McCLOUD RIVER REDBAND TROUT
***Oncorhynchus mykiss stonei* (Jordan)**

Critical Concern. Status Score = 1.4 out of 5.0. McCloud River Redband Trout populations are very small, fragmented, and exist in limited habitats so status could change rapidly, particularly related to predicted climate change impacts.

Description: The following description is based on the Sheepheaven Creek population (Hoopaugh 1974, Gold 1977), which was believed to have a somewhat narrower range of meristic characters than the other known populations found in Edson and upper Moosehead creeks. The population found in Swamp Creek was started from Sheepheaven fish in 1973-74, so comparisons have been removed. More recent work (Behnke 1992) considered this population to best represent the subspecies because it is unlikely to have had any history of hybridization with introduced rainbow trout. In 2002, Behnke noted that Sheepheaven Creek were distinct from other Upper Sacramento River redbands, perhaps due to their isolation in this secluded, volcanic spring creek less than 2 km long. Overall body shape is similar to the "typical" trout as exemplified by rainbow trout. It has a yellowish to orange body color with a brick-red lateral stripe. The dorsal, anal, and pelvic fins are white tipped. Adults retain parr marks. Gill rakers number from 14-18 (average 16), which is the lowest number known from any rainbow trout population (Behnke 1992). Pyloric caeca number is 29-42, which is also low. However, the numbers of scales along the lateral line (153-174) and above the lateral line (33-40) are greater than in most rainbow trout. Pelvic fin rays are 9-10 and branchiostegal rays range from 8-11. Many, but not all, McCloud River Redband Trout have basibranchial teeth and an orange slash along the throat, characteristics more typically associated with cutthroat trout, but are most similar morphologically to golden trout (Behnke 1992, 2002, Simmons et al. 2009).

Taxonomic Relationships: Distinct “redband trout” from the lower McCloud River were first recognized in 1885 by Deputy U.S. Fish Commissioner, Livingston Stone, who was responsible for a fish hatchery located on the river. However, the lower portion of the McCloud River (below Middle Falls, historical barrier to anadromy) was historically inhabited by coastal rainbow trout, including steelhead, and other fishes. It is uncertain whether redbands were distributed in these lower reaches and, if so, whether Stone identified them as distinct. The redband trout we recognize today are varieties of inland resident rainbow trout that became isolated in headwater systems thousands of years ago. The taxonomic status of California populations of redband trout has been under much debate, reflecting the diversity of forms that are called ‘redband’ trout and the long isolation of many populations (Legendre et al. 1972, Miller 1972, Behnke 1992, 2002). A complicating factor is that many populations have hybridized with the closely related coastal rainbow trout, which have been widely planted in historical Redband trout streams. Behnke (1992, 2002) considers redband trout in the western U.S. to consist of a number of distinct lineages, each independently derived from early invasions of ancestral forms of trout into headwater systems, with populations then becoming isolated through geologic events. Behnke (2002) indicated that McCloud River Redband trout are part of a Northern Sacramento River basin trout complex in which all populations are, or were, tied to the headwaters of the Sacramento, McCloud, Pit, and Feather rivers. In theory, the subspecies name *O. m. stonei* could be applied to any population in these headwaters, but only a few streams in the upper McCloud River watershed are home to populations of relatively unhybridized and

non-introgressed redbands; these fish should be the exclusive possessors of the subspecies epithet (Simmons et al. 2009).

