^2$) live in 13 Oregon streams under typical conditions; this number is presumably low compared to numbers that existed before streams were degraded by grazing and other activities. Surveys of California streams made in 1993 and 1999, showed 600-1,600 trout per km in Lassen Creek, which suggests that densities/numbers in California and Oregon streams are roughly comparable (CDFW unpubl. data). More recent CDFW multiple-pass electrofishing surveys (Weaver and Mehalick 2010) estimated 114-747 trout per km in Lassen Creek and 313-451 trout

per km in Cold Creek, considerably lower than previous estimates from surveys in 1986 and 1999, but with the caveat that section lengths were estimated in 1999 (J. Weaver, CDFW, pers. comm. 2013), so abundance estimates may or may not be accurate for that year.

ODFW (2005) indicated that most Oregon redband trout streams are impaired to some degree by cumulative effects from irrigation diversion dams, dewatering of streams, and generally poor habitat (from grazing, mining, and roads). Most of the streams also suffer from loss of connectivity to each other and to Goose Lake, and therefore it is likely that these habitats no longer support their potential productive capacity of native fishes (Scheerer et al. 2010). Streams in California face similar challenges although the largest stream, Lassen Creek, seems to be in better condition than most, largely due to extensive habitat restoration efforts such as installing juniper revetments, weirs and boulders, culvert baffles, fish screens, and removal of debris (CDFW 2010). Since 1995, conditions for Goose Lake Redband trout in California have steadily improved because large sections of Lassen Creek and other streams have increased protection from grazing due to changes in USFS allotments and otherwise been restored. These conservation measures have likely improved habitat conditions, which can benefit runs of lake fish to re-establish themselves when hydrologic conditions are favorable. Presumably, headwater populations have increased as well, thanks to better management. Recent habitat improvements in Oregon actually led to an expansion of the distribution of the species from 1995 to 2007, according to ODFW surveys (Scheerer et al. 2010).

Factors Affecting Status: Goose Lake Redband trout populations face many stressors, but habitat degradation and diversions have historically been and remain the greatest threats (Table 1). ODFW (2005) indicated that these two factors, combined, put Goose Lake Redband trout "at risk" in 80% of Oregon streams. Overexploitation and introduced species are, at present, minor problems. However, all threats are exacerbated during periods of severe drought such as the current one. Goose Lake dried up in the 1420s, 1630s, 1926 (with low lake levels from 1925 to 1939), 1992, and 2009, and 2014-2015-2016. As of Fall 2016, Goose Lake is filling as a result of an above normal water year in northern California (P. Divine, CDFW, pers. comm. 2017). The key to long-term survival of Goose Lake Redband trout (and other Goose Lake fishes) is maintenance of populations in tributaries that may have severely reduced habitat during drier periods.

Agriculture. Populations of the lake-dwelling form were reduced because access to spawning areas was blocked by dams, diversions, culverts, and channelization in the lower reaches of many streams but, since 1995, most of these impacts have been mitigated or eliminated. Much of the critical stream habitat for Goose Lake Redband Trout is on private land and, at times, large volumes of water are diverted to irrigate fields. On some streams, small diversion dams are barriers to fish movement (ODFW 2005). Diversions may have disproportionate impacts in dry years because they have the potential to dry longer stream reaches that are refuges for trout and other fishes when the lake is dry. Many fish screens have been installed on Goose Lake tributaries and are helping to reduce some impacts of agricultural diversions (CDFW 2010).

Grazing. Headwater streams containing redband trout have been heavily grazed, resulting in reduced riparian cover and, in places, down-cutting to bedrock. The impact of grazing has been reduced in recent years through a combination of fencing, rotational grazing, installation of erosion control structures, and planting of willows.

Transportation. All streams in the watershed have been degraded by roads to some degree. Highway 395 crosses all tributaries to the east side of the lake and culverts under the highway were once a partial barrier to migration, an issue which has largely been fixed. Roads also impact headwater streams, especially where culverts may be barriers to fish movement or where the road-cuts are a source of silt. Some streams face multiple threats from poor water quality as the result of road building, channelization, and waste materials from uranium mines.

Logging. Timber harvest is a prominent use of the watershed's forests and has contributed to habitat degradation in streams through siltation, road-crossings, and other factors. Logging impacts were more severe historically; many regulations exist today to protect stream habitats from the effects of timber harvest operations.