The population in Sheepheaven Creek, described above, was believed to be distinctive from other McCloud River Redband trout, so Behnke suggested it should be classified as a separate subspecies. Genetic studies by Berg (1987), using electrophoretic techniques, by Nielsen et al. (1999) using microsatellites, and more recently by Stephens (2007) using nuclear DNA methods, support the conclusion that the Sheepheaven Creek form is distinct. However, the most recent studies (Simmons et al. 2009, Simmons et al. 2011), which used both nuclear and mitochondrial single nucleotide polymorphisms, indicate that Sheepheaven Creek fish and fish from three other streams (Edson, Swamp, and Moosehead) should be considered together as the McCloud River Redband trout group. Of the tributaries to the Upper McCloud River, these creeks were found to contain relatively "pure" populations, with few introgressed alleles (<5%) from coastal rainbow trout (Simmons et al. 2011). According to the authors, these populations, despite some introgression, should be managed as a group to maintain genetic integrity and gene flow in the remaining extant variations of the McCloud redband (Simmons et al. 2010, Stephens et al. 2011). Besides Moosehead Creek, most of the southern tributaries to the McCloud River contain redband populations with higher levels of introgression with coastal rainbow trout. Trout Creek (northern tributary) in the Upper McCloud River was chemically treated in 1977 and restocked with Sheepheaven Creek fish. Although Trout Creek was started with Sheepheaven fish, recent genetic testing (Simmons et al. 2009, Stephens et al. 2013) have shown mixed results on the genetic purity of this stream. At this time, more genetic work is needed to determine Trout Creek's population status (M. Dege, CDFW, pers. comm. 2016).

Life History: Available information suggests that the life history of McCloud River Redband trout is similar to that of other *O. mykiss* populations, including golden trout, in small streams. Redband trout caught from Sheepheaven Creek were in reproductive condition in June, indicating that they spawn in late spring (May-June), as do other rainbow trout at high elevations. The largest fish recorded during a 1973 survey (Hoopaugh 1974) was 208 mm FL, and the population was then estimated at 250 fish over 80 mm FL. Four size classes were found in the stream. Observations in August 2008, suggest the same age classes were still present (J. Katz, R. Quinones, and P. Moyle, unpublished observations). However, CDFW surveys of Sheepheaven Creek in 2011 indicated a lack of younger age classes, extremely low abundance, and limited distribution within suitable habitat that declined over time through drought (2012-2016, J. Weaver, CDFW, pers. comm. 2012, M. Dege, CDFW, pers. comm. 2016). Over the course of the drought, 1,597 trout were rescued from Sheepheaven, Swamp, Edson, and Moosehead creeks, which represents a substantial portion of the current extant population. McCloud River Redbands can show territoriality, and were observed cannibalizing their own young during rescue operations in 2013-2015 (M. Dege, CDFW, pers. comm. 2016). Perhaps this territoriality contributes to their relatively low abundance in the available habitats that remain accessible to them in the wild.

Habitat Requirements: Habitat requirements for the McCloud River redband are derived from conditions in Sheepheaven Creek (Hoopaugh 1974, Moyle 2002) and the McCloud River based on descriptions in the 2016 Redband Trout Conservation Agreement (RTCA), which summarizes information from unpublished habitat surveys. This document is currently undergoing CDFW and U.S. Fish & Wildlife Service review and will be finalized soon (M. Dege, CDFW, pers.

comm. 2016). Sheepheaven Creek is a small, spring-fed stream at an elevation of 1,433 m. Water temperature in summer typically reaches 10-13°C and the flow drops below 0.03 m^3 sec^{-1} (1 cfs). The stream flows for about 2 km from the source and then disappears into the porous bedrock. During periods of drought, flows are greatly reduced and streams in the upper McCloud basin become intermittent; as a consequence, summer water temperatures can exceed 22°C, but most streams emerge from springs at around 5-7°C and have maintained temperatures in downstream reaches of about 9-15°C even through historically low precipitation (M. Dege, CDFW, pers. comm. 2016). The portion of the upper McCloud River historically inhabited by redband trout usually flows at 1.2 m^3 sec^{-1} (40 cfs) through a steep canyon. It is extremely clear and cold (<15°C) but becomes very low or intermittent in times of drought.

The present day streams inhabited by putative redband trout are generally small and dominated by riffles and runs with small pools. Pools appear to be preferred habitat for larger fish, especially if they contain dense cover from fallen trees. Spawning substrates are gravel riffles, as described for other small trout (Moyle 2002). Spawning temperatures are usually 5-10°C. Fry rear in shallow water on stream edges for the first weeks after emergence.

Distribution: McCloud River Redband trout are confined to small tributaries of the upper McCloud River (Table 1). All watersheds are wholly or partially located on the Shasta-Trinity National Forest and privately held lands in Shasta and Siskiyou Counties (M. Dege, CDFW, pers. comm. 2016, CDFW 2015). Historically, they were apparently present in the mainstem McCloud River above Middle Falls and perhaps in the lower river and its tributaries as well, especially in reaches not accessible to anadromous steelhead. Redband trout from an unnamed stream located between Sheepheaven Springs and McKay Creek (now known as Sheepheaven Creek, USGS 2012) were transplanted into Swamp Creek in 1973 and 1974 and into Trout Creek in 1977 (RTCA 2016). They are now established in both streams. According to a 2011 CDFW survey, putative redband trout exist in streams with a total length of about 8.9 km, with a total estimated population of 3,560 fish (Weaver and Mehalick 2011). Potential McCloud redband habitat, including the upper McCloud River, is about 98 km (about 50 km in dry years) (RTCA 2016). More recent data suggest that two additional streams that hold presumed non-introgressed McCloud redbands may expand this distribution if confirmed by genetic analysis (M. Dege, CDFW, pers. comm. 2016). Most of these tributary streams remain isolated from the upper McCloud River due to subsurface flows and the highly porous volcanic rock in the area, and may only experience limited connectivity with the McCloud River during extreme high flow events. The exception is Moosehead Creek, the only southern tributary of the group, which can have subsurface flows during drier periods, but also has an artificial fish barrier 2.2 km from the confluence with the McCloud River to prevent upstream migration of non-native or hybridized trout.

Stream	Summer flow class	Redband status	Isolation	Comments
Sheepheaven (McKay)	1	1	3	Key "pure" population.
Trout	2	2	3	Introduced from Sheepheaven Creek in 1977.
Swamp	1	1	3	Introduced from Sheepheaven Creek in 1973-74.
Edson	1	1	3	
Tate	2	3	1	
Moosehead (upper)	1	1	2	
Raccoon	1	3	2	
Blue Heron	1	3	2	Possibly extirpated.
Bull	1	2	2	
Dry	1	2	2	
Upper McCloud	3	0	1	Dominated by hybridized and non-native trout.

Table 1. Redband trout streams in the upper McCloud River. Summer flow class: 1 = < 1 cfs, 2 = 1-5 cfs, and 3 = > 5 cfs in late summer in most years. Redband status: 0 = all trout hybridized, 1 = 'pure' population, 2 = relatively 'pure' population with little introgression, 3 = good Redband population but slightly higher levels of hybridization. Isolation: 1 = no barriers to non-native trout, 2 = connections present in wet years in lower reaches, 3 = no passable connections with other streams.

Trends in Abundance: McCloud River redband presumably once had interconnected populations in the Upper McCloud River and tributaries, so the present isolated populations represent greatly reduced remnants of historical populations. Recent genetic analyses indicate that all populations sampled from across the upper McCloud watershed shared alleles in common with the distinctive Sheepheaven Creek population, indicating that redband trout with common ancestry were once widely distributed throughout the basin (Simmons et al. 2009, 2011). Existing redband trout streams were surveyed a number of times from 1975-1992 and in 2011 (Figure 5 in RTCA 2016; Weaver and Mehalick 2011). Numbers of fish estimated were highly variable and depended on the stream and habitat sampled; numbers ranged from 53 to 1,100 per km. Repeated drought cycles (e.g., 1976-1977, 1987-1992, 2012-2016), combined with the predominance of loamy volcanic soils in the watershed, have intermittently reduced surface flows in most McCloud basin streams and limited populations of McCloud redband trout. The same is expected under future drought conditions and will likely be exacerbated by the effects of climate change. If population estimates are confined to the relatively non-introgressed populations in Sheepheaven, Edson, upper Moosehead and Swamp creeks, then abundance is estimated at 3,500 putative McCloud redband trout in late summer, with large error bars around the estimate (Weaver and Mehalick 2011).