Harvest. When lake-dwelling fish are moving upstream to spawn, they are vulnerable to poaching, especially when confined below culverts or other partial barriers. This may have been a factor in the decline of the Lassen and Willow Creek populations. At present, only catch-and-release angling for redband trout is permitted in Goose Lake's California tributaries and legal fishing pressure remains light (CDFW 2010).

Alien species. Brook, Brown, and Rainbow trout have been introduced into streams of the Goose Lake drainage and Brown trout are known to persist in Davis and Pine creeks in California (Hendricks 1995, S. Purdy, unpubl. obs. 2006, P. Divine, CDFW, pers. comm. 2012). Brook trout are still present in at least one Oregon stream (ODFW 2005, Scheerer et al. 2010). California has not stocked any Rainbow trout in the drainage since 1980, when electrofishing studies indicated that the native redbands were distinct; planting of hatchery Rainbow trout apparently was discontinued in Oregon tributaries in 1961, although Cottonwood Meadows Reservoir, on Cottonwood Creek, is still planted with hatchery Rainbow trout (ODFW 2005). Behnke (1992) thought that some Goose Lake Redband trout populations in California showed evidence of past hybridization with Rainbow trout, based on meristic measurements, but there is no biochemical evidence of this. Recent information suggests there is little risk of hybridization with rainbow or Redband trout in the Goose Lake Basin (ODFW 2008).

The potential for future unauthorized, illegal introductions to impact native trout and other sensitive Goose Lake fishes remains although is unlikely. Possible effects to native fishes could occur through disease, hybridization, predation, or competition; however, but not hybridizing. Past introductions of warm-water fishes were largely unsuccessful because of the lake's extreme environment, though Brown trout do persist in some tributaries to Goose Lake and compete with and may consume Goose Lake Redbands (P. Divine, CDFW, pers. comm. 2013).

Beavers were historically distributed in the Goose Lake basin and likely provided ecological riparian benefits (CDFW 2013). Beaver dams in Lassen Creek's middle reaches have created intermittent dams and may have blocked lake fish runs from reaching preferred spawning habitat (J. Weaver, unpubl. obs. 2012). The California Department of Fish and Wildlife has, in the past, periodically used explosives to remove beaver dam complexes in Lassen and Willow creeks in order to improve upstream passage for Goose Lake Redbands, although this practice is no longer utilized (P. Divine, CDFW, pers. comm. 2012). Beaver dams may need to be evaluated in the future to determine if fish passage is being impeded and the overall ecological benefits they can provide. For example, their impediments to passage of large adults may be offset by their provision of back flooded habitats and water storage, especially as seen during recent drought years (M. Dege, CDFW, pers. comm. 2016).

Factor	Rating	Explanation
Major dams	n/a	
Agriculture	High	Water diversion and return flows from irrigation lower base flow and increase water temperatures; dams may block migration of lake fish, and these impacts are compounded in drought.
Grazing	Medium	Pervasive in the area, especially in meadows with redband streams; reduced impacts in recent decades with improved management but still an important factor.
Rural /residential development	Low	Rural development may impact a few streams in California through diversions, but is mostly an issue on the Oregon side of Goose Lake.
Urbanization	n/a	
Instream mining	n/a	
Mining	Low	Old uranium mines in watershed; unknown impacts.
Transportation	Low	Roads are a source of erosion and sediment input into streams and culverts have blocked access in the past.
Logging	Low	Logging and associated roads likely contributed to stream degradation, increased water temperatures and reductions in water quality, though greater impacts were in the past.
Fire	Low	Fire suppression, coupled with increasing aridity predicted with climate change, may contribute to increased fires.
Estuary alteration	n/a	
Recreation	Low	Off road vehicles a potential threat but not demonstrated.
Harvest	Medium	Poaching is potentially a problem during spawning; legal fishing pressure is light and limited to catch-and-release.
Hatcheries	n/a	
Alien species	Low	Trout introductions not regarded as a major threat, though competition and predation by brown trout may occur where both species overlap (P. Divine, CDFW, pers. comm. 2013).

Table 1. Major anthropogenic factors limiting, or potentially limiting, viability of populations of Goose Lake Redband trout in California. 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 moderate. See methods for explanation.