Habitat conditions and consequently abundance of McCloud River Redband trout waned in 2012-2015 due to extremely dry conditions (M. Dege, CDFW, pers. comm. 2016). During drought, available wetted habitat was reduced significantly across all streams in the region, including spring-fed streams such as Sheepheaven Creek. The population has likely dwindled

from the 2011 CDFW estimate, when less than 100 fish were captured in electrofishing surveys in Sheepheaven Creek (CDFW unpubl. data). It is likely that each of the four habitats for non-introgressed McCloud Redbands may only support stream populations of just fewer than 100 to 500 individuals during extreme dry years. The mechanics of how drought effects each stream are not well understood at this time. Dual drought within a single year, as occurred in 2013-14, saw a hard freeze on top of low flows and frozen stream sections throughout the McCloud Redband range and then drying of streams the following summer and fall (M. Dege, CDFW, pers. comm. 2016).

An increase would be expected due to the many ongoing habitat restoration and protection efforts that have taken place, post-drought. Presumably, habitat protection and restoration, including protection of springs, has moderated population fluctuations and reduced vulnerability to drought, but these impacts have not been tested. In future years, the population would likely rebound to exploit higher flows and access to greater wetted habitat availability, but cumulative impacts associated with climate change and redband-rainbow hybrids could limit the ability of the species to bounce back. It will take considerable effort to maintain McCloud Redband trout populations, especially through extended droughts.

Factors Affecting Status: Long-term survival of populations of McCloud River Redband trout confined to small, isolated, streams such as Sheepheaven Creek is tenuous because stream habitats are largely diminished during drought years, a process which can be accelerated by drought, climate change, and poor watershed management practices impacting upland and riparian areas (Table 2). Fortunately, interest in conservation and management of McCloud River Redbands has resulted in recent efforts to relocate and rescue individuals in disconnected habitats. Factors which threaten McCloud River Redband trout populations are: (1) alien species, especially coastal rainbow-redband trout hybrids, (2) long-term drought, (3) fire, (4) grazing, (5) roads, (6) logging, and (7) climate change. Upper McCloud streams can be regarded as exceptionally vulnerable to these factors due to their geologic and hydrologic nature (isolation, low flow in summer months, etc.). CDFW (2008) found that many road crossings and culverts showed signs of scour and could potentially be barriers to upstream fish migration; the report called for a comprehensive study of these potential barriers and habitat degradation due to logging and grazing practices.

Alien species. Coastal rainbow trout (*O. mykiss*), brown trout (*Salmo trutta*), and brook trout (*Salvelinus fontinalis*) have been repeatedly introduced into the upper McCloud watershed and have established self-sustaining populations. In particular, the McCloud River has received substantial numbers of stocked hatchery rainbow trout in the past to support a "put-and-take" fishery, although stocking of coastal rainbow trout in the upper McCloud River was discontinued in 1994 (RTCA 2016). Generally, where alien trout are present, redband trout are absent or have become hybridized. The exact causes of redband trout disappearance from the McCloud River itself have not been documented, but presumably it was a combination of predation on young (brown trout), competition for space (all species), disease introductions (all species), and hybridization and introgression (coastal rainbow trout). A number of redband trout streams are thought to be too small or isolated to be subject to introductions, although some (e.g. Trout Creek) were nevertheless invaded at one time or another by unknown means.

Hybridization between coastal rainbow trout and redband trout is a natural event: both are native to California and hybridization would have occurred where their populations overlapped (e.g. lower McCloud River and tributaries). However, due to planting of rainbows above natural

barriers, hybridization has become a primary threat to headwater redband population persistence in the basin. Once hybridization occurs, the rainbow trout phenotype tends to dominate, resulting in a loss of the distinctive, brightly-colored redband trout form. This is likely coupled with a loss of adaptability to the distinctive streams where redband trout evolved. Rainbow trout and rainbow-redband hybrids have replaced McCloud River Redbands in the majority of their historical range.

Fire. The 2016 RTCA considered fire a potential threat to this subspecies because fire suppression has greatly increased the amount of fuels in surrounding forests and increased the potential for high intensity fires. Such fires can cause direct mortality to fishes (high water temperatures), as well as indirect impacts from increased sedimentation and reduction in riparian vegetation and associated instream shading.

Grazing. Grazing by cattle and sheep has taken place in the McCloud River watershed for over 125 years and was especially intense in the first half of the 20th century. Heavy grazing, especially by cattle, reduced trout habitat by eliminating streamside vegetation, collapsing banks, making streams wider and shallower, increasing temperatures, reducing bank undercutting, polluting the water with feces and urine, silting up spawning beds, and generally making the habitat less complex and suitable for trout. The reduction of grazing pressure in the late 20th century and the increasing willingness of land managers to implement improved grazing practices and to use exclusion fencing along streambanks has led to better condition of small streams in the McCloud River watershed and improved habitat for redband trout. Today, much of Sheepheaven and lower Trout creeks have been fenced to exclude cattle. The grazing allotment associated with Sheepheaven Creek has not been active for several years, but this could change in the future.

Logging. The region in which McCloud River Redband trout live contains a checkerboard of private and public ownership, with most public lands as part of the Shasta-Trinity National Forest. According to the RTCA (2016) "Potential impacts to McCloud Redband and their habitat from past logging practices include loss of shade canopy, increased water temperatures, increased sedimentation, reduced recruitment of large woody debris, loss of fish habitat diversity, and increased peak storm flows".

These impacts continue into the present day through continued logging, including culverts potentially blocking or limiting instream movement, removal of water for dust control on dirt roads, erosion of sediment from roads, and similar factors. Fortunately, greatly improved logging practices have reduced the effects of logging and logging roads on streams, in good part because both private and public land managers recognize the uniqueness of the McCloud River Redband trout and their habitats (RTCA 2016).

Harvest. It is likely that harvest was never a major problem in the small streams of the McCloud basin but redband trout populations are small enough that even occasional harvest by anglers or scientific collectors could reduce populations (RTCA 2016). Special angling regulations are in place for the following streams: Sheepheaven, Edson and Moosehead creeks (closed to all fishing all year); Swamp Creek (last Saturday in April through November 15 – zero limit, artificial lures with barbless hooks only) (CDFW 2015-2016).

Transportation. Roads, mainly from logging, are numerous and widespread throughout the upper McCloud River basin, providing a source of sediment input into streams, potentially covering spawning gravels. They also provide easy access to most redband streams in the watershed. Recently, all major timber companies in the region that own private land adjacent to

streams and the US Forest Service have decommissioned roads to reduce these impacts (M. Dege, CDFW, pers. comm. 2016).

Factor	Rating	Explanation
Major dams	Low	Major dams are downstream of remaining McCloud River Redband habitat but their construction may have contributed to fragmentation of habitat in the past.
Agriculture	n/a	
Grazing	Medium	Historically pervasive in the area but currently limited on private and U.S. Forest Service lands through attrition and better grazing management.
Rural /residential development	n/a	
Urbanization	n/a	
Instream mining	n/a	
Mining	n/a	
Transportation	Medium	Roads are widespread in the upper McCloud basin and are sources of sediment input into streams; culverts etc. can prevent movement.
Logging	Medium	Logging is the major land use in the region; associated water drafting may reduce stream flows and cause direct or indirect mortality.
Fire	Medium	Headwater areas could be altered by more severe fires than occurred historically.
Estuary alteration	n/a	
Recreation	Low	Off-road vehicles a potential threat.
Harvest	Low	Light angling pressure in open streams; special fishing regulations to protect key redband populations.
Hatcheries	Low	Hatcheries are used to hold fish rescued from drought conditions; potential genetic effects if hatchery breeding program instituted.
Alien species	High	Major potential threat of competition, hybridization and introgression and cause of limited distribution.