Effects of Climate Change: Goose Lake is located in an arid, high desert region so any reduction in precipitation or increased frequency of droughts will further stress streams and the lake. Climate change models predict both in the future (Moyle et al. 2012). During low flow periods, streams in the Goose Lake basin already reach temperatures (24-26°C) that are nearly lethal to redband trout. Any increase in air temperature, combined with reductions in stream flow through diversions, could reduce or even eliminate most California populations, especially

in lower reaches of streams where diversions are more common. Upstream reaches of streams, which are largely free from diversions and provide shaded habitat, cool springs, canyon reaches, and intact meadows, are likely to provide refuge for Goose Lake Redbands in the future (M. Dege, CDFW, pers. comm. 2016). An increase in fire frequency or intensity could reduce riparian shading, add sediment, and otherwise impair streams. Increased frequency of Goose Lake's known desiccation and lake temperatures could reduce the lake part of the population. Moyle et al. (2013) rated Goose Lake Redband trout as "critically vulnerable" to climate change, with extinction likely in California in the next 100 years if present climate change trends continue. Increasing likelihood of long-term drought will exacerbate these likely impacts.

Status Score = 3.1 out of 5.0. Moderate Concern. Goose Lake Redband trout face no immediate extinction risk, but their populations are not secure because: (a) of the 19 extant populations, only 6 are in California, (b) most stream populations are small, and (c) drought is predicted to increase over the century, which causes lake populations to disappear and stream populations to shrink. Warmer temperatures reduce the quantity and quality of stream refuges.

The Goose Lake Redband trout has been given various designations by state and federal agencies: (a) USFWS, Category 2 Candidate Species (now, Species of Concern); (b) USFS, Region 5, Management Indicator Species; (c) USFS, Region 6, Sensitive Species, (d) ODFW, Vulnerable or At Risk species and CDFW, Species of Special Concern (Moyle et al. 2015). The American Fisheries Society lists it as "Vulnerable," while NatureServe lists it as "Imperiled" (T2) (Jelks et al. 2008). In 1997, the USFWS was petitioned to list Great Basin Redband trout, which includes Goose Lake Redband trout, as threatened or endangered. In 2000, the petition was denied (Congressional Record, March 20, 2000:65 (54):14932-14936) because following a 1994 drought and reduction in Goose Lake Redband trout abundance, the population rebounded and the fish were estimated to inhabit 59% of their historical range. Since then, it is likely the population has shrunk due to drought, especially from 2010-2015.

USFWS analysis also cites the many successful restoration projects in the Goose Lake Basin as further reason for finding that listing was not justified. Goose Lake Redbands in California depend largely on just two streams, Lassen and Willow creeks, for survival. These populations could face extirpation from California even if there are viable populations in Oregon. Simmons (2011) indicated that there was substantial gene flow between the Lassen Creek population and others in the Goose Lake Basin, in support of its high genetic diversity. This may be supported by Passive Integrated Transponder (PIT) tagging studies by Oregon Department of Fish and Wildlife documenting lake fish moving to stream mouths in the spring (P. Divine, CDFW, pers. comm. 2017). More current information on California populations and better resolution of levels of movement (or lack thereof) of lake dwelling fish between tributaries, both in Oregon and California, would change their status. A fish rescue in 2014 and 2015 has given evidence that populations in Lassen and its tributary, Cold Creek, have declined since the last surveys in the 1990s and are susceptible to drought impacts (CDFW 2010).

Metric	Score	Justification
Area occupied	4	Present in six streams in California and 13 in Oregon.
Estimated adult abundance	3	Populations greatly reduced in drought years.
Intervention dependence	4	Long-term decline reversed by restoration actions; over 220 Redbands were rescued from Cold Creek during drought in 2014 and 2015; may require future rescue if drought conditions persist.
Tolerance	4	Indirect evidence suggests they are more tolerant than most salmonids of adverse water quality.
Genetic risk	3	Genetic risks are currently low; potential impacts from isolation of headwater populations need investigation.
Climate change	2	Distribution in isolated, small streams increases probability of extirpation due to prolonged drought.
Anthropogenic threats	2	1 High, 2 Medium threats.
Average	3.1	22/7.
Certainty (1-4)	2	Mostly 'grey' reports and expert opinion.

Table 2. Metrics for determining the status of Goose Lake Redband trout in California, 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 moderate. See methods for explanation.