Table 2. Major anthropogenic factors limiting, or potentially limiting, viability of populations of McCloud River Redband 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 fact that existing redband trout streams are so small and flow through highly permeable volcanic soils means that they are exceptionally vulnerable to stressors such as floods, drought, and fire, which are likely exacerbated and compounded in complex ways

under climate change scenarios. However, the persistence of distinctive trout in Sheepheaven Creek is due to the springs that maintain some level of surface flow at cool temperatures (albeit for a short distance), even during severe drought. Most of the other streams occupied by McCloud River Redbands have similar 'safe' water sources. It is also worth noting that spring flows can be eliminated by even minor volcanic or seismic activity and these streams are located in a relatively geologically active region. Additionally, most streams currently inhabited by redbands are already subject to seasonal reductions in flow (during non-drought periods), so increases in air temperature or reductions in snow pack during prolonged drought may dramatically reduce available wetted habitat, as was seen in during the 2012-2016 drought.

Moyle et al. (2013) consider McCloud River Redband trout to be "critically vulnerable" to climate change because of the small size of their streams, warmer temperatures, and the potential effects of lengthy droughts. While there is no evidence of long-term changes in stream temperatures in Sheepheaven Creek or the other three critical streams in the region, the ongoing drought has severely reduced available wetted habitat and reduced connectivity between relatively non-introgressed populations (Simmons et al. 2009, M. Dege, CDFW, pers. comm. 2016). The McCloud River Redbands are a unique and robust species that have persisted through historic drought before, but may be facing additional challenges with the likely impacts of climate change that will create more and longer lasting unfavorable conditions for the species (M. Dege, CDFW, pers. comm. 2016).

Status Score = 1.4 out of 5.0. Critical Concern. Long-term drought, fire, or other factors that affect stream flows or habitat suitability, coupled with genetic risks associated with isolation of small populations, threaten McCloud River Redbands with possible extinction. Populations are especially vulnerable to rapid changes in status due to their small, isolated populations. While high levels of interest and management scrutiny seem to preclude *immediate* risk of extinction, recent events such as rescue efforts and movement of vulnerable populations into suitable habitat and artificial holding tanks in Mount Shasta Hatchery is of serious concern. Rescue operations by CDFW in 2013-15 greatly reduced the drought mortality of the species.

While rescue operations were carefully deemed warranted, the quality of habitat for McCloud River Redbands has not seemed to change very much during historic drought; rather, it appears as if only the total amount of habitat has waned. Should average or above average water years return in the future, it seems likely that the species will enjoy a resurgence (M. Dege, CDFW, pers. comm. 2016). In longer time frames, extinction probability will increase as the climate becomes warmer and droughts more frequent and prolonged. Genetic risks increase with habitat reductions, potentially leading to bottlenecks in small, isolated populations.

The McCloud River Redband trout is considered to be vulnerable by American Fisheries Society (Jelks et al. 2008) because of its limited distribution and exposure to multiple threats. It was considered to be a Candidate Species for listing by the USFWS in 1994 but, following the signing of the 1998 RTCA by the USFS and other cooperators, it was removed from consideration. However, the conservation agreement does not actually preclude listing under the Endangered Species Act if needed (M. Dege, CDFW, pers. comm. 2016). The USDA Forest Service lists it as a Sensitive Species, while NatureServe considers it to be an imperiled subspecies. CDFW considers McCloud River Redband trout a fish species of special concern (Moyle et al. 2015).

Metric	Score	Justification
Area occupied	1	Four 'core' populations clustered fairly close to each other and all are in Upper McCloud watershed, so are treated as one 'watershed.'
Estimated adult abundance	1	Population prior to the 2012-2016 drought was likely somewhat less than 3,000 fish over 80 mm FL, with each stream having 100-1,000 fish. In drought years, total numbers of fish over 80mm FL was likely less than 1,250 fish.
Intervention dependence	2	Drought necessitated rescue of several populations and relocation to holding facilities until natural conditions improved; ongoing implementation and recent revision and expansion of a Conservation Strategy is critical for survival.
Tolerance	3	It is likely they are fairly tolerant of high temperatures, as are other redband trout, but water quality in their small streams has to be monitored during drought years.
Genetic risk	1	Hybridization risk with rainbow trout is high; small isolated populations result in genetic bottlenecks and inbreeding depression.
Climate change	1	Vulnerability is high in all streams because of small size and cumulative effects of a changing climate and drought.
Anthropogenic threats	2	1 High and 4 Medium threats.
Average	1.4	10/7.
Certainty (1-4)	4	Most published information is on Sheepheaven Creek population, though recently more studies have come from Edson, Moosehead, and Swamp creeks habitats.

Table 3. Metrics for determining the status of the McCloud River Redband trout, 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. See methods section for further explanation.

Management Recommendations: Conservation of McCloud River Redband trout is active and ongoing, thanks to the leadership of the McCloud Redband Core Group (RCG), a multi-partner organization (California Department of Fish and Wildlife, Shasta-Trinity National Forest, U.S. Fish and Wildlife Service, private landowners, and others), which is dedicated to the conservation of the McCloud River Redband trout. In addition, the western states, several tribes, and Trout Unlimited have been coordinating all recovery efforts under a formal Conservation Agreement, with regular meetings and information updates (Inland Redband Conservation Agreement 2014).

The California Department of Fish and Wildlife has undertaken significant genetic studies, fish rescue operations, and creation and implementation of conservation hatchery plans at the Mount Shasta Hatchery to protect McCloud River Redband trout from severe impacts to extinction in the wild. In the past, most management attention focused on the Sheepheaven Creek population because of its historical reputation on being so distinctive. Recent attention has focused on the broader populations within the upper basin and four 'core conservation populations' (Sheepheaven, Edson, Swamp, and Moosehead) have been identified and will be managed collectively (J. Weaver, CDFW, pers. comm. 2012). Private and public landowners actively cooperate on conservation, particularly those who comprise the RCG. On private lands, considerable effort has been made to improve roads in ways that minimize impacts to streams, to

fence streams from livestock, and to assist in restoration and management activities. The conservation agreement is an effort to provide a systematic framework for all restoration and management activities in the watershed. It is crucial that this agreement be finalized as the working plan to improve conditions for McCloud River Redband trout. The following recommended actions to increase protection for redband trout and their habitats are largely drawn from this agreement. Recommendations are not in order of importance.

Establish a McCloud River Redband Refuge. A portion of the upper McCloud River basin should be managed for the protection and enhancement of McCloud River Redband populations and their habitats. The refuge should include the main stem McCloud River and its tributaries above the Middle Falls and, within this broader refuge, a 'core conservation area' should be established to provide further protections for populations with low (or no) levels of introgression with coastal rainbow trout (Sheepheaven, Swamp, Edson, and Moosehead creeks, Interior Redband Trout Conservation Agreement 2016). While the refuge area contains all the streams known to contain presumed redband trout at the present time, suitable reaches of other perennial streams should, nevertheless, be evaluated for their potential as future translocation/restoration sites. Streams that have potential for expanding the range of redband trout (particularly within-basin, but also outside of the McCloud basin as warranted) would be of great value in terms of offsetting climate change impacts or stochastic events that may lead to the extirpation of one or more existing populations. Management plans that include eradication of non-native trout should be developed and construction of barriers to prevent alien trout invasions considered. In particular, the upper McCloud River itself should be evaluated as a refuge during periods of reduced stream flow caused by prolonged drought or climate change.