Management Recommendations: There has been interest in conserving populations of endemic fishes in the Goose Lake Basin. During the 1987-1992, 1994 drought, a proposal was developed to list the Goose Lake fish fauna as threatened under the federal ESA. In response, the Goose Lake Fishes Working Group was formed in 1991, made up of representatives from both California and Oregon, and comprised of private landowners, state and federal agencies, non-governmental organizations, and universities. The organization signed a Memorandum of Understanding in July, 1994, to protect and, where needed, reestablish native fishes in the Goose Lake basin. In 1995, the Goose Lake Fishes Conservation Strategy was completed. According to USFWS (Congressional Record, March 20, 2000:65 (54): 14936), the goal of the strategy is to conserve all native fishes in Goose Lake by: reducing threats, stabilizing populations, and maintaining an intact ecosystem. Since 1996, many improvements have occurred to remove barriers to migration, such as culvert replacement, passage improvement, diversion reparations, and various habitat surveys, as well as sediment reduction projects such as road improvement.

In the lower reaches of most streams, restoration actions included making road under-crossings passable to trout. A fish ladder was installed over a major diversion dam on Thomas Creek in 1992 by the Oregon Department of Fish and Wildlife. In Willow and Lassen creeks, the California Department of Fish and Wildlife has removed natural and artificial migration barriers. Headcut control, bank stabilization, stream fencing, planting of riparian vegetation, modified grazing practices and other protective measures have also been undertaken on a number of streams in recent years. These measures have greatly improved habitat and water quality in Goose Lake tributaries, including the lower reaches that flow through agricultural land. Monitoring of water quality, insects, and fish demonstrate the improvements (Tate et al. 2005); however, continued effort is needed to maintain (and ideally increase) the populations of trout

and other fishes, especially during periods of severe drought (CDFW 2010). It is likely that populations have declined considerably during the drought years 2012-2016. Management recommendations (not in order of priority) include:

1. Identification and modification of barriers to fish movement, especially diversion dams. Restoring stream-lake connectivity would enable full expression of various life history potential in migratory fish like Goose Lake Redbands (Scheerer et al. 2010).
2. Identification, protection, and improvement of stream reaches that are critical for spawning, rearing, and refuge during drought. Cold Creek (tributary to Lassen Creek) and Buck Creek (tributary to Willow Creek) have already been identified as important habitats. At present, a diversion structure often diverts flows from lower Buck Creek. Lower Willow Creek habitat conditions are poor (bank sloughing, minimal riparian or instream cover, heavy sedimentation), along with multiple diversion dams. Although these dams were, at some point, improved with fish ladders, some of these structures appear badly deteriorated and fish passage needs to be reevaluated (J. Weaver, unpubl. obs., 2012). Implementation of water conservation measures could help increase streamflow and ensure habitat is available during low water years.
3. Regular quantitative monitoring (every 3-5 yrs) of fish populations in both upstream and downstream reaches of Lassen and Willow creeks, and at least qualitative monitoring of fishes in other streams. While no California-Oregon collaboration currently exists for basin-wide monitoring, CDFW and ODFW have been participating in range-wide assessments and collaboration under the recently-signed Interior Redband Trout Conservation Agreement (Redband Trout Conservation Agreement 2016). Invasive Brown trout should be removed to benefit the native fish assemblage (Goose Lake lamprey, Tui chub, and sucker) through reduced predation and competition. Together with Goose Lake Redbands, these four species are all endemic to the basin and are listed as state Species of Special Concern (Moyle et al. 2015).
4. Improved management of headwater areas to protect streams from livestock grazing and other stressors through the use of exclusion fencing, off-channel water sources for livestock, and working with landowners to improve riparian habitat through management changes.
5. Prevent the illegal importation/stocking of non-native fish in the Goose Lake Basin, and eradicate existing populations where possible. Bans on introductions of alien fishes or invertebrates that could alter the forage base or negatively impact native fishes should continue.
6. Adult lake-form trout in small streams are susceptible to poaching. Regular patrols by wardens and others should be conducted to prevent poaching adults in spawning areas.
7. The Goose Lake Fishes Conservation Strategy should be fully implemented and revisited periodically to ensure it is up to date. This is currently ongoing. The continued involvement of private landowners and public agencies is crucial to this effort, as is the continued involvement of University of California Cooperative Extension, which has provided coordination and scientific studies to support conservation efforts.

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