Maintain and enhance existing habitats. McCloud River Redband trout survive in remarkably small and fragile habitats, so continued work is needed to improve the ability of these habitats to support redband trout and to reduce the impacts of human activities. Of particular concern are grazing and logging practices, but other factors such as fire protection, angling, and off-road vehicles have also been taken into consideration. While management plans and agreements are in place to protect streams, continued vigilance is required to avoid long-term loss of habitat. Creation or enhancement of pool refuge and barrier removal in these habitats should be prioritized to reduce genetic bottlenecks and mitigate the effects of drought on remaining populations.

Protect genetic integrity of existing populations. The present populations of McCloud River Redband trout are highly vulnerable to loss of genetic integrity (and phenotypic distinctiveness) due to hybridization with introduced rainbow trout, introgression, and potential for genetic bottlenecking due to isolation of existing redband populations from one another. Efforts are needed, therefore, to protect populations from further inappropriate introductions (e.g., by making vehicle access difficult) or from 'natural' invasions from downstream areas (e.g., through construction of barriers). This program should include genetic and phenotypic monitoring as part of the assessment of population health. Consideration should also be given to active movement of putative redbands in order to promote and restore gene flow and increase genetic heterozygosity, in order to offset potential impacts from past and ongoing isolation of existing populations (e.g., mixing genetically distinct McCloud River Redband streams, Upper McCloud River Redband Trout Reintroduction Plan 2013).

Continue to develop and enforce angling regulations appropriate for protection of redband trout. Sheepheaven, Edson, and Moosehead creeks are closed to all fishing all year. Catch-and-release angling is allowed in Swamp Creek from the last Saturday in April to

November 15th, using artificial lures with barbless hooks. These regulations need to be strictly enforced with frequent monitoring of streams to minimize impacts on the fragile remaining populations at this time.

Develop and implement a genetic management plan for all populations. Initial steps in genetically managing McCloud River Redbands have been undertaken by CDFW. Genetic management elements have been implemented for rescued McCloud River Redbands during hatchery operations and reintroduction, and a formal plan from CDFW is forthcoming (M. Dege, CDFW, pers. comm. 2016). Genetic management and conservation elements include enhancing local genetic diversity by crossing rescued fish between populations and minimizing the influence of captivity on rescued fish. To date, over 1,700 offspring have been produced from parents rescued from Edson, Moosehead, and Swamp creeks based on a genetic matrix designed to increase diversity among the population as a whole and to maintain the genetic integrity of captive populations (M. Dege, CDFW, pers. comm.). Reintroduction efforts occurred during the fall of 2016 (see below). (M. Dege, CDFW, pers. comm. 2016). Moving forward, out-of-basin translocations of these offspring should be considered to create a refuge population that can mitigate against potential devastating drought, fire, seismic activity, or other catastrophic events.

Establish a regular habitat and population monitoring program. This should be established for all putative redband trout populations and monitoring should occur at least once every 4-5 years (one redband generation).

Develop a formal re-introduction plan and perhaps a captive broodstock plan. Nearly 600 rescued McCloud River Redbands of all size and age classes are being held separately according to their resident stream (Edson, Moosehead, and Swamp creeks,) in nine holding tanks in the Mount Shasta Hatchery (CDFW 2015, M. Dege, CDFW, pers. comm. 2016). After a wet season of above average precipitation in the Upper McCloud River basin and meeting reintroduction and flow criteria, the fish will be re-introduced and/or outplanted into genetically distinct McCloud River Redband streams (M. Dege, CDFW, pers. comm.).

After a full year of average flows, the surviving F1a offspring and their rescued parents were released in September 2016 to their native streams, with a mixing of 10% of fish to different streams to mimic natural straying and recolonization rates (M. Dege, CDFW, pers. comm. 2016). In total, 349 rescued fish and 930 F1a offspring were reintroduced back into Edson, Moosehead, Swamp, and Sheepheaven Creeks based on the management plan. Should future drought and below-average precipitation return to the McCloud basin, this approach could be followed to allow the small population of McCloud River Redbands to persist. A captive broodstock program may be developed based on the work of Simmons et al. 2011 and colleagues with captive fish that were spawned in the hatchery in 2015 and 2016.

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